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A) Projektdaten

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B) Projektübersicht

1 Kurzfassung

Das primäre Ziel von RiskAdapt bestand darin, vor dem Hintergrund des Klimawandels politikrelevante Erkenntnisse und Schlussfolgerungen über das gegenwärtige System des integrierten Hochwasserrisikomanagements in Österreich zu liefern. Zu diesem Zweck hat das Projekt die verfügbaren Optionen, aber auch die bestehenden Hindernisse für eine effektive Risikominderung durch integrierte Anpassungsstrategien identifiziert und analysiert. Die Arbeitspakete und die Aktivitäten des Projektes lassen sich wie folgt zusammenfassen:

In WP1 erfolgte die Beurteilung der Hochwassergefährdung unter Berücksichtigung von potentiell nachteiligen Folgen des Klimawandels auf die Hochwasserabflüsse. Diese wurde auf (1) Makroebene für Österreichs Gemeinden, sowie auf (2) lokaler Ebene (Mikroskala) für drei ausgewählte Fallstudiengemeinden (Altenmarkt im Pongau/Flachau, Gleisdorf und Perg) durchgeführt. Als Grundalge für die Zunahme der Gefährdung wurden die HORA-HQ_{200} Abflussspitzen mit einem +10% Klimawandelzuschlag adaptiert. Für Österreich konnten folgende Schlussfolgerungen abgeleitet werden: (i) die Zunahme der Überflutungsfläche aufgrund der Auswirkungen von Klimaänderungen ist in Gemeinden mit flacher Topografie stärker als jene in alpinen Gemeinden; (ii) für 69% aller Gemeinden sind die Änderungen der Überflutungsflächen jedoch sehr niedrig bis niedrig; (iii) in 25% aller Gemeinden ist mit einer deutlichen Zunahme der Hochwassergefährdung zu rechnen. Auf lokaler Ebene variieren die Ergebnisse je nach Fallstudiengebiet. In alpinen Regionen ist die Veränderung der Überflutungsflächen zwar gering, die Überflutungstiefen nehmen jedoch deutlich zu. Im Flachland ist die Zunahme der Überflutungstiefe minimal, jedoch kommt es zu einer deutlichen Vergrößerung der Überflutungsflächen mit geringer Überflutungstiefe.

In WP2 wurden die aktuelle und die zukünftige Exposition (Zeithorizont 2030) gegenüber Hochwassergefahren sowohl auf nationaler (alle Gemeinden Österreichs) als auch auf lokaler Ebene (anhand der drei Fallstudien Altenmarkt im Pongau/Flachau, Gleisdorf und Perg) ermittelt. Die Ergebnisse der Untersuchung auf nationaler Ebene zeigen, dass - anhand des Anteils der Betroffenen Personen in den Abflussbereichen eines 200-jährlichen Hochwasserereignisses - gegenwärtig viele städtische Agglomerationen sowie dichter besiedelte alpine Talräume die größte Hochwasserexposition aufweisen. Für 2030 ist in jenen Gemeinden, in denen die Hochwasserexposition bereits jetzt hoch ist und für die eine starke Bevölkerungszunahme prognostiziert wird, die größte Exposition gegenüber Hochwasserereignissen zu erwarten. Das sind wiederum städtische Bereiche mit Bevölkerungswachstum sowie siedlungsdynamische Regionen und Tourismuszentren in alpinen Talräumen. Die Analyse der Hochwasserexposition auf lokaler Ebene macht deutlich, dass die aktuelle Exposition vom Ausbaugrad der bestehenden Hochwasserschutzmaßnahmen abhängt. Die gegenwärtige Exposition ist in Altenmarkt im Pongau/Flachau sowie in Gleisdorf gering, wohingegen in Perg eine beträchtliche Zahl von Einwohnern und Gebäuden bereits von einem 100-jährlichen Hochwasser betroffen ist. Unter Berücksichtigung der Klimawandelszenarien nimmt die Hochwasserexposition in allen Fallstudiengemeinden zu, besonders in Gleisdorf und Perg. Der Einfluss der zukünftigen Siedlungsentwicklung auf die Hochwasserexposition hängt von den verfügbaren Baulandreserven (innerhalb und außerhalb potentieller Hochwasserabflussgebiete), vom vorhandenen Dauersiedlungsraum sowie von der Art der geplanten Siedlungserweiterung (Wohnnutzung, gewerblich-industrielle Nutzung) ab.

In WP3 wurde die Anfälligkeit von Gebäuden und Menschenleben gegenüber Hochwasser untersucht. Die Ergebnisse wurden als Basis zur Beurteilung des Hochwasserrisikos herangezogen. Mehrere Beurteilungsmethoden wurden analysiert und anschließend eine geeignete Methode zur Bewertung der Hochwassersensibilität in RiskAdapt definiert. Die Hochwassersensibilität auf Makroebene wird stets aufgrund der Veränderungen des Risikos, welches bis 2030 für eine Region oder Gemeinde zu erwarten ist, abgeschätzt. Auf Mikroebene wird die Hochwassersensibilität über

die Suszeptibilität von Anlagen gegenüber Hochwasser in monetären Einheiten ausgedrückt. Dafür wurden geeignete Schadensfunktionen für verschiedene Gebäudekategorien in den Fallstudiengebieten ermittelt.

In WP4 wurde auf der Grundlage einer Literatur- und Dokumentanalyse sowie 45 Experteninterviews die Entwicklung der Anpassungskapazitäten im Hochwasserschutz seit 2002 auf den Ebenen des Bundes, der Länder und der Gemeinden analysiert. Die Bewertung auf der Makro-Ebene zeigte deutliche Verbesserungen der institutionellen, finanziellen, politischen und informationellen Kapazitäten auf der Bundes- und Länderebene. Die lokalen Fallstudien in den drei ausgewählten Gemeinden bestätigten prinzipiell dieses Ergebnis, verdeutlichten aber zugleich einige zentrale Unterschiede bei der Entwicklung der lokalen Anpassungskapazitäten.

Im Rahmen von WP5 erfolgte die Beurteilung des Hochwasserrisikos unter dynamischen Bedingungen. Dabei wurden Veränderungen der Gefährdung (WP1) sowie der Vulnerabilität (WP 2-4) berücksichtigt. WP5 beinhaltet eine Beurteilung sowohl des derzeitigen, als auch des zukünftigen Hochwasserrisikos (für das Jahr 2030). Die Ergebnisse zeigen eine Zunahme des Hochwasserrisikos speziell für Gemeinden mit großem Anteil der Überflutungsflächen an der Gemeindefläche und einer hohen Bevölkerungsdynamik. Dies trifft besonders auf regionale Zentren im Flachland sowie schnell wachsenden alpinen Gemeinden zu. Auf der Mikroebene fielen die Ergebnisse der Risikobewertung sehr unterschiedlich aus. Während in der alpinen Region Altenmarkt-Flachau die Veränderung des Risikos vor allem durch Landnutzungsänderungen hervorgerufen wird, wirkte sich in den flachen Regionen Gleisdorf und Perg primär der Klimawandel verschärfend auf das Hochwasserrisiko aus. Der Anstieg der jährlichen erwarteten Schäden variiert in den drei Fallstudien zwischen 45 und 450 Prozent. Die Veränderung der Hochwassergefahr könnte dazu führen, dass technische Hochwasserschutzmaßnahmen im vorgesehenen Ereignisfall nicht richtig funktionieren. Folglich können Bereiche, die derzeit gegen ein HQ_{100} Ereignis geschützt sind, in Zukunft durch ein aHQ_{100+CC} Ereignis überschwemmt werden. Daher sollten Neubauten in Restrisikogebieten möglichst vermieden werden.

In WP6 wurde in jeder der drei Fallregionen ein Stakeholder-Workshop durchgeführt. Im Rahmen der Workshops wurden die Bewertung und das Management der gegenwärtigen und zukünftigen Hochwasserrisiken mit verschiedenen Stakeholdern diskutiert. Mit den Workshops wurden drei Ziele erreicht: (i) die Reflexion der wesentlichen Faktoren des Hochwasserrisikos auf der Basis von Hochwassergefahren– und risikokarten, (ii) die Verifizierung der lokalen Kontextbedingungen und laufender politischer Entscheidungsprozesse, und (iii) die Entwicklung und Priorisierung von Anpassungsmaßnahmen für seltene Hochwasserereignisse.

2 Executive Summary

The overall goal of the RiskAdapt project was to provide policy-relevant insights and conclusions regarding the current Austrian system of integrated flood risk management in light of climate change scenarios, also pointing out the opportunities and barriers for decreasing vulnerability by means of integrated adaptation policy approaches. The work packages and the work we have accomplished can be summarized as follows:

In WP1 we dealt with the assessment of hazard, which is represented by current fluvial floods and under consideration of potential climate change impacts on flood magnitudes. The hazard assessment in WP1 was performed for (1) a national, macro-scale level and (2) a regional to local or micro-scale level (three selected case studies – Altenmarkt im Pongau/Flachau, Gleisdorf, Perg). To account for changes in hazard due to potential climate change impacts on flood magnitudes the HORA-HQ200 flood runoff values were increased. In the application, an increase of +10 % was proposed. For Austria the following conclusion were reached: (i) Generally the municipalities with relatively flat topography are more sensitive to changes in flood hazard; (ii) for over 69% of the municipalities changes are however very low to low; (iii) 25% of the municipalities are classified with a high change in future hazard. On micro scale the potential impact of climate change on the

inundation areas are different for the three case studies. In mountainous regions the changes in inundation areas are quite low, whereas increases in the inundation depth are observed. In plains the increase of inundation depth is minimal. However climate changes scenarios provoke an increase of the inundation area characterized by low inundation depths.

In WP2 we assessed the current and future exposure (until 2030) to flood hazards both on a macro-scale (all Austrian municipalities) as well as on a local scale (three case studies). Findings from the macro-scale exposure assessment show that - according to the share of people in 200-year flooding areas - densely populated areas (i.e. many urban and economic centers) as well as many alpine municipalities have the highest current exposure to flood hazards. In 2030 all municipalities with a high current exposure and a high population growth can expect high levels of future hazard exposure (i.e. in general dynamic urban and peri-urban municipalities and many alpine valley regions). The local assessments indicate that the current flood exposure depends on the existing level of structural flood protection. Gleisdorf and Altenmarkt im Pongau/Flachau are only marginally exposed whereas Perg has a considerable number of residents and buildings in 100-year flooding areas. However, the climate change allowance significantly increases flood exposure in all selected case studies, especially in Gleisdorf and Perg. The influence of settlement development on future hazard exposure depends on the availability of building land (inside and outside potential flood plains), the amount of land suitable for permanent housing and the kind of land development intended (housing, commercial or industrial development).

In WP3 we assigned damage functions to different utilisations to enable an overall flood risk assessment. A methodology for the analysis of sensitivity in the context of flood risk was developed on the macro-scale level as well as on the micro scale level. On a macro scale level sensitivity was defined as the dimension of changes in risk of a municipality due to changes in hazard and land-use. On micro scale, sensitivity was defined as the susceptibility of single objects on flood events, expressed in monetary values. Therefore appropriate damage functions were allocated to different object categories in the three selected municipalities.

In WP4 we build upon a literature review, desk research and 45 expert interviews to assess the development of flood-related adaptive capacities at the national, provincial and local level since 2002. The macro-scale assessment showed the progress made in terms of increasing institutional, financial, political and informational capacities. The case studies confirmed the general conclusions in the three selected communities, but highlighted also some differences in the development of adaptive capacities at the local level.

A dynamic risk assessment approach was applied in WP5 considering the temporal developments of both aspects of risk – hazard (WP1) and vulnerability (WP2-4). Accordingly, WP5 includes the assessment of current and future risk (for the year 2030) on a macro-scale as well as on a local scale. The results for future flood risk show that communities with a high share of potential flood plains and high population dynamics have to cope with an increasing flood risk. This is mostly expectable to urban-rural communities in the lowlands and growing communities in alpine valley areas. On micro-scale the results of the risk assessment were quite different. While in the mountainous region of Altenmarkt-Flachau the change of risk is mainly provoked by land use changes, in plain regions, such as Gleisdorf and Perg, climate change induced increases of risk are dominating. The increase of the annual expected damages varies in the three case studies between 45 and 450%. Changes in hazard might provoke, that technical flood protection measures do not work properly until the calculated design event. Consequently areas, which are currently protected against a HQ_{100} event might get flooded by aHQ_{100+CC} event in future. Hence the housing in residual risk areas should be discouraged.

In WP 6 a stakeholder-workshop was conducted in each case study region. The task of the workshops was to discuss the assessment and management of current and future flood risks. The workshops more precisely aimed at i) reflecting determinants of risk based on different scenarios (maps), ii) identifying/verifying local context conditions and preexisting policy processes, and iii) developing and prioritizing adaptive measures for extreme flooding scenarios.

3 Hintergrund und Zielsetzung

In the recent decade, Austria suffered from heavy floods affecting thousands of people and causing billions of Euro in economic losses (e.g. 2002, 2005, and 2013). Currently, there is no proof that these extreme events are a direct consequence of climate change. Nevertheless, they may indicate future tendencies concerning extreme flood events and increased hazard. Besides assumed climate effects, land use changes may influence and increase flood risks. Housing, commercial, industrial and infrastructure development in former floodplains result in increased exposure and sensitivity, since they lead to an increase in economic values in flood-prone areas. The vulnerability of any system is not only determined by exposure and sensitivity, but also by its adaptive capacity, i.e. the ability of a region or community to adapt to the expected effects or impacts of climate change. Hence, there is an urgent need for integrated flood risk management as outlined in the EU directive 2007/60/EC and to develop and implement adaptation strategies in regions that are to be assumed highly vulnerable to floods under conditions of climate change.

The overall aim of RiskAdapt was to provide policy-relevant insights and conclusions regarding the current Austrian system of integrated flood risk management in light of climate change scenarios, also pointing out the opportunities and barriers for decreasing vulnerability by means of integrated adaptation policy approaches.

More specifically, RiskAdapt aimed at:

(1) providing a GIS based data base referring to flood hazard and vulnerability in Austria considering (a) the current state; (b) anticipatory development scenarios for floods and population developments on different scales that can be combined with reliable climate model results – as soon as they are available; (c) mapping of the overall flood risk in Austria under consideration of a climate change allowance for flood magnitudes and a projection concerning the population development for 2030; (d) identification of regions with high risks of flooding for (e) deriving priority regions with the most immediate need for action in the context of climate change adaptation.

(2) Analyzing adaptive capacities on the national level as well as in local case studies, specifically focusing on institutional, organizational and actor capacities that are relevant to integrated flood-risk management.

(3) Testing community based participatory methods (stakeholder workshops) as tools for deriving dialogue-based recommendations for the improvement of integrated flood risk management at a local to regional level

4 Projektinhalt und Ergebnis(se)

a) Activities performed within the framework of the project, including methods employed

WP1 dealt with the assessment of hazard, which is represented by current fluvial floods and under consideration of potential climate change impacts on flood magnitudes. The hazard assessment in WP1 was performed on (1) a national, macro-scale level and (2) a regional to local or micro-scale level.

Macroscale

Hazard was designated for (1) current and (2) possible future changes on municipality level based on a flood event of low recurrence interval. To account for changes in hazard due to potential climate change impacts on flood magnitudes the HORA-HQ_{200} flood runoff values were increased. In the application, an increase of +10 % (climate change allowance - BMFLUW, 2011, LfU, 2005) was proposed. However, a general increase of 10 % for all runoff values would result in different

recurrence intervals, depending on the river size and location. This would lead to an inconsistent data set. Therefore it was decided to increase the runoff values of the Austrian Danube by 10 % and to calculate a mean resulting recurrence interval based on flood statistics. In our case a recurrence interval of 500 years was calculated. Based on this return period and the Gumbel distribution, which is used within HORA, new runoff values were calculated for all other rivers and streams. In the following the return period of 500 years (HQ500) is referred to as HQcc, with "cc" representing "climate change". Note that the calculated return period of 500 years is as a number very uncertain. This has several reasons. The fitting and parameters of the Gumbel flood distribution is uncertain. The time-series on which the statistics are based on are mostly relatively short. Further uncertainties arise due to the extrapolation based on given HQ_{30}, HQ_{100} and HQ_{200}. Nevertheless, this approach enables a robust detection of areas or regions which are strongly affected by higher flood magnitudes.

Based on the inundation depths of HORA-HQ_{200}, the HORA-HQ_{200}-runoff values and the new HQcc-runoff values, new water depths were calculated assuming rectangular stream geometries. For all municipalities a weighted mean change of water depth was derived by weighting the individual depth values with the associated discharge value. This approach considers the more severe hazard originating from larger rivers compared to minor streams.

The inundation areas of HORA-HQ_{200} were enlarged on basis of topographical information provided by the digital elevation model. Thereby new inundation areas were calculated for different water depth changes on the basis of HORA-HQ200 and classified in different Δh-classes: +10 cm, +25 cm, +50 cm, +100 cm and +150 cm.

As an indicator for the *current hazard* the flooded area within a municipality due to the HORA-HQ_{200} data was used. The calculated values of the flooded area within a municipality were classified in five hazard classes: 0-5 % (marginal hazard), 5-10 % (low hazard), 10-25 % (medium hazard), 25-50 % (high hazard) and >50 % (very high hazard).

As an indicator for *future hazard* the relative changes of inundated areas within a municipality were derived on the basis of the modified inundation areas due to HQcc. The relative changes in hazard for every municipality were again divided into five hazard classes: 0-5 % (marginal hazard), 5-10 % (low hazard), 10-25 % (medium hazard), 25-50 % (high hazard) and >50 % (very high hazard).

Microscale

In accordance with the project proposal, the hazard assessment has been realized for three case studies on micro-scale level.

The hazard assessment on the micro-scale is based on simulated flood inundation areas and inundation depths for four different flood hazard scenarios. These include

i. the flood with a return period of 100 years (HQ_{100}),
ii. the flood with a return period of 100 years increased by 10 % to include a climate change allowance (HQ_{100+CC}; BMFLUW, 2011, LfU, 2005)
iii. the flood with a return period of 300 years (HQ_{300}),
iv. the flood with a return period of 300 years increased by 10 % to include a climate change allowance (HQ_{300+CC}; BMFLUW, 2011, LfU, 2005)

For the derivation of detailed inundation maps, hydrodynamic models have been set up for the three different case study areas. As modelling software HYDRO_AS-2D (Hydrotec, 2014) is used. The hydrodynamically calculated inundation areas were imported into a GIS-system. The inundation areas of every scenario are then categorised in the following depth classes which are then used as basis for the risk assessment on the micro-scale:

1. 0 - 0.5 m
2. 0.5 - 1.5 m
3. >1.5 m,

In **WP2** we assessed the current and future exposure to flood hazards on a macro-scale (for all Austrian municipalities) as well as on a local scale (for three selected case studies). For the *macro scale assessment of hazard exposure*, a nationwide GIS analysis of current hazard exposure was conducted based on the indicator "potentially affected persons" (main and secondary residents as well as working population) in calculated flooding areas with a 200 years' recurrence interval. For the assessment of Austrian municipalities' future exposure to flood hazards with a timeframe of 2030, population development scenarios were related to the results of the current exposure assessment. Future hazard exposure on the macro scale is thus a function of current exposure ("number/share of potentially affected persons") and future population dynamics. In the *micro-scale exposure assessment* we conducted an in-depth analysis of current and future flood hazard exposure for three selected case studies. Current exposure was determined based on three indicators: a population-based indicator (number of main and secondary residents in flooding zones - according to the digital housing and building register), a building-based indicator (number and area of (different types of) buildings in flooding zones - according to the digital housing and building register) and a land-use based indicator (area of designated land uses in flooding zones - according to digital local land use plans). For the assessment of future changes in flood hazard exposure we developed a settlement scenario individually for each case study on the basis of land-use information, demographic and economic data as well as the analysis of spatial planning instruments and expert interviews with local planning authorities and planning consultants. This scenario was mapped in GIS (according to the nomenclature of the building and housing register), merged with the data sets of current hazard exposure and finally intersected with the respective flooding scenarios to assess future hazard exposure according to the building-based exposure indicator (number and area of different building types in flooding zones).

The objectives of **WP3** were to: (i) support the identification of highly vulnerable regions and municipalities; (ii) enable the identification of highly flood sensitive areas, and (iii) assign damage functions to different utilisations to enable an overall flood risk assessment. In a first step, relevant terms, such as risk, vulnerability and hazard, were defined, following the guidelines published in IPCC (2007). Concepts for exposure, hazard and risk assessments have been compiled and defined, based on national and international publications. This included ex-post analyses of data collected in the aftermath of the 1999, 2002, 2005 and 2006 flood events in Austria, but also international investigations. Depending on the scale of investigation, different applicable methods were categorised in macro- and micro-scale approaches. A methodology for the analysis of sensitivity in the context of flood risk has been developed on the macro-scale level as well as on the micro scale level. On a macro scale level sensitivity has been defined as the dimension of changes in risk of a municipality due to changes in hazard and land-use. This has been used for WP5 for the designation of highly flood sensitive regions.

On micro scale, sensitivity has been defined as the susceptibility of single objects on flood events, expressed in monetary values. Therefore appropriate damage functions have been allocated to different object categories. The damage functions are based on the results of different studies and had to be adopted for the case studies. Individual damages for the different classes and different categories of buildings and infrastructure were assigned for:

- Single-family houses and multi-family houses
- Industrial buildings
- Livestock buildings
- Warehouses
- Highways
- State roads and municipal roads
- Railways

In **WP4** we build upon a literature review, desk research and 45 expert interviews to assess the development of flood-related adaptive capacities at the national, provincial and local level. The adaptive capacities were assessed along five dimensions: (1) financial capital in terms of investments and costs; (2) the institutional dimension in terms of laws, regulations, and political

strategies; (3) the knowledge and information base; (4) the political capital in terms of high levels of coordination and participation resulting in good decision-making and governance; and finally (5) the innovativeness of the system reflected by the openness and willingness of key actors to learn from past experiences. Most importantly, the framework has been used to analyze the changes in adaptive capacities that occurred in the time period between 2002 and 2012, thereby applying not a static, but a dynamic perspective on adaptive capacities.

In **WP 5**, a dynamic risk assessment approach was applied considering the temporal developments of both aspects of risk – hazard (WP1) and vulnerability (WP2-4). Accordingly, WP 5 includes the assessment of current and future risk (for the year 2030) on a macro-scale (for all Austrian municipalities, project period 1) as well as on a local scale (for selected case study municipalities).

The evaluation of the current flood risk for Austrian municipalities on macro scale considers the number of people potentially affected by flood on the basis of the "Hochwasserzonierung Austria (HORA)", a nationwide designation of HQ_{200}-flooded areas. The risk assessment takes into account people with primary and secondary residences, as well as employees in the respective communities. To quantify risk the proportion of those, affected by a HQ_{200} flood in relation to the total population, was calculated. Determining the future flood risk changes of the risk components, hazard and vulnerability, were analyzed. To assess the risk and potential impact of climate change on future floods, the discharges from the HORA data set were increased by a surcharge factor of 10 %. Based on this, new flood plains were calculated. By comparison with the current flood plains a qualitative analysis of the future flood risk were reported individually for every municipality. Since the future number of people affected by flooding is directly related to the expected population dynamics in the respective communities, future changes in vulnerability were estimated by a trend extrapolation of the population development. The future flood risk arises as a function of changes in vulnerability and hazard. The risk assessment is based on the assumption that both a potentially climate change-induced expansion of flood plains and the development of settlements in flood-prone areas increase the future flood risk. Due to coarse resolution on macro scale the inclusion of adaptation capacities for the assessment of communities at high flood risk was not possible.

Based on the results of the assessment of future flood risk on macro level three case study areas were selected. As the highest risk class provides 417 municipalities all over Austria further selection criteria had to be implemented:

- data availability: in particular hydrological data and suitable hydraulic models;
- suitability for stakeholder workshops: in order to enable the participation of stakeholders with expertise for the whole municipal area, not just for some neighbourhoods, the population of possible case study municipalities was limited to a maximum of 10.000 inhabitants;
- increasing municipal population and dynamic economic development: in order to assess both, the influence of climate change and an increasing hazard exposure, as drivers of future flood risk;
- different spatial characteristics: in order to reflect the influence of different topographic and socio-economic framework conditions.

According to the criteria set and by approval of the projects´ advisory board Gleisdorf in Styria, the neighbouring municipalities of Altenmarkt in Pongau and Flachau in Salzburg and Perg in Upper Austria were selected as case study areas. From the viewpoint of hazard exposure Gleisdorf represents a district town close to an urban agglomeration with a very good connection to high-ranking traffic infrastructure and thus very favourable conditions for industrial and commercial development. Development potential within the municipal area, however, is limited. Altenmarkt im Pongau/Flachau is an alpine case study with limited land resources suitable for housing and commercial development. Besides that tourism is an important economic factor. Both municipalities were selected because of jointly realized flood protection measures. Perg is a case study in the wider agglomeration zone of Linz with a dynamic population development and extensive land

resources for housing and commercial development, many of them potentially endangered by extreme flood events.

The risk assessment on micro scale has been accomplished for the three case study regions. The detailed results of the hazard assessment with hydrodynamic models, the exposure and sensitivity assessment, as well as the adaptive capacities have been used to estimate the current and future risk. Risk is defined as the integral of the product of hazard and vulnerability over the flood recurrence intervals. Scenarios were generated to detect changes of risk in future. A Scenario for changes in hazard, exposition, hazard and exposition, as well as a scenario without any changes were created. The estimation of the total risk would require a series of expected damages for floods with determined recurrence interval. This information however is only available for HQ_{100} and HQ_{300} floods. Consequently the risk assessment was realized by evaluating the future changes in risk compared to the status quo. The change of risk was quantified by the change of damage potential at HQ_{100} and HQ_{300} as well as by the change of the annual expected damages provoked by inundations with a recurrence interval higher than 100 years. The evaluation allowed to identify risk drivers and to better estimate the adaptive capacities. The results served as an input for the discussions in the workshops and helped to develop the adaptation and mitigation strategies in the affected regions.

In **WP 6** a stakeholder-workshop was conducted in each case study (Altenmarkt and Flachau, Gleisdorf, Perg). The task of the workshops was to discuss the assessment and management of current and future flood risks. The workshops more precisely aimed at i) reflecting determinants of risk based on different scenarios (maps), ii) identifying/verifying local context conditions and preexisting policy processes, and iii) developing and prioritizing adaptive measures for extreme flooding scenarios.

In preparation of the case study workshops, we interviewed local and regional stakeholders from the field of policy-making, public administration and emergency response to acquire further information regarding, e.g., flood protection infrastructure, the level of flood preparedness or current measures or risk-awareness. These inputs of local context conditions were used to define the thematic focus and the process design for the case study workshops. The interviews were also used to sensitize and mobilize stakeholders for the workshops.

The workshops were moderated, lasted for four hours and consisted of presentation, brainstorming, discussion and deliberation components. The basic communicative rule was that every stakeholder must have a say and that all opinions and perceptions must be tabled. The workshop participants consisted of fourteen stakeholders in Gleisdorf and Perg and twelve stakeholders in Altenmarkt im Pongau/Flachau (a complete list of all participating stakeholders can be found in the annex). The representatives mostly come from the municipal political sphere, local and regional public administration, planning offices and emergency services. Upon the mayor's request, neither the general public nor all stakeholders with a tentative interest in the subject (e.g., representatives from the business community, civil society or individuals affected by flooding) were invited. It was perceived that the workshops should be manageable in terms of size, resources and duration and that – given the uncertainties related to future flood risk dynamics – non-specialists and laypersons might prevent an open debate of long-term flood management options. Five researchers from the RiskAdapt team completed the group of workshop participants.

To stimulate discussion, the workshops began with a presentation of the quantifiable results of the flood risk assessment. This scientific input was delivered in an interactive setting via plotted maps and aimed at providing an impetus for the discussion and development of adaptation measures in a World Café setting. Based on the cycle of flood risk management, the discussion was grouped into three roundtables (with three to five representatives) each having a different focal point: structural measures of flood protection; planning measures of flood prevention; and coping measures to increase flood preparedness.

One researcher from the RiskAdapt team moderated each table. The moderator's task was to guide the discussion, stimulate debate and sum up all contributions. After twenty minutes of discussion, each participant moved to a new table. The idea behind the World Café is that the participants

have enough time to speak and listen in a non-hierarchical setting. Ideas and opinions should move and develop from table to table so that at the end everyone has contributed to each topic. The participants were encouraged to establish their own views and visions on the issue of anticipatory flood risk management and were asked to select elements and parts of the scenarios that seemed reasonable to them.

At the end of the World Café, all adaptive measures from the roundtable discussions were presented by the moderators in the plenum. In a next step, the participants prioritized the different measures and activities according to their own preferences. Each workshop participant could assign six priority points on a flipchart on which all the measures discussed in the World Café were tabled. A weighting of priority dots was possible (e.g., workshop participants could assign six points to six different measures or award individual measures with more points). Finally, a questionnaire was distributed to all workshop participants. The aim of the survey was to provide insights with regard to how the workshop participants assessed the suitability of the workshop format, the relevance of the topic for local decision-making processes and the plausibility of the presented scenarios. The findings on the stakeholders' perception are based on questionnaires in which workshop participants were asked to comment whether certain statements apply (1) or do not apply (6).

b) Description of the results and project milestones

WP1: Hazard assessment

WP 1 provided an in-depth account of flood hazards in Austria under climate change scenarios. The results of WP 1 are published in:

- Nachtnebel, H. P. & Apperl, B. (2015): Beurteilung des Hochwasser-Schadenspotenzials unter dynamischen Bedingungen. Österreichische Wasser- und Abfallwirtschaft, 67(3-4), 120–130. doi:10.1007/s00506-015-0220-4
- Nachtnebel, H.P.; Schulz, K.; Apperl, B.; Herrnegger, M.; Senoner, T. (2015): HORA-HQCC -Dokumentation. BOKU -IWHW

The following table provides an overview of the milestones (M) and deliverables (D) within WP1:

Task	Description	Status
M1	data collection for hazard assessment	completed
M5	estimation of inundation areas under climate change scenarios	completed
D2	shape files of flood scenarios for the current state and under climate change scenarios for Austria	completed
M12	data collection for hydrodynamic models	completed
M14	model runs completed	completed
D7	report and maps of inundation areas as the basis for micro scale risk assessment	completed

The proposed methodology on macro scale allows the assessment of changes in flood runoff on inundated areas on the basis of existing flood maps, without additional hydrodynamic simulations. The macro-scale assessment is a good indicator to identify municipalities, which are sensitive to changes in flood runoff. For Austria following conclusion were reached:

- Generally the municipalities with relative flat topography are more sensitive to changes
- For over 69% of the municipalities changes are however very low to low
- 25% of the municipalities are classified with a high change in future hazard.

On micro scale the potential impact climate change on the inundation areas are different for the three case studies. In mountainous regions the changes in inundation areas are quite low, whereas

increases in the inundation depth are observed. In plains the increase of inundation depth is minimal. However climate changes scenarios provoke an increase of the inundation area characterized by low inundation depths. Special attention must be given on technical flood protection. In Altenmarkt-Flachau and Gleisdorf retention basins serve as protection against HQ_{100} floods. In case of climate related changes of the HQ_{100} discharge, the adopted discharge HQ_{100+CC} might exceed the design event and the flood protection fails. This can provoke a vast increase of the inundation areas.

WP2: Exposure Assessment

The aim of WP2 was the assessment of current and future flood hazards on a macro-scale (for all Austrian municipalities) as well as on a local scale (for three selected case studies). The results of WP 2 are published in:

- Seher, W. and Löschner, L. (2015): Vertical and Horizontal Risk-Sharing in Flood-Related Planning: Coping with Climate Change Related Uncertainties. In: Hepperle, E.; Dixon-Gough, R.; Kalbro, T., Mansberger, R. (Eds.), Governance Structures in Land Management, vdf Hochschulverlag AG, Zürich, pp. 301-310.
- Seher, W. and Löschner, L. (forthcoming): Settlement dynamics in floodplains: from assessing future flood hazard exposure to developing spatial adaptation measures [full paper at 13th Congress Interpraevent 2016; submission by Sept 2015).

The following table indicates the status of the milestones (M) and deliverables (D) within WP2:

Task	Description	Status
M2	data collection for exposure assessment	Completed
M4	qualitative assessment of current exposure	Completed
M6	qualitative assessment of future exposure	Completed
M11	data collection and expert interviews in case study areas	Completed
M13	exposure assessment for case study areas	Completed
D2	report and shape files of clustered current and future exposure for all municipalities in Austria	Completed
D8	report and shape files of current and future exposure in 3 case study areas	Completed

Findings from the *macro-scale exposure assessment* (for all municipalities in Austria) indicate the following for current flood hazard exposure in Austria:

- in absolute terms (number of people in 200-year flooding areas), densely populated areas (i.e. urban and economic centers as well as alpine municipalities in tourism regions) have the highest current exposure to flood hazards;
- in relative terms (number of potentially affected persons in relation to total population), there is a greater variety in current flood hazard exposure, as not all urban areas are highly exposed to flood hazards (e.g. Vienna is only marginally exposed) while some rural municipalities have a large share of potentially affected persons in hazard zones.

As future flood hazard exposure was assessed based on a function of current exposure and expected changes in population (until the year 2030) findings indicate that:

- in absolute terms (see above) all municipalities with a high current exposure and a high population growth can expect high levels of flood future hazard exposure (i.e. in general dynamic urban and peri-urban municipalities);
- in relative terms (see above) fast-growing cities (such as Graz or Salzburg) as well as dynamic and densely populated alpine and tourism regions can expect high levels of flood hazard exposure in the year 2030.

The results of the macro-scale flood hazard assessment were a key input for the macro-scale risk assessment and the selection of the three case studies (see WP5).

On the *local scale*, *flood hazard exposure* was assessed for Gleisdorf (Styria), Altenmarkt im Pongau and Flachau (Salzburg) and Perg (Upper Austria). Regarding current flood hazard exposure, the local assessments indicate the following:

- the three municipalities are exposed to different degrees to 100-year floods. Gleisdorf and Altenmarkt im Pongau/Flachau are only marginally exposed due to expansive flood protection schemes whereas Perg has a large number of residents and buildings in 100-year flooding zones;
- in 300-year flood events all case studies have a high exposure to flood hazards, however the degree of exposure varies according to the type of buildings affected. In Gleisdorf, predominantly large-scale commercial and industrial buildings are affected, while in Altenmarkt im Pongau/Flachau and Perg mainly residential buildings are located in 300-year flooding zones;
- in both 100- and 300-year flood events the climate change allowance significantly increases flood hazard exposure in the selected cases. As flood protection schemes are usually designed for a 100-year flood, a 10% increase in peak discharge would lead to a sharp increase in the number of affected buildings and persons, especially in Gleisdorf and Perg.
- for the assessment of future hazard exposure, a settlement scenario was generated, mapped and combined with the current levels of exposure. As all case studies can expect high population and economic growth until the year 2030 they each face an increase in flood hazard exposure. However, the different levels in increase indicate that
- increases in flood hazard exposure are to a large extent determined by the kind of building land (residential, commercial etc.) displayed in the zoning plans;
- the supply of building land (i.e. vacant lots and development areas) in floodplains is a key driver of future flood hazard exposure;
- "context matters", i.e. that flood-related options in spatial planning are strongly influenced by topographic conditions (e.g. the amount of land suitable and available for permanent settlement).

WP3: Sensitivity assessment

The milestones and results M7 and D3 have been accomplished and completed successfully. The comprehensive documentation is attached (see work package documentation, part 1 macro scale). On micro scale the milestone and results M15 und D8 have been accomplished and completed successfully. M15 covers the assignment of damage functions to building categories. The final report (D8) describes the micro scale sensitivity assessment under consideration of case study specific land use and population characteristics (see Work package documentation). The following table provides an overview of the fulfilment of milestones (M) and deliverables (D) within WP3:

Task	Description	Status
M7	definition of quantitative sensitivity indexes based on ex-post and ex-ante analyses (national & international literature)	completed
D3	working paper on how to assess sensitivity on a macro scale in Austria	completed
M15	assignment of damage functions to building categories	completed
D8	working paper on micro scale sensitivity assessment under consideration of case study specific land use and population scenarios	completed

The results of WP3 served as a fundamental basis for the risk assessment in WP 5.

WP4: Adaptive capacities

WP 4 provided an in-depth account of flood-related adaptive capacities at national, provincial and local level, and analyzed their development between 2002 and 2012. The results of WP4 are published in:

- Nordbeck, Ralf (2014): Climate change and adaptive flood risk management: the development of adaptive capacities in Austria (2002-2012). InFER Discussion Paper 2-2014 (in German).

The following table provides an overview of milestones (M) and deliverables (D) within WP4:

Task	Description	Status
M3	Elaborated conceptual framework for a national scale assessment	Completed
M8	National scale document analysis and interviews	Completed
D4	Working paper on national scale adaptive capacity	Completed
M10	Local scale interview guideline	Completed
M16	Local scale document analysis and interviews	Completed

The analysis of flood-related adaptive capacities between 2002 and 2012 shows that important changes took place at the federal and provincial level to increase and mobilize the necessary adaptive capacities, and that those changes help to develop an anticipatory flood risk management in the future. In more detail, the analysis revealed the following changes and developments:

- *Financial capital:* The investments made to protect against floods have risen in the last decade, mainly driven by the flood events in 2002, 2005 and 2013. The total investment for flood protection through federal, provincial and municipal authorities is currently around 320 million euro per year, distributed among the competent public organizations: the Federal Water Engineering Administration (BWV: 140 mill. Euro), the Forest Engineering Service on Torrent and Avalanche Control (WLV: 90 mill. Euro), and the Federal Waterways Authority (80 mill. Euro). In the next five years the total annual investment for flood protection will rise to approximately 450 million.
- *Institutional capacities:* several amendments of laws and regulations governing flood protection and regulating the financing of flood protection measures have been adopted since 2002. These changes in the legal base are mainly driven by the domestic implementation of the EU directive on the assessment and management of flood risks (EU/2007/60). Altogether, the new EU floods directive is considered as a big step forward, implementing a new paradigm of flood risk management. In addition, a new regulation for hazard zone plans was adopted. At the provincial level, amendments to spatial planning laws were adopted in several, but not all provinces to improve the coordination between flood protection and spatial planning.
- *Knowledge and Information*: The new EU floods directive has introduced several new informational instruments such as the preliminary risk assessment and the flood hazard and risk maps that might help to improve the knowledge and informational base for decision-makers, public authorities and interested groups concerned with flood risk management. In addition, further information on flood risks is available for the general public through several websites such as eHORA.
- *Political capital (Coordination and Participation):* The issue network is composed of public administrators, scientists, interest groups and non-governmental organizations. The network is clearly dominated by state representatives. Two important bodies for vertical coordination exist: (1) the Working Group "Floodwater" comprises around 60 members of

different public authorities at the federal and provincial level, and (2) the "Round Table Water", which also includes interest groups and NGOs. The working group is the main coordination body for decision-makers concerning flood risk policies, whereas the round table deals with all water-related problems, i.e. flood protection is just one among many important issues. Participation of societal groups mainly takes place in form of information and consultation. At the sub-national level, experiences with new forms of broader public participation were made through so-called "Water Dialogues" in four provinces.

The assessment of adaptive capacities in the three selected local communities confirmed the general conclusions, but highlighted also some differences in the development of adaptive capacities:

- The institutional capacities have been improved significantly since 2002. The legal framework has been amended and offers now more incentives for preventive flood protection. The reforms of spatial planning laws and building regulations at the provincial level created the legal framework for a better integration between flood protection and spatial planning.
- The horizontal coordination between the various decision-makers in the municipality (mayor, head of building authority, fire department, etc.) runs well in all three communities. The vertical coordination with authorities at the regional level works also well, although there have been occasional coordination problems and the municipalities would like to see more support from regional authorities in the often complicated negotiations with landowners. However, the horizontal and vertical coordination is often ad hoc and bilateral, and depends highly on personal relationships rather than on institutionalized forms of co-ordination such as risk management committees.
- All three communities could afford to pay their share of the investment costs for flood protection measures without any problems. The municipal investments in flood protection measures are correspondingly high and in two of the three municipalities the costs are significantly above the current provincial average.
- Information capacities are generally higher nowadays due to the increased use of preventive planning instruments and publicly available information. Nevertheless, the extent in which informational instruments have been used by the three municipalities varies widely. The active involvement of landowners in the planning process however has become the rule, in particular to identify problems and objections from local stakeholders and to solve these issues at an early stage.
- The openness to discuss future developments and related flood risks also varied considerably between the three communities. In two of the three communities, the debate is very focused on present times and revolves exclusively around the implementation of already planned flood protection measures in the near future. A forward-looking perspective on future flood risks caused by climate change and urban development is missing in these communities.

WP5: Risk assessment

In WP 5, a dynamic risk assessment approach was applied considering the temporal developments of both aspects of risk – hazard (WP1) and vulnerability (WP2-4). Accordingly, WP 5 includes the assessment of current and future risk (for the year 2030) on a macroscale (for all Austrian municipalities) as well as on a local scale (for selected case study municipalities). The results of WP5 are published in:

- Löschner, L., Herrnegger, M., Apperl, B. and Seher, W. (forthcoming): Flood risk dynamics: Assessing the sensitivity of future flood risk to climate change and settlement development (planned submission, Regional Environmental Change)

- Nachtnebel, H. P., & Apperl, B. (2015). Beurteilung des Hochwasser-Schadenspotenzials unter dynamischen Bedingungen. Österreichische Wasser- und Abfallwirtschaft, 67(3-4), 120–130. doi:10.1007/s00506-015-0220-4

The following table provides an overview of the final status of the milestones (M) and deliverables (D) within WP 5:

Task	Description	Status
M9	qualitative risk assessment based on risk categories (low-high)	completed
D5	shape files illustrating the dynamic flood risk under consideration of spatio-temporal variability and climate change scenarios	completed
AB M1	Advisory Board: Discussion of draft report "Macro Scale"	completed
M17-19	quantitative micro-scale risk assessment for case studies 1-3	completed
AB M2	Advisory Board: Discussion of draft reports "Micro Scale – case studies"	completed
D10-12	report micro scale risk assessment for 3 case studies	completed

According to the evaluation of the current flood risk, regional centers, such as Salzburg, as well as densely populated alpine valley areas with limited permanent settlement, for example, the Tyrolean Inn Valley, show an increased flood risk. The results for future flood risk show that communities with a high share of potential flood plains and high population dynamics have to cope with an increasing flood risk. This is mostly expectable to urban-rural communities in the lowlands and growing communities in alpine valley areas. Detailed results and shape files illustrating the dynamic flood risk under consideration of spatio-temporal variability and climate change scenarios (D5) can be found in the annex.

On micro-scale the results of the risk assessment were quite different. While in the mountainous region of Altenmarkt im PongauFlachau the change of risk is mainly provoked by land use changes, in plain regions, such as Gleisdorf and Perg, climate change induced increases of risk are dominating. The increase of the annual expected damages varies in the three case studies between 45 and 450%. Special attention was given to residual risk areas. The residual risk is defined as the remaining part of the risk after implementing a protection system. The residual risk covers the accepted risk, the unknown risk and the risk due to false judgement or inadequate countermeasures and decisions (Faber, 2006). Changes in hazard might provoke, that technical flood protection measures do not work properly until the calculated design event. Consequently areas, which are currently protected against a HQ_{100} event might get flooded by aHQ_{100+CC} event in future. Hence the housing in residual risk areas should be discouraged. Detailed results and conclusions can be found in the final report of WP5 in the annex.

WP6: Local adaptation policy assessment (Stakeholder workshops)

WP 6 used the knowledge and insights from WP1 to WP4 and especially the synthesis of the risk assessments of WP5 as the scientific input and stimuli for a localised discussion about the potential drivers, mechanisms, context conditions and processes of anticipatory flood risk management under climate change scenarios. The results of WP6 focusing on the case studies Altenmarkt im Pongau/Flachau and Gleisdorf are published in:

- Löschner, L., Nordbeck, R., Scherhaufer, P. and Seher, W. (forthcoming): Scientist-stakeholder workshops: a collaborative approach for integrating science and decision-making in Austrian flood-prone municipalities, Environmental Science and Policy.

The following table provides an overview of the final status of the milestones (M) and deliverables (D) within WP 6:

Task	Description	Status
M20-22	Testing an integrated approach to enhance the quality of information about the contextual conditions, barriers and drivers for anticipatory flood risk management and deepening the understanding of the likely impacts and vulnerabilities and resulting adaptation options	completed
AB M3	Advisory Board: Discussion and validation of all six draft final reports	completed
D13	Report on adaptation policy assessments 1-3: findings and synthesis which aims at reducing the overall flood risk; conclusions on transferability of the integrated approach to other highly vulnerable communities	completed

One aim of the workshops was to reflect determinants of risk with regard to local context conditions. The workshops showed that the workshop participants' perception of flood risk did not fully correlate with the science-based assessment of future changes in flood risk. The scientific flood risk assessment indicates that both climatic change and settlement growth increase the risk of flooding (albeit to different degrees) in the case study areas by the year 2030. In Altenmarkt e.g., the expected annual losses would increase by +200% in the settlement growth scenario (relative to current flood damage), whereas climate change would lead to a +150% increase. In Gleisdorf, on the other hand, climate change would lead to a stronger increase in annual loss (+75%) than the settlement growth scenario (+5%). While the Altenmarkt workshop participants' perception of flood risk mirrors the scientific assessment, the Gleisdorf stakeholders' views (as expressed in the questionnaires) seem to contradict the science-based findings in that climate change is estimated to have a lesser impact on future flood risk than settlement development.

In addition to the plausibility-check of the science-based flood risk assessment, a key aim of the workshops was to develop prioritized flood adaptation measures. In the annex a summary of all measures for the fields of flood protection (i.e., structural measures), flood prevention (i.e., spatial planning measures) and flood preparedness (i.e., coping measures) is tabled.

Regarding the tentative implementation of the proposed measures in a subsequent policy process, there is a strong demand for horizontal coordination between different policy sectors. Whereas some measures may be implemented within specific policy domains (e.g., local land use planning) several of the proposed measures, such as the construction of retention basins or the formation of water boards, would require coordinated approaches, particularly between planning and water management authorities. The strong municipal leverage to implement many of the proposed measures suggests that the workshops were able to provide a substantial impetus for anticipatory adaptation in Austrian flood-prone municipalities. This is confirmed by the workshop participants, who reported that the workshop results are useful (Altenmarkt im Pongau/Flachau: 2.08; Gleisdorf: 2.45; Perg: 2.31) - and that the proposed measures are able to reduce the future risk of flooding (Altenmarkt im Pongau/Flachau: 1.92; Gleisdorf: 2.18; Perg: 1.92).

Aside from substantive, policy-relevant results, the workshops also generated less tangible outcomes related to the workshops' procedural dimension and the applied method of linking knowledge domains. In the case studies, the workshop assembled stakeholders from different policy fields and levels of government who do not usually exchange knowledge, share experiences or voice opinions in a comparable setting. The analysis of the questionnaires shows that the number and composition of the workshop participants was overwhelmingly considered to be adequate (Altenmarkt im Pongau/Flachau: 1.33; Gleisdorf: 1.83; Perg: 1.77). In all workshops, however, the participants indicated that they would have appreciated the inclusion of non-state actors, especially potentially affected people and representatives of civil society and of the commercial sector.

The format of the workshops, i.e., the mix of scientific input, discussion and the opportunity to voice opinions, was considered to be well-balanced (Altenmarkt im Pongau/Flachau: 1.36; Gleisdorf: 1.27; Perg: 1.62). Most stakeholders felt that their opinion and expertise was valued in

the workshops. Regarding the results of the workshops, the participants considered that the following three aims were achieved: i) the sensitization of the workshop participants for the anticipatory management of flood risks, ii) the appreciation of cross-sectoral problems, and iii) the provision of a basis for developing adaptive measures. Finally, the stakeholders found that they were able to expand their knowledge of flood risk management over the course of the workshop (Altenmarkt im Pongau/Flachau: 2.08; Gleisdorf: 2.45; Perg: 2.00).

5 Schlussfolgerungen und Empfehlungen

The macro-scale risk assessment was completed for the current and future risk of flooding. The future flood risk (for the year 2030) was assessed on the basis of a set of criteria (current level of flood risk, expected changes in flood hazard, expected changes in flood exposure) for all Austrian municipalities. Findings show that current flood risk is particularly high in alpine valleys with intensive land uses and future changes in flood risk (due to climate change and land use change) can be expected in particular along the Danube and its large tributaries. In sum, about three in ten Austrian municipalities face a future increase in flood risk, and about 18% of Austrian all municipalities can expect very high future flood risk. The results indicate a strong need for flood prevention and flood protection measures, in particular in alpine valleys with high settlement dynamics. Alongside large rivers, specifically along the Danube, a comprehensive management of flood risk should be developed including the consideration of the likely climate change impacts in local and regional land use plans.

From the micro-scale risk assessment of the Austrian case studies, the following **general conclusion** can be drawn:

- Due to settlement development flood hazard will increase with varying degrees in 100-year flooding areas until the year 2030. In Gleisdorf, flood hazard will remain low (three buildings with a total of 420m^2 flooded) because no new buildings are expected to be developed in flood hazard areas. Altenmarkt, on the other hand, faces a substantially higher future flood hazard (25 buildings/9,400m^2) in the year 2030. As current levels of flood hazard are low, future flood hazard is mainly due to land development in 100-year flooding areas. Perg, finally, faces the highest absolute level of flood risk (184 buildings/42,370m2) in the year 2030. This is mainly due to high current flood hazard and exposure, whereas the influence of settlement dynamics in 100-year flooding areas is relatively small (15 buildings/2,500m^2).
- Flood hazard is expected to increase in areas of residual risk (>HQ100) across the examined case studies: The increase in flood hazard is particularly strong in areas of residual flood risk in Altenmarkt, which faces a 58% increase in the affected building area (+11,300m2) in a 300-year flood event. In Gleisdorf and Perg, the expected increase in flood hazard is similarly high in absolute terms (+10.500m2 respectively +9.400m2), but comparatively small in relative terms (+11% resp. +9%).
- The type of building land allocated in flooding areas significantly affects future levels of flood exposure: From the average area of buildings affected in future flood events one can differentiate the type of settlement developments pursued in the respective case studies. Accordingly, the large average expected area of new buildings in Gleisdorf (ca. 1,050m^2 per building) suggests that predominately large-scale commercial or industrial buildings will be realised in the respective zoning areas. In Perg, on the other hand, small average building areas (around 190m^2) suggest that the focus of future settlement development will be placed on residential buildings. In Altenmarkt, finally, a medium-sized average building area (ca. 390m^2) indicates that both residential and commercial/industrial buildings will be developed in the respective zoning areas displayed in the local land use plans.
- The availability of suitable building land is a key driver of flood exposure: All case studies exhibit high socio-economic and land use dynamics with correspondingly strong demand for building land. The municipalities, however, dispose of different options for steering settlement

developments due to differences in building land reserves (i.e. supply of building land) as well as topographic conditions (i.e. share of area suitable for permanent settlement). With a large amount of building land reserves Perg, accordingly, has the possibility to provide alternative (i.e. flood safe) locations to companies currently exposed to flood hazard and thus pursue multiple focuses in the city's settlement development. On the other hand, Altenmarkt's settlement development options are significantly constrained by the alpine topography and the lack of area suitable for permanent settlement. Because its building reserves are nearly depleted Altenmarkt faces the challenge of developing residential, commercial and other (highly vulnerable) land uses in the alpine valley while keeping flood risk as low as possible. In Gleisdorf, building land reserves are equally scarce, however, not for topographic reasons, but because most of the unbuilt building land is privately owned and thus only at a limited disposal for settlement development.

- The potentially climate-change induced increase in flood discharge may significantly increase the risk of flooding and the yearly expected flood damage: In particular in areas of residual flood risk land uses may become more vulnerable to flood hazards following the likely exceedance of the design levels of existing flood protection infrastructure. We thus recommend to take potential climate change effects into consideration when developing flood protection schemes and to keep areas of residual flood risk free from vulnerable land uses. If this is not possible we recommend promoting structural measures for potentially affected buildings in order to minimize individual flood damage potentials.
- The analysis shows that (with the exception of area of residual flood risk) the potential changes in flood hazard often lead to a small increase in flood depth. In such areas strengthening flood risk awareness and promoting individual responsibility as well as personal provision for future flood risks can substantially decrease potential flood damage on the scale of individual buildings.
- Finally, adaptive capacities could be strengthened through the adoption of a national flood protection program as strategic policy framework and the establishment of a "National Platform for Flood Protection" as a public forum for risk dialogue and awareness-building. Its members should consist of public officials, scientific experts, and representatives from business associations and non-governmental organizations.

C) Projektdetails

6 Methodik

The conceptual framework of RiskAdapt aimed at integrating the analytical perspectives of hazard and vulnerability assessment, the latter comprising the analyses of exposure, sensitivity and adaptive capacities. Accordingly, it started with hazard and impact assessment but then broadened the analyses to an extended understanding of vulnerability, where vulnerability is not only considered as a linear result of changing biophysical conditions and a few quantifiable non-climatic factors, but also as effectuated by dynamic contextual conditions deriving from socio-economic, institutional (political) and technological structures and changes. The framework was, furthermore, based on the idea that different assessment approaches are tied to different interpretations of vulnerability and, therefore, produce different types of knowledge and adaptive policies. We proceed on the assumption that both vulnerability and adaptation policy assessment are needed in order to combine the various levels of governance (spatial scales) and, most importantly, to make a scientific input applicable and useful to concrete local contexts.

The methodological approach of RiskAdapt was based on:

- ✓ *Two spatial scales - macro scale (federal territory of Austria) and micro scale (3 regional/local case studies).*
- ✓ *Two temporal scales – the current state and the development of land use and population until 2030.*
- ✓ *Two hydrologic scenarios for the current state- HQ100 and HQ300.*
- ✓ *Two hydrologic scenarios considering a climate change allowance –HQ100 and HQ300 increased by +10% in peak discharge.*

In WP1 we dealt with the assessment of hazard, which is represented by current fluvial floods and under consideration of potential climate change impacts on flood magnitudes. The hazard assessment in WP1 was performed for (1) a national, macro-scale level and (2) a regional to local or micro-scale level (three selected case studies – Altenmarkt im Pongau/Flachau, Gleisdorf, Perg). To account for changes in hazard due to potential climate change impacts on flood magnitudes the HORA-HQ200 flood runoff values were increased. In the application, an increase of +10 % was proposed. For Austria following conclusion were reached: (i) Generally the municipalities with relative flat topography are more sensitive to changes; (ii) for over 69% of the municipalities changes are however very low to low; (iii) 25% of the municipalities are classified with a high change in future hazard. On micro scale the potential impact climate change on the inundation areas are different for the three case studies. In mountainous regions the changes in inundation areas are quite low, whereas increases in the inundation depth are observed. In plains the increase of inundation depth is minimal. However climate changes scenarios provoke an increase of the inundation area characterized by low inundation depths.

In WP2 we assessed the current and future exposure to flood hazards also on a macro-scale as well as on a local scale. Findings from the macro-scale exposure assessment show that in absolute terms (number of people in 200-year flooding areas) densely populated areas (i.e. urban and economic centers as well as alpine municipalities in tourism regions) have the highest current exposure to flood hazards. In 2030 all municipalities with a high current exposure and a high population growth can expect high levels of flood future hazard exposure (i.e. in general dynamic urban and peri-urban municipalities). In particular fast-growing cities (such as Graz or Salzburg) as well as dynamic and densely populated alpine and tourism regions can expect high levels of flood exposure. The local assessments indicate that Gleisdorf and Altenmarkt im Pongau/Flachau are only marginally exposed due to expansive flood protection schemes whereas Perg has a large number of residents and buildings in 100-year flooding zones. However, the climate change allowance significantly increases flood exposure in the selected cases.

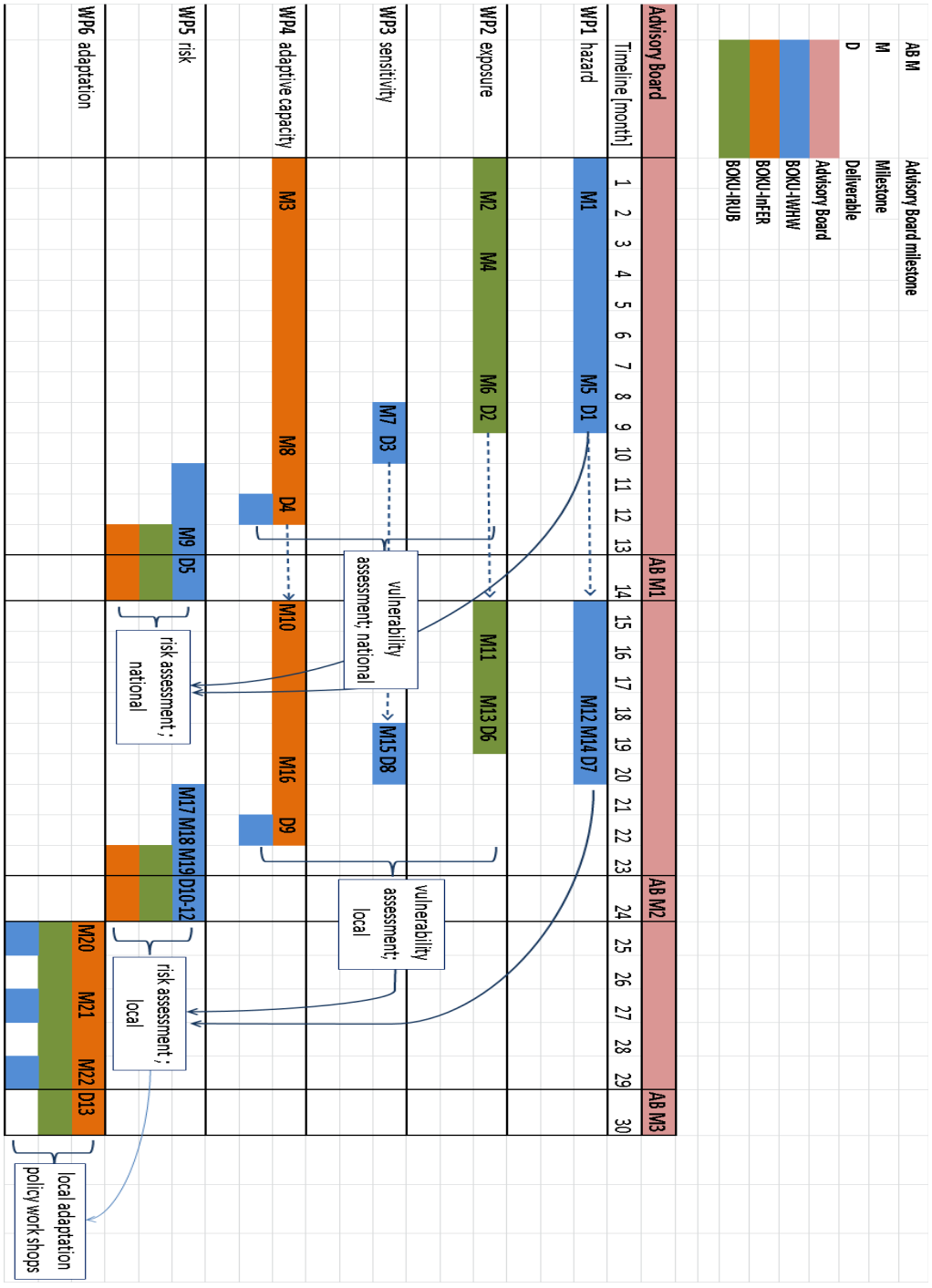
In WP3 we assigned damage functions to different utilisations to enable an overall flood risk assessment. A methodology for the analysis of sensitivity in the context of flood risk has been developed on the macro-scale level as well as on the micro scale level. On a macro scale level sensitivity has been defined as the dimension of changes in risk of a municipality due to changes in hazard and land-use. On micro scale, sensitivity has been defined as the susceptibility of single objects on flood events, expressed in monetary values. Therefore appropriate damage functions have been allocated to different object categories in the three selected municipalities.

In WP4 we build upon a literature review, desk research and 45 expert interviews to assess the development of flood-related adaptive capacities at the national, provincial and local level since 2002. The macro-scale assessment showed the progress made in terms of increasing institutional, financial, political and informational capacities. The case studies confirmed the general conclusions in the three selected communities, but highlighted also some differences in the development of adaptive capacities at the local level.

A dynamic risk assessment approach was applied in WP5 considering the temporal developments of both aspects of risk – hazard (WP1) and vulnerability (WP2-4). Accordingly, WP 5 includes the assessment of current and future risk (for the year 2030) on a macro-scale as well as on a local scale. The results for future flood risk show that communities with a high share of potential flood plains and high population dynamics have to cope with an increasing flood risk. This is mostly expectable to urban-rural communities in the lowlands and growing communities in alpine valley areas.

In WP 6 a stakeholder-workshop was conducted in each case study region. The task of the workshops was to discuss the assessment and management of current and future flood risks. The workshops more precisely aimed at i) reflecting determinants of risk based on different scenarios (maps), ii) identifying/verifying local context conditions and preexisting policy processes, and iii) developing and prioritizing adaptive measures for extreme flooding scenarios.

7 Arbeits- und Zeitplan



8 Publikationen und Disseminierungsaktivitäten

As outlined in the project proposal, the main channels of dissemination and utilization were stakeholder workshops, academic publications, conference presentations, and teaching classes at BOKU University.

Project Workshops

One important channel of dissemination and utilization were local stakeholder workshops in three selected municipalities addressing decision-makers and interest groups from the provincial, regional and local level. In total 40 people attended the three workshops and discussed the project findings and potential adaptation measures with the project team. The results of the stakeholder workshops were distributed among the participants and beyond. Minutes of all three stakeholder workshops conducted in Altenmarkt im Pongau/Flachau, Gleisdorf and Perg can be found in the annex.

Publications (6 journal articles planned: 3 realised, 1 under review, 2 more in preparation)

WP	Papers actually published/submitted	Papers planned
1	Nachtnebel, H.-P., Apperl, B. (2015) Assessment of flood risk damage in Austria (in German) ("ÖWAW")	
2	Seher, W., Löschner, L. (2015): Vertical and Horizontal Risk-Sharing in Flood-Related Planning: Coping with Climate Change Related Uncertainties (book chapter)	Seher, W., Löschner, L. (2016): Settlement dynamics in floodplains (full paper submission to Interpraevent 2016)
4	Nordbeck, R. (2015): Development of flood-related adaptive capacities in Austria (in German) ("Austrian Journal of Political Science - currently under review)	
5		Löschner, L., Herrnegger, M., Apperl, B., Seher, W. (2015/16): Flood risk dynamics (submission to "Regional Environmental Change")
6	Löschner, L., Nordbeck, R., Scherhaufer, P. and Seher, W. (2015): Scientist-Stakeholder Workshops ("Environmental Policy & Science")	

Löschner, L., Nordbeck, R., Scherhaufer, P. and Seher, W. (2015): Scientists-stakeholder workshops: an integrated assessment of flood risk and an evaluation of local response options. In: Environmental Science & Policy (in press, available online 20 August 2015)

Seher, W. and Löschner, L. (2015): Vertical and Horizontal Risk-Sharing in Flood-Related Planning: Coping with Climate Change Related Uncertainties. In: Hepperle, E.; Dixon-Gough, R.; Kalbro, T., Mansberger, R. (Eds.), Governance Structures in Land Management, vdf Hochschulverlag AG, Zürich, pp. 301-310.

Nachtnebel, H. P., Apperl, B. (2015): Beurteilung des Hochwasser-Schadenspotenzials unter dynamischen Bedingungen. Österreichische Wasser- und Abfallwirtschaft, 67 (3-4), 120–130.

Löschner, L.; Thaler, T.; Seher, W. (2014): Tracing the 'Spatial Turn' in Flood Risk Management: a Co-Evolutionary Perspective on Policy Change. In: AESOP (Ed.), AESOP Annual Congress: From Control to Co-Evolution. eBook of Abstracts

Seher, W., Löschner, L., Ronacher, M. (2014): Integrating spatio-temporal dynamics: Towards an anticipatory assessment of hazard exposure. In: AESOP (Ed.), AESOP Annual Congress: From control to co-evolution, eBook of Abstracts.

Apperl, B.; Herrnegger, M.; Hogl, K.; Löschner, L.; Nachtnebel, H.-P.; Neuhold, C.; Nordbeck, R.; Seher, W.; Senoner, T. (2014): Antizipative Bewertung von Hochwasserrisiken unter

Berücksichtigung von Veränderungen des Gefahrenpotentials und der Vulnerabilität. In: Climate Change Centre Austria CCCA (Hrsg.), Tagungsband 15. Klimatag

Löschner, L. (2013): Communicating Risks and Uncertainties in Flood-Related Planning: Towards Resilient Flood-Prone Regions. In: AESOP Young Academics (Ed.), RESILIENCE - Rethinking sustainability in urban planning and rural development from a social, ecological and economic perspective, Book of Abstracts.

Löschner, L.; Seher, W. (2013): Assessing current and future exposure to flood hazards – proceedings of the project RiskAdapt. In: European Geosciences Union (Ed.), Geophysical Research Abstracts, Vol. 15.

Seher, W.; Löschner, L. (2013): Flood risk governance - a framework for coping with climate change related uncertainties? In: Association of Collegiate Schools of Planning (Eds.), AESOP / ACSP 5th Joint Congress. Planning for resilient cities and regions. eBook of Abstracts.

Apperl, B.; Hernegger, M.; Hogl, K.; Löschner, L.; Nachtnebel, H.-P.; Neuhold, C.; Nordbeck, R.; Seher, W.; Senoner, T. (2013): RiskAdapt: Antizipatorisches Hochwasserrisikomanagement – Von der Bewertung des Hochwasserrisikos bis zur Anpassungsstrategie. In: Climate Change Centre Austria CCCA (Hrsg.), Tagungsband 14. Österreichischer Klimatag. Klimawandel, Auswirkungen und Anpassung sowie Vermeidung.

Apperl, B.; Hogl, K.; Löschner, L.; Nachnebel, H.-P.; Neuhold, C.; Nordbeck, R.; Seher, W., Senoner, T. (2013): RiskAdapt: Vorausschauendes Hochwasserriskomanagement unter Berücksichtigung von Klimawandel Szenarien: Von der Risikobewertung zur Klimawandelanpassung. In: Umweltbundesamt (2013): Klima | Wandel | Anpassung, Online Newsletter, Juli 2013, Wien.

Neuhold, C.; Hogl, K.; Seher, W.; Nordbeck, R.; Scherhaufer, P.; Nachtnebel, H.P.; Löschner, L. (2012): Anticipatory flood risk assessment under climate change scenarios: from assessment to adaptation. In: European Geosciences Union (Ed.), Geophysical Research Abstracts, Vol. 14.

Scherhaufer, P.; Haberl, U.; Hogl, K.; Löschner, L.; Nachtnebel, H.-P.; Neuhold, C.; Nordbeck, R.; Seher, W. (2012): Antizipatorisches Hochwasserrisikomanagement – Methodische und konzeptionelle Herausforderungen in RiskAdapt. In: Klimaforschungsinitiative AustroClim, Climate Change Centre Austria CCCA (Hrsg.), Tagungsband 13. Österreichischer Klimatag. Klima, Klimawandel, Auswirkungen und Anpassung sowie Klimaschutz in Österreich.

Seher, W.; Löschner, L. (2012): Sicherheit des Lebensraums – Planen unter Unsicherheit. In: Universität für Bodenkultur Wien (Hrsg.), Quo vadis, Universitäten? Festsymposium 140 Jahre Universität für Bodenkultur Wien, Wien.

Conference Presentations (planned: 6; realized: 10)

Nordbeck, R., Scherhaufer, P., Löschner, L., Seher, W., Apperl, B., Senoner, T., Herrnegger, M. (2015): Stakeholder-Workshops und die vorausschauende Anpassung an zukünftige Hochwasserrisiken auf Gemeindeebene. 16. Österreichischer Klimatag, 28.-30. April, Wien.

Apperl, B., Herrnegger, M., Hogl, K., Löschner, L., Nachtnebel, H.-P., Neuhold, C., Nordbeck, R., Seher, W., Senoner, T. (2014): Antizipative Bewertung von Hochwasserrisiken unter Berücksichtigung von Veränderungen des Gefahrenpotentials und der Vulnerabilität. 15. Österreichischer Klimatag, 2.-4 April 2014, Innsbruck.

Löschner, L. (2014): The Implementation of the 'Spatial Turn' in Flood Risk Management. Coping with the Complexities of Policy Change. AESOP PhD Workshop, Juli 5-8, 2014, Delft/Netherlands.

Seher, W., Löschner, L. (2014): FloodScapes - on the interaction of land use and flood protection. 4th International and Interdisciplinary Symposium of the European Academy of Land Use and Development, Sept 4-6, 2014, Krakau/Poland.

Seher, W., Löschner, L. (2014): Negotiating Upstream-Downstream Relations - Experiences and Challenges from Austrian Case Studies. Workshop Flood Retention and Resilience in River Catchments, November 21-22, 2014, Usti nad Labem/Czech Republic.

Seher, W. (2013): Risikominimierte Raumnutzung - Herausforderungen und Strategien. Risikominimierte Raumnutzung - Beiträge der Raumplanung. 27. Seminar Kulturtechnik und Wasserwirtschaft - heute, 26. November, Universität für Bodenkultur Wien.

Apperl, B., Herrnegger, M., Hogl, K., Löschner, L., Nachtnebel, H.-P., Neuhold, C., Nordbeck, R., Seher, W., Senoner, T. (2013): RiskAdapt: Antizipatorisches Hochwasserrisikomanagement – Von der Bewertung des Hochwasserrisikos bis zur Anpassungsstrategie. 14. Österreichischer Klimatag, Wien.

Löschner, L. (2013): Decision-Making in a Complex Risk Environment. The Role of Collaborative Planning Processes in Supporting Local Authorities' Flood Management Decisions. ARL International Summer School 2013 „Sustainable Governance of Land and Water.", August 25-28, 2013, Utrecht/ Netherlands.

Löschner, L. (2013): Mit robusten Planungsentscheidungen zu resilienten Regionen? Das Resilienz-Konzept als Teil eines integrierten Hochwasserrisikomanagements, 27. Seminar Kulturtechnik und Wasserwirtschaft – heute, "Risikominimierte Raumnutzung – Beiträge der Raumplanung", 26. November, Universität für Bodenkultur Wien.

Löschner, L. (2013): Coping with Complexity: Decision Making in Flood Risk Management, 3rd Vienna Workshop on Sustainable Development for Doctoral Students, November 20, University of Natural Resources and Life Sciences Vienna/Austria.

Teaching at BOKU University

RiskAdapt insights related to future changes in flood hazard exposure and flood risk adaptation were used as teaching and study material in the following courses:

- Ordnungsplanerisches Projekt: Integrierte Flächenwidmungs- und Bebauungsplanung im Lichte von Hochwasserresilienz (PJ, WS 2014/15)
- Vorlesung Alpine Raumordnung (VO, SS 2014, SS 2015)
- Spezielle Raumplanung (VO, WS 2014/15)
- Seminar Waldpolitik (SE, WS 15/16)
