LIST OF CONTENTS

1. INTRODUCTION 23
(*Bölscher, J.; Ergenzinger, P.; Obenauf, P.; Schnauder, I.*)

1.1 Objectives and Achievements of RipFor 23
1.2 Structure of the Final Scientific Report 24
Chapters and Subchapters 24
Subchapters, Workpackages and Responsibilities 24
2. MATERIAL AND METHODS 26
2.1 Field Work at the Upper Rhine (FS1) 27
(*Bölscher, J.; Ergenzinger, P.; Obenauf, P.*)

Flow Field Measurements 27
Sedimentation and Erosion 28
Sediment Traps 28
Geodetic Survey 28
2.2 Field Work at the Wien River (FS3) 29
(*Rauch, H.-P.; Meixner, H.; Vollsinger; Florinett F.*)

Introduction 29
Construction 29
Artificial Flooding 30
Monitoring of the Riparian Vegetation 30
2.3 Field Work at the Fersina (FS4) and Enz river (FS2) 31
(*Defrancesco, C.; Siligardi, M.; et al.*)

Objectives 31
Evaluation of Stream Ecological Aspects using Short Term Retention Measurements 31
"Leafpack" Methodology 32
Benthos Quantitative Sampling 32
Morphological and Ecological Features (FFI-Fluvial Functioning Index) 33
Monitoring and Guidelines at the Enz river (FS2) 33
Morphological and Ecological Features at the Enz River (FS2) 33
2.4 Flume Experiments on Riparian Flow Field 34
(*Schnauder, I.; Ruether, N.; Dittrich, A.; et al.*)

Introduction 34
Interaction Phenomena 34
Floodplain Vegetation and its Properties 35
Experimental Equipment: Flume and LDV 36
Experimental Equipment: Vegetation Prototypes and Properties 37
2.5 Flume Experiments on Riparian Morphology 39
(*Schnauder, I.; Ruether, N.; Dittrich, A.; et al.*)

2.6 Flume Experiments on Floodplain Vegetation and Sediment 40
(*Schnauder, I.; Ruether, N.; Dittrich, A.; et al.*)

Introduction: Resistance of Vegetation 41
Introduction: Vegetation and Sediment Transport 19
Hydrodynamic Resistance of Isolated and Group of Real Plants 42
Effect of Vegetation Presence on Sediment Transport 43

2.7 Physical Model of the Wien River (FS3) 43
(Righetti, M; Piccoli, A; Armanini, A; et al.)

Flow Resistance of Vegetated Banks at the Wienfluss Physical Model 43
2.8 3D Numerical Modelling of Riparian Flow Field 44
(Ruether, N.; Schnauder, I.; Dittrich, A.; et al.)

3D Numerical Model 44
2.9 1D Numerical Modelling of Flood Wave Propagation 45
(Yoshida, H.; Ruether, N.; Schnauder, I.; Dittrich, A.; et al.)

Description of the Data and the Study Site 45
Description of the Model 46
1D Flow Simulations 46
2.10 Riparian Succession at the Upper Rhine (FS1) 47
(Ledesma, G.; Dister, E.)

3. RESULTS AND DISCUSSION 48
3.1 Field Work at the Upper Rhine (FS1) 48
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.)

Characterization of the Test Site 48
Description of the Hydrological Situation between 2000-2002 51
Flow Field Measurements 52
Flow Field Measurements Grass Area 53
Flow Field Measurements Willow Area 53
Local Discharge 57
Seasonal Effects of the Flow Field 58
Sedimentation and Erosion: Main Aspects 60
Sedimentation and Erosion: Analysis on the Data Base of Geodetic Survey 60
Sedimentation and Erosion: Analysis on the Data Base of Sediment Traps 62
Microscale Roughness – Grain Size Distribution with Regard of Temporal and Spatial Changes and the Impact of Vegetation 63
Spatio-temporal Changes of Flow Field under Impact of Floodplain Vegetation 65
Spatio-temporal Changes of Sedimentation and Erosion under Impact of Floodplain Vegetation 67
3.2 Field Work at the Wien River (FS3) 68
(Rauch, H.-P.; Meixner, H.; Vollsinger; Florinett F.)

Bank Protection by Means of Vegetation 68
Flow Velocity Distribution 68
Relationship between Discharge and Water Level 68
Damage to the Plants due to Floods 70
3.3 Field Work at the Fersina (FS4) and Enz river (FS2) 71
(Defrancesco, C.; Siligardi, M.; et al.)

FFI (Fluvial Functioning Index) of the Fersina 71
Short Term Retention Measurements 72
Leaf-packs 73
Benthos Quantitative Sampling 74
FFI (Fluvial Functioning Index) of the Enz River 75
3.4 Flume Experiments on Riparian Flow Field 76
(Schnauder, I.; Ruether, N.; Dittrich, A.; et al.)

Momentum Exchange Processes 76
Depth-averaged and Lateral Velocity Profiles 77
Floodplain Vegetation 78
3.5 Flume Experiments on Riparian Morphology 80
(Schnauder, I.; Ruether, N.; Dittrich, A.; et al.)

Influence of Emerged Rigid Vegetation on Bed load Transport in Trapezoidal Channels of Variable Width 80
Influence of Emerged Rigid Vegetation on Bed Forms in Trapezoidal Channels 82
Transportation/Sedimentation Processes at the Boundary of the Floodplain and the Main Channel ("Rehnen"-formation) 84
3.6 Flume Experiments on Floodplain Vegetation and Sediment 85
(Schnauder, I.; Ruether, N.; Dittrich, A.; et al.)

Hydrodynamic Resistance of Isolated and Group of Real Plants 85
Effect of Vegetation Presence on Sediment Transport 87
3.7 Physical Model of the Wien River (FS3) 89
(Righetti, M; Piccoli, A; Armanini, A; et al.)

Flow Resistance of Vegetated Banks and the Wienfluss Physical Model 89
3.8 3D Numerical Modelling of Riparian Flow Field 92
(Ruether, N.; Schnauder, I.; Dittrich, A.; et al.)

3.9 1D Numerical Modelling of Flood Wave Propagation 93
(Yoshida, H.; Ruether, N.; Schnauder, I.; Dittrich, A.; et al.)

Validity of the Flow Simulation Programme 93
Retardation of Flood Waves 94
Retention Volumes in the River Course 94
3.10 Riparian Succession at the Upper Rhine (FS1) 94
(Ledesma, G.; Dister, E.)

4. CONCLUSIONS 98
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.; Schnauder, I; et al.)

4.1 Individual Workpackages 98
Field Work at the Upper Rhine (FS1) 98
Field Work at the Wien River (FS3) 98
Field Work at the Fersina (FS4) and the Enz River (FS2) 99
Flume Experiments on Riparian Flow Field 100
Flume Experiments on Riparian Morphology 100
Flume Experiments on Floodplain Vegetation and Sediment and Physical Model of the Wien River (FS3) 101
3D Numerical Modelling of Riparian Flow Field 101
1D Numerical Modelling of Flood Wave Propagation 101
Riparian Succession at the Upper Rhine (FS1) 102
4.2 Synthesis of Individual Workpackages 102
Floodplain Stability 102
River Bed and Bank Stability 104
Roughness and Flood Protection 104
Floodplain Ecology and Riparian Succession 105
4.3 Closing Words 106

5. EXPLOITATION AND DISSEMINATION OF RESULTS 107
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.; et al.)

Publications, Conferences and Workshops 107
Teaching and Lectures 107
Public Presentations and Exhibitions 107
Guidelines 108
Technical Improvements 108
6. POLICY RELATED BENEFITS 109
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.; et al.)

7. LITERATURE CITED 112
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.; et al.)

8. PUBLICATIONS AND ABSTRACTS 117
(Bölscher, J.; Ergenzinger, P.; Obenauf, P.; et al.)

APPENDIX: NAS

A1. INTRODUCTION 126
(Iordache, V.; Bodescu, F.; Neagoe, A.)

A2. METHODS 126
(Iordache, V.; Bodescu, F.; Neagoe, A.)

A3. RESULTS 127
(Iordache, V.; Bodescu, F.; Neagoe, A.)

A3.1 The Place of Riparian Forests in the Macrolandscape 127
A3.2 The Role of Riparian Forests in the Macrolandscape 129
A3.3 Principles for Managing the Forests in a Landscape Context 131
A3.4 Case Study: Restoration Scenarios in the Big Island of Braila 135
A4. DISCUSSION 136
(Iordache, V.; Bodescu, F.; Neagoe, A.)

A5. CONCLUSIONS 139
(Iordache, V.; Bodescu, F.; Neagoe, A.)

LIST OF FIGURES

2.2 Field Work at the Wien River (FS3)

Fig.2 (top left): Construction phase of the test flume
Fig.3 (top right): schematic view of the test flume and the soil-bioengineering measures: (a) fascine layer (b) branch layer and (c) brush mattress with willows
Fig.4 (left): Construction of the test flume: upstream view towards wicket dam and sheet piling
Fig.5 (right): The test flume after completion: downstream view
Fig.6 (top left): Measuring devices: acoustic Doppler profiler used top-down for vertical velocity profiles
Fig.7 (top right): Measuring devices: acoustic Doppler velocimeters used for point-measurements at different locations in the cross-section
Fig.8 (left): Measuring bridge with signal analyser equipment at profile 15 during a flooding campaign
Fig.9 (right): Cross section at profile 15 (within fascine layer) with the measuring devices

2.4 Flume Experiments on Riparian Flow Field

Fig.10 Photograph of interaction phenomena: horizontal vortices with vertical axes for vegetated floodplain and small relative water depths (Pasche, 1985)
Fig.11 Measurements of secondary currents and typical main channel vortex modified after Tominaga et al. (1989)
Fig.12 Schematic view of the flume cross section
Fig.13 Schematic view of the data collection grid for the different sections
Fig.14 Pictures of the tested vegetation elements (from left to right): rigid cylinders (side view), leafy cylinders (seen in flow direction) and flexible cylinders (side view with cm-grid)
Fig.15 Waving, bending and compression of a young willow for different mean flow velocities modified after Oplatka (1998)

2.5 Flume Experiments on Riparian Morphology

Fig.16 Definition sketch of the influence of flood plain vegetation on the hydraulic/sedimentologic processes

2.7 Physical Model of the Wien River (FS3)

Fig.17 Plan view of Wienfluss and characteristics of Section 14.
Fig.18 Measurement points into the generic cross section and different cross sections

2.9 Numerical Modelling of Flood Wave Propagation

Fig.19 Study site
Fig.20 Details of vegetation parameters

3.1 Field Work at the Upper Rhine (FS1)

Fig.21 (left) Location of the Test site FS1 Hartheim / Upper Rhine
Fig.22 (right) The test site FS1 Hartheim / Upper Rhine during a smaller flood event (top) ($Q=900m^3/s$), at normal water level and as aerial photograph (bottom)
Fig.23 Geomorphology of the test site Hartheim / Upper Rhine; location of equipment
Fig.24 Test site Hartheim / Upper Rhine; types and distribution of vegetation
Fig.25 Gauging station Rheinweiler between 2000-2002 / Periods of inundation at the test site Hartheim
Fig.26 Bird-eye view of the test site Hartheim /Upper Rhine; location of Acoustic Doppler Current Profiler inside a willow grove and at a grass covered area

Fig.27 Situation before a flood event in August 2002
Fig.28 Flood event in August 2002, maximum water level at the floodplain 2,75 m, (Q= 1600m^3/s)
Fig.29 Flow velocities during a flood event at a grass covered floodplain area – test site Hartheim Upper Rhine
Fig.30 Flow velocities during a flood event at a willow grove at a floodplain area – test site Hartheim Upper Rhine
Fig.31 The direct comparison of data at same Points in time between the Willow and Grass area
Fig.32 A comparison between two test sites at selected water levels before and after the peak of flood
Fig.33 Local discharge under standardized conditions for grass and willow area
Fig.34 Approximated discharge for the test site
Fig.35 The impact of the seasons on the vertical distribution of the flow field
Fig.36 Mean velocities and retention effect of willows compared with grass
Fig.37 The impact of the seasons on mean velocities in months August, September, November
Fig.38 Digital elevation model -DEM- of the test site Hartheim / Upper Rhine in spring 2001
Fig.39 DEM; Sedimentation and erosion rates between spring 2001 and winter 2002 at the test site Hartheim / Upper Rhine
Fig.40 Sedimentation rate along longitudinal profiles of different location within the test site Hartheim for the period 2001-2003
Fig.41 Grain size distribution for longitudinal profiles at the upper floodplain level
Fig.42 Grain size distribution for longitudinal profiles at the lower grass covered floodplain level
Fig.43 Grain size distribution for longitudinal profiles at the lower willow covered floodplain level
Fig.44 Hjulstroem diagram, modified after Sundborg (1965)

3.2 Field work at the Wien river (FS3)

Fig.45 (top left): succession of willows after 3 years in 2001
Fig.46 (top right): artificial flooding July 2002: some plants still resist the drag forces exerted by the flow
Fig.47 (left): natural flood event August 2002: situation of total submergence
Fig.48 Flow velocity profiles: open channel (profiles "adp70stat" to "adp220stat") vegetated bank (profiles "adp270stat" and "adp320stat")
Fig.49 Relationship between water level and discharge observed during floodings in 1999 and 2001
Fig.50 Damage due to floodings: breaking of willow branches due to longitudinal (Fig.18, top) stress exerted by the flow
Fig.51 Damage due to floodings: breaking of willow branches due to transversal (Fig.19, below) stress exerted by the flow
Fig.52 Damage due to floodings: breaking of willow branches due to transversal (Fig.20, below) stress exerted by the flow

3.3 Field Work at the Fersina (FS4) and Enz River (FS2)

Fig.53 Fluvial functioning indices of the right bank of the Fersina torrent
Fig.54 Fluvial functioning indices of the left bank of the Fersina torrent
Fig.55 Cumulative number of leaves captured in the four monitoring campaigns
Fig.56 Leaf degradation expressed as weight loss against day-degrees
Fig.57 Logarithmic regression of leaf decomposition
Fig.58 Results of FFI-Method for the Enz river with its tributaries Grosse Enz and Nagold

3.4 Flume Experiments on Riparian Flow Field

Fig.59a (top left) Horizontal profiles of primary mean velocities for setup S4q20
Fig.59b (left) Horizontal profiles of primary mean velocities for setup S4q20 for the interaction zone
Fig.59c (top right) Vertical profiles of primary mean velocities for setup S4q20
Fig.60 Horizontal profiles of depth-averaged primary mean velocities for the interaction zone (low plant densities)
Fig.61 Vertical profiles of lateral mean velocities at location $y/(B+b)$=0.48 (low plant densities)

Fig.62 Horizontal profiles of depth-averaged primary mean velocities for the interaction zone (high plant densities)
Fig.63 Vertical profiles of lateral mean velocities at location $y/(B+b)=0.48$ (high plant densities)
Fig.64 Properties of leafy cylinders as function of Re_s-number: (●) S6 and (○) S5
Fig.65 Properties of flexible cylinders as function of Re and Re_s-number (▲) S4 and (Δ) S2
Fig.66 Head-loss data: Drag forces per plant as function of averaged mean velocity on the floodplain

3.5 Flume Experiments on Riparian Morphology

Fig.67 Definition sketch of the parameters which influence bed load transport in a symmetrical trapezoidal channel with rigid vegetation (b_{So} = width of the river bed)
Fig.68 Vegetation coefficient σ_B for a symmetrical vegetated channel based on the transport formula of MEYER-PETER/MUELLER (1949)
Fig.69 Definition sketch of the dune formations depen-ding on the vegetation zones on the banks
Fig.70 Averaged dune heights separated in dune crests and vales in the series without vegetation and with vegetation on both banks (the whole bank is vegetated)
Fig.71 Averaged dune heights separated in dune crests and vales in the series with vegetation on one bank only (the whole bank is vegetated) and with partly vegetated banks
Fig.72 Definition sketch of the conducted experiments
Fig.73 Cross section of the tilting flume
Fig.74 Definition sketch of the transport processes with rigid sticks on the flood plain
Fig.75 Distance b_{Boe} plotted as function of $b_{m,\,II}$

3.6 Flume Experiments on Floodplain Vegetation and Sediment

Fig.76 Variation of the parameter C_dA_p with square of velocity and flow depth
Fig.77 Variation of the drag coefficient C_d with plant Reynolds number and flow depth
a) (left) partially submerged conditions; b) (right) fully submerged conditions.
Fig.78 Ratio between the plants' drag per unit bed surface and the overall bed shear stress evaluated by momentum equation ($\gamma R_h i_e$).
Fig.79 Estimated K_{Seq} as a function of relative submergence, for the *dense* and *sparse* salix configurations.
Fig.80 Dimensionless solid discharge for the various experiments with vegetated bed.
Fig.81 Experimental values of correction factor of ξ_V as a function of vegetation density.

3.7 Physical Model of the Wien River (FS3)

Fig.82 Discharge curves for various simulated flood in the Wienfluss (dots, as evaluated by BOKU) and for the laboratory simulation for rigid and flexible simulated plants (lines), at different densities of plants.
Fig.83 Dimensionless streamwise velocity distribution in the cross section $U_{(y,z)}/U_{mean}$, (where $U_{mean}=Q/A$) for intermediate density $\lambda=d_p^2/a_xa_y=1.17*10^{-1}$, at discharge Q=31 m^3s^{-1} (prototype scale). Measured with microADV. a) (left) rigid plants; b) (right) flexible plants.
Fig.84 Dimensionless transversal double averaged turbulent stress, $\tau_{turb}/\tau_0=<\overline{u'w'}>/\gamma R_H i_f$, distribution in the cross section for intermediate density $\lambda=d_p^2/a_xa_y=1.17*10^{-1}$, at discharge Q=31 m^3s^{-1} (prototype scale). Measured with microADV.
a) (left) rigid plants; b) (right) flexible plants
Fig.85 Dimensionless transversal turbulent stress , averaged along the vertical $-\frac{1}{h}\int_0^h(<\overline{u'w'}>/\gamma R_H i_f)\,dy$, distribution for rigid dense config. $\lambda=d_p^2/a_xa_y=1.67*10^{-1}$, at discharge Q=31 m^3s^{-1} (prototype scale).
Fig.86 Maximum dimensionless transversal turbulent stresses , averaged along the vertical, measured for different density of plants at discharge Q=31 m^3s^{-1} (prototype scale).
a) (left) rigid plants; b) (right) flexible plants

Fig.87 Comparison between measured $K_{S_{eq}}$ in section with vegetated bank, as obtained by eq.(5), and the estimation of $K_{S_{eq}}$ using the classical E-H approach and the Trento-UniTN method (eq.(6) with n=0.2 n=0.4)

Fig.88 Shear between vegetated and not vegetated banks, calculation by Pasche and Trento-UniTN methods for (model) flexible, interm. density at discharge Q=31 m^3s^{-1} (prototype scale) and the corresponding direct measurements; also the direct measurements in Wienfluss using ADV (filled symbols), for a discharge Q=28 m^3s^{-1}, are reported for comparison.

3.8 3D Numerical Modelling of Flow Field

Fig.89 Cross section of laboratory flume at different discharges and vegetation densities

Fig.90 Horizontal velocities in a cross section at different discharges vegetation density 10 cm x 10 cm (S1)

Fig.91 Rating curve of the physical model S1 10x10 cm, S3 10x5 cm, S8 5x5 cm

Fig.92 Horizontal velocities in a cross section at different discharges; vegetation density 5 cm x 5 cm (S6)

3.9 1D Numerical Modelling of Flood Wave Propagation

Fig.93 Comparison of hydrographs between measurement and simulation at Hartheim during the course of the flood event in May 1999

Fig.94 Simulated hydro-graphs during the course of the designed flood at Hartheim in Cases 0, 1, 2, 11S, 12S and 13S (Tab.1)

Fig.95 Simulated hydro-graphs around the time of peak discharge at Hartheim in Cases 0, 1, 2, 11S, 12S and 13S (Tab.1)

Fig.96 Temporal courses of retention volumes during the course of the designed flood event in Cases 0, 1, 2, 11S, 12S and 13S

Fig.97 Temporal courses of retention volumes around the time of peak discharge in Cases 0, 1, 2, 11S, 12S and 13S

4.2 Synthesis of Individual Workpackages

Fig.98 Flow conditions for vegetation (figure 98 is also used in the summary as Fig.1a-d)

LIST OF FIGURES - APPENDIX: NAS

A2. Methods

Fig.1 Current state of the Danube floodplain in the Big Island of Braila (BIB) Sector. Grey areas are diked, deep grey areas are not diked. Thin lines within the BIB indicates farms limits

A3.2 The Role of Riparian Forests in the Macrolandscape

Fig.2 Inclusion relationships (black arrows) between riparian forests and their integrating systems. *Legend*: ml = microlandscape, ML = macrolandscape, TA = terrestrial aquatic, TWA = terrestrial-wetland-aquatic, W = wetland, SOB = small order river basin, MOB = medium order river basin, HOB = high order river basin, LOE = low order ecoregion, HOE = high order ecoregion

A4. Discussion

Fig.3 The relationships between the categories of stakeholders

LIST OF TABLES

2.5 Flume Experiments on Riparian Flow Field

Tab.1 Overview of the setups and typical characteristics
Tab.2 Summary of the observed properties and parameters for their determination

2.9 Numerical Modelling of Flood Wave Propagation

Tab.3 Details of vegetation parameters
Tab.4 Simulation cases

3.1 Field Work at the Upper Rhine (FS1)

Tab.5 Hydrological date gauging station Rheinfelden
Tab.6 Location and consecutive numbering of sediment traps
Tab.7 Vertical distribution of velocities at different location and different stages of the flood event at the willow area

3.3. Field Work at the Fersina (FS4) and Enz River (FS2)

Tab.8 Cumulative number of leaves at the Fersina torrent

3.8 3D Numerical Modelling of Flow Field

Tab.9 The simulated combinations of discharges and vegetation densities. Numbers in bold are simulated

LIST OF TABLES - APPENDIX: NAS

A3.1 The Place of Riparian Forests in the Macrolandscape

Tab.1 The natural capital directly and indirectly relevant for the management of the riparian forests. Explanation in text. *Legend:* TA microlandscape - microlandscape composed of terrestrial and aquatic systems, TWA microlandscape = microlandscape composed of terrestrial, wetland and aquatic systems.

A3.2 The Role of Riparian Forests in the Macrolandscape

Tab.2 The complementarities between riparian forests and other types of ecological sytems in the macrolandscapes production of the natural services.
Tab.3 Compatibility matrix between the maximizations of the production of different natural services at riparian forest level (above the diagonal) and macrolandscape level (below the diagonal). C= compatible, N = not compatible, NR = not relevant
Tab.4 Deterioration pathways affecting the production of services by macrolandscapesm which should be assessed in view of macrolandscape management.

A4. Discussion

Tab.5 Steps for designing a plan for the management of a macrolandscape
Tab.6 The general principles for managing macrolandscapes.