Utilising Spatial Technologies to Support the Catchment Based Approach to Landscape Management

Sarah Helen Taigel

Thesis submitted for the degree of Doctor of Philosophy

School of Environmental Sciences

University of East Anglia

May 2016

Abstract

Much of the UK's water environment is degraded due to centuries of intensive land management. Driven by the combined pressures of EU targets for water quality, climate change, urbanisation, and population growth the requirement for better management of water resources has led to the adoption of catchment scale management. Despite fewer funding opportunities available to catchment organisations government expectations remain high. Spatial technologies have much to offer to aid collaboration between catchment organisations and stakeholders in their aims to improve the water environment, but research evaluating the application of low cost spatial technologies to support the Catchment Based Approach within the UK has to date been limited. Through three case studies this thesis explored how spatial technologies could support the development of future sustainable and multifunctional river catchment landscapes. The methodology of each case study retained a practitioner focus and evaluated both practitioner interaction with the technologies and the technology development itself. The research examined the strengths and weaknesses of spatial technology in practice and identified barriers to wider adoption by the catchment partnerships and rivers trusts.

Results indicate untapped potential for spatial technologies to support the Catchment Based Approach (CaBA) but three barriers to adoption exist. First, there are technological restrictions which need to be overcome with further development. Secondly, significant resources are required, and thirdly, the disruptive influence of technology on institutional structure must be accommodated. Even with the suggested further development the spatial technologies evaluated in this thesis remain outside of the scope of many catchment institutions in terms of skill, understanding of best practice and the resources to support implementation. The future of our water environment and the wider landscape is constrained not by those carrying out the work but the lack of funds and governance frameworks for catchment institutions to work together.

Table of Contents

Chapter 1. Introduction 1

1.1 Catchments: a natural administration boundary for water management 1

1.1.1 Ecosystem services: the building blocks of the catchment landscape 2

1.1.2 Defining catchment management 4

1.1.3 River Restoration: how practical action can support a multifunctional landscape 7

1.2 Managing the water environment 9

1.2.1 Policy change and its influence on the transition to landscape scale planning 9

1.2.2. Statutory responsibilities 11

1.2.3 The Ecosystem services Approach (EsA) and Catchment Based Approach (CaBA) to integrated landscape management 12

1.2.4 Introducing Payments for Ecosystem services (PES) 13

1.3 Supporting stakeholder engagement at a catchment scale: tools to involve catchment stakeholders with the decision making process 14

1.4 Research Aims 15

1.5 Outline of the Thesis Structure 17

Chapter 2. Framing the thesis: a literature review 18

2.1 Introduction 18

2.2 Engaging the unengaged with the concept of ecosystem services 19

2.2.1 Technology for communicating information and promoting engagement with ecosystem services and catchment management 20

2.3 Catchment scale framework for visioning sustainable futures 24

2.3.1 Frameworks for landscape scale planning process 25

2.3.2 Visualisations to support catchment scale planning processes 29

2.3.3 Spatial technology to support the development of visualisations 32

2.4 Engaging stakeholders with catchment scale monitoring 35

2.4.1 Issues with Citizen Science and VGI 37

2.4.2 Use of VGI for whole catchment monitoring 38

2.4.3 Exploring the interaction between the technical and the social – Actor Network Theory 39

2.5 Summary and research questions 41

Chapter 3. Case study design and implementation 43

3.1 Introduction 43

3.2 The adoption of catchment planning in the UK 44

3.2.1 Regulatory drivers and current funders of catchment scale planning 45

3.2.2 River trusts: Implementers of catchment scale planning? 45

3.2.3 Water companies: future funders of catchment scale planning? 47

3.3 Catchment planning in Norfolk: The influence of local organisations on the development of the empirical case studies 48

3.4 Topological and hydrological characteristics of the case study catchments 50

3.4.1 Base Flow Index (BFI) and influence on catchment ecosystem services 52
3.4.2 The impact of water management on catchment ecosystem services 53
3.4.3 Influence of catchment character on the case study design 55
3.5 Case Study Partners 55
3.5.1 Gaywood Valley Project 58
3.5.2 The Norfolk Rivers Trust 58
3.5.3 River Waveney Trust 59
3.5.4 Summary 59
3.6 Timeline of the research 60

Chapter 4. The role of immersive visualisations as an aid to communicating ecosystem services to stakeholders in the urban rural fringe 62
4.1 Introduction 62
4.2 Methodology 63
4.2.1 Development of the augmented reality application 63
4.2.2 GIS Support and development of supporting text 65
4.2.3 Evaluating the communication potential of the application 68
4.3 Results 71
4.3.1 Quantitative Feedback 71
4.3.2 Qualitative feedback 73
4.4.3 Observational feedback 76
4.4 Discussion 77
4.4.1 Improvements to the research methodology used 80
4.5 Conclusion 80

Chapter 5. Application of a climate change visioning framework to the development of future catchment management plans. 82
5.1 Introduction 82
5.2 Framing the case study 83
5.2.1 Background 83
5.2.2 Nine Chalk Rivers project 83
5.2.3 Introducing the Stiffkey and the catchment 85
5.2.4 Introducing the visualisation framework and CommunityViz 86
5.3 Adopting a climate change visioning framework for future catchment management planning 89
5.3.1 Modifications to the CALP climate change framework 90
5.3.2 Data collection and scenario generation 92
5.3.3 Workshop sessions 102
5.3.4 Facilitating the Qualitative and Quantitative Data Collection 106
5.4 Results 109
5.4.1 Adaptation of CommunityViz for use within the Catchment Planning Process 109
5.4.2 Evaluating stakeholder understanding of technology 109
5.4.3 Stakeholder views on the future of the Stiffkey catchment 111

5.4.4 Stakeholder views on the visualisations 112
5.4.5 Observational feedback during stakeholder sessions 116
5.4.6 Community feedback on visualisations 116
5.4.7 Interview with the Norfolk Rivers Trust staff 119
5.5 Discussion 122
5.5.1 Making a parcel based urban planning system fit for purpose in catchment visioning 122
5.5.2 Comparison of interactive high tech and static low tech tools 125
5.5.3 Adapting a climate change visioning ‘framework’ for landscape visioning 127
5.5.4 Reflections on case study design methodology 130
5.5.5 Barriers to adoption 131
5.6 Conclusions 133
5.6.1 CommunityViz – fit for purpose? 133
5.6.2 Are the days of paper maps over? 133
5.6.3 Adopting visualisations– can this help or hinder community engagement? 134
5.6.4 Can the adoption of a visioning framework bring the visioning process within the sphere of river trusts? 134
5.6.5 Improving evaluation of the process 135

Chapter 6. RiverEYE - a citizen science tool for improving water quality and the environment at a catchment scale 136
6.1. Introduction to the research 136
6.2. Introduction to the case study 137
6.3. Method 139
6.3.1 The creation of the citizen science app (RiverEYE) 139
6.3.2 Deploying the RiverEYE app for testing 141
6.3.3 Evaluation of RiverEYE with the River Waveney Trust 142
6.4. Results from the trial of RiverEYE with the River Waveney Trust 145
6.4.1 Review of data uploaded to the website 148
6.4.2 Review of feedback from the post phone use survey 153
6.4.3 Review of feedback from the end of trial wrap up workshop 154
6.5. Discussion 158
6.5.1 Evaluating the development of the citizen science process and the use of the RiverEYE app 158
6.5.2 Did catchment characteristics play a part in the success of the project? 159
6.5.3 Benefits to adopting citizen science for catchment organisations and the barriers to adoption 159
6.5.4 Improving the project – extending the functionality of RiverEYE 161
6.5.5 Actor Network Theory application 162
6.5.6 Improvements to the process 164
6.5.7 Barriers to the implementation of a citizen science approach to monitoring 165
6.6. Conclusions 167
6.6.1 Are there constraints on the types of observations which river trust volunteers can be asked to report on? Can the design of a citizen science smartphone app assist with mitigating these? 167

6.6.2 By utilising the principles of volunteered geographic data does a mobile citizen science app have the potential to fill the resource gap faced by catchment organisations? 167

Chapter 7. Conclusions 169
7.1 Introduction 169
7.2 Existing potential of spatial technologies 169
7.2.1 Reflections on augmented reality to communicate ecosystem services 170
7.2.2 Reflections on catchment scale visioning 171
7.2.3 Reflections on volunteered geographic information for catchment management 174
7.2.4 Summary 175
7.3 Barriers to adopting spatial technologies 176
7.4 The future of spatial technologies 181
7.5 Future evaluation 182
7.6 The changing role of catchment organisations over the next five years 183
7.6.1 Governance and funding 183
7.6.2 River trusts 184
7.6.3 Water companies – the future funders? 185
7.7 Conclusion 186

Appendix 1
VesAR Surveys for case Study 1 187

Appendix 2
Digital Landscape Architecture Conference Abstract Zurich 2014 196

Appendix 3
CommunityViz Surveys for Case Study 2 202

Appendix 4
A5 Visual Prompt Card for Case Study 3 209

Appendix 5
RiverEYE Surveys for Case Study 3 212

Acronyms 215

References 216

List of Figures

Fig. 1.1 Categorising ecosystem services (adapted from Millennium Assessment 2005) within a catchment landscape 3

Fig. 1.2 Stages in the modern history of Ecosystem Services (Gómez-Baggethun et al. 2010 p. 1213) 4

Fig. 1.3 Examples of the balance between Ecosystem Pressures and Ecosystem Services (RRC 2014) as they affect the water environment at a catchment scale. 5

Fig. 1.4 Comparison of benefits score for reconnection of the river to the floodplain by the removal of flood defence or bank reprofiling (RESTORE 2014) 6

Fig. 1.5 Comparison of benefits scores for managing sediment in an appropriate way (RESTORE 2014)........ 7

Fig. 1.6 Joining up the spatial scales of restoration from a catchment to reach based level 8

Fig. 1.7 River Ravensbourne Restoration in Lewisham, UK ((London Borough of Lewisham, 2010). 8

Fig. 1.8 The key objectives of the Water Development Framework (Griffiths, 2002) 10

Fig. 1.9 Drivers for working with natural processes (Barlow et al. 2014) 12

Fig. 1.10 Early 19th Century Landscape visualisation by Humphry Repton (1803) at Wentworth House, South Yorkshire........ 15

Fig. 1.11 The CaBA or Catchment Based Approach Framework used in structuring this thesis 16

Fig. 2.1 Spatial technologies explored in each data chapter in the context of the CaBA framework .. 18

Fig. 2.2 Arnstein's ladder of participation (Arnstein 1969) 19

Fig. 2.3 Examples of moving marker based animated Augmented Reality. The GE Wind turbines, activated when printed page (left) is shown to a PC webcam a set of animated wind turbines appear on the screen (right), blowing on the PC microphone causes the turbine blades to turn. 22

Fig. 2.4 Examples of marker based augmented reality (left) when viewed through a device (webcam or phone camera) this museum ticket becomes the platform for a 3D dinosaur, AR has potential for educational apps and extending the interaction of cultural displays with additional or ‘augmented’ information (www.lm3labs.com). (right) The same technology is being trialled in healthcare with training surgeons in the use of instruments for complex laparoscopic (keyhole) surgery (Botden and Jakimowicz 2009) 22

Fig. 2.5 An example of marker-less augmented reality, this art installation is viewed through an app on a smartphone Augmented Reality. Miró Alien Chest-Burster by Jon Rafman –installed at the top steps at Philadelphia Museum of Art (from Philly 360 2011) 22

Fig. 2.6 Composite image developed to reflect a neighbourhood augmented with information from various marker-less apps installed on a phone. The full details can be found here (http://ngm.nationalgeographic.com/big-idea/14/augmented-reality), the apps show details of crime, tweets in the area, restaurant reviews, and public transport information, housing prices, the price of fuel and star constellations. 23

Fig. 2.7 Levels of participation and engagement in citizen science projects (Haklay 2013 p. 116) 37

Fig. 3.1 The first case study (Chapter 4) reflected the characteristics of the Gaywood, Upper Yare and Wensum catchments, the second case study (Chapter 5) was set in the Stiffkey catchment, a pilot for the third case study was set in the Babingley and the final study was held across the accessible sections of the Waveney catchment (Chapter 6). 43
Fig. 3.2 DEFRAs interpretation of how the new catchment partnerships will sit between the local stakeholders and those with responsibility to design the large RBMS (River Basin Management Plans) which cover several hydrologically similar catchments but which have historically lacked stakeholder engagement (Defra 2013c, p. 9) 44
Fig. 3.3 Cumulative number of river trusts by year and drivers for improvement 46
Fig. 3.4 The evolution of the existing relationship between the river trusts and Catchment Partnership in Norfolk – those with a thick outline are organisations worked with in the case study research for this thesis (further details in Section 3.4). 49
Fig. 3.5 The location of and extent of the Broadland Catchment Partnership 49
Fig. 3.6 The hydrological and tological influences across the case study region 51
Fig. 3.7 Base Flow Index is an indicator of the catchments sensitivity to various pressures, the greater the value the more influence groundwater has on the river flow. The lighter grey was the study scoped but not completed 53
Fig. 3.8 A canalised section of the Gaywood chalk river showing the raised banks and disconnection from the floodplain. Here the water is deep with little natural plant life and a layer of silt covers the gravel bottom; precipitation results in quickly raised river levels increasing flood risk downstream. 54
Fig. 3.9 A more natural bank gradient allowing good connectivity with the river floodplain (the upper Gaywood Chalk River), in stream vegetation and the marshy bank to the left is evident of recently raised water levels. The smaller inset picture shows a healthy gravel bed of the river in the previous reach where faster flow moves silt off the gravels. 55
Fig. 4.1 The CaBA Framework - this chapter focuses on the Engaging stage 62
Fig. 4.2 The interaction between the servers and phone which make up VesAR 64
Fig. 4.3 An example of the screen display when viewing VESAR on an HTC Android phone 64
Fig. 4.4 An example of POI clustering where several POIs appear on the screen at once 65
Fig. 4.5 Allocating 3D location to POIs 66
Fig. 4.6 The Hoppala Content Management System (CMS) which provided details to the LayAR server and in turn consumed by VesAR, The Climate Regulation POI is being edited to remove a spelling mistake while the list to the right hand side shows other POIs in this area. 67
Fig. 4.7 VesAR evaluation locations 69
Fig. 4.8 A view through the camera showing an example of the POI over the fields and the associated text describing a provisioning service for crop production. 70
Fig. 4.9 The guided ramble tri-fold paper handout 70
Fig. 4.10 A close up of the tri-fold handout, the example here is the UEA Campus walk in the Yare catchment 71

Fig. 4.11 Participant event within the Gaywood Valley in June 2012 showing the tablet and leaflet in use while the researcher discusses the study with a participant, below are quotes from participants on the walks 73
Fig. 4.12 Barriers to the adoption of augmented reality by practitioners........ 78
Fig. 5.1 The CaBA Framework - this chapter focuses on the Using Data and Delivering stage 82
Fig. 5.2 Chalk rivers and their associated wildlife conservation designations (Taken from The State of England's Chalk Rivers, Summary report by the UK Biodiversity Action Plan Steering Group for Chalk Rivers, 2004) with the location of the Stiffkey highlighted in blue. 84
Fig. 5.3 The location of the Stiffkey catchment is shown in red, the lower half of the catchment is the North Norfolk AONB and the River Wensum to the south is an SAC from its source to Norwich........ 85
Fig. 5.4 The Stiffkey catchment, from top right clockwise the AONB North Norfolk Coast (© Visit Norfolk.com), Binham Priory with the Binham Stream in the background (© English Heritage), the shrine at Walsingham (© Walsingham Village Website, 2015) and the Iron Age fort at Warham with the canalised river bisecting the chalk escarpments (© Hamish Fenton) can be seen. 86
Fig. 5.5 The CALP process for developing climate change visioning (Sheppard et al, 2011) 87
Fig. 5.6 Climate change visioning framework , stages described (Sheppard et al, 2011).................... 87
Fig. 5.7 CommunityViz - side by side scenario comparison 89
Fig. 5.8 CommunityViz Scenario 3D showing the 'future' re-meandered river and surrounding land use........ 89
Fig. 5.9 Stiffkey Study Section (© Crown Copyright 2013. Red lines are the Public Rights of Way with the black line running North to South indicating the line of the Wells railway) 93
Fig. 5.10 Looking upstream on the Stiffkey River during the walkover survey. High water levels are drowning out the pool riffle sequence in the fenced section however the difference in bank quality between the fenced and unfenced sections can be clearly seen. Poaching by cattle introduces damaging matter to the riverine system. Silt was also being introduced at this point via the bridge. 94
Fig. 5.11 Erosion of verge grips due to heavy machinery, only the fact that the ground was frozen prevented additional silt being washed into the ditch on the other side of the hedge............. 94
Fig. 5.12 L: Example of a grip silt entry point (Hampshire County Council 2011) common in the Stiffkey area), R: Explaination of the movement of water over drained field and roads - this water carries silt and pollutants directly into the river network, which each storm more is washed down. 95
Fig. 5.13 GIS Model for automating the placement of MOPS wetland, the box shown in grey is the only one where some form of GIS processing was not required. 96
Fig. 5.14 (left) diagram of a two stage ditch within a deeply incised channel or where flood banks remain due to property (right) example of menadered channel within a straightened reach with two stage bank improving flood storage........ 97
Fig. 5.15 CommunityViz - comparing the Current and Future river channel, an example of the side-by-side comparison........ 98
Fig. 5.16 Chart Statistics in CommunityViz – As the GIS is edited then the chart updates 99

Fig. 5.17 An example of an OS Leisure Map and an example of the map within it. 99
Fig. 5.18 The 'Possible Future Land Use A0 visioning tool' this had a description, copyright, research logos, scale bar and additional graphs exported from CommunityViz to show the increase in the length of PROW and the land use. 100
Fig.5.19 Timeline representing the approximate time allocations within the two hour workshops 103
Fig. 5.20 The layout of the workshop sessions in the education room at Copys Green Farm as seen in Fig 5.21, the village hall was set up to give participants a similar experience. 104
Fig. 5.21 The Agency session held in the education room at Copys Green farm, Wighton. The Observer can be seen to the right while the NRT project officer is introducing the session. Supporting information is shown on poster board upper left with the desktop computer set up to the lower left. 104
Fig. 5.22 The larger screen used at the Community feedback event, here the researcher can be seen discussing the catchment with two members of the community, a poster board collecting responses can be seen to the right. 105
Fig. 5.23 A section of the map populated by attendees at the final stakeholder meeting. The information collected was digitised and included in the Stiffkey Catchment Management Plan. 107
Fig. 5.24 User preference on the two tools presented at the first round of workshops. Those shown in pale grey reflect questions on the current catchment, those in black the questions on the future catchment, mid grey is not specific to scenario. 113
Fig. 5.25 Preferences for the Computer (0) vs the paper maps (4) with black dots representing the 95% confidence level 114
Fig. 5.26 Responses from the four hour drop in session to the question of why they thought the visualisations were useful 117
Fig. 5.27 Responses from a pin board map at the last session with the NRT and stakeholders, this was included in the Stiffkey Catchment Management Plan published by the Norfolk Rivers Trist after the visualisation exercise 118
Fig. 5.28 Barriers to the adoption of visioning by practitioners 132
Fig. 6.1 The CaBA Framework - this chapter focuses on the Monitoring stage 136
Fig. 6.2 The location of the RiverEYE trial 138
Fig. 6.3 Forms within EpiCollect+ and the data types which can be collected within those forms (EpiCollect Website)..140
Fig. 6.4 The RiverEYE process of volunteer training, steps in grey are fields within the RiverEYE app..140
Fig. 6.5 The small phone and a laminated visual prompt which all volunteers were given showcasing the twelve catchment issues to report (double sided)..142
Fig. 6.6 Timeline of events for engaging volunteers and trialling the citizen science app 143
Fig. 6.7 The EpiCollect Table View..146
Fig. 6.8 The EpiCollect+ portal onto the data collected in the RiverEYE trial. Functionality includes the options to search by time, field or to change symbolisation as well as an option to graph data...146
Fig. 6.9 An example of an analysis flow using the EpiCollect+ web portal in the map view 147

Fig. 6.10 Total number of reports within each category 148
Fig. 6.11 Activity by team 149
Fig. 6.12 RiverEYE recording by the day of the week 149
Fig. 6.13 Distribution of problem type recorded by team 150
Fig. 6.14 Measures the degree to which features are concentrated or dispersed around the geometric mean centre 151
Fig. 6.15 Creates standard deviational ellipses to summarize the spatial characteristics of geographic features: central tendency, dispersion, and directional trends. 151
Fig. 6.16 The three data sheets which were collected at the wrap up workshop – dots indicate where a statement previously made has been agreed with by a subsequent participant. 155
Fig. 6.17 Collecting evidence from the workshop session. Different coloured post it notes on the three large A0 sheets differentiated the phone users from the non-phone users 156
Fig. 6.18 LandEYE - a schematic of the complex decision tree 162
Fig. 6.19 Barriers to the adoption of VGI and Citizen Science 166

List of Tables

Table 2.1 Key questions in the development of a citizen science project (after Tweddle et al. 2012)....38

Table 3.1 WFD status of the case study catchments (US refers to Upstream) data compiled from EA 2014 50

Table 3.2 Overview of the catchment characteristics....57

Table 3.3 Timeline of the case studies written up within Chapter 4, 5 and 6, those in italics reflect the time spent on case studies which did not result in sufficient data collection for inclusion in the thesis 60

Table 4.1 Examples of POI text used in the VESAR application 68

Table 4.2 Average scores on the ES questions by age group and communication tool used 72

Table 4.3 Average ratings of communication tools in terms of location and benefits of ES 72

Table 4.4 Responses on the tool most effective vs most preferred 73

Table 4.5 Participant comments on the smartphone tool compared with IT Literacy....74

Table 4.6 Participant comments on their preferred method grouped to presented the most frequently mentioned responses about the advantages and disadvantages to the two tools 75

Table 4.7 SWOT analysis of the augmented reality technology 77

Table 5.1 The application of the CALP visioning process to the Stiffkey community catchment plan..91

Table 5.2 GIS Data used in the visioning process for the Norfolk Rivers Trust....92

Table 5.3 Creating transparency for the modelling carried out on behalf of the NRT....101

Table 5.4 Age groupings across the three different stakeholder groups 110

Table 5.5 Assessing the technological background of the stakeholders who attended the participation events Values in brackets form the variable IT Literacy....110

Table 5.6 IT Literacy across stakeholder groups 111

Table 5.7 Would the Stiffkey Catchment benefit from a change in land use? Results by stakeholder group 111

Table 5.8 Summary of the main dialogs held during the stakeholder group meetings, showing that while the information given to each group was similar the discussions were quite different....112

Table 5.9 Comparing CommunityViz with A0 paper maps, ranking evaluation statements by mean rating (after Salter et al. 2009 p. 2097) across all groups where CommunityViz = 0 and Paper Map = 4. 114

Table 5.10 Cross tabulating tool preference to the stakeholder background....115

Table 5.11 Stakeholder feedback from March workshops....115

Table 6.1 Fields included within the RiverEYE app....141

Table 6.2 Volunteered data on the river functions (ecosystem services) which were being affected, these criteria were more subjective with less support. 153

Table 7.1 The three approaches and case studies....170

Table 7.2 The barriers to (filled circles) and considerations for (hollow circles) adopting spatial technology....177

"I'll start small though this time. A different approach……..involve the community more and make it their project not ours - that's the way to protect it"

Salmon fishing in the Yemen, 2011, screenplay by Simon Beaufoy
based on the book by Paul Torday, 2007

Acknowledgements

This thesis has been made possible through the funding of the ESRC and the patience and guidance from all my supervisors who have enabled me to achieve my lifelong dream of completing a PhD. I would like to thank Professor Andrew Lovett for giving me the confidence to take the PhD in the direction which I wished to do so and whose pragmatic advice was invaluable throughout the case studies and the writing of this thesis. I would like to thank Dr Katy Appleton for all her patient explanations throughout the four years and her assistance with many of the events which I ran. Sincere thanks must also go to Professor Kevin Hiscock whose questions taught me how to defend my research and maintain absolute clarity.

Alongside I have had support and advice from so many directions. Dr Amii Harwood and Dr Nem Vaughan must of course be mentioned for their positive help which kept me going as well as very practical assistance with practitioner events. Dr Ruth Welters for her advice, Dr Barnaby Andrews for his ability to explain complex economic theories in a complex non-economic way. Gilla Sunnenberg, Dr Trudie Dockerty, Dr Faye Outram, Dr Emilie Vrain, and Dr Richard Cooper from the Wensum DTC project have all provided continual assistance and advice on farming methods. I am truly grateful to everyone who assisted me with the numerous events which I ran throughout the course of the PhD and indebted to the people who attended to tell me their thoughts on the rivers and the technology. I owe Gemma Clark and Dr Jonah Tosney of the Nine Chalk Rivers project a debt of gratitude for working with me to complete my second case study with the immovable deadline of my second child. So many others have offered advice, boosted motivation and suggested ways to keep going – thank you to you all.

My gratitude goes as well to the incredible network of organisations and people who manage our water environment. I would also like to thank staff at the Norfolk Rivers Trust, the Norfolk Wildlife Trust, and the Broadland Catchment Partnership, the Broads Authority, Natural England, the River Waveney Trust and the Essex Catchment Partnership. All have contributed time to support the work which I have done and to answer questions about the beautiful rivers which we have in this region. I must also make mention of the following people; Dr Jenny Mant (previously of the River Restoration Centre) for validating the need for this research and for allowing me to present year on year at the RRC National Conference – her support has meant a great deal; Michelle Walker of the Association of Rivers Trusts for her enthusiasm. I must thank Dr Rory Sanderson and Bridget Marr from the Environment Agency for their help and advice and Eleanor Starkey for the peer to peer support in the final stages.

Starting out the PhD with a 5 month old baby has meant a rollercoaster combination of learning both how to parent and carry out PhD research. I will forever be thankful to my children Sophie & Yvaine for giving me the confidence to keep on going and much time awake at night to condense my thoughts. To my friend Sarah thank you so much for your never-ending support and laughter; to Karissa and Shaina I really could not have done this without your encouragement from halfway around the world. To my family who saved the day at the end of this long meandering road – thank you. I would like to dedicate this PhD to the memory of my father who spent his life restoring churches and historic monuments with the same passion I have for rivers and geospatial technology; I am truly sorry he never saw what technology could achieve.

Dedicated to the memory of

Roger John Taigel

June 1948 – July 1995

Chapter 1. Introduction

A decade ago the Millennium Assessment (2005) evaluated the impact of human activity on the state of the natural environment at a global scale. This focus on ecosystem services; that is the goods and services provided by the environment which support life on the earth revealed that many such services are degraded with some in urgent need of restoration. Within the UK the outcomes of the National Ecosystem Assessment (2011) and the Follow on National Ecosystem Assessment (2014) reinforce how water is crucial to life, lying as it does at the heart of many ecosystems, economic activities and human wellbeing. As pressures from urbanisation, population growth, climate change and energy needs intensify the degraded nature of the water environment impacts biodiversity, food production, fishing, and many other societal benefits.

European policies which have shaped historic water management and contribute to the future of catchment management are outlined in this chapter to show how a number of factors are driving forward the increased focus on water policy. At an international level the move to whole catchment management within Europe has been influenced by the concepts outlined in Section 1.1. As impacts of climate change have become better understood the UK Government has adopted national targets to reduce greenhouse gas emissions and increase renewable energy generation while also prioritising the need for food and water security (HM Government 2009). It has become evident from research studies that to build resilience into our catc16hment landscapes a more multifunctional and sustainable approach is required with direct action to restore degraded landscapes.

1.1 Catchments: a natural administration boundary for water management

A river catchment or drainage basin is the area of land drained by a river and its tributaries; it is a natural geographical and hydrological unit and includes any groundwater which is present within the catchment.
(Selman 2010b)

River catchments have traditionally been used by engineers and scientists as a means of dividing up the landscape; the size, shape and the boundary with neighbouring catchments defined by topography. Each river catchment is unique, Starkey and Parkin (2015) define the uniqueness as a combination of influences including topography, climate, geology, land cover (land use) and human activities. Sometimes very large catchments, such as in the Wensum catchment in Norfolk, are divided into smaller sub catchments. Many landscape features make up the water network within a catchment, while rivers and streams are often recognised as part of the water network there are other features such as ponds, winterbourne streams, lakes, dykes, ditches, estuaries and groundwater which should be considered together for a comprehensive view of a catchment.

While catchments are in themselves unique the issues which they face such as climate change and the pressures they are under can be grouped as flooding, drought, poor water quality and quantity, degradation of habitats and the invasion of non-native species such as the White Crayfish or Floating Pennywort (Starkey and Parkin 2015). While flooding is an example of a natural event, the impact from such events is becoming greater as human activities including farming, residential developments and costly infrastructure such as roads and bridges are placed at risk in floodplains. In addition, methods such as channel management which have traditionally been used are increasingly found to reduce the catchments ability to function as a whole system and mitigate such damaging events. Increased awareness of the gap between demand and availability of natural functionality and resources has focused attention on the state of our natural environment and on the benefits which healthy catchment ecosystems provide. Working within catchment boundaries allows for the discovery of interconnected problems and encourages a cohesive approach for a range of organisations to work together to develop and implement holistic solutions often with multiple benefits. Section 1.1.2 develops further the potential for catchment boundaries act as an administrative boundary replacing the traditional administrative patchwork approach.

1.1.1 Ecosystem services: the building blocks of the catchment landscape

Ecosystem services or nature's benefits (Layke 2009) are the subject of ever continuing research by academics and government agencies seeking to balance multiple demands on our landscape (The Millennium Assessment 2005; National Ecosystem Assessment 2011; NEA Follow on 2014). Several classification systems have emerged as the research into ecosystem services has progressed. A common framework was devised by the Millennium Assessment (2005) which categorised ecosystem services into provisioning, regulating, supporting and cultural as can be seen in Fig. 1.1. Historically provisioning services such as food and timber were prioritised over water and air quality (regulating services), recreation (cultural service) or biodiversity (supporting service) (Howley 2011; Cauldrick and Smith 2014). As organisations have started to operationalise ecosystem services more detail is needed, and classifications have emerged such as CICES (Haines-Young and Potschin 2012). CICES (Common International Classification of Ecosystem Services) creates a clear distinction between final ecosystem services which retain a clear connection to the processes which produce them such as flood water retention; and ecosystem products or goods and ecosystem benefits which are derived but no longer connected such as food or timber. Classification systems such as CICES have a role to play in developing the means to integrate ecosystem services with decision making and to accurately estimate ecosystem services in valuations (Fisher et al. 2009) using intermediate services, final services and benefits.

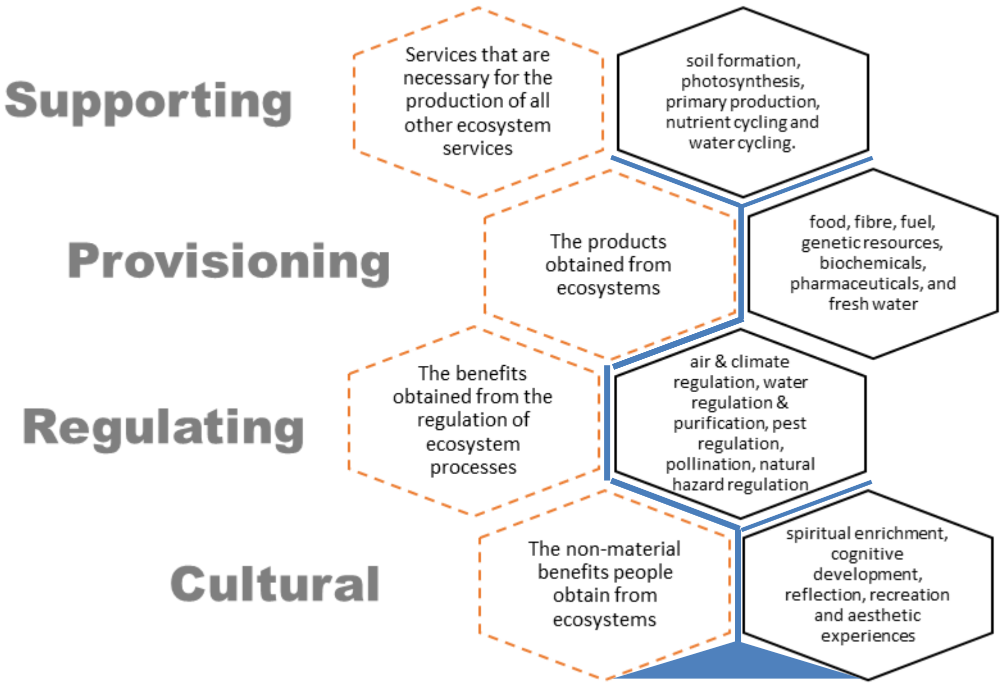


Fig. 1.1 Categorising ecosystem services (adapted from Millennium Assessment 2005) within a catchment landscape

Describing the benefits which healthy ecosystems provide as ecosystem services is not a recent phenomenon, existing as it does as far back in scientific literature as the late 1970s. Fig. 1.2 illustrates how the ecosystem services concept has evolved to support more integrated thinking (Gómez-Baggethun et al. 2010). The complexities of environmental economics as applied to the valuation of ecosystem services lie outside the scope of this thesis but the emerging understanding of valuing ecosystem services for use in decision making is discussed further in Section 1.2.4. While the deliberations over the full impact of climate change on ecosystem services continue there is sufficient evidence to show that we should improve the resiliency of ecosystems which we rely upon (Seabrook et al. 2011). This has a direct relevance to the benefits of managing at a catchment scale where the location of ecosystem services which we rely on at a local scale can be identified in order that an assessment can be made of their condition, protect those in good status and if necessary restore those which are degraded.

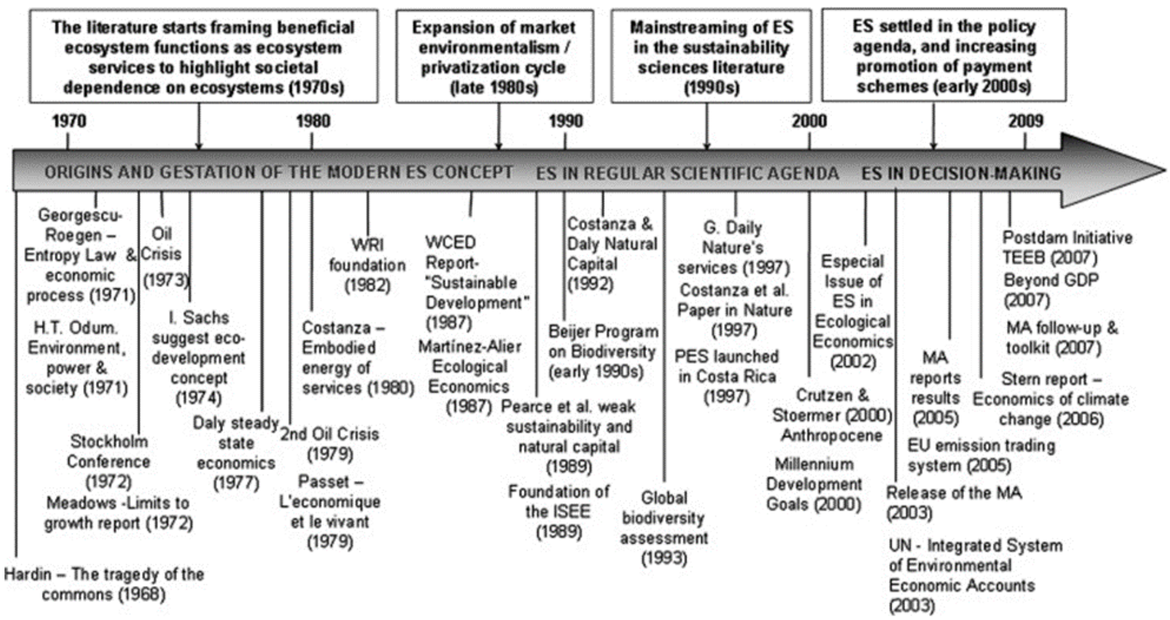


Fig. 1.2 Stages in the modern history of Ecosystem Services, (Gómez-Baggethun et al. 2010 p. 1213)

In addition to the rapid change in research focus the audience interested in ecosystem services has become wider; from academia to government policy makers and to practitioners (Gómez-Baggethun et al. 2010). This is of particular relevance now that a 'paradigm shift' in decision making has prompted greater inclusion of a wider range of stakeholders and practitioners contributing to processes which were previously the domain of expert planners (Lange and Hehl-Lange 2010). Although the scale at which landscape is managed has moved forward, the language of ecosystem services has remained academic. As a result practitioner disengagement and confusion continues as to how, at a practical level, ecosystem services provided by our environment can be valued and included in decision making (Pretty et al. 2011; Wissen Hayek et al. 2015).

1.1.2 Defining catchment management

Catchment management is a subset or type of landscape management (MacFarlane 2007) which approaches sustainable resource management from a catchment perspective, in contrast to the traditional piecemeal approach that artificially separates land management from water management. A watershed or river catchment is recognised as an appropriate scale at which to develop effective future integrated policies (Dawson and Smith 2010) with the greatest potential for developing 'win-win' trade-offs, for example a river restoration project which also enhances water quality, biodiversity and recreation values (Smith et al. 2013). UK agencies responsible for planning at a catchment scale have had to evaluate the state of the water environment and pressures upon it (climate change; flooding, population growth), as well as the need for continued agricultural productivity. Traditionally rural spaces have been shaped by agricultural policies and agricultural land has been considered either as multifunctional or monofunctional; increasingly the concept of 'multifunctionality' has become synonymous with sustainability in all rural land use management (Wilson 2010). Catchment scale management promotes multifunctionality allowing as it does for the interconnected nature of the landscape, the relationships between ecosystem services which exist both spatially and temporally (Fisher et al. 2009) and resource management to be evaluated. Increasing visibility of ecosystem services (including enhancing understanding via improved communication) is a key factor in protecting less visible services such as air quality, soil formation and biodiversity which underpin other benefits, not least because literature shows that when people cannot see something they are less likely to act to defend it or protect it (Nicholson-Cole 2005).

Management practices until recently have broken the landscape down into component parts, focusing on habitat management, recreation needs, water management, agricultural practices (Cauldrick and Smith 2014), which fails to take into account the heterogeneous nature of the ecosystem services which catchments provide (Fisher et al. 2009). Additionally many catchment features provide multiple ecosystem services which can be enhanced or diminished by land management practices (Fig. 1.3) or seasonality and therefore introducing more integrated catchment management is beneficial; particularly for ecosystem services which are hard to see but vital to life on earth. The National Ecosystem Assessment (2011) and Vira et al. (2011) propose that the key to delivering multiple benefits from catchment ecosystem services is the development of multifunctional policy approaches which fully address the ways in which water, land and nature are interlinked (Cauldrick and Smith 2014) resulting in biodiversity and the resiliency of all ecosystem services being improved. Consequently at the same time as assessing the state of the water environment for European-wide policies responsible agencies have had to merge operationally-focused management policies which focus on a single land use (Cauldrick and Smith 2014) into forward facing sustainable and multifunctional longer term strategies which provide multiple benefits (Spray and Rouillard 2012). While it is possible for land to be managed for the benefit of multiple ecosystem services, the dynamic relationships between different ecosystem services provided within a landscape are to a degree still being mapped (Albert et al. 2015; Wissen Hayek et al. 2015) making it challenging for decision makers to embed ecosystem services within existing planning processes.

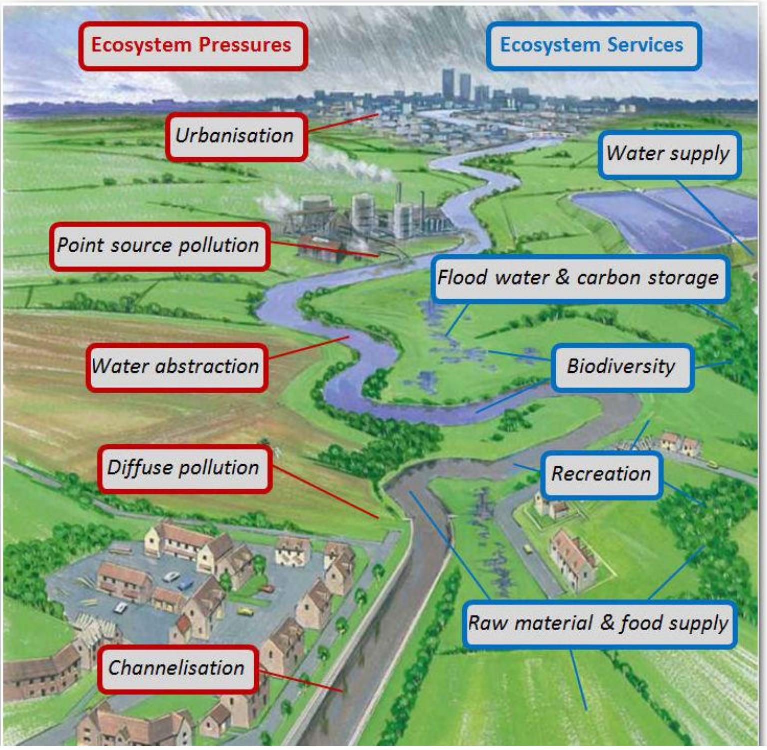


Fig. 1.3 Examples of the balance between Ecosystem Pressures and Ecosystem Services (RRC 2014) as they affect the water environment at a catchment scale.

Despite this it has also become evident that landscapes also need to be managed at an appropriate scale to restore and protect the ecosystem services which the environment provides (Selman 2010). Evidence shows how policies based on administrative boundaries often fail to consider spatial and temporal relationships between ecosystem services within a catchment (Bannister et al. 2005; Smith et al. 2013). The variety of scales at which catchment ecosystem services operate at, as well as the different extents of restoration projects focuses attention on the potential of spatial tools to assist in planning. With a move from traditional reach-based river restoration on the main channel towards catchment scale restoration attention is now focused on the wider network of channels and water pathways which when degraded can have a cumulative impact on the main channel; the importance of small reach-based projects in improving the overall health of the catchment should not be underestimated (The Rivers Trust and Defra 2014). The web based resource 'Heathy Catchments' developed by DEFRA and the Environment Agency hosts a number of case studies to illustrate integrated solutions to the list of improvements set out by the EA to meet the European targets discussed in Section 1.2.1. Figures Fig. 1.4 and Fig. 1.5 are taken from the Heathy Catchment example to show the visual methods used to encourage practitioners to consider the multiple benefits of a project. These visual tools fail to indicate the spatial scale at which these projects operate – thus some additional means are required to indicate to stakeholders the significant aesthetic and recreation potential of reconnecting floodplains originally engineered as a flood mitigation measure (Fig. 1.4) and the linkages between headwater restoration retaining silt and the improved current flow and flood risk downstream (Fig. 1.5) (RESTORE 2014).

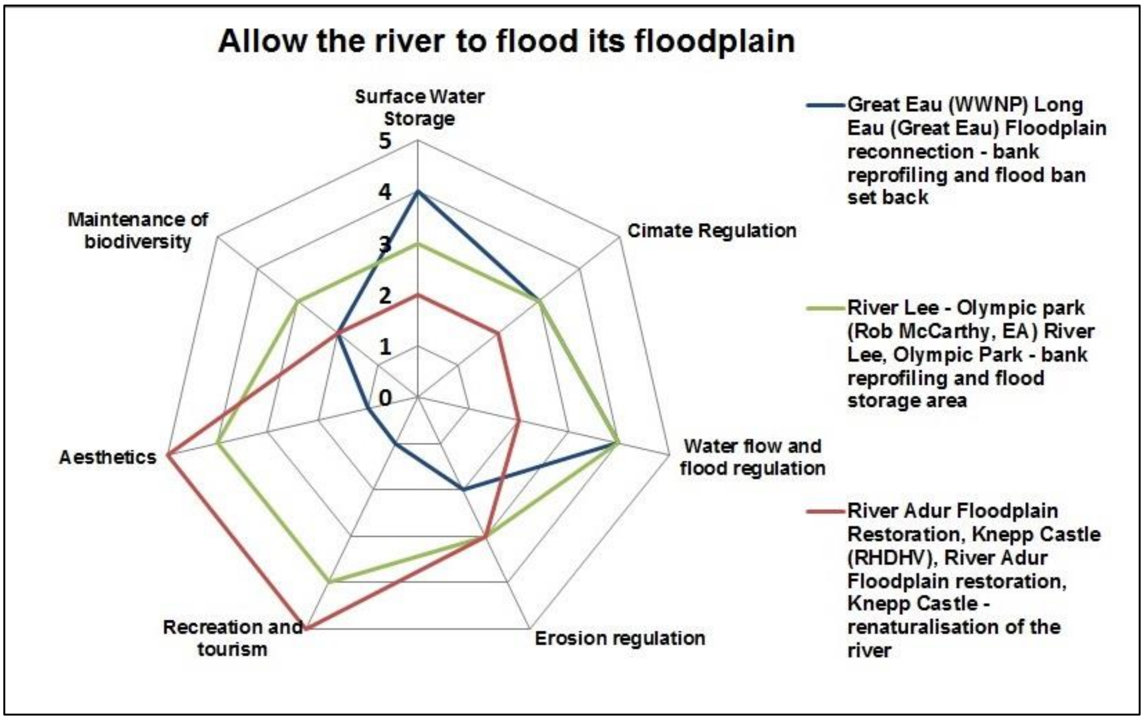


Fig. 1.4 Comparison of benefits score for reconnection of the river to the floodplain by the removal of flood defence or bank reprofiling (RESTORE 2014)

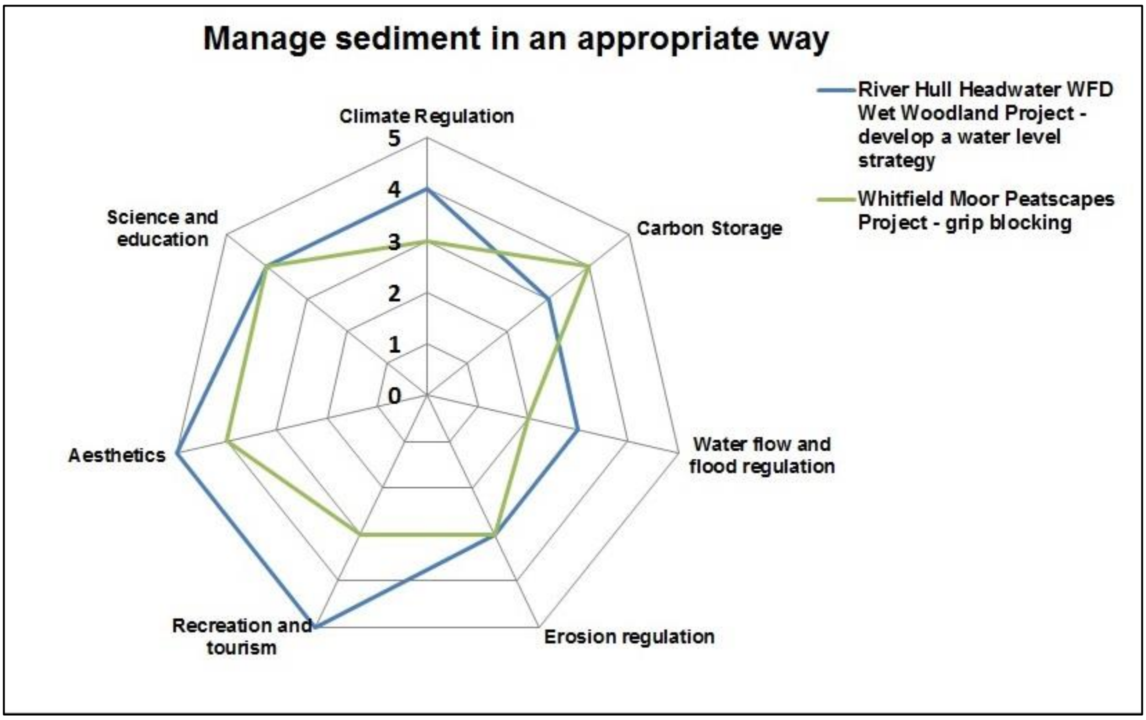


Fig. 1.5 Comparison of benefits scores for managing sediment in an appropriate way (RESTORE 2014)

1.1.3 River Restoration: how practical action can support a multifunctional landscape

Traditionally river trusts and catchment organisations have focused on a river reach scale carrying out reactive improvement such as removing barriers to fish passage, fencing off channels from stock and in stream enhancements such as increasing woody debris to improve habitat. As realisation of the importance of ecosystem services provided by rivers and the impact of canalisation has increased then larger scale projects such as river channel modifications (remeandering) over a longer stretch have become more common although the expense and uncertainly around risk makes these long term projects. As part of river remeandering projects efforts are made to reconnect the river to its floodplain reducing food risk and working with natural processes. More recent however is the concept of restoration at a catchment scale; this brings into sharp focus the benefits of all the different scales of restoration and promotes the requirement for collaborative working at a landscape scale between a range of organisations (Fig. 1.6).

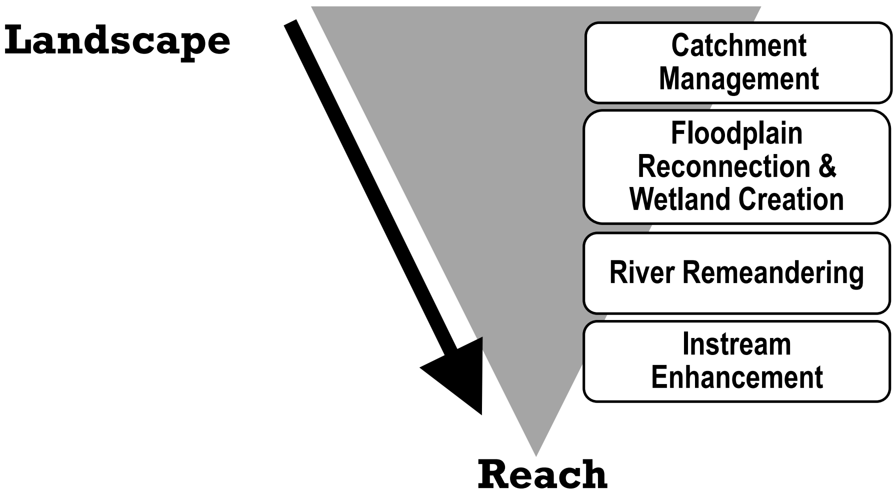


Fig. 1.6 Joining up the spatial scales of restoration from a catchment to reach based level

The European Centre for River Restoration defines the process of river restoration as an array of 'ecological, physical, spatial and management measures and practices' aimed at restoring the natural state and functioning of the river system in support of ecosystem services such as biodiversity, recreation, flood management. Fig. 1.7 shows a stretch of the River Ravensbourne in Lewisham where as part of an urban regeneration scheme a £350,000 project was carried out in 2007 to remove the concrete channel and reprofile the banks. The result was an attractive open space with access to the river for recreation, the lower banks to one side facilitate a flood storage area protecting downstream urban centres and wildlife in the river and around has flourished (London Borough of Lewisham 2010 p. 51). The restoration of more natural conditions increases the resilience and functionality of river systems within a catchment. This in turn improves ecosystem services (such as flood regulation and water quality) meeting the aims of the Water Framework Directive. An illustration of links between local river restoration and positive influences of catchment ecosystem services was provided in Figs 1.4 and 1.5.

Fig. 1.7 River Ravensbourne Restoration in Lewisham, UK (London Borough of Lewisham 2010)

River restoration projects are often a key means by which communities can be engaged with to work together to implement schemes, and also to manage the site(s) on a longer term basis. River restoration at a catchment scale requires stakeholder input to create a vision to ensure all work together to create a sustainable and multifunctional future landscape. Bannister et al. (2005) set out some guidelines on catchment scale restoration. First that catchment restoration should not mean restoring the catchment to a flawless condition, this would be economically prohibitive and in some places create unacceptable risk for human life or property. Instead catchment based restoration should be used as a framework to take account of all the processes and restraints within the catchment; the potential for improvement can then be assessed and areas in need of restoration or where the greatest multiple benefits from restoration will be achieved can be identified.

1.2 Managing the water environment

1.2.1 Policy change and its influence on the transition to landscape scale planning

Water legislation in Europe originated four decades ago in 1975 with standards set for any water body abstracted for drinking water and there was a focus on pollution from urban waste water and agriculture; in 1980 further legislation required member states to meet targets for fish and shellfish waters, bathing and groundwater (EC 1991). Since the 1970s the UK has adopted several pieces of European legislation of relevance to water management including the Nitrates Directive (EC 1991) and the Habitats Directive (EC 1992). Adopted in 1991 the Nitrates Directive (EC 1991), aimed to reduce the leaching of nitrates into surface and groundwater from fertiliser use. Under the Nitrates Directive EU member states are required to identify where nitrate concentration is above, or at risk of, exceeding 50 mg/l NO_3 in surface and ground waters. Agricultural areas within catchments where water bodies have been identified as exceeding or being at risk of exceeding the 50 mg/l NO_3 norm are designated a Nitrate Vulnerable Zone (NVZ) and restrictions are placed on farming practices. Within the UK the implementation of the Nitrates Directive has been modified several times, the most recent round of guidance being released at the beginning of 2013 resulting in a smaller area designated (Dwyer 2011). NVZs are assessed every four years with consultation taking place between farmers, water companies and government agencies to improve the guidance; the most recent guidance proposed moving to a catchment approach for managing nitrate pollution. Adopted in the UK in 1992 the Habitats Directive (EC 2992) also directly informs landscape management and has been amended several times since. Aiming to promote and enhance the biodiversity of an area and to protect wild species under the Habitats Directive, one example relevant to catchment management is the development of trout, salmon and eel management plans to increase failing fish stocks.

Prompted by the continued poor state of water bodies within European Member States despite the Nitrates and Habitats directives, the European Water Framework Directive (EC 2000) has accelerated the application of catchment-scale planning to resolve the poor state of water bodies in the UK (Griffiths 2002). With a focus on safeguarding Europe’s water resources the EU Water Framework Directive (hereafter referred to as the WFD) came into force within the UK in 2000, the key objectives are set out in Fig. 1.8. The WFD requires that Member States aim to achieve Good Ecological Status in all water bodies with interim targets to be set for 2015 and 2021, leading to full compliance by 2027. Under all conditions, it requires that there should be no deterioration in status. The WFD not only informs member nations that catchment scale planning will enable the directive to be met most efficiently but also “establishes several innovative principles for water management, incorporating public participation in planning and the integration of economic approaches, including the recovery of the cost of water services” (EC 2008 p. 1).

The European Union has promoted the use of WFD River Basin Managements Plans to provide a means by which river catchments within Europe spanning more than one country can be better managed and which set out the actions which will be taken. River Basin Management Plans (RBMP) are described by DEFRA (2013) as strategic; providing river basin stakeholders a measure of certainty about the future protection and sustainable use of the water environment in that district; objectives for each water body being specified as well as a summary of measures necessary to reach those objectives. The UK has no shared water boundaries with other nations however a whole landscape approach can be greatly beneficial to riparian corridors which can be affected negatively by the variety of inconsistent management techniques on the land which they run through (MacFarlane 2007). The EU Water Framework Directive underlined the need for a holistic landscape scale approach in order to meet the target of 'good' status (low pollution and good ecological health). However nearly half of all EU surface water bodies will not reach this ambitious target nor the target of good or high status by 2027 (EC 2015a) despite calls for the process by which water bodies are assessed to be made more reflective of the true state of the water body (House of Lords 2012 p. 55).

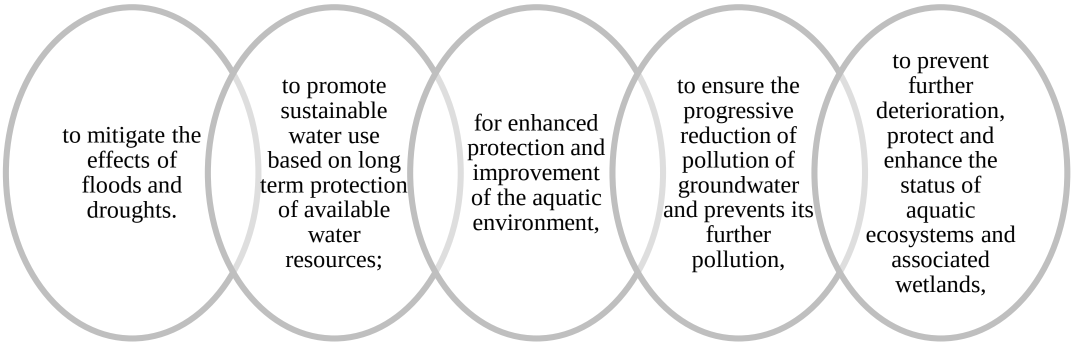


Fig. 1.8 The key objectives of the Water Development Framework (Griffiths 2002)

The WFD has offered guidance on how to go about fulfilling its aims via innovative elements including the move to a catchment scale, the requirement for increased public participation, consideration of both ground and surface water bodies, and the consideration of cost effective actions. Two have particular relevance to this thesis. First is the move from administrative boundaries towards landscape scale boundaries to better manage the water environment using a holistic catchment based method (Section 1.1.2). The second is the improved inclusion of all stakeholders within the decision making process surrounding the water environment. The promotion of 'bottom up' rather than 'top down' in planning a more multifunctional and sustainable landscape has necessitated greater coordination between stakeholders across multiple tiers of governance and across wider spatial scales. With both comes a requirement for spatial tools to facilitate communication between different groups when planning a multifunctional future landscape and the ecosystem services it provides.

Within England and Wales DEFRA released funding for river improvement (The River Improvement Fund) in 2010 to meet the objectives of the first cycle of the European Water Framework Directive, the amended Habitats Directive, Eel Management Plans, and Salmon Action Plans. The River Improvement Fund (RIF) was administered and managed wholly by The Rivers Trust (a non-governmental organisation) between 2010 and 2014 with work carried out on the ground by grassroots river trusts across England and Wales. While the primary aims of the RIF benefited ecosystem services they were not the focus; instead barriers to fish migration were removed, spawning habitat was created, diffuse pollution and acidification were reduced, channel morphology was improved and work to reduce sedimentation was carried out. The work done, although successful, took place on a reach basis and failed to adopt the whole catchment approach promoted by the WFD indicating that an approach with clearer allocation of responsibilities was required.

1.2.2. Statutory responsibilities

The publication of a number of documents supporting the government's targets and the WFD are shown in Fig. 1.9; while many of these are non-legislative, all recommend a more holistic approach and integrated approach to the environment as evidenced by the Environment Agency's project 'Working With Natural Processes'. The Natural Environment White Paper (Defra 2011a) and the Water White Paper (Defra 2011b) in particular specify that more must be done at a local level to restore ecosystems by making better, more informed and more joined up choices.

The roles and responsibilities at a regional and local level are detailed more in Chapter 3, however it is fair to say that over the past decade they have changed a great deal. Increasingly the role which grass root river trusts, wildlife trusts, national parks and volunteer local community groups play is vital to the future development of a sustainable and multifunctional landscape. Experience amongst these groups however is less than in the governmental organisations such as SEPA, DEFRA and the Environment Agency who have traditionally taken responsibility for managing the water environment. In order to support the less experienced but vital groups in their new roles; and to encourage better collaborative working new approaches have been designed. Therefore, institutions such as the EA, DEFRA and the Internal Drainage Boards are essential to understanding the mechanisms surrounding catchment scale management of the landscape. Institutions can be understood, following Peters (2005) as structures steering the behaviour of individuals in groups involved in decision making and governance around water management for society at large.

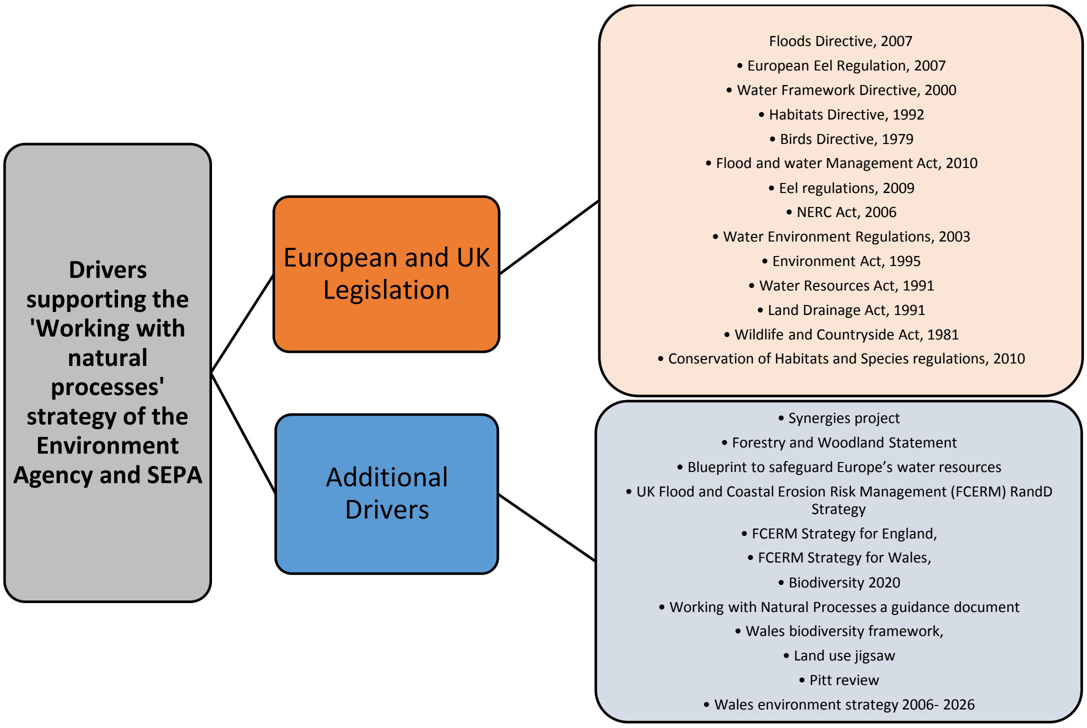


Fig. 1.9 Drivers for working with natural processes (Barlow et al. 2014)

1.2.3 The Ecosystem services Approach (EsA) and Catchment Based Approach (CaBA) to integrated landscape management

While the adoption of the Water Framework Directive has initiated the argument for progressing to catchment scale planning, additional weight is added to the arguments by research evaluating the positives of landscape scale stewardship on the grounds of enhancing biodiversity and sustainability (Dolman et al. 2001). Alongside mitigating for impacts from climate change, economic driven changes to agri-environment policies (CAP reform) and the adoption of an ecosystem services approach by government agencies reinforce the need for a sustainable multifunctional catchment landscape (Seabrook et al. 2011; Southern et al. 2011). Compared to many other countries, DEFRA (England and Wales) and SEPA (Scotland) have been relatively late in adopting a Catchment Based Approach to support River Basin planning which has been successfully used internationally in Australia (Bryan 2003; Boyd and Banzhaf 2007; Bohnet et al. 2011), Tanzania (Swetnam et al. 2010), Belgium (Maurel et al. 2007) and the US (Prato and Herath 2007; Molle 2009).

In order that ecosystem services are considered in decision making the adoption of a framework which has the natural environment as a focus throughout the decision making process has increased in popularity. Known as the Ecosystem services Approach (EsA) results from the National Ecosystem Assessment (2011) encouraged forward thinking practitioners to adopt this approach as best practice in land management. In 2007 Defra published both *Securing a healthy natural environment: An action plan for embedding an ecosystem approach* (Defra 2007a), and *An introductory guide to valuing ecosystem services* (Defra 2007b) both of which were aimed at policy making and delivery. These together formed the basis of Defra's Natural Value Programme promoting a more strategic and systematic approach encouraging improved understanding of nature's value to society, and brought together stakeholders interested in the multiple benefits to be obtained by an ecosystems approach. Combining the EsA with the influence from European WFD legislation has fundamentally changed the scale at which policy makers assess and manage catchments.

Partnerships between agencies to manage the landscape have long existed (MacFarlane 2000); however, particularly where the lead partner is a local voluntary organisation, these partnerships are at risk of bias where one issue becomes a focus such as fish passes on salmon rivers or where wildlife trusts (who are less focused on improvements to the water environment) consider biodiversity a priority (Spray and Rouillard 2012). Thus structure and clearly defined roles are required to enable organisations to work together. In May 2013 DEFRA released a framework for a whole landscape scale management approach for England and Wales. Entitled the Catchment Based Approach (CaBA) the framework introduced the concept of catchment partnerships for policy makers and stakeholders designed to promote collaborative working between tiers of governance to manage the water environment at a catchment scale. The CaBA framework included a key principle stating that 'the proposed catchment partnerships must consider the water environment in terms of all the ecosystems services which exist within a healthy catchment and have an aim to better integrate planning and activities which will deliver multiple benefits' (Defra 2013c). Four clear objectives were outlined; to deliver a better quality water environment, to encourage collaborative working, to recognise the role of both existing and new partnerships in collaborative catchment and to encourage long term self-sustaining funding agreements. Catchment partnerships have been shown to be a catalyst for partnered investment which have, through a process of river restoration, improved water quality, enhanced habitat and biodiversity, reduced flood risk, improved landscape resilience to a changing climate and developed community engagement with local rivers (The Rivers Trust and Defra 2014). This has been achieved through the use of a framework designed to support even the newest catchment partnerships in delivering well designed projects at a catchment scale. However Spray (2012) reports some degree of confusion remaining when marrying the EsA with CaBA exacerbated by the lack of spatial tools to identify and incorporate ecosystem services within existing catchment planning process.

In 2011 a number of pilot catchment initiatives were undertaken by DEFRA to promote local understanding and engagement with the water environment, and provide sustainable outcomes at a catchment scale to meet the aims of the WFD. The Catchment Restoration Fund (CRF) was released by DEFRA in 2012 which only third sector led partnerships could bid for. The Catchment Restoration Fund encouraged a holistic landscape approach to improve water bodies (Bracken and Oughton 2014) using an ecosystem services approach. While the CRF had similar aims to the River Improvement Fund a distinct difference was the inclusion of a wider and more local stakeholder network making decisions about the water environment.

1.2.4 Introducing Payments for Ecosystem services (PES)

Within England and Wales there is a compelling evidence for the adoption of the beneficiary pays principle (or PES) replacing the conventional polluter pays principle; where those that pollute are charged for the process of remediation (OFWAT 2011; DEFRA 2013a). At a basic level the PES approach works on the basis that those who provide ecosystem services within the landscape should be reimbursed for doing so. Existing opportunities for PES of relevance to catchment management include water quality, flood risk and forestry management as well as the linkage of environmental stewardship mechanisms with a PES approach. Upstream catchment schemes (such as those trialled by United Utilities and Wessex Water) where improving land management practices results in better water quality reducing costs of water treatment are well known PES examples, however other PES examples to improve water quality could include constructed wetlands to deal with wastewater discharge or nutrient enriched water from development. The slow implementation of PES schemes as opportunities for funding environmental improvements relates to improving confidence in this approach for buyers (e.g. water companies), providers (e.g. farmers) and intermediaries (e.g. river trusts or the Environment Agency). Key to the PES approach being adopted more widely was the release by DEFRA in May 2013 of a best practice guide to adopting PES (Smith et al. 2013). This guide details development of markets for ecosystem services where both the providers and the beneficiaries are brought together, despite this guide currently mechanisms for developing PES are not clearly defined. Although outside the scope of this thesis the PES approach brings the value of environmental economics into the catchment management arena and provides additional weight for the need for organisations across multiple tiers of governance to work together as well as introducing a mechanism to fund future sustainable landscapes. Critically DEFRA (2013) emphasise the need to introduce a spatial basis for planning future PES schemes.

1.3 Supporting stakeholder engagement at a catchment scale: tools to involve catchment stakeholders with the decision making process

It is worth reinforcing again that to translate the multiple policies, white papers and directives which exist in the rural arena to a catchment scale and to then communicate these to stakeholders at a local level so that they can play an informed role in decision making is challenging (Cauldrick and Smith 2014). It is not straightforward to engage communities and stakeholders with the unseen pressures on their surrounding landscape (Appleton 2004). Spatial technologies such as maps, Geographical Information Systems (GIS) and visualisations have a long history of being used for improving communication in decision making and planning for the future (Bishop and Lange 2005; Dockerty et al. 2006; Stock et al. 2007; Pettit et al. 2011). From Humphry Repton's red books in the 19th Century (Fig. 1.10) to state of the art wearable technology in the 21st Century there is demonstrable value in visioning and communicating options prior to implementing landscape change. The use of visioning in catchment scale projects in Australia and the US has indicated that there is potential for spatial technologies to improve communication between stakeholders, raise awareness of issues and improve dialogue. Spatial technologies can be used both as a tool in catchment management such as modelling or analysis and also to support approaches in catchment management which integrate different governance and science-based methods (Smith et al. 2015). GIS within catchment management can be used not only to show where problems exist but to show how solutions can be designed, and when linked to a display capability also give some visual representation of the changes.

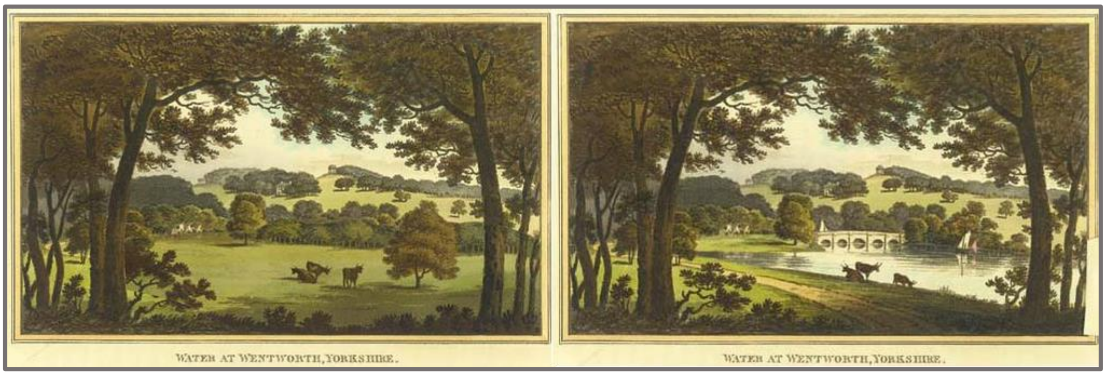


Fig. 1.10 Early 19th Century Landscape visualisation by Humphry Repton (1803) at Wentworth House, South Yorkshire.

Decision making at a landscape scale such as a catchment can be supported by the use of visualisations and GIS, in addition when spatial technologies are integrated with an ecosystem services approach decision makers can evaluate the multiple benefits from change and communicate these to non-experts (Lowell et al. 2009). GIS has been adopted by wildlife trusts and national parks both in the UK and the US to vision and map ecosystem services. The Wildlife Trusts have a project called EcoServ-GIS (Winn and Brocklebank 2013), the US Geological Society has SolVES which assesses, maps and quantifies the social values of ecosystem services (Sherrouse et al. 2010a), and the Westcountry Rivers Trust uses ArcView to provide detailed ecosystem services visualisations at a catchment scale through a repeatable protocol (Cauldrick and Smith 2014). While these projects are developed for use with easily accessible map data the process of carrying out an ecosystem services assessment using these tools still lies within an expert domain; in addition as these projects are outside academia the value of ecosystem services visualisations to stakeholders was not robustly evaluated. However the process of communicating ecosystem services and designing tools to embed ecosystem services within decision making has been evaluated positively by Mahmoud et al. (2009), Albert et al. (2015) and Wissen Hayek et al. (2015). While these projects support the value of using spatial tools to embed ecosystem services within planning processes (including those at a catchment scale) there is potential for further work to evaluate the degree to which the general public might engage with the ecosystem services concept when they are not directly involved with needing the information in a decision making process .

Despite the benefits of spatial tools such as GIS and visualisations in catchment scale planning the use of these spatial technologies to their full potential remains outside of the scope of many river trusts and partnerships. The skills required, the cost of data and software licences and the implementation of GIS best practice all combine with resource deficits to create barriers to wider adoption. Given the literature (Caminiti 2004; Stock et al. 2007; Pettit et al. 2007; Pettit et al. 2011) demonstrates the benefits of using spatial technologies to support many elements of the Catchment Based Approach such as stakeholder engagement, improved restoration project planning, dissemination of policy documents then there is a gap to be explored regarding the means by which these technologies can be made more accessible.

1.4 Research Aims

Catchment partnerships are supported through the development of catchment projects with the four stage CaBA framework (engage, use data, deliver, and monitor). This framework has therefore been a strong influence in structuring this research although it should be noted that for the purposes of the thesis stages two and three were combined (Fig. 1.11). Research evaluating the application of low cost spatial tools used to support the Catchment Based Approach has to date been limited. This lack of attention and gap in the research is significant as despite fewer funding opportunities to carry out restoration projects practitioners are facing increased expectations by government agencies to meet the aims of the WFD. A deeper understanding is needed of the barriers to adopting spatial technologies, of the adaptations to make spatial technologies usable by practitioners and other institutions, as well as of the ways in which the technologies can be used by stakeholders and practitioners to support the catchment approach to water management.

Therefore this thesis asks what technologies can be developed or adapted and made further available in order to support catchment management as a process with involvement from catchment stakeholders and practitioners in relation to relevant institutions.

This thesis aims to answer the research question by:

- exploring how spatial technologies can support the development of future sustainable and multifunctional river catchment landscapes.
- examining the strengths and weaknesses of spatial technology in practice through the adoption of existing robust evaluation practice and,
- working with stakeholder groups and third sector trusts to identify barriers to wider adoption of spatial technologies by these groups and implications for governance.

A key focus of the research was communication of the scientific concept of ecosystem services which is challenging for non-experts who are increasingly engaged in participatory decision making planning processes. The findings of the research are relevant for catchment management practitioners interested in the use of spatial technologies to support their management objectives.

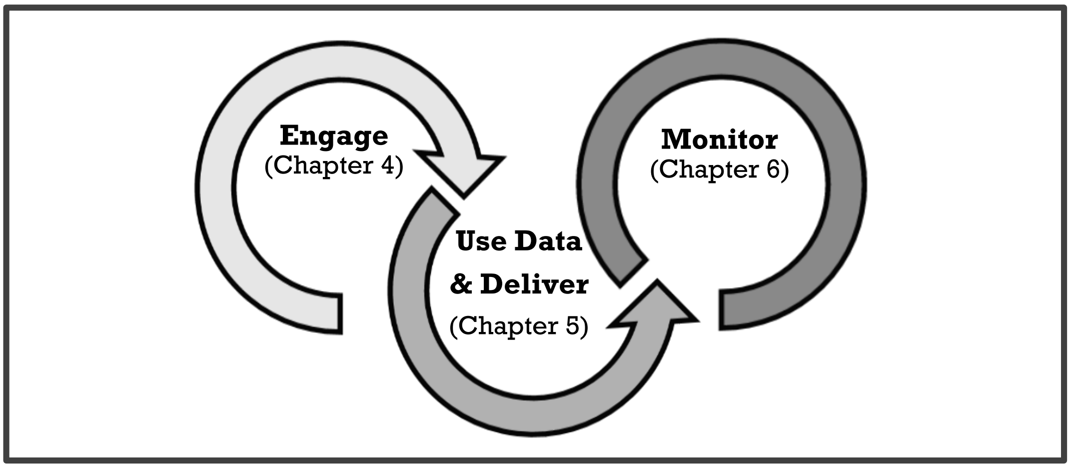


Fig. 1.11 The CaBA or Catchment Based Approach Framework used in structuring this thesis

1.5 Outline of the Thesis Structure

The research presented in this thesis contains case studies carried out within the East Anglia region chosen to reflect the stages of the Catchment Based Approach (CaBA). It was advantageous to carry out the research in this area using case studies to evaluate the role of spatial technologies in the implementation of CaBA for three reasons. Firstly as a result of centuries of land management practices to both reduce flooding and support nationally important agricultural productivity East Anglia is failing many components of WFD compliance providing opportunities to work with multiple organisations at a catchment scale to achieve WFD targets. Secondly the catchment organisations and river trusts within this region were not well established and were seeking processes to bring together large volumes of data across several spatial scales to create catchment management plans. Finally because there has been little or no existing participatory engagement with catchment stakeholders in the region (unlike other areas such as the South West or Cumbria) there was less chance of stakeholder fatigue and demand from the new river trusts to build stakeholder networks was high. The decision to work with the new organisations is evaluated in more detail within the conclusions chapter.

This thesis is set at a point in time where National and European legislation demands considerable improvements in the water and habitat sectors to improve ecosystem services. The UK has been late to adopt a catchment scale approach in part due to the historical separation between the management of land and water. When the scale at which the landscape is managed increases so does the network of stakeholders involved in locally focused decision making (Bracken and Oughton 2014). This thesis researches the utilisation of spatial technologies to support the Catchment Based Approach to landscape management. Chapter 1 has introduced the thesis subject and outlined the problem, this is followed by Chapter 2 which reviews literature focusing on how spatial technologies have to date facilitated catchment management. During the thesis the role of local organisations and the hydrological character of the catchment repeatedly influenced the design of the three case studies (the methodology of each case study retained a practitioner focus and evaluated both practitioner interaction with the tools and the technology development itself); these are covered in Chapter 3 which provides additional background information to the three empirical data chapters. Chapter 4 presents an augmented reality smartphone application aimed at engaging catchment stakeholders with the location of, and information about, catchment ecosystem services to evaluate the barriers to more widespread adoption of this type of immersive technology. Chapter 5 presents research into the adaptation of a low cost visualisation tool and evaluates the application of a climate change visioning framework to contribute to the production of a real-world catchment management plan. In Chapter 6 a smartphone tool previously used in epidemiology is adapted to monitor the health of a river and some of its catchment using a citizen science approach. In addition, Actor Network Theory is used to describe relationships within and between the technology and organisations involved. Key themes are summarised in Chapter 7 where the thesis concludes.

Chapter 2. Framing the thesis: a literature review

2.1 Introduction

Spatial technologies such as those evaluated within this thesis (Augmented Reality, Visioning and Geographical Information Systems, and Volunteered Geographical Information and Citizen Science) have the potential to be used individually or together to support one or more stages of the CaBA framework (Fig. 2.1). This chapter will review the literature to show the need for, and problems of, communicating complex science to stakeholders, the limited range of visioning tools suitable for use within an existing planning process, and the untapped potential of volunteered geographic information in monitoring at a catchment scale. The issues of managing volunteered geographical information and the emerging problems with the use of data contributed by citizens are evaluated before methods for examining the influence of technology on social organisations are appraised. The detail of catchment organisations together with the influence of landscape scale funding and catchment hydrology on the case study design is discussed in Chapter 3.

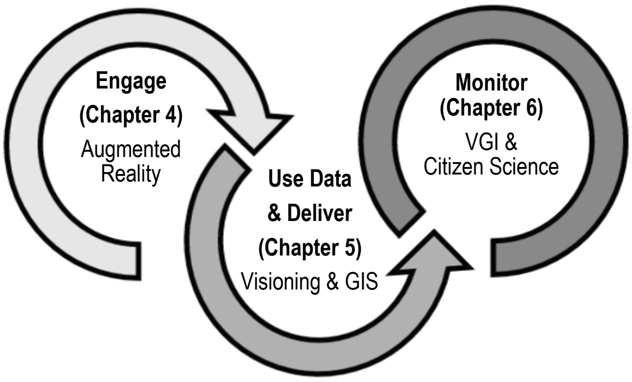


Fig. 2.1 Spatial technologies explored in each data chapter in the context of the CaBA framework

Article 14 of the Water Framework Directive promotes three tiers of participation between catchment stakeholders and the decision makers; these are active involvement, consultation, and information supply (Maurel et al. 2007). Arnstein (1969) developed a typology to illustrate the degrees to which citizens are involved within participatory processes from the perspective of those on the receiving end rather than those in power (Cornwall 2008). Known as Arnstein's ladder of participation (Fig. 2.2) this ladder has been used in the literature to explore roles within planning processes and evaluate the degree of engagement during the use of participatory spatial tools (Sieber 2006). When Arnstein's typology is applied to the WFD levels of participation only the active involvement option meets the required interactivity between citizens and power holders to be considered participatory, with both consultation and information remaining within Arnstein's tokenism stage providing citizens with a voice but no power. In response to literature which advocates the wider inclusion of stakeholders within the planning process and decision making (Sieber 2006; Cornwall 2008; Southern et al. 2011; Spray and Blackstock 2013) the three case studies within the thesis are guided by Arnstein's (1969) ladder to ensure that with each case study citizens who took part moved up the ladder towards citizen control.

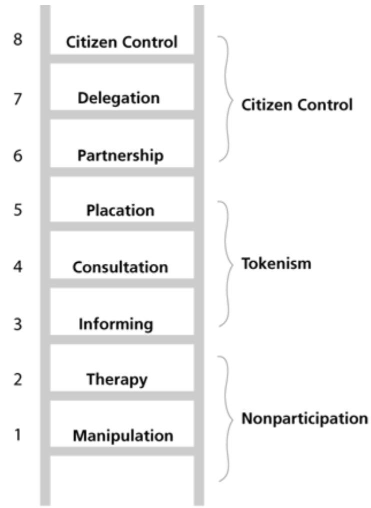


Fig. 2.2 Arnstein's ladder of participation (Arnstein 1969)

2.2 Engaging the unengaged with the concept of ecosystem services

Within the catchment landscape drivers for change frequently act at a scale greater than both individual and local community decision-making processes (Stoate 2012; Spray 2012). The causes of environmental change are complex (Spray 2012) and challenging to communicate at a local scale (Cauldrick and Smith 2014). Similar to the science of climate change ecosystem services are a complex discipline, the language is academic and the interconnected nature of the processes involved is outside the scope of many lay-stakeholders understanding (Defra and COI 2007). The ecosystem services approach (EsA) in Section 1.2.3 aims to mitigate these issues by involving multiple disciplines, bringing together community and expert knowledge, alongside the use of participative techniques to review alternative scenarios which bring ecosystem services into the forefront of resource decision making (Spray 2012; Petheram et al. 2012). Similar to the ecosystem services approach the WFD aims to increase public participation by encouraging a bottom up approach to planning decisions within the catchment landscape although it has been less prescriptive in how this can best be done. This has left WFD practitioners with much to aim for but little guidance on how to achieve it. What is clear is that any catchment planning process should engage with a wide range of stakeholders to reflect the diverse functions which the landscape supports (Benson et al. 2014).

The complexity of ecosystem services should not be considered a reason to avoid the introduction of ecosystem services concepts as motivations for increased understanding of the way in which natural resources are currently consumed and managed (Defra and COI 2007). The evaluation of the means by which complex science of hydrology can be communicated to lay stakeholders has shown the use of visual models to be successful (Lowell et al. 2009) but that an amount of supporting information is required. Climate change is similarly complex, Nicholson-Cole (2005) evaluated the use of visualisations to represent impacts of climate change to influence behavioural change and reduce energy consumption at a local level. When describing the communication of a complex scientific concept Nicholson-Cole (2005) summarised the characteristics which any form of visualisations should incorporate as being easy to relate to both spatially and temporally, as scientifically trustworthy as possible, instructive, attention grabbing and tailored to the target audience. Stakeholder characteristics known to influence stakeholder preference for visualisations include; the stage of life people are at, their knowledge of the issue, educational background and lifestyles (Nicholson-Cole 2005; Bishop 2014). This would suggest therefore that to establish the success of any tool designed to communicate ecosystem services a number of questions need to be asked of study participants in order to ensure a representative sample evaluates the use of the tool. Evaluation of a tool designed to communicate ecosystem services must consider first whether there is a target audience to which tools might appeal as well as identifying any stakeholder characteristics which might influence the interaction with different versions of the same tools.

2.2.1 Technology for communicating information and promoting engagement with ecosystem services and catchment management

Having established that there is a requirement to encourage people to become more focused so as to link their behaviour to their surroundings (Stoate 2012; Nicholson-Cole 2005) this section provides examples of how spatial technologies can support engagement with the landscape around us. For this section the process of engaging stakeholders with information about their landscape is purposely separated from the process of engaging participants within a decision making planning process which is covered within Section 2.3.1.

Appreciable work has been done by those outside academia on the process of engaging decision makers with ecosystem services (Sherrouse et al. 2010b; Winn and Brocklebank 2013; Cauldrick and Smith 2014), however at the time of designing the research studies fewer academic studies had been carried out to engage members of the public (lay-stakeholders) with the concept of ecosystem services. Despite GIS solutions emerging for decision makers to plan at a catchment scale using the ecosystem services approach (Sherrouse et al. 2010a, Westcountry Rivers Trust 2013), there are fewer attempts made within the literature to directly involve lay stakeholders with the science of ecosystem services and promote a deeper understanding of the catchment landscape (Mahmoud et al. 2009; Albert et al. 2015; Wissen Hayek et al. 2015). Using a random sampling strategy of local residents Brown and Weber (2011) utilised Public Participation Geographical Information Systems (PPGIS) to gather data on the ease with which residents could identify ecosystem services within a local nature reserve. Each household was provided with an authentication code to ensure the web based survey had a high level of response validity. Participants were invited to choose a type of ecosystem service and click on the map where they believed that service was to be provided. Results showed cultural and recreation services were most likely to be chosen, interestingly only a small proportion of respondents identified the majority of the ecosystem services suggesting that the understanding of ecosystem services is limited. Post survey the authors concluded that it would have been helpful to give a one page summary of what ecosystem services are and where they are most likely to be found within the landscape highlighting the need for supportive information in such engagement (Sheppard 2001; Salter et al. 2009; Pettit et al. 2011; Bishop et al. 2013) . With both sustainability and multifunctionality important factors in the design of future catchments then all tiers of stakeholders involved in planning decisions should be encouraged to understand the role of ecosystem services; thus there is a need to improve the way in which the concept is communicated.

As an educational device, spatial tools have potential to communicate the location of ecosystem services across the landscape to improve lay-stakeholders understanding of surroundings. By enhancing (or augmenting) someone's current perception of reality additional information can be communicated (Goldiez and Liarokapis 2008). Signboards and static information posts have long been used by museums and nature reserves to inform visitors. Museums have been quick to adapt to audio trails giving users the opportunity to acquire information using more than one sense and interactive displays are becoming increasingly common; evidenced by the growth of digital signage and projects such as 'The Hidden Museum' in Bristol (Roberts 2015) which uses iBeacons to explore and promote activities around the city's museums. Another example of spatial technology is augmented reality (AR). Developed in the 1990's by Boeing and Logitech AR remained a gimmick until 1999 when Hirokazu Kato released the AR toolkit allowing images to be overlain on any existing image (Henrysson and Ollila 2011). The most recent innovation has been the use of AR with modern smartphones i.e. those which have a GPS, and a camera as well as internet functionality and typically a large touch screen. Used in gaming for many years, usually with headsets, AR offers a unique means to interact with surroundings adding an extra dimension for the user (MacIntyre and Mynatt 1998). Rose et al. (2010) class AR into two types, marker (Fig. 2.3, Fig. 2.4) or marker-less (Fig. 2.5, Fig. 2.6). Marker based AR requires a trigger to activate such as QR codes or images embedded in online and paper media. Used to convey additional information in computer gaming or bring magazine articles to life, markers are translated by the webcam on a PC or the camera on a handset which in turn triggers the augmented information to appear, often in the form of an animation. Downsides to marker based technology include requirements for the latest version of multimedia plugins such as Flash and the most up to date internet browsers as well as the need for an external trigger; within rural landscapes these could be a target of vandalism or deterioration.

Marker-less AR (Fig. 2.5, Fig.2.6) instead makes use of the on board GPS of a phone to know the location in 3D space of the handheld device before updating the device screen with predetermined points of information (POIs). In September 2010 the National Geographic published an article 'The Big Idea' about AR, this suggested that by the end of 2010 we would have eyewear enabling augmented reality and by 2015 contact lenses would support this technology. The accompanying image to the National Geographic article is shown in Fig. 2.6 where a National Geographic staff member captures a scene on his phone from his neighbourhood and demonstrates the range of augmented information from various marker-less apps which are available at that location. While the recent launch of Google Glass has had a mixed response the development of Oculus Rift; a lightweight VR headset which pairs with headphones and game controllers has great potential for use in visualisations. While no accurate release date has been set the gaming industry is predicting a date of early 2016, the headset will sell for around £200 (Egan 2015) making this technology affordable and pushing the future boundaries of developing in situ visualisations. With regards the technology which is available at the moment and influenced by the needs of the river trust or catchment group marker less technology is more appealing; it can be managed from a central resource across a large area such as a river catchment and data can be easily changed to reflect the seasonality of the features or highlight features behaving in a certain way. It is less likely to suffer from vandalism as there are no permanent elements in the landscape. That said it is less likely to attract ad hoc users as most would need to be informed of its existence to download any necessary software before visiting the augmented area.

Fig. 2.3 Examples of moving marker based animated Augmented Reality. The GE Wind turbines, activated when printed page (left) is shown to a PC webcam a set of animated wind turbines appear on the screen (right), blowing on the PC microphone causes the turbine blades to turn.

Fig. 2.4 Examples of marker based augmented reality (left) when viewed through a device (webcam or phone camera) this museum ticket becomes the platform for a 3D dinosaur, AR has potential for educational apps and extending the interaction of cultural displays with additional or 'augmented' information (www.lm3labs.com). (right) The same technology is being trialled in healthcare with training surgeons in the use of instruments for complex laparoscopic (keyhole) surgery (Botden and Jakimowicz 2009)

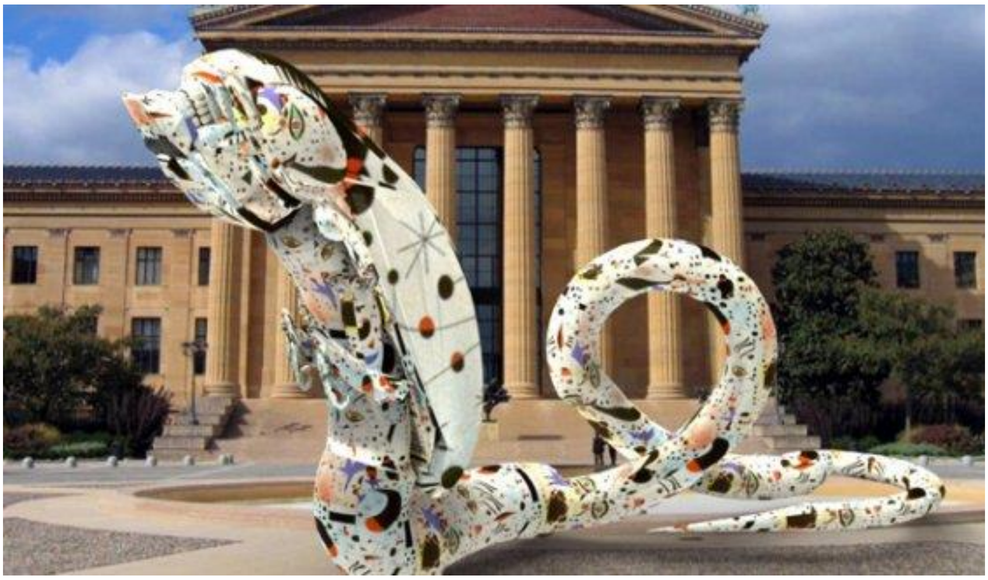


Fig. 2.5 An example of marker-less augmented reality, this art installation is viewed through an app on a smartphone Augmented Reality. Miró Alien Chest-Burster by Jon Rafman –installed at the top steps at Philadelphia Museum of Art (from Philly 360 2011)

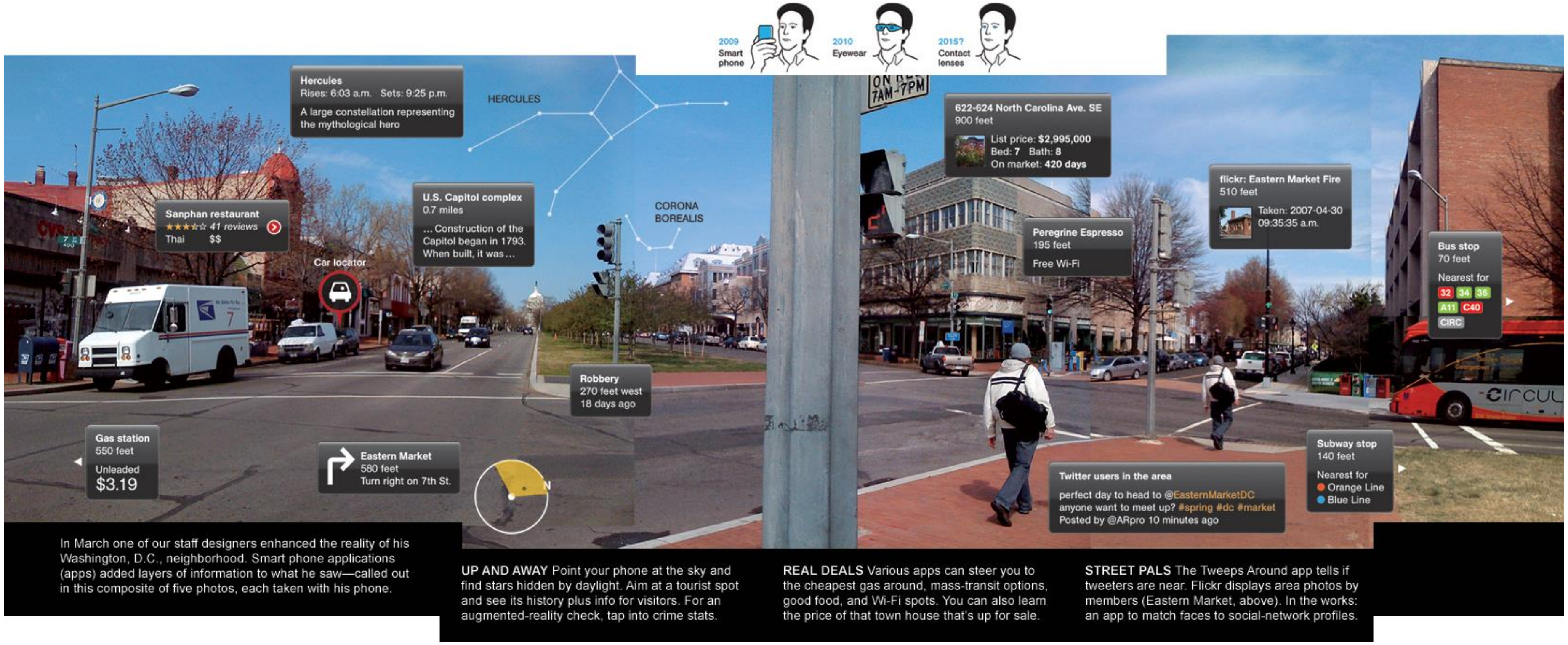


Fig. 2.6 Composite image developed to reflect a neighbourhood augmented with information from various marker-less apps installed on a phone. The full details can be found here (http://ngm.nationalgeographic.com/big-idea/14/augmented-reality), the apps show details of crime, tweets in the area, restaurant reviews, and public transport information, housing prices, the price of fuel and star constellations.

Augmented Reality offers the user a full and complete sensory engagement. While other studies have explored the benefits of using sounds with visualisations (Carles 1999; Gouveia et al. 2004; Lange 2001) few have evaluated the potential of AR for exploring a wider range of environmental data (Bishop 2011). Location based information is usually found within the commercial and gaming sectors; and closely linked to the objects in view at the time (Bishop 2014). Bishop (2011) proposes the use of technology such as augmented reality could provide information about the surrounding landscape on a wide range of topics e.g. agricultural output, forest habitat value, carbon sequestering, water quality; many of which pertain directly to the science of ecosystem services. Indicating which features within a catchment provide ecosystem services and where these features are located also fits with the ideal provided by Nicolson-Cole (2005) of making visualisations easy to relate to spatially. During the course of the PhD the potential of Location Based Information on mobile devices was explored by Bishop (2014) who concluded that the main areas to explore were in the applicability of data, technology and user interface; using techniques such as augmented reality introduces a more playful aspect (Lange 2011) to the process of communicating a complex topic such as ecosystem services, and potentially such an attention grabbing option will appeal to a different target audience (Nicolson-Cole 2005). Bishop (2011) saw potential in the use of smartphones to support decision making, planning and engagement at a landscape scale. In the majority of studies to date visualisations have been presented to viewers away from the landscape which is being visioned through maps, photo montages, 3D models or flythroughs (Bishop et al. 2013). Lange (2011) proposed that the use of location based technologies could revolutionise planning applications with people able to see the proposal in situ. While some work has been done on visioning a user's own locality the research to date has evaluated the success of immersing users with information about their landscape primarily in urban settings (Chou and ChanLin 2012; Cirulis and Brigmanis 2013), or where the mode of travel through an a rural landscape is a car (Bishop 2014). Less research has been carried out on the use of visualisations as viewers walk through a rural landscape. There is a research gap as to how people interact with immersive technologies in rural settings in contrast to the different types of information in the built environment and little is known about what obstacles exist to the more widespread use of spatial technologies within a rural landscape to communicate information about a feature at a given location.

2.3 Catchment scale framework for visioning sustainable futures

A 'visualisation' is a model or representation of a real world landscape and can take several different forms. Within the context of this body of work visualisations are taken to mean those created by computer software although other types discussed in the next literature section include paper maps, photo-montages and 3D models which can be presented in virtual reality theatres or on desktop PCs. This section looks at the use of visioning frameworks within participatory planning processes, after which the development of visualisations to support the participatory process at a catchment scale is reviewed; followed by an evaluation of spatial technologies which can be adapted for use in developing visualisations.

2.3.1 Frameworks for landscape scale planning process

The Water Framework Directive explicitly states that public participation is required in the development of River Basin Management Plans (Stoate 2012; House of Lords 2012 p. 19; Benson et al. 2014). Sustainable catchment management inherently forces increased interaction between a wide range of practitioners and policy makers who manage the landscape, these include natural and social scientists, land and water users, land and water managers, planners and policy makers (Pettit et al. 2007; Southern et al. 2011; Spray 2012; Starkey and Parkin 2015) but a lack of integration between policies covering land and water management are resulting in uncertain outcomes of conflicting and competing policy measures (Macleod et al. 2007). Participatory planning techniques have long been used in decision making (Lange and Hehl-Lange 2010; Pettit et al. 2011), and landscape management is a process which benefits from multiple stakeholder input both to design future management options and to evaluate them (Bishop et al. 2005) reinforcing their use in catchment planning.

Participatory processes often use maps within reports, face to face meetings, two way online information gathering exercises and large stakeholder events (Herzele and Woerkum 2011). An example of public participation in the planning process is the use of a focus group to gather views from a stakeholder group or sector of a community; however depending on the stage at which these views are asked for there is uncertainty around whether they influence the process (Scott 2011). In addition criticisms of participatory planning processes include the complexity of the process, stakeholder fatigue, and one way communication from decision makers in consultation stages (the tokenism stage in Arnstein's ladder (1969) see Section 2.1). Despite the introduction of the planning portal in 2008 streamlining the application process, and the introduction of neighbourhood planning increasing the abilities of communities to get involved within England and Wales planning meetings have remained a traditional form of public participation in the planning process (Cullingworth et al. 2015). Kingston et al. (2000) suggest that there are a number of problems with this format of engagement;

- Potential for face to face conflict which is less likely to contribute to positive information exchange,
- Dominance by some participants leading to a situation where the views held by a few outweigh the view held by many,
- Physical location cannot be accessed by everyone, the elderly and disabled may also be more challenged to attend,
- Hard to get a representative cross section of the community, those with time to dedicate to planning issues are retired, planning meetings are often held in the early evening, inconveniencing and excluding those working shifts or with young children who may find it more difficult to attend.

Despite the increase in online mechanisms (such as the planning portal) for engaging communities with planning the 'decide, announce, defend' process of planning still hold true (Cullingworth 2015 p.511). Further criticism is provided by Rantanen and Kahila (2009 p.1982) who state that the current top down approach to planning only supports a one way flow of information, "*when the process is fair and open, the stakeholders can more easily accept, as well as commit themselves to, the outcome of the process"*. In changing the focus of the planning process to become more inclusive and empowering for citizens a challenge is to improve the link between spatial tools for engagement and active participatory processes (Rantanen and Kahila 2009), and to develop an arena in which new communities of practice can be established (Lave and Wenger 1991). Cullingworth (2015 p.509) recounts how the number of stakeholders who actively get involved with planning processes is in direct proportion to the distance from their home; a particular problem therefore across large catchments where the spatial and temporal relationships are poorly understood by catchment stakeholders.

One means of bringing together tools for engagement and participatory processes to support decision making is through the use of a framework; which can be defined as a basic structure underlying a system representing the relationships between components (Georgina et al. 2011). In evaluating frameworks for participatory processes the work of Steinitz (1990) is notable with Geodesign including a set of iterative questions designed to understand the study area, specify the methods to be used and perform the study. Steinitz (1990) described Geodesign (also known as changing geography by design) as encompassing many different disciplines such as landscape designers, scientists and planners and offering a scalable solution to couple the creation of design proposals with exploring the potential of such proposals. The scope of Steinitz's approach meets the requirements of visioning at a landscape scale as it is broad in nature and as such readily applicable to a range of different case studies; however the approach is targeted at design practitioners rather than the lay practitioners in river trusts and requires a degree of interpretation by an expert facilitator. A more inclusive framework is required in catchment management, one which is designed for communicating to and gathering information from, the wider experience base of lay stakeholders, catchment specialists and agencies and visioning the information which they develop together.

Southern et al. (2011) concluded that within the UK at the time when a detailed catchment scale study in whole landscape design was carried out there was no cohesive framework for implementing or visioning landscape scale governance. While frameworks exist for climate change visioning; such as the project by the Collaborative for Advanced Landscape Planning (CALP) in British Columbia (Sheppard et al. 2011), few exist for the specific process of visioning at a catchment scale. Similarities between the two visioning processes exist. Like climate change visioning, catchment stakeholders have to assess and downscale multiple planning policies and national guidelines, the software used shouldbe able to vision at a range of scales to take into account data set at a regional level (e.g. climate change) alongside local planning data. The WFD encourages a participatory approach (Maurel et al. 2007; House of Lords 2012, p. 19) as does the CaBA (released during the final stages of this PhD) but at the time of this study there was no framework designed specifically for catchment management visioning across tiers of governance incorporating multiple disciplines to reduce the gap between the level of stakeholder engagement needed and that which exists. Identifying, adapting and applying a suitable visioning framework could meet the requirement of the

WFD to engage stakeholders with two way information transfer and engaging communities with planning processes at a catchment scale.

An existing framework for engaging communities with climate change is a possible contender for use in catchment visioning. Referred to as the CALP framework barriers to communicating science at a local level identified by the developers of the British Columbia climate change framework included complex scientific data, insufficient data on socio-economic factors, information not seen as salient to local users and few structured processes for engaging with the community (Sheppard et al. 2011). These barriers similarly can be said to exist in communicating with communities about the state of their catchment and the need to move to a more sustainable and multifunctional landscape. Sheppard at al. (2011) proposed that the use of a visioning framework at a local community level could encourage 'two way information transfers' encouraging communities to more easily understand scientific information while policy makers can take on board more of the stakeholders ideas and attitudes; as well as facilitating understanding of how costs to avert harm now will be of benefit to further generations. The geodesign model developed by Steinitz in the 1990s the CALP framework released in July 2010 by Sheppard et al. (2011) shared a number of similarities. Both were developed to encourage collaboration between people and encourage a process of structured communication in order to solve problems within the landscape via a predetermined framework. Neither however are particularly flexible. The Steinitz framework advises how to think about the planning questions, and less practical visioning advice making this 'geodesign' framework less accessible and harder to communicate. Maurel et al. (2007) highlight the need to ensure that public participation must be tailored by practitioners to suit the needs of the specific catchment which it is being used within. Carrying out a meaningful study with both the CALP study and even more so with the earlier Steinitz geodesign model requires a significant investment by all parties placing its scalability and adaptability in doubt.

Given the benefits of the use of frameworks within a visioning process (Sheppard et al. 2011; Steinitz 2012) it is surprising that the UK Government did not release an appropriate visioning framework for catchment management until 2013. The Guide to Collaborative Catchment Management (Defra 2013c) offers catchment organisations the following framework for collaborative working in a catchment process; summarised as: identifying problems, agreeing aims, planning, taking action and achieving outcomes. Within the framework little mention is made of the requirement to move towards a more integrated land and water management approach which in turn requires a means to incorporate multiple spatial scales (Macleod et al. 2007). Pressure to include ecosystem services within frameworks which are used to vision catchment futures has increased since the results from the National Ecosystem Assessment (2011) highlighted the importance of freshwater systems and the variety of ecosystem services which they support and provide. Ensuring an ecosystem services approach in a wide range of water and land management policies is fundamental to further integration and progress for integrated catchment management, new accessible tools and methodologies need to be produced to help 1) identify, map and value ecosystem services and 2) enhance stakeholder engagement, scenario building, measuring and monitoring.

Embedding the ecosystem services approach within planning at a catchment scale in the UK has not been straightforward with tools to take forward the Catchment Based Approach in their infancy as are the competency by practitioners and policy makers to use them (Spray 2012). Examples of visioning frameworks developed includes Brown and Weber (2011) who aimed to improve the ad hoc approach used by national park managers to collecting data for use in planning processes; they concluded that the use of a structured methodology and opportunities for spatially enabled contributions by members of the public using web base tools increased two way confidence in the process and increased trust by the public in park agencies decision making processes. Winn and Brocklebank (2013) developed a local ecosystem services toolkit framework to enable wildlife trusts to work within the existing planning application process and establish where the landscape is in balance and where it needs improving. Although released after the case study methodology was completed mention should be made of the visioning framework for catchment management released by the Westcountry Rivers Trust for practitioners; described as an 'ecosystem services visualisation framework' using a GIS based evidence process (Westcountry Rivers Trust 2013). The stakeholder led process is facilitated by technical specialists collaborating with a facilitator (expert) to review all the policies and documentation as well as available data relating to ecosystem services within the catchment. Once the data is collected the group work together to define critical areas of the catchment for various ecosystem services supported by the data analysis from the GIS. The Westcountry Rivers Trust manual (Westcountry Rivers Trust 2013) describes the process as beneficial in allowing the stakeholders to develop shared understanding and a shared language which can in turn be used to discuss the catchment problems and develop solutions. The most serious disadvantage of this framework is that the process is complex and reliant on both technology and a GIS expert being within the team, while the wide range of datasets required from many different sources introduces a potential for error. The process however of bringing together stakeholders from multiple backgrounds is clearly of benefit to participatory processes at a catchment scale.

While the literature shows that some spatially based visioning frameworks for the development of integrated catchment management exist these primarily centre on ecosystem services and were released after the case study methodology was developed. There was little evidence that a framework designed specifically for visioning development at a catchment scale existed at the time of the study. Looking to frameworks which are tried and tested with representative groups of stakeholders' focuses attention on those which have been developed to deal with climate change such as the CALP British Columbia study; this includes data from multiple sources, scales policy documents and develops indicators which represent the unique area which is under investigation. The CALP framework clearly sets out the requirements for each stage of the visioning process, allowing the role of the visualisation expert to be clearly defined and increasing the value of the stakeholder input (Schroth et al. 2009; Sheppard et al. 2011). However the barriers to adopting such frameworks within a catchment planning process are unknown and it remains to be seen what changes have to be made to the CALP framework in order for it to vision multifunctionality in future catchments, this thesis will aim to address the research gap.

2.3.2 Visualisations to support catchment scale planning processes

The use of visualisations within an environmental context tends to have one or both of the following objectives; either to communicate information or improve understanding of data already collected (Maurel et al. 2007; Bishop et al. 2013). Visual images have the potential to interest and to engage people with the surrounding landscape and to communicate complex concepts (Nicholson-Cole 2005). Visualisations can show data at different scales and can differ in realism depending on what software is used (Dockerty et al. 2005) and the perception of both the viewer and the creator of the visualisation. Advantages to the use of visual images are summarised by Nicholson-Cole (2005) as being easy to recall, facilitate the condensing of information, be evaluated quickly, reinforce potential change, provide a visual accompaniment to narrative and discussion and fit with a culture used to having information presented visually. All these benefits are of direct relevance to the process of visioning landscape scale changes between the multiple agencies and lay stakeholders involved in developing sustainable future catchments. Klosterman (2001), Stock et al. (2007), and Lange and Hehl-Lange (2010) all provide evidence that the ability to explore issues within a 'What If?' visioning framework encourages communities in directing their own future and consequently assists in shaping longer term management goals. Despite this as recently as 2011 Southern et al. concluded that there was yet unexplored potential within the UK for spatially related technology to vision landscapes at a catchment scale. When dealing with the spatial scales inherent in landscape visioning the use of models can be invaluable (Caminiti 2004 p.1) turning a simple process into a more complicated decision support system. While others (Von Haaren and Warren-Kretzschmar 2006) have developed full landscape planning tools which map the interactions within a full SDSS (Spatial Decision Support system) it is outside the scope of this thesis to develop such a tool; this thesis focuses on visualisation tools for use within participatory process and in particular those accessible to river trust practitioners not GIS experts.

Lange and Hehl-Lange (2010) describe 3D visualisations as potentially being a perfect tool to communicate scenarios of future landscapes because of the ability to provide images and views to enable those planning the landscape to evaluate possible options. Certainly the potential of 3D visualisations within the planning process has much mileage in not just communicating the impact of a decision on the future landscape but also being able to influence future changes (Dockerty et al. 2006; Lange et al. 2008), however increasing development of powerful computer technology has meant that the line between reality and virtual reality is becoming increasingly blurred. With 3D visualisation software utilising gaming technology (Lange and Hehl-Lange 2010) it is now possible for lakes to have ripples and trees to sway in the wind; but the ability to develop accurate renderings to communicate future scenarios raises several ethical questions. Visualisation software has transformed the way in which we can 'vision' the future landscape based on two or more scenarios with a range of indicators. However issues have arisen with the rise in popularity of this technique; with regards to bias, accuracy, time, cost and ability in creating visualisations (Sheppard and Cizek 2009). Any 3D landscape visualisation work such as that done to visualise catchment futures must subscribe to an ethical and transparent methodology (Sheppard 2001; MacFarlane et al. 2005); this is particularly important as the way landscape change portrayed by visualisations is perceived by audiences in decision making processes has yet to be fully determined (Lange 2011).

Within visualisations interactivity can be defined as the process by which the display changes in response to a user action (Crampton 2002), while greater interactivity can benefit user engagement there is a trade off with the speed of the response and the detail which can be included in the visualisation (Appleton et al. 2002). Interactivity can cover the degree to which the user can interact with the display (for example through a mouse at a desktop computer, a touchscreen, AR in situ or a headset), or the degree to which the visualisation can interact with data not seen such as indicators and models providing data to the visualisation (such as in CommunityViz). The EU project VisuLands demonstrated examples of interactivity can include the scale at which the visualisation can range (from an overview to a close-up), and the amount of data which is shown to a wide range of stakeholders; challenges of interactivity include ensuring that indicators of social and economic data are adequately represented to those viewing the representations (Wissen et al. 2008). While many visualisation tools reflect the pan and zoom 'user' interactivity element fewer have the functionality to demonstrate the linkages between the underlying data and the GIS or visualisation and between indicators which make up the presentation. With the wide range of scientific, technical, environmental and social data which is used in catchment management for visioning futures a tool is required which can go some way to meeting these requirements to communicate with stakeholders the holistic approach which is needed.

In Australia the role which spatial technologies can play when dealing with catchment scale planning, the benefits of visualisations to bring together stakeholders remotely or in situ, and evaluating the options for the future landscape based on land management practices have been more widely researched than in the UK (Bishop et al. 2005; Bohnet et al. 2011; Pettit et al. 2011). This is in part likely to be due to the federal structure in Australia which unlike the UK has facilitated the landscape being managed at a catchment scale since the 19^{th} century (Benson et al. 2012). A study within the Murray Darling catchment evaluated the strengths and weaknesses of the use of visualisations in different stakeholder groups who are likely to play a role in landscape management (Pettit et al. 2011). While the study by Pettit et al. (2011) concluded that landscape visualisations are a useful, well recognised tool in exploring future change, it did highlight variances in the way different user groups perceived landscape visualisation tools. Within the group which consisted of land managers and planners targeted messages were popular, as was transparency around the underlying datasets, flexible scenario options, and technology which facilitated easier multi scenario comparison such as the provision of tiled windows (Pettit et al. 2011). Future users made up of students were more interested in the functionality of the technology such as enabling fly-throughs and enabling a better linkage between the visualisation and the map. Overall Pettit et al. (2011) suggests that there are opportunities to improve the technology for landscape visualisations, greater inclusion of stakeholders earlier in the process for developing visualisation and a more transparent engagement strategy as part of the process would assist in better collaborative working between practitioners and scientists in communicating future catchment landscapes (Pettit et al. 2011 p. 240). With the intention to work with river trusts and multiple agencies these factors can be incorporated into a framework designed for use in visioning catchment futures.

Known criticisms of visioning are the time which it takes to develop visualisations using a participatory process (Southern et al. 2011), the cost of software (Appleton et al. 2002) and the expert knowledge required to develop visualisations (MacFarlane et al. 2005). Detail of visualisations is important; Appleton and Lovett (2003) show that although higher quality visualisations (which take up more processing time, are more difficult to create, and bring more concerns over accuracy) do enhance the understanding by the public of a visualisation but not all elements of landscape are equal, in particular efforts should concentrate on the realism of the ground, including vegetation and especially in the foreground. Given that detail in a catchment management plan can range from farm wide land use change to small scale reach restoration (Fig 1.6) the need to maintain a realistic visualisation should be evaluated on a case by case basis and projects within a catchment plan visualisation viewed at differing scales in a pilot study before use. Aside from the ethics of over dramatising the future landscape there is also evidence to suggest that this may dis-engage audiences if the scenarios lack credibility (Dockerty et al. 2006) and if the proposed changes seem too real then there is potential for users to feel that the outcome is a foregone conclusion (Appleton and Lovett 2005). This should not be underestimated as a potential issue in the development of catchment scale visualisations and could be mitigated for with a clear indication of the likelihood of a change occurring either within the visualisation or with supporting documentation.

With visualisation (3D) tools now regularly used in planning processes many remain focused on the outcome of the planning proposal (Lange 2011) rather than an inclusive process of learning together; an integral part of the use of visualisations is the evaluation at the end of the process of whether or not they have been successful in improving the stakeholder engagement. Maurel et al. (2007) propose that in evaluating the success of a public engagement tool a series of questions should be answered. These include evaluating the functionality of the tool(s), the resources needed to it set up and run and its applicability to stages in the participatory process. Evaluation facilitates the collaboration between researchers allowing best practice to be continually refined and processes updated. Evaluation of visualisations is however challenging. In the study by Salter et al. (2009) a pertinent conclusion was the difficulties in evaluating the visioning process including the lack of time to evaluate the scenarios, the need for multiple facilitators and supporting information, the optimal group size, and the cognitive load on participants. Bishop et al. (2013) identified how a good evaluation of visualisations takes time (a minimum of two hours), that because of this the sample size will necessarily be quite small and that the stated preference by a user does not necessarily reflect the tool best at delivering a particular message thus tracking use is critical even if this means creating a more controlled environment. Data with similar visualisation trial results could be combined but this would require strict procedures to ensure validity; another option is a longitudinal study which would require commitment from participants (Bishop et al. 2013). In working with real world catchment organisations the processes used to evaluate the success of the visualisations should therefore be led by existing research.

A special edition of Landscape and Urban Planning (Volume 100, Issue 4) included two papers theorising future directions for the development of landscape visualisations. First the application of gaming technologies not just for the purpose of bigger and better visualisations but also as a tool for decision making (Bishop 2011) and the potential of mobile augmented reality to support participatory planning processes (Lange 2011). During a planning process when stakeholders are asked to choose from several scenarios linked to existing policies then decisions and ideas are already constrained, by using simulation and the idea of games to solve problems then the process will become more 'fun' and perhaps result in higher levels of engagement (Bishop 2011) capturing the attention of those currently unengaged with both planning and the environment around them (Lange 2011). As discussed in Section 2.2 AR holds promise in potentially being able to deliver the multi-sensory aspect to real landscapes (Lange 2011). Noise is often considered in environmental assessments and studies as a negative factor, however sounds add value to the perception of a landscape and the visual sense can influence the auditory sense for example by viewing a pleasant landscape the perception of unpleasant sounds such as traffic can be mitigated (Carles et al. 1999). The study by Carles et al. (1999) found that sounds which are wholly natural are considered positive and add value to both rural and urban landscapes, particularly the sound of water and birdsong, and showed images and sounds could influence each other. Lange (2011) suggests future research in landscape visualisations should consider including additional senses for landscape visualisations such as sound, potentially mitigating for geographic dirtiness which Cartwright et al. 2005 describes as affecting the realism of rural landscape visualisations such as where a rural photomontage fails to capture the smell of the pig farm out of sight or the sound of an airport over the hill. Lange (2011) identifies the challenge of perception is heightened when dealing with past and future landscape, not only how people perceive visualisations but indeed how the researchers validate the accuracy and validity of visualisations. Increasing the focussed use and development of landscape visualisation will almost certainly improve public participation in the planning process (Lange 2011).

2.3.3 Spatial technology to support the development of visualisations

Traditionally a visioning process is iterative between the visualisation expert and the sample of stakeholders who work together within a visioning framework to identify the areas to focus on (Lange 2011) and develop visualisations. Landscape visualisations have in the past taken the form of drawing or maps, as technology has advanced so have the techniques and tools available; meaning visualisation development has become cheaper, more accessible, and more realistic as gaming algorithms have been introduced and software has moved from large desktop computers to small mobile devices increasingly suited to public engagement exercises (Lange 2011). The use of "spatial databases, physical environmental models, visualisation techniques and the analytical capabilities of GIS" can now create effective decision support systems for landscape planners; replacing the traditional map based landscape classifications lacking the flexibility and adaptability required for planning complex landscapes that have competing ecosystem services and demands (Bryan 2003 p. 237). Different technologies can be used to create the visualisations, Pettit et al. (2011) used Google Earth, Sherrouse et al. (2010a) used ArcGIS, Appleton and Lovett 2005, Wissen et al. 2008 and Ode et al. 2009 all used Visual Nature Studio (VNS) and Salter et al. (2009) used Placeways CommunityViz and ArcGIS. Other software includes Virtalis Geovisionary which has the capability for rendering large national datasets at high speed within a virtual reality theatre or for use within participation events on a very high spec laptop. Budgets for visualisation software vary considerably. At the top end Geovisionary is in the region of £7,000 (Virtalis 2015), VNS is £2-3000 (3D Nature 2015) and CommunityViz (Placeways 2015) is £500-£1000 depending on the cost of the underlying ArcGIS licence. It is difficult to be accurate with regards the cost of the desktop ArcGIS licence as it depends on the licencing arrangements but costs are around a £1,000. ArcGIS Online is beginning to gain traction as a tool providing map analysis, and it remains to be seen whether this is reflected with a Placeways extension working with ArcGIS Online. Visualisation software remains expensive which is a barrier for adoption by many resource stretched river trusts, while 3D open source software is still limited, though increasingly open source GIS software such as Q-GIS has additional options for visualising data (Chen et al. 2010); open source software tends to be lower in cost there is an increase in the overhead of learning how to use such a platform, and training is done through an online community.

Before the emergence of geographical information systems (GIS) decision makers were limited in their ability to investigate the options for various landscape management practices (referred to as 'What If?' scenarios), as the paper based tools prevented the analysis of multiple datasets interactively (Sharma et al. 2011). As discussed in Section 2.3.1 the conventional planning system works in a top down manner (Lange and Hehl-Lange 2010; Lange 2011), and this is reflected in the established use of GIS where data is 'provided, manipulated and presented by technical experts' (Talen 2000 p. 280) within the planning process. In 2007 Macleod et al. (2007) evaluated available spatial technologies (including GIS, scenarios, indicators and multi-criteria analysis) and summarised that the integration with participatory planning processes has the potential to support sustainable catchment management. Talen (2000) demonstrated how GIS in a workshop setting can be used as a means to acquire spatial information from residents about their perceptions of the local environments rather than simply being used to communicate facts and data in a hard form. Described as Bottom Up GIS (BUGIS) the results of the trial indicated that residents become increasingly able to integrate complex information in their expression of issues and preferences, and BUGIS becomes a useful tool for representing individual or group preferences due to the wealth of data it can efficiently store and retrieve (Talen 2000). While this form of GIS does not entirely do away with alternative forms of stakeholder interaction, Talen has highlighted there is value in enabling spatial thinking prior to preferences being given to decision makers suggesting several stages should be developed within the catchment planning process. Problems highlighted by Kingston et al. (2000) with the planning system (Section 2.3.1) can similarly be addressed by the advent of web based systems (PPGIS) which allow all residents to have a say, when incorporated into a GIS a powerful tool can be created assisting residents and planners to work together to develop solutions and identify development solutions. PPGIS solutions can range from the 'click on the map and enter a text comment' of the Virtual Slaithewaite (Kingston et al. 2000) to fully integrated planning portals such as SoftGIS developed by Rantanen and Kahila (2009) or the PPGIS created by Brown and Weber (2011) which assessed ecosystem services awareness among local residents. These community focused data collection spatial tools have potential within a catchment setting where it is difficult to get a representative section of the community together to share views, and where different groups within the stakeholders may be at odds.

However the inability of GIS to be able to support real time visualisations in participatory settings is an area requiring more work (Stock et al. 2007; Ghadirian and Bishop 2008). Literature reveals the lack of options for practitioners wishing to make use of dynamic interoperability between a GIS which can store data and models, and visualisation software; particularly as visualisations can be valuable tools in the development of a multifunctional and sustainable catchment by providing a common focus for discussion between various groups (Macleod et al. 2007). A limitation of the more traditional landscape visualisations is the time it takes to create such models and the need for more 'on the fly' software which allows stakeholders to experiment with alternative options and scenarios in situ such as the CommunityViz software developed by Placeways. Dolman et al. (2001) and Macleod et al. (2007) describe the benefits of scenarios for catchment planning as facilitating policy makers and stakeholders to evaluate and explore options for future landscapes without risk of implementing them; particularly useful where there are uncertainties in the decision making process. While there is a body of literature indicating how scenarios have been used to model climate change (Dockerty et al. 2006; Sheppard et al. 2011; Pettit et al. 2011; Bishop et al. 2013; Bishop 2014) there is less of evidence to indicate how this same scenario development could be used to vision change with a much more immediate implementation such as the timeframe for the WFD.

Placeways CommunityViz which Salter et al. (2009) used to create interactive visualisations to represent several planning decisions on Bowen Island in British Columbia is a fully functional but small scale portable GIS Visualisation tool. In their study the visualisations were used to engage community stakeholders within a digital workshop, attendees were chosen to represent those who make planning decisions for the wider community. While the study was shown to be effective in engaging stakeholders with the information required for planning decisions and the software supported the elements of the workshop well some limitations were reported. The first was the limitations of time; and the impact on participant interaction. Recruiting participants for a workshop lasting 2-3 hours is problematic; particularly when it is a not a 'real' planning process. Within Salter et al's (2009) study the visioning process involved expert planners with the collection of the data and the design of the scenarios which were presented to the stakeholders at the digital workshop sessions however the stakeholder group were not involved with selecting the issues which would be visualised. While time constraints made this decision understandable there is the potential it would lead to a reduced feeling of transparency in the visioning process, more could have been done to present the supporting information in a relevant form to improve the ability of participants to provide informed responses within a short timeframe (Wissen Hayek 2011) and this will be of relevance to non-experts engaging in catchment issues.

Perkins and Barnhart (2005) identify three hurdles to overcome while using visualisations within a design process – these are 1) being able to reach a silent majority of stakeholders, 2) presenting information in an engaging accessible manner and 3) providing a means by which to collect data. CommunityViz would go some way to being able to meet both 2) and 3) with the use of a well-designed communication strategy aiming to engage with the silent majority. Of relevance to river trusts and catchment managers alike is the ability of the CommunityViz visualisation software to link dynamically with the GIS, data could be gathered from the stakeholders attending meetings, married with existing data, visualised and if necessary changed in situ. CommunityViz has not been used to date to create visualisations to support a participatory catchment visioning process. However the use by Salter et al. (2009) with small focus groups suggested that it has potential to meet the criteria set out in previous sections, the software is relatively low cost, it has the functionality deemed important by Pettit et al. (2011) and Bishop et al. (2013) with side by side windows assisting lay stakeholders in understanding change and it has the dynamic interoperability between the GIS and the 3D models. The CommunityViz software includes the functionality to display indicators providing stakeholders at workshops with sliders to explore the trade-offs between different land use strategies. Less is known of the limitations of the software in working at a catchment scale and trade-off with the level of detail which can be handled, or the level of realism the visualisations can provide on a desktop PC away from a dedicated virtual reality theatre.

2.4 Engaging stakeholders with catchment scale monitoring

Volunteered Geographic Information (hereon referred to as VGI) describes the increasing phenomenon of user generated content within spatial data holdings and online maps such as OpenStreetMap (Goodchild 2007a). VGI was further defined by Goodchild (2007b) as referring to data collected by human beings acting as sensors of their environment, reporting on one or more observations at a given location. Goodchild (2007b) wrote that if humans are regarded as sensors then there are over six billion sensors upon the earth's surface to return information. However user generated content cannot be contributed without a protocol, a means to capture data, collate the data and review that same information. There is also a distinction made by Harvey (2013) between that which is volunteered (opt in, specific, controlled) and contributed (opt out, vague, little or no control over data collection or reuse). A significant factor in the growth of VGI has been the evolution of digital technologies, the increase in handheld smartphones (Graham et al. 2011) and the improved accessibility of the Web 2.0 and the Internet which together enable the contribution of user derived observations to spatial data holdings. One such example is the technification of citizen science (Wiggins and Crowston 2011). Citizen science can be defined as the collaboration between citizens (volunteers) and scientists; while some VGI examples fall within the remit of citizen science, not all citizen science project involve VGI (Haklay 2013).

Traditionally citizen science is used to describe the process whereby members of the public can take part in bona fide scientific projects to solve real world problems (Wiggins and Crowston 2011). Supported by the increasing availability of technology to collect, report and analyse data the rise of this type of VGI is well documented (Graham et al. 2011; Elwood et al. 2012; Sui et al. 2013). Silvertown (2009) identified three key factors in the rise in popularity of citizen science;

1. Increasing use and availability of technology (both for recruiting people to the project and also for collecting data),
2. Recognition of the financial benefits of citizens as a data collection resource,
3. Increased expectation of research councils and funding bodies for improved science outreach and communication.

Positive features of citizen science can be categorised into four areas (Pocock et al. 2014). First; the collaboration between non-scientists and scientists with varying degrees of association (Wiggins and Crowston 2011) defined by Tweddle et al. (2012) as,

- contributory; with citizens focusing on data collection and least involved in project design which is done by scientists,
- collaborative; where citizens play a role in data collection, data analysis or project design or,
- co-created where scientists and citizens work together through all stages.

The second benefit is cost effective data collection (Conrad and Hilchey 2011) with the opportunity to explore improved ways of working such as the trialling of multi-species recording. The third advantage is one of scale; a group of volunteers can cover a larger geographic area than a single scientist (Silvertown 2009; Science Communication Unit 2013); finally citizen science can promote public engagement with science and the environment (Dickenson et al. 2010); particularly in areas of income deprivation. All these factors remain of relevance to the process of engaging stakeholders to monitor catchments.

Citizen science corresponds to the highest rungs of Arnsteins's ladder of participation with varying degrees of partnership, delegated power and citizen control (Fig. 2.2). With citizen science however greater participation does not equal better in all situations. Haklay (2013) suggests that a citizen science project should not be defined solely on power balance (such as that proposed by Arnstein 1969) but recognise the relationships between the citizens and the scientists. For instance, any typology for citizen science should reflect that participants in some citizen science programmes are happy to remain in the lower rungs of the ladder by submitting data (or observations) and have no desire to invest in greater involvement moving themselves up the ladder (Haklay 2013). Haklay instead suggests a typology which focuses on the degree of participation and engagement with citizen science projects (Fig. 2.7) to cater for the wide range of citizens and skills required to in turn complete the different aspects of diverse citizen science projects.

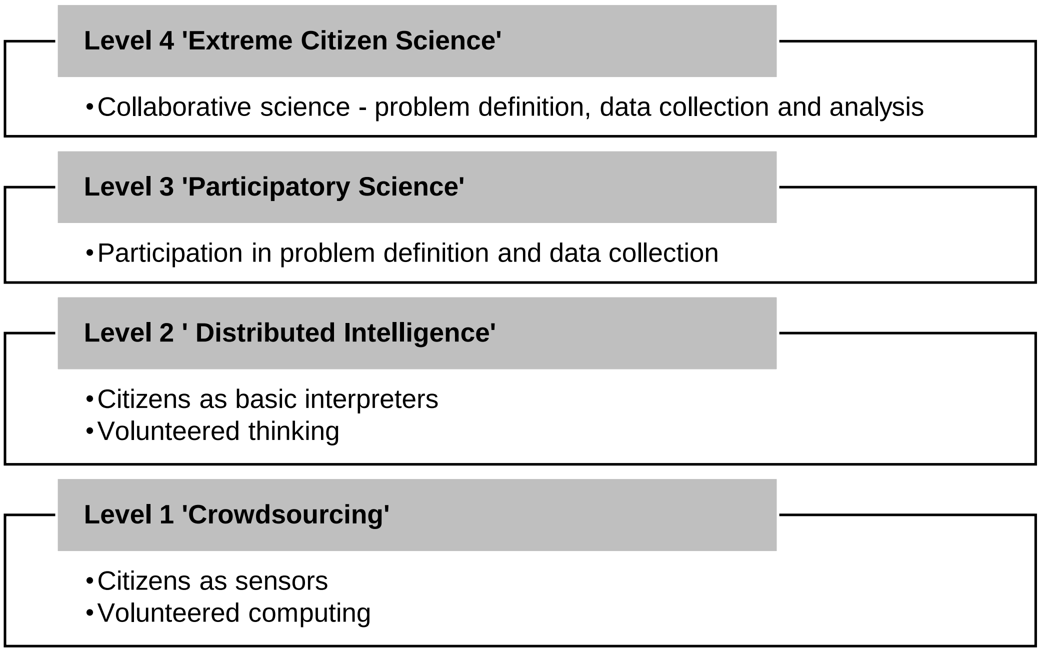


Fig. 2.7 Levels of participation and engagement in citizen science projects (Haklay 2013 p. 116)

2.4.1 Issues with Citizen Science and VGI

Citizen science has some well recognised issues including spatial bias, accuracy, time, cost, recruitment, and data management (Science Communication Unit 2013). Geographically the known effect of spatial bias (where volunteers repeatedly return to one location leading to over representation) can be problematic. Opinion of citizen science by the scientific community has tended to be negative with the data collected by volunteers and lay people deemed less accurate. However the opposite holds true; not only is the data collected by volunteers comparable in accuracy to that collected by scientists but that in some cases it is of higher quality (Science Communication Unit 2013), particularly when supported by technology. The Centre for Ecology and Hydrology (Roy et al. 2012) evaluated the success of a wide range of citizen science projects. One key theme which emerged was the overhead of continual recruitment to maintain sufficient record collection. There were however fewer suggestions on how to carry out this recruitment of citizens other than the reliance on social media (e.g. Twitter, Facebook), with recruitment bias in areas with limited internet connection.

The processing of data records submitted by citizen scientists can be a bottleneck (Science Communication Unit 2013), additionally data incompleteness can be an issue if privacy concerns restrict records released. When relying on smartphones for data collection there is also the risk that rapid app turnover, lack of ongoing support agreements, high development costs and the alienation of some sectors with less access to smartphones will occur. While the growth of mobile phones networks has continued since the initial use of this technology in the first case study (Chapter 4) many areas of rural landscape remain without mobile data coverage. This reinforces the requirement for apps to have the functionality to store and synchronise data adding to the complexity of the protocol that the citizen scientist must follow. There is a need as defined by (Graham et al. 2011) to continually refine the role of mobile tools in line with the demands of the scientific community and the willingness and abilities of the citizens taking part; this makes easily adaptable technology attractive in its adaptability to cater to the dual demands of both communities. The role of mobile technologies can also offset some of the other issues such as spatial accuracy, data error, over complex protocols and cost.

Other concerns in the use of citizen science surround the analysis of the data which is gathered and the ability of organisations to make use of this data intelligently. With real time updating of data collected recognised as vital to participants in rewarding their participation this means additional technological complexity outside of the realm of organisations (such as river trusts) who have limited access to hosting solutions required by large-scale citizen science projects. One solution could be the adoption of an open source project such as EpiCollect which provides web hosting, website design, database management and a means to visualise data which has been submitted. The time to set up projects and associated costs as well as required resources can also be a negative (Pocock et al. 2014) but by following best practice guidelines (see such as those set out in Table 2.1) some of these observed challenges of citizen science can be mitigated.

Table 2.1 Key questions in the development of a citizen science project (after Tweddle et al. 2012)

Key considerations in the development of a citizen science project

1. What geographic or temporal scale are you aiming to cover?
2. How much data do you want to gather and analyse?
3. Can volunteers help to gather and analyse these data?
4. Are there other ways of gathering or analysing the data?
5. To whom will your project appeal?
6. Can you support participants' involvement by providing training and co-ordination?
7. What might be their motivation for taking part?
8. Do you have the resources to develop and publicise the project and share findings with participants?
9. Are similar projects already in existence?

2.4.2 Use of VGI for whole catchment monitoring

Defra states that monitoring should play a key role in collaborative catchment working, providing evidence of project completion and evaluating successful projects for feedback to local communities (Defra 2013c). Monitoring can vary from structured longitudinal studies (e.g. biological surveys or fixed point photography of channel morphological changes post-restoration) to one off ad hoc reporting on issues such as pollution or hazards. Environmental monitoring however of any landscape is expensive and catchment organisations tend to be resource poor (L. Couldrick 2015, pers. comm., May). Within the US this resource gap has been filled by citizen science projects which assist government agencies in managing and monitoring river networks and the health of the wider catchment. Citizens collect observations such as water samples in the Columbia River Keeper programme and the South Yuba River Citizens League in California and report problems such as sewage discharges in the Charles River catchment in Boston, Massachusetts (Roy et al. 2012). There is a lack of research as to whether this approach could work within the UK catchment partnerships and the role that VGI has with the increasing requirement for accurate catchment scale monitoring.

Due to the acknowledgement by the WFD of the role of both citizens and citizen groups in increasing engagement and participation to underpin environmental policy Roy et al (2012) proposed increased adoption of citizen science methods by catchment partnerships. An example of this is the Haltwhistle Burn project in Northumberland, UK which has adopted a citizen science approach. Born out of a focus on flood monitoring the project collects data in the catchment using monitoring equipment and has developed means to 'engage communities with knowledge regeneration and extend gathering of catchment information' in order to develop a catchment management plan (Starkey and Parkin 2015). The project (which is ongoing) recruits communities to become citizen scientists taking observations of weather, river flow, issues and landscape change. Training cards available on the website evidence ten different methods for the citizens who take part to record data, and three different protocols for submitting records via social media or email. The diverse protocols adopted by the catchment project mean an amount of processing by the research team before the observations, values or photographic evidence can be input into scientific models to predict further flood events or highlight areas for restoration and improved management. The inconsistency in recording and reporting protocols has potential to affect accuracy of records within the database and there is an emergent need for data collection protocols to become more streamlined, reducing input errors and the time between data being collected and available for analysis.

2.4.3 Exploring the interaction between the technical and the social – Actor Network Theory

In researching and evaluating spatial technologies to support the Catchment Based Approach the thesis primarily maintains a technological focus, but due to the vital role of citizens in the use of spatial technologies the social influences on the use of these tools also require investigation. One method of investigating these relationships was suggested by Miranda et al. (2012) who proposed that the sharing of data between scientists, policy makers and the general public (such as the wide variety of stakeholders within a catchment partnership) can be described as a "community of practice", a concept first proposed by anthropologists Lave and Wenger (1991). While the use of the communities of practice concept to explore citizen science is shared by others (Davis Jr et al. 2009), this anthropological based theory focuses on the social interactions around the creation and sharing of spatial data. It however does not take into account the role technology can play in influencing organisational structure and data collection processes such as those involved in volunteered geographical information at catchment scale.

Socio-technological interaction is of particular importance when discussing volunteered geographic information (VGI) where human sensors contribute observed data through technological protocols (Goodchild 2007b). Following Goodchild's (2007a) logic that humans act as sensors of the environment, there needs to also be a consideration of the means by which humans report the observations that they make. This can include the Internet, the use of GPS and email as well as the smartphones. Volunteered geographical information (and within that citizen science projects such as that discussed in Chapter 6) is not an object as such but instead an integrated network of social and technological elements or 'actors'.

Actor Network Theory (ANT), developed by Michel Callon, Bruno Latour and John Law (Sismondo 2010), is a framework which applied to spatial technologies, allows the representation of relationships between the human sensors in VGI (Goodchild 2007b) and the technology which supports the capturing, collating and reviewing of data; ANT is of particular interest when working with multiple agencies. For example Alexander and Silvis (Alexander and Silvis 2014) applied ANT to a health system which contained within it many human actors (doctors, nurses, patients, software designers) and technology actors (electronic patient records, x-rays, iPads, databases) alongside rules on medicines and legislative guidelines; all of these 'actors' affect each other but none are more important within the network than another. Alexander and Silvis (2014) propose that ANT is particularly well suited to the exploration of information systems research as ANT denies that there is a difference in importance between humans and the technology they use. ANT does not promote people or technology focusing instead on the relationships (or network) between people and technology; this is of relevance to the interconnected processes and agencies in catchment management as both are defined as actors fulfilling roles which must be continued in order for the network to be maintained.

Palmer and Kraushaar (2013) successfully applied ANT to a citizen science project where citizens captured extreme weather events, technology facilitated the transfer of data to expert meteorologists who in turn then disseminated the information to recipients as weather warnings using media tools. Palmer and Kraushaar (2013) argued that ANT provides a means to prioritise the key actors within a network, and show how technology based processes convert individual pieces of locally sourced text based information contributed by humans acting as sensors into stronger networks with more reliable information which is then returned to the media and general public. Similarly considering the human technology interface inherent in citizen science using this socio-technological framework has potential to expose the barriers and potential limitations of using citizen science within a catchment partnership.

Taking an ANT approach facilitates an understanding of the heterogeneous nature of relationships between the actors in the network and as a result of that co-production of different types of knowledge can occur (Maynard 2013). For the purposes of this research ANT was selected as an appropriate means to evaluate a catchment citizen science tool as it provides a means to consider all social and technological elements involved in the development of a citizen science tool for monitoring and reporting at a catchment scale.

2.5 Summary and research questions

While there is undoubtedly overlap in the functionality of spatial technologies to support stages of the CaBA in this thesis different technologies are kept relatively separate; within the concluding discussion (Chapter 7) an overview will indicate where overlap could prove more streamlined protocols and efficient use of spatial data holdings.

The use of AR in landscape visualisation has been written about positively (Section 2.3.2) but not enough is known of its potential as a communication tool within rural landscapes. Bishop (2014 p.11) highlights that further research is still required to understand more about how the use of AR 'might affect our perception of surroundings and innate enjoyment of the environment' but that 'based on the conclusions from an urban AR driving simulator suggest the affects would be positive'. The research questions which Chapter 4 will address are as follows;

a) To what degree can mobile augmented reality be used as an immersive technology to communicate the location of and information about ecosystem services within a catchment landscape?
b) Is the current level of mobile phone technology and infrastructure sufficient to support spatial applications in rural settings?

With the move by the WFD to engage communities at a local level (Maurel et al. 2007) investigation is required into how stakeholder groups can contribute to visioning exercises when the WFD lies outside of the usual planning processes. Consequently within this thesis attention is focused on the adoption of a local scale visioning process previously used within climate change to research a framework against which visualisations can be developed meeting known ethical criteria relevant to catchment scale planning. It remains to be seen what changes have to be made to the framework in order for it to vision multifunctionality in future catchments. In addition the strong participatory element to the second and third stages of the Catchment Based Approach implies the time is right to evaluate visualisation tools to support the management of natural water resources (Cauldrick and Smith 2014). Technological uncertainties abound also, as to whether there is potential for visioning issues at a catchment scale outside of a VR Lab using an accessible low cost planning tool (Salter et al. 2009). Further research areas involve whether different technologies serve different groups (Nicholson-Cole 2005) and the barriers to adopting these spatial technologies.

The research in Chapter 5 aims to resolve the following research questions;

a) To what extent is it possible to adapt a parcel based urban planning GIS and visualisation package (CommunityViz) to catchment visioning?

b) In what way do computer based visualisations compare to traditional paper based maps; what role does each play in the process of stakeholder engagement with future landscape change?
c) What potential exists for visualisations to be employed for community engagement in catchment management?
d) To what extent can a climate change visioning 'framework' be utilised for catchment visioning?

Existing citizen science projects have a focus on species recording and/or biological monitoring; examples of more policy focused citizen science projects are emerging (e.g. the Haltwhistle Burn Flood and Weather app). The UK Government has recognised Citizen Science as a means to involve the public in the development of research, monitoring and evidence gathering to inform policy (PostNote 2014b). Despite the evidence of the benefits to citizen science in catchment management and monitoring, at the time the last empirical study for this thesis was being developed the Google Play store contained no apps for dedicated environmental monitoring of rivers for communities in the UK. There is therefore a research gap evaluating whether smartphone apps could enable river trust volunteer networks to record observations within their catchment. What type of data collection is most relevant to river trusts? What restrictions exist in the development and use of such an app? Despite the overhead of training and recruiting volunteers could this be a cost effective means to monitor a catchment by resource strapped river trusts and catchment partnerships? The research questions which Chapter 6 will answer are as follows;

a) Are there restraints on the types of observations which river trust volunteers can be asked to report on? Can the design of a citizen science smartphone app assist with mitigating these?
b) By utilising the principles of volunteered geographic data does a mobile citizen science app have the potential to fill the resource gap faced by catchment organisations?
c) Consider the human technology interface inherent in citizen science to review the limitations of volunteered catchment data.

Following this review of the literature and the definition of research questions the subsequent chapter focuses on the influences of catchment character and the changing funding landscape on the design of the three case studies.

Chapter 3. Case study design and implementation

3.1 Introduction

The previous chapters can be considered context to the research process; this chapter acts as context to the case studies which follow in separate empirical chapters. Fig. 3.1 shows the location of the case studies set within the East Anglia region. During the course of the research two external factors particularly influenced the design and implementation of the case studies and thus are considered of sufficient importance to require a separate chapter;

- the approaches local river trusts and catchment partnerships have taken in interpreting and acting upon national frameworks,
- the influence of catchment hydrology on the WFD targets each river trust or catchment partnership must achieve and subsequent effect on case study design and stakeholder responses.

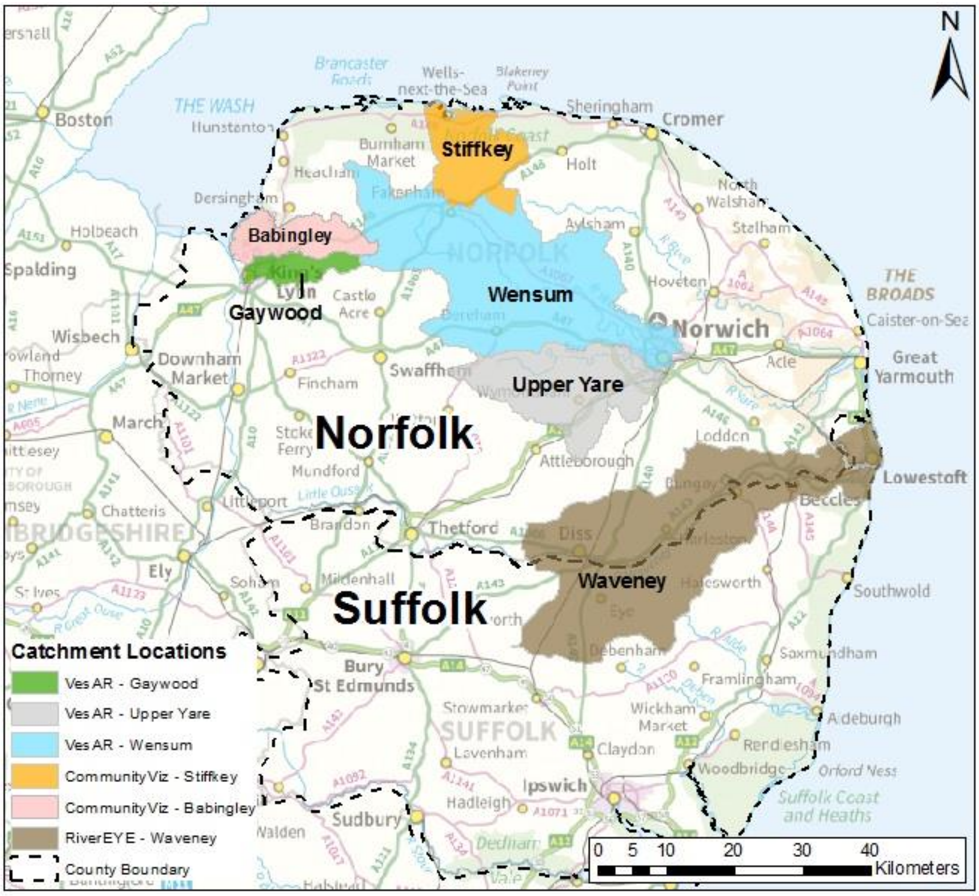


Fig. 3.1 The first case study (Chapter 4) reflected the characteristics of the Gaywood, Upper Yare and Wensum catchments, the second case study (Chapter 5) was set in the Stiffkey catchment, a pilot for the third case study was set in the Babingley and the final study was held across the accessible sections of the Waveney catchment (Chapter 6).

3.2 The adoption of catchment planning in the UK

This section provides background to the paradigm shift by organisations towards catchment scale thinking within England to meet the European Water Framework Directive (WFD) objectives. At the heart of the shift has been collaboration between organisations and sectors forming working coalitions to improve the water environment and a move from top down to more participatory bottom up approaches in decision making (Lange and Hehl-Lange 2010). While catchment partnerships have taken time to emerge and become established they are now the means by which non-statutory responsibilities in the water environment will be managed in the future. Fig. 3.2 shows the means by which DEFRA proposes catchment partnerships will become a key connection between WFD statutory river basin plans, other land use policies and local level planning and organisations such as local river trusts, wildlife trusts and other organisations with a stake in the planning process.

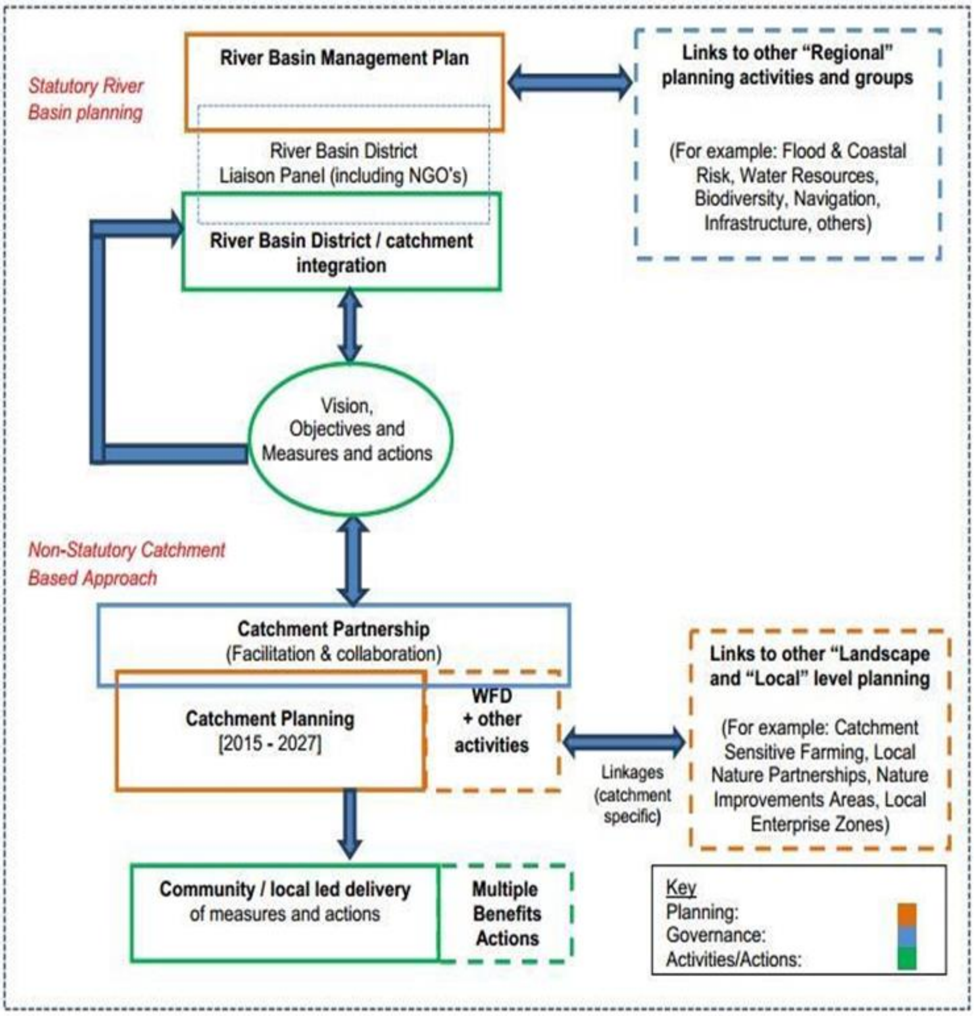


Fig. 3.2 DEFRAs interpretation of how the new catchment partnerships will sit between the local stakeholders and those with responsibility to design the large RBMS (River Basin Management Plans) which cover several hydrologically similar catchments but which have historically lacked stakeholder engagement (Defra 2013c, p. 9)

3.2.1 Regulatory drivers and current funders of catchment scale planning

European drivers for improvements to the water environment include the Nitrates Directive (EC 1991), the Habitats Directive (EC 1992), the Water Framework Directive (adopted in 2000) as well as the Salmon Action Plans (1996) and Eel Management Plans (2007) see Section 1.2.1. While the WFD clearly indicated what member states had to achieve by 2015 it was less prescriptive on how to deliver the necessary improvements in habitat, water quality and sustainability across so many differing water bodies. As part of a larger consultative process to meet the WFD mandated iterative cycle of river basin management Defra and the Welsh Assembly Government released planning guidance to the Environment Agency (EA). Of particular interest in the planning guidance for the case study design is the need for the EA to "coordinate river basin management across a hierarchy of geographical scales" and the requirement for "active and early involvement of a broad cross section of stakeholders" (Defra 2007a). Rather than consider each water body as a separate entity the Water Framework Directive proposed a holistic approach where water was considered at each stage of the hydrological cycle across all water bodies in a catchment including groundwater, estuaries and coastal margins. This approach would result in a more complete understanding of the relationships between land use and water management issues. River basin management districts (eleven within England and Wales) were created in 2006; each was required to develop a strategic plan on a six year cycle working towards the aims of the WFD. River Basin Management Plans (RBMP) are described by Defra (2006) as strategic; providing river basin stakeholders a measure of certainty about the future protection and sustainable use of the water environment in that district; objectives for each water body had to be included as well as a summary of measures necessary to reach those objectives. The outcomes of Defra's consultation process to meet the WFD informed the creation of several funding mechanisms. To curb the agricultural sources of diffuse pollution the Catchment Sensitive Farming initiative was launched in 2006 in 40 priority catchments. This included a Capital Grant Scheme administered by Natural England in partnership with the Environment Agency and Defra for farmers and landowners offering up to 50% of the total expenditure on measures aimed at reducing diffuse water pollution. From 2015 Catchment Sensitive Farming will become part of the new Countryside Stewardship environmental land management scheme managed by Natural England, the Forestry Commission and the Rural Payments Agency. This scheme is advertised by Defra as focusing on the impacts of agricultural practices on biodiversity, water quality and flood management (Davies 2015). Government funding has gradually moved from an initial reactive focus on reducing pressures on the water environment towards more proactive water environment restoration (e.g. via the River Improvement Fund, WFD Fund and Catchment Restoration Fund).

3.2.2 River trusts: Implementers of catchment scale planning?

River trusts represent large sections of rivers and catchments across England and Wales, similar organisations exist in Scotland and Northern Ireland. Most began with an aim to improve a stretch of water for fishing or riparian habitat and particularly since 1990 they have begun to make significant improvements to the water environment in England and Wales. Fig. 3.3 shows the relationship between drivers for change, funding streams and the proliferation in the number of river trusts; a pattern is seen with two phases of growth, the first follows the introduction of legislation, and the second the introduction of funding to meet this legislation.

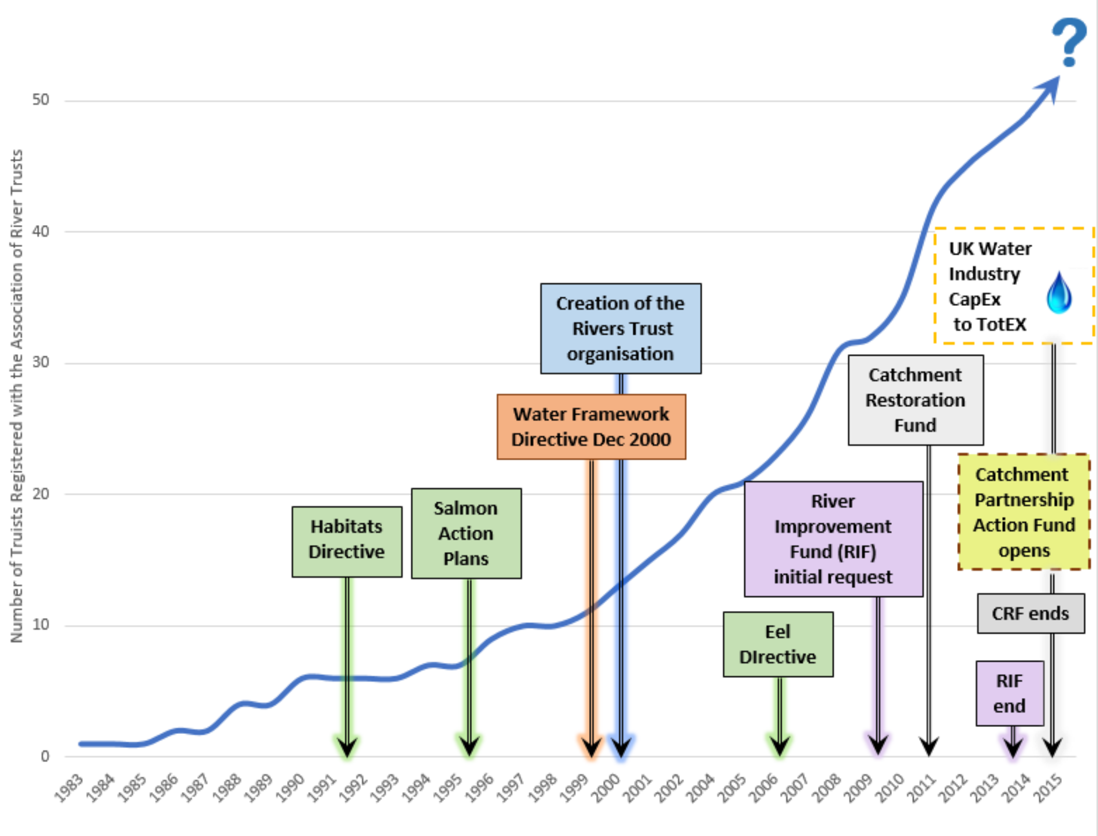


Fig. 3.3 Cumulative number of river trusts by year and drivers for improvement

In 2010 the Association of River Trusts on behalf of DEFRA administered the River Improvement Fund (RIF) focusing on barriers to fish migration, lack of spawning habitat, acidification, morphology, and sedimentation. In a project spanning four years river trusts worked with a range of national partners (Natural England, Environment Agency, and Wildlife Trusts) to deliver 240 projects resulting in over 2,800km of rivers with improved ecological potential. A key part of the RIF was the engagement with stakeholders and communities, the RIF was worth £6m but additional co-financing resulted in the total value of the projects being nearer £8.4 million (The River Trust and Defra 2014). In April 2011 a total of £92 million was provided by the Secretary of State over the subsequent four years to achieve the aims of the WFD. In 2011/12 £18 million was provided to the government and non-government organisations including the river trusts (£2.58m) and wildlife trusts (£1.1m), the EA (£9m) and Natural England (2m), the Coal Authority (£1m) and the Non-Native Invasive Species Secretariat (£0.9m). In the years 2012/2013, 2013/2014 and 2014/2015 to meet the aims of the WFD set out in the RBMPs a total sum of £28m was made available to third sector groups via the Catchment Restoration Fund (Defra 2013c). The CRF overlapped with the delivery of RIF projects but moved focus from river to catchment scale restoration with the objectives to restore features, reduce the impact of manmade structures and lower diffuse pollution.

DEFRA published strategies for collaborative working between river trusts who had won CRF financing and existing experienced organisations with responsibilities towards the water environment who had been unable to bid for the catchment restoration money (Fig 3.1). These collaborative multi-organisation working efforts are termed catchment partnerships, and are central to the Catchment Based Approach, (Fig 3.3) offering increased '*locally focussed decision making and action'* (Defra 2013c p. 1) and increasing stakeholder engagement with the water environment. The first round of Catchment Restoration Funding ran from 2012 – March 2015 with opportunities to bid for the second round of catchment restoration funding opening in early 2015 but subsequently hit by a number of delays including the pre-election purdah beginning on the 30th March 2015 (purdah being the process by which any new government initiatives are prevented so that no electoral candidate can benefit from something which may be advantageous to them). More recently, the CRF has been merged with the Catchment Based Approach process and support will now be available through Catchment Partnership Action funds. The delay in opening the fund for bids, and the evolution of funding streams across both the water sector and the agricultural sector has led to river trusts having to look to the private sector to continue to deliver improvements to the water environment. With this comes a need to evidence the applications for new sources of funding, the use of spatial technology can assist in the integration of data and communicating both problems and solutions; but there is inconsistency amongst river trusts in its use and best practice.

3.2.3 Water companies: future funders of catchment scale planning?

Private water companies are an emerging funding source for river trusts and catchment partnerships to continue work to meet WFD aims. Created during privatisation of the water industry in 1989 ten water companies within England and Wales were formed from the public regional water authorities (established under the 1973 Water Act), at the same time the regulatory section of the old water authorities became the responsibility of the National River Authority (NRA) and the economic regulatory body OFWAT was formed. The Drinking Water Inspectorate responsible for monitoring water safety and quality was formed in 1990. The NRA became part of the Environment Agency in 1996 and has retained the responsibility for regulation to enhance and protect the whole environment in England (and Wales until 2013). Since 1990 the water industry within England and Wales has been managed in five yearly cycles known as Asset Management Plan (AMP) periods. AMP plans are reviewed by OFWAT who place limits on the prices the water companies can charge for services after both the capital investment the water companies propose and the expected operational efficient gains are considered. Since privatisation in 1989 the water industry has focused primarily on investing in new infrastructure to meet EU legislation for water discharge and reduce impacts on wildlife habitats. Capital expenditure (CAPEX) was the focus of water companies from the first AMP cycle (1990-1995) until AMP4 (2005-2010). While these five year plans have provided structure to the water industry and certainly improved water infrastructure they have not encouraged long term sustainable investment where returns are seen outside of the AMP period (Davey 2012).

Within AMP5 and leading into AMP6 the regulatory body OFWAT has encouraged a move away from CAPEX investment towards existing infrastructure and operational expenditure (OPEX) by relaxing rules on projects which water companies can fund. This has facilitated investment by water companies in longer term sustainable solutions such as those offered by catchment management. Examples from projects such as Scamp (United Utilities) and the South West Water Upstream Thinking initiative have revealed that paying farmers to change land management practices (such as the application of fertiliser near watercourses) the water quality can be improved, thus reducing treatment costs and passing on savings to customers (Davey 2012; Everard and McInnes 2013) . The PES approaches trialled by United Unities and Wessex Water have been shown to provide a mechanism for improving the water quality and supplementary benefits to wildlife and recreation (OFWAT 2011; Davey 2012; Defra 2013b); which in turn could provide river trusts and catchment partnerships with a potential source of funding to carry out catchment restoration. The challenge which lies ahead for the water companies is not least how to value the wider environment given the uncertainty of the future climate and how to then convert this to a financial saving to meet OFWATs conditions of improved efficiency savings (Davey 2012; Smith et al. 2013; Everard and McInnes 2013).

3.3 Catchment planning in Norfolk: The influence of local organisations on the development of the empirical case studies

Drivers for improvement range from European amendments to agricultural policy, the national release of the water and nature white papers from central government, the regional influence of new building regulations for the management of sustainable drainage schemes all the way down to local agreements with landowners and wildlife trusts. The influence of these policy drivers has been evident within the case study region of East Anglia in the gradual evolution of river projects or associations founded to improve the river by enthusiastic volunteers metamorphosing into river trusts with greater responsibilities (Fig. 3.4). Although slow to develop in this region compared to other areas of the UK groups within Norfolk have evolved from awareness raised by a pollution incident, loss of species diversity or the collaboration between users of the river (e.g. anglers) to improve a stretch of river for recreational purposes.

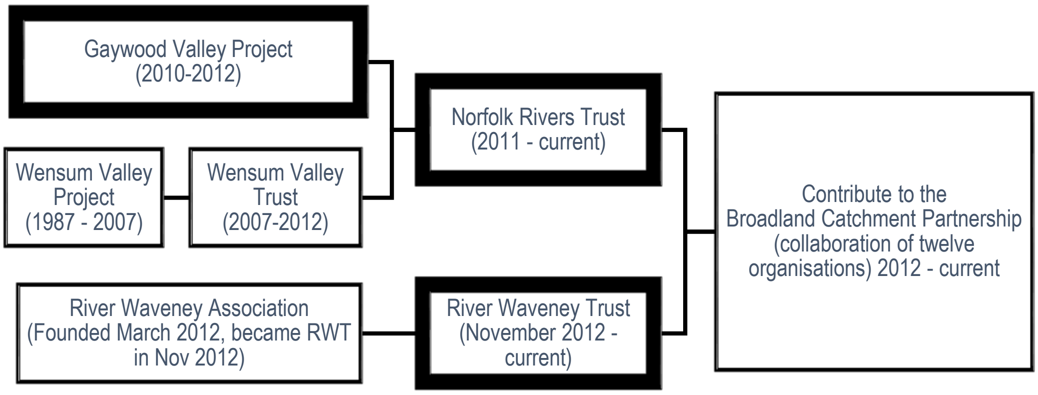


Fig. 3.4 The evolution of the existing relationship between the river trusts and Catchment Partnership in Norfolk – those with a thick outline are organisations worked with in the case study research for this thesis (further details in Section 3.4).

The Broadland Catchment Partnership covers the Norfolk Broads National Park and includes all those who share responsibility for the water draining into the Broads region from the Yare, Bure, Waveney and Wensum (Fig. 3.5). The stakeholders involved within the Broadland catchment partnership are multidisciplinary, with a mix of private, academic and third sector representatives. Stakeholders involved in the Broadland catchment partnership include two local river trusts (the Norfolk Rivers Trust and the River Waveney Trust), alongside academics from the Wensum Demonstration Test Catchment Project, private water companies, NFU, Natural England, Norfolk County Council and the RSPB. Other catchment partnerships shown in Fig. 3.5 include the North Norfolk Rivers and West Norfolk, both of which are hosted by the Norfolk Rivers Trust.

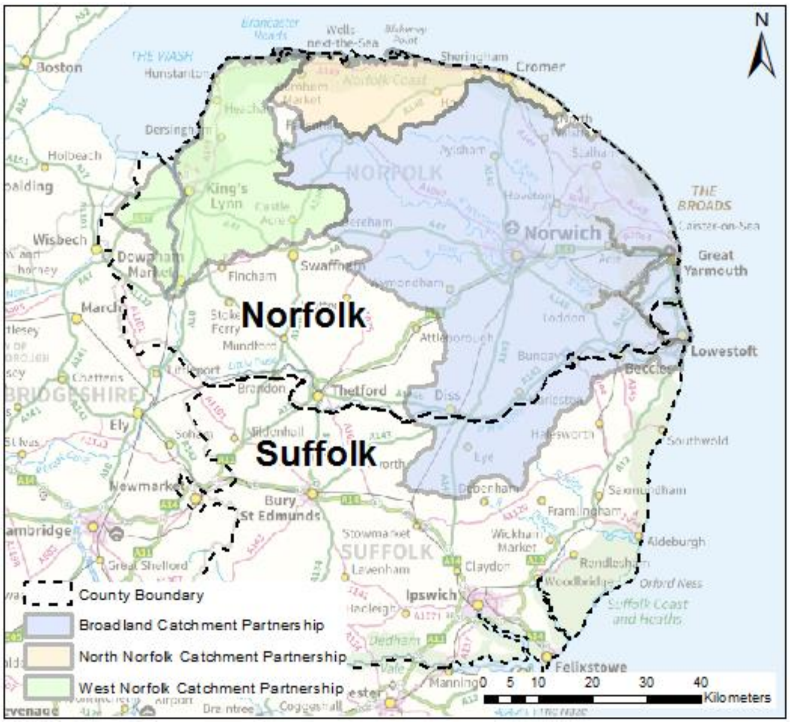


Fig. 3.5 The location of and extent of the Broadland Catchment Partnership

3.4 Topological and hydrological characteristics of the case study catchments

This section reviews the manner by which catchment characteristics influenced case study design and stakeholder responses. Agricultural productivity in the East Anglian region where the case studies were conducted is nationally important; the demands of irrigation, drainage and crop production are in conflict with those of the Water Framework Directive and the ecological well-being of the catchments (Norfolk Rivers Trust 2013). Fig. 3.1 indicates the location of the catchments used in the case studies, none of which met WFD standards at the time of the study. All the catchments have some degree of statutory designation but high levels of runoff (silt and pollutants), heavily modified channels (Environment Agency 2009), and impeded fish passage indicate that ecological function of the rivers and the catchments could be improved (Table 3.1). The WFD classification system changed in 2009/2010 – and will change again shortly as the Environment Agency reflects on the best means by which to report the improvements made to the water environment to meet the aims of the WFD.

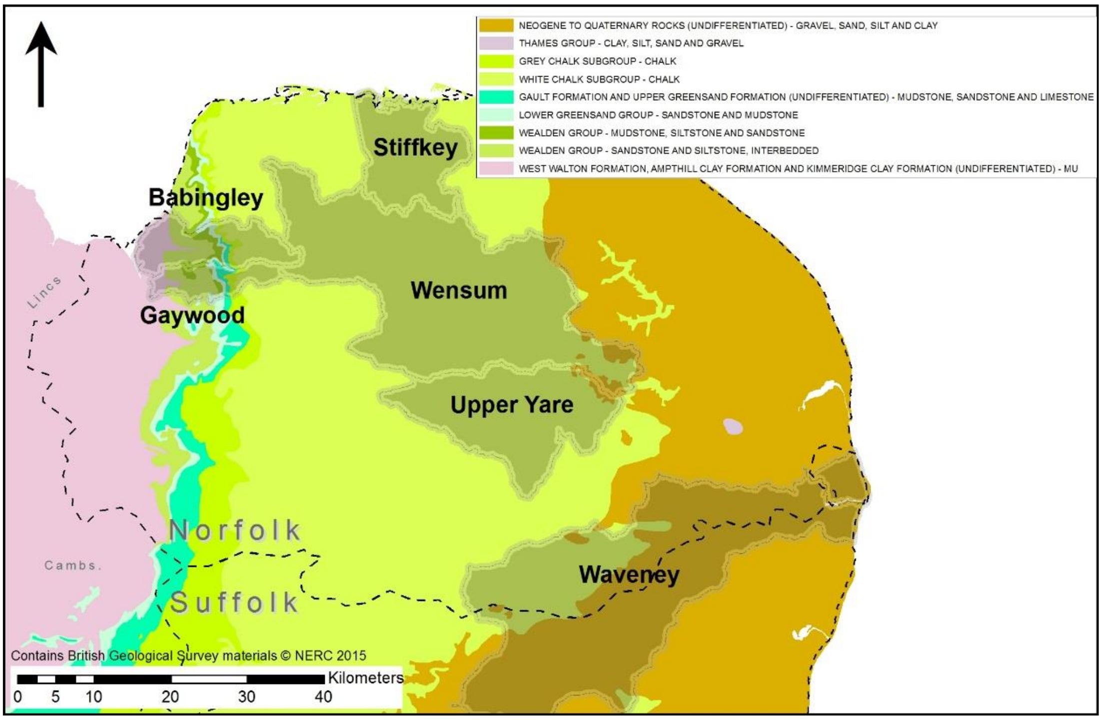
Table 3.1 WFD status of the case study catchments (US refers to Upstream) data compiled from EA 2014

Case Study	Catchment Name	Catchment	Overall Status			
			2009	2010	2011	2012
Chapter 4	North West Norfolk	Gaywood	Good	Moderate	Moderate	Moderate
Chapter 4	Broadland Rivers	Wensum (US Norwich)	Bad	Bad	Poor	Poor
Chapter 4	Broadland Rivers	Yare (US Norwich)	Poor	Poor	Poor	Poor
Chapter 5	North Norfolk	Binham Tributary	Moderate	Moderate	Moderate	Moderate
Chapter 5	North Norfolk	Stiffkey	Poor	Poor	Poor	Poor
Pilot for Chapter 6	North West Norfolk	Babingley	Moderate	Poor	Poor	Poor
Chapter 6	Broadland Rivers	Waveney	Moderate	Moderate	Moderate	Moderate

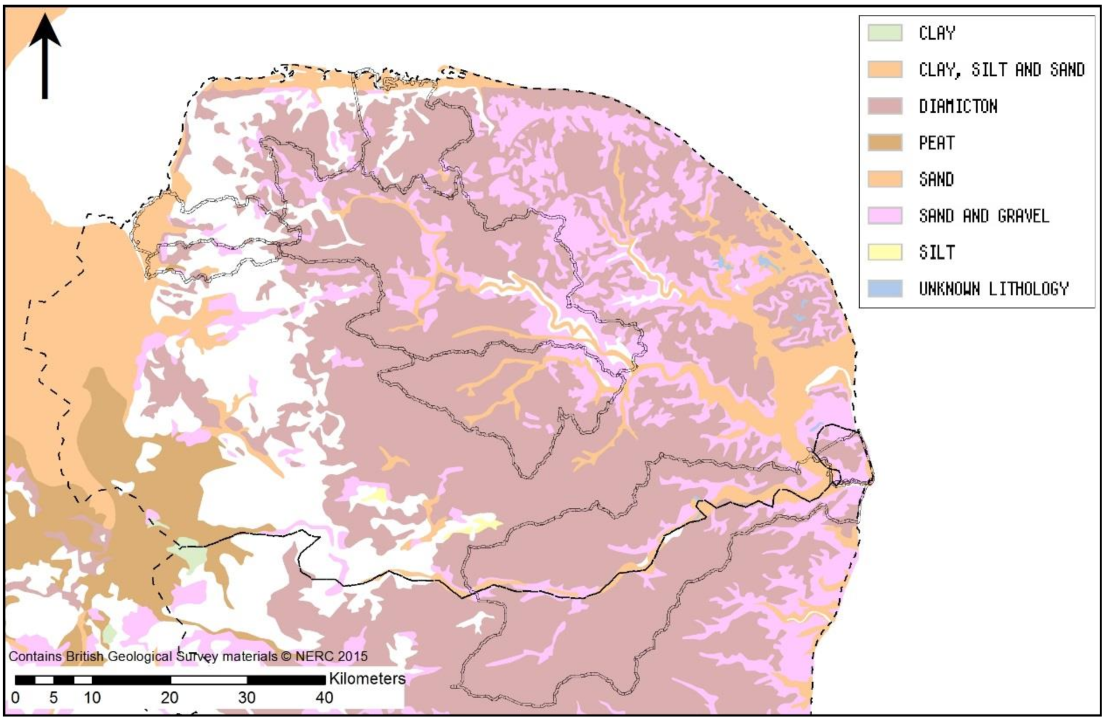
Fig. 3.6 illustrates the hydrological influences across the six catchments (the Binham stream is included in the Stiffkey catchment). The strong influence of the bedrock geology on the river characteristics can be seen in Fig 3.6a with all apart from the Waveney catchment overlying chalk and the spring line of the Gaywood and Babingley catchments is evident where chalk bedrock is replaced by mudstone and siltstone. Fig 3.6b indicates the superficial drift geology of the catchments highlighting the dominant sand and gravels which allows precipitation to percolate quickly to the underlying aquifer (Fig 3.6c) carrying with them agricultural pollution. The sand and gravels in the Wensum and Yare catchments are of particular high quality and have been quarried since the 1900's

leaving large flooded gravel pits along the valley which have an influence on the catchment hydrology.

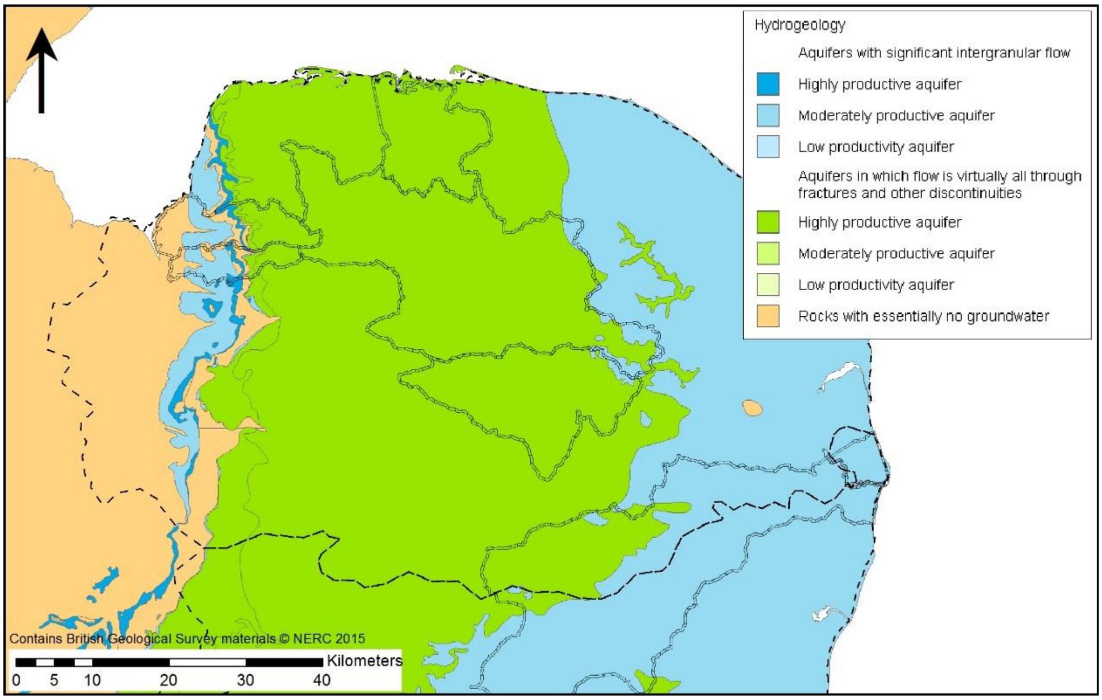
Fig. 3.6 The hydrological and tological influences across the case study region (BGS 2014)



a) 1:625 000 scale BGS Bedrock Lithology with case study catchments and counties labelled (BGS 2015)



b) 1:625 000 scale BGS Superficial Deposits Lithology with case study catchments outlined (BGS 2015)



c) 1:625 000 BGS digital hydrogeological data aquifer classification with case study catchments outlined in grey (BGS 2015)

3.4.1 Base Flow Index (BFI) and influence on catchment ecosystem services

Precipitation either evaporates, flows over ground; or infiltrates into the groundwater where water is stored in aquifers before it is abstracted or naturally emerges at spring lines to become part of the over ground flow. In contrast to the surface water in our landscape the role of groundwater in the water cycle is often overlooked. The Base Flow Index (BFI) was developed in 1992 by the Centre for Ecology and Hydrology (CEH) to provide a measure of the groundwater influence on the volume of water in a river. In rivers which drain clay catchments then the BFI is usually 0.15 - 0.35. Rivers draining chalk catchments have a BFI of greater than 0.75 - 0.90 reflecting the groundwater component to these unique and rare rivers. CEH calculates the base flow index of all rivers, giving a useful indicator of the influence of underlying geology on the river flow and by association an indication of the problems which a specific catchment may face; this data is stored in the National River Flow Archive (CEH 2015). Establishing the base flow index in a river is an integral component in evaluating the key pressures on ecosystem services in the catchment landscape and determining the priorities for improvement. In catchments where river base flow is predominantly groundwater (Fig. 3.7) the pressures on the catchment are more likely to include those associated with over-abstraction for irrigation or drinking water, slow recovery from long periods of drought due to infiltration to aquifers, and potential long term nitrate contamination. In catchments where river flow is predominantly surface water such as the River Waveney a different set of pressures (eutrophication, flashiness, silt and nutrient runoff and pollution) are likely to be main concerns of the catchment partnerships tasked with meeting the Water Framework Directive objectives in that river basin.

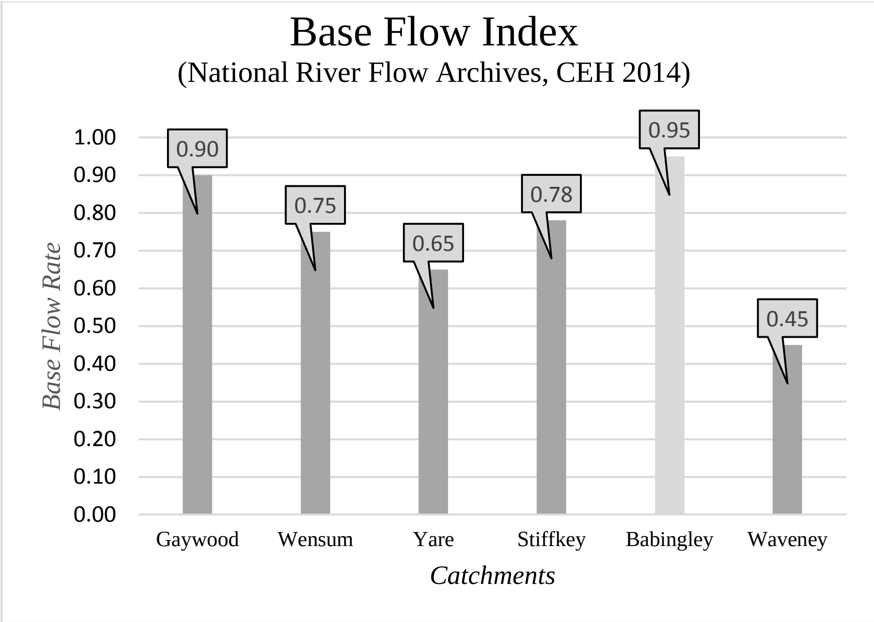


Fig. 3.7 Base Flow Index is an indicator of the catchments sensitivity to various pressures, the greater the value the more influence groundwater has on the river flow. The lighter grey was the study scoped but not completed

The impact of catchment characteristics on the case studies is particularly applicable to the Chalk Rivers (i.e. those with the highest Base Flow Index) where the underlying geology results in chalk filtered groundwater providing pristine gravel beds, clear waters and unique wildlife within the river system. Furthermore the geology influences biodiversity throughout the whole catchment with widespread springs and low gradients producing wet woodlands and meadows; some of the UKs' most threatened habitats. Any interruption to the groundwater component results in catastrophic impacts to the riverine ecosystem. The catchments of the Gaywood, Upper Yare, Wensum, Babingley and Stiffkey (Fig. 3.1) used in case studies for this thesis all have a base flow rate which highlights the vulnerability of these particular rivers to the impact of abstraction.

3.4.2 The impact of water management on catchment ecosystem services

Extremes of flood and drought are often portrayed negatively in the media. It is less well reported that these natural processes have invariably been exacerbated by centuries of river channel modifications. Water bodies within all of the trial catchments have been modified over many centuries by straightening, dredging and embanking as well as the installation of structures for industry, flood protection and transport. Over deepening (Fig. 3.8), over widening and straightening has resulted in all the rivers in the case studies becoming highly efficient drainage networks impacting on the rivers ability to slow flow and store water (regulating services). In turn this swift removal of water reduces that which is available for infiltration into the groundwater ready for use as a provisioning service for drinking water or irrigation to grow crops. Improvements in water quantity and quality within catchments are central to the aims for the WFD, and have a direct influence on the number of and quality of the ecosystem services which can be supported.

The ecosystem services approach suggests that by working with nature rather than against it (i.e. by enabling the natural functions of the river to be reinstated) flood risk is reduced (Barlow et al. 2014). By providing better habitats, increasing flood protection, improving ecological networks and overall creating better resilience to climate extremes of flooding and droughts then catchment and river restoration aims to support improved multifunctionality of land use and the provision of ecosystem services improving water and food security. Smith et al. (2013) do advise comprehensive hydrological modelling is required before carrying out a scheme which may impact on the catchments flood risk and put infrastructure or farmland at risk of increased flooding; this is due in part to the nature of flood risk being spatially specific and depending of local factors such as topography, rainfall and land use and emphasises the need for appropriate scales of change to be identified. Thus a multi-agency approach is required during the process of developing catchment plans and information from stakeholders is important in identifying local flood patterns and groundtruthing hydrological modelling.

Fig. 3.8 A canalised section of the Gaywood chalk river showing the raised banks and disconnection from the floodplain. Here the water is deep with little natural plant life and a layer of silt covers the gravel bottom; precipitation results in quickly raised river levels increasing flood risk downstream.

Disconnection of the river from its floodplain by dredging the channel and embanking the spoil (Fig. 3.8) has serious repercussions for the environment and on the ability of the catchment landscape to provide the full range of ecosystem services. These modifications have an impact on all rivers, but particularly on chalk where the rivers are so directly influenced by groundwater and with a low base flow are unable to return their channel to a more functional shape (Fig. 3.9). When reflecting on the impact of morphology on the case study catchments then those described as chalk streams would originally have had a meandering or braided profile which allows natural river processes to move silt downstream in a cycle of erosion and deposition keeping gravel beds clear for native fish to spawn.

Fig. 3.9 A more natural bank gradient allowing good connectivity with the river floodplain (the upper Gaywood Chalk River), in stream vegetation and the marshy bank to the left is evident of recently raised water levels. The smaller inset picture shows a healthy gravel bed of the river in the previous reach where faster flow moves silt off the gravels.

3.4.3 Influence of catchment character on the case study design

Across the case study catchments land use is predominantly agriculture (Cefas 2012). The most damaging agricultural runoff consists of gravel-smothering silt and dissolved nutrients such as nitrates and phosphates giving temporary high concentrations that can breach water quality standards. Sediments can carry the nutrient phosphorus, some of which is reactive (it helps algae to flourish at the expense of bigger water plants). Within the Stiffkey sediments are not the only danger to the aquatic ecosystem; faecal matter is washed down through the catchment resulting in bivalve molluscs farmed in the harbour being deemed unfit for human consumption (Cefas 2012). The catchment character influenced the trials of spatial technologies in support of the Catchment Based Approach in three ways, the range of ecosystem services under discussion, the influence of hydrology and the visibility of features in the landscape.

3.5 Case Study Partners

The land use in a catchment influences both the range of ecosystem services that exist and the priorities for improving the health of the catchment. Table 3.2 summarises the characteristics of the catchments where case studies were held. The size of the catchments varied considerably, with the Gaywood the smallest at only 59 km^2 and the Waveney thirteen times larger at 812 km^2. All the catchments were to a degree influenced by the chalk geology, with the lower reaches of the Stiffkey and the majority of the Waveney influenced by drift geology. The catchments retained a diverse range of habitats despite all being dominated by agriculture; in the Wensum and the Yare sand and gravel extraction in valleys is extensive leaving past workings as large lakes influencing the catchments water resources. Issues across the catchments vary although most have heavily modified channels and disconnected floodplains, structures across the channel for flood defence and for water power (mills) prevent fish passage and cause problems of impounded and slow moving water where silt settles over the river bottom smoothing ecology. In the Waveney a combination of factors lead to eutrophication becoming a particular problem.

During the course of the research projects none of the organisations collaborated with (Fig. 3.4) had, or planned to have, dedicated resources within their organisation to develop spatial technology to support the development of a Catchment Based Approach. When questioned about the low uptake of spatial technology the organisations alluded to lack of time, lack of expertise and crucially lack of money. While two of the three organisations had access to limited GIS the data weres at a rudimentary level and the GIS was not used for data management or analysis but to making site maps or graphs for inclusion within leaflets. Considering the availability of spatial data provided by the Environment Agency, DEFRA and the umbrella river trust then this resource deficit implies an impact on the ability of the local trusts for joined up spatial thinking. While the future directions of data availability and aggregation are discussed further in Section 7.5 it is worth noting that even as recently as June 2015 DEFRA is arranging for another 8,000 datasets to be released to the public for use in app development and by voluntary organisations (Defra and Truss 2015).

Table 3.2 Overview of the catchment characteristics

		Chapter 4			Chapter 5	Pilot for Chapter 6	Chapter 6
Statistics	**Catchment**	**Gaywood**	**Upper Yare**	**Wensum**	**Stiffkey**	**Babingley**	**Waveney**
	Area (km^2)	59	280	684	163	107	812
	Base Flow Rate *(CEH 2014)*	0.90	0.65	0.75	0.78	0.95	0.45
	Geology	Chalk			Chalk/Boulder Clay	Chalk	Gravel, Sand, Silt and Clay
	Land Use	Agriculture, Quarrying, Heath, Grassland, Fen, Floodplain	Agriculture, Quarrying, Woodland, Grassland, Floodplain	Agriculture, Quarrying, Wetland, Grassland, Floodplain	Agriculture, Wetland, Woodland, Grassland, Floodplain	Agriculture, Structures, Grassland, Floodplain	Agriculture, Wetland, Quarrying, Urban, Floodplain
	Designations?	Yes	Yes	Yes	Yes	Yes	In Part
	Known Problems	• Heavily Modified Channel • Flooding • Disconnected floodplain • Poor access • Over abstraction • Lack of community engagement	• Agricultural land use leads to higher levels of pollutants • Some flooding	• Urban • Disconnected • Undervalued • Agricultural land use leads to higher levels of pollutants • Some flooding (not urban)	• Silt runoff • Smothered gravels • Compromised habitats • Channel modifications • Poor flows • Lack of fish passage • Lack of community engagement	• Heavily Modified Channel • Impounded • Disconnected floodplain • Poor access • Over abstraction • Lack of community engagement	• Agricultural runoff • Invasive species • Navigational Hazards • Bank erosion (cattle) • Cracked willow • Flooding • Eutrophication • Structures
Details	**Technology**	Mobile Augmented Reality			Desktop (indoors) CommunityViz GIS	Desktop (indoors) CommunityViz GIS	Mobile Citizen Science
	Organisation	Gaywood Valley Project	n/a	n/a	Norfolk Rivers Trust	Norfolk Rivers Trust	River Waveney Trust
	Dates of empirical data collection	June 2012 – October 2012			Dec 2012 – May 2013	May 2014 – Aug 2014	Oct 2014 - Nov 2014
	Impact of organisation structure on case study design?	Yes	n/a	n/a	Yes	Yes	Yes
	Impacts of catchment characteristics on case study design?	Yes	Less so	No	Yes	Yes	Yes

3.5.1 Gaywood Valley Project

With a different emphasis to the trusts engaged with in later stages of the PhD the Gaywood Valley Project (GVP) was funded by the INTERREG North Sea programme as part of the international Sustainable Urban Rural Fringes initiative (SURF 2010-2012). With a budget of £500,000 one full time project officer worked with local partner organisations (statutory and voluntary) to encourage local communities to contribute to the future of the area. The GVP was one of a number of pilot projects seeking to improve the social, economic and environmental quality of urban fringe areas. Working closely with the wildlife trust responsible for the Gaywood Living Landscape the project was sited within the arbitrary boundary of the Gaywood valley, rather than the boundaries of the hydrological river catchment.

Influenced by the inclusion within the DEFRA funded EMBED project (Haines-Young and Potschin 2008) the GVP took an ecosystem services approach (EsA) to decision making. Much of the GVP focused on realising the multiple benefits this valuable but degraded landscape could provide such as flood storage, cross catchment walks and education for areas of community deprivation. Soon after the start of the GVP several project partners withdrew support for an innovative flood storage scheme so the GVP sought to redevelop the project as a holistic approach to planning the future of the river valley.

The aims of the GVP informed by the ecosystem services approach included;

- making the area more accessible for recreational activities (cultural)
- providing varied learning opportunities, (cultural)
- improving wildlife habitats helping to safeguard species, (provisioning?)
- exploring the issues of flooding and climate change in the area, (regulating)
- bringing local communities together to create a shared vision for the valley (cultural).

A strong focus of the GVP to engage the community with the potential of the natural landscape informed the decision to use this location for the trials of the augmented reality tool. The severe degradation of the landscape through centuries of land management and impact of intensive channel modification was not overlooked. In showing the range of ecosystem services that the valley supported, despite its poor state, the tool validated the GVPs opinion of this landscape as an important area for restoration.

3.5.2 The Norfolk Rivers Trust

With an ambitious aim to conserve and restore many of Norfolk's wetlands and river habitats in line with the Water Framework Directive the Norfolk Rivers Trust (NRT) was established as a charity in 2011 running projects on behalf of the World Wildlife Fund and Coca Cola. Following a successful bid for catchment restoration funds in October 2012 the trust launched the *9 Chalk Rivers* project focussed on the restoration of nine chalk river catchments in Norfolk. In the largest of the nine catchments the NRT had already scoped projects to restore the health of the catchment but wanted an innovative means to interactive with and gather feedback from catchment stakeholders. The collaboration with the Norfolk River Trust meant benefit of real world engagement, echoing Bishop et al. 2013. In visioning the solutions proposed by the NRT the UEA research case study gathered data on the use of visualisation tools to support the Catchment Based Approach to river basin management. The NRT obtained feedback about the proposed plans in the Stiffkey catchment using expert tools, increased its profile and established stronger links with all catchment stakeholders.

Within the remit of the Water Framework Directive the NRT wanted to focus upon;

- Silt runoff and build up within the river channel requiring river dredging
- Lack of river function due to canalisation and the river being detached from its floodplain
- Low flow, flooding and lack of buffering (no wetlands)
- Lack of access for communities to enjoy the recreation potential of the catchment

The landscape scale adopted by the NRT in this catchment informed the decision to use the project as a research case study to assess the role of dynamic visioning software to support catchment scale management. The objectives of the NRT influenced the visioning process in a number of ways; the range of data required, the area of the catchment which could be visioned and the timeframe for the project.

3.5.3 River Waveney Trust

Formed in 2012 the River Waveney Trust has rapidly developed a large (700+) membership. The large membership base supports the work of the river trust financially and active volunteer led working parties focus on improving the health of the river for communities along it. The trust has a visible presence in the community with links to education at all levels of the curriculum, and regular art and environmental days at its headquarters on the River Waveney.

Response rates from the previous studies highlighted the challenges in recruiting a representative sample of participants to the research case studies. The size of the membership base at the River Waveney Trust was vital in enabling the final case study to run at short notice and gather sufficient feedback on the technology and the volunteering of geographical information. While the trust acted as gatekeeper for recruiting to the trial there were improvements made to the communication process with a snowball sampling technique applied. This was the principal motivation for working with this trust for the last case study project. The input from the UEA research project focused on giving the trust an opportunity to experiment with extending the functionality and interoperability of their recently delivered GIS system.

3.5.4 Summary

These actors and catchments set the scene for the work within the thesis. The three studies were selected to represent different scales of organisations with different funding mechanisms over catchments which were under different pressures. With a strong community element and a small scale catchment across a rural urban fringe the first case study provided an interesting patchwork of ecosystem services and land uses in which to work. The structured focus of the second case study was facilitated by the Catchment Restoration Fund and the requirement for feedback from a wider range of stakeholders. The final case study was not directly influenced by the catchment characteristics, but was able to go ahead because of the size of the local river trust membership list.

3.6 Timeline of the research

This PhD began in January 2011 with the thesis submitted for examination in August 2015 (see Table 3.3); over the four year period of research a total of five case studies were designed to trial spatial technologies to support the Catchment Based Approach to landscape scale management. A seven month period of intercalation was taken between the 1st June 2013 and the 31st December 2013.

Table 3.3 Timeline of the case studies written up within Chapter 4, 5 and 6, those in italics reflect the time spent on case studies which did not result in sufficient data collection for inclusion in the thesis

	J	F	M	A	M	J	J	A	S	O	N	D
2011					Chapter 4					*Gaywood visualisations*		
2012	*Gaywood vis*				Chapter 4		Chapter 4			Ch. 4	Ch. 5	
2013	Chapter 5		Chapter 5				Intercalation					
2014	Ch.5	Chapter 5			*Babingley*			*Bab.*		←	Chapter 6	→
2015												

Key
Development Evaluation Analysis Leave

The first case study (Chapter 4) had a long development phase and subsequently a delay in evaluation due to poor winter weather preventing trials outside; opportunities to evaluate with members of the public were seized over the next twelve months in the Gaywood, Yare and Wensum valleys. The next case study (Visioning the Gaywood Valley) was designed to carry out a comparative evaluation of visualisation tools in the urban rural fringe of King's Lynn where the Gaywood Valley is situated. Preliminary discussions with the Gaywood Valley Project and the Norfolk Wildlife Trust scoped out three possible future landscapes for this rural/urban fringe. These scenarios were as follows a) an ecological, sustainable landscape rich in biodiversity with ecological services intact and a restored river profile showing evidence of low carbon energy sources with wind and solar power in use, b) an intensive arable agriculture future with high intensity land use and c) an urban sprawl future with more housing and industry and little green space for recreation or wildlife. A large ArcGIS database gathering a range of ecological and hydrological data were developed to support the case study. This case study failed to move beyond initial discussions due to the organisations involved changing focus in March 2012 to support the newly formed Norfolk Rivers Trust in a funding bid to restore nine chalk rivers in Norfolk.

Following the successful award of CRF funds to the NRT (as the lead partner) opted to delay work on the Gaywood valley and focus instead on the Stiffkey so the comparative evaluation of the visualisation tools was transferred to that project. The successful case study evaluating two different visioning tools was carried out between November 2012 and May 2013 and is written up in Chapter 5. With the intention of continuing the work with the NRT a final case study was designed in May 2014 to communicate the ecosystem services within the Babingley catchment using visualisation tools. While this pilot study in July/August 2014 failed to collect sufficient data the research showed discussions of ecosystem services with lay stakeholders required a purpose. Ecosystem services are useful in the context of developing a management plan for landscapes or in weighing up options for policy changes but remain too abstract an idea even for those who profess to be engaged in the environment to take on board. The last case study (Chapter 6) returned to mobile technology and worked with a different river trust to evaluate the potential use of citizen science using mobile technology for monitoring at a catchment scale.

Chapter 4. The role of immersive visualisations as an aid to communicating ecosystem services to stakeholders in the urban rural fringe

4.1 Introduction

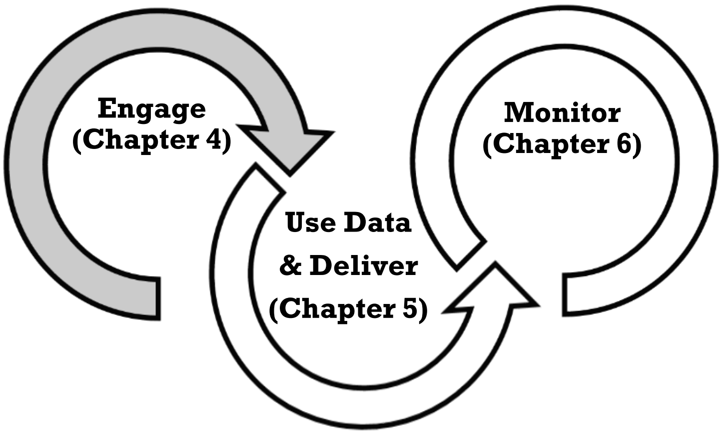


Fig. 4.1 The CaBA Framework - this chapter focuses on the Engaging stage

Chapter 1 discussed the Catchment Based Approach (CaBA) and its framework which was released in the UK part way through the PhD (2013). The first stage of the CaBA framework (Fig. 4.1) emphasises the need for targeted, cost effective and innovative engagement techniques to engage catchment stakeholders (CaBA 2013). This chapter[1] addresses this challenge through the development and subsequent evaluation of low cost immersive augmented reality technology to engage catchment stakeholders with ecosystem services. Chapter 2 discussed a number of the ways in which visualisations have historically been used to support public participation in environmental decision making. With an explosion in the availability of location-aware mobile technology there is research interest in the potential of augmented reality to enable those using the handsets to see information of landscape change in situ. These landscape changes cover a number of disciplines; existing augmented reality tools include future planning proposals (Lange 2011), and dynamic ecology information such as species diversity on a university campus (Rose et al. 2010).

The research questions which this chapter will answer are as follows;

1. To what degree can mobile augmented reality communicate the location of and information about ecosystem services within a catchment landscape?
2. Is the current level of mobile phone technology and infrastructure sufficient to support spatial applications in rural settings?

[1] Work within this chapter was submitted to the Digital Landscape Architecture conference in Zurich, 2014. The conference abstract is attached as Appendix 2.

The research contained within this chapter was carried out in 2011/2012 (prior to catchment restoration funding being released) with a small grassroots organisation unusual at that time in its focus on catchment management. The subsequent growth of river trusts (Chapter 3) and catchment partnerships have led to a more holistic approach to catchment management with an ecosystem services focus becoming more mainstream. Furthermore, as with any technology-based research, the next generation of smartphones and improved mobile coverage in rural areas have since reduced some of the limitations found during this study; however the nature of human technology interaction remains an area with potential for further research in mobile augmented reality.

4.2 Methodology

During the literature review it became evident that while many studies have been carried out on the effectiveness of visualising a wide range of subjects there have been fewer which evaluated what the visualisations contribute. The benefits of comparative evaluation were applied in this case study with participants taken on a short walk during which they evaluated two different tools to learn about the ecosystem services in the catchment. The tools which were compared were an augmented reality handheld device (mobile phone or tablet) and a trifold paper leaflet created using ArcGIS. The leaflet was an exact replica of the information served via the VesAR app and was used as a comparative tool to establish the success of the VesAR app in meeting the research questions and prompt feedback from participants on how they felt about the two methods. Data collected during this study was via a mixed method approach. Participants completed sections of a paper survey before, during, and after the trial of the mobile app which provided quantitative data for analysis. After each session a group debriefing provided additional insights both into the success of the app as a communication tool and the technological restrictions.

4.2.1 Development of the augmented reality application

This section describes the development of a marker-less augmented reality app which was labelled VesAR (Visualising ecosystem services using Augmented Reality). VesAR was developed using a suite of internet-based applications (Fig. 4.2) including the Hoppala web service (Hoppala 2011) and the LayAR™ augmented reality provider (LayAR 2013). The LayAR shell which the VesAR applet runs within was originally created by LayAR to be used as a marketing tool or as a game platform, and at the time of the case study being developed the application to landscape visualisation had been limited. As with many other augmented reality apps VesAR is to some degree a gimmick, a fun application of technology, but with its free download and its ease of use and accessibility VesAR has the potential to appeal to a section of the population who would not otherwise engage with the outdoor landscape (Nicholson-Cole 2005) and thus not realise the benefits nature gives us. VesAR utilises the modern smartphone combination of camera, GPS, compass, accelerometer and a high quality mobile internet (or data) connection: GPS determines the exact location of the device (within a few meters) and the compass and accelerometer determine the orientation and direction of device defining the field of view. The person using the device sees the world via the camera image which is displayed on the screen; additional digital information such as text, images and animations are augmented on top of the camera view via mobile Internet and accessed by the user touching the Point of Interest (POI) as it appears in the field of view (see Fig. 4.3).

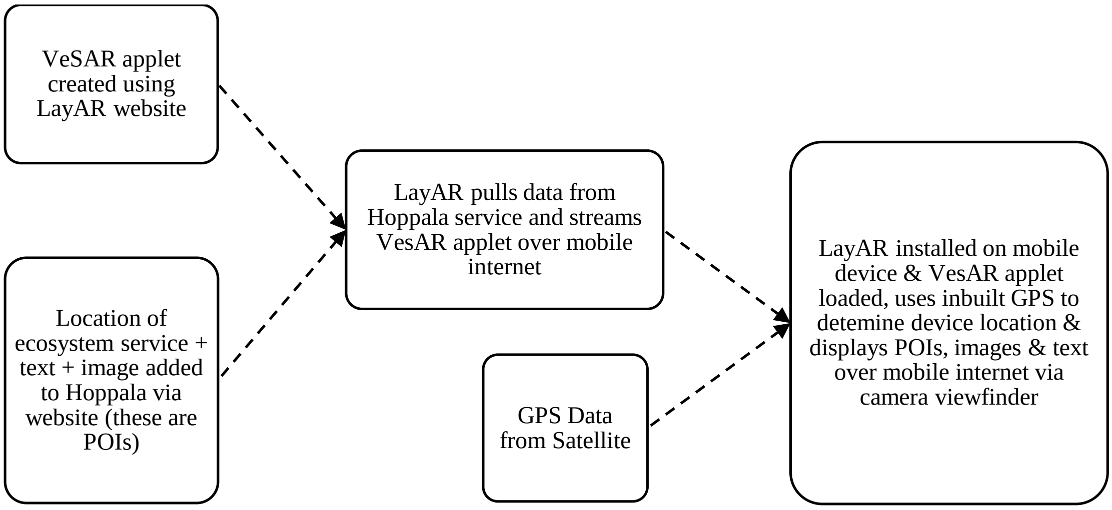


Fig. 4.2 The interaction between the servers and phone which make up VesAR

Fig. 4.3 An example of the screen display when viewing VESAR on an HTC Android phone

4.2.2 GIS Support and development of supporting text

Pilot Study

An initial feasibility pilot was carried out in river valleys around Norwich to establish the reliability of the app and the criteria which would lead to successful evaluation by members of the public. A selection of POIs located around the outskirts of Norwich were entered into VesAR via Hoppala and also printed onto paper maps. The POIs were given a number as a unique identifier (Fig. 4.4) and walks taken by the researcher assessed the distance that the POIs could be seen from, the clustering of POIs, the strength of data signal required and the diversity of ecosystem services along the route. The pilot established three factors in the development of the VesAR applet which would benefit from preliminary spatial analysis in ESRI ArcGIS 10. First the selection of suitable walk routes within catchments, second the identification of ecosystem services within the viewshed of that walk route and third the appropriate density of POIs along the walk route.

Fig. 4.4 An example of POI clustering where several POIs appear on the screen at once

VesAR Route Selection

To identify characteristics of locations with ecosystem services typical of a lowland catchment landscape a number of trial walks were carried out within river valleys across Norfolk. These walks established the following protocol for route selection; the walk should traverse a range of land uses, the path should run alongside or cross the river channel and there should be a component of recreation and where possible an archaeological feature. England has no right to roam laws in the countryside apart from open access designated land, with this in mind walks had to therefore take place on existing public rights of way[2] and out of courtesy always with permission of the landowner. Using ESRI ArcGIS 10 the vector public rights of way dataset from Norfolk County Council (released under data agreement) was intersected with the Ordnance Survey MasterMap water layer and eight potential walk routes within river valleys in Norfolk were identified.

[2] A Public Right of Way is a route or way over which the public has a legal right to pass and re-pass. All public rights of way are public highways. (Norfolk County Council 2014)

Walks also had to be within a certain distance from cell phone masts to provide sufficient mobile internet for the VesAR app to work. The availability of mobile data signal along the routes was assessed using *Open Signal*, this app is available on Android and Apple platforms and gives a speed test of 3G, 4G, WiFi and also provides a map of the strength of signal. Signal data combined with data from ArcGIS resulted in the identification of four sites across three different catchments where participants would be able to view the river, walk on a maintained public right of way, and be shown one POI at a time while the technology would have sufficient mobile data signal. Evaluating this stage of the process reduced the number of walk locations from eight to four highlighting the role of this process in site selection.

POI Selection

To ensure that a representative sample of catchment ecosystem services (10-12 along each route) were shown on the screen of the handheld device during the walks further site analysis was required. Additional land use details were ascertained using a desk based study for the potential routes for the controlled case study walks. Google maps and data from Land Cover Map 2000 (CEH 2000) indicated ecosystem services within view of the paths. Subsequent site visits to the walk locations provided more precise data on location of the features providing ecosystem services. Transient features providing ecosystem services such as the provisioning service offered by beef or dairy herds were avoided to improve the accuracy of the data seen through the screen. With LayAR having the functionality to include not just x,y coordinates but also z (reflected as height or depth) there is the potential to create POIs which float high above the ground (climate regulation) or below ground (such as soil formation, a supporting service) to reflect the 3D nature of ecosystem services (Fig. 4.5). These ecosystem services were deemed too difficult to visualise to members of the public who took part in the trials of VesAR and so the 3D functionality was not explored further.

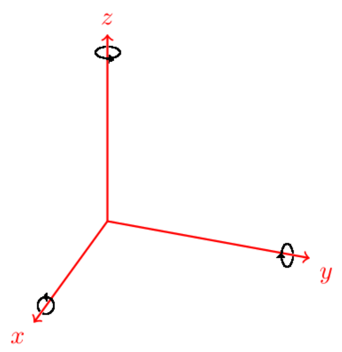


Fig. 4.5 Allocating 3D location to POIs

POI Refinement

To reduce the clustering of POIs on the device screen when using VesAR (Fig. 4.4) required some careful placement to ensure that each POI was equidistant from the path and one another. While the LayAR application has a search radius setting which can be set anywhere from 100 meters to 5 kilometres this is set at the applet level and cannot be set per POI. Landscape features viewable from the walk route providing ecosystem services were noted on the site visits and digitised into ESRI ArcGIS 10 as point vector data. The point vector data were then used to create POIs located within the 100m buffer to be indicative of the location of the feature offering ecosystem services, the VesAR app then had the search radius set to 150meters which reduced the chance that users of devices would see more than one POI at a time. Once the POIs were shown to be working the coordinates for each POI were obtained in WGS84 coordinate system for adding by hand into the POI server Hoppala which broadcasts the data consumed by the LayAR server and is transmitted over a mobile data connection to the smartphone VesAR app (Fig. 4.2). The finalised positional details with the text attributes for the four walk routes were entered into the Hoppala point of interest server via the web based GUI (Fig. 4.6) as there is no direct import functionality from a GIS.

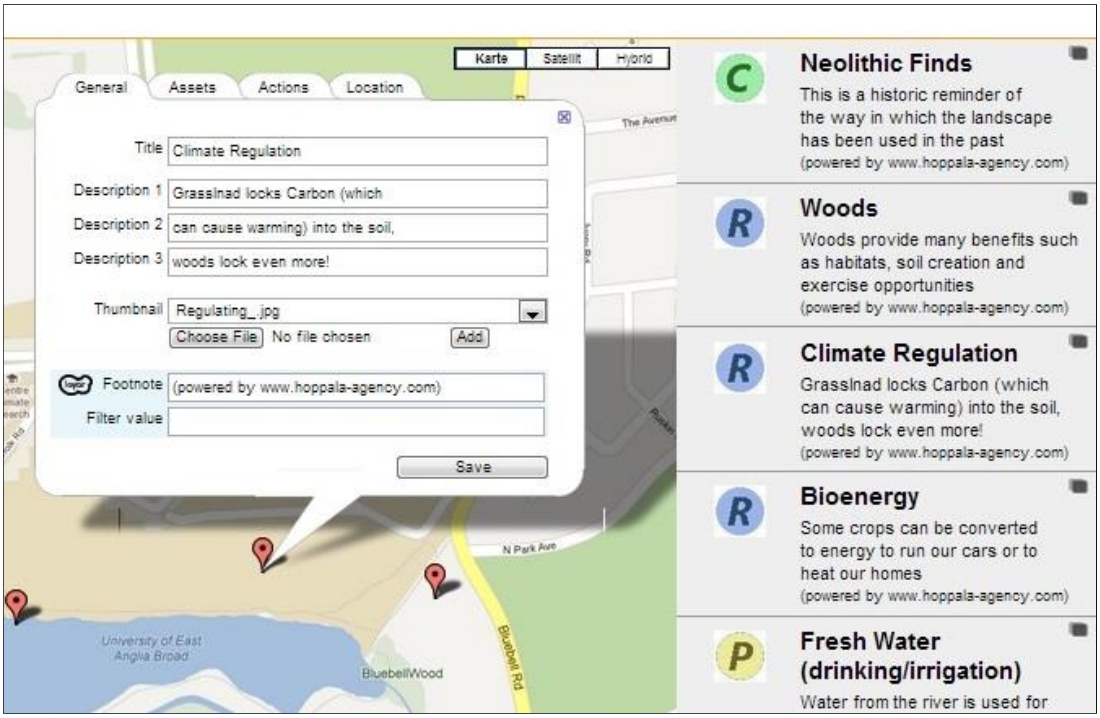


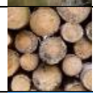
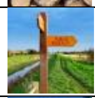
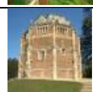
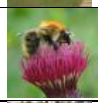
Fig. 4.6 The Hoppala Content Management System (CMS) which provided details to the LayAR server and in turn consumed by VesAR, The Climate Regulation POI is being edited to remove a spelling mistake while the list to the right hand side shows other POIs in this area.

Using VesAR

The Millennium Assessment (2005) and the National Ecosystem Assessment (2011) were used to describe the types of ecosystem services in the selected river catchments. On opening the VesAR app a splash screen gave an overview of the type of ecosystem services that the participants would see on the walk (cultural, provisioning and regulating) and this information was mirrored on the inside fold of the leaflet (Fig. 4.9). Symbols were used to indicate the type of POI, again the leaflet closely matched the data seen on screen (Fig. 4.8, Fig. 4.9, Fig. 4.10). Introducing ecosystem services (or nature's benefits) in this manner mitigated to some degree the restrictions in the amount of text shown on screen.

Descriptive text displayed on the phone screen (Fig. 4.8) is limited to three lines of 30 characters not by the developer of the LayAR technology but by the creator of the Hoppala content provider. Condensing large and complex scientific research into more accessible language while maintaining the message was not a straightforward process with multiple revisions required (an example of the finished version can be seen in Table 4.1); many were adopted to suit each site (such as the cultural references) while others were more generic. Supporting services were not included in the application due to the difficulties in communicating this type of ecosystem service. Also shown are images originally planned for use in the app which were removed to reduce the load time in areas of poor signal.To increase the participants understanding beyond the bite sized text, further information about the ecosystem service which the POI represents can be accessed by tapping the “More about...” area which takes the users to a webpage with more details about the ecosystem service (Fig. 4.8). The decision not to include imagery on this webpage was taken to reduce the wait time in areas with lower data speeds. The user of the device can also tap “Take me there” which opens a plan map of the area with all the POIs shown, and from there select a list view to show details of all the ecosystem services currently within radius.

Table 4.1 Examples of POI text used in the VESAR application

Site Type	Name of POI	Type of POI	Text description (as seen on the phone and in the leaflet on the printed map)	Images
Rural	Flood Alleviation	Regulating	Drainage ditches allow flood waters to drain away slowly and recharge groundwater	
Rural	Woods – Timber Production	Provisioning	In large woodlands and forests, timber is logged and sold to maintain the woods	
Rural	Recreation	Cultural	Footpaths criss cross our land and offer opportunities to explore the countryside	
Urban	Chapel of the Red Mount	Cultural	Beautifully refurbished Grade II listed building adds a focal point to the Walks park	
Urban	Crop Pollination	Provisioning	Bees pollinate crops, urban flowerbeds are an important source of nectar	
Urban	Noise Reduction	Regulating	Road noise impacts on the health of urban dwellers, but parks can help absorb these sounds	

4.2.3 Evaluating the communication potential of the application

After the initial development phase a series of public events subsequently took place at both urban and rural sites around King’s Lynn and Norwich in Norfolk, UK (Fig. 4.7). Further details of the catchments and influence of the catchment characteristics on the design of the case study can be found in Chapter 3. The events were scheduled during June and July 2012 but due to extremely poor weather conditions during the summer numerous events had to be cancelled. Additional events were run in the autumn of 2012 to increase survey responses. In total 44 people took part in the trials of VesAR.

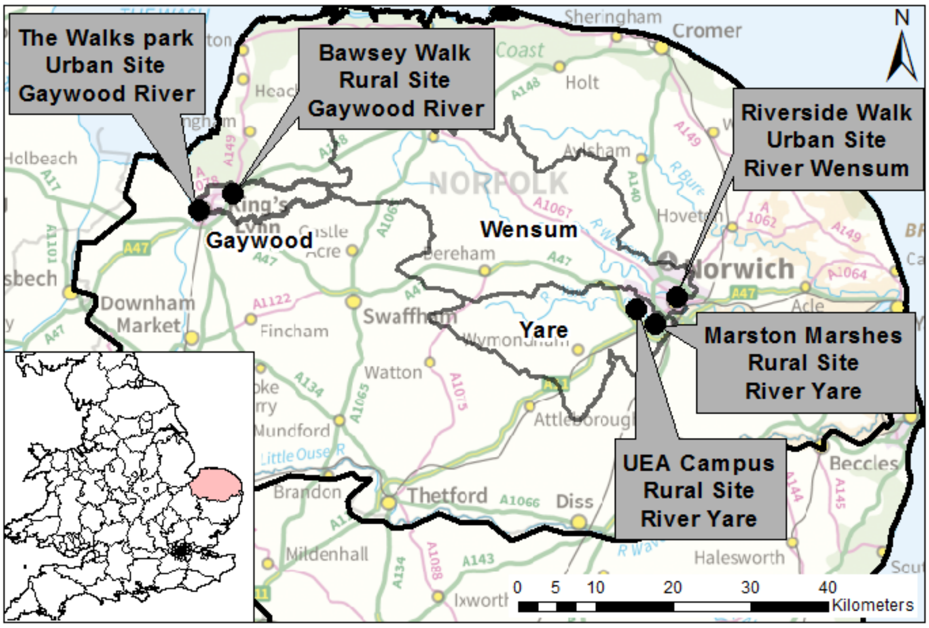


Fig. 4.7 VesAR evaluation locations

Aims of the evaluation exercise were to examine the potential of augmented reality for communicating information about features within the landscape and engaging people with the importance of the ecosystem services they offer as well as technological limitations. An incentive was offered for attendance at the sessions, with optional inclusion into a prize draw after a completed survey was handed back to the researcher. Recruitment for the sessions was organised in a variety of ways, social media was used (Twitter, Facebook, local parenting sites) and word of mouth, as well as local papers and inclusion in local event listings. Sessions in June and July 2012 within the Gaywood Valley were arranged by the Gaywood Valley project officer who acted as gatekeeper to the study recruitment process. Later sessions within the Wensum and the Yare catchments were with the approval of groups managing the sites (Norwich Fringe Project and Norwich City Council), the recruitment was managed by the researcher with support from the UEA media team to improve response. Although the sessions were held across several months and within several catchments efforts were made to ensure that the format of the sessions was identical.

At the commencement of the session the purpose and aim of the session was communicated to the participants by the researcher. Participants were introduced to the tools which they were to use and initial questions responded to, particularly necessary for those who had not previously used a mobile phone or tablet. Accompanied by the researcher and assistant the participants were taken on a short walk which lasted about 30minutes in each direction depending on the amount of support participants required to use the devices. During the walk participants were shown the area's ecosystem services using the two tools: a handset with the VESAR application installed (Fig. 4.8) and the paper handout (Fig. 4.9). Participants used one tool on the way out from the start, and a different tool on the way back walking the same route. Participants were encouraged to look for the POIs to increase the level of interest with the activity. Efforts were made to ensure that the participants explored all the features of the applet and were able to view a number of different POIs, in some sessions an air of competitiveness emerged to be the first to find new features. Due to the number of devices the maximum group size was six although one session of eight was run.

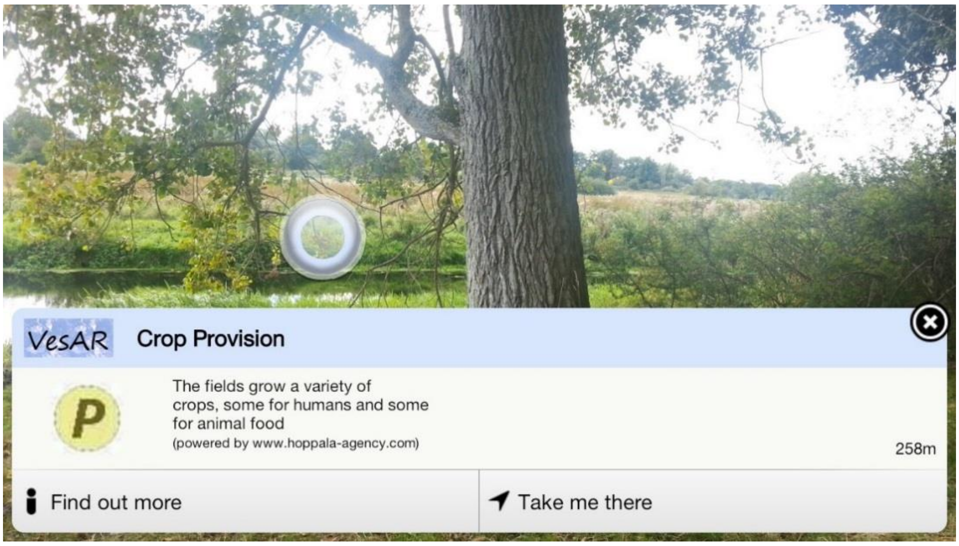


Fig. 4.8 A view through the camera showing an example of the POI over the fields and the associated text describing a provisioning service for crop production.

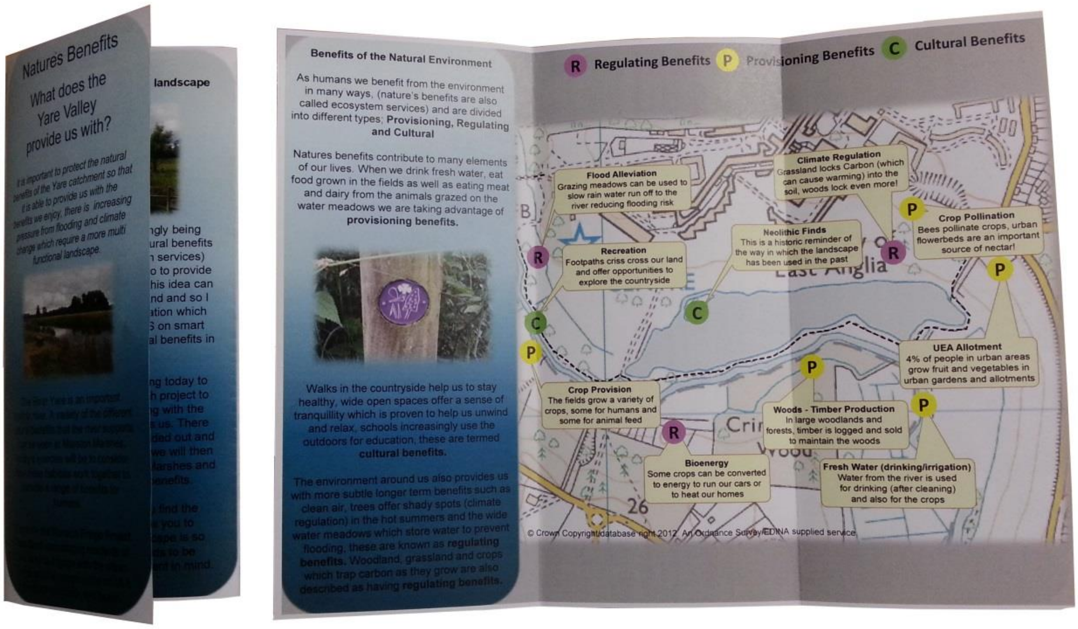


Fig. 4.9 The guided ramble tri-fold paper handout

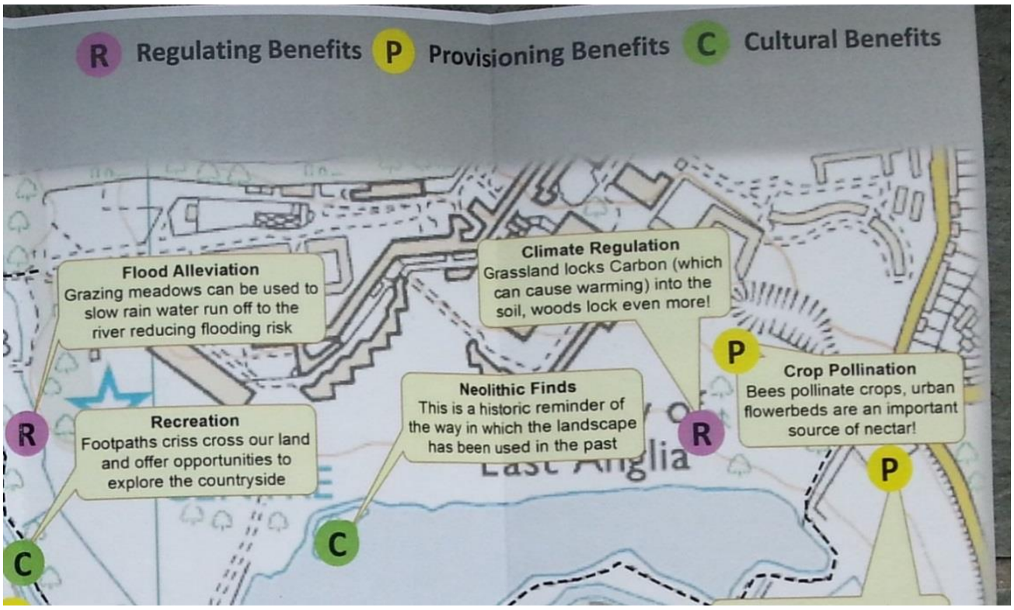


Fig. 4.10 A close up of the tri-fold handout, the example here is the UEA Campus walk in the Yare catchment

To establish which tool was most effective and which was preferred; paper based surveys were handed to each participant on arrival. The survey was split into three sections to be completed before the ramble to collect baseline data, during the ramble at the mid-point after the test of the first tool and at the end of the ramble after the second tool was trialled. Demographic information was also collected to examine any differences in responses due to age, technological familiarity, and other factors. After the surveys were collected participants were encouraged by the researcher to discuss the session, these post session debriefings provided valuable insight into the use of the tools.

4.3 Results

4.3.1 Quantitative Feedback

Of the 44 completed surveys 59% were women and 41% men. Technical awareness was quite high with 93% owning a computer or laptop and 57% a smartphone (defined as a Blackberry, Nokia Symbian, Android or iPhone). The IT Literacy of users was determined by adding together their responses to whether they owned a smartphone, a laptop or a PC (No = 0, Yes = 1) and the degree to which they were familiar with email and online maps (Not at all = 0, Slightly = 1, Moderately = 2, Very = 3). Of the participants 57% had previously heard of ecosystem services. It was anticipated that age would be a key influence on how people engaged with the ecosystem services communication tools. Seven participants were aged up to 25, fifteen in the range 26-35, eighteen from 36-60 and four over 60. Ideally there would have been more participants, particularly of younger ages, but for the purposes of analysis the sample was simply divided into two equal sized groups of those aged up to 35 and those older. Analysis of the questionnaire data indicated that slightly higher proportions of the younger age group had heard of ecosystem services and owned a computer or laptop. A stronger contrast existed in smartphone ownership (73% in the younger age group and 41% in the older one). When asked at the end of the event which communication tool they liked best, of those who expressed a preference the proportion favouring the smartphone application was 50% in the younger age group and 33% in the older one. However, none of these differences between age groups were statistically significant at the 0.05 level when evaluated using Chi-Square tests.

During the walk participants completed twelve multiple choice questions about ecosystem services after using their first tool and another similar set after the return walk to assess what had been learnt (see Appendix 1). Table 4.2 summarises the average scores (out of a maximum total of 12) according to age group and which tool was used first. The results indicate that there was a slight tendency for the test score to be higher in the younger age group after using the smartphone application while for older participants the better scores were more clearly associated with use of the paper leaflet. However, neither of these differences was statistically significant at the 0.05 level when assessed using Mann-Whitney U tests.

Table 4.2 Average scores on the ES questions by age group and communication tool used

Communication tool used first	Aged up to 35		Aged 36 or older	
	ES Test Score 1	ES Test Score 2	ES Test Score 1	ES Test Score 2
Smartphone	10.2	10.2	9.0	9.4
Paper leaflet	10.1	10.3	9.9	8.9

At the end of the activity the participants were also asked to rate the two communication tools on a 1-5 scale (5 highest) in terms in terms of how well they helped them understand the locations of ES and the benefits provided. Average ratings for each question by age group and overall are shown in Table 4.3. These results indicate that the smartphone was evaluated as less useful by older participants while there was no age difference for the leaflet. Across the entire sample there was no significant difference in ratings of the two tools in terms of helping to understand ES locations, but for benefits a Mann-Whitney U test indicated that those of the leaflet were significantly higher at the 0.05 level.

Table 4.3 Average ratings of communication tools in terms of location and benefits of ES

Age group	Smartphone helped understanding of ES locations	Leaflet helped understanding of ES locations	Smartphone helped understanding of ES benefits	Leaflet helped understanding of ES benefits
Aged up to 35	2.9	2.9	3.0	3.2
Aged 36 or older	2.4	2.9	2.6	3.2
Total	2.6	2.9	2.8	3.2

Participants in the evaluation trials were asked which tool they thought was best at communicating the benefits from the landscape and which tool which they liked best (Table 4.4). Of the 44 responses 31 chose the same tool for both questions, however 13 respondents (29.6%) chose different preferences. Those who chose VesAR as a more effective tool but selected the leaflet as their preferred tool described the app as distracting and intrusive but yet novel and there was an entertainment element to learning in this way. These same users reflected that their preference for the use of a leaflet was in being able to see everything at once, the ability to stop and read as and when during the walk in addition to taking the leaflet home for future reference. Similar responses were described by the users who chose the leaflet as a more effective tool but preferred VesAR, these liked the novelty of the app but again felt too disconnected from the landscape preferring a tool they chose when to reference, and reported that while there was great potential there was more development needed in the display and the provision of a proximity alert. Those that felt the leaflet was more effective but liked VesAR commented on the ability to show the precise location of services on the screen without having to first orientate themselves on the map provided in the leaflet and the functionality to overlay information on the screen being novel and engaging.

Table 4.4 Responses on the tool most effective vs most preferred

Q17. Which tool do you think was most effective at communicating the benefits we get from the landscape around us?	**Q18. Which tool did you like best?**	**Number of Responses**	**%**	**Average IT Literacy**
Android	Android	9	20.5	6.5
Android	Leaflet	5	11.4	7.6
Leaflet	Android	8	18.2	7.5
Leaflet	Leaflet	19	43.2	6.1
Both	Both	3	6.8	8
	Total Responses	44		6.7

4.3.2 Qualitative feedback

Fig. 4.11 Participant event within the Gaywood Valley in June 2012 showing the tablet and leaflet in use while the researcher discusses the study with a participant, below are quotes from participants on the walks

As described in the methodology the participants were debriefed after their walk (Fig. 4.11) by the researcher and the assistant giving the research study additional qualitative data. In total 59 comments were made about the experience, some within the surveys and some noted during the debrief session – a full list of these can be seen in Table 4.6. This section summarises the qualitative data which wagathered, first quotes from participants which took part show the diversity of feedback which was obtained. This is followed by the specific comments from the users combined with their IT Literacy indicating that the users returning positive comments had a higher IT Literacy than those reporting negative comments. Many users provided feedback not just on why they liked one tool but also why they didn't like the other; these further comments are shown in Table 4.6 and grouped to highlight the most popular statements.

Four statements from participants who took part are quoted below.

"It's (the augmented reality) like lifting the lid on the landscape, similar to an engineering circuit diagram of all the things happening out of sight"

"The leaflet was clear and easy to follow, it provided a map and all the relevant info. You could refer back to it when needed. The activity was enjoyable, it was good to see a new technology although I did not really enjoy using it"

"Easy to understand, (AR) provides a better sense of direction and location; very useful to be able to navigate to exactly where you want to be and learn about nature interactively. Greener than leaflets. Was interesting to find out that apps can be developed for nature activities and learning"

"The leaflet gives a broad overview of the area and demonstrates the balance and spread of benefits whereas the app allows more on the spot, detail and additional info."

Additional examples of comments collected during the survey and debriefing sessions which provide further perspectives on the two tools are shown in Table 4.5 and Table 4.6. These illustrate positive aspects of the VesAR application such as the interactivity, but also negative dimensions. Table 4.5 combines the comments with the level of IT Literacy which was assigned to the users who took part based on their familiarity with smartphones, PC/Laptop, email or web maps. It can be seen that there is a trend for higher IT Literacy being associated with positive remarks on the smartphone, however the data sample size prevented any further statistical evaluation of the relationship between IT Literacy and the feedback on the use of augmented reality.

Table 4.5 Participant comments on the smartphone tool compared with IT Literacy

Positive smartphone comments	IT Familiarity	Negative smartphone comments	IT Familiarity
Smartphone can give a greater range of data	8	Liked the leaflet, it's what I'm used to!	5
Smart data can be changed easily to update information about species seen in an area	7	Leaflet can be used in all weathers, the phones didn't like the rain	7
Smartphone provides a much better sense of direction and location of POIs	8	You could see all the points at once (with the leaflet), it would be easy to miss one with the android.	8
Knew the area well, but learnt lots of new info in a new way	8	The countryside should offer freedom from technology	8
Smartphone much greener – no litter or waste!	8	Smartphone distracted me from my walk	2
Really interactive and fun	7	Android phone is just a novelty, not durable	8
Good way of engaging my children in the surroundings	7	Using a smart phone while walking is difficult	7
Like the idea of using it to find historical sites	7	Smartphone made me feel too disconnected from outdoors	7
I liked the overlaying of information using the screen	8	Map availability on leaflets helped to identify location of benefits	4
Average	*7.5*	*Average*	*6.2*

Table 4.6 lists the comments from completed surveys; the number in brackets indicates the number of times that this statement was made. It can be seen that there are few criticisms of the leaflet, the difficulties of maintaining the data without reprinting and the impact on paper resources being the only two reported. The most commonly reported benefit to the leaflet was in presenting an overview of the site, users felt that the leaflet with the map gave an excellent overview of the area but VesAR was able to show details of a feature and be more indicative of the location of an ecosystem service evidencing the different scales at which the applications could be used. Of interest too were comments about the benefits to having the leaflet as reference tool, not just for at a later date but also as a transferable resource during the session, users also reported it was easier not just to use but also easier to absorb the information which was being presented without having to hunt for the information. This could in part be due to the need to train users in how to access the maps, overview information and additional data for VesAR whereas the leaflet had no hidden options. Users commented on the ease of use and accuracy of ecosystem services in the landscape for both tools suggesting that existing user preferences heavily influence how well they engage with VesAR vs the leaflet.

Table 4.6 Participant comments on their preferred method grouped to presented the most frequently mentioned responses about the advantages and disadvantages to the two tools

Positives of the smartphone (VesAR)	**Negatives of the smartphone (VesAR)**	**Positives of the leaflet**	**Negatives of the leaflet**
• Novel (5) • Interactive (5) • Fun (3) • Potential (3) (Conservation and History) • Overlay (2) • Available • Easy to use • Provides better orientation • 3D • Responsive • Accessible • Engaging • Liked option for additional information • Wider range of data • Better Detail • Environmentally Friendly	• Disconnected (Distracted) (8) • Better Design (lack of Proximity Alert) (7) • Needs Development (3) • Better Design (Text too small) (3) • Better Design (better symbols) (2) • Unreliable • Affected by weather • Display unreadable outside • Disconnected (Refuge) (2) • Language Formal • Insufficient information	• Overview of whole site (13) • Easy (4) • Accurate location of ecosystem services (4) • Better absorption of information (3) • Non-Intrusive (3) • Longstanding Familiarity (2) • More accessible • Inexpensive • Subject definitions better explained • Clarity • Keep for reference at a later date • Keep for reference and can review during site walk; transferring knowledge during the session	• Printed material less sustainable • Overhead of maintenance

Negatives of VesAR focused on the need for development and improving the design particularly with the size of the text and the lack of imagery; users reported both a lack of and the correct amount of available information suggesting that this was influenced by their familiarity with the smartphone technology. In addition the reliablility of the VesAR app was called into question with the POIs dancing on the screen making it difficult for users to press on them and bring up the information. The performance of the technology was also commented on (the touchscreens of the hardware were affected by raindrops on the screen and bright sunshine causes glare prevented the screen being read). Comments were made on the use of formal (scientific) language being a barrier to understanding the information. From the comments in Table 4.6 it is also apparent that far from engaging people in the landscape for some participants the smartphones detracted from the enjoyment of the open space due to needing to constantly review the phone screen. Participants reflected on how the phone disengaged them from their surroundings both in terms of distracting them and also in the countryside should provide a refuge from the use of technology. Despite this some users did comment on the novelty of being able to overlay information and the 3D functionality with others excited by the potential of the app as an educational tool. Participants enjoyed the activity, sessions were fun to take part in and this was commented on a number of times.

4.4.3 Observational feedback

In addition to the data which was collected from participants via survey and debriefing the researcher and assistant engaged in participant observations during the walks. Four key technological restrictions were noted by the research team while observing the participants engaging with this technology. During the debriefing sessions feedback indicated that all of these led to some participants choosing the leaflet as their favoured communication method.

The first restriction was the difficulties with screen glare in sunny weather. Despite all three handsets using an "anti-glare" protector and the researcher adjusting the display brightness there was difficulty in clearly viewing the phone or tablet screen on days where the sun was very bright or directly overhead. This was reported in particular in the wide open spaces of the Gaywood Valley where there was little shade along the route. It was discovered that increasing the screen brightness to increase visibility outdoors impacted in the battery life of the handsets. The battery life is the second technological restriction whereby during the pilot site visits it became apparent that the phones needed to be turned off between evaluation walks, or the battery charged, due to the GPS accuracy being directly affected by the battery strength. The third restriction noted during the sessions was in the accuracy of the POIs, in particular on the HTC phones where the POIs had a tendency to 'dance' and disappear from the field of view when a device was stationary. This is primarily a GPS accuracy issue and varied across handsets, other LayAR users have reported this problem so it was not unique to VesAR. The problem could usually be managed by restarting the application and was less apparent on later versions of the LayAR™ software. Finally it became apparent through a process of comparative evaluation of all the sites where VesAR sessions were run that the application worked better as a communication tool where there were open vistas such as across farmland and on a wetland nature reserve; use within a more built-up area became confusing when POIs appeared and the associated feature was not within the line of sight and it would be worth exploring whether the concerns with the line of sight could be minimised by setting a smaller display radius for POIs in urban areas. To bring together the results from the paper survey with the participant comments, a SWOT assessment of the finding has been summarised in Table 4.7.

Table 4.7 SWOT analysis of the augmented reality technology

Strengths	**Weaknesses**
• Quick to update • Fun • Lack of waste • LayAR is multiplatform so any smartphone can access it • Increased awareness of ecosystem services in some demographics • Good for seeing detail	• Battery Life • Lack of accuracy • Screen Glare • Display off-putting • Requires data signal • Distracts user from their surroundings (potentially may cause falls!)
Opportunities	**Threats**
• Quick to update new information to reflect land use change or inform users • Novelty factor • Lack of waste • Can include 3D element of z axis to engage with ecosystem services under the ground or in the atmosphere	• Single point of failure in the content management system • Changes to operating system requiring updating of code if customisation takes place

4.4 Discussion

This section discusses the findings of the case study and highlights the barriers to adopting augmented reality as a communication tool. VesAR aimed to be easy relate to both spatially and temporally, as scientifically trustworthy as possible, instructive, attention grabbing and tailored to the target audience. The distilling of NEA information, at that time only just published gave VesAR scientific credibility and it was hoped that this unique approach would appeal to a wide range of users. Following trials the greatest praise given by the users of VesAR centred on it being novel, interactive, fun and having great potential for future use; particularly when applied to the communication of history and conservation aspects of landscapes. However criticisms of the augmented reality app focused on its unreliability, the need for better design, and how by its nature it distracted the user from their surroundings. These findings are at odds with Lange (2011) who suggests that augmented reality may facilitate the communication of information while in the field which then both enables the non-visual senses to be engaged, and stimulates a sense of interaction impossible within a building. The latter also enables users to experience '*geographic dirtiness'* (Cartwright 2005 p. 3040) compared to visualisations which do not take into account the less wanted sounds and smells of the countryside.

The barriers to the adoption of augmented reality can be summarised into four main areas; subject matter, technology, performance of the tool and user preference (Fig. 4.12). The subject matter in this case study was commented on both positively and negatively indicating that this barrier is made up of several variables such as adaptation of the subject matter, the person converting the data, the recipient preferences and to a degree the capacity of the technology to display the information as intended. Interestingly despite some criticisms of the abridged extracts of the NEA, described as '*language formal and boring - needs to match the informal delivery'* there were no such concerns of the leaflet;

the information shown in both was identical, signifying that perhaps users had different expectations of the two tools. The degree to which the person converting the information understands the subject and the way the technology will display this are likely to be vital. This barrier therefore can only truly be mitigated by carrying out a pilot study before release of tools with a representative sample of the intended audience.

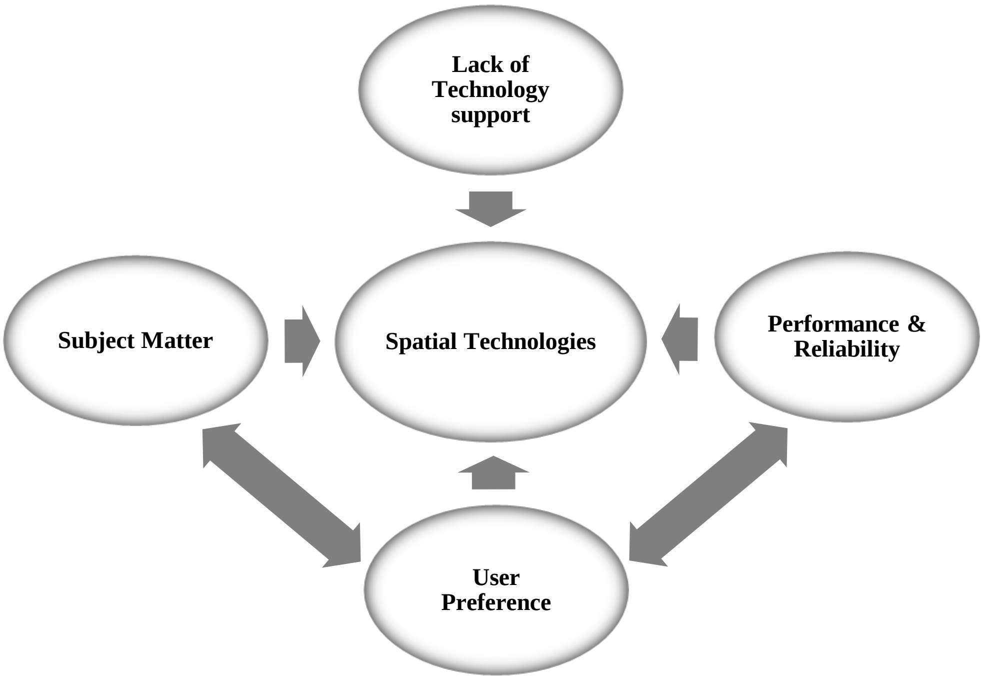


Fig. 4.12 Barriers to the adoption of augmented reality by practitioners

The second barrier relates to the technology itself. While the construction of VesAR was relatively straightforward there was an overhead of time to collect, digitise and validate the information which it contained even for a GIS expert. To develop POIs at a wider catchment scale some degree of automation was explored using ESRI ArcGIS to identify various land use types known to reliably provide ecosystem services. While there is some potential in adopting this approach an automated data generation process would require strict validation to ensure that the users of the application were shown accurate information and that POI clustering (Fig 4.8) was kept to a minimum. One way of mitigating the overhead of validation is to empower the community to correct its own data, this approach is utilised in mobile apps such as #Ashtag – an app developed to track the spread of disease in Ash trees where users photograph trees for experts to evaluate. This is an area further explored in Chapter 6 as the lack of interoperability between the content management system (Hoppala) and the desktop GIS (ESRI ArcGIS 10) restricted the opportunities to explore automated data generation and validation. In the development stage of VesAR development (2011) only three point of interest servers were available (PorPOISe, Poiz and Hoppala) with Hoppala the one requiring the least coding and sever hosting infrastructure hence its selection. Other content management systems which act as a ‘point of interest server’ to LayAR do now exist and have improved support for uploading spatial data. In the most recent release of the LayAR third party tools list Hoppala is described as a basic web based map interface for adding data to a POI server and it has not been upgraded to support the more recent LayAR API. The lack of support for this type of technology to be rolled out on a wider scale by river trusts or catchment partnerships remains a barrier, relying as it does on resources unlikely to be found within these organisations and the lack of a nationally accepted spatial infrastructure and data models.

Separate from the development of the technology the performance of the technology is another barrier identified particularly in the more rural landscapes which had poorer signal quality. The participants in the trials commented on VesAR’s unreliability; and the difficulties of using the hardware both in wet weather and direct sunlight. Users commented on the need for better design of the app, specifically that the text was too small, the symbols for different service types were not clear enough and there was a need for a proximity alert to prevent the user having to continually focus on the screen in case a POI was missed. These issues identified during the trials are excellent examples of the trade-off to be made when choosing a spatial technology between the convenience of off-the-shelf components and the amount of control over the resulting system. The creation of a proximity alert would be the greatest single improvement to reduce the feeling for users that the app distracts and disengages them from their surroundings and would increase the usability of a tool which has potential to communicate ecosystem services in a novel and fun way. Other elements of the augmented reality app which would benefit from further development include implementing the relative POI function which exists in the more advanced LayAR toolkit (Madden 2011). This function uses the on board GPS together with the coordinates of the downloaded data resulting in the phone recognising its location relative to the POIs in the landscape. The application of this function to the augmented reality app for use in rural areas could mitigate for poor data signal ensuring that the application could store the images and data transmitted by the LayAR server in advance of heading out on a walk improving the scope for use in sites with poor mobile data access. Coding an application from scratch would improve the reliability of the technology. During the final phase of testing the Hoppala server became unavailable (due to reasons unknown) and with no contract of service provision this had a detrimental effect on the volume of data collection and prevented further conclusions which could have been drawn from this unique piece of research. The performance of the technology in terms of reliability and functionality is an area where developments have already moved on in software, hardware and the mobile internet coverage in many rural areas; and the intended rollout of 4G networks in the UK should improve the data coverage further.

The barrier of user preference influenced both the reception of the subject matter and the expectations the user had of the technology performance. The almost contradictory nature of the feedback comments indicate that there is more research required on the way people interact with visualisation tools in situ, and that user preferences play a sizeable role in the uptake of a tool such as VesAR. Bishop et al. (2013) concluded that sometimes user preferences are for a tool which gives inferior result, thus adapting preferred techniques to make them more effective and discovering more about why a tool has been chosen is important. The results indicate that there is potential in developing this tool further; but that there should be a focus on working with a range of users to understand how user preference can influence uptake of this type of spatial technology.

During the trials of VesAR a participant reflected "*How do you properly appreciate the landscape for what it is when you are looking at the screen rather than using eyes, ears, nose?*" suggesting that further investigation into how senses may be affected by the focus required to use a handheld device would be worthwhile. Somewhat unanticipated was how, after a short exposure to the technology, the participants came up with a variety of ideas for other applications of this technology with an outdoor landscape focus. Ideas included details of species within a region, bird sightings, education on wildlife and the outdoors in general, location of archaeological finds and historic monuments or conservation work being carried out in the area. While these ideas were of great interest there was limited discussion of how these applications might be developed, who would have the responsibility to collect the required data or to maintain POIs. However the fact that users had understood the concept and had applied it to their own areas of interest indicates how transferable the technology is.

4.4.1 Improvements to the research methodology used

The research methodology to recruit participants to the survey could have been improved, and this should be reviewed in any further studies of this type. From the beginning the aim was to reduce bias by ensuring a representative selection of the community were engaged with rather than pick from the student body on the university campus. In the Gaywood catchment the Gaywood Valley Project was engaged with in order to recruit from their membership base, however due to poor timing of the sessions or a lack of interest in the subject matter there were few participants and sessions moved to the larger population centre of Norwich. This was exacerbated by the relatively recent launch of the Gaywood Valley Project with the consequence that they were not a well-established group and had relatively small mailing lists. Local media was engaged with via the Gaywood Valley project and via the university media outreach team. Social media was also used but despite incentivising the numbers remained low and the overhead of resources which went into running the events was high. Numbers were insufficient to robustly identify additional variables which may have influenced the participant's interaction with the mobile phone application. This was in part due to a wet summer which prevented sessions being run and those which did run were occasionally called off part way through as the inclement weather hindered the screen response. On reflection it would have been better to incentivise each person rather than offering one reward, and to have a defined focus for the walks, rather than simply advertising them as a chance to discover nature's benefits.

4.5 Conclusion

The events and evaluations discussed above indicate that mobile devices such as augmented reality applications on smartphones do have considerable potential for communicating the extent and nature of ecosystem services in catchment landscape settings. Not only that but the participants within the study identified further applications which they felt would merit investigation in the subjects of history and conservation. As such the first objective of the study, to evaluate the degree to which augmented reality can communicate the location of and information about ecosystem services was met. With regards the second aim of the case study - whether or not the current level of mobile phone technology and infrastructure is sufficient to support spatial applications in rural settings - then at the time of the case study the availability of signal was patchy, the technology was to a degree unreliable and there was a lack of infrastructure to assist in this type of development. The novelty of such an application will generate interest, particularly amongst experienced smartphone users, but this research also indicates that at present there are a number of practical limitations and that some members of the public are likely to prefer more traditional communication methods such paper leaflets. With the restrictions river trusts and catchment partnerships have in accessing spatial technology it is likely that this technology will be difficult to implement. There would be benefits for river trusts or catchment partnerships who could update information across the catchment from a central website including projects which are occurring along a river or within the catchment; alerting anglers or canoeists to stretches of work which will be carried out or promoting sites which are already of good quality.

These problems and attitudes may well change over time as devices such as smartphones become more ubiquitous and supporting technology such as GPS and mobile data signals improve, but based on the experience of this study not everyone will appreciate having their attention distracted from their surroundings. It therefore seems likely that while smartphone-based augmented reality could become a valuable tool for the landscape planner or designer it will not be a universal solution and to gain the maximum benefit from such technology it will be important to embed it in appropriate wider decision-making processes. In common with many other aspects of landscape visualisation (Bishop et al. 2013) there is consequently still much to learn about how to best apply such communication tools. In conclusion therefore, the collection of both quantitative and qualitative feedback suggests that there is potential in the use of augmented reality to communicate information about features in the catchment providing ecosystem services. However, the case study has also established that at the time the research was carried out there were technological limitations to the use of such software within rural landscapes.

Chapter 5. Application of a climate change visioning framework to the development of future catchment management plans.

5.1 Introduction

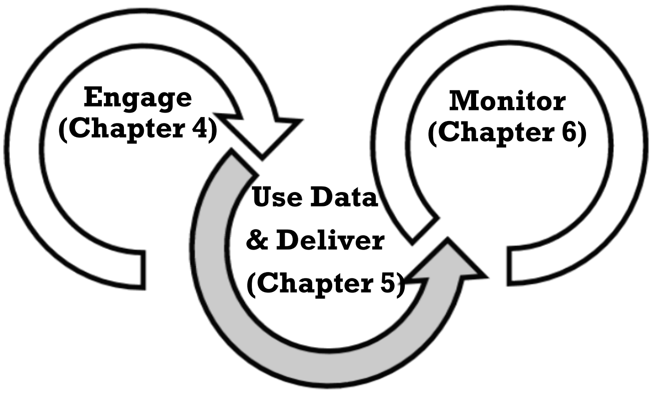


Fig. 5.1 The CaBA Framework - this chapter focuses on the Using Data and Delivering stage

Chapter 4 discussed the use of augmented reality to support the first stage of the Catchment Based Approach (CaBA) of engaging people with their catchment landscape. CaBA's second stage recommends that stakeholders and technical partners work together with a facilitator to "collate and scrutinise all of the data and evidence relating to environmental infrastructure and ecosystem services provision for their area/catchment of interest" to drive an evidence led process (CaBA 2013). Subsequently the third stage of the CaBA strategic framework mandates that the work to be done and the locations to be improved should be ascertained through stakeholder led planning before "delivery of catchment management interventions that will achieve the best possible environmental and economic benefits for all of the interested parties" (CaBA 2013). This case study combines stages two and three of the Catchment Based Approach (CaBA).

To meet the objective of multifunctional and sustainable catchment management requires increasing the level of collaboration between different agencies and across differing spatial scales (Macleod et al. 2007). Fortunately different land uses and potential interactions between ecosystem services mean that river catchments are an optimum scale at which to maximise transdisciplinary research (Dawson and Smith 2010) described as that which involves multiple tiers of governance across many disciplines. While experts involved in decision making are often able to visualise the changes which will occur under different land use scenarios; this information is more difficult to understand for non-experts increasingly included in the decision making process. This chapter continues the appraisal of spatial technologies to support the CaBA with the application and evaluation of a visioning framework previously used in a stakeholder climate change project and two visualisation tools within the combined second and third stages of CaBA (Fig. 5.1).

Research covered in this chapter had a practitioner focus throughout due to collaboration from the outset with the Norfolk Rivers Trust (NRT). Due to the range of stakeholders the NRT wished to interact with and the mix of experts and laypersons needed to consider the array of catchment processes then a transdisciplinary approach was most suitable (Schroth et al. 2011). Evaluation of the catchment visioning was carried out through a mixed methods approach during stakeholder workshops with follow up interviews with the NRT staff at a later date.

The research in this chapter aims to answer the following research questions;

1. To what extent is it possible to adapt a parcel based urban planning GIS and visualisation package (CommunityViz) to catchment visioning?
2. In what way do computer based visualisations compare to traditional paper based maps?
3. What potential exists for visualisations to be employed for community engagement in catchment management?
4. To what extent can a climate change visioning 'framework' be utilised for catchment visioning?

5.2 Framing the case study

5.2.1 Background

In order to meet the aims of the WFD the Norfolk Rivers Trust (NRT) applied for catchment restoration funding (CRF) for nine chalk catchments in Norfolk, UK. In October 2012 the funding was secured and to meet the funding criteria of the CRF a catchment management plan had to be written. In the largest of these nine catchments (the Stiffkey), stakeholder feedback was key to the proposed catchment management plan however the timescale to gather this information was short. Thus the Stiffkey catchment was selected as a case study for the evaluation of a visioning framework, and the comparison of two visioning tools during the stakeholder consultation period.

5.2.2 Nine Chalk Rivers project

Of 200 chalk rivers in the world, 170 are in England and found in a band of chalk bedrock from Dorset to Yorkshire which includes famous trout fishing streams such as the Test and the Itchen (Fig. 5.2). Underlying porous chalk geology influences on chalk streams include;

- a slow release of clean filtered water from the groundwater aquifer ensures river flows remain constant (when abstraction influences are removed) compared to surface fed rivers,
- the quality and chemical composition of the water is mineral rich, particularly in calcium (Ca),
- the river bed is comprised of gravels eroded from the bedrock which is a perfect fish spawning habitat,

- meandering river profile producing a pool riffle sequence migrating silt down river and keeping river beds clean.

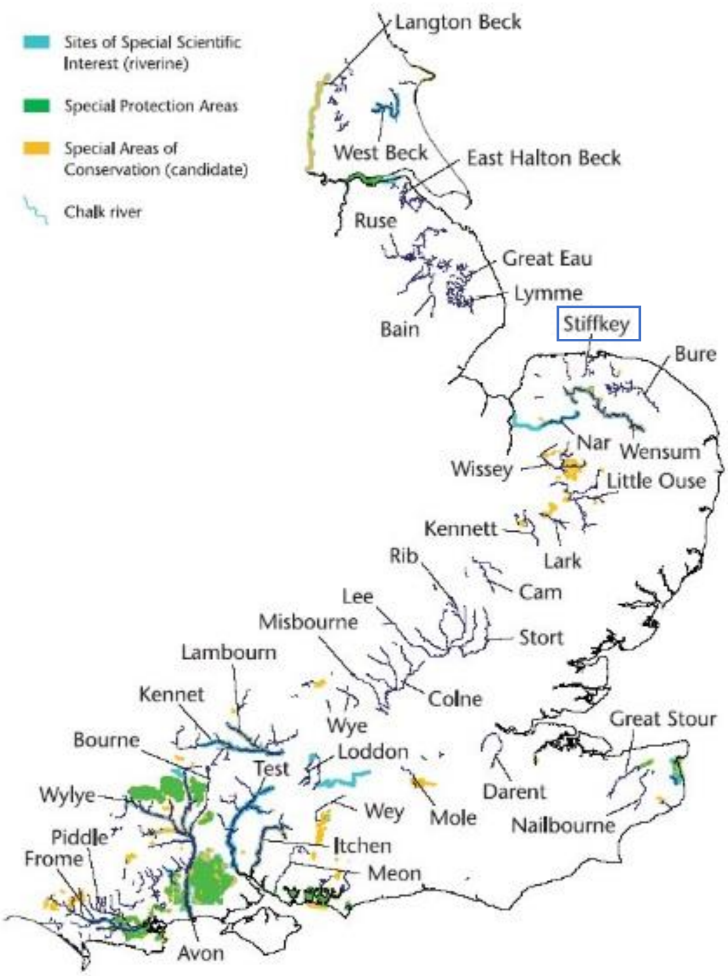


Fig. 5.2 Chalk rivers and their associated wildlife conservation designations (Taken from The State of England's Chalk Rivers, Summary report by the UK Biodiversity Action Plan Steering Group for Chalk Rivers 2004) with the location of the Stiffkey highlighted in blue.

These factors influence the life within chalk streams which when in good health support 'iconic English species' such as kingfishers, crayfish, brown trout and a rich invertebrate community (Norfolk Rivers Trust 2013). With some of the UKs most threatened habitats of wet woodlands and meadows created from the combination of soft slopes and springs it is evident that throughout chalk catchments the underlying geology influences more than just the riverine habitats and ecosystems. Within Norfolk there are a number of these unique chalk rivers; few of which function well due to the combined demands on the rivers and the underlying chalk aquifers. In April 2012 Norfolk Rivers Trust developed the *9 Chalk Rivers Project*; focusing on the restoration of nine chalk rivers which outfall to the Wash and the North Sea off the Norfolk coast (Fig. 5.3). In the largest of the nine chalk catchments; the Stiffkey; the Norfolk Rivers Trust aspired to work with stakeholders to scope and deliver a development plan to carry out a whole catchment restoration process.

Unlike the Test and the Itchen, the Stiffkey and its main tributary (the Binham Stream) are currently failing the Water Framework Directive measures due to channel modification, low dissolved oxygen content and lack of phytobenthos, (microscopic plants that live attached to substrates such as rock/stone or large plants). Despite failing WFD indicators the Environment Agency class these rivers as having good ecological potential. Centuries of intensive land management due to agriculture have resulted in the channels being heavily modified and some indicators; dissolved oxygen on the Stiffkey and lack of phytobenthos (in both the Stiffkey and the Binham Stream) have been exacerbated by lack of shade, siltation and low flows. The influence of catchment characteristics on the design of the case studies was covered in Section 3.4; and the significant influence of the catchment geology on the diverse landscape of a chalk stream such as the Stiffkey should not be underestimated.

Fig. 5.3 The location of the Stiffkey catchment is shown in red, the lower half of the catchment is the North Norfolk AONB and the River Wensum to the south is an SAC from its source to Norwich

5.2.3 Introducing the Stiffkey and the catchment

Fig. 5.3 shows the location of the River Stiffkey which rises from springs throughout the catchment and is joined by several tributaries (the most prominent – the Binham Stream – is also shown) before the main river channel flows out through outfalls to the North Sea via a tidal gate across saltmarshes. Along its length the Stiffkey passes through multiple (national and international) statutory designated sites. The middle section of the catchment is of particular religious and archaeological interest with the shrine at Walsingham, the Priory at Binham and the Iron Age hill fort at Warham; tourism is also a key feature in the catchment with the North Norfolk Coast Path and the lower reach of the catchment of particular interest for wildlife tourism (Fig. 5.4).

Land use in the Stiffkey catchment is predominantly agriculture, (primarily wheat, barley, potatoes, sugar-beet), with cattle for beef and dairy. The topsoil in the region is shallow and vulnerable; a single rainstorm can remove 150 years of topsoil deposition (Norfolk Rivers Trust 2013). Issues identified by the Norfolk Rivers Trust in the catchment are intrinsically linked and challenging to explain to non-expert catchment stakeholders. Through the development and use of a catchment management plan Norfolk Rivers Trust aimed to restore the rivers natural chalk stream functions, improve ecosystem services to support a multifunctional and sustainable future catchment landscape and meet the aims of the Water Framework Directive.

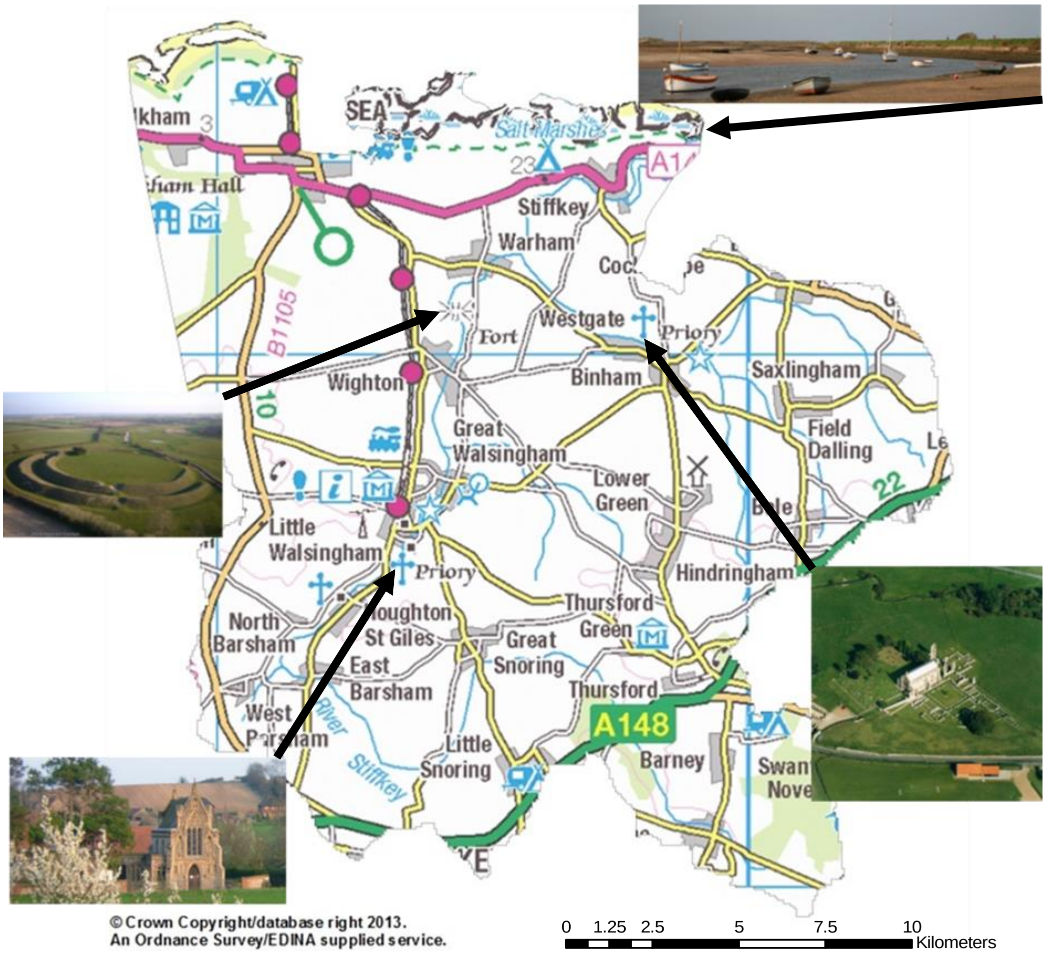


Fig. 5.4 The Stiffkey catchment, from top right clockwise the AONB North Norfolk Coast (© Visit Norfolk.com), Binham Priory with the Binham Stream in the background (© English Heritage), the shrine at Walsingham (© Walsingham Village Website 2015) and the Iron Age fort at Warham with the canalised river bisecting the chalk escarpments (© Hamish Fenton) can be seen.

5.2.4 Introducing the visualisation framework and CommunityViz

The use of a Climate Change Visualisation Framework

The framework developed by the Centre for Advanced Landscape Planning (CALP) for visioning climate change was designed specifically to link scientific information about climate change with local community activities and opinions via a visioning process (Sheppard et al. 2011). While climate change and catchment planning work over different timeframes and scales there are similarities in the requirement for disseminating spatially based expert information to lay persons in order to collate feedback for the planning process.

The ten step CALP framework is shown in Fig. 5.5 and Fig. 5.6. Steps are defined as participation (pink), data integration (green) and production (yellow), with clear guidance on each phase of the visioning process as applied to the Stiffkey case study being presented in Table 5.1. Working with the Norfolk Rivers Trust a transdisciplinary collective of catchment stakeholders was recruited over several months to vision a healthier catchment. The intention to fully evaluate the visioning process was supported by the indicators agreed with the NRT and range of functions within the chosen software using predictive scenarios, also known as *What If?* or forecasting scenarios (Borjeson et al. 2006; Schroth et al. 2009).

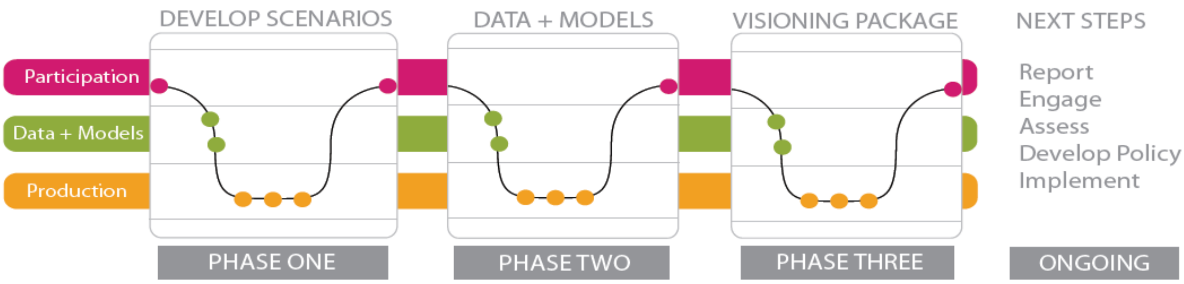


Fig. 5.5 The CALP process for developing climate change visioning (Sheppard et al. 2011)

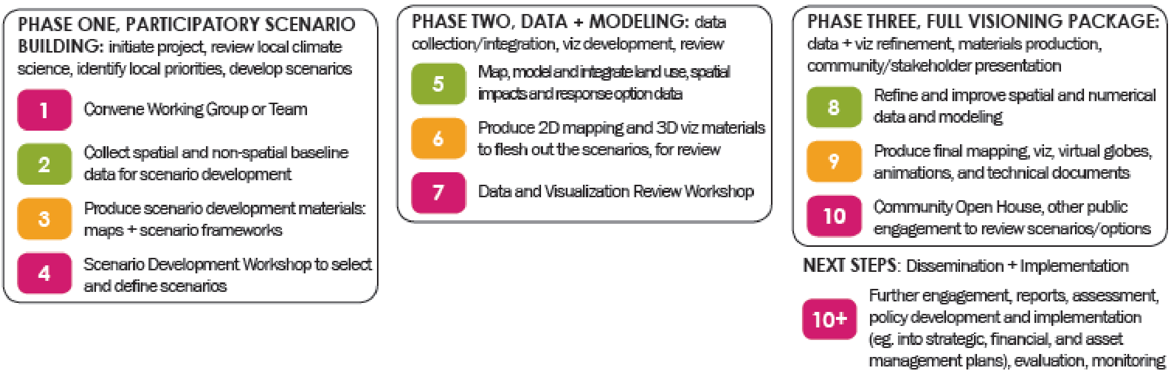


Fig. 5.6 Climate change visioning framework , stages described (Sheppard et al. 2011)

The CommunityViz software package

Developed by Placeways™ CommunityViz is a scenario based visualisation tool. CommunityViz offers powerful dynamic functionality within the ESRI ArcGIS application; a comprehensive suite of tools offer linked 2D and 3D modelling alongside dynamic chart and statistical information all of which change in real time when edits are made to the GIS data. While CommunityViz shares many of the same windows and functionality as the underlying ESRI ArcGIS there is an additional acquisition of knowledge needed to work with CommunityViz and build scenarios. Previous research (Bishop et al. 2009; Salter et al. 2009; Schroth et al. 2011) employed inbuilt fully customisable indicators and performance measuring tools in CommunityViz to evaluate planning scenarios using variables such as water supplies, green space and residential building. CommunityViz has a number of extensions, these are described by Placeways as falling into four subsets which relate to analysis, decision making, visualisation, and engagement. For this case study CommunityViz 4.3 was installed onto a desktop computer with a Windows 7 64-bit operating system, 8Gb RAM, and IntelCore i7-2600 CPU @3.40GHz processor.

CommunityViz enables presentation of both spatial data and associated statistical data across two or more scenarios using the *analysis* subset of extensions. These tools work across two or more scenarios to enable users to sketch directly on the map, allocate land uses to land parcels (polygons), clone existing features, use slider bars to vary assumptions about the model inputs, or calculate potential of changes by area. Particular strengths in CommunityViz include the ability for scenarios to be presented within the GIS side by side on the screen (Bishop et al. 2013) as shown in Fig. 5.7 and the ease with which this data held in GIS (2D) can be linked to the flythroughs (3D) seen in Fig. 5.8. CommunityViz has the functionality to display simultaneous information in 2D GIS and in 3D models using the Scenario 360 extension. The 2D and 3D displays are linked so that data can be edited and reviewed on the fly.

Additional planning decisions can be explored using the suite of *decision* extensions. Decision extensions include the Scenario 360 Common Impact wizard which facilitates the ability to automatically calculate impacts for every aspect of planning development from population change to revenue, environment, recreation, demographics and transportation based on data entered by the GIS expert via wizards. The custom impact wizard allows for many geometric algorithms to be built such as features in a location, amounts per feature attribute such as the volume of water needed to fill a winter storage reservoir. Additional extensions exist for the Land Use Designer which facilitates analysis based on alternative land use plans which can be adapted with the click of a mouse, the Suitability Wizard which has sliders to dynamically change the weighting of factors included in surface calculations, and TimeScope which provides visual results on assumptions set to show incremental landscape changes year by year.

Scenarios and analyses created within CommunityViz using these extensions are automatically linked to a 3D extension (Scenario 360) and dynamic charts (Fig. 5.16) within the *visualise* extension subset. Data and scenarios can also be linked to ESRI ArcScene dynamically, and exported for use with Google Earth^{TM} or ArcGIS Explorer. At the time of the study the *presentation* extensions were simple text and .jpeg image output to an HTML page. Since then, new CommunityViz presentation extensions take advantage of ESRI's ArcGIS Publisher and ArcReader extensions to share the Scenario 360 analyses with clients and partners in a more interactive manner.

While the case study set out to explore all of the functions of the CommunityViz software, due to constraints put in place by the NRT there was only sufficient time to explore the Scenario 360 Analysis and 3D tools which CommunityViz offers; there was insufficient time to fully evaluate the Decision and Presentation tools.

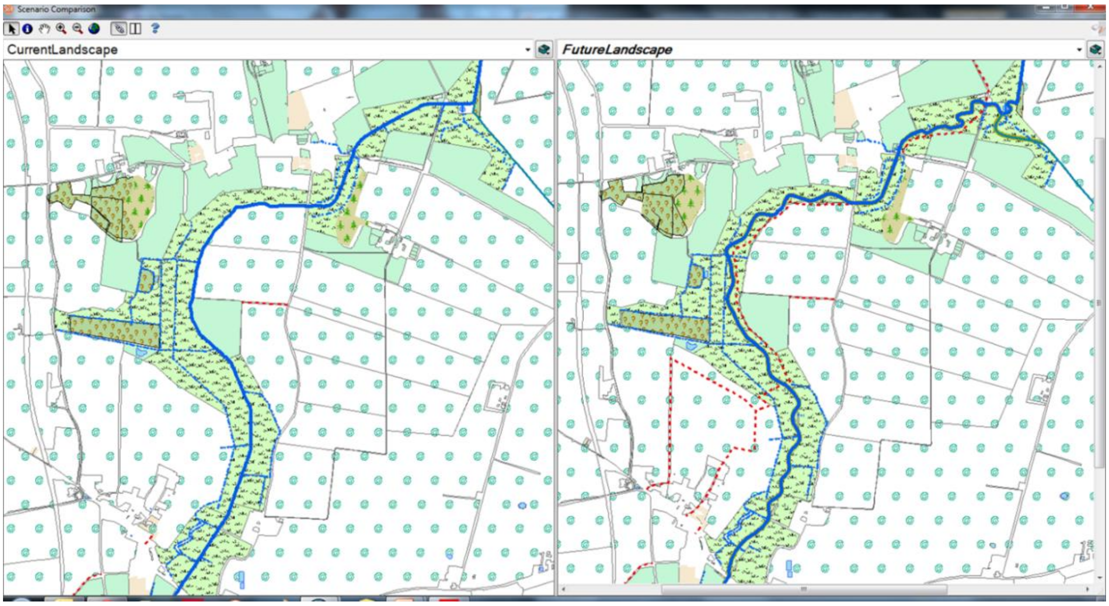


Fig. 5.7 CommunityViz - side by side scenario comparison

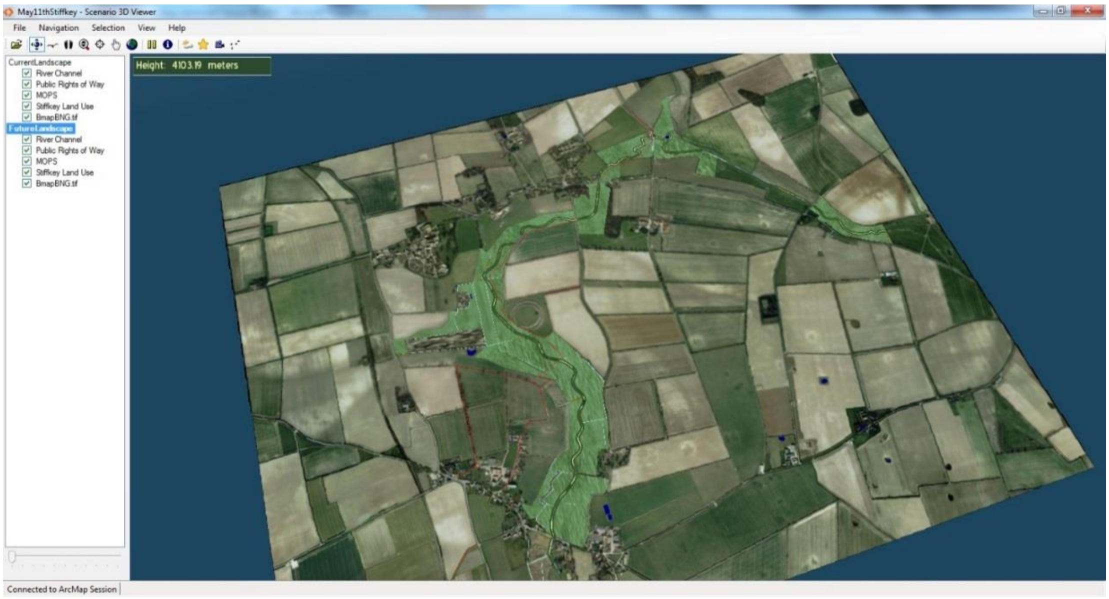


Fig. 5.8 CommunityViz Scenario 3D showing the 'future' re-meandered river and surrounding land use

5.3 Adopting a climate change visioning framework for future catchment management planning

Engaging communities as part of the planning process reflects the paradigm shift in bottom up decision making as evidenced by Lange and Hehl-Lange (2010), the EU WFD and CaBA. The benefits of using visualisation frameworks are discussed in Section 2.3.1. The design of the CALP visioning process (Sheppard et al. 2011) is considered well suited to the challenges of visioning catchment changes and integrating with a real world planning process in that it is flexible, tried and tested with a range of stakeholders. This project evaluated whether the CALP climate change visioning framework could be adapted for use in a catchment management plan; and at the same time compared high tech and low tech visioning tools. The methodology used to evaluate the use of CommunityViz (high-tech) and A0 paper maps (low tech) in a real world planning process is discussed in the next section.

5.3.1 Modifications to the CALP climate change framework

The process of developing scenarios to support the Norfolk Rivers Trust in the development of the Stiffkey Catchment Management Plan began with the application of the CALP framework to the collaboration between the Norfolk Rivers Trust and the researcher. During the first step of the CALP framework it became apparent that the NRT wanted to gather feedback from catchment stakeholders on restoring the catchment using techniques already identified during the bid for the CRF. Rather than recruit stakeholders to gather feedback as to how to solve the problems in the Stiffkey catchment the NRT wished to build relationships with catchment stakeholders and seek feedback on identifying locations where river restoration techniques used successfully in other chalk catchments could be implemented to meet the WFD aims in the catchment. This required a shift away from explorative scenarios (evaluating what is possible) towards the development of normative scenarios, which aim to meet specific targets (Borjeson et al. 2006; Schroth et al. 2009). Table 5.1 demonstrates how each step in the CALP framework was interpreted with the NRT and the 9 Chalk Rivers project in the Stiffkey catchment; it is interesting to note how the CommunityViz functionality affected step 8 and 9 which supported editing at workshops.

After discussion of the framework and the responsibilities for data gathering and stakeholder recruitment the NRT agreed to use the visioning process and create two scenarios; to show the catchment as it is (degraded current); and the catchment with the changes they felt would best meet the aims of the Catchment Restoration Fund (restored future). Initial discussions and data gathering began in late 2012; on the ground development and evaluation of the visioning process was carried out within a tight timeframe of five months which meant that there was a reduction in the number of CommunityViz functions which could be evaluated. It also emerged that the NRT was intent on reducing the timeframe and the range of participants included in the process as they were under pressure to obtain the necessary permits for working in stream. The effect on the trial of the CALP framework was that the Norfolk Rivers Trust project team summarised catchment wide issues for step four (Table 5.1), which were then imported to the GIS.

Table 5.1 The application of the CALP visioning process to the Stiffkey community catchment plan

Stage 1 – Initiate the project, review the local catchment, identify local priorities and develop scenarios	1	**Mid November 2012**	UEA and NRT meet to discuss a case study; the NRT propose visioning the Stiffkey as they had poor links with the stakeholders in that region and wish to do work to improve the catchment in line with CRF funding.
	2	**Late November 2012**	Baseline GIS data on the land use and landscape features of the Stiffkey catchment was collated in preparation for scenario development.
	3	**December 2012**	GIS database used in discussions with NRT project officer and community officer about the NRT work in the Stiffkey catchment
	4	**January 2013**	Rather than a scenario development workshop a river walkover located key issues in the catchment, and contributed to the identification of four issues which could be improved with a sustainable catchment management plan. Photographs taken highlighted the problems along each reach and assisted in accurate digitising.
Stage 2 – Data generation and integration, visualisation development and review	5	**January/ February 2013**	Spatial data to support the visioning process was resourced and land use datasets upgraded after the ground truthing carried out in January. Indicators for the improvements were developing including that for sinuosity and river health.
	6	**January/ February 2013**	With the dynamic CommunityViz which interlinked with GIS and 3D there was no need for a separate step to visualise the current issues and the solutions proposed by the Norfolk Rivers Trust in map form and in 3D form.
	7	**Early March 2013**	First round of workshop sessions for stakeholders were held within the catchment. To ensure that stakeholders felt relaxed all the sessions were held in accommodation sensitive to the stakeholders surroundings.
Stage 3 – Data and visualisation refined, materials produced, community and stakeholder presentation	8	**Late March 2013**	Data gathered at stakeholder workshops was evaluated and where necessary the GIS data and visualisations modified. Due the dynamic nature of the CommunityViz software this was a relatively easy process to carry out.
	9	**April 2013**	
	10	**May 2013**	Feedback to community at launch of the Norfolk Rivers Trust River Stiffkey project (part of the 9 Chalk Rivers project).

5.3.2 Data collection and scenario generation

5.3.2.1 Creation of a GIS Database supporting the CALP process

To bid for the Catchment Restoration Fund the NRT had already identified a number of locations where improvements to the river channel or surroundings could be made via restoration projects. NRT had identified these via walkover surveys and informal gathering of local knowledge. This information was not held digitally. Table 5.2 shows the data which was included in the ESRI ArcGIS 10.1 geodatabase taken to the meetings for the third stage of the CALP framework with the NRT where their non-digital information was digitised into the database. This GIS database was required to support the next stage in development of the two normative scenarios (Step 2 of the CALP framework – see Table 5.1).

Table 5.2 GIS Data used in the visioning process for the Norfolk Rivers Trust

Date	Name	Structure	Scale	Source	Features of interest
30/11/12	OS MasterMap	Vector	Digitised at 1:10000	EDINA	Water, Roads
2/10/12	Agricultural Stewardships	Vector		Magic Portal	
2/11/12	Statutory Designations	Vector	Digitised at 1:10000	Magic Portal	
23/05/11	PROW	Vector		Norfolk County Council	
6/12/12	Land Use	Vector		Norfolk Biological Information Service (Norfolk County Council	
21/2/13	Scheduled Monuments	Vector	Digitised at 1:10000	Norfolk Historic Records (Norfolk County Council	
7/2/13	EDINA Historic Mapping	Raster		EDINA	River Channel
n/a	OS Open Data	Raster		WMS Service	
30/01/13	Fadens Map	Raster	1:500000	Map Service	
13/12/12	1948 Aerial Imagery	Raster	1:250000	Norfolk Historic Maps	
13/12/12	Tithe Maps	Raster	1:250000	Norfolk Historic Maps	
07/12/12	Google Aerial Photography	Raster	Georectified at 25:000	GoogleMaps	
14/11/12	5m Contours	Vector		Derived from landmap.co.uk 2010	

Preliminary trials of the CommunityViz 3D visualisation tool demonstrated that the level of detail required by the NRT would restrict the size of the area which could be modelled. While the geodatabase contained a range of catchment wide datasets, the decision was made to focus on the area between Walsingham and Binham/Stiffkey confluence where there were known conflicts and restoration options were less certain (Fig. 5.9). This cropped area had sufficient problems to be indicative of the overall degraded catchment. An area for future research would be the use of rasters under compression to improve the efficiency of rendering larger study areas.

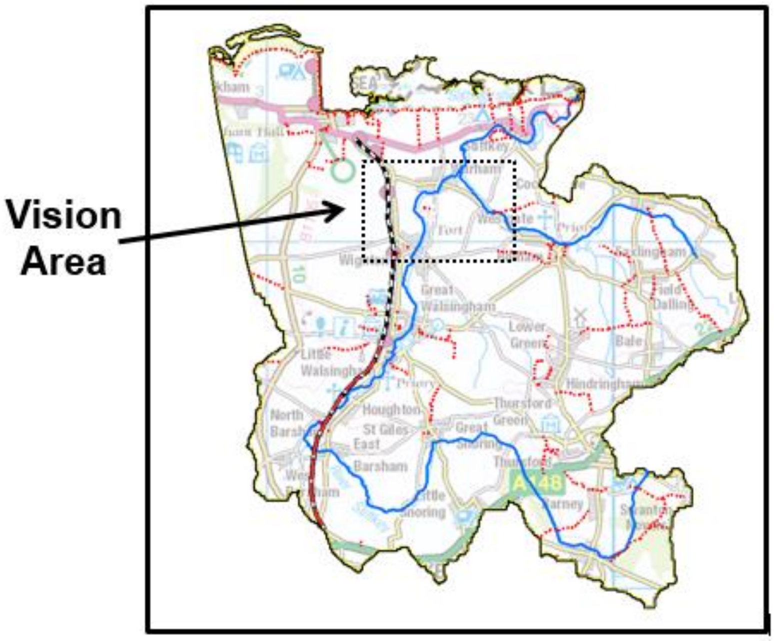


Fig. 5.9 Stiffkey Study Section (© Crown Copyright 2013. Red lines are the Public Rights of Way with the black line running North to South indicating the line of the Wells railway)

5.3.2.2 Groundtruthing GIS Geodatabase

Groundtruthing of the land use data and information provided by the NRT was carried out in January 2013 in line with the CALP framework (Table 5.1). Two members of NRT staff and the UEA researcher obtained permission from landowners to walk over from the Binham stream where it entered the study area (Fig. 5.9) north to the confluence with the Stiffkey River; then west and south along the main Stiffkey channel. During this walkover the water levels were high; photographic evidence was collected of pumps draining the higher quality agricultural land, water standing on fields unable to drain away, cattle poaching and associated urine and faecal matter. Habitat diversity was poor because of the time of year (January), although there was a distinction between fenced and unfenced sections of river in terms of biodiversity potential (Fig. 5.10). Each crossing point around the study area (roads, tracks and farm bridges) was photographed and silt movement observed. Silt pathways directly into the river were evident and scouring due to the straightened channel could also be observed. Evidence that grips (a drainage channel from the road to a ditch) in the study area were being eroded by heavy farm machinery was also photographed (Fig. 5.11).

Fig. 5.10 Looking upstream on the Stiffkey River during the walkover survey. High water levels are drowning out the pool riffle sequence in the fenced section however the difference in bank quality between the fenced and unfenced sections can be clearly seen. Poaching by cattle introduces damaging matter to the riverine system. Silt was also being introduced at this point via the bridge.

Fig. 5.11 Erosion of verge grips due to heavy machinery, only the fact that the ground was frozen prevented additional silt being washed into the ditch on the other side of the hedge

As mentioned in Section 5.2.3, issues in the chalk catchment are interlinked with the conflict between human and natural demands on the landscape which has led to its deterioration. Core solutions in the catchment were summarised by the NRT as follows; reduce silt in the main river channel, remeander stretches of the river channel, restore riparian margins, and increase recreational access. Visualisations of the current landscape in the study area were created using CommunityViz after the walk over survey in January 2013.

5.3.2.3 Creation of GIS models and development of CommunityViz scenarios

The Norfolk Rivers Trust agreed on the development of two scenarios for the Stiffkey study area ‘current degraded’ and ‘future restored’. To visualise how the solutions the NRT proposed would improve the catchment four GIS models were created; these correspond roughly to reducing silt, remeandering the channel, improving flood storage and recreation. Key factors to consider during this stage included the translation of science/ecology literature into accessible language. Although the possible course of the future river channel through the visioning study area was hypothetical, there was a need to ground the proposed solutions in evidence.

Model 1: Reducing silt in the river channel

Agricultural runoff in the catchment consists of gravel smothering silt and dissolved nutrients such as nitrates and phosphates giving temporary high concentrations that can breach water quality standards. Sediments can carry the nutrient phosphorus, some of which is reactive encouraging algae to flourish at the expense of bigger water plants indicative of a chalk stream habitat. A method to reduce the impact of silt is to trap it in wetlands which meet the specification detailed by the Mitigation of Phosphorus and Sediment (MOPS) project (Bailey et al. 2013). The sediments enter the river network via grips, roads (Fig. 5.12), field drains and overland flow into the drains, ditches and subsequently to the river.

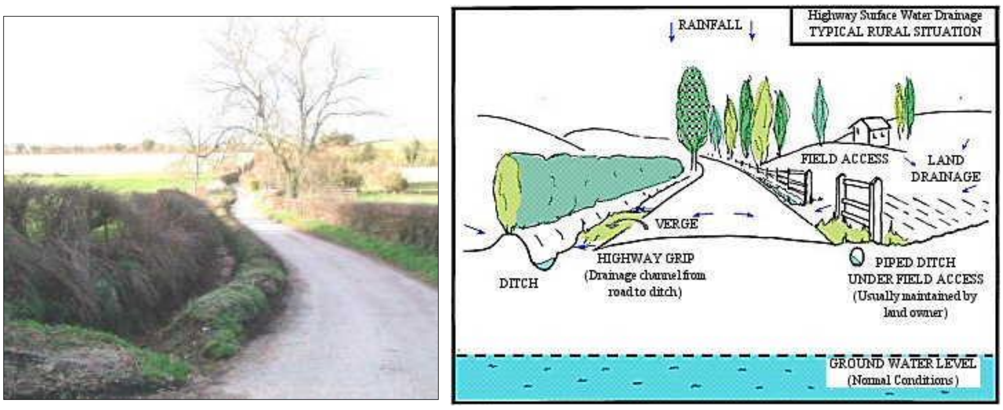


Fig. 5.12 L: Example of a grip silt entry point (Hampshire County Council 2011) common in the Stiffkey area), R: Explaination of the movement of water over drained field and roads - this water carries silt and pollutants directly into the river network, which each storm more is washed down.

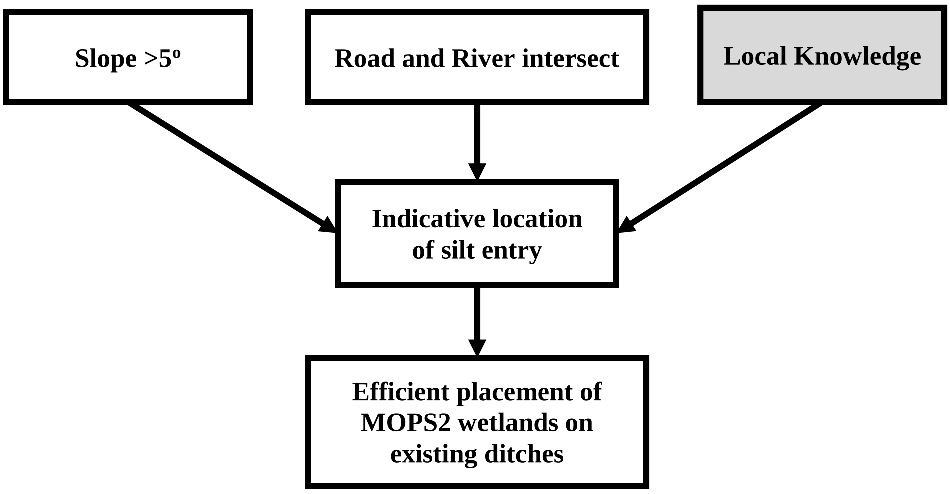


Fig. 5.13 GIS Model for automating the placement of MOPS wetland, the box shown in grey is the only one where some form of GIS processing was not required.

To determine the location of silt ingress within the scenarios known factors in silt movement were modelled (Fig. 5.13). Intersection of roads (or tracks) and water were digitised as points and overlain with a raster showing where slope > 5° which was calculated from a DEM using 3D Analyst in ArcGIS. Evidence of silt movement at these crossings was reviewed using photographs taken during the walkover survey. In the 'future' scenario MOPs wetlands were placed where the GIS indicated most runoff risk. The total area of MOPS wetlands was calculated in line with Bailey *et al* (2013) who state that to be effective 0.05% of the catchment should be in MOPS wetlands or 50 m^2 for each 10 ha.

Model 2: Increasing channel sinuosity for the health of the river

There is a positive relationship between the sinuosity of a river, river function and habitat quality (Spellman and Drinan 2001) therefore the future catchment vision increased the sinuosity of the hypothetical new channel in each river reach (currently defined as 'sections which are affected by similar issues') in the study area. Within the ArcGIS project the use of archaeological GIS data and georectified 1948 aerial imagery (Norfolk Historic Maps) confirmed the Stiffkey River had historically been straightened and moved across the floodplain.

The study section of the catchment is an area of dense archaeology preventing the main channel of the Stiffkey being returned to its 'original' course. One solution is a functional meandered river channel created within the current banks (Fig. 5.14). The hypothetical future river channel was digitised using the old aerial photography as a guide, other options included the use of high quality LIDAR data. Using aerial data was not an immediate solution; firstly the river at this stage would naturally have been braided depositing its silt load as the river lost momentum so channels were not as deeply incised into the soft alluvium, and secondly due to the length of cultivation over the old channels further erasing traces.

To model the increased sinuosity between the current (degraded) channel and the future (restored) channel the equation below was used where S is sinuosity. A straight channel will have a value of zero, and a highly sinuous channel will have a value of 1. The sinuosity value of each reach was calculated, the future sinuosity of reach (following restoration) was calculated and the percentage change calculated to display in the visualisations.

$$\boldsymbol{S = \frac{Channel\ Length}{Valley\ Length}}$$

Model 3: Increase recreational access

The current vector Public Rights of Way data were reviewed and additional routes were digitised in ArcGIS. The hypothetical new routes were informed by the location of existing farm tracks and roads, DEFRA permissive paths and local information from the NRT.

Model 4: Restoring riparian zones

The river for the most part has little riparian zone, the river is also deeply incised leaving it detached from the floodplain. The NRT officers proposed the creation of riparian habitat alongside the new channel and as part of this lower the banks for improved floodplain connectivity. Where banks could not be moved a similar effect could be created with the river placed within a stepped (or two stage) channel which proves the benefits of a wetland margin and yet offers sufficient capacity in flood events (Fig. 5.14). Additional benefits to providing a two stage channel include enhancing sediment removal and nutrient uptake during high water levels, the rough surface of the bench slows flood runoff.

Fig. 5.14 (left) diagram of a two stage ditch within a deeply incised channel or where flood banks remain due to property (right) example of menadered channel within a straightened reach with two stage bank improving flood storage

In order to reflect a potential two stage channel the future hypothetical sinuous river channel was buffered using ArcGIS in three bands of 2.5 meters to indicate the stepped ledges of wetlands either side of the river channel. This was unioned with the future land use map, and all areas which intersected were changed to wetland land use.

5.3.2.4 Visualisations for catchment management planning

Stakeholders invited to the first round of workshops proposed in the Stiffkey catchment had the option to look at possible future solutions via two tools, i) laminated A0 maps displayed on a table and ii) a desktop computer running CommunityViz with an output via a 32” screen to show the same information. Supporting information on the issues facing the Stiffkey River was displayed via one poster per ‘theme’. The desktop based CommunityViz tool had additional chart and table data about the current and future scenarios (see Fig. 5.15) and these were shown to stakeholders who took part in discussions around the computer. The same chart data were printed on the A0 maps.

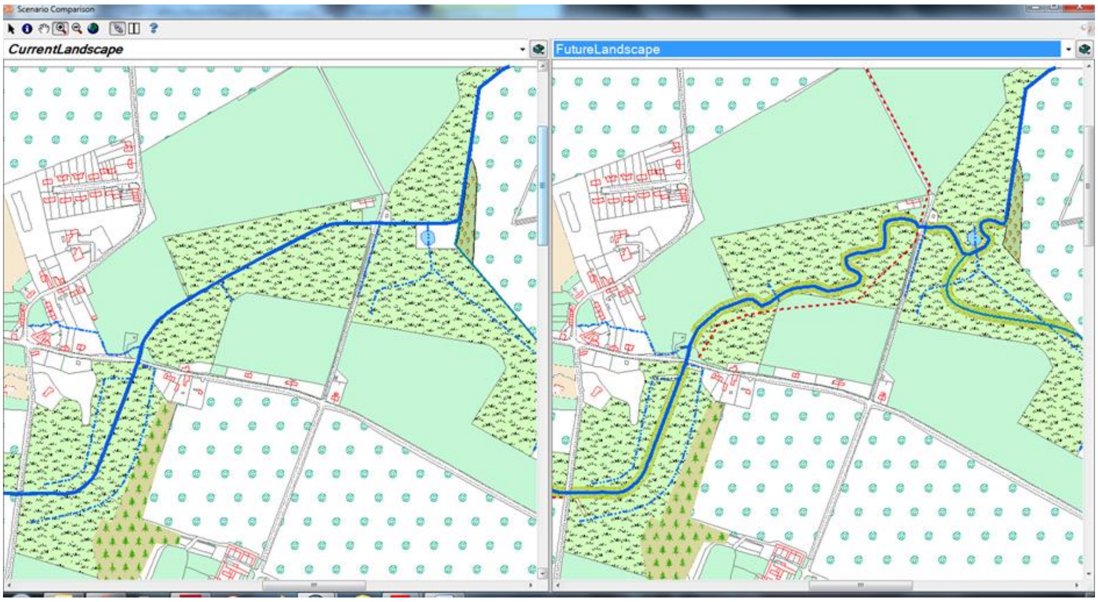


Fig. 5.15 CommunityViz - comparing the Current and Future river channel, an example of the side-by-side comparison

Despite the visualisation work being hypothetical the science behind the scenarios needed to be defensible and believable in order to gather accurate data on the feasibility of visualisation tools in catchment visioning (Sheppard 2001). The use of frameworks in visioning provides structure to the visioning process. An integral feature of the CommunityViz application is the ability to display land use change statistics in table and chart form (Fig. 5.16), during the workshops charts showed information relating to;

- the change in footpaths (%) as an indicator of catchment accessibility,
- the change in land use (%) for remeandering and new flood storage area,
- the increased sinuosity (%) reflecting the improved health of the river,
- the area of silt trapping wetlands within the catchment, and associated formula which calculated P and N trapping rates.

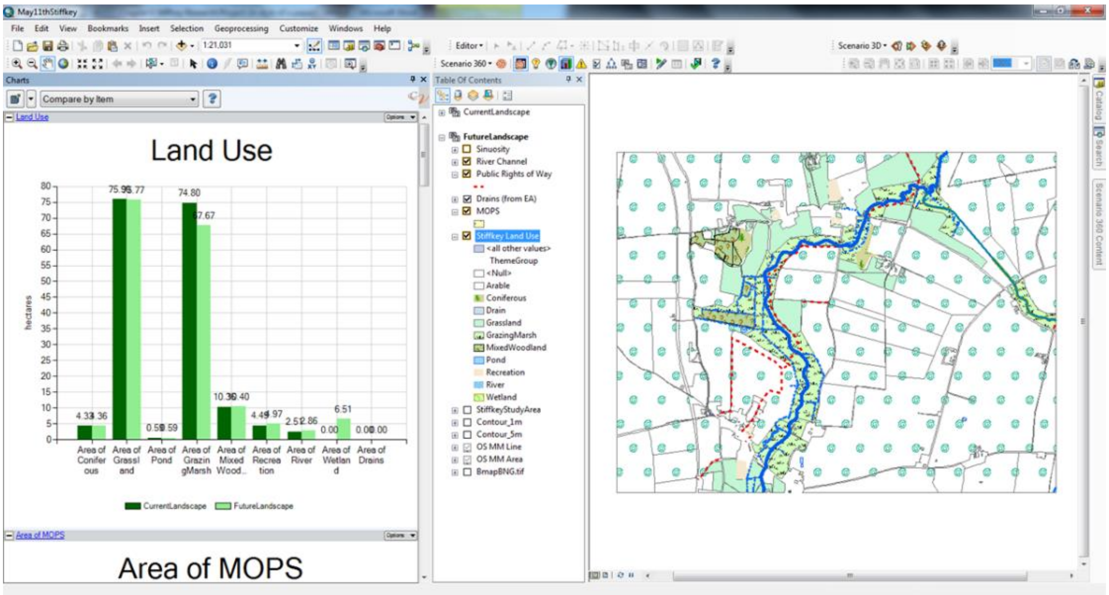


Fig. 5.16 Chart Statistics in CommunityViz – As the GIS is edited then the chart updates

The NRT use Ordnance Survey Explorer leisure maps (1:25000) as shown in Fig. 5.17 to provide a spatial reference at engagement events, the map was annotated or post it notes added when participants volunteer information. CommunityViz has been described as a lower cost alternative to many larger visioning tools, while this is in many cases true; the cost of ArcView licences and training still puts this software outside of the reach of many river trusts. To execute a more in depth evaluation of the use of visualisations to support the Catchment Based Approach to landscape management the data portrayed in the CommunityViz application was also printed from ArcGIS for use in the workshops on A0 sheets (example in Fig 5.18) to mirror the use of leisure maps in trust events.

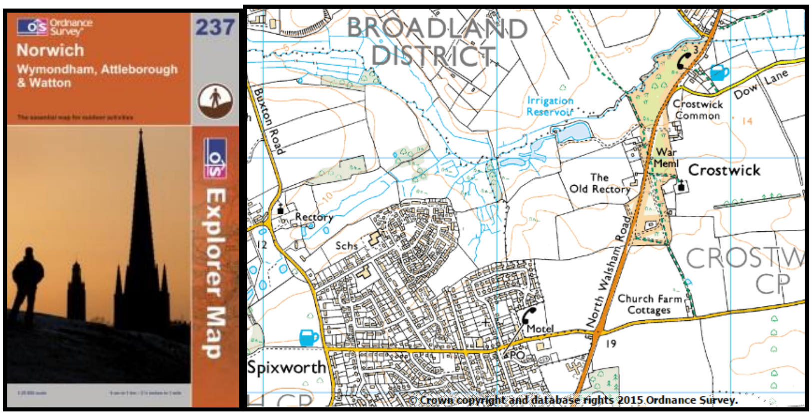


Fig. 5.17 An example of an OS Leisure Map and an example of the map within it.

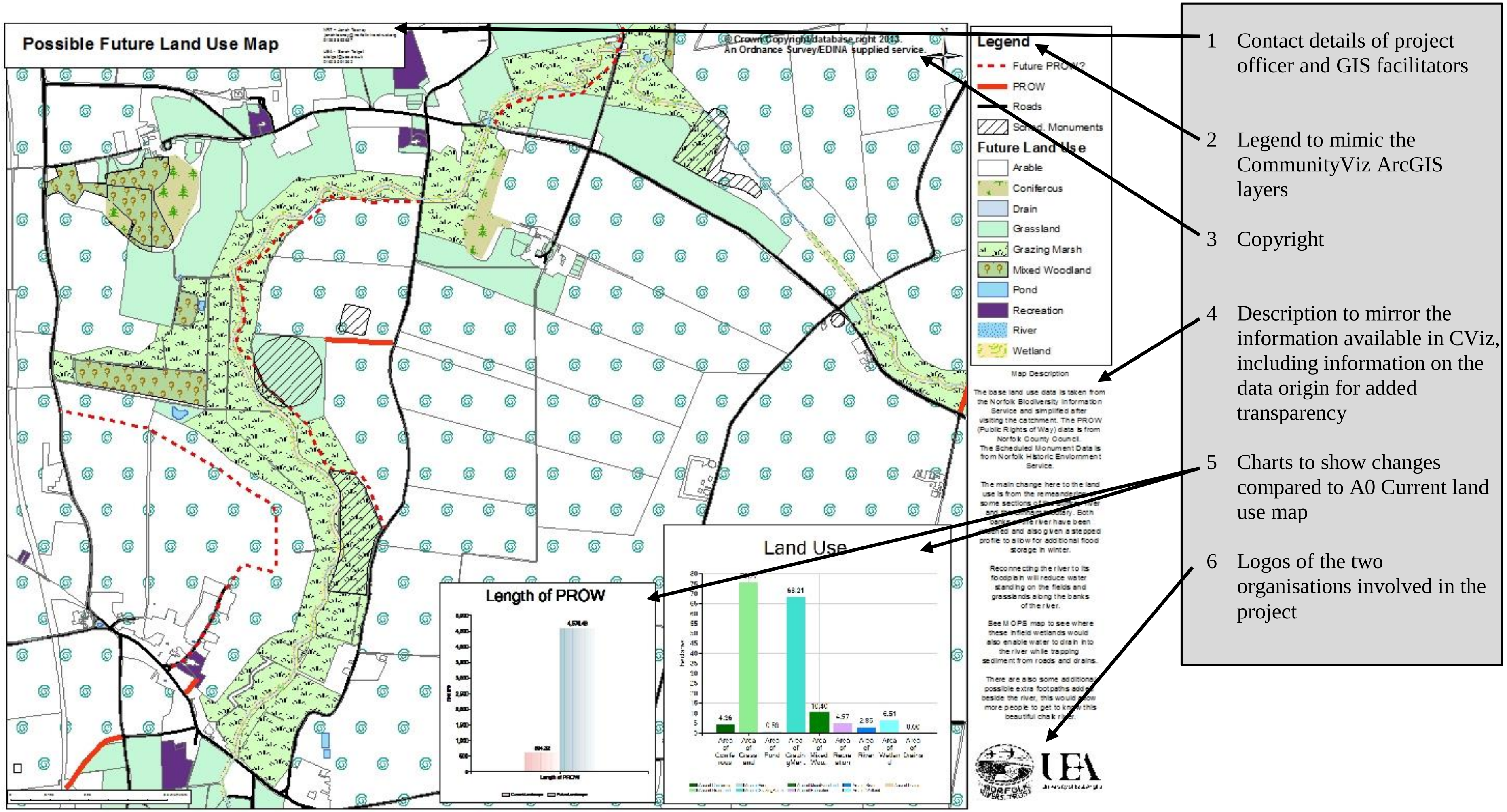


Fig. 5.18 The 'Possible Future Land Use A0 visioning tool' this had a description, copyright, research logos, scale bar and additional graphs exported from CommunityViz to show the increase in the length of PROW and the land use.

5.3.2.5 Supporting information for the visualisation process

Six A2 posters were designed to support the information shown in the visualisations and reflect the aims of the Norfolk Rivers Trust (NRT) within the catchment. The posters were displayed at the March workshop sessions and were aimed at giving contextual information to stakeholders who attended. The posters covered the four 'themes' of work identified by the NRT. Images were used to illustrate a healthy chalk river and indicate the problems that the NRT were seeking to resolve. Diagrams explaining more complex engineering elements such as the creation of a two stage channel, mitigation wetlands and case studies carried out in other areas were showcased. The poster title posed questions and statements for the workshop participants as they viewed the visualisations;

- River Health - the river is made up of deep straight channels which have less wildlife and fewer fish, how to restore the rivers' natural functions?
- Water Levels - the river has low flow for much of the summer so it cannot clean the gravel beds of silt, in winter the higher levels cause flooding, how to create a balance?
- Water Quality - this unique chalk river suffers when soil and pollutants are washed off the land, how do we keep the soil on the land to grow crops and out of the river?
- Recreation and Heritage - increased recreation opportunities benefit tourism and being outdoors improves our health – could we increase footpath and our views of the river?

One A2 poster mapped explicitly the relationship between the themes of work and the GIS data layers shown in the visualisation tools in order to provide transparency (MacFarlane et al. 2005) between the four themes of work and the data which had been used in the GIS (Table 5.3).

Table 5.3 Creating transparency for the modelling carried out on behalf of the NRT

Aim	Criteria used on the maps	Benefits
Improve Water Quality in line with Water Framework Directive	Creation of small low cost MOPS wetlands (area of wetland allows an estimate of the amount of sediment to be calculated) in existing ditches or boggy sites.	• MOPS reduce runoff into the river • MOPS can be emptied periodically and nutrient rich top-soil reused on crops
Water Volume	Removal of high banks, and creation of wetland strips by the river channel – area of land use change from grazing or grassland can be calculated.	• The reconnection of the river reduces water standing on the fields • When water levels are high the additional area allows water to sink into the groundwater enables longer abstraction periods in the summer
River Health	Restoring a more natural channel is directly linked to better river health and habitat in the channel and around it, the sinuosity of the river can be calculated.	• Improved habitat in the river will encourage fish • Opportunities to improve recreational shooting in the area
Recreation/ Heritage	Hypothetical footpaths have been created along field boundaries and the old river course.	• Increased access to the countryside improves health in the community • More routes improve tourism opportunities • Access also allows more people to gain an understanding of where our food comes from.

5.3.3 Workshop sessions

5.3.3.1 Review of visualisations with stakeholder groups

Stage 7 in the CALP framework research design was met with the running of workshops held in March 2013. Specific issues included in the workshops had potential for conflict such as lack of countryside access, runoff caused by farming practices and poor roadside ditch management contributing to silt in the river network. To maximise the constructive discussions within stakeholder groups rather than between them stakeholder groups were divided into farmers and landowners (including estate mangers as much of the catchment is tenanted), agency staff (including Natural England, Environment Agency, County Council Highways and a County Archaeologist) and the community. NRT carried out the event organising for the workshops and a snowball sampling procedure was used (Petitt et al. 2011) with key stakeholders contacted by phone or email and asked to spread the word. Posters were put up within village halls and at local shops, while social media and an advert in the local paper also raised awareness of the sessions.

Three key stakeholder groups were identified (landowners/farmers, agencies and community) and people within these sectors were invited to two hour workshops to gather feedback on the issues within the Stiffkey catchment. Separate workshops were held for each group (n = 12, n = 12, n = 14). These workshops aimed to inform the stakeholders of the problems in the Stiffkey catchment, ask for the stakeholders support in evaluating the solutions proposed by the NRT (or adding new ones) and gathering feedback on the visioning tools. Interest in the project was shown by a wider range of stakeholders than first anticipated by the NRT. The location of the workshop was considered to be important in making the stakeholder groups feel at ease and engaged with the events. Workshops for farmers and the agency staff were held in an education room (Fig. 5.20 and Fig. 5.21) on Copy's Green Farm in Wighton; a farm within the study area. Community workshops were held within a village hall. All events were held intentionally to be within sight of the river and took place at times known to be better for focus groups (farmers during the week and the community at weekends).

Workshop structure

Each workshop followed a standard format with similar structure to the format of the session (Fig.5.19) and the layout of the rooms (Fig. 5.20 and Fig. 5.21). An introductory presentation to the workshop by the NRT project officer lasted around 15 minutes. The presentation listed the aims of the NRT in the catchment and the dual purpose of the workshop in collecting data for use in the catchment management plan and for the UEA research project. Some customisation to the talk given at the start by the Norfolk Rivers Trust project officer was required for the community session to improve understanding for the stakeholders and increase success of data collection across all three groups for the (real world) Stiffkey catchment management plan.

At the end of the presentation the participants were informed that they would be shown how the NRT proposed to improve the health of the river and meet the aims of the WFD using two visualisation tools with supporting information on poster boards (see Section 5.3.2.5). Participants were asked to spend equal time at each of the two visioning tools (the CommunityViz one managed by the researcher and the A0 maps managed by the NRT Project Officer) and reminded that before leaving they would be required to complete a paper survey (see Appendix 3) on the ideas proposed by the NRT and visioned by the UEA. Workshop participants had the opportunity at this stage to ask questions to ensure that they were clear on the aims of the workshop and discuss workshop aims.

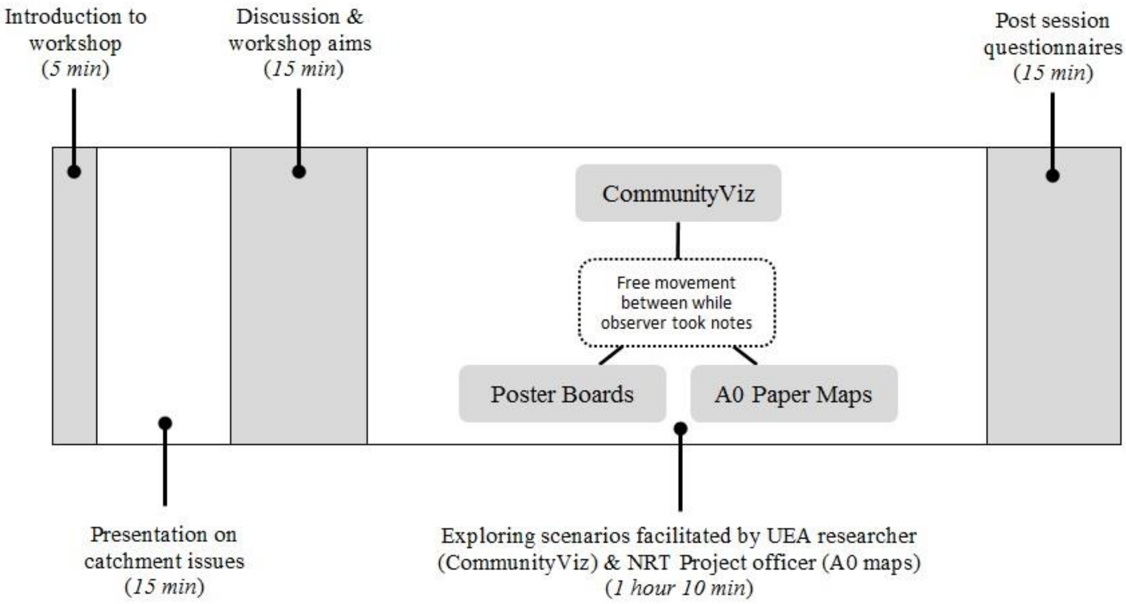


Fig.5.19 Timeline representing the approximate time allocations within the two hour workshops

While no script was used for the demonstrations the two facilitators first introduced the current catchment and show where the WFD failing measures were located. On the maps and on the computer each ‘theme’ was covered in turn - the over straight channel, the roadside grips, silt ingress points, lack of footpaths. The facilitators then switched to the future model, and showed where the NRT proposed to make changes to improve each of those problems. The facilitators used the charts to show the changes statistically between the two scenarios. The CommunityViz facilitator showed themes first in the GIS, then in the 3D allowing workshop participants to drive the model if they wanted. Efforts were made to ensure that participants spent equal time at the three visual aids; during discussions around the computer edits could be made in situ by the researcher to reflect the comments of stakeholders. An observer was present at all times recording participant interaction via note taking (see also Fig. 5.21).

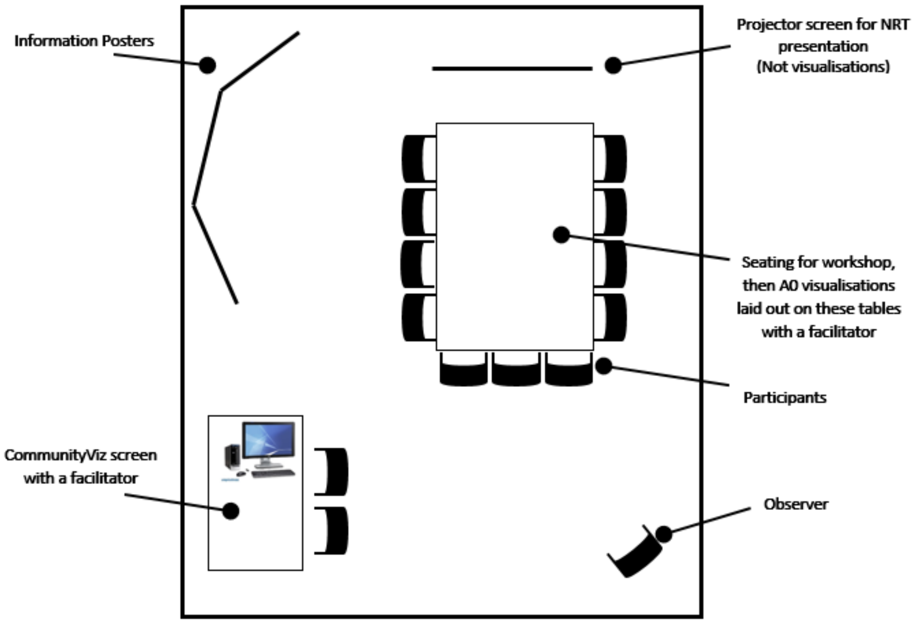


Fig. 5.20 The layout of the workshop sessions in the education room at Copys Green Farm as seen in Fig 5.21, the village hall was set up to give participants a similar experience.

Fig. 5.21 The Agency session held in the education room at Copys Green farm, Wighton. The Observer can be seen to the right while the NRT project officer is introducing the session. Supporting information is shown on poster board upper left with the desktop computer set up to the lower left.

5.3.3.2 Modifications to the scenarios following the first round of workshops

After the workshop data were analysed, and following further discussions with the Norfolk Rivers Trust some modifications were made to the 'future solutions' scenario. Within CommunityViz the 'future restored' scenario was edited to remove dangerous stretches of road from the hypothetical new footpath dataset, and remove potential MOPS wetlands where the farmers had reported the water ran clear with no silt movement and had high biodiversity values. It would have been useful for farmers to indicate where additional MOPS could be installed on ditches that were acting as a silt pathway. The agency workshop had highlighted the installation of a MOPS wetland on Wighton Common as requiring further investigation as it is a County Wildlife Site, however there are currently no species on that area which are protected.

5.3.3.3 Presentation of proposed catchment plan to wider stakeholder group

Using contact details collected from the paper based opinion surveys all participants of the original workshops were invited via email to see the changes to the proposals at the feedback session in May 2013. The CommunityViz desktop computer was set up in a corner of the hall, the facilitator demonstrated the GIS map first, then the 3D allowing participants to drive the model if they wanted (Fig. 5.22).

Learning from difficulties of seating more than three people around the smaller 19” screen used at the initial round of stakeholder workshops a 32” Samsung TV screen (Fig. 5.22) was connected to the desktop PC to enable larger groups of people to take part in demonstrations. Throughout the four hour session held in the village hall the CommunityViz desktop tool was popular with in excess of twenty people wanting to be given a tour of the area. Each tour lasted between 10-15 minutes, as in the previous workshops the locations of WFD failing measures were covered in turn - the over straight channel, the roadside grips, silt ingress points, lack of footpaths. Switching to the future model the facilitator showed where the NRT proposed to make changes to improve each of those problems. The facilitators used the chart function to show those listening to the demos an indicator of the impact of various mitigation measures.

Fig. 5.22 The larger screen used at the Community feedback event, here the researcher can be seen discussing the catchment with two members of the community, a poster board collecting responses can be seen to the right.

5.3.4 Facilitating the Qualitative and Quantitative Data Collection

Quantitative data were collected via attitude surveys at the initial stakeholder workshops, and supported by observational data collected from a bystander perspective at the stakeholder workshops. The aim of the attitude survey was twofold; i) to gauge the stakeholders opinions on the proposals for the catchment management plan, and ii) to collect data on stakeholder engagement with the visualisation tools. Attendance at the first round of consultation workshops was high with 38 people attending.

5.3.4.1 Sampling at first round of workshops – March 2013

All three of the stakeholder workshops held during March 2013 had in attendance two visualisation facilitators (the UEA researcher on the CommunityViz and the NRT Project Officer on the A0 Paper maps) as well as an observer who noted participant behaviour and comments about the visioning exercise. The observer also collected notes on the topics which participants discussed during the workshop session (Fig 5.19). An additional member of NRT staff provided support and refreshments. Both visualisation tools (A0 map and CommunityViz on a PC) had a facilitator at all times during the workshop sessions.

Alongside the qualitative observer data additional quantitative data were collected from each session using paper based opinion surveys. Questions were aimed at collecting feedback on the priority of various catchment measures and comparative data about two different forms of visualisation (CommunityViz computer models and A0 paper maps). The survey was divided into several sections. First a baseline was established with participants asked questions on their familiarity with map formats, their understanding of ecosystem services and their familiarity with technology. On behalf of the NRT the second section ascertained the priority participants gave to work in the catchment. Thirdly the participants compared the success of the two visualisations in catchment management using known criteria (Sheppard and Cizek 2009) to assess accuracy, representativeness, level of detail, framing and presentation. Finally demographic data were collected along with contact details for further stages of the framework.

5.3.4.2 Sampling at second round of workshops – May 2013

A community open house was held in May 2013 to show the final recommendations and the action plan the NRT proposed. Attendance at the community session was high with 30-45 people attending. All the stakeholders from the first round of workshops were invited along. Few did so, most likely due to the farming year. As in the original community session participants brought issues unconnected to the river to this community focused gathering leading to some confusion over the purpose of the event. The use of a display board gathered additional information from attendees on the participatory process in three ways. After talking through the visualisations attendees were first given a sticker to answer the question “Do you think a visualisation like this computer display is useful for deciding options on restoring sections of the Stiffkey River?” and secondly a post it note to explain why. Thirdly stakeholders were also asked how they thought the river could be improved, where the problems were, what they saw on their daily walks – a pin was inserted into a map of the catchment and the associated comment written on a post it note (Fig. 5.23).

Not all participated in a demo of CommunityViz (12-18 people approximately as some observed while demos were being given) although 23 people left comments about how to improve the river on the opinion boards. Following the completion of the case study and the publication of the Stiffkey plan semi-structured (or focused) interviews were carried out with two NRT staff who were involved with the project from inception to completion.

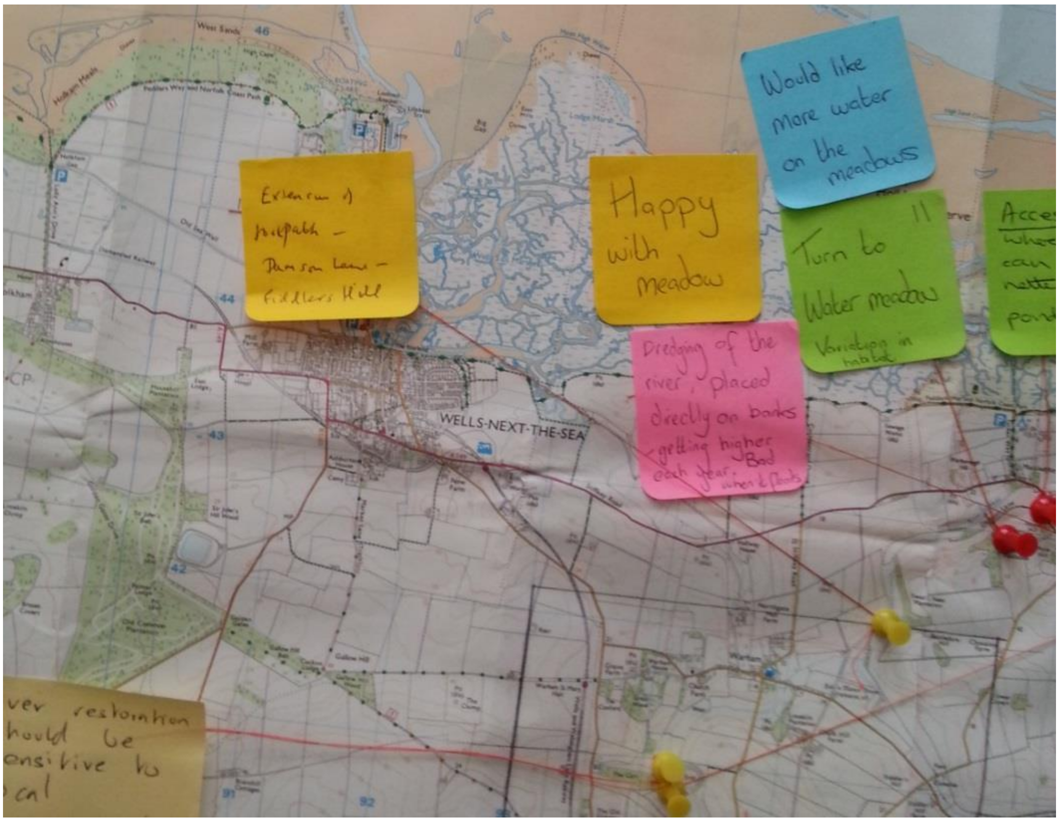


Fig. 5.23 A section of the map populated by attendees at the final stakeholder meeting. The information collected was digitised and included in the Stiffkey Catchment Management Plan.

5.3.4.3 Data Collection –Dialogue with Norfolk Rivers Trust staff – January 2014

Data were gathered on all stages of the framework during the visioning process. Following the publication of the catchment management plan for the Stiffkey a further round of data collection occurred with NRT officers. A short survey was disseminated by email to the catchment project officer for the Stiffkey and the community engagement officer. Following survey completion the officers were individually contacted by telephone to talk through their responses. Questions focused on the effects of incorporating visioning into catchment management for the Stiffkey and the wider application of visioning for catchment management. Officers were first asked to reflect on the visioning process itself in terms of;

- *Usefulness* in development of a catchment management plan,

- *How* the visioning process informed the final catchment management plan,
- *Comparison* with a more traditional stakeholder communication exercise in terms of; what was achieved overall and what information was elicited from stakeholders,
- *Promotion* of thinking at a catchment scale for NRT members and stakeholders,
- *Repeatability* what adjustment would be made regards content (what is visualised and how) and delivery (stakeholders, contact time, event planning/timing) if the visualisation process were run again..

The second section considered the wider application of visioning for catchment management should the framework be adopted by other river trusts. The officers were asked their opinions on considerations that other river trusts should be aware of prior to attempting computerised visualisation of this kind and the main barriers to implementing this type of visualisation/visioning process in catchment planning more widely. Finally the officers were asked to reflect on how this type of catchment-scale planning relates to the objectives/restrictions of the Catchment Restoration Fund with a particular focus on how this type of visioning process supports the change in scale.

5.4 Results

During the research project data were obtained using a mixed method approach. Due to data collection taking place over a number of events the results have been laid out in the following way; first a reflection on the challenges of adapting CommunityViz and the overhead of data management and time frames. Then quantitative data collected from paper base option surveys at the first round of workshops is introduced, followed by qualitative data from the workshops and the final event poster boards. Lastly additional insight from 1-2-1 interviews with NRT staff is reported.

5.4.1 Adaptation of CommunityViz for use within the Catchment Planning Process

The installation of CommunityViz was not straightforward with the software initially failing to run. This was primarily caused by data files being outside of the C:\ root drive on the desktop computer. This is indicative of a legacy system as the C:\ of modern computers is often blocked by IT administrators; the software should be able to cope with the data stored on network drives. Additional problems were encountered with incorrect versions of DirectX controls. Failure of CommunityViz to render the whole catchment led to a reduction in the area which could be evaluated for the catchment management plan. Without further investigation it is hard to know whether the issues with visioning the whole of the Stiffkey catchment were due to CommunityViz, ArcGIS, the scale of the data imported, the rendering to the 3D tool or the desktop PC used.

Development of the four models was done using ArcGIS 10.1 due to the complex processing required. Importing data to the CommunityViz project was relatively straightforward for an advanced GIS facilitator. Once data is in a CommunityViz project failure to edit spatial data using the CommunityViz editing tools erases the fields which determine scenario variables.

CommunityViz includes an extension with the functionality to publish (but not edit) scenarios to web pages. During the first round of stakeholder workshops participants were asked whether they would like to see the data online so that they could share it with other members of the community. Following a positive response initial evaluation of the CommunityViz Presentation web tool showed a lack of interactivity in the webpages the software auto generated. It would have been beneficial to explore some means by which the finished visualisation could have been published online.

5.4.2 Evaluating stakeholder understanding of technology

Stakeholder attendance across the first round of two hour workshop sessions in March 2013 was good (38 attendees across three sessions); prior to leaving all participants were asked to complete the paper survey (87% completion rate). Of the 34 completed surveys 33.3% were women and 66.6% men. The age range was top heavy with only 5 attendees aged 21 – 35 and 29 attendees between the ages of 41 and over 61 (Table 5.4). The agency group had the greatest spread across age groups. Informed by the VesAR study (Chapter 4) the age variable was considered likely to have an impact on the user interaction with the technology. Perhaps due to the sample size no statistical significance between age and IT Literacy or age and visualisation choice could be determined.

Table 5.4 Age groupings across the three different stakeholder groups

Age group	21-25	31-35	36-40	41-60	61+
Landowners/farmers	1	0	0	4	3
Agencies	0	2	1	8	1
Communities	0	1	0	2	11
Total	1	3	1	14	15

Of the completed surveys 53% had previously heard of ecosystem services and 50% the term nature's benefits. When asked to explain what they understood by the term 'ecosystem services' only 41% were able to give an answer which indicated understanding of the term. A greater proportion of farmers and agency staff were familiar with the term ecosystem services than those in the community group; the farmer group (75%), the agency group (50%) and the community group having least (14.3%) familiarity with the term ecosystem services. All except two workshop participants left the workshops knowing more about the location of ecosystem services in the Stiffkey study area and about how they might change in the future. Participants varied in their day to day use of technology outside of the workshops (Table 5.5), there was more variation in the levels of email familiarity and stakeholders' familiarity with online mapping and the use of paper maps. Access to IT was high with 100% computer ownership in the farmer and agency groups and 93% in the community group.

Table 5.5 Assessing the technological background of the stakeholders who attended the participation events Values in brackets form the variable IT Literacy

		Farmer (%)	Agency (%)	Community (%)
Do you own a Smart Phone?	No (0)	25	75	57.1
	Yes (1)	75	25	42.9
Do you own a computer or laptop?	No (0)	0	0	7.1
	Yes (1)	100	100	92.9
Are you comfortable with email?	No (0)	0	0	7.1
	Slightly (1)	0	0	0
	Moderately (2)	25	0	14.3
	Very (3)	75	100	78.6
Are you comfortable with online maps?	No (0)	0	0	7.1
	Slightly (1)	12.5	0	7.1
	Moderately (2)	12.5	25	35.7
	Very (3)	75	75	50
Are you comfortable reading and using paper maps?	No (0)	0	0	0
	Slightly (1)	0	0	7.1
	Moderately (2)	12.5	0	14.3
	Very (3)	87.5	100	78.6

To evaluate impact of IT literacy on the tool preference an additional variable was created. Variables of owning a smartphone (no = 0, yes = 1), laptop/PC (no = 0, yes = 1) and email familiarity (no = 0, slightly = 1, moderate = 2, very = 3) were grouped into IT Literacy – all which were assessed to provide a baseline for any skew in choice for the two tools. Table 5.6 shows the distribution across the workshops of IT literacy. Overall the community group had the lowest score and the greatest deviation from the mean reflecting the wider range of stakeholders at this workshop, the farmers were the most IT literate, with the agency group slightly less literate.

Table 5.6 IT Literacy across stakeholder groups

	Mean	Std. Deviation
Farmer Session	4.5	.76
Advisory Session	4.3	.45
Community Session	4.0	1.36
Average	4.2	.98

5.4.3 Stakeholder views on the future of the Stiffkey catchment

The workshop participants were asked their opinion via the paper survey whether the Stiffkey catchment would benefit from changes in land use and responses are shown in Table 5.7. No group strongly disagreed that the changes would be beneficial. In all three groups there was some disagreement that the land use changes would be beneficial. The farmer/landowner group had the highest percentage of attendees with a tendency to disagree that land use change would be beneficial although more (double that) felt that there would be benefits. The agency group tended to agree with the changes being beneficial, the community group had felt most strongly that a change of land use would be beneficial.

Table 5.7 Would the Stiffkey Catchment benefit from a change in land use? Results by stakeholder group

	Disagree Strongly %	Tend to Disagree %	Tend to Agree %	Agree Strongly %
Farmer Session	0	25	50	25
Agency Session	0	8.3	83.3	8.3
Community Session	0	8.3	66.7	25

The paper survey questioned stakeholders in order to provide feedback to the NRT on the priority that stakeholders gave to work within the Stiffkey catchment. Results indicated unanimous agreement across all three workshop sessions that priority should be given to the reduction and mitigation of silt runoff into the river network. Mitigation of flooding and the improvement of habitat were evaluated as being equally important with slight differences in priority between the famer and agency group. Improving access to the river was the lowest priority for all groups although highest in the community group.

Information presented to stakeholders at the start of the March workshops was consistently the same with minor variations in language. Despite this there were some distinctions in the discussion topics which were observed by the bystander researcher (Table 5.8) below.

Table 5.8 Summary of the main dialogs held during the stakeholder group meetings, showing that while the information given to each group was similar the discussions were quite different

	Observations of the group discussions
Landowners/farmers	• Proposed future of the river and the land practices, • Attence at the session of the Catchment Sensitive Farming officer facilitated immediate answers to questions on funding of mitigation measures
Agencies	• The benefits for example of a wetland to buffer water levels • The remeandering to improve the rivers function of cleaning the gravel beds and reducing dredging costs.
Communities	• The potential of recreational access, • Wildlife and concerns about areas which are at risk of floods

This observational data supports the NRT section of the survey which collated data on the restoration priorities the stakeholders felt the NRT should focus on. During discussions in all of the three workshop sessions the issue which was consistently highlighted as a priority was to reduce the quantity and impact of silt from the farmland and roads entering the river by redesigning roadside ditches, putting in passing places to prevent the verges being eroded and utilising the wetland silt traps. Mitigation of flooding and the improvement of habitat were evaluated as being equally important with minimal differences between stakeholder sessions. The only clear area of different priority came with the community group, where participants spoke more about the recreation aspects and the lack of footpaths than either of the other groups.

5.4.4 Stakeholder views on the visualisations

Quantitative data from the first round of stakeholder workshops

To assess the comparative value of the two tools in the current and future visualisations (Fig. 5.7, Fig. 5.8, Fig. 5.15 and Fig 5.18) participants were asked to report on a five point Likert scale the value of statements which matched known criteria for assessing landscape visualisations. These criteria included accuracy, representativeness, framing and presentation (Sheppard and Cizek 2009). Small multiple models are a means by which to show multiple variables highlighting what the data says rather than how the chart works, Fig. 5.24 uses a small multiples model (after Tufte 1990) to show the participant ratings of the visualisation tools in supporting various elements of the workshop.

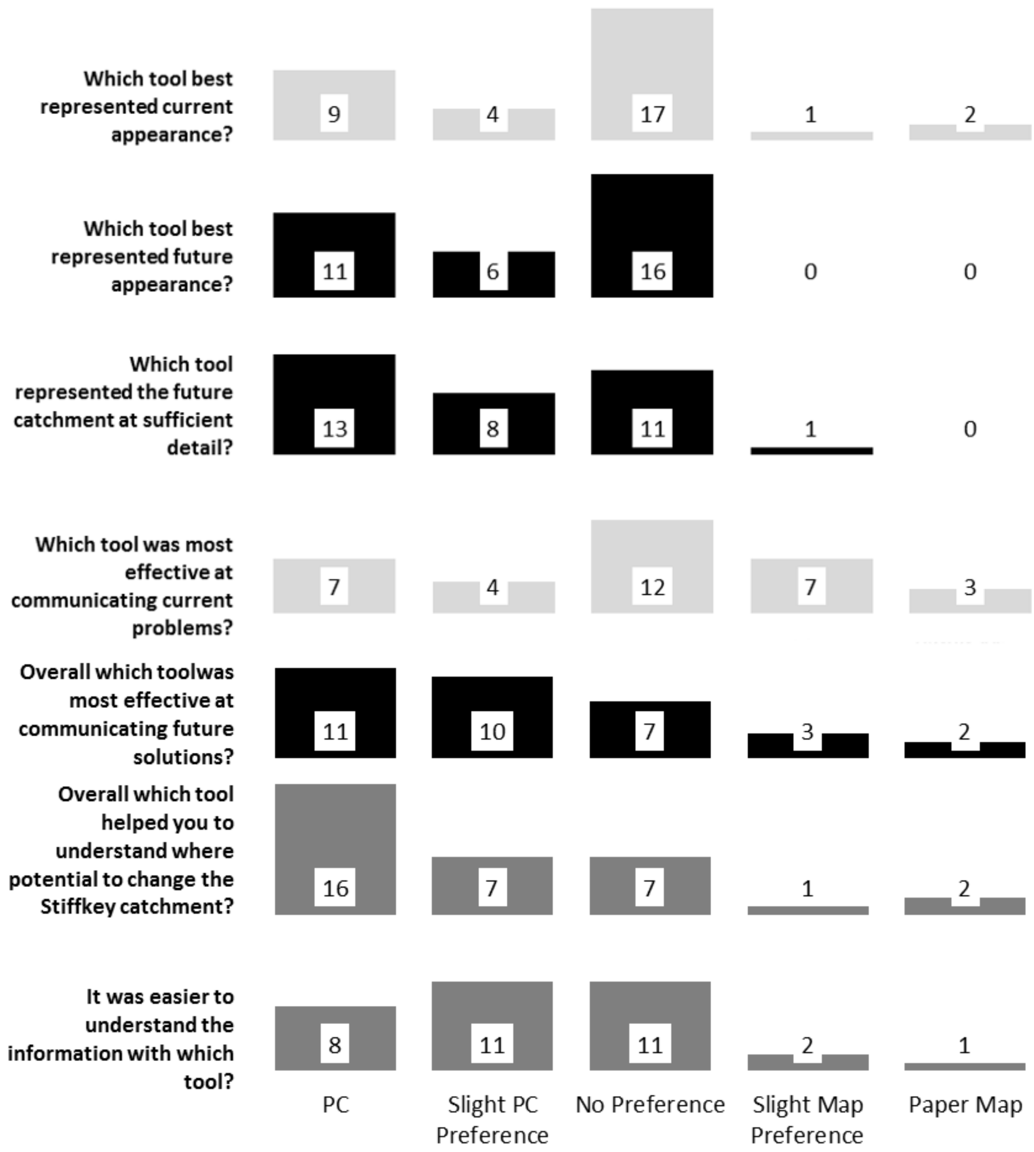


Fig. 5.24 User preference on the two tools presented at the first round of workshops. Those shown in pale grey reflect questions on the current catchment, those in black the questions on the future catchment, mid grey is not specific to scenario.

Reviewing Fig. 24 there is a preference for the computer tool over the A0 map tool. There is less stated preference for the tool which representing the current appearance of the study area, a greater number of respondents preferred the computer than the map tool. Respondents also had little preference for which tool was most effective for communicating current problems with a slight preference for the computer. Respondents either had no preference or opted to prefer the computer for representing the future appearance of the study area. It was seen to be easier to understand the information presented using the map tool although most had no clear preference. The most popular use for the computer tool over the map tool was in understanding the potential to change the Stiffkey and its catchment landscape.

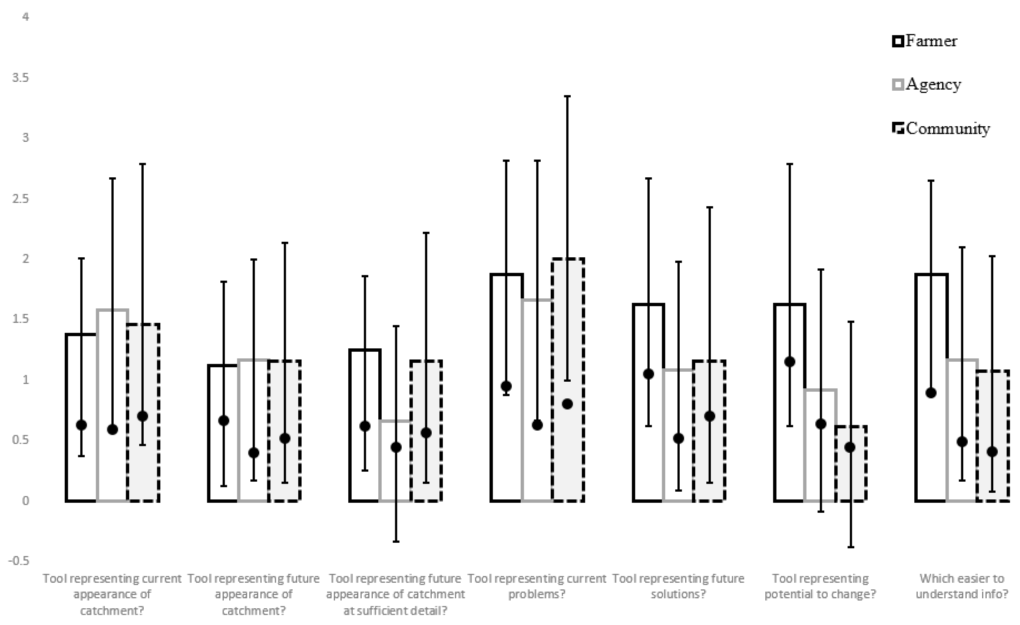


Fig. 5.25 Preferences for the Computer (0) vs the paper maps (4) with black dots representing the 95% confidence level

Fig. 5.25 charts the preferences for each tool by group, results are relatively consistent indicating that there is little difference between the groups on the preference for which tool fulfilling each criteria. The greatest variation between groups is in the tool representing the future appearance where the agency group were more aligned to support the computer tool, and the tool representing the potential to change where farmers expressed less of a clear preference seeing potential in the maps as well. Table 5.9 ranks the mean of the statements visualised in Fig. 5.24 and Fig. 5.25. Of all the statements the stakeholders were asked to evaluate the greatest consensus was that the computer tool provided better understanding of the potential to change the catchment and the least consensus was for the tool which best represented the current problems in the catchment.

Table 5.9 Comparing CommunityViz with A0 paper maps, ranking evaluation statements by mean rating (after Salter et al. 2009 p. 2097) across all groups where CommunityViz = 0 and Paper Map = 4.

	Mean
Tool representing potential to change?	.97
Tool representing future appearance of catchment at sufficient detail?	1.00
Tool representing future appearance of catchment?	1.15
Tool representing future solutions?	1.24
Which easier to understand info?	1.30
Tool representing current appearance of catchment?	1.48
Tool representing current problems?	1.85

When evaluating the preferred tool overall against the user group then lack of responses impeded statistical analysis however all three groups did indicate the computer was their favourite, with a combination the next best option and the paper map the least preferred. With the farmer group being the most IT literate (Table 5.6) it is unsurprising that their preference is skewed towards technology or a combination of the two tools (Table 5.10). Within the Agency group which also had high IT

Literacy more stated a preference for the paper map tool than a combination of the two however the overall preference for the computer tool was highest. The community group had the least preference for the map tool with the greatest variation and lowest overall IT Literacy and indicated the greatest preference for the paper map tool.

Table 5.10 Cross tabulating tool preference to the stakeholder background

	Computer %	Both %	Paper Map %
Farmer/Landowners	57.1	42.9	0
Agency	75	8.3	16.7
Community	54.5	18.2	27.3
Total	63.3	20	16.7

Qualitative data from the first round of stakeholder workshops

To support the quantitative data in the paper based opinion surveys stakeholders were asked to explain their tool preference (Table 5.11). Respondents articulated statements such as "*3D is very useful with the ability to move around large catchments quickly and easily*", "*fantastic tool for exploring an overall view of the catchment and being able to focus into a specific zone*" and " *flexibility - ability to jump between representations, see relationships between different sections of river*". The paper maps were valued more for their simplicity, for the ability to engage a greater number of people around the table at the same time (due to the session setup), supporting a recognised map scale they were referred to as *"a familiar"* spatial tool.

Table 5.11 Stakeholder feedback from March workshops

Comments supporting CommunityViz as the favoured tool	
Ease of use	Better Presentation of Data
	Cohesive data approach
	Much easier to find information
	Picturing features in landscape
	It is the ability to move around large catchments quickly and easily
Disseminating Information	Displayed to wider audience
	Computer maps clearer, easier to see river and landscape
	Computer good for more in depth stuff
Interactivity	Ability to overlay additional layers
	Greater flexibility in moving around
	Flexibility - ability to jump between representations, see relationships between different sections of river
Scalability	Better for zooming in and out,
	The ability to move from overview maps to detail easily
	The ability to change perspective on the computer (3D)
	A fantastic tool for exploring both an overall view of the catchment and being able to focus into a specific zone

Comments from those who liked both tools	
Enhancing	Complement each other
	Paper was good for overview, it showed changes step by step and as an introduction
	Combination of computer and paper maps was very useful

Comments supporting A0 Paper Maps as the favoured tool	
Group Dialogues	Computer is focused on more 1:1 and you can get more people around a map, then you get more interaction/discussion
Familiarity	Familiarity and comfortable with maps having used them for many years, therefore I prefer them, but appreciate what can be done on a screen is quite magical
Simplicity	Simple to use

5.4.5 Observational feedback during stakeholder sessions

Observation of the workshop sessions showed a positive response to the idea of restoring sections of the River Stiffkey. Stakeholders attending the sessions accepted without debate that the 'future' course of the Stiffkey river channel was hypothetical and that the channel of the river would have to be properly surveyed and a design drawn up prior to any real change being made. Within the two hour sessions time was allocated (Fig. 19) to different elements of the workshop. Most of these were sufficient however it became evident that the time allowed for stakeholders to discuss the ideas put forward in the presentation needed to have been longer. While there were no contentious discussions and most stakeholders were positive about improving the river occasionally dominant voices used the stakeholder session as a platform for their own views.

5.4.6 Community feedback on visualisations

During the community event the computer was connected via an HDMI output to a 32" TV screen for better viewing with larger groups. Notes were taken by the GIS facilitator on the queries raised through the use of the computer. Community stakeholders wanted to understand better the cost benefit of fencing the river to prevent poaching, and the creation of wetted buffers. While many were supportive of creating a more sustainable river profile some wondered whether the benefits at a catchment scale were worth such significant changes to the floodplain. This is an element which should be explored further with CommunityViz functionality, potentially incorporating an economic evaluation of ecosystem services decision making at a catchment scale.

Several requests were made with reference to the importance of including the history of the area, suggesting that the application would benefit from a temporal element to the data shown. Residents who had lived in the village close to the river remarked how within past 40 years then river has changed; used to be less deep in certain areas and they could walk much of it with a chalk bottom whereas now it's mostly silty and muddy. The sections of river which had changed most were pointed out on the computer and had the software been set up to do so it could have recorded this data.

Due to the fluid nature of the 4 hour drop in event a three stage process was used to collect feedback about the catchment and the use of the desktop software after participants were walked through the visualisations. Attendees were handed a sticker and asked to answer the question *"Do you think a visualisation like this computer display is useful for deciding options on restoring sections of the Stiffkey River?* on a poster board with Yes/No sections. Then attendees were provided with a post it note on which to explain why they thought the visualisations were useful. The responses from the opinion board showed everyone who sat and listened to the visualisation demo felt it was useful; but the board explaining why they felt it was useful (Fig. 5.26) was not as populated. Despite that the following responses gave an indication of the positive responses to the use of visualisations for understanding changes proposed by the Norfolk River Trust on the river and its surroundings.

- ✓ Seeing the whole area
- ✓ Prompting discussion
- ✓ Visual
- ✓ Great graphics
- ✓ Predicting routes helps with planning best uses
- ✓ Seeing future opportunities

Fig. 5.26 Responses from the four hour drop in session to the question of why they thought the visualisations were useful

Lastly, attendees were asked to populate a map of the catchment with where they felt changes should occur, this was popular and used by 23 people to indicate where they had concerns about the river (Fig. 5.27). Interestingly the study area for the visualisation work concentrated only on the centre section of the catchment, those who attended the drop in session added points to the map which spanned the entire length of the river. The queries pinned to the map were diverse, and some were personal to just a few people (such as the path affected at Little Barney) however the points reflected the issues which the Norfolk Rivers Trust flagged at the start of the visioning process.

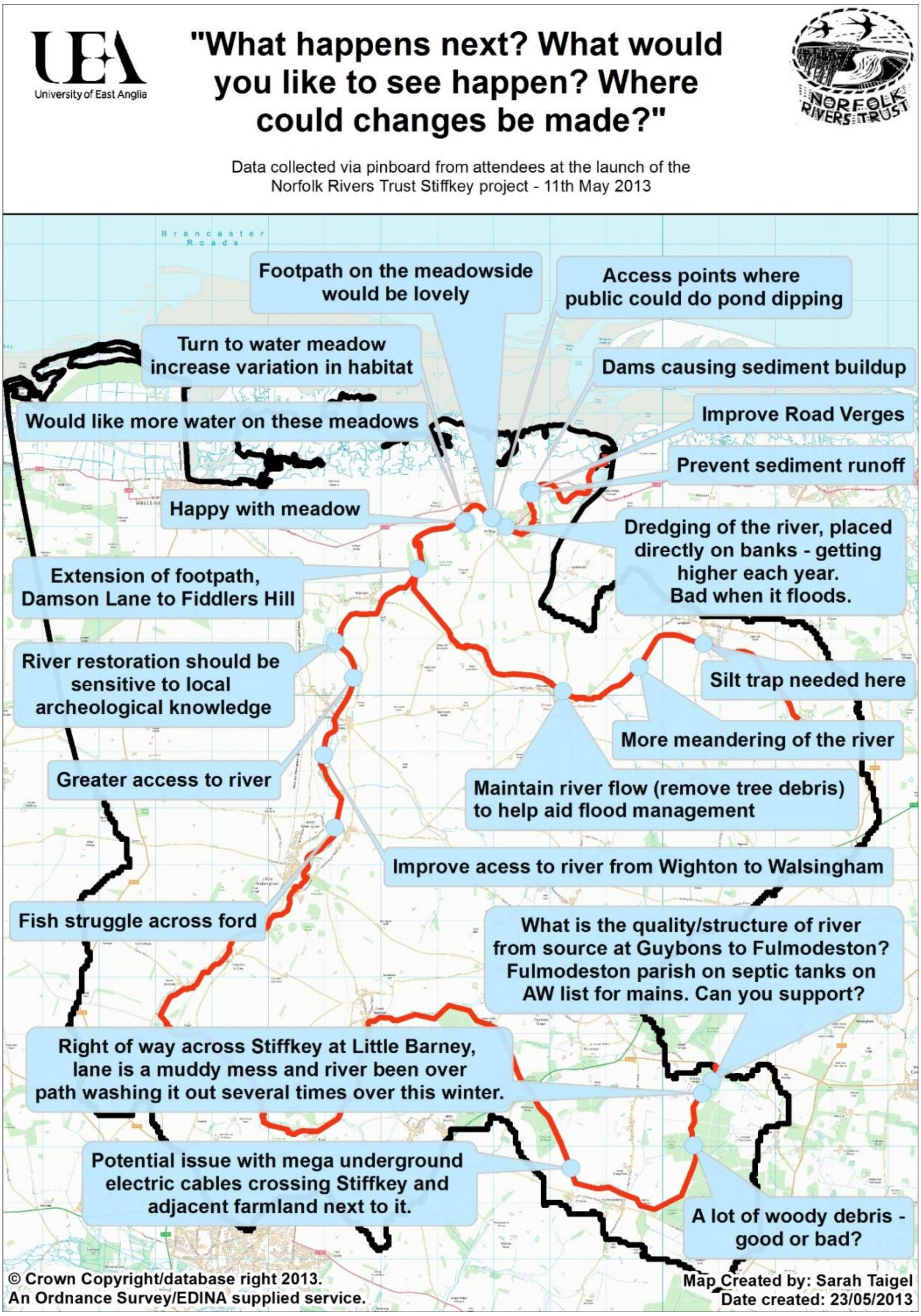


Fig. 5.27 Responses from a pin board map at the last session with the NRT and stakeholders, this was included in the Stiffkey Catchment Management Plan published by the Norfolk Rivers Trust after the visualisation exercise

5.4.7 Interview with the Norfolk Rivers Trust staff

In January 2014, eight months after the publication of the Catchment Restoration plan for the Stiffkey the catchment project officer for the Stiffkey and the community engagement officer were emailed with the aim of inviting organisational perspectives on the visioning process. Questions focused on the effects of incorporating visioning into catchment management for the Stiffkey and the wider application of visioning for catchment management.

More specific responses can be grouped under the following headings shown below *a-h*.

a) Visualisations increased awareness of a river hidden due to morphology and lack of access.

A benefit of the visualisation tool over the map was visualising the way in which the river interacts or could potentially interact with the landscape and it provided an opportunity to get a feel for the overall picture of the river. This is particularly important given the way in which the Stiffkey is mostly hidden from view with the channel incised and poor recreational access.

b) The visioning framework and visualisations are integral to working more holistically

The visualisations promoted the catchment scale way of working and encouraged an awareness of a holistic approach across the landscape and between organisations. People could explore the landscape, the locations of both causes and effects and in this respect the computer tool could be adopted by planning departments, Internal Drainage Boards, river trusts, Environment Agency, Natural England etc. A vital component of the CRF is community involvement, and also catchment scale working, and the use of visualisations within the catchment management planning process promotes both. At a smaller scale across all the workshops audiences went away appreciating that restoration is a fine art that needs to be done sensitively taking a holistic approach and realising that small changes somewhere can cause big problems elsewhere.

c) The framework resulted in a pioneering approach

This was the first opportunity on the Stiffkey whereby farmers, local people and agencies came together to talk in such detail about the river and its surrounding landscape. In terms of what was achieved overall the visioning process was far better compared to a more traditional stakeholder communication exercise for stimulating debate – gave people something to look at, so less confrontational than face to face or a phone call, and it sparked interest. While there could have been barriers presented by lack of engagement from the estate managers the workshops showed that farmers were aware of the issues raised such as silt input and in some cases accepted responsibility and wanted to find practical ways to change the situation using the advice of Catchment Sensitive Farming officer and the river trust officers.

The work which the Trust carries out is completely reliant on landowner consent, within several projects work has to some extent ground to a halt because of landowner issues with the proposals. This is one benefit of using a visualisation tool to add weight to an argument for restoration and explore with all concerned thus dispelling concerns to landowners. Or ensuring that if the landowner is unsure work does not begin wasting time and money on surveys and equipment hire. The use of proactive visioning tools therefore something that the Trust has to seriously consider if they want to continue practical work alongside landowners.

d) The well planned workshops encouraged positive relationships to form

The farmer stakeholders' workshop format worked extremely well. Being held on a local farm of which the farmer is a well-respected member of the community no doubt added to that success. Many of these issues raised during workshop sessions contributed to the catchment plan. The primary issues raised were not so much the problems in river functionality but more about cost, long term management and responsibilities for mitigation measures. This differed from the community event where feedback mostly centred on pinpointing obvious issues and how long these had been occurring.

e) The visualisations provided an improved facility to communicate accurate locations of problems

The workshop format encouraged contributions and the maps enabled participants to clearly point out where the sediment and pollution issues were occurring; **t**here was a recognition in the village which was communicated at the workshops that the river is not functioning well and there are sediment and pollution issues, some locals could pinpoint these very clearly and the length of the time this had been in effect. For a river that is quite discreet, that is to say integrated into farmland with little access this was quite useful information and has informed the Stiffkey management plan.

f) Visioning needs to be well facilitated - the success of the workshops is dependent on the quality of the supporting information given out by the facilitator.

Providing that there is input from someone who knows what they are talking about in terms of river restoration the computer tool is a simple way to get the message that short term choices in land management can cause big long term problems across the catchment. The computer tool is a visual way of indicating to stakeholders the connections along the river and over time as well, especially where impacts are downstream of the location of where the poor management is.

g) Improvements to the visioning framework

Should the NRT utilise a visioning process again in the future a combination of the large maps and on-screen visualisations would again be used. The computer processing power placed a limitation on the size of the area which could be visioned and whole catchments would be preferable, more so for landowners and farmers than community people. The trade-off between the spatial scale of the area being visioned and the length of time to prepare materials is also recognised; particularly in areas of high archaeological interest.

The project officer for the catchment suggested caution to other trusts over the necessary staff time for the preparatory work, barriers mentioned included timescales and funding. Both because of the cost of employing someone and because of the difficulties in spending on something outside of capital expenditure. The community officer and the project officer agreed that while the collaborative project was successful in meeting the aims of the NRT project the timescale was very condensed. Both officers suggested a greater lead in time to the workshops (although attendance was good) with a focus on recruiting important landowners to get some peer group positivity for restoration going beforehand.

Although the NRT took the decision to delay the inclusion of stakeholders to the second round of engagement in the framework on reflection both officers agreed an earlier dialogue with the audiences before the events would have been beneficial so that there was an introduction to the work clarifying things for local people. This decision may in part have been due to the NRT officers being less experienced in the use of visioning processes.

In addition to the stakeholders invited various hierarchies of planning departments should have be involved and information on the visioning process available through other websites such as Local Authorities and Parish Councils for wider collaboration. The outputs of the tool should have been available for people to see via the main organisations website to increase the audience and gain more feedback, although the release of future solutions would have to be carefully communicated.

h) Not all issues raised during sessions can be solved – unrealistic expectations

Issues which were raised at the meeting fell into two categories. Some could be solved but were not suitable for this forum such as problems with traffic and with poor protection of archaeological find within the floodplain. Other problems which were brought along take longer to resolve such as the perennial complaint of access issues which are difficult to reconcile as this is dependent on landowner consent.

5.5 Discussion

The use of visualisation software at a landscape scale (such as a catchment) is one means of increasing stakeholders understanding of current issues and encourages their input into the development of a more sustainable future plan. This case study set out to evaluate whether a visualisation framework (previously developed for use in climate change) could be used in conjunction with a low cost visualisation tool (CommunityViz) to support the development of a catchment management plan. The evaluation was carried out with the Norfolk Rivers Trust (NRT) within the Stiffkey catchment in Norfolk, UK in the first half of 2013. Results indicate that there is certainly potential in both the use of the parcel based software and the adaptation of an existing visualisation framework developed for climate change; however some adaptations to the process need to be made.

The discussion section will first consider two component objectives; how well Placeways CommunityViz extension to ArcGIS supported the catchment visioning; followed by a comparison between traditional A0 paper based maps and the CommunityViz 2D/3D technology. The extent to which the visioning framework could be adapted is then discussed before a summary of the lessons learnt in evaluating this type of visioning case study and the barriers to adoption.

5.5.1 Making a parcel based urban planning system fit for purpose in catchment visioning

During the trial two core components of CommunityViz software were used in the catchment planning process for the Stiffkey in Norfolk. The first component was the Scenario 360 (2D) GIS with chart functionality and side-by-side scenario viewer, and the second component was the 3D visualisation tool (Scenario 3D). Throughout this section where CommunityViz is used it relates to the combined usage of Scenario 360 and Scenario 3D. It should be noted that the person customising the CommunityViz application is an advanced GIS professional and so more able to overcome issues than a river trust practitioner. Customisation of the CommunityViz software for use in catchment visioning was done without the need for additional programming to extend functionality.

Although CommunityViz installation was straightforward small issues took up an amount of time to solve which would have been frustrating for a novice. Additional support from Placeways and high level administrator permissions on the desktop PC were required to overcome outdated legacy code in the Placeways application which for example required that hyperlinked data for the Scenario 3D tool was stored on the desktop root hard drive rather than network drives. Once the CommunityViz software was working optimally vector data from the project geodatabase where models had been created were imported into Scenario 360 using the tools provided by the Scenario 360 extension. It is here that the complexity of CommunityViz became apparent as it was it was discovered through trial and error that although data could be entered in using the default ArcGIS tools it was crucial for the development of scenarios that data were imported using the Scenario 360 editing suite of tools. It would have been clearer for the user to find that the default ArcGIS toolset was disabled when the CommunityViz extensions were enabled. Overall Scenario 360 itself was relatively straightforward to use, additional layers could be added swiftly with as many as desired becoming indicators for charts and statistics. Adapting the software for developing visualisations for the current and future scenarios required GIS proficiency in data management to prevent issues such as incorrect charting, duplicate features across scenarios or broken links; all of which are detrimental in the presentation to stakeholders.

The Scenario 360 dynamic charts (Fig. 5.16) were used during the visualisation demos in the workshops to evidence landscape change (Salter et al. 2009) and improve transparency for changes in land use proposed by the NRT in the future catchment management plan. This is a key advantage of CommunityViz over other visualisation software such as Geovisionary (Virtalis 2015) which has excellent engagement potential but fewer options to demonstrate the change in land use by area in such a dynamic way during in situ workshop events. During the workshops charting of the area of riparian grazing meadow which would be lost in creating meandered stepped channels led to discussions about the feasibility and realism of improving the environment vs traditional land management drainage practices. The chart function contributed to the stakeholder feedback that the computer offered *"better presentation of data"* a key factor in public participation events.

With the incorporation of existing land use datasets the adaptation of CommunityViz for the catchment planning process supported the discussion by stakeholders of the trade-offs in the creation of a multifunctional and sustainable future river catchment. The application of Scenario 360 statistics alongside the visualisation elements was of interest to the stakeholders, particularly when indicators included were financial such as the real world costs of implementing small drainage wetlands and recovering expensive nitrogen fertiliser for reuse (Wissen et al. 2008). Potential also exists to include the output from land use management applications, diffuse pollution risk mapping such as SciMap (SciMap 2015), or GIS datasets created by precision farming techniques. In catchments of historic mineral extraction other datasets which might be included relate to the location of minewater drainage points from mines. While the Stiffkey catchment was within a single administrative boundary, many larger river catchments cross administrative boundaries, so there is potential of CommunityViz to act as a communication portal.

There are some technological issues with visioning at a landscape scale using CommunityViz on a portable desktop computer, and so to some degree the use of CommunityViz software is constrained by the reliability of the ArcGIS platform on which it sits. CommunityViz supports several options to visualise data held in Scenario 360 to 3D. These include Google Earth, ESRI ArcGlobe and the CommunityViz Scenario 3D extension. Adapting CommunityViz for showing 3D high resolution data using Scenario 3D at the scale at which the NRT wanted to display the catchment reduced the size of the area which could be visioned. This is recognised trade off in the development of visualisations (Appleton et al. 2002) where the level of detail increases the amount of processing power required. With more time and experience a combination of layers to provide more detailed land use coverage in areas of change with a lower resolution in areas of no change might provide a workable compromise.

The use of Scenario 360 was reported by the stakeholders and the NRT officers as valuable – with the ability to *"jump between representations, see relationships between different sections of river"*; and the side-by-side scenario comparison tool within the 2D GIS being adaptable and easy to use. The Scenario 360 component of CommunityViz was more reliable with greater functionality in comparison to the Scenario 3D extension which relies upon the ESRI ArcGlobe extension but does not have the full range of ESRI features. When compared to more expensive visioning software such as Geovisionary the Scenario 3D tool was lacking in detail, often slow to respond and had reduced symbology making it less realistic for visualisations. This reduction is realism is not necessarily a bad thing, previous research has also shown how increasing detail can result in disengagement by participants in the visioning process (Appleton and Lovett 2005). However results from the Stiffkey study show that the stakeholders felt that the computers had sufficient detail to communicate a future landscape and so the reduced functionality of the 3D Scenario extension was not considered detrimental to the overall catchment visioning exercise.

The final phase of the framework was the release of material to stakeholders who had attended sessions and wanted to share details of the project to the wider community. Given the changes to the river channel shown in the visualisations were hypothetical the NRT officers opted not to release these to the internet where misunderstanding and negative feedback might be created. Stakeholders were informed of their contributions to the planning of a future catchment using the NRT published Catchment Management Plan; available both in hard copy and as a downloadable file from the NRT website. It would have been of great interest to many to see the future catchment plan via an internet portal however the NRT did not have the resources to manage this platform and instead opted for the traditional paper communication option.

Further work

Within its native use of decision making in residential planning CommunityViz has sizable potential for a more explorative application in catchment planning. While Scenario 360 and 3D Scenario tools were adapted to the visioning process further areas of research can be identified. The first is the creation of a more interactive 'What If?' Type catchment scale visualisation tool using the CommunityViz Common Impact, Land Use Designer and Suitability Wizard extensions to explore the growth and development of a spatial area. The time taken to prepare the data and the adaption of the CommunityViz to a more environmental application should not be underestimated. The time it would have taken to parameterise rural and environmental factors as required by the software was found to be outside the scope of this study. The knowledge and understanding needed to build robust indicators was also in excess of the time available and was be considered within the context of this project case study to be 'a sledgehammer looking for the nut' (Von Haaren and Warren-Kretzschmar 2006 p. 98). There is clearly great potential for adapting Scenario 360 to explore economic change within catchment scenarios, from full Payments for Ecosystem services (PES) schemes to the cost of mitigation measures such as fencing for stock control in more detail. It is unclear how easy it would be however to access this potential given the need to set up transparent calculation of costs, the interaction between grant schemes and the economics of ecosystem services.

Another area for further work in the adaptation of CommunityViz is the inclusion of stakeholders using web tools to allow both participation and dissemination of visualisations. At the time of the case study CommunityViz software facilitated the dissemination of visions created from a static cut of the data and published as HTML webpages. A trial of the export function created webpages which were basic with poor functionality. Since this case study Placeways has upgraded the functionality of the web export tool to show the details in 2D web pages or in 3D through Google Earth as well as exploring options through ESRI platform for disseminating spatial data. It would be worth evaluating the use of CommunityViz within the CALP framework over a longer period of time to explore the full potential of the presentation extensions.

5.5.2 Comparison of interactive high tech and static low tech tools

This research evaluated the most suitable type of visualisation tool for use within a catchment planning process by comparing a high tech solution (CommunityViz) with a low tech solution (A0 Paper Map) traditionally used by the NRT at stakeholder groups. During the first round of workshops stakeholders were asked to spend equal time at the two visualisation tools and then complete a paper based opinion survey comparing the two tools against known criteria for landscape visualisations. Although the results of the paper based opinion study showed a greater number of respondents indicated an overall preference for the computer than the A0 paper tool there were some elements of the catchment visioning where one tool was stronger than the other.

Observations from the stakeholder sessions revealed that the maps were a vital element of all the workshops, with stakeholders using them to find details of small drains, unmarked forded river crossings, habitat monitoring points and potential silt entry points. The paper maps were described positively as providing an overview of the entire area. This preference may have been due to an overhead of facilitation required for the visualisations on the computer; facilitators had to move the 3D vision to the scale and location on request whereby the stakeholders could immediately interact with the large paper maps. In addition the preference may have been influenced by the relatively small computer screen compared to the A0 maps. The paper maps were reported as being valued for their simplicity, for the ability to engage a greater number of people around the table at the same time (possibly due to the session setup), supporting a recognised map scale, and acting as a familiar spatial tool to many; particularly at the community session.

When asked respondents either had no preference or favoured the computer for representing the future appearance of the study area. The computer tool was preferred for multiple reasons; particularly to switch between scenarios and discuss the possible future. Comments on the dynamic nature of the CommunityViz app included mention of the ability to operate at a multitude of scales, compare data side by side, move around the landscape to different viewpoints and look at historic data with the click of a mouse. In support of this were stakeholder statements such as "*3D is very useful with the* *ability to move around large catchments quickly and easily*", "*fantastic tool for exploring an overall view of the catchment and being able to focus into a specific zone*" and " *flexibility - ability to jump between representations, see relationships between different sections of river*". The CommunityViz statistics tool could not be replicated on the paper maps, and this an element where there was a clear advantage to the computer tool. Additional justifications that participants gave for preferring the computer tool such as scalability and interactivity are difficult to replicate in a static paper map tool. Some of the justifications provided by those preferring the paper maps could be mitigated for by improved facilitation of the computer models, enhanced design reflecting a simple approach and larger screens for better group discussions such as in the virtual reality theatre at the UEA in Norwich. Those who liked both tools highlighted the way that they complemented each other.

There are a number of benefits to the use of computer based visualisations in engaging catchment stakeholders with the process of future catchment management plans. During the workshops discussions were held around both the computer and the maps, and attendees were observed reading the posters which provided supportive information highlighting the benefits to the room layout. Reflecting on quantitative feedback from the stakeholder workshops advantages of the computer based tool over the paper maps can be summarised by ease of use, information dissemination, interactivity, and scalability. There is a conceptualising overhead needed to fully engage with the computer map tools; and as shown by the results there is a degree of alignment between the IT literacy and tool preference. While the sample size prevented statistically significant conclusions to be determined the range in variation of feedback indicates that visioning at a catchment scale should use both abstract and realistic visualisations tools (Wissen Hayek 2011) to appeal to all sectors of the population. This is supported by the NRT officers who agreed that they would use both together should they run a similar scale project again due to the combination of CommunityViz computer tool and the A0 paper map tool supporting group discussions. Audiences who looked at the CommunityViz tool were able to discuss in more detail wider catchment issues rather than just pinpointing single issues which seemed to be a factor in the paper maps. The level of detail in the computer 3D visualisations was such that it enabled stakeholders to acquire their bearings but ensured relatively few queries were about the minor details of the landscape.

As seen above feedback from stakeholders on their interactions with the two visioning tools was overall positive. To explore the potential for visualisations to be incorporated within the catchment planning process the two tools were evaluated by a series of statements and expressing a preference on a five point Likert scale within the post workshop survey. The criteria of accuracy, visual clarity, interest, legitimacy, framing and presentation proposed by Sheppard (2005) to evaluate visualisations formed the basis of the statements in the paper based opinion survey completed by stakeholders. Answers resulted in a more detailed understanding as to where the two visioning tools were most effective in various elements of the planning process, Fig. 5.24 and Fig. 5.25 and Table 5.9 together build up a picture of the stakeholder preferences for the two tools.

CommunityViz was the preferred tool for all seven of the statements which stakeholders were asked to evaluate. The greatest consensus of opinion was that CommunityViz was considered most suitable for representing the potential of a landscape to change. This was possibly due to the scenario comparison tool which is inherent to CommunityViz and not necessarily a reflection of all visualisation software. The tool representing current problems in the area had the least consensus. Of those who did indicate a preference for the tool showing current problems then it was distributed evenly across the two tools, with the greater number of those expressing a preference for the CommunityViz tool expressing a strong preference and the greater number of those indicating a preference for the maps indicating a moderate preference. The range in preferences was the largest across all questions (Fig 5.20), and the confidence levels the lowest (Fig 5.21). There was also a greater range in responses and less obvious preference when considering which tool most clearly represented the current appearance of the catchment. The CommunityViz tool was more strongly preferred when representing the future appearance of catchment (where nobody preferred the maps) and representing at sufficient detail (where one response indicated a moderate preference for the paper maps). When asked which tool was most successful at representing future solutions at sufficient detail the responses showed some preferred the paper maps.

Combining data returned from the statements with the feedback from free text sections of the survey the following conclusions can be drawn. There is little to distinguish between the two tools in presenting elements for the visioning process for the current scenarios, and paper maps are superior for providing a larger overview of the whole area. The CommunityViz tool was preferred to show the appearance of the future landscape, to enable comparisons to be drawn as well as show locations where change will occur. Potential exists therefore for visualisations to be used to communicate change at a landscape scale during the information gathering and when employing visualisations to represent the current problems in an area. Different stakeholders will require the information in different ways adding weight to the argument that the different strengths of the two tools used together are required in future catchment visioning.

5.5.3 Adapting a climate change visioning 'framework' for landscape visioning

The timeline behind the development of the Catchment Based Approach is detailed in Chapter 3. While the policy for catchment management was released by DEFRA in May 2013 (Defra 2013b) and the guide to collaborative catchment approach was released in August 2013 (Defra 2013c), prior to this there was relatively little advice for trusts. CALP's framework was designed to encourage two way information and communication while disseminating scientific information developed at a scale greater than the community level; the CALP visioning framework was successfully integrated with existing planning mechanisms encouraging collaborative working across tiers of governance. With this in mind evaluating how the CALP visioning framework could be applied to catchment management planning which existed at the time of the project is not straightforward as very little existed. Therefore to evaluate how the CALP visioning process integrated with the catchment planning process the framework is discussed as to how it assisted with the scoping of the project, development of solutions, and then the communication and implementation of the visioned ideas.

Despite the UK government adopting the WFD in 2000 the means to encourage collaborative working across traditional layers of governance have only recently been developed which encourage 'citizen engagement and decision making' which Sheppard et al. (2011) deemed so important in climate studies and which led to the development of the CALP framework. Both the geodesign model developed by Steinitz in the 1990s (Steinitz 2012) and the CALP framework of 2010 (Sheppard et al. 2011a) share a number of similarities which were discussed in the literature review. Neither are particularly flexible and results from the Stiffkey case study highlighted the importance of any framework used to vision at a catchment scale to be able to adapt to the needs of a project on the ground. The Steinitz framework aims to inform on how to think about the planning questions, not on the ground practical visioning advice, the CALP planning manual fulfils this requirement, providing information in an accessible and understandable manner. The CALP framework clearly set out the roles and responsibilities of the different partners coming together to scope the project and collate data and information. Due to the use of the CALP framework a timeframe was quickly established at the start of the project and having the ten step framework allowed deadlines to be set, most importantly though the use of a recognised framework with a published manual gave confidence to the NRT that this was a recognised process to evaluate landscape change. While the NRT initially wanted to only incorporate stakeholders at the second and third rounds of engagement after the process was completed they agreed that it would have been beneficial to have had greater levels of stakeholder engagement earlier.

In developing solutions at a catchment scale geodesign brings in a number of disciplines making it suitable to use as a means to evaluate the role of ecosystem services in the catchment. CALP and its focus on climate change adaptation is very much about looking to the future, longer term, disseminating national scale guidelines. Whereas in fact catchment visioning while it looks to the future must also look to the past as the historic land management practices have a direct influence on both the issues (intensive drainage, channel morphology and siltation) and the cost effectiveness of solutions (new infrastructure or river corridor morphology). Added into the CALP framework adaptation was the added need for practical on the ground walkover surveys which play a vital role in the work of practitioner groups such as the NRT.

Finally the CALP framework influenced the way in which NRT communicated and disseminated the visualisations which were created. Normal practice would have been for the NRT to have gathered data on the issues, devised solutions and then engaged with landowners before securing grant funding and necessary permits. The use of the CALP framework required the NRT to consider a wider group of stakeholders outside the usual groups of landowners and agency staff which resulted in a catchment plan more illustrative of stakeholder viewpoints and better relationships long term. The voices of the community are notably absent from catchment plans also developed by the NRT which do not use a visioning framework. With the CALP study and even more so with the earlier Steinitz geodesign model carrying out a larger more meaningful study would have taken longer, required more iterations and would not have been possible in the context of the catchment management at this scale. This is mostly due to the need to gather a representative sample of stakeholders combined with the farming year and the restrictions of funding bodies who do not allow time for this type of holistic planning approach.

Did the use of CommunityViz influence the visioning process?

While the application of the climate change visioning framework controlled the interactions between the actors within the visioning process the use of the CommunityViz software created shortcuts around the CALP process. This was of benefit as unlike the climate change process set out by CALP the practitioners at the NRT had neither the time nor the wherewithal to hold multiple events with the same stakeholder group. Rather than visioning a scenario building process for the catchment with multiple indicators and multiple outcomes the NRT wanted to have a more distinct two stage process. This allowed the NRT to focus on the means to engage stakeholders with the actions required to move from the 'current degraded' catchment to the 'future functioning' catchment landscape. The CALP visioning process was weighty to be used within this example of catchment planning however for a much larger true visioning programme it would likely be a better fit.

The use of CommunityViz within the visioning framework as set out by the CALP project provides a potential opportunity for the ten step process to be circumnavigated. One example would be that edits to the landscape scenarios could be made at the initial stakeholder workshops during discussions and verified with the stakeholders at that point. While this reduces the need for a formal iterative process to verify the stakeholders' comments on changes which they suggest; where stakeholders have been divided into groups based on background then some discussion between them would be worthwhile.

During the first round of stakeholder workshops participants responded positively to the questions of whether they would like to see the data online so that they could share it. CommunityViz includes an extension with the functionality to publish (but not edit) scenarios to web pages. While the reasons for not releasing these plans have already been discussed (Section 5.5.1) it would have been beneficial to explore means by which the finished visualisation could have been published online. The map board at the community event was on behalf of the NRT in order to gather catchment wide data on the health of the river, something which the technology had been unable to do due to the scale of data required influenced the computing power required for rendering at a catchment scale. Feedback from the engagement events where the current and future 3D visualisations were shown has subsequently been published in the Norfolk Rivers Trust Stiffkey catchment management plan.

5.5.3 The potential to employ visualisations for community engagement in catchment management

This application of the CALP visioning framework was constrained by the processes involved in catchment management. Like other visioning frameworks (Steinitz 1990; Wissen Hayek 2011) the CALP process includes several steps whereby stakeholders were consulted in a collaborative iterative process. During the visioning process on the Stiffkey it was not (due to the farming year) possible to ensure all the stakeholders returned during the second session where the changes to the plan were communicated. This therefore asks the question of how much stakeholder retention there would have been had there been two, three or four rounds of engagement. Obtaining necessary permits to work in channel and around bird nesting habitat on floodplains further add weight to temporal factors playing a role in the success of catchment visioning. In addition the rules around the funding which had been awarded to carry out catchment works did not include a long period for consultation needed to fully apply the CALP framework. This highlights the need for a visioning framework to reflect practices on the ground which in turn reacts to the needs of the project.

If the entire catchment had been visioned, if more complex scenarios had been built or if the NRT had been starting from scratch on the catchment management plan then ensuring the stakeholders returned to see the finished future scenario would have been fundamentally integral to the process. The process was carried out before the release of the catchment partnerships process which would have potentially embedded the visioning within a wider planning level framework. It became apparent during the early workshop sessions the stakeholders were in general agreement about the changes planned along the river and the use of the visualisations prompted sufficient feedback for the Norfolk Rivers Trust to use in a catchment management plan. It was simply not necessary to run the fact finding workshops again. Thus circumstances under which the catchment project was funded, an appreciation of the farming/ecological year and flexibility in stakeholder engagement may have to be introduced to the visioning framework when used in a catchment planning context for wider scale uptake.

5.5.4 Reflections on case study design methodology

This project set out to a) evaluate the application of the CALP framework and b) evaluate two visualisation tools. The challenges of evaluating the success of the visualisation tools is something which is of the moment with Bishop et al. (2013) highlighting some of the challenges in the evaluation of successful visioning. It should be recognised that a full implementation of CALP based visualisation framework is a long process; the Kimberly case study carried out by Sheppard et al. (2011) lasted around a year. As discussed above the application of the CALP framework to catchment planning was constrained by the circumstances of catchment management both in terms of agricultural year and also by ecological permits.

Focus groups have advantages over other forms of quantitative data collection in ensuring that there is a high level of interaction; the small sample sizes impede statistical evaluation of data collected via a post workshop survey. While the requirements of the visioning framework were met by a series of small (6-12) people in each stakeholder workshop a detailed evaluation of the technology would require far greater numbers. Bishop et al. (2013) propose one means to improve the evaluation of the framework would be to consider multiple longitudinal studies. In practice this would require the research team to manage a representative number of case study projects all evaluating the application of a visioning framework over the course of a catchment planning process. What this would not solve would be the seasonal availability of certain sectors of the group (farmers) who would be restricted and so as a population they would most likely be under represented.

While initial observations during the workshops suggested the computer was used more in the discussions about the future and the paper maps were used more in the discussions about the current landscape it was challenging to develop evidence to conclusively show this. Bishop et al. (2013) propose better tracking of the use of visioning tools using video recording software which would provide results on the time a participant spent interacting with tools and Salter et al. (2009) demonstrate how this is possible within a laboratory environment. This case study focused on recruiting local opinion from a local population throughout the visioning process meaning that meetings were carried out at locations in the catchment to ensure full engagement with the local population. Hosting visioning exercises on the UEA campus in a dedicated virtual reality suite would have facilitated the stringent approach to evaluation suggested by Bishop et al. (2013) and Salter et al. (2009) however travel would have reduced the engagement with the variety of stakeholders within the rural catchment. The development of mobile video recording tools to record the amount of time each stakeholder engaged with the visualisation tools may be a future solution.

5.5.5 Barriers to adoption

This section provides an overview to the main barriers to the adoption of this technology and the visioning framework in the support of the Catchment Based Approach. While the interview with the NRT in January 2014 stressed the impact of lack of resources (time, money, skills) on adopting this type of stakeholder engagement other barriers exist (Fig. 5.28). Distilling the technical and scientific information needed to give credibility to this type of visioning into accessible language while maintaining sufficient detail was challenging; this was mitigated in part by the development of posters which assisted in communicating background knowledge for those less familiar with land management practices. User preferences influenced the level at which they engaged with the subject matter and the degree to which the two tools were interacted with. In particular during the workshops the computer tool was operated by a GIS Facilitator whereas the maps were freely accessible, had participants been asked to use the computer tool it is likely that fewer would have seen its true potential. A barrier therefore is the access to a GIS Facilitator for river trusts who want to carry out regular workshops using this type of technology. User preference showed that the tools had complimentary functions; reports indicate that these tools should not be used in isolation but alongside one another to engage with the greatest range of stakeholders. The framework was shown to require commitment from stakeholders to attend, although the CommunityViz technology could in theory support a more iterative process given its functions of editing in situ.

The development of CommunityViz scenarios required technical expertise in the use of GIS and data management, lack of access to these skillsets within the river trusts organisations is most likely the greatest barrier to the adoption of this type of technology. Although there were no issues with the software during the workshop sessions it emerged during development that CommunityViz was unable to vision the whole catchment at high levels of detail. The trade-off in the performance of the technology with the level of detail has an impact in the suitability of this particular piece of software for working across much larger catchments and this may well be seen as a barrier to adoption given the detail the stakeholders reported as useful to report silt entry points such as ditches, drains and unmarked river crossings. With river trusts and catchment organisations constrained by funding cycles and local planning timeframes the time constraints associated with this type of process are also a potential barrier to adoption. The technology must be able to work within these existing processes particularly if the CommunityViz technology is utilised as a hub of information within a catchment partnership. The final barrier to the adoption of this type of technology and the visioning framework is the lack of evidence that it is cost effective and beneficial. At the time of the case study few frameworks existed for developing visioning at a catchment scale. Since the study some have emerged but there is little evidence as to the details of why these can help, particularly as the availability of GIS and spatial expertise is not a given for catchment management programmes or organisations which take part in them. (Smith at al. 2015)

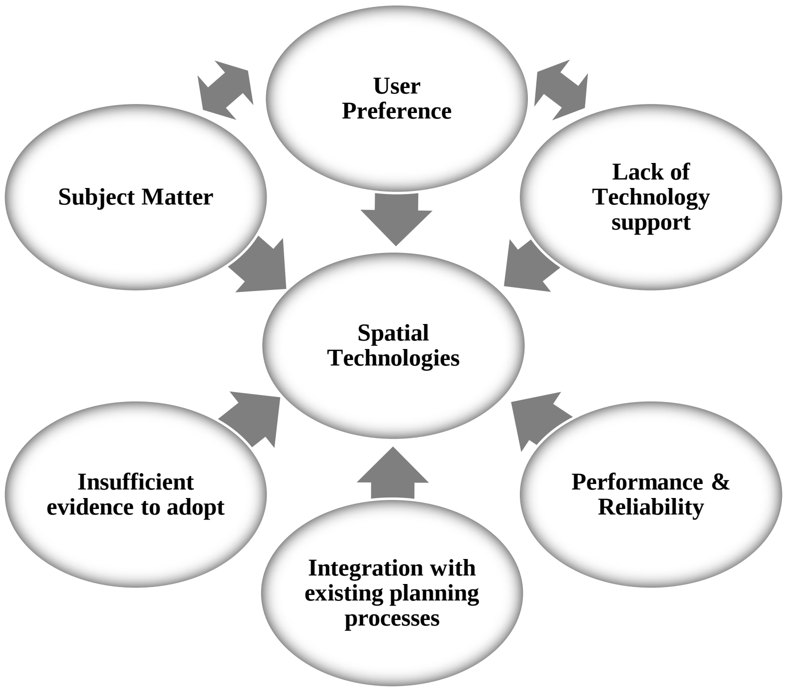


Fig. 5.28 Barriers to the adoption of visioning by practitioners

5.6 Conclusions

To recap, the research in this chapter set out to evaluate the degree to which it is possible to adapt an urban parcel based GIS and visualisation package to catchment visioning and make it fit for purpose. In addition the collaborative study between the NRT and the UEA researcher explored whether computer based visualisations can replace traditional paper based maps, and what potential exists for visualisations to be employed for community engagement in catchment management. Finally the research evaluated the application of a climate change visioning framework to catchment visioning for the purpose of supporting future catchment management, and highlight the need for better means of evaluation.

5.6.1 CommunityViz – fit for purpose?

Following a trial of CommunityViz in the development of the management plan for the Stiffkey catchment in Norfolk UK the research indicates that CommunityViz has the potential to vision landscape scenarios at a catchment scale however further work is needed to make it fully fit for purpose. Initially CommunityViz was chosen as the visualisation software to explore the creation of "What if?" scenarios catchment scale visualisation tool primarily because of the CommunityViz indicator functionality. Timescales (in part caused by the funding body) prevented the full assessment of the various tools which CommunityViz offered. It became apparent that the development of scenarios on CommunityViz requires expert input from a GIS specialist with the result that the visioning process remains outside of the resource sphere for many river trusts. There was also an apparent need for protocols in managing data and editing within the CommunityViz application, if these were well documented this could make it easier to redo this case study.

The benefits to using CommunityViz within this setting were clearly evident, despite only some of the functionality being used. The software was lower in cost than others (such as Geovisionary), and the dynamic charting, GIS and 3D models meant that questions could be easily answered and solutions explored in site at workshop events. There is further potential to include output from other land use decision tools meaning that particularly where catchments cross administrative boundaries the software could be used as a communication portal. In order to do this, and to fit better with the CALP framework then the means by which the scenarios are published and made available to wider stakeholder groups does require some additional investigation. This may have been to a degree mitigated for by the most recent version of CommunityViz which makes full use of the ESRI platform for disseminating spatial data. Areas of future work could involve the parameterisation of environment indicators as they relate to the catchment land uses, the linkage of CommunityViz to financial models and payment for ecosystem services schemes and the ongoing need for better presentation to stakeholders.

5.6.2 Are the days of paper maps over?

Known criticisms of visioning are the time which it takes to develop visualisations (Miranda et al. 2012), the cost of software (Appleton et al. 2002) and the expert knowledge required to develop visualisations (MacFarlane et al. 2005). With the use of CommunityViz the study aimed to use a lower cost tool than many on the market. The use of this application alongside the visualisation framework intended to condense the time taken to develop visualisations of sufficient detail and accuracy for use in a catchment plan, and mitigate the expert input required for visioning. Data showed that more participants preferred the high tech CommunityViz over the low tech paper maps; however many stakeholders reported that they liked both tools, their opinion was that the tools complimented each other not only appealing to different sectors of the population but serving different purposes at workshops. With that in mind it is recommended that workshops such as these with a diverse group of stakeholders are best supported by the use of both interactive and static tools.

5.6.3 Adopting visualisations– can this help or hinder community engagement?

Overall the visioning process was described by the two NRT officers as very useful in the development of the catchment management plan. The visioning process stimulated discussion amongst land-owners about sites within the study area and stimulated a wider debate between NRT and the landowners about the whole catchment. With regards the information elicited during the visioning process the response to the NRT proposals was positive in terms of what farmers would allow, or in other cases had already thought about. The interaction with stakeholders was valuable in two ways, first it provided a much clearer idea of what landowners would welcome and perceive as possible, and secondly promoted engagement with people outside the usual landowner and agency circle. The NRT Officers did however highlight several factors which in their opinion would reduce the chances of practitioners adopting a visioning process. The project would not have been able to go ahead unless there had been input from the PhD researcher, the NRT staff not having the time or the finances to be able to employ experts to carry out the process.

5.6.4 Can the adoption of a visioning framework bring the visioning process within the sphere of river trusts?

Timescales within catchment planning play an integral role as to what is possible. When dealing with landowners the effects of the farming calendar cannot be underestimated, neither can the deadlines for permits to work around fishing and biodiversity restrictions. With the small scale of the visioning process carried out with the NRT on the Stiffkey it simply was not necessary to continually recall participants to review the normative scenarios which had been created. Had the catchment been bigger or had less been known about the state of the environment and the issues in the river then it would have been more important to ensure longer term recruitment. Thus any visioning framework which works at a catchment scale trusts need to be scalable with the ability to focus on key areas at any one time.

Applying a framework to the visioning process gave the NRT a process to follow in developing a catchment management plan at a time when there was little national guidance. The framework was particularly successful for the transparent allocation of responsibilities to project partners and in setting realistic deadlines from the outset of the project. Some customisation was required to the framework with the incorporation of on the ground walkover surveys and collection of photographic imagery as part of the data collection stages. If the visioning process was repeated it would be of interest to compare catchment planning in two or more catchments using two or more frameworks. Through the use of the visioning framework the process had a clear structure, the aims of the NRT were identified at the start, data were collected in a consistent manner, workshops were planned in advance and a representative sample of stakeholders attended the sessions. In addition visioning was completed within the expected timescale and was of great benefit in the catchment planning process.

However the CALP framework was not particularly flexible, an issue when dealing with practical on the ground projects which have an agreed timeframe set by the farming year. Due to its origins in climate change the CALP framework also looked to the future; catchment management has to also look to the past and the historical land use in order to not just learn from the cause of problems but evaluate the cost effectiveness of possible solutions. Finally the CALP Framework for visioning the future forced the NRT to work differently to their usual insular approach. The project gained much wider exposure through the use of the workshops and the level of community involvement in contributing to the plan is notably absent from other catchment plans carried out by the NRT which did not use this framework.

5.6.5 Improving evaluation of the process

The adapted CALP framework and the adaptation of CommunityViz were designed to be replicable but this was not evaluated due to the case study time constraints. While it was outside the scope of the study it would be most interesting to repeat the process by recruiting catchment partnerships for a longitudinal case study. It would be useful if in future catchments reflected the diverse land uses and issues which affect catchment strategy across the UK, in particular looking at ways of embedding the visioning framework with existing planning processes which could provide long term funding solutions to developing sustainable future landscapes.

For more evidence of how visioning can support the Catchment Based Approach to landscape management there would benefits to carrying out a more robust lab based evaluation of how people interact with their surroundings rather than relying on self-reporting. This would have to account for the ways in which people engage with visualisations when detached from their environment. The potential for this type of catchment framework is in linking tiers of governance; by meshing with existing planning mechanisms across administrative boundaries catchment visioning can support a paradigm shift in the way we manage land and water. Opportunities to use visioning tools continue to emerge, for example in the creation of catchment laboratories which are currently in the scoping stage by the Environment Agency; in the increased focus of reducing floods through working with natural processes and in the continued discussions around the practicality of developing PES mechanisms.

Chapter 6. RiverEYE - a citizen science tool for improving water quality and the environment at a catchment scale

6.1. Introduction to the research

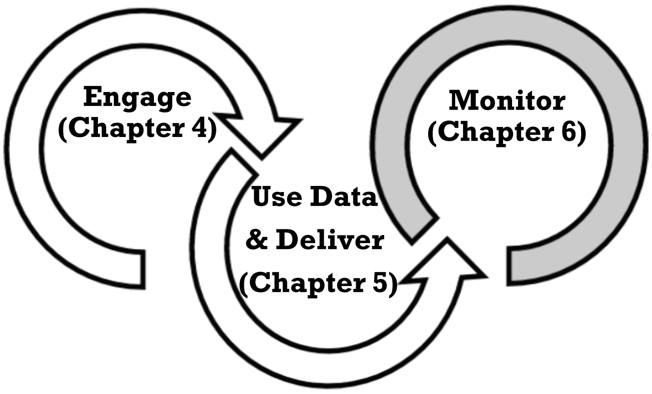


Fig. 6.1 The CaBA Framework - this chapter focuses on the Monitoring stage

Initially reviewed in Chapter 2 the last stage of the CaBA framework (Fig 6.1) reinforces the ongoing requirement for monitoring completed restoration projects; and collecting data to build an evidence base for future funding opportunities. The fourth stage (monitoring) of the Catchment Based Approach framework states that catchment intervention/restoration should be “timely, targeted and necessary to investigate river condition, identify threats to ecosystem services and create integrated catchment management plans” (CaBA 2013). Observing can take the form of monitoring (regular review of known issues or restoration sites), surveying (collating specific data) or reporting on river condition (issues). In particular the spatial and temporal variability of issues across catchments hampers water companies and resource stretched river trusts and government agencies in their efforts to meet the aims of the Water Framework Directive. Supported by the advent of smartphones, collaborative mapping and an increase in location based services the final case study evaluates a volunteered geographic approach to support the future management of river catchments.

Defined by Goodchild (2007a) volunteered geographic information (VGI) refers to data collected by human beings acting as sensors of their environment reporting on one (or more) observations at a given location. Citizen science can be defined as the collaboration between citizens (volunteers) and scientists, and it is important to note that while some VGI examples fall within the remit of citizen science, not all citizen science project involve VGI (Haklay 2013). This project focused solely on volunteered rather than contributed geographical data (Harvey 2013). Influenced from the findings from Chapter 4 a citizen science app was trialled with a local river trust to capture visual and spatial data on a dozen pre-selected catchment problems. In order to inform best practice for future citizen science apps in catchment management a science and technology studies framework was used to explore results.

Chapter 3 provides background as to how the catchment partnerships introduced as part of the DEFRA Catchment Based Approach have improved the communication between stakeholders and the agencies ultimately responsible for catchment policy (DEFRA, Environment Agency, and SEPA). Despite improved communication organisations dealing with rivers and catchments face an increasing requirement for both spatial and temporal data on issues whose occurrence cumulatively affects the river network. For river trusts and catchment partnerships to meet WFD objectives requires both a good evidence base and a well maintained reporting network with strong links to other rural and water organisations. The research questions which this chapter will answer are as follows;

1. Can a citizen science smartphone app for community volunteers assist river trusts in indirectly monitor the quality and quantity of ecosystem services in their catchment?

2. By utilising the principles of volunteered geographic data does a mobile citizen science app have the potential to fill the resource gap faced by catchment organisations?

3. What social and technological barriers exist in the implementation of a citizen science approach to monitoring at a catchment scale?

6.2. Introduction to the case study

As the first round of Catchment Restoration Funding approaches completion the work by river trusts to meet the targets of the WFD via the Catchment Based Approach is threatened by the lack of ongoing funds from DEFRA and the Environment Agency. Many resource stretched river trusts are now looking for innovative ways to maximise the potential of volunteers recruited during the last few years through outreach schemes such as River Guardians (Norfolk River Trust), Catchment River Wardens (Essex Catchment Partnership) and the award winning Wandle River volunteer pollution watch scheme (South East Rivers Trust). Currently many wildlife and river trusts ask volunteers to report anything ‘out of the ordinary’ by email, text or phone (Norfolk Rivers Trust 2013). Despite volunteers often having a passionate interest in the improvement with their river(s) reports submitted are often unverified and the data which is collected from these reports is rarely standardised. Locations can be difficult to trace with local knowledge being needed by river trust officers, and sometimes the problem being reported has moved on before an officer can get there. This final empirical data chapter designed to support the last stage of the CaBA framework focuses on whether the use of citizen science can mitigate some or all of these known issues by trialling a mobile citizen science app with the River Waveney Trust (Fig. 6.2).The app utilised the principles of volunteered geographic data with the case study evaluating the potential of the mobile citizen science app to fill the resource gap and examining possible barriers to longer term implementation.

The River Waveney Trust was formed in 2012 and has over three years grown rapidly with a large (700+ people) membership base. The River Waveney Trust was chosen due in part to this existing network of volunteers which is based in five towns along the main channel of the River Waveney from Diss through to Bungay. Below Bungay the river becomes tidal and is not worked on by the volunteers for health and safety reasons. Each working group has a team leader who liaises with the trustees of the River Waveney Trust to build a bigger picture of issues in the catchment. The volunteer network has a strong sense of community at a grassroots level regularly carrying out working parties both on the banks and in stream (subject to appropriate licencing) to protect and conserve the river. The volunteers often live locally to the stretch of river which they work on, and their familiarity with the river over the year and changing water levels mean that they are in a strong position to act as the eyes and ears of the river. The River Waveney Trust also has a strong working relationship with the Environment Agency and water companies with several of the board of trustees having worked within the EA as engineers and operation managers over the last few decades.

In encouraging the community within the Waveney catchment to collect data on the state of the environment the project is influenced by US projects where citizens collect data on their watershed and the ecosystem services within them rather than the European approach which traditionally centres on biological recording (Conrad and Hilchey 2011; Tulloch et al. 2013). The study carried out with the River Waveney Trust used the UK Environmental Observation Framework publication (Roy et al. 2012) as a guide to inform the use of citizen science in this project. The case study did not use comparative evaluation to assess the citizen science mechanism against the existing form of reporting due to the short timescales involved in the project (Section 3.6).

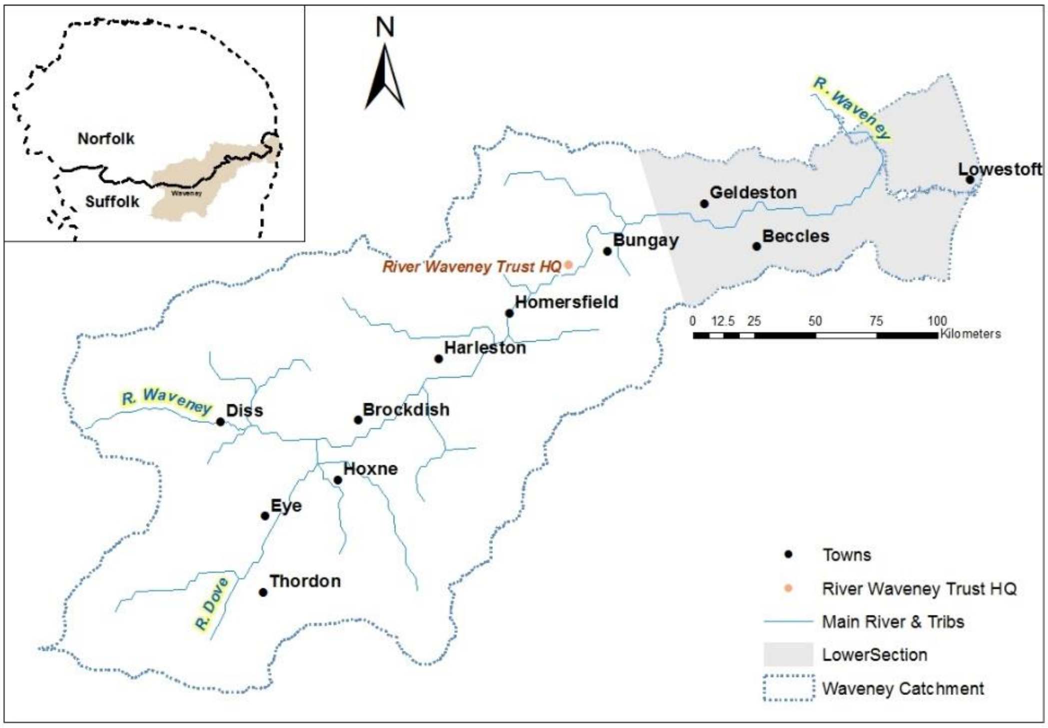


Fig. 6.2 The location of the RiverEYE trial

6.3. Method

This section begins with an overview of the citizen science app and functionality as well as the overall methodology for evaluation. This is followed by the specifics of the app design and the supporting materials as well as the scoping, recruitment, training and appraisal of the citizen science process using paper based surveys and a wrap up workshop.

Data collection within the trial followed a scientific protocol and data analysis and visualisation of the data collected also adhered to predetermined processes (Haklay 2013). Quantitative data were collected via a paper based attitude survey and qualitative data were collected at the wrap up workshop. The attitude survey gauged interaction with the phone app and motivation for participation in the trial. A wrap up workshop at the end of the trial provided in depth responses from users about the citizen science process. Eight trust volunteers attended the initial training, all of these were retained and a further five joined the project resulting in thirteen attendees at the wrap up workshop.

6.3.1 The creation of the citizen science app (RiverEYE)

Due to the eight week timeframe of the project the development of a citizen science tool looked to existing solutions. FieldTripGB developed and hosted by EDINA at the University of Edinburgh was initially selected. Using the web based interface provided a form was designed but after a pilot the user interface on the phones was shown to be not sufficiently friendly and there were consistent errors with the offline maps. While the platform had the option of exporting data for use in an external GIS there was a delay in the viewing of photographs which were tied to the data records. Overall the FieldTripGB product was not fit for purpose. Attention then turned to the EpiCollect and EpiCollect+ solutions developed at Imperial College London funded by the Welcome Trust for use in epidemiology (Aanensen et al 2009). The EpiCollect and EpiCollect+ applications are open source, available on GitHub and superior to FieldTripGB; although a negative of the advanced version (EpiCollect+) was that at the time of the study it was only available for Android operating systems. In July 2015 EpiCollect+ was released on the Apple store making it dual platform. The EpiCollect platform is made up of two parts; 1) the phone front end which facilitates data collection and upload, and 2) a web portal which is accessed via google authentication to add, edit and remove data records as well as analyse the data which has been collected.

After logging onto the EpiCollect+ website with a Gmail account the project 'RiverEYE' was created using the EpiCollect+ web forms. Fig. 6.3 shows the range of data types which can be used within the forms, the RiverEYE project aimed to use least complex datatypes to collect data. Fields included the means to take a photograph, record the location and offer a dropdown list of the problem being reported. For the RiverEYE project one form was created as opposed to a hierarchy or branched form option. This single form sequentially requested data from users, with only the checkbox and free text fields able to be skipped to promote good quality data collection without boring the user and disengaging them from the trial.

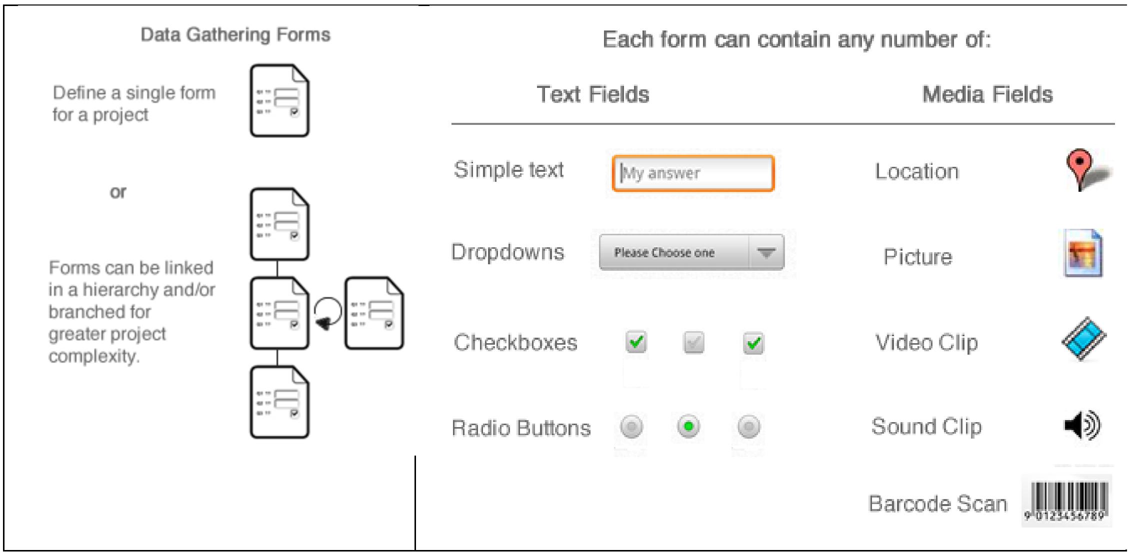


Fig. 6.3Forms within EpiCollect+ and the data types which can be collected within those forms (EpiCollect Website).

Working with the River Waveney Trust from the outset the aim was to recruit up to 20 river volunteers following the creation of the RiverEYE project on the EpiCollect+ platform to try the app out within the catchment over the course of a month. Volunteers who took part in the trial were brought together first at a training session, and then at a wrap up workshop to gather detailed feedback on both the use of the app and barriers to the future use of a VGI approach. Fig. 6.4 details the information flow from volunteer training, through to the RiverEYE data fields (in grey) within the app and the feedback mechanisms within the context of the wider research project, to the final feedback workshop.

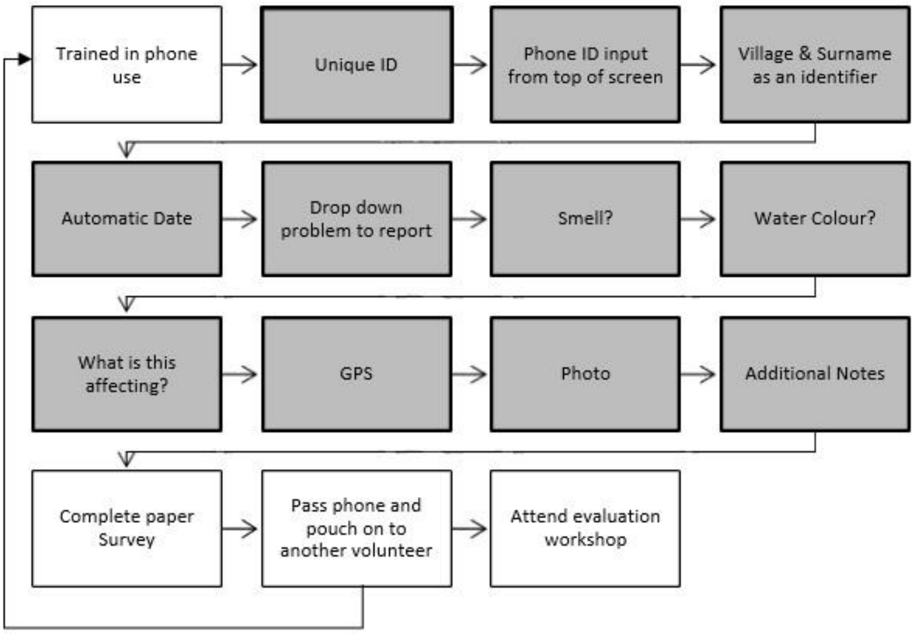


Fig. 6.4 The RiverEYE process of volunteer training, steps in grey are fields within the RiverEYE app

6.3.2 Deploying the RiverEYE app for testing

A key factor in encouraging volunteers to get involved with citizen science projects is to ensure they understand the relevance of their data collection to the aim of the overall project (Roy et al. 2012). Although it would have been relatively simple to gather a list of the problems within lowland river catchments there was a danger these would not necessarily reflect the catchment aims of the River Waveney Trust. With that in mind after discussions with the River Waveney Trust the options in the app were customised (Table 6.1). Specifically the field which allowed the user to report an issue from a dropdown list was determined based on the known issues previously reported by trust volunteers. Issues which the Waveney River Trust were interested in having reported included those within the channel, on the bank and across the wider catchment. As the River Waveney has navigational rights then the trust has a statutory obligation to report navigational hazards, this is reflected in the hazard option in the problems to report field. To ensure that the volunteers were given visual examples during training images were selected to represent the twelve issues listed in the app. The list of issues also included the option to report an invasive species; it was not however an invasive species reporting app and this was reiterated through the case study.

Inspired by several citizen science projects which gather data on species recording (Pocock et al. 2014) a visual prompt was also designed alongside the mobile phone app (Fig. 6.5) which included the images which had been selected originally for training. The use of this A5 visual prompt (Appendix 4) became part of the RiverEYE protocol. It acted as a reminder about the problems which the citizen science project was collecting data on and facilitated the volunteers selecting the correct category improving data quality. By providing this visual prompt in a laminated form it was more robust for use outdoors.

Table 6.1 Fields included within the RiverEYE app

	Field Name	Field Type	Required?	Options
Tracking data	Unique ID	Hidden Key	Yes	
	PhoneID	Number	Yes	Required by the project to track participants
	Your Village and Surname	Text	Yes	Required by the project to track participants
	Date	Date	Yes	Set by the phone but can be edited
	Time	Time	Yes	Set by the phone but can be edited
Observational data	Problem to Report	DropdownList	Yes	In channel weeds, Fish kills, Trees at risk, Sediment in river, Sediment in road drain, Sediment on field entrances, Litter, Statutory hazards, Invasive species, Bank poaching (erosion), Pollution from a road, Pollution on the water surface
	Smell?	DropdownList	Yes	Yes/No
	Water Colour?	DropdownList	Yes	Normal, Brown, Green, White
	Affecting?	Checkbox	No	River Health and Habitat, Water Quality, Water Flow, Recreation
	GPS	Location	Yes	
	Take a Photo	Photo	Yes	
	Additional Notes	Multiline Text	No	

RiverEYE was installed on six Android Samsung Galaxy Ace GTS5830i smartphones. The GTS5830i has a screen size of 3.5 inches and a screen resolution of 320 x 480 pixels, the on-board camera is 5 megapixels and the version of Android is Froyo (2.2). The GTS5830i has an on-board compass and accelerometer as well as the GPS functionality needed for the RiverEYE project. Devices were pay as you go with no credit to endeavour to ensure that the phones would not be used for anything other than the purposes of the RiverEYE trial.

Fig. 6.5 The small phone and a laminated visual prompt which all volunteers were given showcasing the twelve catchment issues to report (double sided)

6.3.3 Evaluation of RiverEYE with the River Waveney Trust

This section covers the recruitment and training of volunteers, the volunteer data collection and the appraisal of the citizen science process using paper based surveys and a wrap up workshop. The section ends with a summary of how the project met best practice guidelines.

Recruitment of volunteers

The recruitment of volunteers was done wholly through the River Waveney Trust, and begin mid October 2014 and ended late November 2014, Fig 6.6 shows the stages of the project over the six weeks of the case study. With six phones and a minimum trial period of a week the maximum number of volunteers which could be recruited over the four weeks was twenty four. The project was launched with a five minutes presentation to an evening workshop at the River Waveney HQ at Earsham. This was followed immediately by a written request to the River Waveney Trust for volunteers which made it clear that those who wished to take part on the month long trial had to be fully committed to two workshop sessions (training and wrap up) and to using the phones on a regular basis outdoors during autumn weather for a minimum duration of a week. The River Waveney Trust followed a snowball sampling procedure via emailing an advertisement to their membership list, placing a post on their trust forum, and personal contact by telephone. The recruitment emails were managed by the head office of the River Waveney Trust.

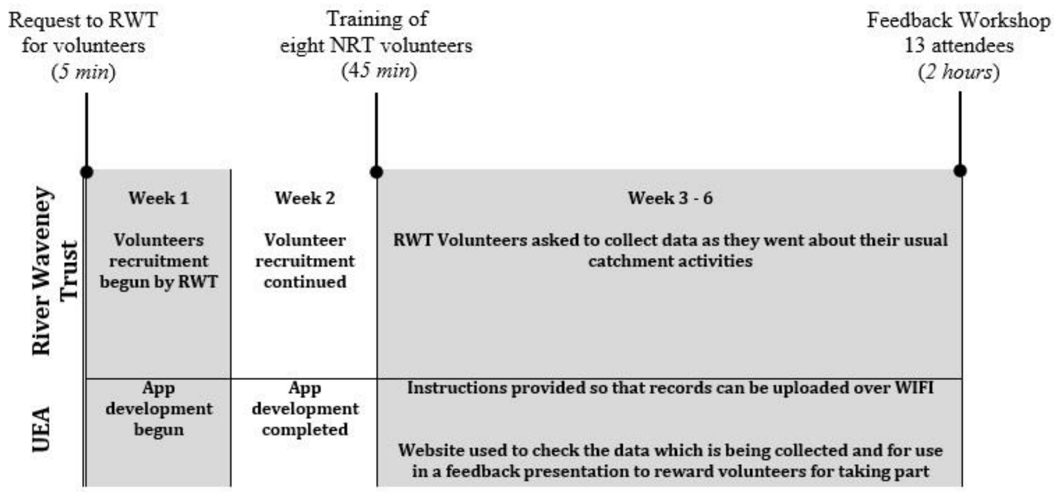


Fig. 6.6 Timeline of events for engaging volunteers and trialling the citizen science app

Training of volunteers

Volunteers were asked to attend a training workshop at the start of the trial as well as a wrap up workshop at the end of the trial. Due most likely to the short lead in to the project there was only interest from around fifteen people with eight volunteers attending the initial training session. The training session lasted for forty five minutes and was held at the RWT HQ at Bungay, a site that all RWT volunteers know well and which has a dedicated training and education room. The session was designed to be short as feedback from the email recruitment indicated that many found it difficult to attend the short notice weekend slot. The training began with a fifteen minute oral introduction by the researcher to the use of Citizen Science in environmental projects and on the overall aim of the PhD research project. Each volunteer was provided with a waterproof pouch containing a visual prompt, a phone charger which had been electrically tested, an ethics consent form, a brief post phone survey (see Appendix 5) and visual instructions on how to use the phone. Users were given contact details of the researcher and informed that they could get in contact any day of the week for advice and support. Those taking part were cautioned against taking photographs of people within the catchment, and reminded that care was needed when recording information near to water or on the road as attention can easily wander.

A short walk was taken within the grounds of the River Waveney Trust site to familiarise users with the RiverEYE app for 15-20 minutes. Users were clearly told that this was a trial project, and that any data collected would be destroyed once the PhD was complete. The training was designed to be simple enough to be repeated to train the next round of volunteers hierarchically trained by the initial volunteer group. In reality increasingly autumnal weather prevented many of these handovers from occurring with just two volunteers hierarchically trained, one of whom did not complete the post phone feedback form. All users were asked to aim to use the phone over at least one week and briefed not to go out searching for problems but to go about their day to day habits within the catchment and to record any indicator of problems which they found.

Appraisal of the citizen science process – paper surveys and wrap up workshop

Maintaining interest during citizen science projects in a known issue (Pocock et al. 2014). Rather than wait until the wrap up workshop and have volunteers forget details or through volunteer non-attendance lose important feedback a paper based survey was devised for completing after the volunteers finished using the phone for the final time. Both qualitative and quantitative data were collected using these paper based attitude surveys. Questions were aimed at collecting feedback on the motivation for taking part in the study and the ease of use of both the phone and the RiverEYE app, participants were asked whether taking part influenced their opinion on the priorities in the catchment and the role of citizen science from a volunteer perspective. In addition demographic data were collected. During training volunteers were reminded that after they finished using the phone for the last time that they must complete this short paper survey. While eight volunteers attended the training workshop it was uncertain how many would join over the next month.

At the end of the trial volunteers were required to attend a wrap up workshop held again at the HQ of the RWT. At the wrap up workshop in November a total of 13 people attended (Fig. 13). This included all those at the original session (n = 8), two people who had been hierarchically trained to use the phones and three people who had not used the phones but who were interested in the citizen science project for use in their own catchment projects. At the wrap up session all phones were checked to ensure records had been uploaded. Via the online EpiCollect+ web portal tools (Section 6.4) data which had been collected by the volunteers during the course of the four week trial were displayed. After the data were discussed a short refreshments break gave those who had not used the phone during the trial (n = 5) a chance to get a feel for the app by taking it for a short walk outside.

Following this the eleven participants were divided into three groups, (n = 4, n = 4, and n = 3) and asked to consider three key areas of feedback; a) the research project, b) the RiverEYE app and c) the future of an app like RiverEYE within the River Waveney Trust. Three A0 posters were provided, one for each area of feedback and users were asked to respond on green (non-phone user) and pink (phone user) post it notes to identify comments from the phone users and non-phone users. The groups were given twenty minutes per poster to complete their independent feedback on the three topics. Workshop participants were informed that if they agreed with a statement made by someone else then they were to place a sticky dot next to it (Fig. 6.16) – reducing the overhead of data entry and highlighting those feedback statements which the majority agreed with.

Best practice

In order to meet best practice criteria the following was agreed with the River Waveney Trust following guidelines set out by (Roy et al. 2012) which can be found in Section 2.4.1, Table 2.1. To summarise;

- The Waveney catchment excluding the tidal section below Bungay and the area which is part of the River Dove catchment was set as the geographic extent of the project (Fig. 6.2).

- The four week trial set out to encourage volunteers to report sightings of the twelve issues determined by the RWT throughout the catchment and gather sufficient data and exposure to give an indication for the use of the app within a catchment management setting.
- Volunteers were the main focus of the data gathering, but in depth analysing by volunteers was somewhat outside of the remit of the project given the short time frame.
- The EpiCollect+ application facilitated not just the phone app but also a webpage entry as well; due to timescales this was not evaluated in the trial.
- The project in the short term was deemed to appeal to volunteers signed up with the River Waveney Trust who wanted to try out a new tool to report problems they saw; in the longer term the project was considered to potentially appeal to a wider group of catchment organisations and trusts.
- Training was designed and provided for all those taking part with access throughout the trial with a phone contact provided in case of difficulties.
- The motivation for participants to be involved was assessed during the trial via a paper based survey, it was anticipated that it would be due to a love for the river but that most would take part because of a combination of factors rather than one specific reason.
- The collaboration between the UEA researcher and the RWT meant sufficient resources for developing and publishing the project, the inclusion of a wrap up workshop within the trial period ensured that the findings could be shared with participants.
- At the time of the trial there were no others apps or projects in existence focused at the collection of monitoring or reporting data across a river catchment.

6.4. Results from the trial of RiverEYE with the River Waveney Trust

Results are presented in three sections. First the data captured by river trust volunteers is reviewed (section 6.4.1), this includes looking at the spatial and temporal variability of the data collected by the nine volunteers who actively collected data on the health of Waveney catchment and an overview of the web portal functionality. Secondly data collected from the post phone survey is reviewed (Section 6.4.2) and summarised before the final section where the feedback from the wrap up workshop held at the end of the trial is detailed (section 6.4.3). Due to the focused engagement with a small group of river trust volunteers responses which were collected were not sufficient in number for statistical tests to be carried out. When researching the context for this case study the timely nature of the research is highlighted with many river trusts registering interest in the project as they turn to citizen science to fill funding gaps for longer term monitoring.

The web portal of the EpiCollect+ system

The EpiCollect+ web portal has two views; a table view (Fig. 6.7) and a map view (Fig. 6.8). In the table view search tools allow records to be selected or exported to carry out further analysis in a GIS or be imported into an external database. Over the duration of the trial the records collected on phones were uploaded at the users' discretion over Wi-Fi. The app can also synchronise data within signal areas if the phone has sufficient credit; this option was disabled for data reasons in the trial. Photographs collected during the trial are shown in the table view (Fig. 6.7) and proved to be indicative of the range of problems in the Waveney catchment. Within each record the issue being reported is visible in the photograph attached although the resolution and size of the images being returned are variable due to the different handsets used to collect data. The potential of the map view in the EpiCollect+ web portal to review and analyse issues captured by the volunteers can be demonstrated in a few relatively simple steps (Fig. 6.9) where a combination of field variables can be applied alongside the option to graph the data which has been returned.

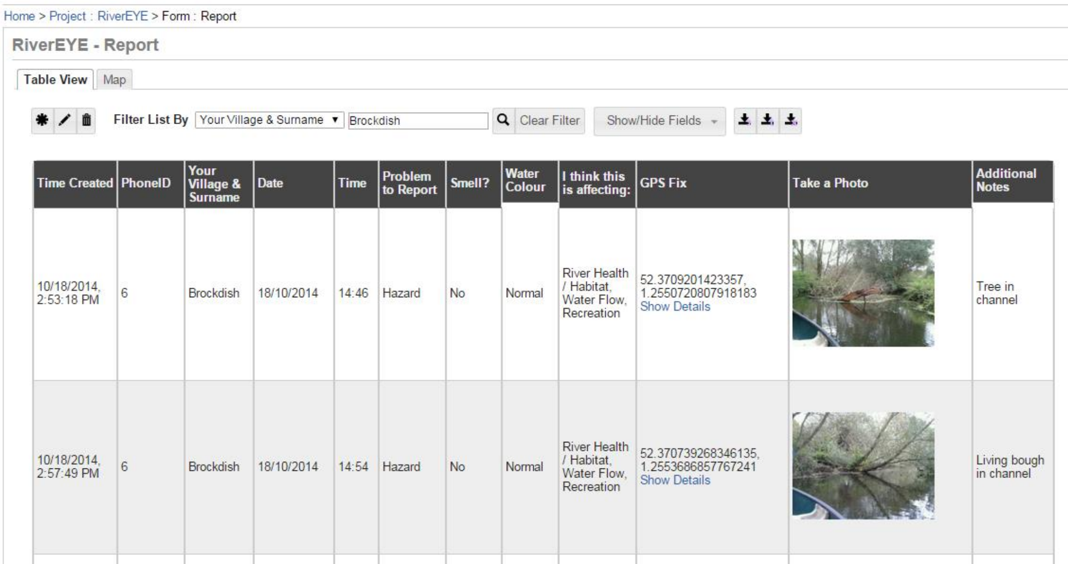


Fig. 6.7 The EpiCollect Table View

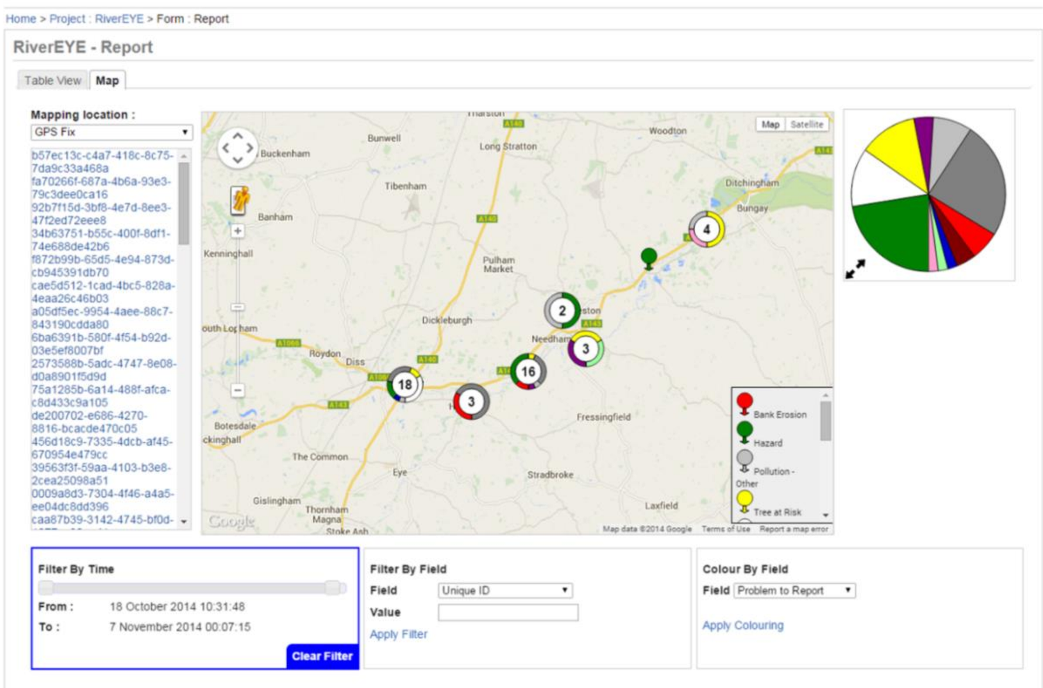


Fig. 6.8 The EpiCollect+ portal onto the data collected in the RiverEYE trial. Functionality includes the options to search by time, field or to change symbolisation as well as an option to graph data

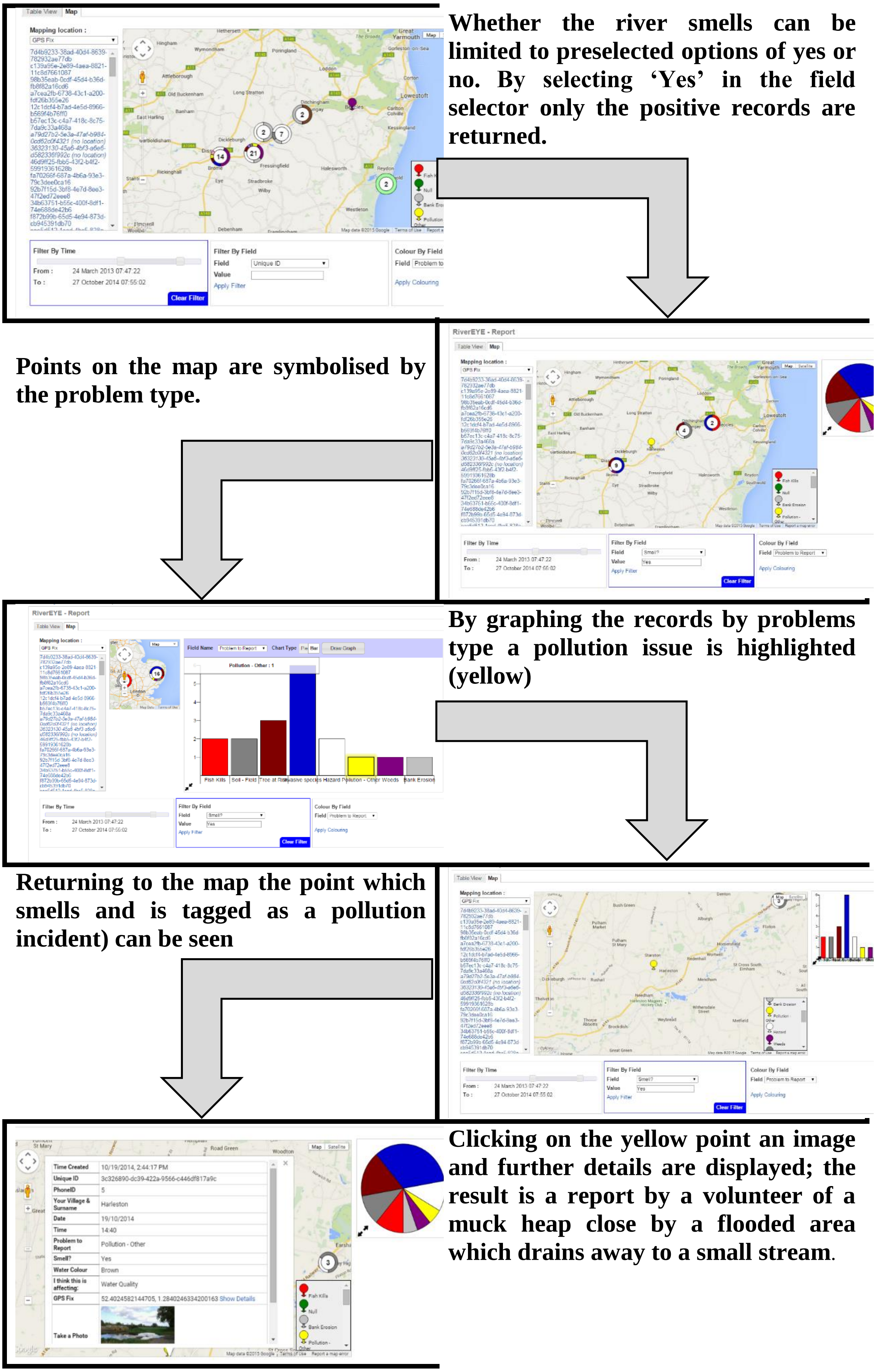


Fig. 6.9 An example of an analysis flow using the EpiCollect+ web portal in the map view

6.4.1 Review of data uploaded to the website

Data gathered can be summarised as follows. In total 80 records were collected by the participants and uploaded to the website using mobile devices over the duration of the four week case study. Due in part to the way in which volunteers had been asked to collect data there were some duplicates, and some records had failed to complete leaving empty records with no data or GPS location. With these erroneous data removed from the dataset a total of 73 records can be counted. During the wrap up session another data entry error came to light whereby one volunteer had thought that the aim of the trial was to simply use the phone – not to record real life issues. Once the six incorrect entries provided by them were identified and removed then a total of 67 records could be analysed. Of the twelve issues identified during the initial interaction with the River Waveney Trust the most popular was hazards; with weeds and trees at risk also widely reported (Fig. 6.10). Three of the issues on the dirty dozen card were not reported; pollution from a road, pollution on a road surface and fish kills. This last may have in part been due to the time of year as fish kills are triggered by oxygen depletion in turn caused by agricultural runoff, higher temperatures and drought – all more likely in summer months where there is less water within the river system and less flow to flush pollutants.

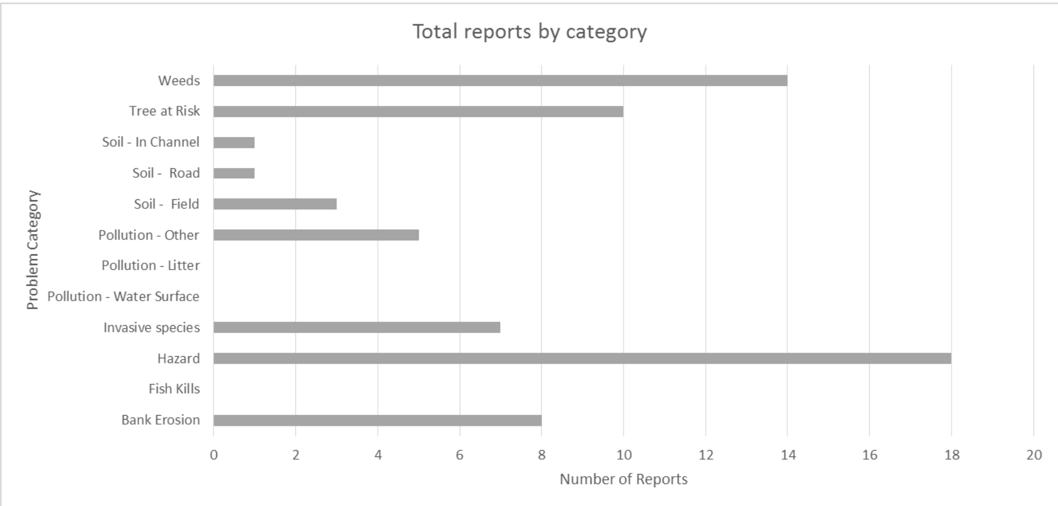


Fig. 6.10 Total number of reports within each category

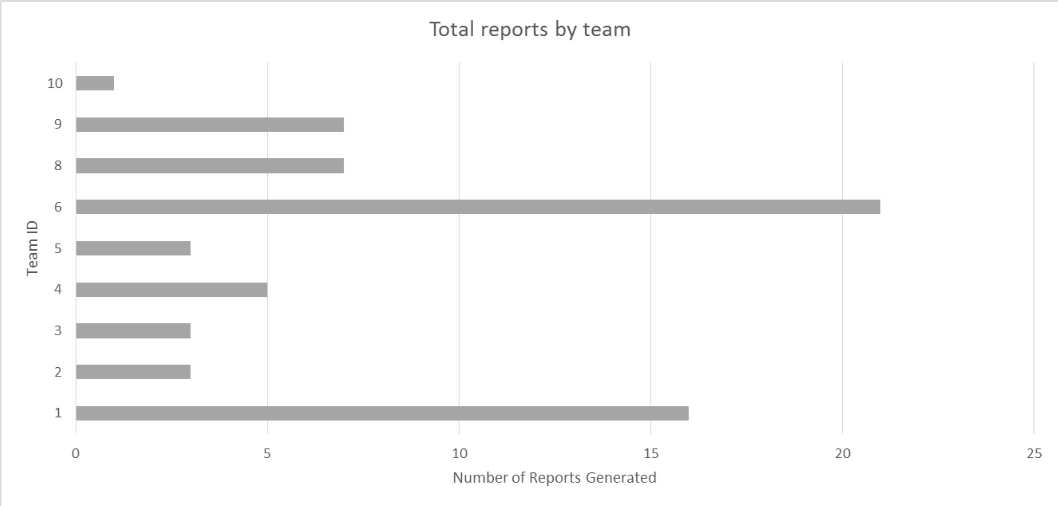


Fig. 6.11 Activity by team

After the dataset was cleaned the number of records collected by the ten different volunteers can be seen to vary. The most records collected by one person was 21 and the least was 1 (Fig. 6.11) with an average of 7 records per volunteer. With a maximum of 12 problem types to record the distribution of problem types recorded by the ten volunteers ranges from one to seven (Fig. 6.13), the average being 3.4 with a median of 3. While this seems very few in number the volunteers did have the phones for a short time only and being autumn daylight hours were short and the weather was not conducive to data collection. Volunteers had also been briefed not to go out searching for problems but to go about their day to day habits within the catchment and to record any indication of problems which they found. Fig. 6.12 shows the records collected over the course of the trial; there were some concerns that the phones would be used more at the start of the trial than at the end, and to a large degree this was true. Sections highlighted in blue show the weekends and those in yellow are the weekday, with 68.6% records collected at weekends indicating the volunteers had a greater presence within the catchment at weekends.

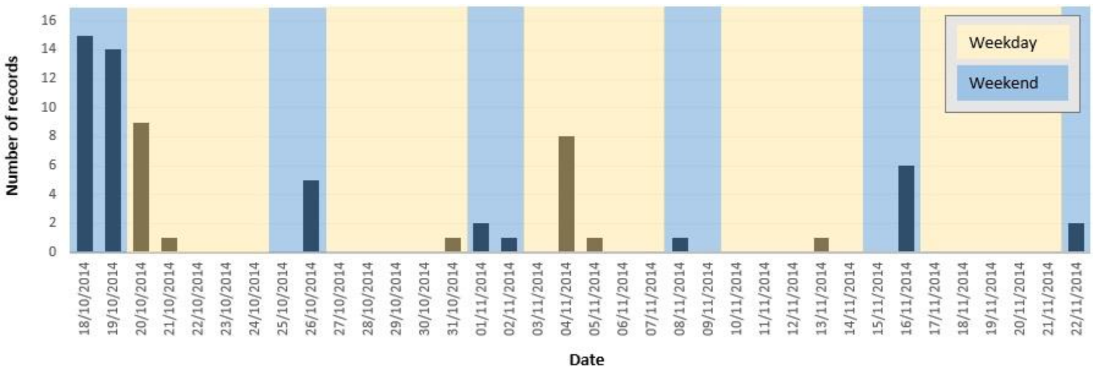


Fig. 6.12 RiverEYE recording by the day of the week

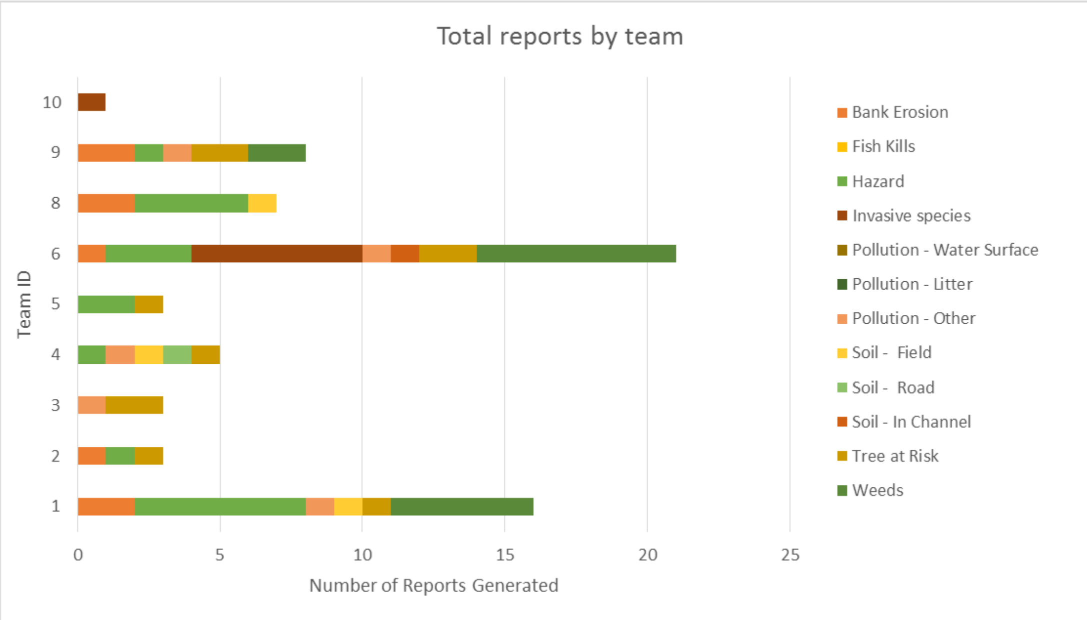


Fig. 6.13 Distribution of problem type recorded by team

Having summarised the records which were reported it is also worth looking at the geographical distributions of different phone users. Fig. 6.14 shows the location of RiverEYE records symbolised by user, the rings are a measure of the degree to which the features records by each phone user are concentrated or dispersed by a standard deviation of 2 from the mean location. This gives an indication of the different ranges that volunteers using the phones have. The user with the greatest spatial range took the phone everywhere that they visited for the time that they had it and recorded a great deal of information about the catchment fully engaging with the aim of the trial. Other smaller circles are more representative of the working groups which took part at weekends.

Although the spatial mean is a useful indictor of the range that a volunteer using the phone might travel Fig. 6.15 summarises the spatial characteristics of records collected by each user during the four week trial. In particular the use of standard deviational ellipses emphasises the directional trends which adds further insight to volunteer movement. All but one of the ellipses follow the line of the main river channel with only one of the users bisecting the catchment demonstrating how much the river trust volunteers maintained their connection to problems on the main river rather than in the wider catchment. This may be due to river trust volunteers travelling on established paths or roads. It is worth noting at this stage that although the engagement with the River Waveney Trust set out to work at a catchment scale this was not fully possible as the lower half of the Waveney catchment is mostly marshes with poor access and dangerous currents (so not suitable for small boats which the RWT use in river work). The main tributary of the River Dove which runs north from Eye (Fig. 6.2) was not covered by any of the volunteers despite this river failing WFD standards and being the focus of some quite considerable intervention by the Environment Agency.

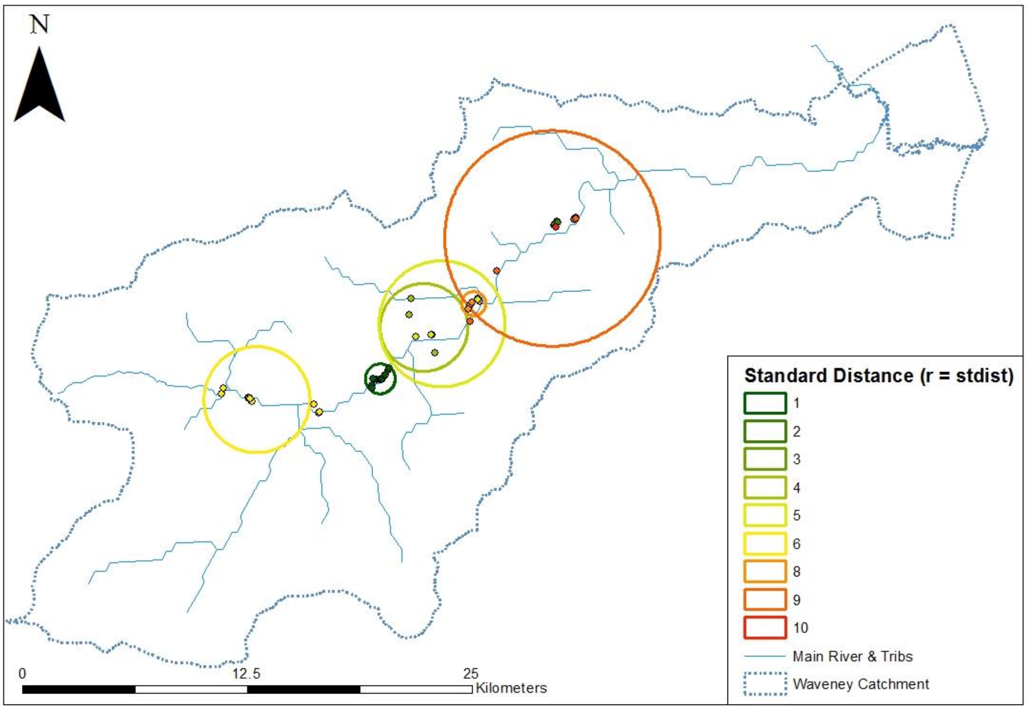


Fig. 6.14 Measures the degree to which features are concentrated or dispersed around the geometric mean centre

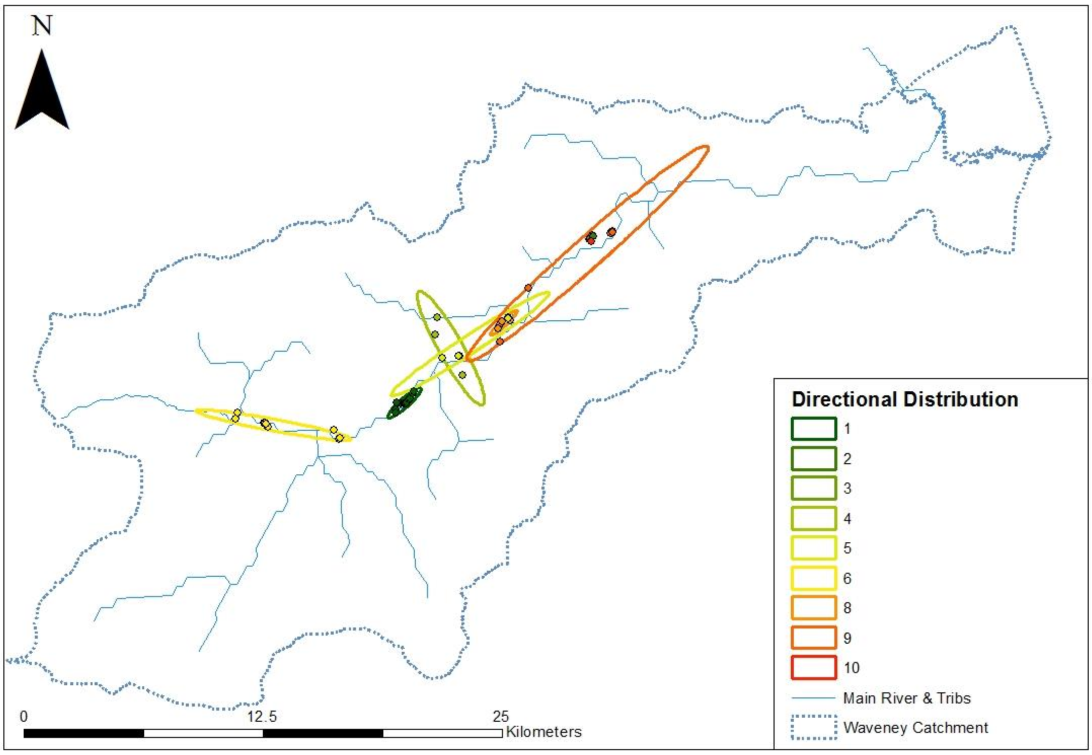


Fig. 6.15 Creates standard deviational ellipses to summarize the spatial characteristics of geographic features: central tendency, dispersion, and directional trends.

The final element of data uploaded to the website aimed to determine whether volunteers could indirectly monitor various ecosystem services within the catchment. The introduction of this subject within the form was intended to make the volunteer reflect on what they were reporting and how it contributed to the bigger picture of catchment wellbeing. The chart showing data collected can be seen in Table 6.2, this was an optional field within the RiverEYE app and as such there were a few blank responses. Overall the data indicated that River Habitat and Health was most regularly seen as affected, with hazards and trees at risk being the categories most associated with this ecosystem service. Water Flow (i.e. the regulatory function of the river) was next most reported, issues which contributed to this were weeds, in channel hazards, and trees at risk. Water Quality was next with hazards and invasive species, pollution and weeds all criteria aligned with this variable. Volunteers reflected that recreation was affected by hazards (for anglers and canoeists) and weeds, this was the ecosystem services least reported on. What is clear from looking at the data is that the quality of this subjective data is less consistent than the more objective problem reporting data; some volunteers were inconsistent with the way in which they interpreted the question - some chose just one tick box others selected several.

Table 6.2 Volunteered data on the river functions (ecosystem services) which were being affected, these criteria were more subjective with less support.

	HealthandHab		**WaterQual**		**WaterFlow**		**Recreation**	
	Count	%	Count	%	Count	%	Count	%
Bank Erosion	4	13	3	13	0	0	1	6
Hazard	11	**35**	5	**22**	7	29	9	**56**
Invasive species	2	6	5	**22**	0	0	0	0
Pollution - Other	3	10	4	17	1	4	2	13
Soil - Field	3	10	1	4	1	4	0	0
Soil - Road	1	3	0	0	0	0	0	0
Soil - In Channel	0	0	0	0	1	4	0	0
Tree at Risk	6	19	1	4	6	25	2	13
Weeds	1	3	4	17	8	**33**	2	0
TOTAL %	**33**		**24**		**26**		**17**	

6.4.2 Review of feedback from the post phone use survey

During the trial with the River Waveney Trust two volunteers installed it onto their own devices which were a Samsung S5 and a Samsung Galaxy 10 inch tablet. To establish a baseline of the technological competence of river trust volunteers who took part in the trail the survey asked on a four point scale the users familiarity with email, online maps and paper maps; all responded that they were fully comfortable with these tools. The eight completed surveys returned in the phone packs showed that two women and eight men took part; two phone users did not complete a survey. Of those who completed the post phone survey the age range was wide, the youngest was 17 and the oldest 87. The users were asked the degree to which they visited the river Waveney or tributaries, all visited either a great deal (n = 5) or quite a lot (n = 3), the options of not much, very little or not at all were unselected indicating all those who took part were engaged with the river and its catchment. This is further supported by the responses to the question of why the users wanted to take part in the citizen science trial; the greatest motivation (n = 6) was a love for the Waveney and a desire to be able to get involved, secondary motivation was an enjoyment of technology (n = 4), third was though knowing others taking part (n = 2). Users could select more than one option and no users selected the option that they were motivated by an interest in citizen science.

Users were also asked whether using the RiverEYE app had changed their perspective on; (1) the priorities that the Waveney should have, (2) the potential of mobile technology to collect data, (3) the benefits of a citizen science approach in collecting data and (4) the benefits of a citizen science approach to feeling more engaged with solving problems. All users responded that the RiverEYE trial had changed their perspective on all of these areas to some degree. On the priorities that the Waveney should have the responses were mixed with one user saying a lot, four users saying moderately and two saying slightly – one user wrote that they didn't know the priorities in the catchment. Question 2 had an overwhelming response all but one user (n = 7) said that using RiverEYE had changed their perspective a lot on the potential of mobile phones to collect data. For questions 3 and 4; the benefits of a citizen science approach to collecting data and feeling involved with solution the results showed that users were split equally between a lot (n = 4) and moderately (n = 4), no users selected slightly or not at all.

Users were then asked to rate how easy the phone was to use, one declined to answer everyone else said easy with the user saying there were a few problems adding *"difficult to use with large fingers!"*. Moving on to the use of the supporting A5 laminated card six of the eight users referred to this for a visual reminder to check the category an issue fell into. When asked which categories the prompt was useful for checking against two users replied *"everything"* suggesting that they used the A5 prompt as a key part of the RiverEYE protocol. The remaining four users listed specific elements which they had to check before entering. Of these bank erosion was checked the most (4), with field entrances, hazards, trees at risk and pollution next (3) and silt on road and weeds least checked (2).

In the last section of the survey users were asked to suggest ways in which the app or the research processes could be improved and were prompted to consider the uses of the app, the map and the way in which the information was presented. While most were content with the design of the research project a few criticised the need to enter their user ID name over and over again as it was difficult with a small keyboard. There was a request to make the app multiplatform, one user was an avid Apple supporter but overcame this to take part using an android device. Several suggestions on the design of the app were made including the request to start by taking a picture of the problem and then log details about it; and to combine the drop down list of problems on the RiverEYE with the images from the A5 laminated card. Another user suggested that there should be an 'other' category to encourage people to report problems without disengaging them from contributing through lack of knowledge when starting to use the app. While this would be of benefit to users beginning to report problems it increases the likelihood of non-specific entries increasing the data management overhead of sorting images once loaded to the database. Finally feedback indicated that it was difficult to assess some elements within the catchment such as water quality, this is perhaps an area where experience will build confidence for the users who choose to use RiverEYE.

6.4.3 Review of feedback from the end of trial wrap up workshop

At the feedback session in November a total of 13 people attended. As detailed in the methodology (Section 6.3.3) there were three A0 posters, one for each question, and users were asked to respond on green (non-phone user) and pink (phone user) post it notes (Fig. 6.16). The results were interesting and can be summarised as follows.

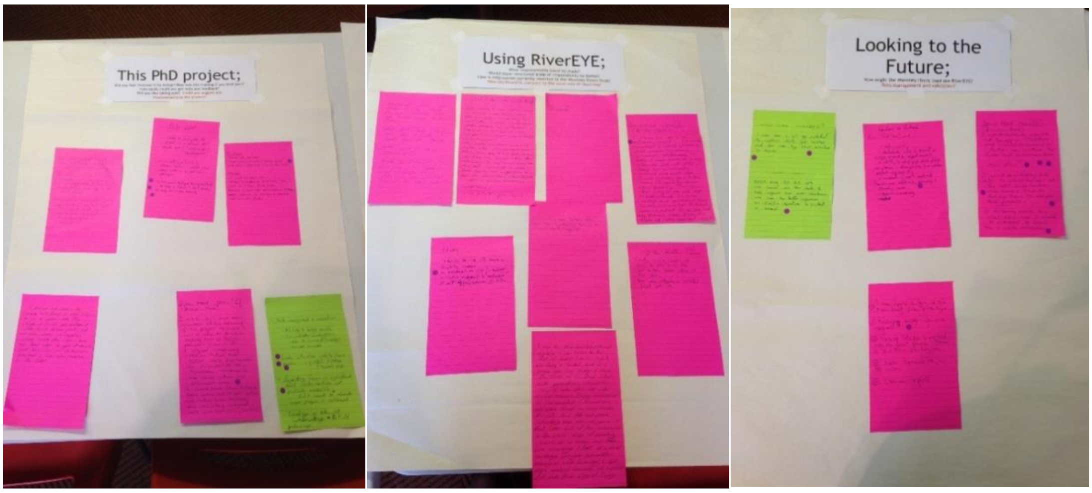


Fig. 6.16 The three data sheets which were collected at the wrap up workshop – dots indicate where a statement previously made has been agreed with by a subsequent participant.

Beginning with the feedback on the training for the RiverEYE research project the responses were positive. While all those who attended the training (Fig. 6.17) were happy it provided what they needed there was a mixed response from those who were not at the training session with one feeling the handover from another volunteer was inadequate and another feeling that they had misinterpreted the aim of the trial and they would have enjoyed the data collection more had they been at that initial session. Telephone and email support provided by the researcher throughout the trial was noted to boost confidence in not worrying about 'breaking' the phone and just getting on and using the app. All the workshop participants agreed that the process had been fun, and worthwhile to explore the options available to a small organisation in changing a reporting system which does not currently work well. A trustee of the organisation suggested that it would have been better to have a longer lead time to the project, and that from a strategic perspective the process had been worthwhile in introducing the management of the river trust to the needs of a PhD research project.

Fig. 6.17 Collecting evidence from the workshop session. Different coloured post it notes on the three large A0 sheets differentiated the phone users from the non-phone users

The next topic was the use of the RiverEYE app itself, workshop participants were prompted to think not just about what worked well but also what did not work and what could be improved. Several workshop participants felt it would have been good to have been involved at an earlier stage to contribute to the dirty dozen issues in the catchment. Not all workshop participants felt that the twelve items selected by the chair of the River Waveney Trust necessarily reflected the on the ground issues which they regularly saw. Workshop participants agreed that the aim of the app needed to be clear. That while there was an attraction in recording as much data as possible about the catchment by adding too many images or by linking the app with species data then it would fast become unusable. Participants at the session highlighted a clear need for the app to replace an ad hoc reporting system with a number of comments on the means by which RiverEYE could improve the reporting process which is currently in place at the Waveney Trust; "*far easier and less time consuming*", the speed to report was also mentioned with "*incidents can immediately be relayed back to HQ*", and the ability to bring relevant organisations together to record problems. Another response prompted by the size of the catchment and the management of the Waveney (split by the River Waveney Trust into five reaches or work zones) was that workshop participants could access the data held within the database using a terminal at the HQ as they were interested in the problems others reported up and down the river. There is the potential for maintaining volunteer engagement by encouraging them to look at the problems faced by other sections and sharing their expertise within their own section.

Workshop participants were also asked to envisage how RiverEYE could be used in the future. This was where those who had not taken part in the trial were asked to expand on the potential as they saw it in their catchments. Workshop participants asked that RiverEYE be redeveloped in a number of ways with the option to take a photo at the start of the record, and to take multiple photographs per record. This would be a simple change to make. The GPS location on the phones is accurate enough to flag up where issues are seen although there was a lower degree of accuracy in wooded areas; this is an area which could be researched further. There was requests for the app to become dual platform, on Apple iOS not just Android and to gain a better understanding of costs involved (hardware, software, communications and licensing issues). Interest was shown by an Environment Agency officer who wanted to adapt RiverEYE for use by river wardens in Essex catchments who are tasked with collecting data during walkover surveys which are important in meeting the aims of the WFD. Participants also asked for the functionality to configure data fields on the phone and change then in situ (which is not possible); and adapt the data collection for specific projects in the catchment – which is possible. Interestingly two participants flagged up that they would like to be able to record not just problems but to make positive reports on their environment. Discussions took place during the workshop which evidenced "*a clear need at the River Waveney Trust for an app like RiverEYE*", there was also a suggestion that the web mapping capability of the RiverEYE web portal could be linked with the new GIS which is based on open source software at the RWT headquarters.

Finally the means by which the RiverEYE database could be given a degree of intelligence in the ability to manage problem reports which need dealing with swiftly was discussed. Ten days after the launch of the RiverEYE trial a participant spotted a green plant which had formed a mat in a storm water run-off drain close to their house. Using the A5 visual prompt the user correctly identified a previously unknown refuge of a Non-Native Invasive Species. The species recorded was the river smothering Floating Pennywort (*Hydrocotyle ranunculoides*), the user was able to photograph the weed and get an accurate location using the phone. Workshop participants were of the opinion that the RiverEYE database would be improved by extending its functionality to email a single record to a subject expert, or to send the details of problems to the correct recording authority. This suggests that the RWT organisation has the awareness to make use of the data collected intelligently (Haklay 2013) but that the technology currently does not support their needs without further development.

Two of the workshop participants felt strongly that the reporting of issues caused by agricultural practices should be managed carefully to maintain the working relationships which had been developed. A concern which was mentioned by the trustees of the River Waveney Trust (i.e. those a strategic level) was to be mindful of relationships which have been built with agricultural stakeholders and the avoidance of a 'policing' approach to whole catchment monitoring. In discussions at the final workshop session it was felt by the three strategic attendees that reports which are taken of field gateways should be private and not released onto a public arena (even with logins there is the risk of images becoming public). Instead it was deemed more discreet for images identifying agricultural runoff to be assessed by selected members of the river trust and sent to the Catchment Sensitive Farming Officer responsible for the farm who has the means to encourage farmers to improve their land management. Reflecting on the advice from the PostNote (2014b) it is not unusual for the retention of some records to maintain privacy but this does lead to an incomplete dataset with other the upper tiers of the organisation being able to see the bigger picture.

6.5. Discussion

First the discussion focuses on the evaluation of the development of the Citizen Science process and trial of RiverEYE. The barriers to setting up a citizen science project at a local level are reviewed and improvements to the data collection process such as data resolution are considered. Lastly the interaction between the technology and the organisations involved is explored using Actor Network Theory.

6.5.1 Evaluating the development of the citizen science process and the use of the RiverEYE app

Section 6.3.3 gives an overview of how the project met best practice citizen science standards. The aim of the study was clear and explicit; RiverEYE was evaluated for use in building a robust evidence base for monitoring twelve issues in the Waveney catchment and the potential went beyond that of an ongoing stakeholder led data collection tool to contributing to project monitoring where before and after stages could be recorded. The volunteers remained engaged with the project attending both the beginning and end workshops, the greatest motivation to take part was down to a sense of place (n = 6) and a desire to be able to get involved, secondary motivation was an enjoyment of technology (n = 4*)*, third was though knowing others taking part (n = 2). The spatial and temporal scale could have been improved with more records across the catchment; over the trial period there were records taken at a number of different points despite the inclement weather of October and November 2014.

The use of EpiCollect+ for RiverEYE kept the protocols simple, the visual prompt supported users of the app in selecting the correct problem category for issues they reported. While the growth of mobile phones has continued since the first case study (Chapter 4) many areas of rural landscape remain devoid of mobile data coverage; so apps must have the functionality to store data and synchronise which adds to the complexity of the protocol that the citizen science must follow. When relying on smartphones for data collection there is the additional risk that high app turnover, high development costs and the alienation of some sectors with less access to smartphones will occur. With a customisable front end app to collect and upload data as well as a web portal to analyse data by location and time RiverEYE includes not only the means to collect the data but also to manage and analyse for initial indications of problems in the catchment. Tweddle et al. (2012) indicate that the use of graphs used alongside maps allow for ‘easier interpretation of data’; a function provided within the map portal of the EpiCollect+ system. Within the portal the map view (Fig. 6.8) also includes a slider to select time ranges, an option to select by field and symbolise the points on the map. This inbuilt functionality on the web portal enables a combination of variables to be applied to the data without having to export to another GIS or RDBMS for analysis. Something which is particularly important when keeping costs low for third sector organisations.

While the objective data which users were asked to collect was relatively accurate and well understood asking users to assess the more subjective criteria of how the problems which they were reporting impacted ecosystem services proved interesting. Reviewing the data (Table 6.2) indicates that reporting this variable was quite specific to the individual. Volunteers did report on the ecosystem services which they thought were being impacted, the photographs show that only a few were wrong but the evaluation has proved the importance of good training and support materials. This serves as a useful reminder as to the importance of clear protocols within a citizen science app so that volunteers using the app can submit accurate and relevant data.

Duplicate reports of the same problem were discovered using the functions within the EpiCollect web portal table view. Through discussions with the volunteer group who took part this was due to two reasons, the first through user error, and the second through the desire to record more than one picture of a problem, from different angles for example. This supports the requirement for additional development of the app and also for the need for additional crowd control of the records uploaded. While reviewing the data collected it can be seen that there were also records taken during the trial where the user was standing outside of the catchment. Additional coding on the back end would be able to bring in the outline of the catchment into the map view, and upgrading the code in the front end view could flag up to the user when they are outside of the catchment. This development would potentially rely on the mobile phone checking its location (so needing to be in signal area) compromising one of the most important elements of the RiverEYE app; simplicity of offline use.

6.5.2 Did catchment characteristics play a part in the success of the project?

Two key factors influenced the success of this citizen science project with the River Waveney Trust volunteers. The first was the existing network of volunteers who are active in the catchment as part of working parties or educational activities. The second was reasonable access for the volunteer working parties using the network of footpaths and roads meaning greater chances of problems being spotted and the ability of volunteers to safely record those problems. This is in direct contrast to some of the North Norfolk rivers which are deeply incised, narrow and run through mostly private land.

6.5.3 Benefits to adopting citizen science for catchment organisations and the barriers to adoption

The RiverEYE app enhances the collaboration between a range of agency and practitioner groups on the ground (to survey and to monitor) and engages people in the processes of delivering a healthier catchment environment. Discussions with the River Waveney Trust and other river trusts imply that a citizen science smartphone app such as RiverEYE could be used within catchment management in several ways, meeting all four of the positive elements set out by the Government PostNote (2014b). Meeting the second and third advantages of citizen science the discussions with the RWT highlighted both the data collection potential as well as the scalability of this product. River trusts rely heavily on their networks of volunteers, these volunteers need to feel valued; and their efforts to report problems that they see need to be recognised. A tool like RiverEYE supports the public engagement which river trusts carry out in both rural and urban areas, with a better developed web portal the activity of project(s) could act as an incentive for more people to get involved (Tweddle et al. 2012).

RiverEYE was designed to collect data on various scenarios which river trusts and catchment partnerships have to deal with. Most of these scenarios focus on negatives such as those on the dirty dozen visual prompt developed for the RiverEYE trial. Feedback from the River Waveney Trust volunteers who took part in the month long trial and an Environment Agency catchment officer raised the question of whether RiverEYE could be used to report *positive* information for protecting and enhancing ecosystem services within our catchments. Ideas suggested were places people like to visit or positive features along the riverbank which have no designation so that Environment Agency operation teams can take these into account when carrying out river bank maintenance. This is an area worth further exploration – and indicates that the potential of the process can highlight cultural ecosystem services as well as those more commonly associated with rivers such as provisioning and regulating.

Despite the evident potential of this citizen science approach there are three barriers to the adoption of RiverEYE as it stands. The first is financial, appreciable resources must be found for funding for a hosted solution which has been further extended to become multiplatform with improved authentication and to provide support for future handset upgrades. Second there is a requirement for organisational level training in protocol design and spatial data management; with a better central platform river trusts could have more than one iteration of RiverEYE for different projects, for example versions for specific monitoring projects vs a catch all for the state of the environment. The third identified barrier to widespread adoption is the management of data collected. The RiverEYE app was met with enthusiasm, but very quickly questions began to be asked about the way in which this data would grow, and how it could be managed with little or no spare resource for data management.

> *"This is great, this app, I can report problems about any stretch of water. Or indeed any park or woodland. Can I ask though what if I see it as a problem but someone else doesn't? What happens to my data once I've collected it? Where does that information go? How does the database know who to tell about the problem I have seen? How do I find out when it (the problem) has been resolved?"* (Anon event attendee, pers. comm., 08/11/2014 less than five minutes after being shown how to use the mobile phone app).

One solution might be the use of a crowd managed database where users who knew the system well would earn points and become power users, able to push up the priority of important records to those who needed to deal with them. This manner of crowd managed databases means that there are usually sufficient people on hand to deal with or remove offensive inputs. Another solution proposed was to embed intelligence within the database with certain problem types being automatically directed into those organisations reporting systems. This would introduce many and varied elements of data interoperability between various reporting systems of external organisations. While these could be overcome the security needed to be a part of those data warehouses may be outside of the capability of the river trust at this stage. Either way – the process of managing the data which will be collected needs to be determined proactively rather than reactively. This study supports known concerns of the analysis of the data which is gathered and the ability of organisations to make use of this data intelligently (Haklay 2013).

6.5.4 Improving the project – extending the functionality of RiverEYE

Section 6.3.1 describes the single form layout (Fig. 6.3) of RiverEYE, each question the user was required to answer was independent of the answer to the previous question. One area of improvement from the feedback workshop was the requirement to have the option to collect more data (such as more photographs) if the situation warranted it. Thus some exploration of integral decision trees was deemed to be a benefit to increase the versatility of the smartphone app and investigate whether it was possible improve the resolution of the data without increasing the number of questions the user had to answer. This would make the app more appealing to river trusts and catchment partnerships who, based on feedback from the WRT trial, would want to customise the app to suit their own data collection.

Engaging with the Wensum Demonstration Test Catchment project (Wensum Alliance 2015) provided an opportunity to explore the wider versatility of the EpiCollect+ system with a more complex version of RiverEYE called LandEYE. The hypothetical aim of this exploratory study was to consider the issue of sediment movement with potential users being farmers, land managers, agencies and DTC researchers in the sub catchment. The structure of the LandEYE app was kindly reviewed by the DTC principal investigator who contributed expertise in posing likely questions which would be of relevance and specific to monitoring sediment movement.

In order to build the series of questions a better understanding of the landscape had to be gathered, variables such as crop types, farming practices and weather were identified and listed as drop down menus. The decision tree can be seen in Fig. 6.18; there was a significant overhead in setting up the questions, and testing the combinations to ensure validity. Based on the phone user's observation an answer was selected, the answer then determined the next question the user would see, users however still only had to complete a maximum of ten questions. The initial setting up was more complex than the RiverEYE app, as the protocols for the decision tree had to be carefully mapped out before beginning the design of the form online. Development of this level of functionality required greater expert knowledge and a longer period to test however it did indicate that there is significant potential for this type of citizen science tool to collect a wide range of data customisable to the needs of a project.

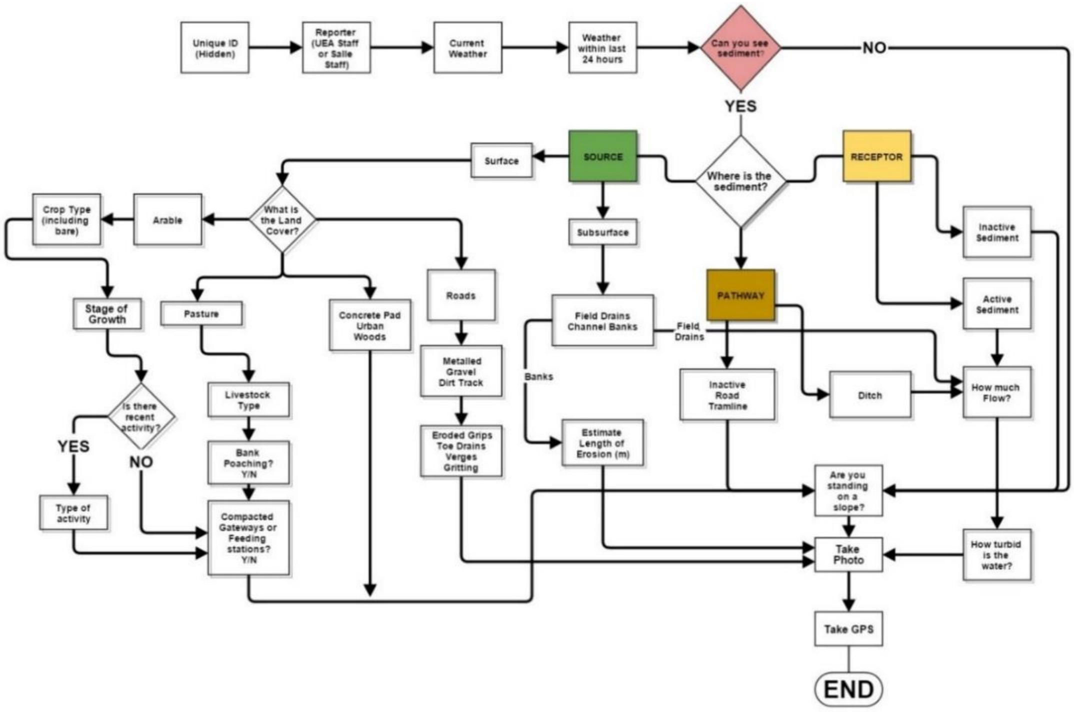


Fig. 6.18 LandEYE - a schematic of the complex decision tree

6.5.5 Actor Network Theory application

Actor Network Theory allows the exploration of the many components around river management and so it has been applied to the RiverEYE study. By mapping the networks which exist, the influences within and between institutions can be evaluated and external factors identified. The words in the following italics are those taken from Latour, Callon and Law; the original proposers of ANT (Law and Hassard 1999).

First attention must turn to those who take part as river trust volunteers (can be thought of as *actors* working within a *decentralised network*). Within the research trial the backgrounds of the trust volunteers were diverse in age, motivation and experience. Although now retired some of these *actors* have spent years as engineers working for the Environment Agency or the Internal Drainage Boards; others have a practical farmer and agronomist background. There are those for whom the recreation potential of canoeing or angling have led to their inclusion, young college students and the retired also play an active role as do teachers and residents. The chairman and volunteers (who are also *actors*) manage the headquarters at Earsham and act as a focal point or *centre of calculation* for the reports gathered by the volunteers. Despite their different *skills* these *actors* together form a *network* which fulfils the aims of the River Waveney Trust.

Turning these *actors* into human sensors can be done with the use of a new *intermediary* like RiverEYE. RiverEYE has a front end to collect data, and a back end which enables analysis and intelligence to be gleaned from the reports. RiverEYE might also be considered an *actor* with its on-board GPS, camera and ability to transmit data to the *centre of calculation;* it brings the existing network closer together and makes it more efficient. With RiverEYE having a tightly controlled set of data standards the data submitted by the *decentralised network* converges with the *centre of calculation*. The *actors* at the *centre of calculation* carry out a number of other important roles such as guarding access to the data which has been submitted (for example with regards privacy for records collected of agricultural practices) and evaluating the spatial and temporal data which has been submitted to look for patterns. The River Trust HQ (as a *centre of calculation*) then *translates* this data to share with other *distant entities* such at other river trusts, agencies such as the water companies, Environment Agencies or the Catchment Partnerships.

An ANT approach offers an opportunity to interpret these relationships in terms of their evolution over time. Within the case study actors interacted with RiverEYE and the data collected during the trial in forming opinions and potentially improving river management. Through the use of ANT it is possible to see that over time volunteers are being given a greater say in terms of the river management compared to the previous reporting mechanisms. RiverEYE both increases the types of knowledge production and enables knowledge dissemination as a result of the interaction of these actors with other institutions and their intermediaries.

In this case study, the use of ANT in evaluating the processes within the catchment citizen science project suggests that the influence exerted by the RiverEYE *actor* is disruptive and influences the social and organisational structures within the network including the *centre of calculation*. The use of ANT to evaluate the relationships between the actors using RiverEYE suggests that a move to a co-production of data by communities of users and the adoption of big data principles (PostNote 2014a) is required; it is not enough to just collect the data, the way in which this data is analysed, released and used to inform policy must also be considered from the outset. The barriers which exist to implementing this type of citizen science app relate to the technological development, resources and organisational structure. In conclusion technology facilitates spatial solutions for catchment scale monitoring and reporting; but for these to be used effectively to their full potential both the organisation and the setting(s) in which they are employed must be considered. Since the case study trial was completed, a version of RiverEYE is now in use by Zoological Society London for a catchment walkover survey on the Crane in London. This is a good example of evolving coproduction of knowledge being facilitated by a spatial technology. Gathering catchment walkover data on sewage outfalls was until relatively recently a statutory task carried out by government agencies. Driven by policy change and reducing running costs the Environment Agency is becoming receptive to catchment groups submitting data on water quality, and the volunteers are able to contribute because technologies such as RiverEYE allow standardisation of data. By bringing together all those actors in the catchment this is an example of coproduction of knowledge in a prearranged format which is useful to those who are ultimately responsible for the management of the catchment, enabling a more participatory way of discussion, participation and creation of new knowledge such as that also found by Maynard (2013).

6.5.6 Improvements to the process

This case study was carried out at short notice hence the minimal number of volunteers taking part. To improve the study it would be interesting to have a longer lead in time to assess whether there would be an increase in the number of participants. It would also be interesting to further evaluate whether the influence of catchment character and access have an effect on the quantity and quality of data collected. Overall the training went well, although further input is needed around the hierarchical training of volunteers; while the users had fun they did not all clearly understand the purpose of the project (Section 6.4.1) leading to data inaccuracies. An area where the data could have been improved was the subjective reporting of the impacts of issues on ecosystem services across the catchment. While there was some correlation between the problem types and the ecosystem services affected there was less consistency by users who it seems followed their own interpretation of the impacts on water quality, quality, river health and recreation. Volunteers who took part in the project wanted to be involved from an earlier stage, and be able to contribute to the type of problems which they felt should be reported. It would be interesting to note whether a catchment character changed sufficiently over the length of the river channel to merit different problems for reporting in different sections of the catchment.

Technologically speaking it would be interesting to assess whether the use of small phones limited people's enjoyment and engagement of the app and the process and whether larger brighter phones increased peoples engagement. It would be worth evaluating in more detail whether people would load data using the web form, and the role that this could play in citizen science at a catchment scale. Feedback around the design of the form (collecting the photograph was at the end of the record entry) was critical suggesting the photograph should be the first thing recorded and that there should be the option to collect more than one image. This could be easily done. Another suggestion was that there should be an 'other' category to encourage people to report problems without disengaging them from contributing through lack of knowledge when starting to use the app. While this would be of benefit to users beginning to report problems it increases the likelihood of non-specific entries increasing the data management overhead of sorting images once loaded to the database.

Interest from river trusts and catchment partnerships indicate that there is a real world need for this type of app for catchment management. The information gained from the RiverEYE evaluation with the River Waveney Trust will directly improve the process for the other river trusts who have registered interest in a product. Training will be enhanced by the information that people need to move away from the main channel and to look at the smaller tributaries and waterways around the catchment (depending on the topography), users need reminding to visit stretches regularly rather than just at weekends and that the low cost and lightweight phone works sufficiently well without a large outlay on expensive equipment.

Reflecting on the role of the social and technological interface it would be a valid exercise to establish what degree of hierarchy and experience is needed for a group of users to process the data which is collected by volunteers on the ground. There is interest by volunteers to find out information about the problems that other areas of the catchment suffer, and to gain a more joined up understanding of the whole catchment rather than their immediate vicinity. Different catchments develop different protocols, some have an ad hoc reporting and other implement a structured beat based process; would the citizen science approach support these approaches equally? Other river trusts will be encouraged to follow the same stages in developing their citizen science projects – most importantly clearly stating the aim of the project and gathering only what is needed will cut down on the overhead of data management.

6.5.7 Barriers to the implementation of a citizen science approach to monitoring

Results from this case study propose that the citizen science approach is well supported by the technology which has shown to have a significant amount of potential. Barriers however exist which are shown in Fig. 6.19. Critical to the success of a citizen science project is the recruitment, both at the start and during the project life cycle. The means of retaining citizens in projects include regular feedback of the data which they contribute, such as the easy to use data analysis webpage in EpiCollect+, and by connecting with other projects and organisations. Some members felt that the subjects they felt most important within the catchment had not been clearly communicated and that they would have preferred to have a greater role in the type of data which was collected. Feedback from users in the trial agreed on the need to maintain a clear focus for the app subject matter; for example to avoid collecting data on species recording where plenty of other apps exist. Again, this is related to the requirement to assess user expectations within the development phase. Ensuring that the data collected is representative of the issues within a catchment was seen by both the stakeholders and the management as critical, requiring a shift from a collaborative citizen science project to a co-created approach (Tweddle 2012 p 4).

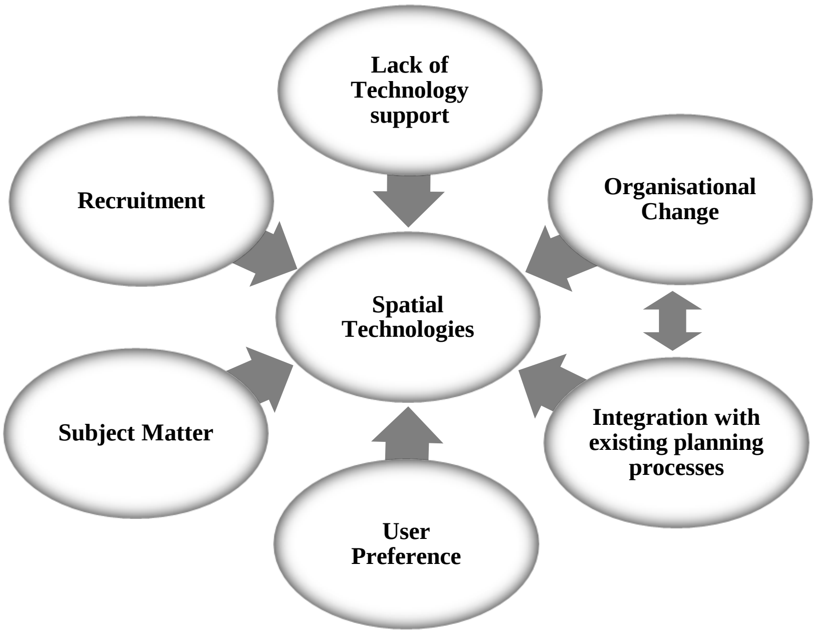


Fig. 6.19 Barriers to the adoption of VGI and Citizen Science

The paramount obstacles for the adoption of this technology by river trusts and catchment partnerships relate to the technology itself and the management of data collected. In particular the lack of support for further technological development at a national level, the lack of resources which the river trust has access to comprised what is required to set up a VGI project and the lack of expertise in developing protocols to integrate the technology with existing planning processes. While the growth of mobile phones has continued since the first case study (Chapter 4) many areas of rural landscape remain devoid of mobile data coverage introducing the requirement for apps to have the functionality to store data and synchronise adding to the complexity of the protocol that the citizen science must follow. When relying on smartphones for data collection there is the additional risk that high app turnover, high development costs and the alienation of some sectors with less access to smartphones will occur. User preference from the workshop indicated that not all users would want to use technology for reporting problems, and that some would prefer to use the web or the old protocols of telephone or email necessitating a means to maintain rather than replace these pathways to prevent some sectors being unable to contribute. An unexpected hurdle to the implementation of VGI by river trusts in supporting CaBA is the disruption to existing organisational structure particularly with regards management of the data collected. Concerns remain following the study around of the use of data which is gathered and the ability of organisations to make use of this data intelligently (Haklay 2013).

6.6. Conclusions

6.6.1 Are there constraints on the types of observations which river trust volunteers can be asked to report on? Can the design of a citizen science smartphone app assist with mitigating these?

The users of RiverEYE were asked to record the observations which they made within the catchment by completing fields in the smartphone app (Table 6.1). These can be summarised as objective (the problem type) and subjective (how the problems which they reported affected ecosystem services in the catchment – specifically water quality and quantity (flow), habitats and recreation). The evaluation of the data from the RiverEYE app shows that river trust volunteers who took part in the project were able to correctly evaluate the impact of a range of problems on ecosystem services within the catchment despite not being trained explicitly on this variable and the visual prompt containing no guiding information. The use of this variable usefully highlighted;

a) The importance of good form design in allowing or restricting users to choose just one or a random number of answers;

b) The power of the citizen science app is dependent by the quality of training and/or supporting materials which are provided.

This is most critical for catchment organisations to take on board; if sufficient supporting materials are provided then there is no reason why volunteers could not report on any observations required across a catchment. Catchment organisations also need to understand the consequences of how the form is designed upon the quality of the data which they will have returned.

6.6.2 By utilising the principles of volunteered geographic data does a mobile citizen science app have the potential to fill the resource gap faced by catchment organisations?

The case study trial with the RWT indicated that the EpiCollect+ platform worked well to collect a range of data types for catchment projects. The customisation of the app was straightforward and could be done with little need from outside help as long as a collaborative approach was taken between the scientist and the data collectors. It was important for the data collection forms to remain specific to the catchment project in hand rather than try to be a catch all. The app was viable in remote rural areas, data signal is only needed to update the project design or to synchronise reports which have been collected. The RiverEYE project would have collected more participants and thus more data had it had a longer lead time into the trial. There would have been a benefit to being able to run a pilot beforehand. It would have been interesting to compare the process with the same app in other catchments to evaluate whether the visibility of the river within the catchment or the engaged membership were most influential in the success of the project. It would also have been interesting to see if volunteers using the app would have been more active at other times of the year, whether a more diverse background to the users increased the number of reports and whether allocating beats would have increased the engagement.

Analysis of the technology and qualitative analysis of workshop sessions revealed potential real world application of the tool although additional work is needed to enable the data to be intelligent enough to be of use. Use of a structured form and on-board GPS minimises user error (two main errors in VGI). The initial analysis possible via the web portal was explored at the wrap up session and met with positive reactions supporting the need identified by Pocock et al. (2014) to keep volunteers informed. Further trials with users on the interface of the web portal would be interesting as would redeveloping RiverEYE with a single sign on and tiered administration structure to promote better processes behind crowd management of data. For a citizen science project to be a success (i.e. create and manage a dataset which covers sufficient area) a good network with the wider community is required. The size of this network is not directly proportional to the size of the spatial area being managed but rather to the aims of each individual citizen science project. For example, to collect all the silt flow across the entire Waveney catchment over one bank holiday weekend would require vast people resources, but the monitoring of all footpaths which cross the river over a six months period would be less. Thus scoping of the resource gap and the project are key factors in the success of the citizen science project.

RiverEYE was designed to collect data on various scenarios which river trusts and catchment partnerships have to deal with. Most of these scenarios focus on negatives but the question of whether RiverEYE could be used to report *positive* information for protecting and enhancing ecosystem services within our catchments is worth further investigation. In conclusion it can be said that the use of citizen science within a river trust organisation has significant potential to fill the resource gap which so many catchment organisations are facing over the next five years and it is worth further exploration as to how the findings from this case study can be rolled out to this group of organisations.

However; barriers to the adoption of this technology do exist. Although this case study was run only over a short period of time sufficient feedback was gathered to indicate that there are six critical barriers which anyone seeking to VGI to support CaBA should consider. While funding cycles continue to be short term and while little money is set aside for monitoring implementing a VGI solution is outside the control of all but the largest river trusts or those with access to technological expertise amongst their volunteer base. The lack of technology support at a national scale for enterprise data collection and management along with the difficulties in accessing financial resources for set up and maintenance remains a significant obstacle. User preference for the design of the app, the subject matter which is included and the protocols for ongoing recruitment to the project are all vital elements of the early stages of designing a successful VGI app. Finally, the influence of VGI on organisations and the degree to which new VGI drive protocols can integrate with existing planning processes are two barriers which emerged during the evaluation of RiverEYE but which would benefit from further research.

Chapter 7. Conclusions

7.1 Introduction

The overarching research question in this thesis asks what technologies can be developed or adapted and made further available in order to support catchment management as a process with involvement from catchment stakeholders and practitioners in relation to relevant institutions.

The three case studies were designed to provide insight into the degree of adaptation required to make spatial tools usable by practitioners, the barriers to adopting spatial tools, and the potential future uses of spatial tools to support the Catchment Based Approach. The locations of the case studies were set within a region of degraded catchment landscapes with emerging catchment organisations where little previous research with stakeholders had been carried out. Evaluation looked at both the ways in which the practitioners interacted with the tools and the technological development itself. The methodologies retained a practitioner focus with the application of three different spatial technologies to real world catchment management processes.

Setting the thesis within the framework of the Catchment Based Approach (CaBA) has made it possible to explore the potential of the three spatial technologies to support different elements of the work which catchment practitioners are expected to carry out to meet the aims of the WFD. What has emerged from this thesis is that across various spatial scales and within different types of catchment organisations spatial technologies have much potential and are currently underutilised. At a local scale communities can be engaged with, and contribute to, the monitoring and reporting of problems improving overall catchment health. At a landscape scale spatial technologies can help engage stakeholders with the wider aims of a catchment partnership by bringing together multiple datasets from different regions with various spatial and temporal resolutions improving delivery on the ground. At all scales the use of spatial technologies can assist in aligning the management of catchment processes with existing planning processes.

Despite the potential of spatial technologies the barriers to adoption lie primarily outside the control of river trusts. While much can be done to support the use of GIS within catchment organisations, for a spatial infrastructure to be built then longer term funding arrangements which include allocated funds for monitoring must be introduced and recognition of the importance of catchment organisations in resource management for long term food and water security is required.

7.2 Existing potential of spatial technologies

Over the course of the research changes have occurred in technology, policy and organisation structure. Technology has advanced and new holistic approaches such as CaBA have been promoted by the UK Government to support catchment organisations in meeting EU directives. Integrated catchment management is now seen not only as a means of improving water quality and quality but also of enhancing a wide range of other vital ecosystem services (Smith et al. 2015). As a result there is a recognition that there are significant benefits to the use of spatial tools (particularly GIS and decision support tools) to communicate information across the range of stakeholders involved in catchment planning (Smith et al. 2015 p. 275). This section brings together the results from the three research studies (Chapter 4-6) to provide a synopsis of the work carried out in this thesis. The three technologies evaluated are shown in Table 7.1 along with a short overview of each case study. Results from the three case studies indicate that there is significant potential for river trusts or catchment partnerships to utilise one or more spatial technologies to support their WFD targets.

Table 7.1 The three approaches and case studies

Aim (CaBA)	**Engage**	**Use Data and Deliver**	**Monitor**
Technology	Augmented Reality (phones)	Desktop GIS + CommunityViz	Citizen Science (phones)
Open Source?	Yes	No	Yes
Timeframe (see Section 3.6)	March 2011 – October 2012	Late November 2012 – May 2013	Mid October 2014 – Mid December 2014
Scale	Short two way walks within river catchments	Section of a catchment	Whole catchment project
Focus	Information about catchment ecosystem services and their location in the landscape	Catchment management improvements focused on four themes to improve specific ecosystem services, data from VesAR shown for context on posters	Reporting incidents detrimental to river health and water quality. The RWT choose the issues on which to report. Ecosystem services were specific to the river and its surroundings.
Participants	Anyone – events advertised via local media	People connected with NRT, agencies and out of area	Existing WRT members
Recruitment strategy	Random sampling via local media	Snowball sampling through Rivers Trust	Direct recruitment from membership list
Research Impact	Relevance was to change the way that AR is thought to immerse people in their environment.	Brought agencies together, came up with a focused aim for the catchment. Highlighted considerable resources needed by both researcher and river trust required to run such a process	Highlighted importance of training and supporting materials in citizen science, and the data management overhead as well as the disruptive effects of spatial technologies
Comparative Element?	Yes (Phone/Leaflet)	Yes (GIS/Map)	No
Originality	100%	Visioned NRT concept	WRT selected issues
Data Origin	Millennium Assessment (2005)/National Ecosystem Assessment (2011)	Norfolk Rivers Trust and interpreted to current and future in GIS by researcher	Waveney River Trust members and then put into a visual aid by researcher

7.2.1 Reflections on augmented reality to communicate ecosystem services

This thesis asked: To what degree can mobile augmented reality be used as an immersive technology to communicate the location of and information about ecosystem services within a catchment landscape? Is the current level of mobile phone technology and infrastructure sufficient to support spatial applications in rural settings?

Chapter 4 concluded that mobile devices such as augmented reality applications on smartphones have considerable potential for communicating both the extent and nature of ecosystem services in landscape settings; the novelty of such an application will generate interest, particularly amongst experienced smartphone users. As devices such as smartphones become more ubiquitous and supporting technology such as GPS and mobile data signals improve, the problems identified in the first case study may well change over time. There are clear benefits for catchment organisations to have a means by which information can be communicated from a central point across a wide area, without risk of vandalism or damage by flooding or weather to in situ signage. Catchment partnerships and river trusts could use AR to communicate information about projects along a river, recruit volunteers and increase engagement with a catchment management programme. However the results of this study also suggest that not everyone will appreciate having their attention distracted from their surroundings. Efforts should be made to carry out further investigation into the interaction between user preference and technology; more needs to be discovered as to how augmented reality can be fully utilised as a communication tool within rural landscapes.

Explicit costs of implementing such spatial technologies are not included in Table 7.1. Evaluating the expenses incurred with the real world implementation of the technology is challenging due to the costing of resources such as staff time and data charges when academic licences are not involved. It would however be fair to say that the cost of developing and releasing a version of the Augmented Reality app (Chapter 4) is most likely to be the lowest. Resources required during the implementation of AR would include the time to condense and convert information into points of interest for the app but the open source technology would incur few software or hardware costs depending on where the data is held and whether users would be able to access the app using their own handset and any cost of skills to do this. If the data are held within content management systems used in the VesAR trial (Chapter 4) then no fee is incurred however if greater reliability and functionality is required then a paid for service may be more suitable. The Augmented Reality app was the most difficult technologically to develop at the time due to the lack of support or tutorials and reliance on user groups and poorly maintained European online discussion forums. At the time of the study restrictions in the mobile network coverage and the battery life of the phones limited the degree to which this technology could be used in rural areas although this is now improving. It therefore seems likely that while smartphone-based augmented reality could become a valuable tool for the landscape planner or designer it will not be a universal solution and to gain the maximum benefit from such technology it will be important to embed it in appropriate wider decision-making processes. In common with many other aspects of landscape visualisation there is consequently still much to learn about how to best apply augmented reality communication tools (Bishop et al. 2013).

7.2.2 Reflections on catchment scale visioning

In this thesis, the following questions were raised on the catchment scale visioning research: To what extent is it possible to adapt a parcel based urban planning GIS and visualisation package (CommunityViz) to catchment visioning? How computer do based visualisations compare to traditional paper based maps; what role does each play in the process of stakeholder engagement with future landscape change? What potential exists for visualisations to be employed for community engagement in catchment management and to what extent can a climate change visioning 'framework' be utilised for catchment visioning?

The trial of spatial technologies in the development of the management plan for the Stiffkey catchment in Norfolk UK (Chapter 5) revealed that a combined GIS and visualisation tool such as CommunityViz is very useful to vision landscape scenarios at a catchment scale and further work could explore its integration with planning processes and potential as an information hub or portal. The time taken to adapt the CommunityViz software would have been greater without the researcher having an existing high level of familiarity with ArcGIS spatial technology. Of all three technologies the best level of support (by phone, email and tutorials) was that provided with the CommunityViz software, the only paid-for product. Despite only some of the functionality being used during the trial the benefits of using CommunityViz were evident. Discussions were observed between NRT and the landowners about the whole catchment with a positive approach to changes, indicating that further evaluation of such a tool would be of value. Findings from the workshops showed that more participants preferred the high tech CommunityViz over the low tech paper maps, but many stakeholders reported that they liked both tools; their opinion was that the tools complemented each other, not only appealing to different sectors of the population but serving different purposes at workshops. With this in mind it is recommended that workshops such as these with a diverse group of stakeholders are best supported by the use of both interactive and static tools – a conclusion also arrived at by Wissen Hayek (2011). For more evidence of how visioning can support landscape management there would a benefit to carrying out a more robust lab based evaluation of how people interact with their surroundings rather than relying on self-reporting. This evaluation would have to take into account the ways in which people engage with visualisations when detached from their environment.

The visualisation process framework developed by CALP (Centre for Advanced Landscape Planning) in Canada was adapted for use within this case study (section 5.5.3). The CALP visioning framework is based upon climate change strategies and as such shares many similarities with catchment scale planning including the requirement to work over multiple temporal and spatial scales with a wide range of stakeholders. However it became evident that the CALP Framework was too complex for the short term timescale of the catchment visioning project contained in this thesis, specifically there were fewer iterations required in catchment planning. Benefits to the adoption of the adapted CALP visioning framework process alongside the CommunityViz implementation was described by the two NRT officers as 'very useful in the development of the catchment management plan'. Applying a framework to the visioning process gave the NRT a structure to follow in developing a catchment management plan at a time (late 2012) when there was little national guidance. The framework was particularly successful for the transparent allocation of responsibilities to project partners and in setting realistic deadlines from the outset of the project.

This technology had the greatest financial outlay which along with the significant resource required to develop a visioning process would probably result in it being the one least likely to be adopted for use by river trust practitioners. This however is short sighted; the technology has the greatest potential for supporting decision making within CaBA with its indicator functionality and scenario development having a wide range of applications. How often a single river trust or catchment organisation would need to carry out a visioning process may determine the value for money represented by CommunityViz. As a portal however, CommunityViz has the potential to function as a spatial data infrastructure for importing, aggregating, analysing and sharing information; offering strategic benefit to the multitude of organisations involved in catchment partnerships.

The CommunityViz software also had the functionality to change the visualisations in situ when underlying GIS datasets were edited, but this was beyond the scope of the evaluation process. While the visualisations were not to the high quality photomontage style of VNS or the scale of Geovisionary within a VR lab, this functionality means there was clearly additional potential for stakeholders to take a direct hand in determining the future landscape based on their choices. The visualisation at a catchment scale was without doubt advantageous to the local rivers trust in their development of a catchment management plan for the Stiffkey, but other aspects of participation were also noted as carrying great influence. In particular, timescales within catchment planning play an integral role as to what is possible, even using spatial technologies; the effects of the farming calendar cannot be underestimated, nor can the deadlines for permits to work around fishing and biodiversity restrictions.

Opportunities to use visioning tools continue to emerge; for example in the creation of catchment laboratories which are currently in the scoping stage by the Environment Agency (L Burgess-Gamble 2015, pers. comm., 19 May), in the increased focus of reducing floods through working with natural processes and in the continued discussions around the practicality of developing PES (Payment for Ecosystem Services) mechanisms. The CommunityViz trial was intended to evaluate whether this low cost, off the shelf software package could function as a visualisation tool; it was not assessed as an SDSS (Spatial Decision Support system) but there are three main directions this tool could be taken in:

1. **Two way evidence based communication with farmers** with inclusion of data from other land use decision tools and models such as SCiMap (Defra 2013c), extending the visualisations to reflect more scientific and technical data along with the land use data used within the case study. Areas of future work could involve the parameterisation of environmental indicators as they relate to the catchment land uses, thereby supporting farmers and land managers in developing strategies based around the trade-off of different management options.
2. **Use as an information hub or portal** using extensions to the CommunityViz software which support the creation of visualisations and contribution of information over the web by stakeholders. The true potential of this type of software in catchment management can be seen in linking tiers of governance; by meshing with existing planning mechanisms across administrative

boundaries catchment visioning could support water governance strategies used elsewhere such as the US and Australia.

3. **Basic economic cost-benefit analysis** in land management across catchments. Software such as CommunityViz includes financial reporting tools which could relate to agri-environment schemes or other financial incentives. There is an increased likelihood that a tool such as CommunityViz could support financial models and payment for ecosystem services schemes, and the ongoing need for better presentation to stakeholders.

7.2.3 Reflections on volunteered geographic information for catchment management

On volunteered geographic information, the following questions emerged: Are there constraints on the types of observations which river trust volunteers can be asked to report on? Can the design of a citizen science smartphone app assist with mitigating these? By utilising the principles of volunteered geographic data does a mobile citizen science app have the potential to fill the resource gap faced by catchment organisations and what limitations of volunteered catchment data exist?

The citizen science case study (Chapter 6) demonstrated real world potential. Interest has already been shown by several catchment partnerships and organisations following representation at several conferences, although additional work is needed to enable the data to be intelligent enough to be useful. The app was designed to collect data on various scenarios which river trusts and catchment partnerships have to deal with. Most of these scenarios focus on negatives but the question of whether the citizen science app could be used to report positive information for protecting and enhancing ecosystem services within our catchments is worth further investigation. The EpiCollect+ platform worked well to collect a range of data types for both reporting and monitoring at a catchment scale using citizen science protocols. Users were able to collect a range of observations with the supporting material (Appendix 4). When applying the citizen science approach to catchment monitoring it became apparent that spatial bias through familiarity with an area, which is considered a problem in other disciplines, may in fact be a benefit and further research is warranted. This approach is inexpensive if the existing EpiCollect+ system is used. However the time taken to develop the project and supporting documentation, engage with the participants as well as embed the processes and data collection within existing systems should not be underestimated, particularly if the citizen science process moved to a more co-created approach. To implement the citizen science case study required the lowest level of expertise in spatial technology since EpiCollect+ has a GUI front end and a simple tutorial included; the additional IT expertise required to deliver a project would vary greatly according to the complexity and longevity of the specific assignment. The customisation of the EpiCollect+ app was straightforward and could most likely be done with little need from outside help as long as a collaborative approach (Roy et al. 2012) was taken between the scientist/expert and the data collectors.

Further work could focus on an extended trial of the software, enabling citizen scientists to take a greater role in developing the app to reflect their preferences rather than focusing on a top down view. It would be useful to determine to what degree organisations could share information collected using the backend database and also whether there is a trade off in the volume of data vs the value of the data collected. Further trials with users on the interface of the web portal are required as is redeveloping the app infrastructure with a single sign on tiered administration structure to promote improved management of crowdsourced VGI data. In conclusion it can be said that the use of citizen science within a river trust organisation has significant potential to fill the resource gap which so many catchment organisations are facing over the next five years. Further work should focus on how the findings from this case study can be rolled out to this group of organisations, and meeting the need for a national framework or data model.

7.2.4 Summary

Each of the three case studies has contributed to the understanding of how catchment organisations can benefit from the use of spatial technologies. Reflecting on the use of mobile technology there is certainly a very real need for river trusts to communicate information to interested stakeholders to raise awareness of the catchment such as that in the first case study, but there is an even greater need which will continue to grow for citizen science as a resource to assist river trusts in monitoring and reporting problems. Thus day to day both the augmented reality and the citizen science apps may be of greater applicability to the work of the river trusts and the visioning process will remain the domain of catchment partnerships. All three of the technologies required some additional level of development, including the off the shelf CommunityViz GIS package. The degree of adaptation required to make these spatial technologies useable for practitioners during the case studies varied considerably, with some requiring an experienced GIS or IT professional and scoping the changes required to make them fit for purpose required good communication with practitioners and understanding of the subject matter. Resource implications also exist for example in the CommunityViz case study (Chapter 5) where the overhead of data management was significant.

The use of supporting visual material was found to be critical for those taking part in the case studies, particularly to ensure that those attending understood the issues being reported and so improving the validity of the evaluation. The design and production of supplementary materials which went alongside the spatial technologies, e.g. the leaflets in Chapter 4, the posters in Chapter 5 and the A5 visual prompt in Chapter 6 was also time consuming, placing greater pressures on those wishing to carry out such work. The timeframes of the case study evaluations varied due to the need to work within the constraints of weather, catchment funding cycles and practitioner projects. The first and second case studies involved a degree of comparative evaluation although this was not applied in the last case study and it would have been beneficial to have a means of measuring the success of the reporting mechanism against existing processes.

The research in this thesis has been presented at a number of practitioner conferences over the duration of the study. The outcomes of Chapter 5, visioning to support catchment futures were presented at the River Restoration Conference in 2014, feedback focused on the affordability of the software for catchment organisations who were increasingly turning to open source spatial technologies to save money. The outcomes of Chapter 6, the means by which open source apps can support the vital role of monitoring using VGI techniques were presented via a workshop at the River Restoration Conference in 2015 and included in the closing statements of the conference. Feedback on the VGI tools was overwhelmingly positive with river trusts wishing to know how to implement this type of software for their own projects. It was apparent that the role of monitoring was crucial to building evidence of current catchment issues, demonstrating the impact of projects already implemented, and securing further funds. It was also clear that river trusts were adopting disparate solutions to the monitoring problem, particularly when some projects do not show their full benefits until 5-10 years after their completion.

7.3 Barriers to adopting spatial technologies

Despite GIS being described as 'particularly useful' for both reviewing and communicating the location of current issues and future solutions, the availability of GIS and spatial expertise is not a given for catchment organisations (Smith et al. 2015. p. 228). While the potential of spatial technologies has been demonstrated above, barriers to adopting these at a practitioner level were identified; in particular the technological restrictions (Chapter 4), resources required (Chapter 5) and the disruptive influence of technology on organisational structure (Chapter 6).

Barriers include the resources organisations require to be able to translate subject matter into a form suitable for display within spatial technologies and consumption by their intended audience. The technology itself can present a stumbling block; costs involved are not limited to software and hardware but also the expense of technical expertise and appropriate, reliable spatial infrastructure. The performance of the chosen technology and whether it is fit for purpose is another barrier, one which influences, and is influenced by, the users who are inherently another barrier depending on their existing familiarity with, and expectations of, the spatial technology. Table 7.2 summarises the results of the three case studies; those represented by a solid circle indicate a barrier to practitioners adopting that spatial technology; hollow circles represent those which should be seen as important considerations to be assessed prior to future implementations but which were not a barrier within this trial of the technology. Barriers are not ranked in order of importance although it is clear to see that the GIS and Visualisation application has many more barriers in comparison to the AR study. None of the barriers identified are insurmountable obstacles in their own right to practitioners wishing to adopt spatial technology. It is the combination of them, together with the lack of long term funding and lack of evidence at a practitioner level for their successful use in the context of catchment management which are the greatest impediments to their adoption.

Table 7.2 The barriers to (filled circles) and considerations for (hollow circles) adopting spatial technology

Barrier	Augmented Reality	GIS and Visualisation	VGI and Citizen Science
User Preference	●	●	●
Subject Matter	●	●	●
Inadequate Technology Support	●	●	●
Performance and Reliability	●	●	○
Organisational Change		○	●
Evidence for Adoption		●	
Recruitment		○	○
Integration with existing planning processes		●	○

User Preference

Across all three case studies user preferences influenced both the reception of the subject matter and the expectation of the spatial technology. The almost contradictory nature of the feedback comments within the AR study indicate that there is more research required on the way people interact with visualisation tools in situ, and establishing which of the factors identified by Nicholson-Cole (2005) have the greatest bearing on the uptake of a tool such as VesAR. With CommunityViz, user preferences again influenced stakeholder engagement with the subject matter and interaction with the two tools. During the workshops the computer tool was operated by a GIS Facilitator whereas the maps were freely accessible; had participants been asked to operate the computer tool it is likely user preferences on favourite tools would have been more evident in the results. What was evident from the comparative evaluation in the AR and the CommunityViz case studies was the complimentary functions provided by different tools. While no comparative evaluation was carried out in the VGI case study, feedback from the workshop indicated that not all users would want to use technology for reporting problems, meaning that to maintain contributions from all stakeholders would require different tools. Bishop et al. (2013) concluded that sometimes user preferences are for a tool which gives inferior result, thus adapting preferred techniques to make them more effective and discovering more about why a tool has been chosen is important. Future research should explore variables such as training, design, supporting materials and subject matter, which were shown to influence user preferences. Results from such studies could be used to investigate and improve the take-up of technology across different groups.

Subject Matter

The successful deployment of all the spatial technologies trialled was influenced by the communication of the subject matter to the intended audience. The subject matter in the AR case study was commented on both positively and negatively indicating that this barrier is made up of several variables such as adaptation of the subject matter, the experience of the person interpreting the information, the recipient preferences and to a degree the capacity of the technology to display the information as intended. Based on this feedback considerable time was spent during the process of planning the visualisations with the NRT, refining technical and scientific information into a format that all three of the different stakeholder groups would be able to engage with. Distilling the technical and scientific information needed to give credibility to this type of visioning into accessible language while maintaining sufficient detail was challenging; this was mitigated in part by the development of A3 posters which assisted in communicating background knowledge for those less familiar with land management practices. With the VGI case study a double sided A5 leaflet (Appendix 4) provided visual reminders to the participants and feedback indicated this was sufficient, and indeed essential for understanding the data to collect. Here the use of clear supporting materials assisted in the communication of complex ideas, whereas the lack of supporting information in the AR study could have influenced the clearly defined preferences. Carrying out a pilot study with a representative sample of the intended audience before releasing spatial tools and providing adequate supporting material will help indicate whether the information within the technology is being correctly communicated.

Inadequate Technology Support

All three case studies required technical expertise in the use of GIS and data management. Lack of access to these skill sets within the river trusts organisations is unlikely to alter without changes to funding availability and spending criteria. This barrier is the one most outside the control of individual river trusts and catchment partnerships; throughout all three case studies there was a clear lack of expertise within the partnership organisations in developing solutions, data management and application of best practice. The lack of longer term technological support for spatial technology to be rolled out on a wider scale by river trusts or catchment partnerships remains a barrier, relying as it does on resources unlikely to be found within these organisations and the lack of a nationally accepted spatial infrastructure and data models. In particular, concerns remain around of the use and ownership of data which is gathered and the ability of organisations to make use of this data intelligently (Haklay 2013). Insufficient future planning, due in part to funding cuts experienced by the umbrella organisation (Association of River Trusts), has resulted in many river trusts devising their own method of data collection and spatial solutions. This has resulted in inconsistency and a missed opportunity for a valuable national database to be developed, the existence of which could provide cross catchment learning opportunities, evidence of cost effective projects and long term monitoring of the water environment.

Performance and Reliability

Separate from the development of the technology, the performance of the technology against expectations is another barrier identified particularly in the AR and CommunityViz case studies. The participants in the AR trials commented on unreliability in the more rural landscapes, which had poorer signal quality, as well as the difficulties of using hardware both in wet weather and direct sunlight. Users commented on the need for better design of the app, specifically that the text was too small, the symbols for different service types were not clear enough and there was a need for a proximity alert to prevent the user having to continually focus on the screen in case information was missed. The performance of the technology in terms of reliability and functionality is an area where developments have already moved on in software, hardware and the mobile internet coverage in many rural areas; and the intended rollout of 4G networks in the UK should improve the data coverage further.

It emerged during development that CommunityViz was unable to vision the whole catchment at high levels of detail without adversely affecting interactive performance. This trade-off in the performance of the technology with the level of detail is a general issue that has been identified for some time (Appleton et al. 2002), and here it has an impact in the suitability of this particular piece of software for working across much larger catchments. While technological development has not removed this issue it has raised our expectations of what detail of visioning is available across varying scales. This may well be seen as a barrier to adoption given the level of detail that the stakeholders reported as being useful to report specifics of the catchment character. Any future development should evaluate how the scalability of the GIS can be maintained within the functionality of the visualisation tool. Solutions are varied, however it would be worth exploring use of different GIS base layers, efficient use of pyramids in rasters, and improved graphics capability of the desktop computer to ensure that the adaptation is fit for purpose.

Organisational Change

The trial of the augmented reality did not seek to change or affect organisations, acting only as a one-way communication tool for engagement, but the other two case studies concluded that to successfully implement the spatial technology (CommunityViz and VGI) some degree of organisational change needed to occur. This requirement for organisational change was an unexpected barrier in the implementation of spatial technologies to support the Catchment Based Approach. In the VGI case study the use of technology was disruptive to the internal organisational structure and reporting processes particularly with regard to management of the data collected. To a lesser extent the visioning process carried out with the Norfolk Rivers Trust also required a change in existing internal processes by gathering a wider range of stakeholders than usual to take an active role in the catchment planning process; had the visioning framework been followed much more stringently with stakeholders being involved from the first stage then this may well have been more of a barrier. The impact of technologies on organisations can be evaluated before development using Actor Network Theory (ANT), ensuring organisations understand the impact of the technology and the way in which they may have to change will improve the feedback gathered from stakeholders although it may prevent some organisations unable to change from adopting this spatial technology. The application of ANT in has been useful in providing the means to focus in more detail on the relationships between social and technological actors. It has therefore provided a means to understand how technologies are used, their impact, and possible barriers to further adoption.

Evidence for Adoption

The lack of evidence that spatial technologies are beneficial to the aims of the trust or catchment partnership for stakeholder engagement remains a barrier to organisations committing resources to adopt them; particularly amongst smaller river trusts. At the time of the case study few frameworks existed for developing visioning at a catchment scale; since then some have emerged (Winn and Brocklebank 2013; Westcountry Rivers Trust 2013) but there is little practical evidence of these in use, particularly as the availability of GIS and spatial expertise is not a given for catchment management programmes or organisations which take part in them (Smith at al. 2015).

Recruitment

As reported by the UKEOF Guide to Citizen Science (Roy et al. 2012) an acknowledged barrier to implementation and ongoing success of a citizen science project is the recruitment of volunteers. This is a particular problem where training has to be given to take part, as retention of trained volunteers is even more important. In addition the success of a project over a large area relies on sufficient volume and distribution of volunteers to collect data. While this is of particular relevance to the VGI study the recruitment of sufficient stakeholders to take part in the CommunityViz case study run with the NRT was also challenging. Proven means of retaining citizens in projects include regular feedback on the data which they contribute, such as the easy to use data analysis webpage in EpiCollect+, and by connecting with other projects and organisations.

Integration with planning processes

Related to the influence of spatial technologies on organisational structure was the degree to which the technology could integrate with existing planning processes; in particular any development of CommunityViz as an information hub within a catchment partnership should evaluate the degree to which it is able to integrate within existing planning processes such as the development of neighbourhood plans. The lengthy timeframe of a visioning process is also a potential barrier to adoption with river trusts and catchment organisations constrained by funding cycles and local planning timeframes. Depending on the focus of the stakeholder engagement, consideration must be given to the constraints of the farming year; this is particularly important where an iterative process is required and stakeholders must commit to several sessions. With the VGI project the potential integration with existing planning processes was far-reaching, with the technology potentially being able to share data with the catchment partnerships, local authorities and private water companies.

7.4 The future of spatial technologies

The potential for spatial technologies to support Catchment Based Approach can be summarised into three areas; for communication, as an information hub or decision support system with visualisation functionality, and for reporting and monitoring. The future adoption of spatial technologies to support the catchment management approach is to a degree likely to be dependent on the funding arrangements which occur over the next five to ten years (see Section 7.6).

While the handheld devices used in the first case study performed poorly in wet weather and bright sunshine the advent of Oculus Rift, depending on whether Oculus Rift can be used in wet weather this lightweight VR headset could facilitate innovative means to fully immerse users with future changes to their environment in situ. During the first case study the lack of available mobile 3G data coverage was a hindrance to the use of the technology. However with the European Commission predicting the rollout of 5G by the year 2020 (EC 2015b) there will be a greater potential for augmented information to be used as Lange (2011) predicted to increase public participation in a wide range of planning mechanisms. It is not however known what availability for 5G will be in rural areas. The need for 5G is being driven by development such as the 'Internet of Things' (where objects can be sensed and controlled remotely across computing networks) and the need for a more energy efficient network which facilitates the joining up of devices and users with the physical world. While the concept of the 'Internet of Things' has been mooted for some time it is only now that the technology exists to develop protocols on a global scale; however the process is expected to generate vast quantities of data increasing the need to develop storage solutions alongside the 5G technology to index and interrogate data collected.

With the cost of visualisation software reducing and the increase in computing power and internet bandwidth in rural areas it is likely that as data about the environment increases it will become increasingly possible to disseminate this as information to inhabitants via a portal. There are however, resource implications (and potential bias) in summarising data into more easily digestible information. Adopting an information hub where users can find their location and access data stored in the cloud which had been input automatically by a range of organisations could increase feedback on future planning changes and influence behaviour change such as buying local food (Allerton) or using less water (such as in the Kennet). The management of data for systems such as this is likely to remain an issue in the future as the amount of data collected increases exponentially. In discussing the adoption of technology by citizen science programmes Newman et al. (2012) correctly predicted that emerging technology would streamline data collection and processing, automate quality control checks and also improve communication between citizen and scientists. While these have been seen to have occurred within the study of this thesis moving forward citizen science will also be influenced by the improvements in the 5G technology allowing a wider range of media data to be captured by those in the field and submitted to the umbrella organisation. Adopting the smart city approach organisations must adapt to managing data intelligently, working with other organisations to share information (EC 2015b). As open source and cloud computing storage mechanisms grow this will reduce the costs of data storage further; however it remains to be seen how some of the current issues with citizen science such as volunteer retention will evolve in the future, and how with the increasing technification of the citizen science process whether all sectors of society will be included.

7.5 Future evaluation

The methodology for the first case study used a quantitative design taking a comparative evaluation approach to investigate the influence spatial technology has on learning about the environment in situ. Despite widespread advertising, linking up with existing projects and incentivising to increase attendance at the events it became evident during the pilot stage that the problems Bishop (2013) had identified with gaining sufficient numbers to statistically evaluate visualisations were becoming apparent. Even after recruitment, response numbers were affected by a wet summer which prevented sessions being run; those which did run were occasionally called off part way through as rain affected the screen response. It was therefore not possible to explore some additional variables which may have influenced the participant's interaction with the mobile phone application, which is particularly disappointing given it became evident that one important aspect of the use of spatial technologies was the relationship between the performance of the technology and the user's existing preference. To improve data collection the format of the sessions was modified to include a debriefing stage after participants had completed the questionnaire, which was shown to be successful at increasing the amount and depth of feedback. The data collected from these smaller groups began to take on a more qualitative form, with oral feedback providing insights to the use of AR spatial technology. Overall, the research methodology to recruit participants to the first case study surveys could have been improved, and this should be reviewed in any further studies of this type to ensure sufficient numbers for analysis. In particular, it would likely have been better to incentivise each person rather than offering one reward through a draw, and to have a defined focus for the walks, rather than simply advertising them as a chance to discover nature's benefits.

The adapted CALP framework and the adaptation of CommunityViz were designed to be replicable and initially a comparative study methodology was drawn up which intended to assess the planning processes with the support of the visualisations against a similar planning process in another part of the region which was using more traditional decision making methods. Constrained by the requirements of two real world projects and the farming year, the timeframe became too challenging to manage and focus was instead placed upon the Stiffkey study. The focus groups which took part in the study were small as predicted by Bishop et al. (2013), and this reduced the volume of data which could be gathered about the interaction between the participants and the visualisations. With the locally focused visioning process carried out with CommunityViz (Chapter 6) it was deemed unnecessary by the NRT to continually recall participants to review the normative scenarios which had been created. Had the catchment been bigger or had less been known about the state of the environment and the issues in the river then it would have been more important to ensure longer term recruitment through existing partner organisations. Future research could build on this work by recruiting catchment partnerships for a longitudinal case study (Bishop et al. 2013). Catchments within the study should reflect the diverse land uses and issues which affect catchment strategy across the UK, in particular looking at ways of embedding the visioning framework with existing planning processes which could provide long term funding solutions to develop sustainable future landscapes.

The VGI case study was short and took place during less than ideal weather; it would have benefited from a pilot stage and also a longer trial although the training and feedback workshops worked well. The VGI trial evaluation would have benefited from a competitive element with some volunteers using the app to report problems and other using the existing methods. The case study evaluated only the technology itself for collecting data but it became apparent that more needs to be discovered about how catchment organisations and people can adapt to manage and use VGI data. It could be possible to ask volunteers to fill out a survey using the app for feedback on the usage which could collect useful information on the user preference and technology interactions however the bringing together of users in a workshop was vital to sharing ideas.

7.6 The changing role of catchment organisations over the next five years

Water resources will continue to remain a key challenge for governments with the combination of population growth, urbanisation, and climate change; mechanisms must be adopted which facilitate stakeholder engagement in water resource planning (OECD 2015). Technological advances have assisted particularly with the adoption of online communication to facilitate collaboration such as in work by Pettit et al. (2007), who encouraged stakeholders across a wide spatial area to contribute feedback on a visualisation presented via a webpage, and projects such as the Wensum Alliance (Wensum Alliance 2015), which have used Google Earth to disseminate catchment based information.

7.6.1 Governance and funding

For the government funders of the Catchment Based Approach within England (DEFRA, EA) there is currently great uncertainty regarding the scale of funding they will be able to provide over the next five years. Government organisations will increasingly demand that catchment organisations seek funding sources other than public monies, a perspective noted by Smith et al. (2015). With the increase in the number of parties involved with catchment management government agencies are too under resourced to be able to evaluate the success or failure of every project and partner and so a hierarchical framework for now remains essential (Smith et al. 2015) along with some form of legislative approach. While technical expertise within DEFRA and the EA should continue to be available to river trusts through the mechanisms of catchment partnerships, some form of accreditation must be introduced to encourage the catchment management sector to begin to regulate itself. This is more likely to happen where river and catchment restoration projects incur greater risks to the water environment and human infrastructure (for example where flood walls are removed and wetlands are reinstated).

While there are mechanisms (PES or Agri Environment Schemes) to fund the work begun under the government funded schemes the lack of a governance framework for catchment management in the

UK hampers interaction between the catchment organisations and water companies. Lessons could be learnt from Australia and the US who have been managing water resources at a catchment scale for decades. Within Australia the most recent natural resource management scheme, Caring for our Country, has demonstrated quantifiable improvements to the quality of the natural resources (Benson et al. 2012). Relying strongly on a participatory approach (as opposed to the more rigid regulatory approach of the EU and the WFD) the Australian governance allows community based groups, which include farmers and voluntary groups, to bid for central government funding to solve issues within a catchment (Benson et al. 2012). Although the US approach is more difficult to evaluate due to the lack of data on whether the catchment partnerships have improved water quality, the Environmental Protection Agency allots funds each year to states to reduce non-point source pollution at a catchment scale (Benson et al. 2012) and participation by communities is actively encouraged. The approaches in the US and Australia are described by Benson et al. (2012) as further up Arnstein's ladder of participation; that is, inherently increasing citizen power resulting in more effective participation with decision making.

With catchment partnerships only introduced in the UK over the past three years it is too soon to determine whether this additional tier of governance will increase the adoption of a landscape scale approach for managing the water environment. What is more certain is that as the responsibilities of the catchment partnerships grow they will increasingly benefit from the use of well managed national spatial infrastructures. These will bring together projects across the UK and act as a portal to information between tiers of stakeholders and embed catchment management within planning processes. Together with an increasing trend by government and research councils to focus on 'Big Data,' i.e. the means by which large volumes of data can be utilised to provide information on service and resource provision, the need for tools to manage data is gaining traction. With data gathered by government agencies being released for unrestricted use by organisations and the public (Defra and Truss 2015) then catchment organisations will need to develop data standards and protocols to ensure that data is not misused or misrepresented. It is also likely that greater engagement with academics will also be needed by catchment organisations as they attempt to predict the needs of society and the environment as we go forward into a less certain climate future. Over the next decade the role of government agencies will be to continue to grow the integrated catchment management framework encouraging stakeholders at all tiers to work together and to provide these same organisations with high quality scientific and technical expertise from a range of different scientists and academics both in the UK and worldwide (Smith et al. 2015).

7.6.2 River trusts

During the course of the thesis it became apparent that despite the EU directives encouraging a move towards a holistic approach the historic separation of land and water management in the UK continues to impair efforts to fulfil the WFD aims. This is further hampered by a lack of consistent structure in catchment organisations. Experience, focus, and resources all vary considerably between river trusts; their focus and organisational structure are influenced by the topography of the catchment, the age of the trust, and the origins of the trust e.g. wildlife, angling, water quantity, and water quality. As a consequence a generic river trust does not exist. These factors all influence the ability of the river trust movement to adopt spatial technologies over the next five years. Government expectations of the role which river trusts have in catchment partnerships and the resources which they have access to seem too frequently to be based on the resources and experience of older more established river trusts. Of paramount importance now and in the future is the role of monitoring catchments to build an evidence base for change. This will become important in any collaboration with water companies who have to evidence the cost benefit of projects to their shareholders and regulators. Evidence is also vital in the development of natural flood management, to increase confidence in models which are currently at an early stage (Defra 2013a).

In future river trusts will come under increasing pressure to include the management of riparian corridors, uplands, wetlands and floodplains in any catchment planning (Smith et al. 2015) and as a result river trusts must move away from a focus on river channels. However larger scale projects are constrained by funding requirements making it difficult to move to a landscape scale. With this increase in scope river trusts will have to adopt spatial technologies to manage the increase volume of data, policies and stakeholder input into the planning processes. Future expectations of the role which river trusts can play in improving the water environment must be mirrored by an increase in available funding, recognition of the vital need for monitoring and the implementation of national mechanisms by which PES markets can be developed.

7.6.3 Water companies – the future funders?

Like river trusts, water companies across England and Wales are non-generic; increasing the difficulties of integration for the industry as water companies adopt CaBA and begin to engage with catchment partnerships. Catchment organisations and water companies both want to improve the water environment to meet the aims of the WFD, while river trusts have the relevant practical skills and stakeholder relationships, and water companies have shareholders' money. Section 3.2.3 discusses how the most recent AMP cycle has influenced the ability of water companies to fund projects which improve the quality of water before it enters the treatment plants; the future funding of catchment projects looks set to be in part funded by PES mechanisms facilitating and formalising the interactions between catchment organisations and water companies.

Despite some forward thinking companies (e.g. Wessex Water and United Utilities) demonstrating the benefits of a strategic ecosystem services approach at a catchment scale, difficulties exist around river trusts and water companies collaborating in future. There is an absence of integrated data management examples to showcase the advantages that spatial technologies can offer. As an illustration both the EA and water companies regularly sample water quality but they are unwilling (E Long 2015, pers. comm., 19 May) to share this valuable data due to the lack of legal agreements and standards, with the result that the river trust must find the resources to collect similar measurements. As a result of this continued separation river trusts have turned to citizen science methods and frameworks to gather a cost effective baseline for future funding calls, evidence of post project river changes and assessment of WFD targets. However with no national framework for spatial infrastructure in place there is little consistency in the development of long term robust solutions, the data collected, the analysis of data collected or the aggregation with other data sources. A solution to this data management issue must be found to enable catchment organisations and water companies to work together to improve the water environment.

Brouwer et al. (2003) describe how the current mechanisms to control diffuse pollution from agriculture are too expensive and inefficient in some situations, but also that co-operative agreements between farmers and water suppliers could be a way forward. The uptake of these co-operative agreements in the UK is limited in comparison with much of Europe where water companies are publicly owned. Currently within the UK some water companies are involved in co-operative agreements with farmers as stakeholders rather than being a party included in an agreement (Andrews 2003. p. 153). While the introduction of ecosystem services science to catchment management is still being established; the most promising tools for future funding mechanisms seem to currently be around linking PES with local planning frameworks and funding mechanisms. It must be recognised however that it will be challenging for an industry used to calculating capital and operation costs over the life cycle of a system to adapt to valuing the natural environment within those same life cycles. Communication of PES mechanisms to catchment organisations requires some form of national guidance, and involving lay stakeholders will rely upon good data and techniques to engage them, visualise areas of greatest benefit and inform policy for land management.

7.7 Conclusion

This thesis concludes with the confirmation that there is significant untapped potential for spatial technologies to support the Catchment Based Approach (CaBA). However to implement these technologies well requires appreciable resources which the non-generic river trusts do not have, and is therefore a significant challenge. The barriers to adoption can broadly be divided into three distinct areas. First the technological restrictions which need to be overcome with further development, secondly the resources required and thirdly the disruptive influence of technology on organisational structure within which they must be accommodated. This thesis has evidenced that co-production of data and their more distributed collection and use generate requirements and opportunities for institutional change in terms of relationships between institutions and their component actors. Even with the suggested further development, the spatial technologies evaluated in this thesis remain outside of the scope of many catchment organisations in terms of skill, understanding of best practice and resources to support implementation. Looking to the future, river trusts will have to develop close working relationships with water companies who are themselves going through a period of transition to new regulation. The future of our water environment and the wider landscape is currently being constrained not by the dedication of those carrying out the work but the lack of funds and governance frameworks for integrated working between institutions such as catchment organisations and water companies.

Appendix 1 – VesAR Surveys for Case Study 1

THANK YOU for coming along today to help with my research project. First we will take a walk to Spot Farm and back, cutting straight across the Gaywood Valley, passing the ruin of St James' church and the water meadows. You will be given some information about the landscape around you using two different methods – a leaflet, and a handheld device (smartphone or tablet computer). For each half of the walk, you will use one of these two methods.

I am interested to find out what you learn today and what you think of the information. There is a short questionnaire that I would like you to complete in three sections: before the walk, halfway through, and at the end.

Please note on your returned questionnaires whether you used the Android device or the leaflet first.

If you have any questions about the walk please ask me, Sarah Taigel, or afterwards you can contact me on s.taigel@uea.ac.uk or 01603 591411

Section 1: Before we start walking

The environment around us offers many benefits to humans. These may be referred to as "nature's benefits" or "ecosystem services" and are the subject of ongoing research to maintain and enhance them in a changing world

Q1. Do you consider yourself "environmentally friendly"?

- ☐ Yes ☐ No

Q2. Have you ever heard the term "ecosystem services"?

- ☐ Yes (Please go to Q3a) ☐ No (Please go to Q4)

Q3. Have you ever heard the term "nature's benefits"?

- ☐ Yes (Please go to Q3a) ☐ No (Please go to Q4)

Q3a. **IF** you answered **YES** to Q2 or Q3 please describe below in your own words what you understand by the term "nature's benefits" (also termed ecosystem services).

Q4. Have you ever heard the term "Augmented Reality"?

- ☐ Yes I have heard of it and used it
- ☐ Yes I have heard of it but not used it
- ☐ I have not heard of it

Section 2: Familiarity with technology

5a - Do you own a Smartphone (e.g. iPhone, Android device, Nokia Symbian)?

- ☐ Yes
- ☐ No

5b - Do you own a computer or laptop?

- ☐ Yes
- ☐ No

	Very	Moderately	Slightly	Not at all
5c - Are you comfortable with email?				
5d - Are you comfortable with online maps such as Google maps?				

Section 3: To be completed halfway through the walk

The walk to Spot Farm illustrated some ecosystem services within the Gaywood catchment. Please tell me what you have discovered using the first of the two information sources (leaflet or handheld device) on your walk so far, by answering the following:

Q6. Please tick which method you used first

- ☐ Android
- ☐ Paper Leaflet

Q7. Which of the following do you think are **provisioning benefits?**

- ☐ Recreation (walks in the countryside)
- ☐ Growing crops
- ☐ Rearing cattle and pigs for food
- ☐ Noise absorption (for example the noise from the A149 is hardly heard)

Q8. Which of the following do you think are **regulating benefits?**

- ☐ Pollination
- ☐ Birdwatching
- ☐ Water purification
- ☐ Timber for fuel

Q9. Which of the following do you think are **cultural benefits?**

- ☐ Views across the catchment
- ☐ Pollination
- ☐ Honey from beehives
- ☐ The ruin of St James' church

Section 4: To be completed at the end of the walk

The walk back to Church Farm illustrated more of nature's benefits (also termed ecosystem services). Please tell me what you learnt using the second information source (leaflet or handheld device) on the return part of your walk, by answering the following:

Q10. Which of the following do you think are **provisioning benefits?**

- ☐ Picnic by the ruins of St James church
- ☐ Fresh Water
- ☐ Using wetlands for flood control
- ☐ Timber Production

Q11. Which of the following are **regulating benefits?**

- ☐ Flood Control
- ☐ Gates on footpaths
- ☐ Noise absorption
- ☐ Cattle grazing overgrown areas

Q12. Which of the following do you think are **cultural benefits?**

- ☐ School trips to the countryside
- ☐ A sense of place
- ☐ Wild food growing in the hedgerows
- ☐ Growing bio fuels in fields

For the following section, please state to what extent each statement is true for you. Tick the box closest to your answer.

Q13. "The Android device helped me understand the location of the benefits we get from nature (ecosystem services) within the Gaywood catchment at Church Farm"

Absolutely		Not Really		Not at all
☐	☐	☐	☐	☐

Q14. "The printed leaflet helped me understand the location of the benefits we get from nature (ecosystem services) within the Gaywood catchment at Church Farm"

Absolutely		Not Really		Not at all
☐	☐	☐	☐	☐

Q15. "The Android device helped me understand the benefits we get from nature (ecosystem services) within the Gaywood catchment at Church Farm"

Absolutely		Not Really		Not at all
☐	☐	☐	☐	☐

Q16. "The printed leaflet helped me understand the benefits we get from nature (ecosystem services) within the Gaywood catchment at Church Farm"

Absolutely Not Really Not at all

☐ ☐ ☐ ☐ ☐

Q17. Which tool do you think was most effective at communicating the benefits we get from the landscape around us?

☐ Android ☐ Leaflet

Q18. Which tool did you like best?

☐ Android ☐ Leaflet

Q19. Please can you tell me what you liked about your preferred tool in Q18

Q20. Please could you tell me whether you enjoyed today's activity?

Q21. Are there any ways in which you think today's activity could be improved?

Section 4: Participant Information

It would be very helpful if you could tell us a little bit about yourself.

Q23. Please select your gender

☐ Male ☐ Female

Q24. Please select your age group

☐ 10 – 15
☐ 16 – 20
☐ 11 – 25
☐ 26 – 30
☐ 31 – 35
☐ 36 – 40
☐ 40 - 60
☐ 61 +

Questions 7 - 12 were as follows for the session at The Walks (River Gaywood)

Q7. Which of the following do you think are **provisioning benefits?**

- ☐ Noise absorption (e.g. the noise from the ring road is hardly heard)
- ☐ Allotments **(*)**
- ☐ Recreation activities (sports, picnics, playground)
- ☐ Wild Honey **(*)**

Q8. Which of the following do you think are **regulating benefits?**

- ☐ Walking to work rather than driving
- ☐ Flood control **(*)**
- ☐ Water purification within the rivers (as opposed to treatment plants) **(*)**
- ☐ Timber for fuel

Q9. Which of the following do you think are **cultural benefits?**

- ☐ Views across the park **(*)**
- ☐ The Grade II listed Red Mount which we saw **(*)**
- ☐ Pollination
- ☐ Clean river for ducks and wildlife

Q10. Which of the following do you think are **provisioning benefits?**

- ☐ Growing Flowers in flower beds **(*)**
- ☐ Pretty river to look at
- ☐ Fruit trees **(*)**
- ☐ Using park area for flood control

Q11. Which of the following are **regulating benefits?**

- ☐ Shady areas in hot summers **(*)**
- ☐ Paying for parking in car parks near The Walks
- ☐ Enjoying paddling in urban river
- ☐ Clean air free from traffic fumes **(*)**

Q12. Which of the following do you think are **cultural benefits?**

- ☐ Eggs from chickens kept on allotments
- ☐ School trips to The Walks **(*)**
- ☐ A sense of place **(*)**
- ☐ Noise absorption (for example the noise from the A149 is hardly heard)

Questions 7 - 12 were as follows for the walk at Marston Marshes (River Yare)

Q7. Which of the following do you think are **provisioning benefits?**

- ☐ Recreation (walks in the countryside)
- ☐ Growing crops
- ☐ Rearing cattle and pigs for food
- ☐ Noise absorption (for example the noise from the A149 is hardly heard)

Q8. Which of the following do you think are **regulating benefits?**

- ☐ Pollination
- ☐ Birdwatching
- ☐ Water purification
- ☐ Timber for fuel

Q9. Which of the following do you think are **cultural benefits?**

- ☐ Views across the catchment
- ☐ Pollination
- ☐ Honey from beehives
- ☐ The footpaths

Q10. Which of the following do you think are **provisioning benefits?**

- ☐ Picnic held near to the river
- ☐ Fresh Water
- ☐ Using wetlands for flood control
- ☐ Timber Production

Q11. Which of the following are **regulating benefits?**

- ☐ Flood Control
- ☐ Gates on footpaths
- ☐ Noise absorption
- ☐ Cattle grazing overgrown areas

Q12. Which of the following do you think are **cultural benefits?**

- ☐ School trips to the countryside
- ☐ A sense of place
- ☐ Wild food growing in the hedgerows
- ☐ Growing bio fuels in fields

Questions 7 - 12 were as follows for the walk along Riverside in Norwich (River Wensum)

Q7. Which of the following do you think are **provisioning benefits?**

- ☐ Noise absorption (e.g. the noise from the road is hardly heard)
- ☐ Allotments **(*)**
- ☐ Recreation activities (sports, picnics, playground)
- ☐ Wild Honey **(*)**

Q8. Which of the following do you think are **regulating benefits?**

- ☐ Walking to work rather than driving
- ☐ Flood control **(*)**
- ☐ Water purification within the rivers (as opposed to treatment plants) **(*)**
- ☐ Timber for fuel

Q9. Which of the following do you think are **cultural benefits?**

- ☐ Views across the park **(*)**
- ☐ The Scheduled Monument Cow Tower which we saw **(*)**
- ☐ Pollination
- ☐ Clean river for ducks and wildlife

Q10. Which of the following do you think are **provisioning benefits?**

- ☐ Growing Flowers in flower beds **(*)**
- ☐ Pretty river to look at
- ☐ Fruit trees **(*)**
- ☐ Using park area for flood control

Q11. Which of the following are **regulating benefits?**

- ☐ Shady areas in hot summers **(*)**
- ☐ Paying for parking in car parks near The RiversideWalk
- ☐ Enjoying paddling in urban river
- ☐ Clean air free from traffic fumes **(*)**

Q12. Which of the following do you think are **cultural benefits?**

- ☐ Eggs from chickens kept on allotments
- ☐ School trips to the open space **(*)**
- ☐ A sense of place **(*)**
- ☐ Noise absorption (for example the noise from the ringroad is hardly heard)

Questions 7 - 12 were as follows for the walk at the UEA (River Yare)

Q7. Which of the following do you think are **provisioning benefits?**

- ☐ Recreation (walks in the countryside)
- ☐ Growing crops
- ☐ Rearing cattle and pigs for food
- ☐ Noise absorption (for example the noise from the nearby roads is hardly heard)

Q8. Which of the following do you think are **regulating benefits?**

- ☐ Pollination
- ☐ Birdwatching
- ☐ Water purification
- ☐ Timber for fuel

Q9. Which of the following do you think are **cultural benefits?**

- ☐ Views across the catchment
- ☐ Pollination
- ☐ Honey from beehives
- ☐ The footpaths

Q10. Which of the following do you think are **provisioning benefits?**

- ☐ Picnic held near to the river
- ☐ Fresh Water
- ☐ Using wetlands for flood control
- ☐ Timber Production

Q11. Which of the following are **regulating benefits?**

- ☐ Flood Control
- ☐ Gates on footpaths
- ☐ Noise absorption
- ☐ Cattle grazing overgrown areas

Q12. Which of the following do you think are **cultural benefits?**

- ☐ School trips to the countryside
- ☐ A sense of place
- ☐ Wild food growing in the hedgerows
- ☐ Growing bio fuels in fields

Appendix 2 - Digital Landscape Architecture Conference Abstract Zurich 2014

Framing Nature: Using Augmented Reality to Communicate Ecosystem Services

Sarah TAIGEL[1], Andrew LOVETT[1] and Katy APPLETON[1]

[1]University of East Anglia, United Kingdom · a.lovett@uea.ac.uk

Abstract

Public awareness and understanding of ecosystem services has tended to lag behind the increasing use of the concept in landscape planning and design. Augmented reality tools on mobile devices such as smartphones have the potential to help communicate the provision of ecosystem services in different landscape settings and enhance the scope for more participatory landscape governance. This paper discusses the development of such a smartphone-based tool and examines its merits compared to a more traditional paper leaflet in the context of an evaluation by members of the public attending short organised walks in urban and rural river landscapes in Norfolk, UK.

1 Introduction

The concept of ecosystem services (ES) is increasingly important in environmental and landscape planning (e.g. UK National Ecosystem Assessment 2011; Department of Communities & Local Government 2012). However, public awareness and understanding of the concept has tended to lag behind the level of use by professional planners and designers (The Nature Conservancy 2013). This is a challenge and a potential problem given the move towards more participatory landscape governance (Lange & Hehl-Lange 2010). The use of mobile devices (such as augmented reality applications on smartphones) has considerable educational potential and offers a means of providing supplementary information regarding landscape attributes and changes (Lange 2011; Johnson & Johnson 2013). To date, however, empirical evaluation of such an approach has been focused more on urban environments (e.g. Chou & Chan-Lin 2012) than rural landscapes. This paper therefore discusses the development of a smartphone-based augmented reality tool to communicate ES in river landscapes and then evaluates how it was used by members of the public attending short organised walks in Norfolk, UK. The smartphone tool was also compared with a more traditional leaflet to assess the relative merits of the two approaches in communicating both the locations of ES and the functions of different features within the landscape settings.

2 Developing the Augmented Reality Application

The augmented reality application VESAR (Visualising Ecosystem Services using Augmented Reality) employs a combination of camera, GPS, compass, accelerometer and a high quality mobile internet (or data) connection. GPS determines the exact location of the device (within a few meters) and the compass and accelerometer define the field of view. The person using the device sees the world via the camera image which is displayed on the screen; this image is augmented with additional digital information such as text, images and animations which appear on top of the camera display and are accessed by the user touching Points of Interest (POI) as they come into view (see figure 1). The information is accessed live via the internet rather than being downloaded previously.

Fig. 1: VESAR on an HTC Android phone

VESAR was developed using two internet-based tools: the Hoppala web service (Hoppala 2013) and the layar™ augmented reality provider (Layar 2013), with base data prepared in ArcGIS 10.1 (ESRI 2013). Hoppala holds the location, descriptive and display information for the POIs designated in the base data, while the layar app on the mobile device shows location-appropriate POIs from Hoppala on-screen and allows the viewer to expand them to gain more information (see figure 2).

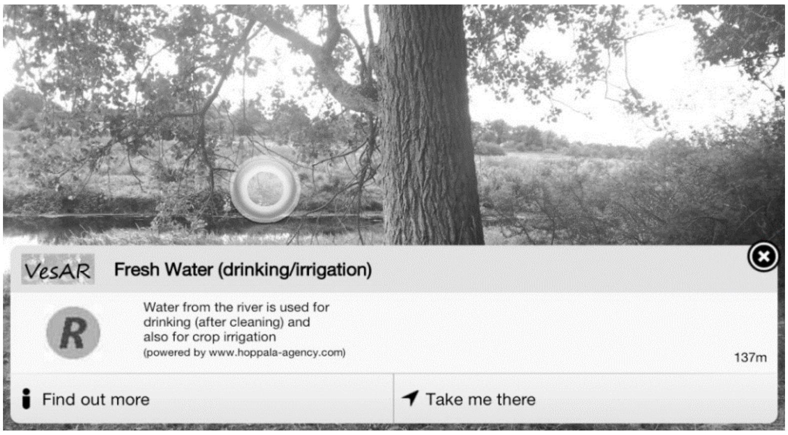


Fig. 2: A view through the camera showing example text

The Hoppala web service limits text files to three lines of up to thirty characters so it was necessary to describe each ES in 90 characters. The MILLENNIUM ECOSYSTEM ASSESSMENT (2005) and the UK NATIONAL ECOSYSTEM ASSESSMENT (2011) were key sources for identifying landscape features providing ES and creating descriptive text about each service. Creating such summary statements proved more challenging than initially anticipated (see examples in Table 1). Based on previous research (DEFRA 2007) it was also decided to adopt the phrase 'nature's benefits' as more meaningful to non-experts than 'ecosystem services', a decision supported by other recent advice (THE NATURE CONSERVANCY 2013).

Initial trials of the augmented reality application highlighted the need for strong GPS and mobile data signals. Evaluation site visits were made to four river valley sites on the fringe of the King's Lynn and Norwich urban areas to assess the quality of signals as well as the range of ES present. Once the strength of signal appeared satisfactory the degree of public access was checked and the features providing ES were recorded using maps and photos, then subsequently digitised into a GIS database. The locations of these features formed the POIs in the augmented reality application. In addition, the route of a planned walk at each site was digitised into the GIS and proximity to the features was assessed to determine a suitable distance buffer within which POIs would become visible in VESAR. Each site had 10-15 different features providing ES.

Table 1: Examples of POI text used in the VESAR application

Name of POI	Type of POI	Text description
Flood Alleviation	Regulating	Drainage ditches allow flood waters to drain away slowly and recharge groundwater
Recreation	Cultural	Many people enjoy the sense of tranquillity provided by the open spaces
Allotments	Provisioning	About 4% of people grow fruit and vegetables within urban spaces including allotments

3 Evaluating the Communication Potential

Participants for the evaluation walks were recruited through collaboration with the Interreg IVB SURF project working in the Gaywood Valley near King's Lynn (HARWOOD et al. 2012), publicity in local press and on social media, and emails to community groups in Norwich. Forty four participants took part in these events during 2012 and early 2013 which involved a group of typically 6-8 people undertaking a guided walk where information on the local ES provision was available via two different tools: the VESAR application on a smartphone or tablet and a more traditional paper leaflet (see figure 3).

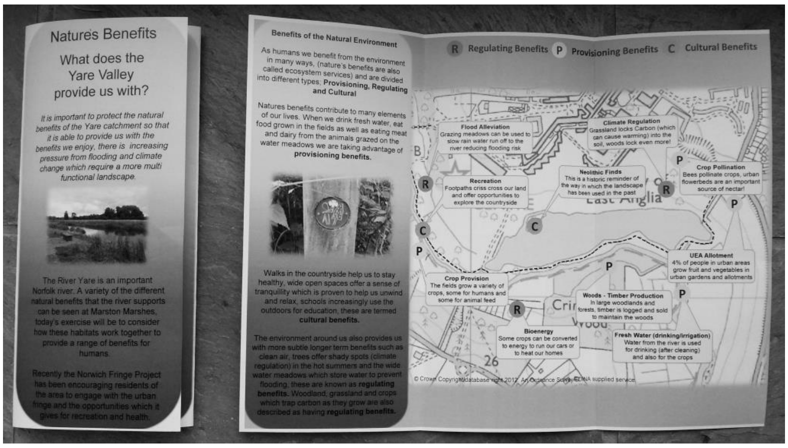


Fig. 3: An example of the leaflet format

The walks lasted between 45 minutes and an hour in total; participants used one tool on the way out from the start, and the other on the way back walking the same route. A three-part questionnaire was answered by each participant. The first section of the questionnaire, completed prior to the walk, evaluated baseline understanding of ES and technological familiarity. The second section was answered after the first tool was used and included multiple choice questions to test understanding of the information shown; the third section was completed at the end of the tour after using the second tool and included similar multiple choice questions.

Additional feedback about the use of the tools was collected via researcher observations during the walks. After each walk participants were encouraged to take part in a debriefing to gather more qualitative data, these post session debriefings provided valuable insight into the way the participants engaged with and used the tools.

4 Results

Of the 44 participants 59% were women and 41% men. Technical awareness was quite high with 93% owning a computer or laptop and 57% a smartphone (defined as a Blackberry, Nokia Symbian, Android or iPhone). However, only 57% had previously heard of ecosystem services.

It was anticipated that age would be a key influence on how people engaged with the ES communication tools. Seven participants were aged up to 25, fifteen in the range 26-35, eighteen from 36-60 and four over 60. Ideally there would have been more participants, particularly of younger ages, but for the purposes of analysis the sample was simply divided into two equal sized groups of those aged up to 35 and those older.

Analysis of the questionnaire data indicated that slightly higher proportions of the younger age group had heard of ecosystem services and owned a computer or laptop. A stronger contrast existed in smartphone ownership (73% in the younger age group and 41% in the older one). When asked at the end of the event which communication tool they liked best, of those who expressed a preference the proportion favouring the smartphone application was 50% in the younger age group and 33% in the older one. However, none of these differences between age groups were statistically significant at the 0.05 level when evaluated using Chi-Square tests.

During the walk participants completed twelve multiple choice questions about ecosystem services after using their first tool and another similar set after the return walk to assess what had been learnt. Table 2 summarises the average scores (out of a maximum total of 12) according to age group and which tool was used first. The results indicate that there was a slight tendency for the test score to be higher in the younger age group after using the smartphone application while for older participants the better scores were more clearly associated with use of the paper leaflet. However, neither of these differences was statistically significant at the 0.05 level when assessed using Mann-Whitney U tests.

Table 2: Average scores on the ES questions by age group and communication tool used

Communication tool used first	**Aged up to 35**		**Aged 36 or older**	
	ES Test Score 1	ES Test Score 2	ES Test Score 1	ES Test Score 2
Smartphone	10.2	10.2	9.0	9.4
Paper leaflet	10.1	10.3	9.9	8.9

At the end of the activity the participants were also asked to rate the two communication tools on a 1-5 scale (5 highest) in terms of how well they helped them understand the locations of ES and the benefits provided. Average ratings for each question by age group and overall are shown in Table 3. These results indicate that the smartphone was evaluated as less useful by older participants while there was no age difference for the leaflet. Across the entire sample there was no significant difference in ratings of the two tools in terms of helping to understand ES locations, but for benefits a Mann-Whitney U test indicated that those of the leaflet were significantly higher at the 0.05 level.

Table 3: Average ratings of communication tools in terms of location and benefits of ES

Age group	Smartphone helped understanding of ES locations	Leaflet helped understanding of ES locations	Smartphone helped understanding of ES benefits	Leaflet helped understanding of ES benefits
Aged up to 35	2.9	2.9	3.0	3.2
Aged 36 or older	2.4	2.9	2.6	3.2
Total	2.6	2.9	2.8	3.2

Table 4 lists some examples of comments provided during the debriefing sessions which provide additional perspectives on the two tools. These illustrate positive aspects of the VESAR application such as the interactivity, but also negative dimensions. In particular, far from engaging people in the landscape for some participants the smartphones detracted from the enjoyment of the open space due to needing to constantly review the phone screen.

Table 4: Participant comments on the two communication tools

Positive smartphone comments	Negative smartphone comments
Smartphone can give a greater range of data	Leaflet can be used in all weathers the phones didn't like the rain
Smartphone provides a much better sense of direction	Liked the leaflet, it's what I'm used to!
Knew the area well, but learnt lots of new info in a new way	Smartphone made me feel too disconnected from outdoors
Smartphone much greener – no litter or waste!	Smartphone distracted me from my walk

4.1 Practical experience of using the VESAR application

Four key technological restrictions were noted by the research team while observing the participants engaging with this technology. Feedback during the debriefing sessions indicated that all of these led to some participants choosing the leaflet as their favoured communication method.

- Screen glare - despite using an 'anti-glare' protector there was difficulty in clearly viewing the phone or tablet screen on days where the sun was very bright or directly overhead.
- Battery life - during the pilot site visits it became apparent that the phones needed to be turned off between evaluation walks, or the battery charged, due to the GPS accuracy being directly affected by the battery strength. Using maximum screen brightness to increase visibility outdoors (see above) added to the power demands.
- Accuracy - the POIs had a tendency to 'dance' and disappear from the field of view when a device was stationary. This is primarily a GPS accuracy issue and varied across handsets, other layar users have reported this problem so it is not unique to VESAR. The problem could usually be managed by restarting the application and was less apparent on later version of the layar software.
- Data Signal - the application worked better as a communication tool where there were open vistas such as across farmland and on a wetland nature reserve; use within a more built-up area became confusing when POIs appeared and the associated feature was not within the line of sight. However, the more rural landscapes had poorer signal quality. The intended rollout of 4G networks in the UK should improve this situation. It may also be possible to reduce problems with feature visibility by setting a smaller display radius for POIs in urban areas.

Several of the hardware issues noted above are dependent on general technological progress for solutions, but two other issues which could be addressed in future research are:

- Display design - there were comments that the text size was too small and hard to read. Improved design coupled with a stronger data signal could increase the amount of imagery contained in the applet and the web links, so improving the content.

- Develop a proximity alert so that there is no need to continually review the information on the screen. This would beep or buzz as the user came within range of an augmented reality POI and alert them to the fact that there was information available nearby.

Design options (such as text size) in Hoppala were limited. Making such improvements would most likely require coding a new applet from scratch. This would also enhance the reliability of the technology compared to dependence on third party services: during the final phase of data collection the Hoppala server became unavailable on several occasions (reasons unknown) and survey sessions had to be cancelled, with inevitable consequences for respondent numbers. As with any free service there is no contract of service provision and so developing a self-hosted service would help guard against such issues. These are two clear illustrations of the trade-offs to be made between the convenience of off-the-shelf components and the amount of control over the resulting system.

5 Conclusions

The events and evaluations discussed above indicate that mobile devices such as augmented reality applications on smartphones have considerable potential for communicating the extent and nature of ecosystem services in landscape settings. The novelty of such an application will generate interest, particularly amongst experienced smartphone users, but this research also indicates that at present there are a number of practical limitations and that some members of the public are likely to prefer more traditional communication methods such as paper leaflets. These problems and attitudes may well change over time as devices such as smartphones become more ubiquitous and supporting technology such as GPS and mobile data signals improve, but based on the experience of this study not everyone will appreciate having their attention distracted from their surroundings. It therefore seems likely that while smartphone-based augmented reality could become a valuable tool for the landscape planner or designer it will not be a universal solution and to gain the maximum benefit from such technology it will be important to embed it in appropriate wider decision-making processes. In common with many other aspects of landscape visualisation (e.g. BISHOP et al. 2013) there is consequently still much to learn about how to best apply such communication tools.

Acknowledgements

This research was conducted as part of PhD research on visioning catchment futures funded by an ESRC studentship (ES/I022139/1).

References

BISHOP, I. D., PETTIT, C. J., SHETH, F. & SHARMA, S. (2013), Evaluation of data visualization options for land-use policy and decision making in response to climate change. Environment and Planning B: Planning and Design, 40, 213-233.

CHOU, T.-L. & CHAN-LIN, L.-J. (2012), Augmented reality smartphone environment orientation application: A case study of the Fu-Jen University mobile campus touring system. Procedia - Social and Behavioral Sciences, 46, 410–416.

DEPARTMENT OF COMMUNITIES & LOCAL GOVERNMENT (2012), National planning practice guidance. http://planningguidance.planningportal.gov.uk/ (29.09.2013).

DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS (DEFRA) (2007), Public understanding of the concepts and language around ecosystem services and the natural environment. Final report for project NR0115, Defra, 83p, http://randd.defra.gov.uk (15.02.14).

ESRI (2013), ArcGIS for desktop. http://www.esri.com/software/arcgis/arcgis-for-desktop (11.10.2013).

HARWOOD, A., LOVETT, A. & TURNER, J. (2012), Extending virtual globes to help enhance public landscape awareness. Proc. Digital Landscape Architecture 2012, Wichmann, 256-262.

HOPPALA (2013), Mobile augmented reality. http://www.hoppala-agency.com/ (11.10.2013).

JOHNSON, J. I. & JOHNSTON, D. W. (2013), Smartphones: Powerful tools for geoscience education. Eos, 94, 433-434.

LANGE, E. (2011), 99 volumes later: We can visualise. Now what? Landscape and Urban Planning, 100, 403-406.

LANGE, E. & HEHL-LANGE, S. (2010), Making visions visible for long-term landscape management. Futures, 42, 693-699.

LAYAR (2013), Welcome to Layar. https://www.layar.com/ (11.10.2013).

MILLENNIUM ECOSYSTEM ASSESSMENT (2005), Ecosystems and human well-being: Synthesis. Island Press, 137 p.

THE NATURE CONSERVANCY (2013), The Language of Conservation 2013. http://www.conservationgateway.org/Files/Pages/language-conservation-mem.aspx (11.10.2013).

UK NATIONAL ECOSYSTEM ASSESSMENT (2011), The UK National Ecosystem Assessment technical report. UNEP-WCMC, 1466 p.

Appendix 3 – CommunityViz Surveys for Case Study 2

The Stiffkey catchment – a sustainable future

Thank you for coming today.

Recent funding has meant new opportunities to work with stakeholders to improve the landscape and restore the once beautiful and unique river. The Norfolk Rivers Trust is interested to hear your thoughts and find out how you might like to be involved in creating a sustainable future for the river and its surroundings.

The project has identified four interconnected themes;

Water Quality, River Health, Water Levels and Recreation

This paper survey will give the project feedback about the next steps and ask a few questions about what you think of the information shown today and the way it has been presented. If you have any questions please ask;

- NRT – Jonah Tosney, jonahtosney@norfolkriverstrust.org or 01263 862657
- NRT – Gemma Clark, gemma.clark@norfolk.gov.uk
- UEA - Sarah Taigel, s.taigel@uea.ac.uk or 01603 591362

Please read the following carefully

Today's workshop involves the use to two tools to discuss the possible future of a section of the Stiffkey River, Norfolk. The session began with a short talk about the aims of the Norfolk Rivers Trust and then discussions around the maps and the computer. An element of the session is contributing to research being conducted by Sarah Taigel at the University of East Anglia in Norwich to discover how much people understand about nature's benefits and about how different visualisation tools can be used.

This study is funded by the Economic and Social Research Council (ESRC) and it is approved by the UEA ethics committee. All responses are treated as confidential, and in no case will responses from individual participants be identified, all data will be published in aggregate form only. An observer will make notes summarising discussions which take place, these notes will not identify any participant. Participation is voluntary, refusal to take part in the study involves no penalty, and participants may withdraw from the study at any time.

	Y	N
I have read and I understand the information written above and have had the opportunity to ask questions.		
I understand that I can withdraw from the study at any time without having to give any reasons.		
I consent to the researcher (Sarah Taigel) taking notes during the course of the discussion.		
I consent to the researcher (Sarah Taigel) taking photographs during any discussions.		
I agree with the publication of the results of this study in research journals. I understand there will be no means of identifying me in these publications.		

Note: Format adapted from University of Boston Informed Consent form

Name (printed):____

Signature:____

Section 1: Your views on the benefits the Stiffkey catchment provides

The environment around us offers many benefits to humans. These may be referred to as "nature's benefits" or "ecosystem services" and are the subject of ongoing research to maintain and enhance them in a changing world.

Q1a. Prior to the session today had you ever heard the term "ecosystem services"?

☐ Yes ☐ No

Q1b. Prior to the session today had you ever heard the term "nature's benefits"?

☐ Yes ☐ No

Q1c. **IF** you answered **YES** to Q1a or Q1b please describe below in your own words what you understand by the term "nature's benefits" (or "ecosystem services").

Q1d. After today's workshop do you feel you understand more about the existing natural benefits of the Stiffkey catchment?

☐ Yes ☐ No

Q1e. Do you feel you understand more about the natural benefits the Stiffkey catchment could have with a change in land use?

☐ Yes ☐ No

Section 2: Your familiarity with maps and technology

Q2a - Do you own a Smartphone (e.g. iPhone, Android device, Nokia Symbian)?

☐ Yes ☐ No

Q2b - Do you own a computer, laptop or tablet (e.g. iPad)?

☐ Yes ☐ No

	Very	Moderately	Slightly	Not at all
Q2c - Are you comfortable using email?	☐	☐	☐	☐
Q2d - Are you comfortable using online maps (e.g. Google maps)?	☐	☐	☐	☐
Q2e – Are you comfortable reading and using paper maps (e.g. OS maps)?	☐	☐	☐	☐

Section 3: Your views on the future of the Stiffkey catchment

Q3a. Norfolk Rivers Trust would like to focus on four themes in this section of the Stiffkey catchment, in your opinion what order should these be prioritised?

Please number 1 – 4 (1 being most important) but feel free to add a new theme

Mitigating agricultural runoff (silt and pesticides) to improve water quality	☐
Improving habitat in the river and nearby areas	☐
Reducing flooding of land in the winter & improving the low flows in summer or lack of water for abstraction	☐
Improving recreational access (e.g. new footpath)	☐
Other issue not mentioned ________________________________	☐

Q3b. Please can you tell us more about what you think is most important?

Q3c. Do you think the Stiffkey catchment would benefit from changes in land use?

☐ I agree strongly ☐ Tend to agree ☐ Tend to disagree ☐ Disagree strongly

Section 4: Your views on the tools presented,

During the workshop you used both the paper maps and the computer to find out about the Stiffkey catchment. Information about the current landscape and a possible future for one area of the catchment was shown on maps and on a computer screen. Please state to what extent each statement is true for you.

Q4a. Which tool best represented the *current* appearance of the landscape for use in catchment management?

	Favourite		No Preference		Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4b. Which tool best represented the *future* appearance of the landscape for use in catchment management?

	Favourite		No Preference		Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4c. Which tool do you think represented the expected (future) appearance of the landscape <u>at sufficient level of detail</u> for catchment management?

	Favourite		No Preference		Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4d. Overall which tool do you think was most effective at communicating *current problems* in the Stiffkey catchment?

	Favourite	Slight preference	No Preference	Slight preference	Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4e. Overall which tool do you think was most effective at communicating the possible *future solutions* in the Stiffkey catchment?

	Favourite	Slight preference	No Preference	Slight preference	Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4f. Overall which tool helped you to understand where there was *potential to change* the Stiffkey catchment?

	Favourite	Slight preference	No Preference	Slight preference	Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4g. It was easier to understand the information using which tool?

	Favourite	Slight preference	No Preference	Slight preference	Favourite	
Paper Map	☐	☐	☐	☐	☐	Computer

Q4h. – Which tool gave you more opportunity to explore and discuss alternative ideas with other attendees?

☐ Paper Map ☐ Computer

Q4i. If you asked questions about the information being displayed which method do you think was best explained by the research team?

☐ Paper Map ☐ Computer

Q4j. Which method do you think had the best supporting information presented alongside the visualisations?

☐ Paper Map ☐ Computer

Q4k. Which tool did you like best?

☐ Paper Map ☐ Computer

Q4l. Please can you tell me what you liked about your preferred method in Q5k

Section 5: Participant Information, please could you tell us a little bit about yourself

Q5a. I feel that compared to when I arrived I now have an increased understanding of the different issues in the Stiffkey catchment

☐ Yes ☐ No

Q5b. I feel that compared to when I arrived I now have an increased understanding of possible future solutions in the Stiffkey catchment

☐ Yes ☐ No

Q6c.Please select your gender

☐ Male ☐ Female

Q6d. Please select your age group

☐ 16 – 20	☐ 26 - 30	☐ 36 – 40	☐ 61 +
☐ 21 – 25	☐ 31 - 35	☐ 41 - 60	

Q6e. If visualisations and supporting information were available on a website would you tell others about it?

☐ Yes ☐ No

Q6f. The information you have given today will be collated and be presented at a second event in April/early May. Would you be interested in attending?

☐ No
☐ Yes – please give an email address for additional details

____

Thank you for being part of this project. Results will be emailed to you if you have requested them, and will also be available through the Future Landscapes blog or the Norfolk Rivers Trust website details of which can be found below.

A follow up event which will bring together details from all of the preliminary engagement events will be run in April/May, the date will be published in the press and your attendance would be much appreciated. Should you be unable to attend the models will be visible on a website and your feedback would again be much valued.

Research Website - http://futurelandscapes.wordpress.com/

Norfolk Rivers Trust Website - http://www.norfolkriverstrust.org/

If you are unable to complete the survey today – please post it to:

Ms Sarah Taigel
School of Environmental Science,
University of East Anglia,
Norwich, NR4 7TJ
UK

Your feedback is very important to this project

Thank you

Group:

Appendix 4 – A5 Visual Prompt Card for Case Study 3

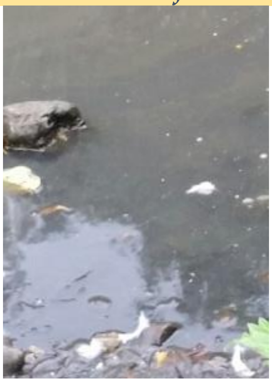
Front of laminated card

River

Visual Prompt Card

Pollution

Water surface



© – Sarah Taigel

E.g. oil or foam on the surface

From a road

© – Norfolk Rivers Trust

E.g. run off from a road, with a grey tinge

Litter

© – Miss Steel, GeoGraph

E.g. Fishing debris, plastic things which shouldn't be in the river.

Soil

In channel

© – Norfolk Rivers Trust

Fine sediment in the river covers the gravels and reduces river health

Road drain

© Jim Sanders

Small pipes and road drains carry sediment into ditches which in turn enters the river..

Field entrance

© JThomas, Geograph

Soil can come from field entrances and road verges.

Reverse of laminated card

River

Visual Prompt Card

Bank erosion

© – Sarah Taigel

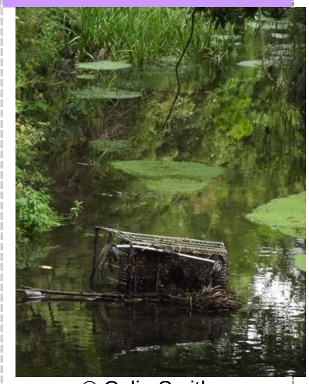
Bank erosion can be caused by livestock or boats and adds sediment to the river.

Fish kills

© Unknown

Fish are sensitive to low oxygen levels as well as pollution

Hazards



© Colin Smith

Large debris (such as trollies) cause hazards for those using the river

Weeds

© – Sarah Taigel

Thick weeds use up the oxygen in the water and reduce river health

Tree at risk

© – Sarah Taigel

Trees with cracks or hanging branches contribute to river hazards & flood risk

Invasive species

Images © GBNNSS

Floating Pennywort

Himalayan balsam

Crayfish

Appendix 5 – RiverEYE Survey for Case Study 3

River **Feedback Form** UEA

Please ensure you sign the ethics form included in the pack – and then complete a copy of this form after you have used the RiverEYE application, data collected will be used to improve the experience for other Rivers Trusts. Please enter the ID of the Phone you used:

Phone_ID

After you have used the RiverEYE application, please complete each statement:

Q1. How often do you usually see or visit the river Waveney or tributaries?

☐ A great deal ☐ Quite a lot ☐ Not much ☐ Very little ☐ Never

Q2. Why did you take part in the RiverEYE study?

☐ I knew people who were taking part

☐ I am interested in citizen science

☐ I enjoy using technology

☐ I love the Waveney and want to be able to get involved

☐ Other:____

Q3. BEFORE you took part in the study in what order would you rank the following as needing improvement? (With 1 the highest and 4 the lowest)

☐ River Health & Habitat ☐ Water Quality ☐ Water Flow ☐ Recreation

Q4. Has using River Eye changed your mind on;	**A lot**	**Moderately**	**Slightly**	**Not at all**
The priorities the Waveney catchment should have?	☐	☐	☐	☐
The potential of mobile phones to collect data?	☐	☐	☐	☐
The benefits of a citizen science approach to collect data?	☐	☐	☐	☐
The benefits of a citizen science approach to feel more engaged with solving problems?	☐	☐	☐	☐

Q5. Having used RiverEYE how did you find;	**Easy**	**A few problems**	**Lots of problems**
The technology (phone or tablet)	☐	☐	☐
The tools in RiverEYE (camera, text, drop down menus)	☐	☐	☐
The website link to add data was	☐	☐	☐

Please explain any problems:

Q6. Did you refer to the visual prompt card to determine the category an issue fell into? **YES / NO**

Please list which categories you checked;______________________________

Q7: Approximately how many times did you use the RiverEYE application overall?

- ☐ Once
- ☐ 2 - 5
- ☐ 6 - 10
- ☐ 11 - 15
- ☐ 16 - 20
- ☐ 20+
- ☐ 30+
- ☐ 40+

Q8. Please suggest any ways in which you think RiverEYE or the research process could be improved (think about the uses of the app, the map, the way the information was presented)

Q9. Did you borrow a Smartphone or Tablet to take part?

☐ Yes (Smartphone) ☐ Yes (Tablet) ☐ No

Q10. Did you use your own Smartphone or Tablet to take part?

☐ Yes (Smartphone) ☐ Yes (Tablet) ☐ No

Q11. Which of the following do you own?

☐ Tablet (Android) ☐ Tablet (iPad) ☐ Laptop PC ☐ Desktop PC

	Yes	**Moderately**	**Slightly**	**No**
Q12. Are you comfortable using email?	☐	☐	☐	☐
Q13. Are you comfortable using online maps (e.g. Google maps)?	☐	☐	☐	☐
Q14. Are you comfortable reading and using paper maps (e.g. Ordnance Survey maps)?	☐	☐	☐	☐

Q15. Please select your gender

☐ Male ☐ Female ☐ Prefer not to Say

Q16. Please select your age group

- ☐ 16 – 20
- ☐ 21 – 25
- ☐ 26 - 30
- ☐ 31 - 35
- ☐ 36 – 40
- ☐ 41 – 60
- ☐ 61 +
- ☐ Prefer not to say

Q17 AFTER you took part in the study in what order would you rank the following as needing improvement? (With 1 the highest and 4 the lowest)

☐ River Health & Habitat ☐ Water Quality ☐ Water Flow ☐ Recreation

---

Thank you for contributing to this project.
Results will be available on the River Waveney Trust website http://www.riverwaveneytrust.org

Acronyms

AMP	Asset Management Plan
ANT	Actor Network Theory
AR	Augmented Reality
ART	Association of River Trusts
BFI	Base Flow Index
CaBA	Catchment Based Approach
CALP	Centre for Advanced Landscape Planning
CEH	Centre for Ecology & Hydrology
CRF	Catchment Restoration Fund
Defra	Department for Environment, Food and Rural Affairs
EA	Environment Agency
ESA	Ecosystem Services Approach
LDF	Local Development Framework
GIS	Geographical Information Systems
NFU	National Farmers Union
NRT	Norfolk Rivers Trust
OFWAT	The Water Services Regulation Authority
PES	Payments for Ecosystem Services
RIF	River Improvement Fund
RBMP	River Basin Management Plan
RWT	River Waveney Trust
SURF	Sustainable Urban Rural Fringe
VGI	Volunteered Geographical Information
WFD	Water Framework Directive
WWF	World Wildlife Fund

References

3D Nature (2015), *3D Landscape Design & Visualisation Software* http://www.3dnature.com/ (Accessed 12th August 2015)

Aanensen, D.M,, Huntley, D.M., Feil, E.J., al-Own, F., Spratt, B.G. (2009), EpiCollect: Linking Smartphones to Web Applications for Epidemiology, Ecology and Community Data Collection. PLoS ONE 4(9): e6968. doi:10.1371/journal.pone.0006968

Albert, C., Galler, C., Hermes, J., Neuendorf, F., von Haaren, C., Lovett, A. (2015), Applying ecosystem services indicators in landscape planning and management: The ES-in-Planning framework. *Ecological Indicators*. DOI:10.1016/j.ecolind.2015.03.029

Alexander, P. M., Silvis, E. (2014), Towards extending actor-network theory with a graphical syntax for information systems research. *Information ResearchInf, 19(2) paper 617*.

Andrews, K. (2003), United Kingdom: Financial and Cultural Constraints pp 151-166. In F. Brouwer, I. Heinz, & T. Zabel (Eds.), *Governance of Water-related Conflicts in Agriculture* (p. 222), Kluwer Academic Publishers.

Appleton, K. (2004), *GIS Based Landscape Visualisation for Environmental Management* Ph.D thesis, University of East Anglia. DOI: 10.13140/RG.2.1.2919.6325

Appleton, K., Lovett, A. (2005), GIS-based visualisation of development proposals: reactions from planning and related professionals. *Computers, Environment and Urban Systems*, *29*(3), 321–339. DOI: 10.1016/j.compenvurbsys.2004.05.005

Appleton, K., Lovett, A., Sünnenberg, G., Dockerty, T. (2002), Rural landscape visualisation from GIS databases: a comparison of approaches, options and problems. *Computers, Environment and Urban Systems*, *26*(2-3), 141–162. DOI: 10.1016/s0198-9715(01)00041-2

Arnstein, S. R. (1969), A Ladder of Citizen Participation. *Journal of the American Institute of Planners*.

Bailey, A.P., Deasy, C., Quinton, J.N., Silgram, M.S., Jackson, R., Stevens, C.J. (2013), Determining the cost of in-field mitigation options to reduce sediment and phosphorus loss. *Land Use Policy*, 30, 234– 242. DOI: 10.1016/j.landusepol.2012.03.027

Bannister, N., Mant, J., Janes, M. (2005), A Review of Catchment Scale River Restoration Projects in the UK Compiled by the River Restoration Centre, (December), 1–42.

Barlow, J., Moore, F., Burgess-Gamble, L. (2014), *Delivering Benefits thourgh Evidence: working with Natural Processes to reduce flood risk*. Bristol: Environment Agency.

Benson, D., Fritsch, O., Cook, H., Schmid, M. (2014), Evaluating participation in WFD river basin management in england and wales: Processes, communities, outputs and outcomes. *Land Use Policy*, *38*, 213–222. DOI:10.1016/j.landusepol.2013.11.004

Benson, D., Jordan, A., Huitema, D. (2012), Involving the Public in Catchment Management: An Analysis of the Scope for Learning Lessons from Abroad. *Environmental Policy and Governance*, *22*(1), 42–54. DOI:10.1002/eet.593

BGS (2015) *Web Map Services- UK Geology Datasets* http://www.bgs.ac.uk/data/services/wms.html (Accessed 12th August 2015)

Bishop, I. D. (2011), Landscape planning is not a game: Should it be? *Landscape and Urban Planning*, *100*(4), 390–392. DOI:10.1016/j.landurbplan.2011.01.003

Bishop, I. D. (2014), Location based information to support understanding of landscape futures. *Landscape and Urban Planning*, 1–12. DOI:10.1016/j.landurbplan.2014.06.001

Bishop, I.D., Hull IV, R.B., Stock, C. (2005), Supporting personal world-views in an envisioning system. *Environmental Modelling and Software*, 20(12 SPEC. ISS.), p.1459-1468

Bishop, I. D., Lange, E. (2005), *Visualization in Landscape and Environmental Planning Technology and Applications*. Taylor and Francis, London.

Bishop, I. D., Pettit, C., Sheth, F., Sharma, S. (2013), Evaluation of data visualisation options for land-use policy and decision making in response to climate change. *Environment and Planning B: Planning and Design*, *40*, 213 – 233. DOI:10.1068/b38159

Bishop, I. D., Stock, C., Williams, K. J. (2009), Using virtual environments and agent models in multi-criteria decision-making. *Land Use Policy*, *26*(1), 87–94. DOI: 10.1016/j.landusepol.2008.01.010

Bohnet, I. C., Roebeling, P. C., Williams, K. J., Holzworth, D., Grieken, M. E., Pert, P. L., et al. (2011), Landscapes Toolkit: an integrated modelling framework to assist stakeholders in exploring options for sustainable landscape development. *Landscape Ecology*. DOI:10.1007/s10980-011-9640-0

Borjeson, L., Hojer, M., Dreborg, K., Ekvall, T., Finnveden, G. (2006), Scenario types and techniques: Towards a user's guide. *Futures*, *38*(7), 723–739. DOI:10.1016/j.futures.2005.12.002

Botden, S. M. B. I., Jakimowicz, J. J. (2009), What is going on in augmented reality simulation in laparoscopic surgery? *Surgical Endoscopy and Other Interventional Techniques 23*, 1693-1700 DOI: 10.1007/s00464-008-0144-1

Boyd, J., Banzhaf, S. (2007), What are ecosystem services? The need for standardized environmental accounting units☆. *Ecological Economics*, *63*(2-3), 616–626. DOI:10.1016/j.ecolecon.2007.01.002

Bracken, L., Oughton, E. (2014), How to make sense of our rivers: using assemblage to understand angling. *Wiley Interdisciplinary Reviews: Water*, *1*(3), 315 – 322. DOI:10.1002/wat2.1025

Brouwer, F., Heinz, I., Zabel, T. (Eds.) (2003), *Governance of Water-related Conflicts in Agriculture* (Vol. 37) Dordrecht: Springer Netherlands. DOI:10.1007/978-94-017-0101-3

Brown, G., Weber, D. (2011), Public Participation GIS: A new method for national park planning. *Landscape and Urban Planning*. DOI:10.1016/j.landurbplan.2011.03.003

Bryan, B. A. (2003), Physical environmental modeling, visualization and query for supporting landscape planning decisions. *Landscape and Urban Planning*, *65*(4), 237–259. DOI: 10.1016/s0169-2046(03)00059-8

CaBA (2013) Catchment Based Approach http://www.catchmentbasedapproach.org/ (Accessed 12th August 2015)

Caminiti, J. (2004), Catchment modelling—a resource manager's perspective. *Environmental Modelling and Software*, *19*(11), 991–997. DOI:10.1016/j.envsoft.2003.11.002

Carles, J. (1999), Sound influence on landscape values. *Landscape and Urban Planning*, *43*(4), 191–200. DOI:10.1016/S0169-2046(98)00112-1

Cartwright, W., Pettit, C., Nelson, A., Berry, M., (2005), Community collaborative decision-making tools: determining the extent of 'Geographical Dirtiness' for effective displays. Paper Presented at International Cartographic Conference. A Coruña, Spain. http://www.mssanz.org.au/modsim05/papers/cartwright.pdf (Accessed: 12th August 2015)

Cauldrick, L., Smith, L. (2014), Catchment partnerships – better planning for our rivers and landscapes How can catchment partnerships use recent research to help balance the increasing demands society puts on our landscapes ? LWEC Policy and Practice Notes No 8. http://www.lwec.org.uk/publications/catchment-partnerships-better-planning-rivers-and-landscapes (Accessed 12th August 2015)

Cefas. (2012), Classification of Bivalve Mollusc Production Areas in England and Wales. *Sanitary Survey Report*. http://cefas.defra.gov.uk/media/549620/final%20liverpool%20bay%20sanitary%20survey%20report%202011.pdf (Accessed 12th August 2015)

CEH. (2015), National River Flow Archive. http://nrfa.ceh.ac.uk/data/search. (Accessed 15th July 2015)

CEH. (2000), Land Cover Map 2007 http://www.ceh.ac.uk/services/land-cover-map-2007 (Accessed 12th August 2015)

Chen, D., Shams, S., Carmona-Moreno, C., Leone, A. (2010), Assessment of open source GIS software for water resources management in developing countries. *Journal of Hydro-environment Research*, *4*(3), 253–264. DOI: 10.1016/j.jher.2010.04.017

Chou, T.L., ChanLin, L.J. (2012), Augmented Reality Smartphone Environment Orientation Application: A Case Study of the Fu-Jen University Mobile Campus Touring System. *Procedia - Social and Behavioral Sciences*, *46*, 410–416. DOI:10.1016/j.sbspro.2012.05.132

Cirulis, A., Brigmanis, K. B. (2013), 3D outdoor augmented reality for architecture and urban planning. *Procedia Computer Science*, *25*, 71–79. DOI:10.1016/j.procs.2013.11.009

Conrad, C. C., Hilchey, K. G. (2011), A review of citizen science and community-based environmental monitoring: Issues and opportunities. *Environmental Monitoring and Assessment*, *176*, 273–291. doi:10.1007/s10661-010-1582-5

Cornwall, A. (2008), Unpacking 'Participation': models, meanings and practices. *Community Development Journal*, *43*(3), 269–283. DOI:10.1093/cdj/bsn010

Crampton, J. W. (2002), Interactivity Types in Geographic Visualization. *Cartography and Geographic Information Science*, *29*(2), 85–98. DOI:10.1559/152304002782053314

Cullingworth, B., Nadin, V., Hart, T., Davoudi, S., Pendlebury, J., Vigar, G., et al. (2015), *Town and Country Planning in the UK* (15th ed.). Routledge, Taylor & Francis Group. DOI:10.3828/tpr.22.3.tl362q6h4377pj60

Davey, A. (2012), Catch of the day. *Utility Week*, (9/7/2012), 21–22. http://www.wrcplc.co.uk/Data/Sites/1/GalleryImages/WebImages/pdfs/articles/catchoftheday.pdf (Accessed 12th August 2015)

Davies, I. (2015), DEFRA reveals funding details for stewardship. *Farmers Weekly*. http://www.fwi.co.uk/news/defra-reveals-funding-details-for-countryside-stewardship.htm (Accessed 12th August 2015)

Davis Jr, C. A., Fonseca, F. T., Camara, G. (2009), Beyond SDI: Integrating Science and Communities to Create Environmental Policies for the Sustainability of the Amazon. *International Journal of Spatial Data Infrastructures Research*, *4*, 156-174 DOI: 10.2902/1725-0463.2009.04.art9

Dawson, J. J., Smith, P. (2010), Integrative management to mitigate diffuse pollution in multi-functional landscapes. *Current Opinion in Environmental Sustainability*, *2*(5-6), 375–382. DOI:10.1016/j.cosust.2010.09.005

Defra (2007a) *Securing a healthy natural environment: An action plan for embedding an ecosystem approach* http://www.biodiversitysouthwest.org.uk/docs/eco-actionplan.pdf (Accessed 1st April 2016)

Defra (2007b) *An introductory guide to valuing ecosystem services* https://www.gov.uk/government/publications/an-introductory-guide-to-valuing-ecosystem-services (Accessed 1st April 2016)

Defra. (2011a), *The Natural Choice: securing the value of nature - The Environment White Paper.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228842/8082.pdf(Accessed 12th August 2015)

Defra. (2011b), *Water for Life* **-** *The Water White Paper.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228861/8230.pdf (Accessed 12th August 2015)

Defra. (2013a), *Developing the potential for Payments for Ecosystem Services: an action plan*. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/200889/pb13918-pes-actionplan-20130522.pdf (Accessed 12th August 2015)

Defra. (2013b), *Catchment Based Approach: Improving the quality of our water environment.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/204231/pb13934-water-environment-catchment-based-approach.pdf (Accessed 12th August 2015)

Defra. (2013c), *Guide to Collaborative Catchment Management*. http://ccmhub.net/wp-content/uploads/2012/10/The-Guide.pdf (Accessed 12th August 2015)

Defra, COI. (2007), *Public understanding of the concepts and language around ecosystem services and the natural environment.* http://randd.defra.gov.uk/Document.aspx?Document=NR0115_5349_FRP.doc (Accessed 12th August 2015)

Defra, Truss, E. (2015, June 25), Environment Secretary unveils vision for open data to transform food and farming. https://www.gov.uk/government/news/environment-secretary-unveils-vision-for-open-data-to-transform-food-and-farming (Accessed 12th August 2015)

Dickinson, J. L., Zuckerberg, B., and Bonter, D. N. (2010), Citizen Science as an Ecological Research Tool: Challenges and Benefits. *Annual Review of Ecology, Evolution, and Systematics*, *41*, 149–172. DOI:10.1146/annurev-ecolsys-102209-144636

Dockerty, T., Lovett, A., Appleton, K., Bone, A., Sünnenberg, G. (2006), Developing scenarios and visualisations to illustrate potential policy and climatic influences on future agricultural landscapes. *Agriculture, Ecosystems & Environment*, *114*(1), 103–120. DOI: 10.1016/j.agee.2005.11.008

Dockerty, T., Lovett, A., Sünnenberg, G., Appleton, K., Parry, M. (2005), Visualising the potential impacts of climate change on rural landscapes. *Computers, Environment and Urban Systems*, *29*(3), 297–320. DOI: 10.1016/j.compenvurbsys.2004.05.004

Dolman, P. M., Lovett, A., Riordan, T. O., Cobb, D. (2001), Designing Whole Landscapes. *Analysis*, *26*(4), 305–335. DOI:10.1080/0142639012009012

Dwyer, J. (2011). UK Land Use Futures: Policy influence and challenges for the coming decades. *Land Use Policy*, *28*(4), 674–683. doi:10.1016/j.landusepol.2010.12.002

EC. (1991) Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. Pub. L. No. 91/676/EEC (1991).

EC. (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. Pub L 206 , 22/07/1992 P. 0007 - 0050 (1991).

EC. (2000), Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. Pub. L. No. 22/12/2000 (2000). Official Journal of the European Union.

EC. (2008), Water Note 1. *Water Notes on the Implementation of the Water Framework Directive*, (March), 1–4. http://ec.europa.eu/environment/water/participation/pdf/ waternotes/water_note1_joining_forces.pdf (Accessed 12th August 2015)

EC. (2015a), *Communication From the Commission to the European Parliament and the Council: The Water Framework Directive and the Floods Directive: Actions towards the 'good status' of EU water and to reduce flood risks.*

EC. (2015b), *Mobile World Congree 2015: EU unveils its vision for 5G*. https://ec.europa.eu/digital-agenda/en/news/5g-european-research-and-vision-showcased-blueprint-showcased-mobile-world-congress-2015 (Accessed 12th August 2015)

Egan, M. (2015), Oculus Rift release date, specs, features and games: Oculus Rift confirmed for 2016 with Xbox One controller, Windows 10 support and Oculus Touch. *TechAdvisor*. http://www.pcadvisor.co.uk/buying-advice/gadget/oculus-rift-release-date-specs-features-hands-on-3522990/. Accessed 25 July 2015

Elwood, S., Goodchild, M., Sui, D. (2012) Researching Volunteered Geographic Information: Spatail Data, Geographic Research, and New Social practice. *Annals of the Association of American Geographers*, *102* (3), 571-590. DOI:10.1080/00045608.2011.595657

Environment Agency. (2009), *River Basin Management Plan Anglian River Basin District*. https://www.gov.uk/government/publications/anglian-district-river-basin-management-plan (Accessed 12th August 2015)

Everard, M., McInnes, R. (2013), Systemic solutions for multi-benefit water and environmental management. *Science of the Total Environment*, *461-462*, 170–179. DOI:10.1016/j.scitotenv.2013.05.010

Fisher, B., Turner, R., Morling, P. (2009), Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643–653. DOI:10.1016/j.ecolecon.2008.09.014

Georgina, M. M., Bateman, I., Albon, S., Balmford, A., Brown, C., Church, A., et al. (2011), Chapter 2: Conceptual Framework and Methodology. In *UK National Ecosystem Assessment Technical Report*.

Ghadirian, P., Bishop, I. D. (2008), Integration of augmented reality and GIS: A new approach to realistic landscape visualisation. *Landscape and Urban Planning*, *86*(3-4), 226–232. DOI:10.1016/j.landurbplan.2008.03.004

Goldiez, B., Liarokapis, F. (2008), Trends and perspectives in augmented reality training. In *The PSI Handbook of Virtual Environments for Training and Education: Developments for the Military and Beyond* (pp. 278–289).

Gómez-Baggethun, E., de Groot, R., Lomas, P. L., Montes, C. (2010), The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes. *Ecological Economics*, *69*(6), 1209–1218. DOI:10.1016/j.ecolecon.2009.11.007

Goodchild, M. F. (2007a), Citizens as sensors: The world of volunteered geography. *GeoJournal*, *69*(November), 211–221. DOI:10.1007/s10708-007-9111-y

Goodchild, M. F. (2007b), Citizens as voluntary sensors: Spatial data infrastructure in the World of Web 2.0. *International Journal of Spatial Data Infrastructures Research, 2*, 24–32.

Gouveia, C., Fonseca, A., Câmara, A., Ferreira, F. (2004), Promoting the use of environmental data collected by concerned citizens through information and communication technologies. *Journal of Environmental Management*, *71*(2), 135–154. DOI:10.1016/j.jenvman.2004.01.009

Graham, E. a., Henderson, S., Schloss, A. (2011), Using mobile phones to engage citizen scientists in research. *Eos*, *92*(38), 313–315. DOI:10.1029/2011EO380002

Griffiths, M. (2002), The European Water Framework Directive : An Approach to. European Water Management Online, 1–15.

Haines-Young, R., Potschin, M. (2012), Common International Classification of Ecosystem Services (CICES, Version 4.1), 1–17.

Haklay, M. (2013), Citizen Science and volunteered geographic information: Overview and typology of participation. In Sui, D., Elwood, S., and Goodchild, M. (Ed.), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in theory and practice* (p. 396). Dordrecht: Springer Science. pp 105 -124

Hampshire Country Council (2011), *Rural Highway Drainage* http://www3.hants.gov.uk/roads/highway-flooding/highways-drainage/rural-roads.htm (Accessed 12th August 2015)

Harvey, F. (2013), To Volunteer or to Contribute Locational Information? Towards Thruth in Labelling for Crowdsourced Geographic Information In Sui, D., Elwood, S., and Goodchild, M. (Ed.), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in theory and practice* (p. 396). Dordrecht: Springer Science. pp 31-42.

Henrysson, A., Ollila, M. (2011), Augmented reality on smartphones. *IEE Review*, 27–28. DOI:10.1109/ART.2003.1320421

Herzele, A. Van, Woerkum, C. Van. (2011), Landscape and Urban Planning On the argumentative work of map-based visualisation. *Landscape and Urban Planning*, *100*(4), 396–399. DOI:10.1016/j.landurbplan.2011.02.013

HM Government. (2009), *The UK Renewable Energy Strategy*. The Stationary Office.

HOPPALA (2013), Mobile augmented reality. http://www.hoppala-agency.com/ (Accessed 11th October 2013).

House of Lords. (2012), *An Indispensable Resource : EU Freshwater Policy*

Howley, P. (2011), Landscape aesthetics : Assessing the general publics ' preferences towards rural landscapes. *Ecological Economics*, *72*, 161–169. DOI:10.1016/j.ecolecon.2011.09.026

Kingston, R., Carver, S., Evans, A., Turton, I. (2000), Web-based public participation geographical information systems: an aid to local environmental decision-making. *Computers, Environment and Urban Systems*, *24*(2), 109–125. DOI: 10.1016/s0198-9715(99)00049-6

Klosterman, R. (2001), The What If? planning support system. In K. Brail and R. E. Klosterman (Eds.), *Planning Support Systems* (pp. 101–112). Redlands, CA: ESRI Press.

Lange, E. (2001), The limits of realism: perceptions of virtual landscapes. *Landscape and Urban Planning*, *54*(1-4), 163–182. DOI:10.1016/S0169-2046(01)00134-7

Lange, E. (2011), 99 volumes later: We can visualise. Now what? *Landscape and Urban Planning*, *100*(4), 403–406. DOI:10.1016/j.landurbplan.2011.02.016

Lange, E., Hehl-Lange, S. (2010), Making visions visible for long-term landscape management. *Futures*, *42*(7), 693–699. DOI:10.1016/j.futures.2010.04.006

Lange, E., Hehl-Lange, S., Brewer, M. J. (2008), Scenario-visualization for the assessment of perceived green space qualities at the urban-rural fringe. *Journal of environmental management*, *89*(3), 245–56. DOI:10.1016/j.jenvman.2007.01.061

Lave, J., and Wenger, E. (1991), *Situated learning: Legitimate peripheral participation.* Cambridge University Press.

Law, J., Hassard, J. (1999), *Actor Network Theory And After* Oxford : Blackwell

LAYAR (2013), Welcome to Layar. https://www.layar.com/ (Accessed 10th October 2013).

Layke, C. (2009), Measuring Nature's Benefits : A Preliminary Roadmap for Improving Ecosystem Service Indicators. *Analysis*. http://environmentportal.in/files/measuring_natures_benefits.pdf

London Borough of Lewisham. (2010), Ravensbourne River Corridor Improvement Plan, https://www.lewisham.gov.uk/myservices/planning/policy/Documents/Ravensbourne_River_Corridor_Improvement_Plan_%20Newformat_Feb%202012.pdf (Accessed 12th August 2015)

Lowell, K., Christy, B., Pelizaro, C., Day, G., Barlow, K., O'Leary, G., Pettit, C. (2009), Making results of complex systems-based landscape models more accessible to non-expert users. *18th World Imacs Congress and Modsim09 International Congress on Modelling and Simulation*, (July), 4029–4035.

MacFarlane, R. (2000), Achieving Whole-Landscape Management across Multiple Land Management Units: A case study from the Lake District Environmentally Sensitive Area. *Landscape Research*, *25*(2), 229–254. DOI:10.1080/713684671

MacFarlane, R., Stagg, H., Turner, K., Lievesley, M. (2005), Peering through the smoke? Tensions in landscape visualisation. *Computers, Environment and Urban Systems*, *29*(3), 341–359. DOI: 10.1016/j.compenvurbsys.2004.05.006

MacFarlane, R. (2007), Multi-functional landscapes: conceptual and planning issues for the countryside. In Benson, J.F. and Roe, M. (eds) Landscape and Sustainability, 2nd Edition. Routledge: London, UK, 138-166.

MacIntyre, B., Mynatt, E. D. (1998), Augmenting intelligent environments: Augmented reality as an interface to intelligent environments. In *Intelligent Environments Symposium (Stanford, CA, Mar. 23–25) AAAI 1998 Spring Symposium Series*. AAAI Press, Menlo Park, CA.

Macleod, C. J. A, Scholefield, D., Haygarth, P. M. (2007), Integration for sustainable catchment management. *The Science of the total environment*, *373*(2-3), 591–602. DOI:10.1016/j.scitotenv.2006.12.029

Madden, L. (2011), *Professional Augmented Reality Browsers for Smartphones: Programming for junaio, Layar and Wikitude*. Wiley.

Mahmoud, M., Liu, Y., Hartmann, H., Stewart, S., Wagener, T., Semmens, D., et al. (2009), A formal framework for scenario development in support of environmental decision-making. *Environmental Modelling and Software*, *24*(7), 798–808. DOI:10.1016/j.envsoft.2008.11.010

Maurel, P., Craps, M., Cernesson, F., Raymond, R., Valkering, P., Ferrand, N. (2007), Concepts and methods for analysing the role of Information and Communication tools (IC-tools) in Social Learning processes for River Basin Management. *Environmental Modelling Software*, *22*(5), 630–639. DOI:10.1016/j.envsoft.2005.12.016

Maynard, C. M. (2013), How public participation in river management improvements is affected by scale. Area, 45: 230–238. doi: 10.1111/area.12015

Millennium Assessment (2005), *Ecosystems and human well-being: Synthesis.* Island Press

Miranda, T. ., Lisboa-Filho, J., de Souza, W. D., da Silva, O. C., Davis Jr, C. A. (2012), Volunteered geographic information in the context of local Spatial Data Infrastructures. *Urban and Regional Data Management UDMS Annual 2011 Proceedings of the Urban Data Management Society Symposium 2011*, 123–138.

Molle, F. (2009), River-basin planning and management: The social life of a concept. *Geoforum*, *40*(3), 484–494. DOI:10.1016/j.geoforum.2009.03.004

National Ecosystem Assessment (2011), *The UK National Ecosystem Assessment technical report*. UNEP-WCMC, 1466 p.

National Ecosystem Assessment (2014), The UK National Ecosystem Assessment Follow On: Synthesis of the Key Findings. UNEP-WCMC, 100 p.

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman, S., Crowston, K. (2012), The future of Citizen science: Emerging technologies and shifting paradigms. *Frontiers in Ecology and the Environment*, *10*(6), 298–304. DOI:10.1890/110294

Nicholson-Cole, S. A. (2005), Representing climate change futures: a critique on the use of images for visual communication. *Computers, Environment and Urban Systems*, *29*(3), 255–273. DOI: 10.1016/j.compenvurbsys.2004.05.002

Norfolk County Council (2014), *Historic Map Explorer* http://historicmaps.norfolk.gov.uk/mapexplorer/ (Accessed 12th August 2015)

Norfolk Rivers Trust. (2013), River Stiffkey Catchment Management Plan. http://www.norfolkriverstrust.org/wp-content/uploads/2014/05/River-Stiffkey-Catchment-Plan-2014.pdf

Ode, A., Fry, G., Tveit, M. S., Messager, P., Miller, D. (2009), Indicators of perceived naturalness as drivers of landscape preference. *Journal of environmental management*, *90*(1), 375–83. DOI:10.1016/j.jenvman.2007.10.013

OECD. (2015), *Stakeholder Engagement for Inclusive Water Governance*. OECD Publishing. DOI:10.1787/9789264231122-en

OFWAT. (2011), *From catchment to customer: Can upstream catchment management deliver a better deal for water customers and the environment?* http://www.ofwat.gov.uk/sustainability/prs_inf_catchment.pdf (Accessed 12th August 2015)

Palmer, M. H., Kraushaar, S. (2013), Volunteered Geographic Information, Actor-Network Theory, and Severe-Storm Reports. In *Crowdsourcing Geographic Knowledge* (pp. 287–306). Dordrecht: Springer Netherlands. DOI:10.1007/978-94-007-4587-2_16

Perkins, N.H., Barnhart, S. (2005) Visualization and participatory decision-making, IN I.D. Bishop and E. Lange (eds) *Visualization for Landscape and Environmental Planning: technology and applications*, Oxford, Taylor and Francis pp 241-250.

Peters, B.G. (2005) Institutional Theory in Political Science. Second Edition. Continuum, London

Petheram, L., Stacey, N., Campbell, B. M., High, C. (2012), Using visual products derived from community research to inform natural resource management policy. *Land Use Policy*, *29*(1), 1–10. DOI:10.1016/j.landusepol.2011.04.002

Pettit, C., Bishop, I. D., Cartwright, W. E., Park, G., Kemp, O. (2007), Enhancing Web Based Farm Management Software Through The Use of Visualisation Technologies. *Modsim 2007: International Congress on Modelling and Simulation: Land, Water and Environmental Management: Integrated Systems for Sustainability*, 1280–1286.

Pettit, C., Raymond, C. M., Bryan, B. A., Lewis, H. (2011), Identifying strengths and weaknesses of landscape visualisation for effective communication of future alternatives. *Landscape and Urban Planning*, *100*(3), 231–241. DOI:10.1016/j.landurbplan.2011.01.001

Philly 360 (2011), *Augmented Reality* http://philly360.visitphilly.com/news?tag=1900-1940 (Accessed 12th August 2015)

Placeways (2015), *CommunityViz: Software for Planners* http://placeways.com/communityviz/index.html (Accessed 12th August 2015)

Pocock, M. J. O., Chapman, D. S., Sheppard, L. J., Roy, H. E. (2014), Choosing and Using Citizen Science a guide to when and how to use citizen science to monitor biodiversity and the environment. *Centre for Ecology and Hydrology*.

PostNote (2014a), *Big Data: An Overview* Number 468 July 2014 Parliamentary Office of Science and Technology

PostNote (2014b), *Environmental Citizen Science* Number 476 August 2014 Parliamentary Office of Science and Technology

Prato, T., Herath, G. (2007), Multiple-criteria decision analysis for integrated catchment management. *Ecological Economics*, 63(2-3), 627–632. DOI:10.1016/j.ecolecon.2007.01.003

Pretty, J., Barton, J., Colbeck, I., Hine, R., Mourato, S., MacKerron, G., Wood, C. (2011), Chapter 23: Health values from ecosystems. In *UK National Ecosystem Assessment Technical Report* (pp. 1153–1182).

Rantanen, H., Kahila, M. (2009), The SoftGIS approach to local knowledge. *Journal of environmental management*, *90*(6), 1981–90. DOI:10.1016/j.jenvman.2007.08.025

RRC (2014), *Why Restore?* http://www.therrc.co.uk/why-restore (Accessed 15 July 2015)

RESTORE. (2014), Healthy Catchments: Managing water for flood risk and the Water Framework Directive. http://www.ecrr.org/RiverRestoration/Floodriskmanagement/HealthyCatchments-managingforfloodriskWFD/tabid/3098/Default.aspx. (Accessed 1 January 2015)

Roberts, D. (2015), Category Archives: The Hidden Museum. http://www.labs.bristolmuseums.org.uk/category/hidden-museum/. (Accessed 15 July 2015)

Rose, S., Potter, D., Newcombe, M. (2010), *Augmented Reality: A Review of available Augmented Reality packages and evaluation of their potential use in an educational context*.

Roy, H. E., Pocock, M. J. O., Preston, C. D., Roy, D. B., Savage, J., Tweddle, J. C., Robinson, L. D. (2012), Understanding Citizen Science and Environmental Monitoring, 179. http://www.ceh.ac.uk/sites/default/files/citizensciencereview.pdf (Accessed October 2014)

Salter, J. D., Campbell, C., Journeay, M., Sheppard, S. (2009), The digital workshop: Exploring the use of interactive and immersive visualisation tools in participatory planning. *Journal of Environmental Management*, *90*(6), 2090–2101. DOI: 10.1016/j.jenvman.2007.08.023

Schroth, O., Pond, E., Campbell, C., Cizek, P., Bohus, S., Sheppard, S. (2011), Tool or Toy? Virtual Globes in Landscape Planning. *Future Internet*, *3*(4), 204–227. DOI:10.3390/fi3040204

Schroth, O., Pond, E., Muir-Owen, S. (2009), Tools for the understanding of spatio-temporal climate scenarios in local planning: Kimberley (BC) case study. *Swiss National Science …*, 33. DOI:SNSF Report PBEZP1-122976

Science Communication Unit. (2013), *Science for Environment Policy In Depth Report : Environmental Citizen Science*.

SciMap. (2015), SCIMAP - Diffuse Pollution Risk Mapping A Framework For Modelling And Mapping Diffuse Pollution Risk Across Landscapes. http://www.scimap.org.uk/

Scott, A. (2011), Focussing in on focus groups: Effective participative tools or cheap fixes for land use policy? *Land Use Policy*, *28*(4), 684–694. DOI:10.1016/j.landusepol.2010.12.004

Seabrook, L., Mcalpine, C. A., Bowen, M. E. (2011), Restore, repair or reinvent: Options for sustainable landscapes in a changing climate. *Landscape and Urban Planning*, *100*(4), 407–410. DOI:10.1016/j.landurbplan.2011.02.015

Selman, P. (2006). *Planning at the landscape scale*. Routledge London ; New York :

Selman, P. (2010), Learning to Love the Landscapes of Carbon-Neutrality. *Landscape Research*, *35*(2), 157–171.

Sharma, S., Pettit, C., Bishop, I., Chan, P., Sheth, F. (2011), An Online Landscape Object Library to Support Interactive Landscape Planning. *Future Internet*, *3*(4), 319–343. doi:10.3390/fi3040319

Sheppard, S. (2001), Guidance for crystal ball gazers: developing a code of ethics for landscape visualization. *Landscape and Urban Planning*, *54*(1-4), 183–199. DOI:10.1016/S0169-2046(01)00135-9

Sheppard, S. (2005), Landscape visualisation and climate change: the potential for influencing perceptions and behaviour. *Environmental Science and Policy*, *8*(6), 637–654. doi:10.1016/j.envsci.2005.08.002

Sheppard, S., Cizek, P. (2009), The ethics of Google Earth: Crossing thresholds from spatial data to landscape visualisation. *Journal of Environmental Management*, *90*(6), 2102–2117. DOI: 10.1016/j.jenvman.2007.09.012

Sheppard, S., Shaw, A., Flanders, D., Burch, S., Wiek, A., Carmichael, J., et al. (2011), Future visioning of local climate change: A framework for community engagement and planning with scenarios and visualisation. *Futures*, *43*(4), 400–412. DOI:10.1016/j.futures.2011.01.009

Sherrouse, B. C., Clement, J. M., Semmens, D. J. (2010a), A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography*, *31*(2), 748–760. DOI:10.1016/j.apgeog.2010.08.002

Sherrouse, B. C., Riegle, J. L., Semmens, D. J., (2010b), *Geographic Analysis and Monitoring Program Social Values for Ecosystem Services (SolVES): A GIS Application for Assessing , Mapping , and Quantifying the Social Values of Ecosystem Service*s http://pubs.usgs.gov/of/2010/1219/pdf/OF10-1219.pdf (Accessed 15 July 2015)

Sieber, R. (2006), Public Participation Geographic Information Systems: A Literature Review and Framework. *Annals of the Association of American Geographers*, *96*(3), 491–507. DOI:10.1111/j.1467-8306.2006.00702.x

Silvertown, J. (2009), A new dawn for citizen science. *Trends in Ecology and Evolution*, *24*, 467–471. DOI:10.1016/j.tree.2009.03.017

Sismondo, S. (2010), *An introduction to science and technology studies.* Chichester, West Sussex, U.K. ; Malden, MA : Wiley-Blackwell, 2010.

Smith, L., Porter, K., Hiscock, K., Porter, M. J., Benson, D. (2015), *Catchment and River Basin Management: Integrating Science and Governance*. Routledge, part of the Taylor and Francis Group.

Smith, S., Rowcroft, P., Everard, M., Couldrick, L., Reed, M., Rogers, H., et al. (2013), *Payments for Ecosystem Services: A Best Practice Guide*.

Southern, A., Lovett, A., O'Riordan, T., Watkinson, A. (2011), Sustainable landscape governance: Lessons from a catchment based study in whole landscape design. *Landscape and Urban Planning*, *101*(2), 179–189. DOI:10.1016/j.landurbplan.2011.02.010

Spellman, F.R., Drinan, J.E. (2001), *Stream Ecology and Self-Purification. An Introduction.* 2nd edition. Technomic Publishing Co. Inc., Lancaster, PA, USA, 261 pp.

Spray, C. J. (2012), *CATCH II – Review Of Operational Experiences and Approaches to the Implementation of an Ecosystems Approach and Ecosystem Services* http://www.crew.ac.uk/sites/www.crew.ac.uk/files/publications/CATCH%20II%20Review%20of%20Ecosystem%20Approach.pdf (Accessed 12th August 2015)

Spray, C. J., Blackstock, K. (2013), *Optimising Water Framework Directive River Basin Management Planning Using an Ecosystem Services Approach.* http://www.crew.ac.uk/sites/www.crew.ac.uk/files/publications/CREW%20WFD%20and%20Ecosystem%20Services%20Approach.pdf (Accessed 12th August 2015)

Spray, C. J., Rouillard, J. (2012), *CATCH II Fully integrated catchment management planning* http://www.crew.ac.uk/sites/www.crew.ac.uk/files/CREW%20CATCH%20II%20ICM%20.pdf (Accessed 12th August 2015)

Starkey, E., Parkin, G. (2015), Community Involvement in UK Catchment Management FR / R0021 Review of Current Knowledge, *Unpublished - sent by author*

Steinitz, C. (1990), A Framework for Theory Applicable to the Education of Landscape Architects (and Other Environmental Design Professionals). *Framework 9*, 136-143

Steinitz, C. (2012), *A Framework for Geodesign*. ESRI Press.

Stoate, C. (2012), Building a common understanding of natural resource management and use within a catchment community - the Eye, *4*(1), 35–41. DOI:10.5383/swes.04.01.004

Stock, C., Bishop, I., Green, R. (2007), Exploring landscape changes using an envisioning system in rural community workshops. *Landscape and Urban Planning*, *79*(3-4), 229–239. DOI:10.1016/j.landurbplan.2006.02.010

Sui, D., Goodchild, M., Elwood, S. (2013), Volunteered Geographic Information, the Exaflood, and the Growing Digital Divide. In Sui, D., Elwood, S., and Goodchild, M. (Ed.), *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in theory and practice* (p. 396). Dordrecht: Springer Science. pp 1 - 14

Swetnam, R. D., Fisher, B., Mbilinyi, B. P., Munishi, P. K. T., Willcock, S., Ricketts, T., et al. (2010), Mapping socio-economic scenarios of land cover change: A GIS method to enable ecosystem service modelling. *Journal of Environmental Management*, 92(3), 563–574. DOI:10.1016/j.jenvman.2010.09.007

Talen, E. (2000), Bottom-Up GIS. *Journal of the American Planning Association*, *66*(3), 279–294. DOI:10.1080/01944360008976107

The Rivers Trust, Defra. (2014), River Improvement Fund Programme, http://www.theriverstrust.org/rifp/ (Accessed 12th August 2015)

Tufte, E. (1990), *Envisioning Information*. Graphics Press, Cheshire, CT, USA.

Tulloch, A. I. T., Mustin, K., Possingham, H. P., Szabo, J. K., Wilson, K. A. (2013), To boldly go where no volunteer has gone before: predicting volunteer activity to prioritize surveys at the landscape scale. *Diversity and Distributions*, *19*(4), 465–480. doi:10.1111/j.1472-4642.2012.00947.x

Tweddle, J.C., Robinson, L.D., Pocock, M.J.O., Roy, H.E. (2012) *Guide to Citizen Science: Developing, Implementing and EValuating Citizen Sceince to Study Biodiversity and the ENvironment in the UK/* Natural History Museum and Centre for Ecology and Hydrology for UK-EOF, London, UK

UK Biodiversity Action Plan Steering Group for Chalk Rivers (2004) *The State of England's Chalk Rivers* http://adlib.everysite.co.uk/resources/000/057/248/Summary_chalk_rivers.pdf Published by English Nature and Environment Agency (Accessed 12th August 2012)

N.B. The above report has been superseded by **WWF-UK** (2014) *The State of England's Chalk Streams* http://assets.wwf.org.uk/downloads/wwf_chalkstreamreport_final_lr.pdf (Accessed 12th August 2015)

Vira, B., Elliott, L. C., Fortnam, M., Wilks, S. (2011). Chapter 27: Response Options. In *UK National Ecosystem Assessment Technical Report* (pp. 1309–1451).

Virtalis (2015), *Geovisionary* http://www.virtalis.com/geovisionary/ (Accessed 12th August 2015)

Von Haaren, C., Warren-Kretzschmar, B. (2006), The interactive landscape plan: Use and benefits of new technologies in landscape planning and discussion of the interactive landscape plan in Koenigslutter am Elm, Germany. *Landscape Research*, *31*(1), 83–105. DOI:10.1080/01426390500448625

Wensum Alliance. (2015), River Wensum Demonstration Test Catchment Project. http://www.wensumalliance.org.uk/. (Accessed 12th August 2015)

Westcountry Rivers Trust. (2013), *Participatory Ecosystem Services Visualisation Framework: Making effective use of data and evidence to inform catchment management planning*.

Wiggins, A., Crowston, K. (2011), From conservation to crowdsourcing: A typology of citizen science. In *Proceedings of the Annual Hawaii International Conference on System Sciences*. DOI:10.1109/HICSS.2011.207

Wilson, G. (2010), Multifunctional 'quality' and rural community resilience. *Geographical*, 364–381.

Winn, J., Brocklebank, H. (2013), *EcoServ-GIS.* http://publications.naturalengland.org.uk/file/5047916536266752 (Accessed 12th August 2015)

Wissen Hayek, U. (2011), Which is the appropriate 3D visualization type for participatory landscape planning workshops? A portfolio of their effectiveness. *Environment and Planning B: Planning and Design*. DOI:10.1068/b36113

Wissen Hayek, U., Teich, M., Klein, T. M., Grêt-Regamey, A. (2015), Bringing ecosystem services indicators into spatial planning practice: Lessons from collaborative development of a web-based visualization platform. *Ecological Indicators*. DOI:10.1016/j.ecolind.2015.03.035

Wissen, U., Schroth, O., Lange, E., Schmid, W. A. (2008), Approaches to integrating indicators into 3D landscape visualisations and their benefits for participative planning situations. *Journal of environmental management*, *89*(3), 184–96. DOI:10.1016/j.jenvman.2007.01.062