TABLE OF CONTENTS

ABSTRACT ........................................................................................................................................ 3
RESUMEN........................................................................................................................................... 4
RESUM................................................................................................................................................ 5
ACKNOWLEDGEMENTS .................................................................................................................... 7
TABLE OF CONTENTS ..................................................................................................................... 9
ACRONYMS......................................................................................................................................... 11
LIST OF FIGURES ........................................................................................................................... 11
LIST OF TABLES ............................................................................................................................ 12
1. INTRODUCTION ...........................................................................................................................13
   1.1. Topic and focus ....................................................................................................................... 13
   1.2. Research motivation .............................................................................................................. 14
   1.3. Objectives ............................................................................................................................. 17
2. PUBLICATIONS .......................................................................................................................... 19
3. RESULTS AND DISCUSSION .......................................................................................................21
   3.1. Introduction ............................................................................................................................ 21
   3.2. Part I: Methodology to integrate pluvial flooding, river flooding and dam failure into flood risk assessment .............................................................................................. 27
   3.3. Part II: Methodology to incorporate fluvial dikes (levees) into flood risk assessment for complex dam-levee systems ......................................................................................... 41
   3.4. Part III: Screening procedure to incorporate malevolent threats into dam risk analysis and flood risk assessment .............................................................................................. 50
   3.5. Towards smart risk governance for flood risk reduction ...................................................... 56
4. CONCLUSIONS ............................................................................................................................. 59
   4.1. Summary of research outcomes ............................................................................................ 59
   4.2. Implications and final remarks .............................................................................................. 60
   4.3. Future research lines: the way ahead ..................................................................................... 61
5. REFERENCES .................................................................................................................................. 63
ANNEXES........................................................................................................................................... 67
   ▪ Annex 1. The value of integrating information from multiple hazards for flood risk analysis and management.
   ▪ Annex 2. Enhancing local action planning through quantitative flood risk analysis: a case study in Spain.
   ▪ Annex 3. A combined risk analysis approach for complex dam-levee systems.
   ▪ Annex 4. Screening procedure for analysing the impact of manmade threats in dam risk management.
Annex 5. Towards an integrated flood risk management in urban areas: pluvial and river flooding including structural collapse.

ACRONYMS

ACSLS  Adjusted Cost per Statistical Life Saved
ANCOLD  Australian National Committee on Large Dams
DHS  United States Department of Homeland Security
EAP  Emergency Action Plan
FRM  Flood Risk Management
IIAMA  Research Institute of Water and Environmental Engineering
IRGC  International Risk Governance Council
MAGRAMA  Spanish Ministry of Agriculture, Food and Environment
NOL  Normal Operating Level
QRA  Quantitative Risk Analysis
SPANCOLD  Spanish National Committee on Large Dams
UPV  Universitat Politècnica de València
USACE  United States Army Corps of Engineers

LIST OF FIGURES

Figure 1. Phases of the methodology and additional contributions to key stages...26
Figure 2. Generic influence diagram: Independent initiating event (Scheme A1)...27
Figure 3. Generic influence diagram: Independent initiating event (Scheme A2)...28
Figure 4. Generic influence diagram: Common initiating event (Scheme B).........28
Figure 5. Combination of outcomes of different risk models. ..........................30
Figure 6. Flowchart of data and models for flood risk analysis.........................32
Figure 7. Influence diagram representing Risk model A for case study 1. ..........33
Figure 8. Influence diagram representing Risk model B for case study 1..........34
Figure 9. Results for three scenarios for case study 1: current situation (Base Case), after dam construction (DEAP-case) and after implementing non-structural measures (NonSt Case). Note: FN graph for the Base Case in Annex 1 shows results only from river flooding. .................................................................................35
Figure 10. Risk model architecture for the case study 2.................................37
Figure 11. FN and FD curves obtained for case study 2.................................39
Figure 12. Example of risk map for case study 2. It can be downloaded from this link. ..................................................................................................................39
Figure 13. Generic combined dam-levee risk model scheme..........................41
Figure 14. Scheme of case study 3.................................................................43
Figure 15. Risk model architecture scheme for case study 3: dam risk model (incremental risk) .....................................................................................44
Figure 16. Risk model architecture scheme for case study 3: dam risk model (total risk). ..................................................................................................................45
Figure 17. Risk model architecture scheme for case study 3: levee risk model....45
Figure 18. Risk model architecture scheme for case study 3: combined dam-levee system risk model.................................................................46
Figure 19. fN pairs from dam and levee risk models. ....................................47
Figure 20. FN curves from dam risk model vs. combined dam-levee risk model....48
Figure 21. Screening procedure for analyzing the impact of manmade threats in dam risk analysis.........................................................................................50
Figure 22. FN graph obtained for case study 4: (a) safety and (b) security risk outcomes ...........................................................................................................55
LIST OF TABLES

Table 1. Objectives and PhD thesis outcomes.................................................................20
Table 2. Societal and economic risk results for case study 1..............................................35
Table 3. Societal and economic risk results for case study 2.............................................38
Table 4. ACSLS results for analysed measures in case study 2..........................................40
Table 5. Risk outcomes for case study 3: dam risk model..............................................46
Table 6. Risk outcomes for case study 3: levee risk models............................................47
Table 7. Risk outcomes for case study 3: combined system risk model..............................47
Table 8. Steps of the screening procedure for analyzing the impact of manmade threats in dam risk management.................................................................51
Table 9. Risk outcomes for case study 4.................................................................53