Nuffield Farming Scholarships Trust

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Water: Managing a vital resource

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Disclaimer

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Acronyms

ADAS	Agricultural Development Advisory Service
ART	Association of River Trusts
AWBA	Arizona Water Banking Authority
BMP	Best Management Practice
CAC	Command and control
CAF	Confined Animal Facility
CAMS	Catchment Abstraction Management Strategies
CAP	Common Agricultural Policy
CARES	Community Alliance for Responsible Environmental Stewardship
CCW	Countryside Council for Wales
CDQA	California Dairy Quality Assurance (Programme)
CMS	Countryside Management Scheme
COC	Constituents of Concern
CPS	Countryside Premium Scheme
CSF	Catchment Sensitive Farming
CSFO	Catchment Sensitive Farming Officers
CWA	Clean Water Act
DC	District of Columbia
Defra	Department of the Environment, Food and Rural Affairs
EA	Environment Agency
EC	European Community
ECSFDI	England Catchment Sensitive Farming Delivery Initiative
ELS	Entry Level Stewardship
EPA	(US) Environmental Protection Agency
EQIP	Environmental Quality Incentives Programme

ESA	Environmentally Sensitive Areas Scheme
EU	European Union
FAO	Food and Agriculture Organisation – United Nations
FIT-FIR	First in Time – First in Right
FWAG	Farming Wildlife Advisory Group
GAP	Good Agricultural Practice
GPS	Global Positioning System
GRLT	Great Rivers Land Trust
HLS	Higher Level Stewardship
IPPC	Integrated Pollution Prevention and Control
IRWMP	Integrated Regional Water Management Plans
JPL-NASA	Jet Propulsion Laboratory – National Aeronautics and Space Administration
LEAF	Linking Environment and Farming
MAF	Million Acre Feet
MBI	Market Based Incentives
MIC	Mutual Irrigation Company
NE	Natural England
NGO	Non-Governmental Organisation
NPDES	National Pollution Discharge Elimination System
NVZ	Nitrate Vulnerable Zones
OECD	Organisation for Economic Co-operation and Development
PES	Payment for Environmental Services
RAFTS	Rivers and Fisheries Trusts of Scotland
RBMP	River Basin Management Plans
RSS	Rural Stewardship Scheme
RSA	Restoring Sustainable Abstraction

RSPB	Royal Society for the Protection of Birds
SEPA	Scottish Environment Protection Agency
SRWUA	Sevrier River Water Users Associations
SSSI	Sites of Special Scientific Interest
SUDS	Sustainable Urban Drainage Systems
SWP	(Californian) State Water Project
SWRCB	State Water Resources Control Board
SWT	Staffordshire Wildlife Trust
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
UK	United Kingdom
UKBAP	United Kingdom Biodiversity Action Plan
UKTAG	United Kingdom Technical Advisory Group
US	United States
USDA	United States Department of Agriculture
WDR	Waste Discharge Requirements
WFA	Whole Farm Approach
WFD	Water Framework Directive
WHIP	Wildlife Habitat Incentives Programme
WPZ	Water Protection Zone
WQT	Water Quality Trading

Quantities/symbols

%	percent
Ha	hectare
km^3	= 1 x 10^{12} litres
Litre	= 1000 cm^3
megalitre	= 1000 m^3
mg/l	= mg/litre
m^3	= 1000 litres
mm	= millimetres
ppm	= parts per million

Executive summary

As world population rises and urbanisation accelerates there will be a growing conflict between cities that need water to function and farmers that require water to grow food. The report compares and contrasts the development of United States (US) and United Kingdom (UK) water rights and the growing demands for "environmental" water. Many US States had developed, or are currently developing, State Water Plans in order to manage their water resources effectively and meet environmental, municipal, energy, amenity and food production needs. The introduction of water quantity trading "water markets" in the US has had a profound effect and will play a huge part in driving future agricultural policy.

The introduction of the Clean Water Act in the US and the Water Framework Directive (WFD) in the European Union (EU) has many parallels especially the development of water quality indicators. Cross-compliance with UK agricultural standards has equivalence with adherence to best management practices in the US. Urban and rural areas are sources of diffuse pollution. Remedial action will need to be funded if such pollution is to be reduced in order to meet the requirements of the WFD. Will the revenue afforded by agricultural environmental payments deliver action in rural areas at the speed required? I do not believe so. Can alternative sources of revenue be identified that provide both financial and social benefits? Water quality trading can deliver such benefits: it will reduce water utility costs and those passed on to the general public. Land users will also benefit from effective use of fertilisers and crop protection products if they remain in-situ rather than entering the water courses. Water quality trading (WQT) will also reduce the carbon footprint of the water utilities as they will not have to provide the current level of treatment or blending of water supplies.

In the wake of Hurricane Katrina, many States have focused their attention on flood management, especially the condition of levees and barriers. In California, the Yolo flood bypass system has been established as a "flood corridor". Flood or conservation easements have great potential for the UK as we review the implications of the EU Floods Directive and the development of flood retention and detention basins. Alternative sources of capital need to be identified for such projects and could include State, European or private equity funding.

Whilst carbon footprint receives most attention, I am certain that water footprint will gain in importance. The transition towards animal product based diets will increase the demand for water in the food supply chain. As supply chains become more global, water footprint, especially external water footprint (outside national borders) will become more important as a policy measure to overcome national drought. Water footprint may also prove a driver in agricultural policy as countries switch to products with a higher calorific value per volume of water used and promote more efficient methods of irrigation.

The study has identified a range of measures that could be implemented within UK water policy that are cost effective, provide new revenue streams for capital projects and will potentially reduce the cost of water at the point of consumption. It has also placed this UK theme within the wider context of how water quality and the quantities available will limit our potential to produce food at a local, regional and global level.

Conclusions and recommendations

Total UK water demand can be managed through metering, pricing and incentives i.e. those who can pay have access to the water. This market mechanism should reduce water waste as users recognise the cost of their activities and practices. However using a single tariff alone will disadvantage those in the community who cannot afford the water and will also not recognise the value of different uses or the varying volumes used.

Recommendation 1: A sliding tariff should be developed for water abstraction/use that recognises beneficial use and social need.

The further development of UK water resources will require changes to existing regulations or hydrologic structures.

Recommendation 2: The further development of strategic and operational water policy should be a collaborative approach with a range of stakeholders. Water policy should utilise both public and private mechanisms to deliver legislative compliance, meet population needs and sustain economic growth.

Water rights' trading provides a market mechanism to prevent over-abstraction of bodies of water, maintain the asset value of the abstraction right and provide added flexibility to water supply. However with agricultural abstraction being suggested as only representing 2% of the total volume of water extracted it does not present the opportunities for reallocation of water that has been seen in the US market.

Recommendation 3: The benefits of developing WQT should be assessed in order to manage demand in specific regions or catchments. WQT could be particularly effective too as an element of drought management planning.

In view of the issues with climate change, the predicted change in rainfall patterns and the increasing demand for water in the East and South of England private, on-farm water reservoirs will need to increase in number in order to mitigate the changes and reduce the pressure on summer abstraction.

Recommendation 4: Businesses should undertake a formal risk management exercise to determine the volume of water they require and how they can offset and/or reduce any financial or operational risks associated with their demand for water. This can include, but is not limited to: development of reservoirs to capture winter/spring rainfall; collection of run-off from roof areas and concrete areas for non-potable uses, effective methods of separating clean and dirty water, and methods for reducing water wastage.

Diffuse, or non-point source pollution has been recognised as a major issue in the UK. Urban and rural areas are sources of such pollution and strategies need to be implemented to address diffuse pollution as a whole. Remedial action will need to be funded if such pollution is to be reduced in order for the UK to meet the requirements of the WFD. Will the revenue afforded by agricultural environmental payments deliver action in rural areas at the speed required? I do not believe so. Can alternative sources of revenue be identified that provide both financial and social benefits?

Recommendation 5: WQT has the potential to deliver significant benefits. Defra estimated that the cost of removing pesticides and nitrates from drinking water is £7 per water customer per year. Effective implementation of WQT will reduce water utility costs and those passed on to the general public. Land users will also benefit from effective use of fertilisers and crop protection if they remain in-situ rather than entering the water courses. WQT will reduce the carbon footprint of the water utilities as they will not have to provide the current level of treatment or blending of water supplies. WQT as a policy should be reviewed by all stakeholders.

Water quality is of importance to both crop and livestock producers.

Recommendation 6: Agricultural businesses should pay attention to water quality and develop a water monitoring programme to determine the effects on crop performance and/or livestock performance, animal welfare and profitability.

Farmers and land managers will play a crucial role in the implementation of the Floods Directive especially in the development of retention and detention basins.

Recommendation 7: Alternative sources of capital for flood alleviation projects need to be identified and could include state, European or private equity funding. The use of retention and detention basins could be paid for by an annual fee irrespective of usage, or the farmer could be paid because they are essentially providing additional storage space to improve water management throughout the year. These basins could also be used to retain water for non-potable uses and to recharge aquifers especially if in some parts of the country ground water supplies are depleted meeting the requirements of drinking/municipal water.

Conservation easements and land trusts as developed in the US could have benefits and provide alternative sources of revenue for capital projects.

Recommendation 8: Policy makers should review the potential benefits of developing conservation easements and land trusts in the UK. The land trusts would deliver societal benefits; individuals or companies that donate to these schemes can gain tax benefits and landowners can realise a financial asset to reinvest in their farming business or an alternative enterprise whilst ensuring that the land will be designated for agricultural use into the future.

Urban areas need to address water efficiency, and diffuse pollution.

Recommendation 9: Water companies should further develop their urban and municipal water efficiency projects. These should include: advice and support in developing use of non-potable water for gardens; washing cars etc and assistance to improve household water efficiency.

Recommendation 10: Programmes should be developed to promote understanding of water footprint at a personal, community and organisational level. Individuals should be provided with information and guidance in how they can take action to reduce their water footprint and save money too!

Introduction

When I was awarded the Nuffield scholarship in January 2007 Thames Water, Three Valleys Water, Southern Water, Sutton and East Surrey Water and South East Water had just removed their 2006 hosepipe bans as a result of above average rainfall over the previous six months. Mid Kent Water was still retaining its hosepipe and sprinkler bans. The Environment Agency (EA), in their report "Early drought prospects 2007", stated that parts of England had been suffering from drought since 2004 and in the summer of 2006 eight water companies implemented hosepipe bans. This affected 15.6 million people (a quarter of the UK population) and it was the second year of bans for 3.4 million people.

By June and July 2007, the situation had changed completely with many areas of the UK experiencing the worst flooding in living memory. This resulted in not only severe personal loss for individuals but also a significant loss of agricultural production as crops were devastated and livestock were lost. In Gloucestershire, the flood water swamped a water treatment plant causing thousands of people to lose their drinking water supply for several weeks and the waters were only just prevented from flooding a power substation. Many farms also faced an instant loss of water supply for their livestock and they were then struggling to find alternative sources of water.

Drought and flooding events can have a significant impact on food safety and food supply, animal welfare, environmental protection and even business viability. If I had started my study expecting to address drought and lack of water, then the summer of 2007 showed that too much water can also have a devastating effect. Therefore on both a national and organisational level effective strategic and operational water policy needs to be in place, primarily to address such extremes, and where possible mitigate resultant risk.

So, why undertake a project on water?

Having been awarded my scholarship, when I looked at the list of previous Nuffield study titles there have actually been very few studies that have looked at water issues compared to specific sector dairy, arable, beef and sheep studies. Those studies that have been undertaken have focused primarily on irrigation techniques, and water system management. I firmly believe that water issues and more importantly, discussions on water security will be an ever recurring mantra in the years to come as we seek to feed the growing world population and grow a higher proportion of our energy fuels. This theme was echoed so many times by the people that I met on my travels.

The UK population is predicted to rise substantially over the coming years and this will put pressure on water resources in terms of availability for municipal supplies; water quality and its impact on drinking water quality; waste water treatment and the requirements of the energy industry for water as energy demand increases. National Statistics has estimated the UK population between 2004 and 2031 and suggest a rise of 7.3 million people i.e. a twelve percent increase in population which is projected to peak at around 70 million (Figure 1). However, growth is not predicted to be uniform across the UK (Table 1) and the impact of population rise on water resources will be felt primarily in England and Wales. The percentage rise in population between 2004 and 2031 is predicted to be fourteen percent for England (7.2 million), ten percent for Wales (0.3 million), six percent for N. Ireland (0.1 million) and static population figures for Scotland.

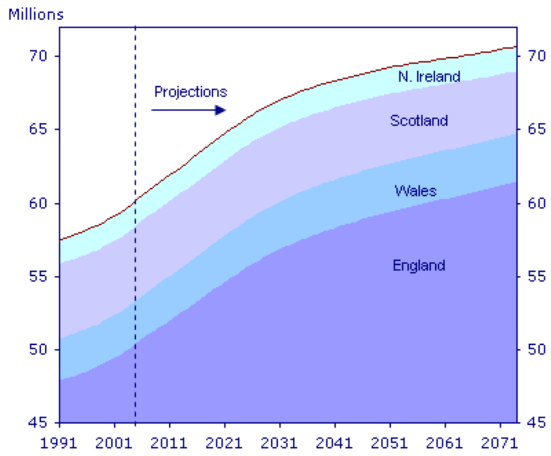

Figure 1: Estimates of population rise in the UK[1]

The average rainfall in England and Wales is approximately 900 mm/year (35.4 inches/year), but this figure ranges from 550 mm/year (21.7 inches/year) in Essex to parts of Wales that exceed 4 000 mm/year (157.5 inches/year). Regional annual rainfall in Scotland varies between 800 mm and 3 000 mm and in Northern Ireland between 800 mm and 1 600 mm.

Table 1: Projected population rise in the UK

	Projected population in millions (Source: National Statistics[1])			
Year	**2004**	**2011**	**2021**	**2031**
United Kingdom	59.8	61.9	64.7	**67.0**
England	50.1	52.0	54.6	**56.8**
Wales	3.0	3.0	3.2	**3.3**
Scotland	5.1	5.1	5.1	**5.1**
Northern Ireland	**1.7**	**1.8**	**1.8**	**1.8**

This means that although average rainfall across the UK may be adequate for all our needs the rain does not always fall in the areas where the water is needed for the general population, industry and agricultural needs. Freshwater Resources Data for 2005[2] from the United Nations Food and Agriculture Organisation (FAO) suggested that the renewable resources for the UK are 2 474 cubic metres (m^3) per person. The EA[3] has also estimated water availability in regions of the England and Wales. Whilst overall water availability in England and Wales is about 1 334 m^3 per person, this reduces to 921 m^3 per person in South-east England and in the Thames Valley region to about 266 m^3 per person. Table 2 compares these figures with global water availability data for a range of countries. The data demonstrates that the water availability in the Thames Valley is one third of the water available per person in Egypt and in the same magnitude as Israel.

Table 2: Freshwater resources 2005

Country	Total actual renewable water resource (km³)	Actual renewable water resource per capita (m³)	Country	Total actual renewable water resource (km³)	Actual renewable water resource per capita (m³)
Canada	2 902	91 419	Afghanistan	65	2 608
New Zealand	327	83 760	**United Kingdom**	**147**	**2 474**
Chile	922	57 639	China	2 830	2 206
Brazil	8 233	45 573	India	1 897	1 754
Russian Federation	4 507	31 653	Germany	154	1 866
Australia	492	24 708	Ethiopia	110	1 519
Sweden	174	19 581	Poland	62	1 598
Ireland	52	13 003	Pakistan	223	1 415
Hungary	104	10 579	**England and Wales**		**1 334**
United States	3 069	10 333	Lebanon	4	1 189
Switzerland	54	7 468	Kenya	30	932
Greece	74	6 764	**South East England**		**921**
Netherlands	91	5 608	Egypt	58	794
Mexico	457	4 357	Tunisia	5	459
France	204	3 371	**Thames Valley**		**266**
Japan	430	3 365	Israel	2	255
Italy	191	3 336	Jordan	1	157
Turkey	229	3 171	Libyan Arab	1	106
Iraq	75	2 917	Saudi	2	96
Ukraine	140	2 898	UAE	0	49
Bulgaria	21	2 721	Kuwait	0	8
Spain	112	2 711			

Source: [2,3]

However, the figures do not take into account water recycling through water treatment facilities and how often that water is reused per annum. The degree of recycling and the general public perception of consuming recycled water varied between the countries that I visited during my study. There is very little thought paid in the UK to the number of times water has been recycled when we are using it, however recycled water i.e. "toilet-to-tap" was a concern among the general public in some areas of the US.

Whilst water availability is of interest the key figure in determining the sustainability of the water supply is the water balance i.e. the water resource available per capita after sectoral withdrawals i.e. usage by industry, agriculture and domestic needs. The data in Table 3 shows that the sector withdrawal for agriculture varies greatly from country to country and that in the UK the sector withdrawal for agriculture is three percent, compared to the US forty one percent, Brazil sixty two percent and China sixty eight percent.

Table 3: National water balances 2005

Country	Sectoral Withdrawal for Agriculture 2000 (%)	Balance of renewable water resource per capita after sectoral withdrawals (m³) per person 2005	Country	Sectoral Withdrawal for Agriculture 2000 (%)	Balance of renewable water resource per capita after sectoral withdrawals (m³) per person 2005
Canada	12	89 925	Bulgaria	21	1 425
Norway	10	83 430	Spain	68	1 837
New Zealand	42	83 202	Afghanistan	98	1 521
Chile	64	56 815	**United Kingdom**	**3**	**2 311**
Brazil	62	45 228	China	68	1 712
Russian Federation	18	31 126	Iran, Islamic Rep	91	873
Costa Rica	53	25 766	India	86	1 119
Australia	75	23 458	Germany	20	1 294
Argentina	74	20 157	Ethiopia	93	1 479
Sweden	9	19 246	Syrian Arab Rep	95	236
Ireland	0	12 707	Czech Rep	2	1 036
Hungary	32	9 816	Poland	8	1 179
United States	41	8 651	Pakistan	96	228
Austria	1	9 308	Lebanon	67	-813
Greece	81	6 052	Kenya	64	880
Netherlands	34	5 108	Egypt	78	-219
Mexico	77	3 566	Tunisia	82	173
France	10	2 697	Israel	63	-83
Japan	62	2 669	Jordan	75	-45
Italy	45	2 565	Libyan Arab Jamahiriya	89	17
Turkey	74	2 621	Saudi Arabia	89	-686
Iraq	92	1 078	UAE	68	-769
Ukraine	52	2 143	Kuwait	52	-190

Source: [2,3]

The figure for UK withdrawal for agriculture is quoted in other literature as two percent, but the magnitude is small compared to other countries. The negative balance figures demonstrate that many countries have active recycling programmes and/or are undertaking desalination. It is also important to bear in mind when looking at the data that whilst water resources may be geographically available in a country the water resource may neither be in the regions that are densely populated nor in the areas where irrigated agriculture is undertaken and thus not be "practically" available. Historically UK agriculture has been largely rain-fed and did not use a significant portion of the surface and ground water resources available. The costs associated with water have continued to rise, and the inability to assure water quality and quantity can be a limiting factor on organisational expansion and development, not only with regard to food production and processing, but also housing development, tourism and leisure and sporting facilities. European legislative drivers such as the WFD or Integrated Pollution Prevention and Control (IPPC) requires organisations to monitor their impact on hydrological systems and their specific water use and implement effective ways of reducing water wastage. Legislation also requires organisations to monitor their impact on local water catchment areas with regard to the water that they abstract and its effect on ecosystems as well as the materials they control that can enter the water system. These materials include nutrients, crop protection products and organic wastes which will affect ecosystems and impact on water quality. Equivalent legislation was also in place in the US.

Aims and objectives of the study

The aim of the study was to determine the impact of water availability and quality on food production. This led to the development of the following objectives:

1) To review how water management policy has been developed at both regional and national levels with a view to availability, water rights and water basin management for all users;
2) To assess the interaction of differing demands for water and the impact of inadequate water supplies;
3) To determine the effective management of diffuse pollution; and
4) To consider how these challenges have been met and seek to identify models of best practice with a view to developing water policy guidelines.

Global water issues

Sustainability of water resources requires equilibrium to be maintained between demand and the supply of water available. Water demand includes water required for domestic use and drinking, industrial use for producing energy, manufactured goods and services, for amenity use, and in the provision of food. The ecological demand for water also needs to be assessed in terms of the water requirement to minimise the environmental impact on surface and groundwater systems and to ensure the overall sustainability of water resources.

Research by the Organisation for Economic Co-operation and Development[4] (OECD) suggests that by 2025, global water use will rise by up to 30 percent in developing countries and over 10 percent in the developed world. The report estimated that the population living in water-stressed areas is set to double over the period 1995-2025, and by 2030 some two-thirds of the world's inhabitants may experience moderate to high water stress in parts of Africa and Asia[5]. The trend in rising population as well as increased international trans-boundary competition for declining water resources that are also reducing in quality could impact on regional development and potentially lead to regional instability. The earth's surface is predominantly covered in water with only twenty four percent of the surface as land comprising four percent of the surface cultivated to arable and one point four percent as permanent crops with irrigated agriculture playing a key role in food production.

So where does the water to sustain life come from? Saltwater oceans hold ninety seven percent of surface water, glaciers and polar ice caps two point four percent, and rivers and lakes comprising nought point six percent. Ninety six point two percent of the total fresh water available is ground water with the rest being made up of surface water, soil moisture, atmospheric water, permafrost and biological water. Global estimates for the rise in human population predict an increase in our global population from 2.56 billion in 1950 to 9.40 billion in 2050. Whilst the future for global food and water security, climate change, and environmental sustainability may, or indeed may not, be careering towards a disaster scenario we cannot discount this possibility completely out of hand. Therefore we need to develop strategic and operational water security policy to mitigate the risk on a local, national and regional level.

Is water a private, public or mixed good?

So who does the water belong to? Is it a public good i.e. it can be used by everyone and no one is excluded from access to the water supply? Clearly water cannot be termed a public good because it can only be used by one person at a time, and when one person is using the water this immediately excludes others from using the same resource, for example, if one farmer uses water for irrigation it immediately reduces the quantity available for other farmers or for other uses. Some parts of the world treat water as a free good whereas other regions implement defined property or user rights, such as the US. In this context, water has been classed as a private good because it has a value and only those who can afford to pay for the water or who have a "right" to use the water can gain access to the water supply.

More recently along with this market argument with regard to water there is increasing focus on the social and environmental aspects that are very often termed "public goods" especially in the context of municipal supply and environmental conservation. Water has therefore both public and private elements and could be classed as a "mixed" good. A river basin could be described as providing mixed goods and in order for this to be sustainable there must be a natural ecological water balance as a result of rainfall, stream inflows and outflows, groundwater, evaporation and transpiration. This natural balance will be affected by abstraction for uses such as drinking water. Water from river basins is subject to a variety of uses including provision of power, transport, amenity, drinking, municipal uses, irrigation for agriculture and ecological protection and these activities can at times be mutually exclusive. Fundamentally, water policy has to be developed on the basis that it will have both private and public elements and conflict could potentially arise where these elements are deemed to be competitive.

How is water utilised in the UK?

In the UK, water is abstracted under licences, granted on the basis of the availability of water resources and consideration of the reasonable needs of the public, industry and agriculture. The volume abstracted has been rising since the mid-1990s. In 2004, figures for England and Wales show that seventy six percent of water abstracted at a given time from non tidal surface water and groundwater was for the public water supply and electricity supply industry (Figure 2). The volumes used for fish farming show an increase in the twenty year period 1984 – 2004 from 1.1 to 4.1 thousand megalitres per day. Water used for crop irrigation has not been identified in this data and would probably therefore fall in the "other" category. Public water supply distribution and supply leakages are currently running at about twenty three percent in England and Wales, that is, about 3 576 megalitres per day. If we look at the level of run-off in the UK i.e. the volume of rain fall that goes into the sea it is sixty percent for Great Britain, seventy three percent for Scotland, sixty two percent for Northern Ireland and drops to forty nine percent in England and Wales[6]. This represents a total outflow to the sea from the UK of 157 billion cubic metres.

How does geographic municipal demand relate to agricultural demand?

Whilst Defra figures identify the geographic regions where crops are grown there is no data on the land that is actually irrigated and the volume of water used for irrigation would seem according to Figure 2 to be rather small, however the water usage for trickle irrigation is not included in the data. The EA regions that have both high urban population and agricultural production are North East, North West, Wales and Anglia. I have tried to ascertain the regional demand for water in terms of energy production. This information has been difficult to source. The energy industry is the largest user of water in the UK accounting for about forty five percent of resources used with direct abstractions from rivers and the sea. Water UK[8] has calculated that to produce one kilowatt-hour of electricity requires 140 litres of water in fossil fuel plants and 205 litres in nuclear power plants, with some water converted to steam, to drive electricity generators. In thermal power generation, most is used for condenser cooling.

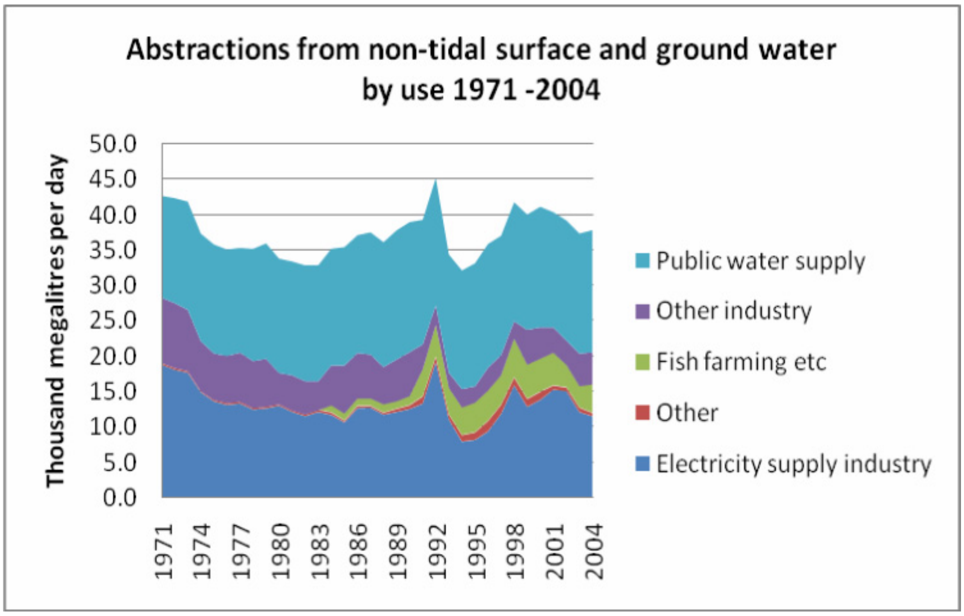

Figure 2: Abstractions from non-tidal surface and ground water by use 1971 – 2004[7]

In the UK there are currently around 200 hydroelectric schemes, generating two percent of our electricity, compared with a global figure of twenty percent. The amenity use of water has significant value and the economic value of the UK angling industry has been estimated at £3 billion per annum. It is also estimated that there are currently around 60 000 boats on the UK's water systems and lakes. 14% of the water abstracted is used for manufacturing. Water UK suggests that the manufacture of a car requires 450 000 litres of water including 80 000 litres to produce the tonne of steel from which the car is made; to produce a desktop computer requires 1 500 litres of water and a tonne of paper requires 30 000 litres.

Water footprint

Whilst this report has contained some figures for water consumption in terms of the goods and services that we purchase, the food we eat also has an impact on the water resources required to maintain our lifestyles. The term "water footprint" has been defined[9] as "*the volume of water needed for the production of the goods and services consumed by the inhabitants of the country*". However water footprint can also be determined at a personal, household, community, regional, national or global level. Key drivers of a nation's water footprint[9] are:

- The volume of consumption of goods and services;
- Food consumption patterns, especially the level of meat and dairy product consumption;
- Climatic factors such as rainfall, growing conditions and the requirements for irrigation; and
- Industrial, municipal and agricultural practices and the degree of water use efficiency.

A nation's water footprint can be "internal" i.e. the volume of water used within national boundaries whilst on the other hand the "external" water footprint is the volume of water used to produce the goods and services imported and consumed by the inhabitants of the country.

Water footprint can be calculated by crop type and growing region. Using wheat as an example (Table 4) demonstrates that for the five countries analysed the crop water requirement varies from 179 – 630 mm/crop period with the average virtual water content of 1 334 m^3/tonne with a range of 738 – 1 588 m^3/tonne. It has been suggested that the Alternative data from the US would suggest that the virtual water content is actually with figures averaging between 1 482 and 2 017 m³/tonne.

Table 4: Virtual water content of wheat by country[10]

Country	Crop water requirement (mm/crop period)	Wheat yield (tonne/ha)	Virtual water content (m³/tonne)	Calculation check
Argentina	179	2.4	738	746
Australia	309	1.9	1 588	1 626
Canada	339	2.3	1 491	1 474
France	630	7.0	895	900
USA	237	2.8	849	846
Global average (all countries)		2.7	1 334	

The virtual water content of wheat is around 1 m³/kg whereas the virtual water associated with meat production can vary between 5 and 13.5 m³/kg[10]. Table 5 gives examples of the average virtual water content of a range of crops and the proportion of the world's water resources that are used to grow the crop. The figures suggest that potatoes have an average virtual water content of 255 m³/tonne compared to rice with a virtual water content of 2 291 m³/tonne. In the context of global food supply chains there is increasing scope to undertake "virtual water trade"[5].

Table 5: Global average virtual water content of primary crops[10]

Crop	Average virtual water content (m³/tonne)	Share in global water consumption for crop production (%)
Wheat	1 334	12.4
Rice	2 291	21.3
Barley	1 388	3.0
Maize	909	8.6
Rye	901	0.3
Oats	1 597	0.7
Rapeseed	1 611	1.0
Potatoes	255	1.2
Sugar Cane	175	3.4
Sugar Beet	113	0.4
Lettuce	133	0.04
Spinach	144	0.02
Tomatoes	184	0.3
Apples	697	0.6
Coffee (Green)	17 373	1.9
Coffee (Beans)	27 218	1.4

Therefore a drought affected or water-scarce region or country can "import" virtual water within food products and thus relieve pressure on its own water resources.

Water footprint can be further classified into green (rain water stored in the soil as soil moisture), blue (surface water and ground water) and grey, the amount of recycled or reprocessed water that is used. Blue water is the main source of water for crop irrigation. Sources of irrigation water are not limited to but include: natural springs, water tanks or purpose built reservoirs; abstraction from rivers or lakes; boreholes, artesian wells, percolation wells; diversion of streams, or irrigation canals; trans-basin water diversion; and water management projects[5].

National food policy could arguably be driven in countries facing water resource challenges by a virtual water policy, so that food crops grown in the region will utilise less water for equivalent calorific benefit and foods that have larger virtual water contents will be imported. There is also the counter argument that exported food/goods with high virtual water contents are actually removing a scarce resource and this may limit growth and development within national borders. This topic engendered lively debate during my study with a range of views expressed on the subject.

The key benefit of green water is that it is "free" i.e. it just falls on the ground. However, users may have to pay for the cost of storing and transferring that water from regions of high rainfall/snow to regions where urban users and/or food production takes place. The use of blue water or indeed recycled water, termed "grey" water, often requires facilities for treatment, storage and distribution before it can be used and this adds to the unit cost of the water. The chemical composition of "blue" water will also vary and inappropriate irrigation techniques can affect soil fertility by causing water logging, soil degradation or increased salinity[5]. With this background the report will now address how water policy has been developed in the US.

Water management policy – US

Introduction

In the US, I visited Utah, California and Washington DC where the drivers of water policy include increasing population, shifts in demand patterns, environmental requirements and the impact of global climate changes on water resource management. This means that both water providers and users need to manage and conserve water resources more efficiently. The right to use water originally developed according to the needs of the population, agriculture and industry. When the US was first settled in the east, water rights were based in English law i.e. that there was open access to water otherwise known as "riparian" rights. The Spanish settlements in the west were in locations where there was a plentiful supply of water i.e. built on rivers or river mouths so there was no need to establish legal water rights. These Spanish rights were known in California as "pueblo" rights.

As settlement moved west, passed the 100th meridian, it was determined that the land would be made available to individuals for private ownership i.e. "staking a claim". An individual could stake a claim for 160 acres, the land had to be actively farmed and a harvest achieved in order to establish and gain property rights.

With knowledge of the topography of the land and the lack of availability of water for agricultural development it was determined that to the west of the 100th Meridian "riparian" water rights would not be a viable approach. Therefore it was decided that water rights would be attributed as property rights to those who took water from the stream and brought it to the land. As a practical matter, the first land settled was close to snow melt fed streams. In some western states the primary agriculture was cattle ranching and in these areas the cattle were fed from springs and as the agriculture developed from bore-holes fed from aquifers. After the Second World War the development of turbine pumps improved the efficiency of water abstraction for cattle. In further western states as they developed including, California, Nevada and Colorado the early use of water was mining and water policy was based more on industry use than municipal or agricultural uses. In California, the situation is more complicated than Utah and Californian law recognises multiple types of water rights, as discussed later.

The development of water policy for the Colorado River

The Colorado River is the primary river of the American Western States, draining somewhere in the vicinity of 242 000 square miles of land, from the states of Wyoming, Colorado, Utah, New Mexico, Arizona, Nevada and California[11]. The drainage basin comprises about one-twelfth of the area of the continental US. The Colorado River provides municipal and industrial water for more than twenty four million people living in the major metropolitan areas of Los Angeles, Phoenix, Albuquerque, Las Vegas, Salt Lake City, Denver, San Diego and hundreds of other communities in the seven states. It also provides irrigation water to about two million acres of land. The river has more than 60 million acre feet (MAF) of storage capacity, and 4 000 megawatts of hydro-electric generating capacity (1 acre foot converts to 1.23 megalitres or 1 233 cubic metres). In this report both measures are used because in the US acre feet are the main unit of measure, whereas megalitres are the main unit of measure used in Europe.

Following his work in the region, the geographer Powell identified that the seven States described would all need to draw water from the Colorado and made a deputation to the Federal Government to that effect stating that a water policy strategy needed to be implemented. The United States Bureau of Reclamation was formed to determine how to turn what was essentially a desert ecosystem into land suitable for cultivation. This included the development of dams and reservoirs at strategic points.

There are three large dams on the Colorado, the Hoover Dam, Lake Powell Dam and the Green River Dam, and a number of smaller dams. In 1922 water was allocated according to the Colorado River Compact. The river system was divided into two areas at Lee Ferry, the Upper Basin and the Lower Basin. It was determined that the annual water supply at that time was 17 MAF per annum, to put this into perspective the flow of the Mississippi and Columbia Rivers is in excess of 100 MAF per annum and the Los Angeles River has an average flow of only 40 000 acre feet per annum. The Lower Basin was allocated 7.5 MAF per annum irrespective of seasonal availability.

It was also established that Mexico should be supplied with a specified volume of water and from 1973 at a defined quality level that is an average annual salinity of no more than 115 (± 30) parts per million over the salinity of water that arrives at the Imperial Dam. In 1974 legislation was implemented authorising the use of federal funds to help control salinity in the Colorado River. A desalination plant was built in 1992 at a cost in excess of $250 million near Yuma, Arizona but as the annual operating cost is in excess of $25 million, the plant has never been operated. Before the Hoover and Glen Canyon Dams were built there were approximately two million acres of riparian areas and wetlands in Mexico, latest estimates suggest that this area has reduced to 180 000 acres. Water availability data since 1922 has shown that the original supply figures over estimated the volumes and the actual figure of supply from the river is closer to 15 MAF per annum. There have also been issues with salinity and silt levels in the water and management practices are being adopted upstream such as changing irrigation practice in order to improve water quality. The sustainability of water use from the Colorado River was questioned in many of my conversations especially the demand for water in Southern California and how it could be met.

California's allocation was 4.3 MAF per annum, but was using 5.3 MAF per annum. The State is currently introducing management plans to reduce usage and was sued in 1963 in the US Supreme Court by Arizona in an effort to reduce California's water use. Nevada was originally allocated 300 000 acre feet per year, well before Las Vegas was conceived so Nevada has continuing issues with historic water allocation and current water needs. Some States are looking to reallocate tributaries of the Colorado as their own water resources to increase their allocation, but the net effect is that the water in the Colorado River basin is still over-allocated.

Utah water rights

The US State with the lowest annual rainfall is Nevada with around 8 inches (200 mm). Utah is the second driest at 13 inches per year (330 mm) with a range of 5" and 50" (130 mm – 1270mm) from the desert regions to the high mountains. In Utah, the primary source of water is snow melt that feeds down through the valleys to the lakes and rivers. The settlement of Utah was based on the development of family and community units. The migration to Utah was essentially managed through a series of companies of people of a given size that would cross the plains to Utah. When they arrived they were allocated an area to live and in order for those communities to be able to establish and develop food security, suitable land and adequate water availability including the identification of "creeks" and the planning of irrigation systems was critical.

The first group arrived in 1847 at the site of what is now Salt Lake City. They dammed the stream and softened the ground so that it could be cultivated and systems of irrigation channels were then developed. From the very beginning, irrigation was seen as essential to the survival of the settlers and they worked together to develop an irrigation system and then formed a Mutual Irrigation Company (MIC). Depending on the work that they had undertaken and the resources they had provided to develop the irrigation system they would then receive shares of stock in the MIC. There is currently 1500 MIC in place in Utah and the volume of water that a farming business can abstract is directly related to the proportion of shares that they hold. Private and mutual reservoirs have also been built, but the usage of water from those reservoirs is regulated.

The system of Utah water rights is termed an "appropriation system" and the right to water is a property right conveyed by deed. When Utah became a State in 1896 water right claims had already been established and the Utah Constitution supported the right to use water, although this is often mediated by the MIC. The Utah State Engineer's Office was created in 1897 and the Utah State Engineer allocates water rights. Water is termed as "public" i.e. state owned, but subject to usage rights. An individual or organisation utilising water has to demonstrate "beneficial use" i.e. that the water is used in an activity that provides goods with an economic value such as food, hydro electric power, fish farming, but in recent years this has included amenity uses.

Water rights are allocated on the basis of source, purpose – reason and nature of use; rate – flow of water, usually measured in acre feet per second; volume – amount of water abstracted usually measured by acre foot; and time i.e. the day, or time of day or indeed time of year. If the flow rate is such that only two or three users can take water at any one time then this influences when water can be abstracted and users would effectively be allocated a time "slot" in which they can take water irrespective of the flow rate in the canal at that time. Since 2005, if users are found to have exceeded the volume of water that they are permitted to use the user will be fined and required to forgo two hundred percent of the excess water volume from future water abstraction.

Any applications for changes to the allocation must be made to the State Engineer. The application will be reviewed to determine if there is enough water available and the impact of the change on other water uses.

Utah water resources

Most of Utah's precipitation comes in the form of snow. The Division of Water Resources and the Board of Water Resources are responsible for the protection of Utah's water resources in terms of promoting effective planning and development, utilisation, and conservation programmes and has the legislative authority to protect Utah's rights to interstate waters. The Division of Water Rights administers water rights and regulation and water quality is the responsibility of another Department, the Department of Environmental Quality. It also protects Utah's right to interstate waters, provides water resource planning and provides technical and financial assistance to encourage the beneficial use of water.

Since 1947, the Board of Water Resources has invested more than $268 million to assist in the development of around 1000 projects with private organisations. The State Water Plan has evaluated existing water resources in Utah and determined the key water related issues and identified a plan for state and federal agencies, water user groups and environmental interests. The Division of Water Resources is also responsible for addressing responsible water use at all levels within the state including the development of water education programmes. Utah's Municipal and Industrial Conservation Plan reviewed the following mechanisms to assist in water conservation:

- Incentive pricing and installation of water meters on all water connections, retrofit, rebate and incentive programmes;
- Best practice guidelines for domestic and industrial use;
- Commercial and residential audits; and
- Leak detection and repair programmes.

One example of the innovative ways in which Utah water resources have been managed is the Sevier River System.

Sevier River System – a virtual watershed

Agriculture accounts for sixty one percent of the water usage in the river basin. As the population increases in the area there are genuine concerns over whether there will be sufficient water to meet drinking water needs. The river system originally fed into a lake which is now a dry bed. The river has been compared to sixty two other river systems and has been identified as the most utilised river of those systems. There is one power plant on the river system but otherwise irrigation is the main activity that means that ninety percent of the precipitation is utilised annually. One of the reservoirs built on the river system as a result of co-operative ventures between 1903 and 1911 has the capacity to hold 238 000 acre feet. This and other reservoirs on the river can store twice the annual rainfall.

The upper region has constraints on water use and it is estimated that a water molecule can be withdrawn and reapplied as many seven times from the upper levels of the river to the lower reaches. There are quality issues with regard to salinity at the lower end of the river. Climate changes appear to have affected the river system and reduced the quantity of water available, but the water users have defined water rights i.e. first in time – first in right (FIT-FIR). The individual water users have addressed this at a local level by either allocating the shortage proportionately or by sticking to the FIT-FIR principle with prior claims having first rights to the water.

In 1983 there was a major snow melt that led to the Sevier Lake being restored for three years with flooding of the surrounding desert, but it is now a dry bed again. In order to more effectively manage the water resource, the Sevier River Basin Hydrologic Web Site was developed. It plays a pivotal role in a system of computer servers, communications links, remote measurement devices, and water gate actuators. Access to the web-site is open to all individuals, but the website primarily enables water managers in the Sevier River Basin to have access to hydrology and weather information and to measure and manage their water resources more effectively.

The Sevier River Water Users Association (SRWUA) includes two river commissioners, managers/ representatives of the canal companies and the water masters who manage the systems and the release of water into the river system. The timeline for developing the virtual watershed was as follows: In 1998 the original web-site was developed and then enhanced with weather information from a real-time weather monitoring website. Two further weather stations were then added. In 1999 it was agreed to develop the web-site to include the entire Sevier River Basin and this was completed by the end of the year. An internet camera was installed at the head of the Richfield Canal in the Upper Basin to take images every ten minutes. This meant that the canal company managers could visually verify the gate settings and determine if there were any problems with the gate. Further cameras were added to verify the controls at other points in the system and the actual weather conditions. Additional software refinements meant that the gates could then be opened and shut from the web browser. Further refinements to the system have included: daily water rights status updates and improvements and refinements to the river modelling techniques. The type of information available is shown in Figure 3, where the current reservoir levels are identified and Figure 4 where flow rate information is available.

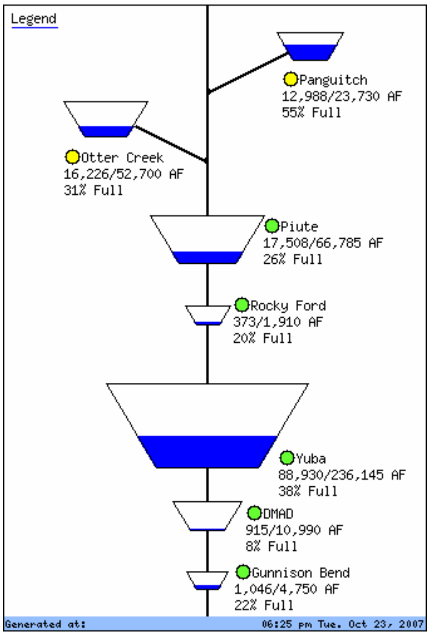

Figure 3: Sevier River teacup diagram[12]:

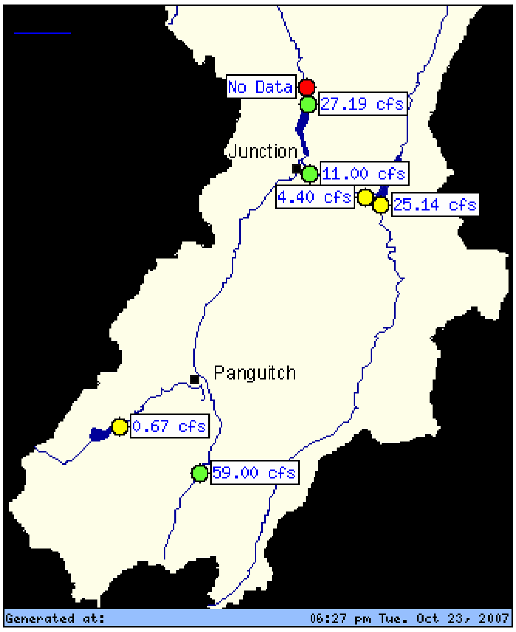

Figure 4: Information on flow rates accessible to users on internet[12]

This example demonstrates the benefit of using new technology to develop and manage water resources. Farmers can gain access and monitor how the canal manager is operating the system. The implementation of this virtual watershed has relied on ensuring that the information is easily available, relatively cheap and provides relevant operational information i.e. value for money with the benefit for the farmers that they can open and shut water irrigation gates remotely and manage their irrigation more efficiently.

The State Engineer determines water allocation on an annual basis and the fees associated with river water abstraction are based on the flow. The fees support the salary of the River Commissioner and the maintenance of the structure of the water system. Ground water may or may not give rise to an annual assessment fee based on the area where the water is being abstracted. In Utah, ground water supplies fall under the water rights system.

Californian water rights

In 1870 there were around 60 000 acres of irrigated agriculture in California, by 1890 this had increased to a million acres. The first water law suits in California occurred when farmers sued mining companies because their method of mining caused sediment run-off which was silting up the waterways and causing flooding. This set the tone for continued litigation in California with regard to water rights. The quality of the canal structures varied from system to system and in one particular incident in the spring of 1905 the Colorado River broke out of a diversion on the canal system in a break a mile wide. This led to the formation of the Salton Sea in Southern California. It took two years to repair the water system and return the water to its previous course. The inland saline lake now covers 376 square miles; the lake is also about 65 metres below sea level. It is a closed system and relies on agricultural run-off to replenish the water supply this is reducing as the farmers transfer their water rights to local communities i.e. no longer apply water to land and/or increase their irrigation efficiency and reduce water run-off. In this context during my visit there was concern being expressed over the long term ecological status of this body of water.

The development of water law through litigation continues due to the number of competing interests in California including agricultural users, fisheries, public, municipal and industry users. The total water supply in an average year is around 194.7 MAF. However, about sixty five percent of the water is consumed through evapotranspiration. Water availability varies annually with an average of 71 MAF and a range of 15 – 135 MAF per annum. This water is divided between environmental uses forty eight percent, agricultural uses forty one percent and urban uses eleven percent. Environmental water would be defined as in-stream wild and scenic flows, management of wetlands and outflow from the Sacramento-San Joaquin Delta. Around 400 MAF of water can be stored in 1200 reservoirs so there is enough water storage capacity available, but not necessarily in the areas where the water is required.

The Department of Water Resources addresses water resource management, but has no regulatory enforcement role. The State of California did not develop a role of State Engineer, instead the State Water Resources Control Board (SWRCB) was created and they effectively manage water rights. In the main the majority of surface water rights consist of either riparian or appropriative rights. The other types of surface water rights include pueblo, federal reserved, prescriptive and adjudicated rights. Federal reserved water rights are rights that are reserved for the use of water on federal property. Appropriation rights pre-1914 are based on the FIT-FIR process and do not require a permit and the volume that can be diverted is limited to the volume diverted in 1914 or determined otherwise in a designated plan. Over 21 000 permits have been issued as post 1914 appropriative rights and the SWRCB regulates the associated permits and licences. The water rights specify the quantity and season of diversion, the place of diversion, and the place and purpose of water use and these conditions cannot be changed other than through the process controlled by the SWRCB. Beneficial use must be demonstrated at the permit application stage. After the vesting of a water right there is a compliance check before the licence is actually issued.

Beneficial use includes municipal and domestic, irrigation, stock drinking water, fisheries or golf courses (deemed irrigation, but consideration would be given to whether they can use reclaimed water) and there is a need to demonstrate both reasonable and beneficial use. The water rights may also contain a curtailment clause in the event of severe drought. The SWRCB has authority to curtail all the rights that include this clause and domestic use and municipal use will have first call, but some municipal activities may also be curtailed to reduce water usage.

Ground water that is not flowing in a subterranean stream, such as water percolating through a ground water basin, is not subject to the permitting authority of the SWRCB. However, the regulatory process has to be followed for appropriation of ground water from an underground stream and the right to withdraw water from the aquifer. An annual fee is required after the license is issued. The annual fee is not based on the amount of water annually used; but on the total face value of the water right (the total amount that has been authorised to be taken from the source). This is because if it was based purely on use, diversions to storage that deplete stream flow but are not used would not be accounted for. It was also suggested that many small farmers do not maintain accurate records of actual water diversion or water use to base billing amounts upon. If a water right holder wishes to reduce an annual fee, they can request a permanent reduction in the authorised face value of the permit or license. As the SWRCB does not have permitting authority over riparian, pre-1914 appropriative and overlying groundwater rights, these water rights are currently not subject to the annual water right fees. Imposition of annual fees on these water rights would require new legislation. There are over 40 irrigation districts that have developed in California as well as 100 groundwater management districts.

Sustainability of water supplies for Southern California continues to be an issue whether from the Colorado River or water systems within the state. From 1941, water was supplied to Los Angeles from the Mono drainage basin. The water levels in the 500 000 year old lake were affected declining at about one foot a year. As the lake had no natural outlet, it has a level of salinity that supported a very specific ecosystem that maintained a Californian gull population. In fact it was the second largest breeding ground and was a stop off for migratory birds. In 1970 a second aqueduct was built and the resultant water from the Mono Lake supplied seventeen percent of the city's total supply. By 1980 the lake's surface had fallen by 45 feet and the volume of the water had halved seriously affecting the salinity levels. The receding waters also caused a land bridge to develop allowing coyotes to access the breeding grounds with a resultant reduction in bird population. During windstorms the salt crust caused a caustic alkali dust with the resultant environmental concerns. In 1978 formal action began to preserve the lake. In the resultant litigation between non-governmental organisations (NGOs) and the city of Los Angeles, the NGOs claimed that the city had violated the Public Trust Doctrine i.e. they were affecting the ability of the public to use and gain benefit from the Mono Lake itself. The final court decision was that water could not be taken from a water body or source without a "careful assessment" of the harm that could be done and this would be measured against the right to reasonable and beneficial use. Negotiations continued until 1994 when it was agreed to reduce diversions and to seek to replace the deficit for Los Angeles with water from waste water reclamation processes.

In recent years the Public Trust Doctrine has also been used in legal cases to argue that general benefit for the community supersedes personal or individual benefit which has caused concern for those holding water rights. Water rights holders can transfer volumes to another individual or group as long as they can demonstrate the transaction does not cause "harm" and there is a means to move water for transfer to take place. Ultimately Public Trust law may put water rights in jeopardy as it could be argued that urban needs are over and above those of the historical holder of the water right, so water rights is proving an area that is subject to ongoing conflict and litigation.

Californian water resources

California has a variety of environments from the north of the state that receives seventy five percent of the rainfall to the south of the state that is essentially a desert. Whilst most of the precipitation is in the north from rainfall and runoff from mountain snowpack, the population is largely in the south. Most irrigated farming is in the Central Valley, with additional areas including the Imperial Valley and the Salinas Valley. In order to determine regional water resources, California has been divided into 10 hydrologic regions according to the major water drainage basins.

Groundwater supplies about one third of California's urban and agricultural water supply (14.5 MAF) and annual average annual use is around 43 MAF. The volume of groundwater used in California accounts for around twenty percent of all groundwater used in the US. Groundwater is the source of drinking water for forty three percent of the population and in some rural communities serves one hundred percent. Groundwater is a key source of water in a dry year and currently around 2 MAF a year that is being pumped from groundwater sources is not being replaced. Whilst estimates of total ground water range from 850 MAF to 1300 MAF this practice is not sustainable in the long term. Overdraft or over abstraction from groundwater sources can impact on supply costs, reduce water quality, and cause environmental degradation, salt water intrusion and land subsidence.

The Sacramento-San Joaquin Delta (the "Delta") is a key hydrological system, because it provides water for twenty five million people. In fact two out of three people in California receive part or all of their water supply from the Delta. State and federal water projects deliver water for irrigation of more than three million acres. The Delta is also the largest freshwater estuary on the coasts of North and South America and is a key ecological habitat. It contains some of California's most productive fisheries and is part of the Pacific Flyway for migrating birds. The Delta is a tidal estuary so salt infiltration of the fresh water system is an ongoing issue.

The Delta is therefore hydrologically managed to ensure that the salt level in the water is controlled and balanced. The Delta smelt, a fish, has been identified as a key species in determining the ecological status of the Delta and in 2005 there was a significant reduction in fish numbers. This caused concern over the long term status of the smelt. Recent litigation has found in favour of protecting the ecological habitat and smelt numbers and reduced the volume of water that can be pumped out of the Delta for municipal and agricultural uses. This could have serious repercussions for the Central Valley and also Los Angeles who depend on this water for irrigation and municipal water respectively. The other major issue for the Delta is flood management and this is addressed later in the report. In order to address the specific issues of the Delta, the Delta Vision Task Force has been set up in order to develop a strategic and operational plan.

The Californian State Water Project (SWP) is the largest state-built and operated multipurpose water and power system in the US with 701 miles of canals and pipelines and the system provides water for irrigation as well as power generation, flood protection, amenity use and helps in maintaining water quality in the Sacramento-San Joaquin Delta. The 1960 project was financed not only by the $1.75 billion obligation bonds, plus interest, but also additional bonds that were issued for further facilities. The water goes to 29 agencies that have contracts for the annual delivery of water. These agencies are not only repaying the bonds, but financing operating costs and the environmental projects that have been implemented to alleviate the impact of operations. To date the contractors have made payments in the region of $9 billion. The agreed payments must be made irrespective of the amount of water that is delivered by the state. The average cost per acre foot can vary between $49 and $665 depending on the water district as some districts have higher transport costs. The water for agriculture has historically also been subsidised and this has not always been seen as fair by the cities that can struggle to source sufficient water and paying much higher costs. A differential in costs affords the opportunity to:

- Provide basic water supplies and enable treatment and distribution of water between users;
- Enable water transfer between users; and
- Provide for emergency planning and protection from flooding.

There are also state water quality standard monitoring programmes, water efficiency programmes and activity to address ecosystem restoration. Californian water management facilities includes over 1200 state, federal and local reservoirs in addition to water treatment plants, canals and levees and these require constant maintenance especially as facilities age.

The first Californian State Water Plan was produced in 1957 and there have been eight updates since, the last being the 2005 Update. Many of the US states have developed water plans including Utah, California, Texas, and New Mexico according to the resources and needs of each state. The key purpose of the 2005 update of the Californian State Water Plan was to:

- Present basic information about California's water resources;

- Assess California's urban, agricultural and environmental water needs;
- Assess available water supplies and demand management actions to help satisfy those demands;
- Provide a framework for decisions by water managers and legislators;
- Provide information on management strategies for developing local plans and solutions; and
- Be comprehensive, and impartial.

The 2005 Update is not mandatory and has no spending authorisation, it a document that addresses strategic planning for water. It proposed 25 resource management strategies (see Appendix 2) and identified the strategies that would deliver the greatest benefit in terms of water conservation. These were urban water use efficiency, conjunctive management and ground water storage, recycled municipal water, agricultural water use efficiency, increased surface storage and conveyance, sea and brackish water desalination, and precipitation enhancement (or cloud seeding). A cost benefit analysis was undertaken as part of the strategy review and can be found in Appendix 2. This cost benefit analysis enabled decision makers to prioritise the resource management strategies and the potential benefits that can be delivered.

Local water management planning has been developed through integrated regional water management plans (IRWMP). The Californian approach has been to develop regional partnerships, IRWMP and diversify regional water management activities. The principles of integrated regional water management have been addressed in Appendix 3. The State Water Plan is due to be updated in 2009 and the strategic review will also address the potential effects of climate change on Californian water resources. The effects could include:

- Reduced snowpack with a change in runoff i.e. more runoff in the winter and less in the spring. This will mean that the current physical water management systems which are designed to manage snow melt may not be able to manage this change in precipitation pattern;
- Rising sea levels and bigger flood events due to higher tides and more intense rainfall; and
- Warmer river temperatures that could threaten the salmon and fishery industry.

Conjunctive management

One of the major sustainability concerns that the SWP addresses is overdraft of ground water, (termed "water mining" in Utah), i.e. the extraction of water from aquifers where the extraction volume exceeds annual supply so that the water table is constantly falling. Conjunctive management is the co-ordinated process of surface water storage and use and groundwater storage use and water facilities such as channels and pipelines to optimise efficient water use. This includes balancing groundwater recharge either by increasing water surface use, and allowing natural recharge of groundwater so that water will then be available if there is a dry year. This balance includes maintaining water quality standards, reducing salt water intrusion and maintaining the water table at pre-determined levels. Groundwater recharging can also be undertaken i.e. the recharging of aquifers with surface or waste water, if sufficient surface water is available such as in a high precipitation year.

Natural recharging of the aquifers relies on precipitation and can also occur with storm runoff, but in the Western US artificial recharging, otherwise known as water banking, is becoming a key method for enhancing water storage capacity for peak usage periods and where possible alleviating historic overdraft.

The first recharge programme in California was in 1889. Aquifer recharging will also occur if there is leakage from conveyance systems such as pipe-work or water channels. Treated waste water is increasingly being used for this activity, but care needs to be taken to ensure the quality of the water used is adequate so as not to contaminate existing reserves. Water can either be injected into wells or be placed in specially constructed recharge ponds, or spreading basins.

If the groundwater in the aquifer becomes contaminated in some way groundwater remediation needs to be undertaken where groundwater is either removed for treatment or treated in-situ. Contamination where remediation is required includes arsenic, nitrate and pesticide contamination. In agricultural areas non-point source contamination with nitrates, salt, selenium or boron can also occur. There are 18 500 sites in California where active groundwater remediation is taking place, with around 15 000 of these being as a result of petroleum release from underground tanks. Groundwater treatment is very expensive and it may be some considerable time before the benefits of the expenditure are realised in terms of improved water quality. It is therefore important to ensure that controls are in place to prevent contamination of natural recharge areas, and planning controls prevent urban storm water run-off and ensures that natural recharge areas are not developed i.e. paved over.

Desalination

Desalination is the process that removes salt from water so that it can be put to beneficial use, for example, with the use of reverse osmosis. California has been undertaking desalination since 1965. There are currently thirty-four desalination plants in California, providing around 79 000 acre feet per annum of water for municipal purposes, with sixteen addressing groundwater, seventeen seawater and a surface water plant. Some of the major disadvantages of desalination are the cost, the amount of energy used in the process, and the disposal of the salt concentrate that needs to be discharged that may also contain other treatment chemicals. There are concerns about discharging the brine into the sea because of its potential impact on marine ecosystems. The desalting water costs identified in the Californian Water Plan Update 2005 are detailed in Table 6.

Table 6: Desalination costs in California

Type of Desalination Plant	Total Water Cost $ per acre-foot[1]
Groundwater	250 – 500
Wastewater	500 – 2000
Seawater	800 – 2000

[1]Unit costs obtained from a variety of reference sources and are not based on standard costing procedure.

These costs are currently higher than the range of costs of water available through the SWP thus acting as a disincentive for desalination.

Floodplain management

In the wake of Hurricane Katrina, many states in the US have refocused their attention on flood management planning especially the condition of their facilities that in some places are suffering from the effects of either seepage through the levees (barriers) or under-seepage. The Sacramento-San Joaquin Delta is faced with a deteriorating flood control facility, that in some places has been washed away, a rising population that is moving into areas that are vulnerable to flooding and a reduction in funding for flood management. Recent court rulings have determined that state and local agencies are liable for flood-related damages when levees fail. During my visit to the US, Governor Schwarzenegger signed legislation to strengthen flood protection for Californians[13].

The legislative package instigated the development of a comprehensive Central Valley Flood Protection Plan. It also proposed reform of the Reclamation Board to improve efficiency, required cities and counties to increase consideration of flood risks when making land use decisions and created a new standard in flood protection for urban development. This is a very important resource because the Sacramento-San Joaquin Delta is the hub of California's water management system. The system also provides for 50 000 acres of productive farming ground and is a land locked sea water estuary. The key problems include:

- Subsidence of Delta islands due to the abstraction of groundwater and the oxidation of peat soils increasing pressure on the levees that protect the islands. This means that the islands are constantly being drained and irrigation of farm land is actually undertaken by turning off the drainage pumps for the appropriate length of time;
- The area is subject to seismic activity and an earthquake might cause multiple levee failures that would allow sea water to enter the Delta making the water unfit for human consumption or irrigation. As previously described, the Delta supports the agricultural systems in Central California and the drinking water supplies of Southern California so the result of such an incident would be devastating and this scenario proves a serious risk to US food security for produce and dairy products;
- Climate change is predicted to cause sea levels to rise and may also increase the magnitude of flood flows. It is estimated that the levees may need to be raised by 2 feet for 1200 miles; and
- Funding for maintenance of levees has not kept pace with the work required, and levee failures are extremely costly to repair.

Flood management requires both short and long term strategies including maintenance programmes, emergency response systems, funding for flood management programmes, ongoing flood modelling and public education and awareness campaigns, review of insurance requirements, and assessment to ensure that taxpayer exposure to costs is minimised. Flood management systems also need to be integrated with ecological and environmental programmes and farmland protection[14].

Flood management in the Sacramento-San Joaquin Delta has included the development of the Yolo flood bypass system. The bypass was established as a "floodwater corridor". This means that there is a natural settling basin and the water can be channelled the way that it would naturally go to the point where in some high flood years for part of the year it forms an inland sea. In the event of a flood, the land would automatically be flooded to protect other areas. Where land has been compulsorily purchased, farmers rent the land on an annual basis, aware of the flood risk and therefore implementing appropriate cropping patterns to ensure that their crop is not flooded. However sometimes the crop may be lost and this will be at the farmer's expense, as they rent the land on that basis.

In other cases a flood or conservation easement agreement has been developed. This plan will only work where all landowners in a flood plain or retention/detention basin comply with the scheme. Flood management is undertaken through a process of developing retention and detention basins. A retention basin as previously described is a constructed wetland that is designed to contain storm water or rain runoff that would otherwise flow into other areas and the water will remain in this area. A detention basin is planned for larger flood events and holds water for a limited period of time from a larger river basin area. It is a short term measure to prevent flooding and may be several hundred acres in size. Detention basins can be used to prevent flooding of urban areas and may or may not be permanently filled with water. When used with regional flood control, the detention basins can have a weir structure or a channel entry and then drain by gravity as the level of water coming into the basin starts to recede.

As an example Salt Lake City, in Utah has thirty-seven flood control detention basins. These basins are designed so that they can also be used as amenity space and are used as parks in the summer, but are available for flood control management at other times of year.

Precipitation enhancement

Precipitation enhancement, otherwise known as cloud seeding, artificially stimulates clouds to increase precipitation levels. Cloud seeding has been used in Utah as well as California for a number of years to boost the natural water supply especially from snow melt. Geographic conditions such as topography, climate and water storage reservoirs make cloud seeding cost-effective. Both states began cloud seeding programmes around 1950. Statistical analysis of the cloud seeding program since it started in Utah shows an average increase in precipitation of eight percent to twenty percent in seeded areas at a cost of about $1.70 per acre-foot for the additional water. This compares very favourably with the costs in Table 6 for desalination of groundwater or waste water.

Cloud seeding in Utah is normally undertaken between November and April and there are currently two licensed operators. Cloud seeding agents include silver iodide which can be applied by aircraft or ground generators. The snow will tend to fall within 15 to 30 minutes after application. Ski resorts in Utah have also undertaken cloud seeding projects. All precipitation is treated as though it fell naturally in terms of subsequent rights to use the water. There has been some discussion that this practice is actually taking the water from Colorado and if water becomes very scarce in the future this may be a potential source of conflict and litigation.

Most cloud seeding projects in California are along the central and southern Sierra Nevada with some projects in the coastal ranges. The number of operating projects has increased during droughts, up to 20 in 1991, but are currently 12 or 13 per year covering an area of about 13 000 square miles. It is estimated that these programmes generate 300 000 to 400 000 acre feet per year which would be about a 4 percent increase in runoff at a cost of about $20 per acre foot per year. This water is also important for generating hydroelectric power and many of the projects are sponsored by power companies.

Many other countries use cloud seeding either to address water demand, hydroelectric power or to modify weather for fog dispersal or hail suppression. There are limitations to this method namely the fact that it cannot be used in a severe drought (no clouds), the degree of precipitation enhancement will vary between regions and there are concerns over the long term effect of silver iodide use. However the Californian Bureau of Reclamation has determined that industry emissions are currently 100 times greater those used for cloud seeding.

Waste water treatment, recycling, reduction and reuse

Water efficiency in both urban and agricultural areas is seen as a key strategy to make water sources meet increasing demand. In urban areas this includes developing washing machine ratings for water efficiency, using high efficiency toilets and addressing use for gardens especially lawns. Waste water treatment will require significant capital costs and federal grants are in place to support such schemes with an element of match or proportional funding. However most cities are downstream and many send their outflows straight to the sea so treatment and reuse may not be viable in all cases. In some coastal regions waste water is being injected into the aquifers to prevent salt intrusion, but it is important, as previously described, that this water meets minimum quality standards.

Recycled water i.e. water that has been used more than once fulfils a key role in water conservation especially in the future in California. Currently, forty six percent of recycled water is used for agricultural irrigation, twenty one percent for landscape irrigation, fourteen percent for groundwater recharge and nineteen percent for all other users. The quality of recycled water will affect its use including microbiological standard, level of salinity, presence of heavy metals and other contaminants. Water recycling in California is currently about 500 000 acre feet per year and by 2030 could have risen to 2 MAF per year. There are defined quality standards for water treatment plants and they include pathogens, total dissolved solids (TDS), heavy metals and nutrients. Water can be discharged to the water course, but the downstream irrigator cannot increase their water right to include the waste water, they are still limited to the conditions of their water right. Therefore “grey” water production essentially firms up existing water rights.

Water quality

The Federal Clean Water Act (CWA) is enacted by Congress and implemented by the Environmental Protection Agency (EPA). The EPA has no regulatory authority for volume only quality, however increasingly maintaining water quality means that a proportion of the available water must be left in the water body/river system so this is a potential source of conflict with those who have water property rights. The EPA has the power to delegate to State Governments to implement the CWA under a State Government programme. The EPA will benchmark state provisions against their requirements and if they conform will allow the state to manage water quality. Utah has received such a delegation of authority.

The SWRCB and the regional boards regulate water quality in California. The role of the SWRCB is to provide funding, administering state and federal loans and grants for the construction of wastewater management and drainage facilities, and developing water quality policy, strategy and programmes for the regional water boards to implement. The regional water boards are then given the responsibility to establish basin plans, to evaluate surface and groundwater quality and develop programmes to protect water from pollution.

Water pollution can be defined into two types: point source and non-point source pollution and the two types of pollution are addressed quite differently with regard to regulation. Point sources are definable activities that discharge waste from a designated point. These activities are controlled through National Pollutant Discharge Elimination System (NPDES) permits that define conditions under which any discharges can occur and also set limits on the waste that can be discharged as they enforce waste discharge requirements (WDRs). These permits are required for municipal, industrial and agricultural point sources such as dairies, feedlots or other facilities where animals are "formally" confined. Crop land associated with these facilities would be considered as a non-point source of pollution as would any range land, agricultural, or mining activities. The pollution that can occur is often called "diffuse" because in the event of pollution being identified in a water course it is very difficult to determine where this pollution has come from.

Non-point source pollution has been addressed in the US by the development of best management practice (BMP) otherwise known as good agricultural practice (GAP) in the UK. BMPs address many management practices including soil management and the need to prevent erosion and sedimentation of water supplies. Point source or diffuse source emissions of microbiological contamination, needs to be effectively managed especially where this could impact on other water uses such as "ready to eat" crop production or water compositional criteria that could impact on animal health, welfare and performance.

The main constituents of concern (COC) from an agricultural point source include: ammonia, nitrates, phosphorous, salts, and bacteria although sediments and metals can also be a problem. Selenium is an ongoing issue in California and the Federal government have purchased 200 000 acres of land that cannot support food production because of the levels of selenium and are seeking to take remedial action to improve the status of the land. Livestock units can cause surface water or groundwater contamination through inadequate collection and storage of manure and inappropriate application to land. Therefore, livestock facilities need to ensure that they have:

- Properly designed and maintained manure and slurry management facilities;
- Effective training programmes to ensure that personnel understand and implement the pollution management procedures that are in place and know what to do in the event of a failure of either facilities or protocols; and
- Developed and implemented a manure (nutrient) management plan.

In California, when undertaking construction at a confined animal facility (CAF) some units will also need to obtain a Construction Stormwater Permit. The annual permit fee for a CAF such as a dairy is between $200 and $4 000 per annum. Some CAF are reviewing the need to develop riparian areas and buffer strips in order to reduce discharges to water systems.

The California Dairy Quality Assurance (CDQA) Programme is a voluntary partnership between government agencies, the University of California and dairy producers, that has come together to address the key issues impacting on agriculture[15]. The CDQA Programme was developed to assist dairy producers with ensuring compliance with legislation and regulations. The programme focuses on food safety, animal welfare and environmental stewardship and provides education, resources and funding for dairy producers to become certified in one or all of these areas. A further organisation in California is a state-wide coalition called The Community Alliance for Responsible Environmental Stewardship (CARES)[16]. The organisation's mission is to ensure the long-term economic and environmental viability of the California dairy industry. CARES undertakes a range of activities including promoting increased participation in the CDQA programme. In

California there are at least 15 CAF units that are using anaerobic digestion of manure, not only to provide an energy source, but also to reduce the amount of methane emitted to the atmosphere.

The Central Valley is a closed basin i.e. there is no natural outflow from the valley due to the man-made hydrological systems and this presents a unique set of problems, because there is no natural flushing of the hydrological basin. There have also been ongoing issues in the valley due to air inversions that have led to a reduction in air quality due to the combination of vehicular emissions, ammonia and methane production. Seventy thousand growers in the Central Valley as well as dairy farmers are reviewing farming practices so the implementation of BMP is being addressed by 12 independent farming groups or coalitions. The conditional permit to cover all the individual organisations is held by the coalition and regional water boards are working with coalitions to implement BMP standards. There is a need to co-ordinate and ensure consistency in what is being required by each location and each coalition in terms of data collection and management plans including: hydrological study, geographical study, and the different levels for potential pollutants for different coalitions and locations. The permit requirements therefore will be location specific, but the coalitions can develop templates for the management plans with assistance from qualified experts e.g. extension scientists.

The costs of the development and implementation of these plans is being met by growers, but the templates must be modified so that they are targeted plans and site specific. The requirement for nutrient management plans will ultimately be established for each water basin as well as requirements for storm water management and treatment plant management. The coalitions vary in their level of enrolment of between forty and one hundred percent. When the coalitions formed they were required to have a minimum enrolment status in order to get a coalition permit, but when the fee structure was implemented then enrolment fell back in some to around forty percent. The legislation was introduced five years ago and some farmers have not gained a permit in a coalition or independently and the SWRCB has started contacting them to determine how they intend to comply with the requirements.

The CWA also established standards for water quality and these standards are used as a regulatory tool to control point and non-point source pollution and a mechanism to fund cleaning up of inadequate water systems. The legislation requires that water pollutants in surface waters do not exceed a "total maximum daily load" (TMDL). Water temperature is also a critical factor for maintaining fish populations and standards can also be set for water temperature. The standards for any pollutants are specific to a water system and the designated uses of the surface water such as if the water source is going to be used for drinking water, irrigation or needs to provide for ecological protection. When developing TMDL's for a water source or water body this is an important distinction so if the water is going to be used for municipal drinking water, or supporting salmon or trout species the standards may well be higher. If a TMDL is exceeded even if all point sources are complying with their NPDES permit requirements then point and non-point sources will be investigated to see how overall pollutant levels may be reduced further i.e. this is a water system based approach.

The TMDL programme requires each state, or territory to undertake a review of all water bodies within its control, identify the beneficial uses of that water body and determine if the water quality supports use. If the water quality does not meet these requirements then the mechanism to reduce impairment and return the water to an acceptable level must be determined and actions implemented. In Utah, 197 water bodies have been identified as impaired and 169 TMDLs have been approved. A TDML must address seasonal variation and provide for a margin of environmental safety. The CWA focuses on surface water and only includes weak provision for groundwater. In 2002, 685 water bodies were listed in California as impaired. In 2005 thirteen percent of California's rivers and streams and fifteen percent of its lake acreage was listed as impaired.

Salinity is probably the biggest concern with irrigated agriculture. A grower has an issue with salinity if salt accumulates in the crop root zone to a concentration where it affects plant growth or causes a reduction in yield. In irrigated areas, these salts can originate either from a saline, high water table or from high salt content of the irrigation water. Thus, salinity management is a key factor for ensuring that yields can be sustained long term for both crop and livestock production.

Salinity management planning requires a detailed knowledge of the soil condition, irrigation water quality, ground water leaching systems and the types of crops that can be planted. In areas where there are problems with salinity, if the grower does not have the water available to leach the soil, i.e. washout the salts or other soluble contaminants, they may well have to leave the ground fallow. However, Jose Tall Wheatgrass is being used in some areas to improve water and soil quality. The wheatgrass can be grown in high salt conditions and some grass varieties have been developed that take up salt into the plant. These crops prove to be a good source of biomass for renewable energy through anaerobic digestion technology as previously described on dairy farms, a potential feed source depending on salt levels, and provide an environmental solution for soil and water remediation.

Urban run-off management is also a key part of water quality policy as is the development of urban water efficiency strategies. Urbanisation will affect water management and water quality with the potential for additional pollutants, changes to rates of evapotranspiration, water use and surface run-off rates and the impact on the ability to recharge aquifers. Traditionally the aim has been to move floodwater and run-off quickly downstream, from urban areas, however the NPDES and TDML systems is applicable to urban areas as equally as it is to agricultural locations.

Economic incentives and the Californian water markets

Economic incentives to develop water management planning and water conservation include both financial assistance in the form of grants, low interest loans, resources to develop water resource plans, subsidised training and support and pricing policies. These incentives will influence the source of water supply, the amount used and the time when it is used and the volume of waste water produced. Water rates are designed to cover water costs and can be fixed, uniform or tiered. Fixed rates are a clear flat rate regardless of usage, uniform where the user pays the same amount for each unit of water and tiered where the user pays a higher or lower rate for water depending on how much they use.

In California, wastewater treatment is currently charged at a flat rate for residential users and commercial users by volume or the quality of the waste water. Water policy rates that increase costs during drought periods can drive efficiency, whereas reducing water costs during wet periods can encourage ground water recharge. Water pricing policy therefore has the potential to drive usage and resource management policy. Increasing the cost of water will also drive efficiency of use although this will impact on different sectors of society inequitably. The rich will always be able to pay for water to water their lawns and fill their swimming pools whilst the poor will struggle to pay for basic supplies.

Water can be moved between users either as a result of exchange or by transfer. Water transfers are essentially voluntary agreements between parties. The transfers are usually for a short term of less than twelve months, but can be permanent. They can be between local users or between users that are geographically separated as long as there is a means to convey and store the water. There are five main methods of transfer[14]:

1. Transferring water from storage that would otherwise be stored until the following year;
2. Pumping groundwater instead of using surface water and transferring the rights to the surface water;
3. Transferring previously banked groundwater either by directly pumping and transferring groundwater or by pumping groundwater for local use and transferring the surface water rights;
4. Making water available for transfer by leaving land fallow, changing crop type, or by implementing water use efficiency measures; or
5. Increasing available water by making return flows or addressing seepage from conveyance systems or canals that would otherwise be lost to the system.

Water markets are a complex interaction of water management strategies including flood management strategies, surface and groundwater storage, conjunctive management, water quality improvements that could mean the water is suitable for other uses, improving conveyance efficiency, increased urban and agricultural efficiency and planned crop change or fallowing land. This complex mechanism is thought to be the solution for effective management of water resources in California.

In 1991 the Department of Water Resources developed a "water bank". The state purchased agricultural water, around 820 000 acre feet for $125 per acre foot and then sold it for $175 an acre foot to other farmers or cities. This was not a true water market because there was only one purchaser and one price. A groundwater banking system is also in place in Arizona. In 1996, the Arizona Water Banking Authority (AWBA) was established in order to firstly increase the utilisation of the state's Colorado River entitlement, and secondly to develop long-term storage credits for the state. At that time Arizona did not use its 2.8 MAF allocation from the Colorado River and the water flowed into California. Essentially the AWBA banks unallocated water so that it can be used when needed in the future and ensure long-term water supplies for Arizona.

How does the system work? The water is transferred through the Central Arizona Project canal and the AWBA pays both the delivery and storage costs. The water is then either "banked" in aquifers (termed "direct recharge") or is used by irrigation districts instead of pumping groundwater (termed "indirect or in-lieu recharge"). The water can then be pumped out of recovery wells when required. How is the scheme paid for? For each acre-foot stored, the AWBA accrues credit that can be redeemed in the future. The funding of the AWBA is from established revenue sources or water user fees.

Temporary and long term transfers in California rose from 80 000 acre feet per annum in 1985 to 1.25 MAF per annum in 2001 and eighty percent of this trade is short-term. Transfer activities increase during drought periods especially where the State has developed water banks. Whilst the water transfer volumes for municipal and industrial uses have remained fairly static between 1988 and 2001, the water transfer volumes for environmental benefit have shown a marked increase.

One of the key aspects of developing water markets is that transaction costs must be kept to a minimum. The SWRCB has been given oversight of water transfers in California and it has been deemed that such transfers must not damage any other legal user nor have a detrimental impact on the environment.

Water markets have provided flexibility for farmers. As water prices rise they can switch to a higher value cash crop if their soil quality will support the crops concerned in terms of salinity, boron or selenium levels, or they can fallow their ground and trade their water right, as a property right. If farmers change their methods of irrigation and increase their irrigation efficiency they can sell the difference in water between their water right volume and the volume they have used.

Some urban areas have provided financial assistance to improve water infrastructure to reduce leaks and then purchased the water that then becomes available for municipal needs. If farmers have riparian rights some municipal areas have paid farmers not to irrigate so that the water is left in the channels to provide them with a water supply. There has historically been informal trading of water rights between farmers, but the Imperial Valley was the first hydrologic system to use water markets in this way. If the transfer is for more than twelve months then the water right licence will need to be amended, so transfers are mainly short term i.e. less than 12 months. The curtailment clause in the event of a drought could affect the value of the "water" and purchasers will buy according to preferential right i.e. if the owner holds a superior right in the event of a drought, the value of that right is higher in terms of dollars per acre foot.

There is also a market for recharging aquifers which have been mined, for example, an urban agency can move a low value water right to recharge an aquifer as a storage facility for use in the future and this will assist in better water planning. Most of these water transfers are local agreements rather than involving state intervention. The market has not developed for inter-state transfer of water, but that may be due to lack of physical infrastructure rather than a weakness in the financial model. The reason why water markets have been so successful in California is because of the inter-tied hydrological system which means that water can be transferred from one region of California to another. It could be argued that water markets will drive agricultural policy into the future as if the water becomes too expensive then it will not be used to grow lower value crops.

Water markets rely on the fact that droughts are progressive so situations can be managed and water markets can be both developed and prices negotiated as the need arises. Flood situations are more sudden and there is less ability to develop markets or add value to the water that is to use it for aquifer recharge. There are currently no contracts to address flood events perhaps because they require a large amount of work up front and the market aspects of flood water are difficult to determine until it happens. The easement payment for the Sacramento – San Joaquin Delta was a one-off payment for farmers and as such does not have a tradable market value.

As the volume of land that is developed for urban uses increases the dynamics of water markets may change. Whilst an acre of houses may use less water than an acre of tomatoes, the storm run-off and waste water produced needs to be treated to prevent contamination and this can lead to poorer quality water. Further, in a drought year whilst an acre of tomatoes can be left fallow in order to support existing water stocks, the acre of houses will still need water. The economic cost of shortage is much greater for an acre of houses than an acre of tomatoes. This makes the water system less flexible and as was suggested to me more "brittle".

Water transfers will influence the labour market in California because if fields are left fallow employment will reduce and this will lead to migration to the cities which will further increase urban demand. The value of urban housing is also driving water markets as the price of houses increases then the price that developers are prepared to pay for existing water rights also increases. Water markets look set to develop and mature but cannot be assessed in isolation of the social and economic drivers that are in place. As the population continues to increase in the US the time inevitably grows closer when the water resources available will no longer sustain the size of the population.

Environmental incentives, cooperative conservation and conservation easements

Environmental conservation and protection is a constant balance with the needs of urban and rural economies and the need for economic stability and growth. This can lead in some cases to economic incentives being required to replace income or support environmental schemes. Environmental incentives in terms of flood management have been previously described in this report. As urban and agricultural development increases it becomes more difficult for migratory birds to stop and rest during their migration. A range of measures, termed cooperative conservation policies have been implemented in the US to protection migratory birds through habitat management.

Cooperative conservation is based on the principle that future environmental challenges can only be met by a cooperative approach between government, private groups and the general public. The Californian Rice Growers, for example, have developed their crop management practices to promote habitat for migrating birds. One of the cooperative conservation policies being developed is called recovery credit trading. Landowners who participate in the scheme would be able to earn recovery credits that they can sell and this scheme would be used to drive habitat conservation. The 2008 federal budget is being developed, but has yet to be approved, to provide conservation tax incentives for landowners who provide conservation easements which are charitable contributions of property rights to ensure the long-term preservation of habitat.

The overall objective of the scheme is to restore a further 200 000 acres by 2009 either in national parks or land in private ownership. There are currently eighteen joint ventures between biologists, land managers and bird conservationists. In addition $509 million has been allocated in the 2008 financial year to assist landowners in preserving and enhancing habitat for migratory birds. The programme includes:

- Restoring desert grasslands through improved livestock grazing and controlled burning;
- Restoring freshwater wetlands through improved water systems and replanting native species;
- Restoring coastal wetlands through better land-use practices, controlling erosion, opening blockages to tidal flow, and replanting areas of mangrove and sea grasses;
- Managing native forests for birds through replanting, thinning, controlling non-native species, and controlled fires; and
- Promoting bird-friendly agriculture with safer chemicals, crop rotation, and improved plant varieties that lessen outbreaks of pests and improve crop yields[17].

It will be interesting to see how this process develops. The USDA has a number of projects that provide economic support. One of these is the Environmental Quality Incentives Program (EQIP). It supports a voluntary conservation program that combines both environmental quality and agricultural production. EQIP provides both technical and financial support (up to seventy five percent) for the implementation of BMP and/or the installation of physical methods to deliver environmental improvements. The maximum term of an EQIP contract is ten years. The scheme addresses environmental measures such as:

- The reduction of nonpoint pollution and air emissions;
- The reduction of soil erosion and sedimentation;
- Ground and surface water conservation; and
- The promotion of habitat conservation for species that are at risk.

The USDA Wildlife Habitat Incentives Program (WHIP) is a further voluntary program that promotes the development and improvement of wildlife habitats on private land. The scheme is implemented through the Natural Resources Conservation Service who provide the technical support and again up to three quarters of the costs to establish and improve fish and wildlife habitat and work on similar time scales to the EQIP scheme.

During my time in the US there was a lot of discussion about conservation easements. These are a transfer of usage rights between a landowner and either a land preservation organisation or municipality. The transfer restricts housing development, commercial and industrial uses depending on the specific agreement. The main purpose of a conservation easement is to protect agricultural land, wildlife habitat, timber resources, water and air quality, or open spaces.

Conservation easements are voluntary and may be either donations or formal sales. The restrictions then become part of the title deeds. The landowner who relinquishes these "development rights" still owns and manages the land and may receive both state and federal tax exemptions for having provided the conservation easement. The easement holder will then monitor future uses of the land to ensure that they comply with the terms of the easement and take enforcement action in the event they are not followed. If the conservation easement is donated then the landowner can qualify for tax exemptions to the value of their donation. The value is independently determined and equals the difference in property value before and after the easement is effective. One of the benefits of this mechanism is that existing agricultural economic activity continues and the financial benefit of the conservation easement can support further economic development and/or conservation practices.

A conservation easement is a legally binding agreement between a landowner and a land trust. The agreement permanently limits the activities that can be undertaken on the property so that its conservation value is maintained. By selling or donating a conservation easement, the landowner permanently gives up certain of the property rights to the land, however, it remains in private ownership. The easement may be for a portion of the farm and give protection to fauna or flora in that area. The monies received can then be spent on the farming business or associated activities. The land trust is responsible for enforcing the easement and can take action against any individuals who violate the agreement in the future. The agreements do not however afford public access to land that is part of a conservation easement.

Agricultural easement specifically addresses maintaining the agricultural use of property. The American Farmland Trust[18] is an example of one of these land trusts that specialises in agricultural easement and I would recommend looking at their website to see the scope of the work that they undertake. The Great Rivers Land Trust (GRLT) with its work in water quality trading is also another interesting group[19] (see later). The land trusts are generally funded by local taxes, private individuals and community groups who want to secure the landscape around them against future development. The benefit of easement contributions as well as their being tax deductable are that as the market value of the land decreases property and inheritance taxes also decrease. This scheme could prove useful in the UK if the current agricultural exemptions on business tax are removed and also as a mechanism of retaining the agricultural status of land.

Water quality trading (WQT)

WQT is another market approach to improve overall water quality and achieve water quality goals. WQT is based on the premise that there can be a large variance in costs to control the different sources of a pollutant in a watershed. The market approach allows for facilities that have high pollution control costs to offset those costs in meeting their regulatory obligations by purchasing environmentally equivalent improvements from other sources on the watershed. The overall water quality standard is therefore achieved at a lower overall cost. In 2001, the EPA estimated that this system could save $900 million and they suggest that market-based approaches can create economic incentives for innovation, emerging technology, voluntary pollution reductions and greater efficiency in improving water quality. Other examples are discussed later in this report, but the first example of WQT is the Illinois American Water Company case study.

Alton, Illinois – a water quality trading case study

The Illinois American Water Company was faced with the need to improve their facilities for water treatment to manage sediment levels. They assessed that whilst direct discharge, which they could not undertake if they were going to comply with relevant permits for their new treatment, would obviously have no economic impact on their business, the required treatment system would cost $7.4 million in capital costs with an ongoing operating and management budget of $0.42 million per annum. The sediment that they would have to remove from the proposed treatment plant would be on average four truck loads per day and end up in land fill with its subsequent environmental impact. They determined that if they were to discharge without treatment they would have to support sedimentation and soil erosion control projects in other areas of the watershed through a local land trust project. This suggestion achieved public support, especially from groups who did not want the facility built, and the cost of the non-point source projects was deemed as being $4 million over 10 years.

The project is facilitated by the GRLT a not-for-profit organisation with administration accounting for about fifteen percent of the cost structure. The trades with regard to sediment were conducted through modifications of the permit, approved by the Illinois EPA with a trading ratio of 2:1 i.e. a reduction of 6 600 tons per year, when their original permit meant the removal of 3 300 tons per year. The measures were achieved through a combination of land acquisition, conservation easements, development of retention and detention basins, grassed strips, stream bank stabilization and riparian areas. The landowners are responsible for the maintenance of the sediment control structures on an ongoing basis. The GRLT organised a series of outreach programmes on sediment control for both rural and urban communities to supplement the physical control measures and all parties are currently positive about how the scheme has been implemented and its effectiveness.

Chesapeake Bay restoration project

The Chesapeake Bay is the largest estuary in the US, being 200 miles long and ranging from 3.4 miles to 35 miles wide. The 64 000 square mile watershed forms part of six states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia) and all of the District of Columbia. The basin is fed by 150 rivers and streams with the Susquehanna River providing about fifty percent of the freshwater entering the Bay. The Bay and the tributaries have approximately 11 684 miles of shoreline/stream banks[20]. During the 1970s and 1980s research showed that the water quality was declining in a number of ways including pollution from agricultural chemicals, toxic chemicals, excess nutrients and sediment. The sources of these COC included municipal wastewater plants, industry, urban and agricultural areas.

Eutrophication was considered at the time to be the main issue for the estuary arising largely from non-point agricultural run-off[21]. In 1983, stakeholders established the Chesapeake Executive Council to develop strategic and operational policy for restoring the Bay. Four years later they agreed the goal of reducing nitrogen and phosphorous loading of the water by forty percent by the year 2000. It was agreed that regulatory authorities would work with farmers to develop and adopt BMP to address nutrient, sediment and pesticide management. Point sources would be addressed by specific legislation. The practices employed are addressed specifically in Appendix 4. The BMPs implemented included conservation tillage, winter crop covers, crop rotation, management of soils susceptible to erosion, stream bank protection, nutrient management planning and budgeting, riparian, tree and grass buffer zones, and waste management systems as well as the structural techniques already outlined in this report.

Cost share funding for farm projects was in line with the USDA programmes previously described. Some states offered a BMP tax credit, such as the State of Virginia that allowed farmers to claim a tax credit equivalent to twenty five percent of the BMP installation costs. What benefits have been seen to date? Total river flow to the Bay between October 2005 and September 2006 was average with the nitrogen load being 331 million pounds, which was comparable to the average load for 1990-2005. This amount is twice the restoration target of 175 million pounds of nitrogen and further measures are being implemented to address nitrogen. Phosphorous levels were only half those of 2005 at approximately 13.4 million pounds where the target level is 12.8 million pounds. Sediment levels have remained constant as have river flow volumes.

Conclusions from the US

My time in the US has provided me with an overview of the current status of water management and an insight into the opportunities, but also the threats to the development of strategic water management policy. The discussions I have had with regard to global water issues show that many of these influences are universal, but more acute in the regions of the world with:

- High population growth;
- Transition of population from rural to urban areas;
- Poor management of water transfer systems either due to lack of infrastructure, financial or technical resources to maintain and upgrade;

- Lack of infrastructure and resources for human sanitation, food safety and waste water treatment; and
- Dwindling environmental resources and environmental damage that is impacting at a personal, social or economic level.

I left the UK believing that water security and the associated strategic and operational policy was important, and this was soundly reinforced by the time I spent in Utah, California and Washington DC. My key conclusions from the US were as follows:

- Rights to water vary across the US, but having definable rights and an interlinked hydraulic system means that there is an active market especially in California for the transfer of water rights. Therefore if the water is of greater value for municipal or high value crop use the farmers can sell that access to water to others for a defined duration. Public trust doctrine may affect the security of these rights in the future as well as origin rights i.e. the proposal that water cannot be transferred from an area if it impacts negatively on the people and businesses in that area. Water markets and economic incentives will continue to be a mechanism that will drive water policy and water management.
- The use of branding to add value to products that have been produced conventionally, but in the context of maximising environmental protection and biodiversity was just beginning to be considered in the US. Local foods, farmers markets are developing in some areas but this was largely a niche market. There was a lot of interest during discussions in the work of LEAF (Linking Environment and Farming[22]) and adding value to food through the LEAF MARQUE scheme. There are brands being introduced in the US that define geographic location e.g. Utah's Own[23] and the work of the Glynwood Centre[24] that seeks to sustain rural communities and the development of Community Supported Agriculture schemes[25].
- Land use development is influencing water use. Whilst housing reduces the need for water to irrigate the land for crops, the municipal requirements for water are increasing. This will ultimately affect drought policy. Historically in times of water plenty farmers would flood fields in an attempt to recharge aquifers and that option is reduced as urban development increases. Many of the areas that were suitable for this activity are being developed for housing so aquifers and river basins are not being recharged and the housing developments are increasing the usage of water from the selfsame aquifers.
- Storm water retention is becoming an issue especially in areas where the land is being concreted. Storm water retention and treatment is now a requirement for housing development in many areas of the US especially the need to mitigate against over application of pesticide and fertiliser on lawns and gardens.
- Groundwater overdraft is not sustainable and has caused significant environmental damage including subsidence in some areas of the US. To address this issue will require the continued development of water banking in groundwater systems.
- Waste water management and the development of recycling and reuse especially of urban water will continue to develop in the US. Increased efficiency of water use in urban areas will also be a key factor in managing water resources.

- Regulatory uncertainty will affect agricultural businesses as they are so reliant on water availability. This could mean that businesses relocate to areas where water is more plentiful and/or where environmental compliance costs are reduced.

- New technology will improve water utilisation including, the use of remote water system control, infra-red technology, Global positioning system (GPS) satellite technology and improved irrigation efficiency through new methods. GPS has assisted farmers to use sub-surface drip irrigation and farmers can plant within ½ an inch of the previous year. However improving individual field efficiency may not necessarily improve regional efficiency as there is less tail water from the first field to recharge water canals and groundwater for the next irrigation system, therefore the second system will still need additional water to improve efficiency. Precipitation enhancement and desalination techniques will continue to support water resource management. If desalination technology is combined with units that provide energy from agricultural waste this will also address the issue of how to effectively manage manure and slurry especially in California.

- Water management systems in the US are set up for snow melt and the systems are not in place to collect and store rain water if climate variation leads to a change in type of precipitation or the pattern of precipitation. Estimates suggest up to seventy five percent of the snow melt could be lost. Water transfer and treatment also increases energy usage, but this may be offset by agricultural waste generation. Utilising biogas digestion will also reduce the volume of organic manure that has to be land spread which could have a positive effect on water quality. Hydro-power generation will be affected if there is a climatic shift from snow to rain.

- Water education programmes must be appropriate, tailored to the audience and should address urban, industry and agricultural use. The role of agricultural extension scientists is a key factor, although farmers utilise a range of advisors such as agronomists, chemical suppliers and technologists. The use of video podcasting, and other forms of social media was discussed and may be used in the future for dissemination of information. The "Roots of Change" programme[26] is an example of how a network is being developed to address sustainable food policy in California.

Water management policy – UK

There are many factors affecting water quantity and quality in the UK, these include:

- Increasing demand for water as a result of increasing population, new housing development, changes in population demand for water;
- Changes to land use;
- Changes in rainfall patterns and weather cycles which make it difficult to manage water; and
- Issues with water availability through over-abstraction in some areas for energy supply, municipal supply and agriculture; and
- Water quality issues from point source and diffuse pollution.

These issues need to be addressed using a range of both traditional and innovative methods. The demand for water can be managed through planning controls for new developments, and the private market route of metering, pricing structures and incentives to save water. Water availability can be addressed by determining the priority of water rights and identifying water bodies that are at risk of over-abstraction, improving water containment and transfer mechanisms, storage capacity and procedures to ensure aquifer recharge after dry periods and the development of additional supplies of water including recycled or reused water. As the population increases, strategies will need to be developed to create more public awareness of the need to use water more wisely and reduce wastage but ultimately the private/public dynamic of water resources is central to any policy development. The development of water resources in the future may require a change to existing regulations or hydrologic structures and will definitely drive the development of collaborative partnerships to address strategic and operational water policy. These factors as seen in the US will call for the development of community driven solutions where specific local issues drive local solutions. However this localisation of policy should be within a framework of national strategy so that individuals and individual organisations are not disadvantaged.

Water Framework Directive (WFD)

This EU Directive requires a change from separate management of water quality and quantity to an integrated approach based on the development of ecological status indicators and targets. This has great parallels to the TDML requirements in the US. The WFD legislation has been implemented essentially to address non-point source pollution and aims to:

- Improve the ecological health of inland and coastal waters and prevent further deterioration, especially by protecting against diffuse pollution in urban and rural areas through better land management. There is a requirement for nearly all inland and coastal waters to achieve 'good status' by 2015;
- Drive wiser, sustainable use of water as a natural resource;
- Create better habitats for wildlife that lives in and around water, for example by improving the chemical quality of water;
- Progressively reduce or phase out discharges, emissions and losses of priority substances and priority hazardous substances;

- Progressively reduce the pollution of groundwater; and
- Contribute to mitigating the effects of floods and droughts[7].

The WFD implementation timetable is defined as follows: In 2006, monitoring programmes were implemented to review the status of each River Basin and this was reported to the EU in March 2007. Between July 2007 and January 2008 the significant water management issues have been agreed for the River Basin Districts. Subsequently, between December 2008 and June 2009 there will be a consultation period on the draft River Basin Management Plans (RBMP). In December 2009, the first RBMP will be developed. This will include determining environmental objectives for each body of water and defining the measures that will be put in place to deliver the objectives. Between 2009 and 2012 these plans will then be enacted followed by a two year review period until 2015, when the RBMP should be in compliance with the WFD[7].

There are six major aquifer systems in England and Wales and in excess of 160 smaller aquifers that are used to support drinking water supplies[27]. In Scotland three point five percent of public water supply comes from groundwater; Northern Ireland six percent, but in England and Wales this rises to thirty three percent overall, but this varies from region to region. Groundwater is also abstracted for other water uses (Table 7) and the required groundwater quality will be dependent on the use.

Table 7: Estimated abstractions from groundwater by purpose in England and Wales (2003)[28]

Purpose	Volume (Megalitres/day)	% of total volume
Public water supply	5099	77.8
Private water supply	27	0.4
Spray irrigation	142	2.2
Other agricultural uses	88	1.3
Electricity supply	24	0.4
Other industry	804	12.3
Fish farming	311	4.8
Other	50	0.8
Total	6 546	100

Initial characterisation of groundwater under the WFD indicated that around eighty one percent of groundwater bodies in England, forty percent in Scotland and thirty five percent in Wales are at risk of failing WFD objectives[7]. In Northern Ireland, there are three areas designated as Nitrate Vulnerable Zones (NVZs) whilst in Scotland this equates to fourteen percent of the land area and Wales this falls to three percent. In England the boundaries of the NVZ equates to fifty five percent of the land area and most of the arable land. According to EA data, in 2004 almost fifteen percent of groundwater monitoring sites in England (none in Wales) had an average nitrate concentration exceeding 50 mg/l. This is largely due to historic industry and municipal practices. In England, sixty percent of groundwater bodies (and eleven percent in Wales) are at risk of failing WFD objectives because of high nitrate concentrations and much of the groundwater used for public supply has to be treated and/or blended before use. In Scotland, nitrate is the main groundwater contaminant although the incidence of contamination of water used for public supply that exceeds the Drinking Water Directive is one point four percent although sixteen percent exceed the guideline value. In 2004, there were six sites where nitrates were believed to exceed or likely to exceed the guideline. Other than agricultural sources the other major source of nitrogen is sewage effluent and the contribution by agriculture varies by region. The areas with the highest agricultural contribution are the South West and Severn Trent and these areas therefore may lend themselves to agricultural land management driven solutions.

The contribution made by sewage effluent remains steady throughout the year, but nitrate losses from the land tend to be seasonal in line with the times of highest rainfall i.e. winter and early spring. The Nitrates Directive requires the identification of waters polluted with nitrate using the following specific criteria:

- Surface freshwaters which contain or could contain if preventative action is not taken, nitrate concentrations greater than 50 mg/l;
- Groundwaters which contain or could contain if preventative action is not taken, nitrate concentrations greater than 50 mg/l; and
- Natural freshwater lakes, or other freshwater bodies, estuaries, coastal waters and marine waters, which are eutrophic or may become so in the near future if protective action is not taken.

If a "polluted" water is identified then all areas of land that drain into that water should be identified and designated as NVZs. Farmers in an NVZ must comply with the measures defined in an Action Programme to reduce the amount of nitrate lost through diffuse pollution. The designations are reviewed every four years.

Around twenty four percent of groundwater bodies in England and seven percent in Wales are at risk of failing WFD objectives because of diffuse urban pollution. The EA suggest the main sources are inadequate or faulty drainage systems allowing groundwater to be polluted by surface run-off, leaking sewers, spilled chemicals, oil and fuel. The results of EA monitoring in 2004 also identified that of the groundwater sites monitored for pesticide twenty five percent had pesticide present. Pollution from mining activities has left fifteen percent of groundwater bodies in Wales and six percent in England at risk of failing WFD objectives, the main contaminants being iron, lead, zinc, cadmium and acidic waters. Specific point source chemical contamination has also been identified in Scotland and there is limited data on this problem in Northern Ireland.

The data collated from the River Basin Characterisation Study is summarised in Table 8 and shows the extent of the problems in the UK. Diffuse pollution is determined as the major concern and one that needs to be addressed if water quality is going to be improved. The table shows that nitrates, pesticides and then phosphorous are the main contaminants of drinking water supplies and have to be routinely removed at treatment plants.

Sediment removal is another significant cost to the industry. Defra estimated that the cost of removing pesticides and nitrates from drinking water is £7 per water customer per year[29]. The EA has reviewed the costs for nitrate and pesticide removal in more detail and defined the capital and operational costs. The operating costs are collated in Table 9 and the costs for removing pesticide and nitrate in 2002-2003 were £59 million with the two largest elements being power and consumables. Table 10 shows the cost depreciation charge of the profit and loss account for maintenance charges. The table also shows that the average capital cost in England and Wales of removing pesticides and nitrates from drinking water between 1998 and 2003 was £71.5 million per annum for pesticides and £2.5 million for nitrates. With the additional operation costs of £59 million this represents a total of £133 million per annum and with a cost of treating groundwater of £41 million per annum.

Table 8: EA river basin characterisation statistics[7]

Pressure		Water bodies at risk, or probably at risk	
WFD Pressure	**Source**	**% of water bodies**	**Area (km²)**
Point source	Authorised discharges	3	3 453
Diffuse	Phosphorous	17	15 804
	Nitrogen	53	58 525
	Pesticides	20	28 113
	Mines and mine waters	6	17 377
	Urban pressures	21	18 175
Abstraction	Abstraction	49	79 456

These figures would suggest that if improvements in agricultural best management practice reduce the level of pesticides and nitrate in water that is currently being treated to reach drinking water standards this would deliver a saving of £1.3 billion over ten years. It should be noted that with ground water there will be a lag phase due to the time it will take to influence the level of contaminants in the aquifer.

The key question therefore is what is the cost to agriculture for delivering the required water quality standard? Historically in the EU the polluter pays principle has been used to determine cost allocation, but in the current UK farming climate, especially livestock farming, farming businesses do not have the capital to invest to address these issues and deliver the required benefits. The costs for current pilot schemes and projects are being met through agricultural schemes and government funding.

Defra published its water strategy for England in February 2008 entitled "Future Water"[30]. The policy document states that "*The WFD requires that all polluters of the water environment should pay, and that implementation of the directive is achieved in a fair and proportionate way across all sectors. The Polluter Pays Principle (PPP) is difficult to apply in practice, particularly in the case of agriculture where farmers' activities have both positive (producing necessary food) and negative (contributing to diffuse water pollution) effects. It will be some time before PPP can be applied fully in this area. In the meantime, solutions still need to be found to tackle diffuse pollution at source*".

Having studied the water quality trading schemes in the US, I would conclude that in order to fast track water quality schemes to meet the requirements of the WFD, alternative revenue streams and sources of capital should be sought. When developing such schemes, where appropriate the role of the tenant farmer and the landlord will also need to be defined, especially the benefits of any capital improvements to the land.

Table 9: Operating expenditure on water resources and treatment of water in England and Wales in 2002-2003[7]

	Total operating expenditure (£m)	% attributed to pesticides	% attributed to nitrates	Cost of removing pesticides (£m)	Cost of removing nitrates (£m)	Total (£m)
Employment costs	69	1	5	3.5	0.7	4.2
Power	47	25	15	11.8	7.1	18.9
Hired and contracted services	37	10	1	3.7	0.4	4.1
Materials and	42	35	5	14.7	2.1	16.8
EA Charges	87	0	0	-	-	-
Other direct costs	26	5	0	1.3	-	1.3
Total direct costs	308	-	-	34.9	10.2	45.1
General support expenditure	128	10	1	12.8	1.3	14.1
Functional expenditure	436	-	-	47.7	11.5	59.2

Payment for environmental services (PES) is a market approach to delivering environmental services based on the principles that those who benefit from the services should pay for them and those who generate the services should be compensated for providing them[31]. This defines a set difference in policy instruments. Payment for environmental services can be delivered by either command and control (CAC) policy, market based instruments (MBI) or a combination of both. CAC environmental policy relies on regulation including standard setting and enforcement as opposed to economic instruments, for example the English system of cross-compliance or agri-environment schemes. MBI provide incentives for environmental performance, rather than CAC which specifies either emission rates or technical standards. Environmental emissions trading and WQT are examples of MBI.

Table 10: Current cost capital maintenance charges for water services in England and Wales (£m)[7]

	1998-99	1999-00	2000-01	2001-02	2002-03	Average per year	2005-10
Current cost depreciation	640	627	647	647	706	653	??
Infrastructure renewals charge	255	249	275	295	307	276	403
Total	895	876	922	942	1 013	930	??
Share of capital maintenance charge attributable to pesticide	8	8	8	8	8	8	18
Capital maintenance charge attributable to pesticide and nitrates (£	72	70	74	75	81	74	72

The WFD measures require quality objectives to be set for other pollutants too, but there are no defined standards within the regulations. Private sources of water can also be affected by pollution and these sources can be used for drinking water or agricultural use. In many locations there is no viable alternative to groundwater and the cost of switching to mains water for irrigation may well be prohibitive. The development of water quality standards will therefore have a significant impact on the future development of water policy at a local, regional and national level. The WFD-UKTAG is the United Kingdom Technical Advisory Group (UKTAG) supporting the implementation of the WFD and is a partnership of UK and Irish environment and conservation agencies[32]. UKTAG was established in 2001 to provide coordinated advice on technical aspects of the implementation of the WFD and at a strategic level balance local, national and EU initiatives. Water quality has issues for drinking water but it also has an impact on food production.

Water quality for livestock and crop producers

Whilst there is a body of research that demonstrates the impact of water quality on crop production, much of this was discussed in the US section of this report, and by Manning (2008)[5] the paper produced as a result of the Nuffield study in the British Food Journal; the impact of water quality on livestock production is a fairly new area of research. The key water quality factors that affect livestock performance are: microbiological contamination especially with pathogens, high levels of minerals and dissolved salts; high nitrogen levels, contamination with bacteria or blue-green algae or chemical contamination following accidental spillage[33]. The degree to which livestock are affected will vary according to type, age and their feed composition. It is therefore important that livestock farmers assess the quality of their livestock drinking water at regular intervals for:

- Taste and smell (organoleptic quality);
- Salinity and hardness (mineral levels e.g. sodium, chloride, sulphates). If some mineral levels are too high in the water and they are also high in the feed this could affect animal health and welfare and performance;
- Contamination. This may involve a laboratory test to determine levels of hydrocarbons, nitrates, pesticides, heavy metals or organophosphates. Formal analysis would also identify any microbiological contamination.

Further research has also concluded that feedlot cattle drinking water with a total dissolved solids (TDS) of 6 000 ppm had lower weight gain than cattle drinking water with a TDS of 1 300 ppm, but that colder environmental temperatures and higher energy rations reduced this influence[33]. The same research showed that milk production by dairy cows had also reduced in summer months with raised TDS in the water. Manning (2008)[5] discusses that if the TDS is increased then the livestock will drink more water but:

- Raised sulphate levels had a laxative effect (see Table 11);
- Nitrate poisoning had been linked to poor growth, infertility problems, abortions, vitamin A deficiencies, reduced milk production and general poor health (see Table 12);
- Waters with a pH outside of the range of 6 – 8 may cause reduced feed and water intake, digestive upset, diarrhoea, or poor feed conversion;
- Blue-green algae contamination of drinking water sources can cause death, convulsions, bloody diarrhoea, ataxia or uncoordinated muscle movement; and that
- Bacterial contamination of water including total bacterial count and levels of coliforms, and streptococci will affect cattle.

Table 11: Concentration of sulphates in drinking water and effect on cattle[34]

Sulphate (ppm)	Comments
0 – 500	No harmful effects to calves
0 – 1 000	No harmful effects to adult cattle. If sulphate exceeds 500 ppm the specific salt should be identified as this will be the key factor in determining toxicity.
2 000 – 2 500	Laxative effect, diarrhoea initially but cattle can become resistant. Affects copper metabolism - deficiency of zinc, iron and manganese - poor conception rates
7 000	Death

Table 12: Concentration of nitrates (NO_3) and nitrate-nitrogen (NO_3-N) in drinking water and expected response from dairy cattle[54]

NO_3 (ppm)	NO_3-N (ppm)	Comments
0 – 44	10	No harmful effects
45 – 132	11 - 20	Safe, if diet is low in nitrates and nutritionally
133 - 220	21 - 40	Dairy cattle at risk; possible death losses.
221 - 660	41 - 100	High probability of death losses; unsafe.
Over 800	Over 200	Do not use; unsafe.

As a result of this Nuffield study, I would therefore recommend that livestock farmers undertake routine screening of their water quality (microbiological and chemical composition) in order to determine if these factors may be influencing animal health, welfare and performance.

UK water rights

If an individual owns land adjoining a watercourse they have certain water rights based on common law i.e. riparian rights. However, there is additional water law that can supersede riparian rights. Riparian rights mean that unless someone else owns the watercourse the landowner owns the land up to the centre of the watercourse; water should be able to flow onto land in its natural quality and quantity, but property owners can protect their land from flooding and erosion and should "pass on" the natural flow of water in the river. Landowners are required to clear debris from waterways, even if it did not originate from them and manage invasive weeds especially where this could prevent the movement of fish and affect the "soundness" of the river banks.

In 1997 a review of was undertaken in England and Wales because of concern that there needed to be more flexibility in the provision of abstraction licences. The main concerns were that some water bodies were over-licensing and also the number of licences that were held in perpetuity. The Restoring Sustainable Abstraction (RSA) Programme was implemented by the EA in 1999 to identify and prioritise sites which may be at risk from abstraction especially sites affected by the EC Habitats Directive, and Sites of Specific Scientific Interest (SSSI).

Surface and ground water resources are managed in England and Wales by the issuing of water abstraction licences by the EA. If an individual or organisation wants to abstract more than 20 m^3 (approximately 4 400 gallons) a day they will need an abstraction licence. In Scotland this is reduced to 10 m^3 per day, and in Northern Ireland notification must be given of abstractions greater than 10 m^3 per day with licensing managed through a differing protocol depending on the volume abstracted. An abstraction licence provides the "right" to use a specified quantity of water, if physically available, from a source. The licence does not secure the quality of the water, but does ensure that if anyone subsequently applies for a water abstraction licence during the term of existing licence that they cannot have access to water that has already been allocated.

Abstraction of water will have an environmental impact to varying degrees and water use will affect landowners and water users downstream. Additional conditions may be placed on the licences in England and Wales and new licences are time-limited, normally for a 12 year period, when there will be a formal renewal process. Apart from the application charge there is an annual charge for the amount of water abstracted. It was identified in the beginning of this report that in some parts of England and Wales water is a scarce resource. The EA has estimated that up to 700 megalitres per day of licensed abstractions may need to be recovered to ensure adequate environmental protection. This is within the context of rising demand from an increasing population. The recovery of this water is being progressed through the RSA Programme. Hydroecology is the term for the balancing the water resources required to maintain the environment and societies demand for water. The EA is the statutory body responsible for developing hydroecology strategy for England and Wales including the strategic management of water resources, flood risk, water quality, land use planning and development. Agencies that work with the EA in this area are Natural England (NE) and the Countryside Council for Wales (CCW)[7].

Catchment Abstraction Management Strategies (CAMS) were launched in 2001 and aim to deliver effective local water resources management for every catchment in England and Wales. CAMS will also help to deliver the requirements of the WFD. The Water Act 2003 also introduced legislation that made it possible to transfer water rights (licences) from one person to another. The Act also addressed the following:

- A statutory requirement for water companies to develop drought plans and water resource management plans;
- Time limits for all new abstraction licences; and
- The facility to revoke abstraction licences that were causing serious environmental damage without compensation. This comes into force in 2012 prior to this date compensation must be paid.

In Scotland and Northern Ireland the RBMP form the basis of river catchment management plans. The Scottish Environment Protection Agency[36] (SEPA) has also developed Catchment Advisory Stakeholder Groups that will be involved at a local level. In Northern Ireland, nine catchment Stakeholder Groups are being formed to provide a conduit for communication to both Statutory Agencies and NGOs[37]. In England and Wales, the 2008 Water Strategy will define water policy with regard to quality and quantity. The proposed outcomes of the Strategy are to address the issues associated with climate change, ensure availability of water and effective drought management, maintain high levels of drinking water quality, minimise deterioration in ecological standards, and improve the opportunities for recreation whilst ensuring fair, affordable charges. It will also address the policy areas of regulation, supply and demand, water quality and the impact of climate change.

As has already been discussed in this report, water right trading is the transfer of the right to abstract water from one individual to another; the rights are then defined in a new abstraction licence. At the time of writing of this report, the legislation has been changed so that water rights can be legally traded in the UK, but the volume of water used by agriculture is relatively small compared to the US and the current market is relatively passive. The EA does not have a brokering role rather a role to enforce water rights and facilitate transfer between one party and another. To date there is no other organisation in the UK that is in place to broker water rights trading. With a view to trading water rights, abstraction licences vary in their status and value as was also found in the US. Historic abstraction rights provide the right to abstract for perpetuity. Since 2001, all licences that have been issued have been time-limited and subject to renewal. This will provide an opportunity for the EA to assess the water resources that are available on a regular basis and amend the licences as required. Water rights trading can be through transfer of the licence, transfer with the land or a farmer can abstract the water according to their licence and then sell that water to a second party for their use. Trading can also be undertaken so that abstractions are transferred to locations where more water is available and there is therefore less impact on the environment. The EA have provided details on four water quantity trading case studies[38]:

- A trade between an industrial abstractor and a water company in south-east England;
- Trading between a water bottling company and two nearby industrial abstractions in south-east England;
- Grouped agricultural licences in East Anglia; and
- Temporary agricultural trades in Lincoln.

Water quantity trading may well prove an important mechanism in the future to manage water demand an alternative mechanism is physical water transfer.

UK water transfer schemes

Water trading can feasibly only be undertaken in the same groundwater system or catchment area. However it would be theoretically possible to extend this system if the current British waterways and canal systems were upgraded and used to transfer water. However, the capital costs would be significant. An example of an existing water transfer scheme that is managed by the EA is the Ely Ouse-Essex Water Transfer Scheme.

This scheme was created following the 1968 Ely Ouse Essex Water Act. The process became operational in 1972 and water is transferred to reservoirs that supply Colchester and Chelmsford. The water is taken from the River Ouse or (Great Ouse) at Feltwell, Norfolk and travels in a tunnel for 20 km to Kennet, Suffolk and in a further 14km pipeline where it is then pumped into the River Stour at Great Bradley at a rate of about 400 megalitres per day. The water then travels to the Abberton Reservoir in Essex[39]. In a normal year about seven percent of Essex's water comes from this scheme, but in a dry year this can increase to between fifteen and thirty five percent. There has been concern raised by anglers and environmental groups on the impact on the environment if transfer levels increase in order to meet the growing demand for urban water in Essex. Environmental concerns are further exacerbated by proposals for 500 000 new homes in the M11 Corridor, Thames Gateway and Milton Keynes. This has led to plans to increase the size of the Abberton Reservoir, which is the largest freshwater body in Essex. It covers 472 hectares and was completed in 1939. The proposal is to raise the level of the reservoir by 3.2 metres, which will allow for an additional sixty percent of water storage. The surface area will be increased from 4.7 sq kilometres to 6.7 sq kilometres. There is an ongoing review of the environmental impact of the scheme and it is hoped that the reservoir will be fully operational by 2014.

London is already experiencing huge population growth placing even more pressure on the already resource-stressed region. London's population has been steadily growing since 1989, and is projected to reach 8.1 million by 2016[40]. The Mayor's London Plan has indicated that 460 000 additional houses will be needed. London currently has a water supply–demand deficit of approximately 180 megalitres per day and most of the city water supply comes from the River Thames, the River Lee and associated pumped-storage reservoirs[40]. Flood alleviation is also a major issue for this area so the development of a strategic conjunctive management plan is critical for London's ongoing development. Planning permission was given in summer 2007 for the UK's first desalination plant. It will provide up to 140 megalitres of drinking water per day enough for around one million people. It is planned that the plant at Beckton, South London will be operational during 2009.

Catchment sensitive farming (CSF)

CSF is a management tool to address non-point source pollution of river catchments through land management practice. With respect to England, forty catchments have been identified as being in need of action. CSF addresses excess nutrient levels in water bodies, and increased sedimentation. This £22 million initiative championed by Defra, the EA and NE will involve a range of stakeholders including water companies, conservation groups, farm advisers, and farmers. The initial study addresses eight catchments namely River Lugg, River Ribble, River Test, River Till, River Torridge, Suffolk East Coast Rivers, Upper Severn, and the Upper Thames. Run-off from urban areas is also of concern not only with respect to the potential contaminants that may be present, but also the increased risk of flooding. This is because drainage has been historically developed to drain away as rapidly as possible into either a watercourse or a soakaway. Most surface water run-off receives little or no treatment before entering rivers and streams. This type of pollution could be managed using grassed swales and wetlands. Mechanisms to address such pollution are termed Sustainable Urban Drainage Systems (SUDS) and include ponds and wetlands, swales, infiltration trenches and filter ditches, and rainwater control at source e.g. rainwater collection and use for toilet flushing, or lawn watering.

The England Catchment Sensitive Farming Delivery Initiative (ECSFDI) was launched to run between April 2006 and March 2008 and identified 40 priority catchments. The ECSFDI involves about 50 000 farmers at a cost of around £22 million and covers about forty percent of the agricultural area of England. The Initiative includes a network of Catchment Sensitive Farming Officers (CSFOs) responsible for individual catchments, and providing advice to farmers either directly or through specialist contractors. Catchment Steering Groups have been developed at the local level and there has been a range of outreach programmes. A £5 million capital grant scheme has also been part of the Initiative where up to £10 000 per farm can be claimed for specific capital works such as watercourse fencing, biobeds or clean and dirty water separation. The CSF advisory tool which has been developed as part of the whole farm approach (WFA) is accessible at http://www.defra.gov.uk/farm/wholefarm/index.htm

Other organisations involved in improving water quality include the Farming Wildlife Advisory Group (FWAG), LEAF, Voluntary Initiative, River Trusts, and Wildlife Trusts. The EA also has lead responsibility for the 39 species and five habitats of wetland character under the UK Biodiversity

Action Plan (UKBAP). The UKBAP identifies the need to take opportunities for enhancing wetland habitats.

Water Protection Zones (WPZ) are a mechanism to restrict or prevent activities that can cause water pollution from sub-catchment to multi-catchment levels. WPZ could be used by the EA to restrict a specific farming practice that is deemed to raise the incidence of pollution or run-off. Only one WPZ is in place following a six-year designation process on the River Dee catchment where it has been implemented to prevent drinking water contamination. However, WPZ may be used in the future as part of the implementation of the WFD. Defra are also encouraging water companies to work with farmers[41].

Agri-environment payments

Following reform to the Common Agricultural Policy (CAP) agri-environment payments became available to farmers in 2005. These payments were implemented to help protect farmland and waters from the adverse effects of diffuse pollutants. In England, the Entry Level Stewardship (ELS) supports baseline environmental practice whereas the Higher Level Stewardship (HLS) has been developed to support deliver significant environmental benefits in high priority situations and areas. Although they have been superseded in England, the Countryside Stewardship Scheme and the Environmentally Sensitive Areas Scheme (ESA) agreements are still in force for some farmers. In Wales, the agri-environment scheme is called Tir Gofal. The Northern Ireland agri-environment schemes that are currently available are the ESA and the Countryside Management Scheme (CMS). In Scotland the ESA Scheme is now closed to new entrants and they have a Habitats Scheme and a Rural Stewardship Scheme (RSS) that replaced the Countryside Premium Scheme (CPS). These schemes have historically driven catchment management but will the level of funding available be able to meet the needs of the WFD or should we be looking for additional revenue streams such as water quality trading?

In the balance between delivering private and public benefits water utility companies have increasingly assumed a social role within their "for profit" service model. It could be argued that water utility companies have increasingly provided goods that were historically seen as government policy. The de-nationalisation of water utility companies means that there is a further interaction with regard to water policy and that is the role of the independent regulator OFWAT. The geographic nature of water and sewerage and "water only" undertakers means that in practice each undertaker has a monopoly in a given area so the market cannot be considered as "free"[42]. OFWAT suggest that competition and market dynamics deliver improvements more efficiently than regulation so can we conclude that water quality trading is a viable option for the UK?

Proposals have been put forward by Defra for consultation on the statutory guidance for social and environmental guidance and the options for delivering water quality and they include reference to many of the collaborative approaches such as MBI that are outlined in this study[43].

WQT provides an opportunity for water and sewerage treatment companies to reduce their water quality costs and meet their regulatory obligations by purchasing or trading "environmentally equivalent or superior reductions from another source at lower cost, thus achieving the same water quality improvement at lower overall cost"[44]. This means undertaking a cost benefit analysis and determining the most cost effective option for meeting the requirements of the WFD. The social, economic and environmental benefits are as follows[45]:

Environmental

- Reduces the total social cost of achieving water quality goals;
- Allows dischargers to take advantage of economic scale and treatment efficiencies that vary from source to source;
- Reduces overall cost of addressing water quality problems in the watershed; and
- Provides incentives for innovations in pollution reduction technology.

Economic

- Achieves equal or greater reduction of pollution at equal or lower cost;
- Creates an economic incentive for dischargers to go beyond minimum pollution reduction;
- Can reduce cumulative pollutant loading, improve water quality and prevent future environmental degradation; and
- May lower political resistance to higher water quality goals over time.

Social

- Encourages dialogue among stakeholders and fosters concerted and holistic solutions for watersheds with multiple sources of water quality impairment.

In order for WQT to be successful, watershed stakeholders and regulatory agencies must be willing to develop a collaborative and innovative approach to address water quality issues. Table 13 highlights the stakeholder interaction and the cost savings in a number of US schemes. The capital and operating savings achieved by many waste treatment plants have been significant as a result of this type of transaction. The financial benefits outlined do not include any increase in social capital or brand value as a result of community interaction and activities. WQT can ensure legislative compliance and provide resource management solutions whilst enhancing financial, human and physical capital assets, therefore I believe that this policy is of value to the UK and should be developed further.

Table 13: US examples of cost savings in WQT schemes[46]

Agreement	Number of Stakeholders (groups listed as "1")	Savings achieved	Location
Action	4	$ 2.25 million annually	Massachusetts, US
Bear Creek	5	Forest Hills Metropolitan District (mitigated cost of upgrading treatment facility) approx $1.2 million	Colorado, US
Boulder Creek Trading Program	5	$ 3-7 million mitigation of upgrading treatment facility	Colorado, US
Grassland Area Farmers Tradable Loads Program	8	$ 14.3 thousand over five years	California, US
Illinois Pre-treatment Trading Program	4	$ 6.9 million for one service area (estimate)	Illinois, US
Long Island Sound	3 (incl.79 treatment works)	$ 200 million over 15 years	Connecticut. US
Piasa Creek Watershed Project	11	$ 3.25 million	Illinois, US
Wayland Business Center Permit	9	$ 1 million	Massachusetts, US

The role of UK River Trusts

A river trust is an independent non-profit making organisation working for the public interest. Some river trusts have been established following a major environmental issue in a river basin or catchment. Charitable status is an advantage as many UK and EU funding streams are only available for not-for-profit organisations; charities have tax exemptions, private contributions can be gift aided and donations are exempt from inheritance or capital gains tax. A trust can also make collaborative bids with other organisations such as the EA or NE.

The Association of River Trusts for England and Wales (ART) was established to increase the interaction between river trusts[47]. There are also river trusts in Ireland and in Scotland the body is the Rivers and Fisheries Trusts of Scotland (RAFTS)[48]. The key aim of ART is to: "co-ordinate, represent and develop the aims and interests of the member trusts in the promotion of sustainable, holistic and integrated catchment management and sound environmental practices, recognising the wider economic benefits for local communities and the value of education." The river trusts have a role in the interaction of stakeholders and seek to develop a collaborative approach to the development of future UK surface water policy.

Flood risk management

Defra has the overall responsibility for flood management through the strategy "Making space for water". Defra also funds projects and the EA's activities in England and in their role the EA is also responsible for increasing public awareness of flood risk management. Floodplains provide for the storage and movement of water during high levels of flow. Flood risk is determined in part by the rate and speed of run-off from land and urban areas. Factors that influence rural run-off include agricultural drainage, afforestation and deforestation, grassland management and cultivation techniques but the way these factors interrelate varies by catchment[49]. Two types of project have been developed at the catchment scale (HA6) and the farm scale (HA7) to identify the role that and use and land management can have in reducing risk at a local and catchment scale either by reducing run-off or its impact on water movement through catchments.

The EU Floods Directive 2007/60/EC on the assessment and management of flood risk became law on 26th November 2007[50]. Member States are required to assess by 2011:

- If river basins and coast lines are at risk from flooding;
- The impact of such flooding on human health, the environment, economic activity and cultural heritage; and
- The measures required to reduce flood risk.

For areas that are deemed at risk, flood risk maps must be developed by 2013 and flood risk management plans must be established by 2015. The Floods Directive will need to interact with the WFD. In this context it is important to differentiate between the terms retention and detention basins, wetlands and washlands. Wetlands are areas such as river valleys where the water table is seasonally or permanently high[51]. They can be natural or artificial areas and can be used for agriculture, amenity and recreational use. Wetlands can also be created as a measure to mitigate flooding risk. Wetlands can provide social, economic and environmental benefits through water storage, groundwater recharge, storm protection, flood mitigation, shoreline stabilization, erosion control, and retention of carbon, nutrients, sediments and pollutants[52]. As such, wetlands are retention basins as they are designed to hold the water indefinitely.

Washlands are normally man-made. They are areas of the floodplain that provide a low level of flood protection. The perimeter banks allow flood water to enter the land and provide a capacity for temporary water storage. These areas too can have agriculture, amenity and recreational use. A flood detention reservoir is an artificial structure designed to store floodwater so as to reduce the risk of downstream flooding especially in times of flash flooding and is a short term measure of flood management.

Flood management needs to address conveyance measures – i.e. actions to speed up the flow of water through an area by either addressing physical obstructions that slow the water down and/or increasing flow through widening, straightening, deepening or otherwise altering water channels[51]. Physical obstructions can include bridges, roads, and natural banks and barriers. Deepening channels and removing silt will increase conveyance but only if the flow is not restricted further downstream. Routine maintenance and dredging of rivers has lost favour in recent times because of its environmental impact and the cost versus the benefits achieved. Widening channels can result in the creation of a retention basin as discussed during the US part of this report. Flood or bypass, channels were also studied in the US, i.e. purpose built channels that take flood water away from an area where natural channels are not adequate or flood banks are not suitable. Washlands and flood detention reservoirs provide a storage solution and the requirements for areas at risk of flooding and the design will be specific to each catchment and river basin.

Farming floodplains for the future – Staffordshire Washlands

The Staffordshire Washlands Working Group was established in May 2003 with representatives from the Staffordshire Wildlife Trust (SWT), EA, NE, Royal Society for the Protection of Birds (RSPB), OnTrent, FWAG, Defra and West Midlands Bird Club[53]. This is a three year Defra funded project addressing land management practices in the Staffordshire Washlands catchment of the Rivers Penk, Sow and Trent which started in 2007[54]. The project also highlights the position of drainage boards in delivering flood risk management solutions and enhancing biodiversity. Increasing conveyance of water especially from agricultural land can create issues further downstream therefore a whole catchment system to retain the water and slow drainage from the land is required. The project will provide financial assistance; access to equipment and advice; and add value to production by promoting the role of the producer in water management and wetland development.

I believe this will be an inherent part of the flood management plans in the UK in the future. During my study a further example of flood management techniques is in the Rhine and Elba river basins[55]. Upstream afforestation may prove a solution in some areas as this will slow the release of floodwaters, but such developments would have to be actively managed in order that they do not themselves cause obstruction of river channels as a result of fallen trees. Further research is ongoing with regard to afforestation and riparian areas. Combining such programmes with carbon offsetting schemes could provide a suitable revenue stream and they will provide further benefits in terms of soil retention.

Conclusions and recommendations for the UK

Total UK water demand can be managed through metering, pricing and incentives i.e. those who can pay have access to the water. This market mechanism should reduce water waste as users recognise the cost of their activities and practices. However using a single tariff alone will disadvantage those in the community who cannot afford the water and will also not recognise the value of different uses or the varying volumes used.

Recommendation 1: A sliding tariff should be developed for water abstraction/use that recognises beneficial use and social need.

The further development of UK water resources will require changes to existing regulations or hydrologic structures.

Recommendation 2: The further development of strategic and operational water policy should be a collaborative approach with a range of stakeholders. Water policy should utilise both public and private mechanisms to deliver legislative compliance, meet population needs and sustain economic growth.

Water rights' trading provides a market mechanism to prevent over-abstraction of bodies of water, maintain the asset value of the abstraction right and provide added flexibility to water supply. However with agricultural abstraction being suggested as only representing 2% of the total volume of water extracted it does not present the opportunities for reallocation of water that has been seen in the US market.

Recommendation 3: The benefits of developing WQT should be assessed in order to manage demand in specific regions or catchments. WQT could be particularly effective too as an element of drought management planning.

In view of the issues with climate change, the predicted change in rainfall patterns and the increasing demand for water in the East and South of England private, on-farm water reservoirs will need to increase in number in order to mitigate the changes and reduce the pressure on summer abstraction.

Recommendation 4: Businesses should undertake a formal risk management exercise to determine the volume of water they require and how they can offset and/or reduce any financial or operational risks associated with their demand for water. This can include, but is not limited to: development of reservoirs to capture winter/spring rainfall; collection of run-off from roof areas and concrete areas for non-potable uses, effective methods of separating clean and dirty water, and methods for reducing water wastage.

Diffuse, or non-point source pollution has been recognised as a major issue in the UK. Urban and rural areas are sources of such pollution and strategies need to be implemented to address diffuse pollution as a whole. Remedial action will need to be funded if such pollution is to be reduced in order for the UK to meet the requirements of the WFD. Will the revenue afforded by agricultural environmental payments deliver action in rural areas at the speed required? I do not believe so. Can alternative sources of revenue be identified that provide both financial and social benefits?

Recommendation 5: WQT has the potential to deliver significant benefits. Defra estimated that the cost of removing pesticides and nitrates from drinking water is £7 per water customer per year. Effective implementation of WQT will reduce water utility costs and those passed on to the general public. Land users will also benefit from effective use of fertilisers and crop protection if they remain in-situ rather than entering the water courses. WQT will reduce the carbon footprint of the water utilities as they will not have to provide the current level of treatment or blending of water supplies. WQT as a policy should be reviewed by all stakeholders.

Water quality is of importance to both crop and livestock producers.

Recommendation 6: Agricultural businesses should pay attention to water quality and develop a water monitoring programme to determine the effects on crop performance and/or livestock performance, animal welfare and profitability.

Farmers and land managers will play a crucial role in the implementation of the Floods Directive especially in the development of retention and detention basins.

Recommendation 7: Alternative sources of capital for flood alleviation projects need to be identified and could include state, European or private equity funding. The use of retention and detention basins could be paid for by an annual fee irrespective of usage, or the farmer could be paid because they are essentially providing additional storage space to improve water management throughout the year. These basins could also be used to retain water for non-potable uses and to recharge aquifers especially if in some parts of the country ground water supplies are depleted meeting the requirements of drinking/municipal water.

Conservation easements and land trusts as developed in the US could have benefits and provide alternative sources of revenue for capital projects.

Recommendation 8: Policy makers should review the potential benefits of developing conservation easements and land trusts in the UK. The land trusts would deliver societal benefits; individuals or companies that donate to these schemes can gain tax benefits and landowners can realise a financial asset to reinvest in their farming business or an alternative enterprise whilst ensuring that the land will be designated for agricultural use into the future.

Urban areas need to address water efficiency, and diffuse pollution.

Recommendation 9: Water companies should further develop their urban and municipal water efficiency projects. These should include: advice and support in developing use of non-potable water for gardens; washing cars etc and assistance to improve household water efficiency.

Recommendation 10: Programmes should be developed to promote understanding of water footprint at a personal, community and organisational level. Individuals should be provided with information and guidance in how they can take action to reduce their water footprint and save money too!

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Glossary

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Acre-foot – unit commonly used to measure volume of water – the amount of water that will cover one acre one foot deep.

Appropriate – to initiate a water right by requesting and receiving permission to use public waters for a beneficial use.

Aquifer – a layer of rock or soil that either stores or transmits water.

Arable land – land suitable for crop production that can be cultivated.

Artesian – an aquifer in which the static water level in a well stands above the top of the aquifer.

Artificial recharge – deliberate addition of water to the ground water reservoir.

Basin – geographic area drained by a single water system.

Beneficial use – use of water for one or more purposes that can include domestic, municipal, irrigation, hydroelectric power, industrial, commercial, recreation, fish propagation and livestock production.

CAF – confined animal facility – this is defined in Californian regulations as "any place where cattle, calves, sheep, swine, horses, mules, goats, fowl or other domestic animals are corralled, penned, tethered or otherwise enclosed or held where feeding is by means other than grazing".

Canal – constructed open channel for transporting water.

CFS – cubic feet per second or second-foot – a unit of flow measurement equal to one cubic foot per second or 448.8 gallons per minute.

Evapotranspiration – evaporation of liquid.

Eutrophication – the process of contaminating water bodies with minerals and organic nutrients that causes a reduction in dissolved oxygen and can lead to an algae bloom.

Ground water – water, excluding soil moisture, which is contained in the saturated portions of soil or rock beneath the land surface.

Hydrology - study of the properties, distribution, and effects of water in the atmosphere, on the earth's surface and in soil and rocks.

Irrigation – the controlled application of water to land to supplement natural water balance.

Leaching – process by which soil soluble materials such as salts, nutrients and chemicals or contaminants are either dissolved and carried away by water or washed into a lower layer of the soil.

Levee – natural or man-made earthen structure along the edge of a stream, lake or river.

Mining (or overdraft)– withdrawal of water from a ground water source at a rate greater than its rate or recharge.

Mitigation – action designed to alleviate, lessen or reduce adverse impacts.

Natural recharge – replenishment of groundwater storage from naturally occurring surface water supplies such as precipitation and stream flows.

Non-point source pollution – pollution discharged over a wide land area by surface run-off and not from a specific location that is carried to lakes and streams.

Non-potable – water that is not suitable for drinking due to the level of pollutants, contamination, minerals or infective agents.

Point source pollution – pollutants discharged from a definable point or activity.

Pollution – the introduction of biological, chemical or physical matter at a level that makes the water unfit for its intended use.

Potable water – water that is fit for human consumption.

Recharge – introduction of surface or ground water into ground-water storage by natural or artificial means.

Recycled water – water that is used more than once before it passes back into the natural hydrological system.

Riparian – pertaining to the banks of a river, stream or any other body of water as well as to plant and animal communities along these bodies of water.

Seepage – loss of water by infiltration into the soil from canals, ditches, laterals, reservoirs or other body of water.

Share – stock in a mutual irrigation company that owns water rights used by shareholders.

State Engineer – official charged with the administration of water appropriation and distribution within the state.

Subsidence – sinking of an area of the earth's surface due to compaction of the underlying material.

Tailwater – water that reaches the lower end of a field.

Total Maximum Daily Load (TMDL) - As defined by the EPA, "is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. [Its] calculation must include a margin of safety to ensure that the water body can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality."

Virtual water content – The virtual water content of a product is the volume of water used to produce the product. The adjective 'virtual' refers to the fact that most of the water used to produce a product is in the end not contained in the product in terms of chemical constituents. The real water content of products is generally negligible when compared to the virtual water content.

Water footprint – The water footprint of an individual, business or nation is defined as the total volume of fresh water that is used to produce the foods and services consumed by the individual, business or nation. A water footprint is generally expressed in terms of the volume of water used per year (www.waterfootprint.org).

Water security - Sustainable access to adequate quantities of water, of acceptable quality, for human and environmental uses, on a watershed basis. (Bakker, 2007)[56].

Water right – the right to use water diverted at a specific location on a water source, and putting it to recognised beneficial uses at set locations.

Publications and articles as a result of the study

Produce Journal: Treading Water - July 2007

International Egg Commission: Water – Business Risk Management. Accessible at: http://internationalegg.com/corporate/news/details.asp?nid=375 July 2007

Farmers Weekly: Talking point: Water footprint, September 2007

Poultry World: Soapbox: Water footprint, October 2007

Poultry World: Report on presentation at Agricultural Resources Event, Newark, December 2007

Manning L., The impact of water quality and availability on food production. Accepted for publication by the British Food Journal October 2007.

Appendix 1: Water footprint methodology

These calculations are described in more detail in the scientific literature published on the water footprint website (www.waterfootprint.org) including the work by Chapagain and Hoekstra (2004)[9,10].

1. Virtual water content of a live animal

The virtual water content of an animal at the end of its life span is defined as the total volume of water that was used to grow and process its feed, to provide its drinking water, and the water used during the production cycle. It will vary according to the breed of the animal, the farming system, water consumption, feed consumption, water used in producing the feed, and the climatic conditions of the place where the feed is grown. There are three components to the virtual water content V_a of a live animal *a*:

$$V_a = V_{a,feed} + V_{a,drink} + V_{a,serv}$$

where $V_{a,feed}$ + $V_{a,drink}$ + $V_{a,serv}$ represent the virtual water content of an animal *a* related to feed, drinking water and service water consumption respectively, expressed in cubic metres (m^3) per live animal (see Figure A1).

2. Virtual water content of a primary crop

The virtual water content of a crop *c* (m^3/tonne) is calculated as the ratio of the total volume of water used for crop production, U_c (m^3) to the volume of crop produced Y_c (tonne).

$$V_c = \frac{U_c}{Y_c}$$

The average virtual water content of a crop c in a country, $V_{c,n}$ (m^3/tonne) is calculated as the ratio of the total volume of water used for the production of crop c (U_c) to the total volume of crop produced in that country. The total volume of water used for the production of crop U_c, is calculated as:

$$U_c = R_c \times A_c$$

where A_c is the total harvest area (ha) of a crop *c* in a country and R_c is the crop water requirement (m^3/ha) for the entire growth period of a crop c. It is usually assumed in these calculations that the crop water requirement is fully met either by irrigation or by rainfall (see Figure A2).

3. Virtual water of processed crop and livestock products

The virtual water content of a processed product relates to the virtual water content of the primary crop or live animal from which it is derived. The virtual water content of the primary crop or live animal is distributed over the different products from that specific crop or animal. The products derived from a primary crop or live animal are called primary products e.g. poultry primary products are meat or eggs. Some of these primary products are further processed into secondary products.

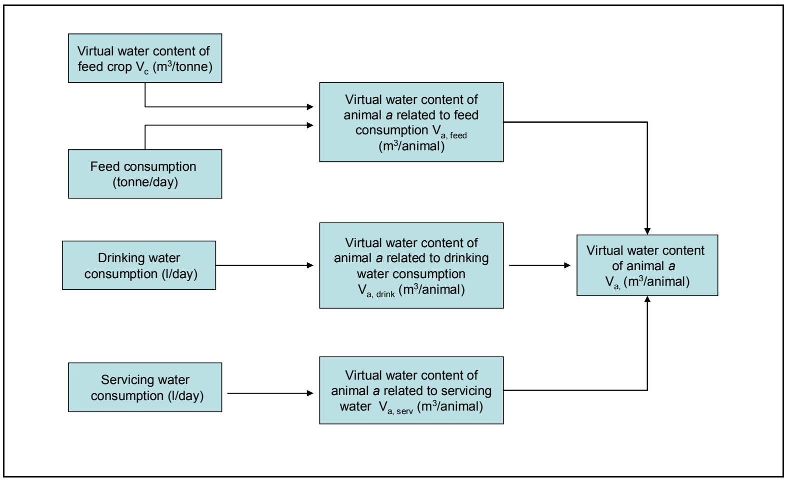

Figure A1: Virtual water content of a live animal

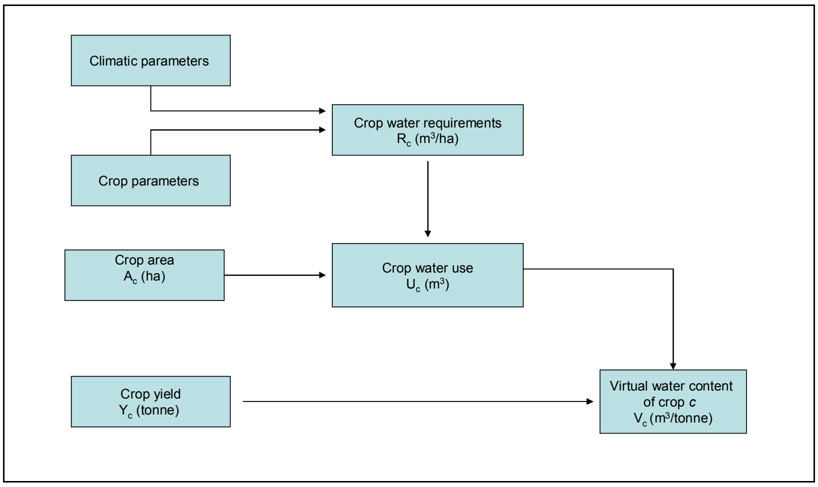

Figure A2: Virtual water content of a crop

The virtual water content of a processed product from a primary crop or a live animal includes the element of the virtual water content of the primary crop or live animal plus the processing water needed. The processing water requirement is calculated as follows:

$$R_{proc} = \frac{Q_{proc}}{x_{proc}}$$

where R_{proc} is the processing water requirement per ton of primary crop *c* or live animal *a* for processing primary products (m³/tonne). Q_{proc} is the volume of processing water required (m³) to process crop *c* or animal *a*. X_{proc} is the total weight of the primary crop or live animal processed. The virtual water content attributed to the final product must take into account the actual yield of the product at the end of processing compared to the live weight or gross weight of the crop or animal prior to processing.

Appendix 2: Resource management strategies

Table B1 identifies the resource management strategies that have been determined in the Californian Water Plan. Table B2 is also from the Californian Water Plan and demonstrates the benefits of each resource management strategy and the cumulative cost of implementation by 2030. Table B3 lists the agricultural land stewardship practices proposed in the same report. Sustainable water management should address:

- The total water balance i.e. the balance between supply and demand for water for all uses;
- Land management issues including market and regulatory drivers such as land value, soil management, nutrient management, manure storage, and best management practice;

Table B1: Resource management strategies

<u>Reduce Water Demand</u> Agricultural Water Use Efficiency Urban Water Use Efficiency <u>Improve Operational Efficiency & Transfers</u> Conveyance System Reoperation Water Transfers	<u>Improve Water Quality</u> Drinking Water Treatment and Distribution Groundwater/Aquifer Remediation Matching Quality to Use Pollution Prevention Urban Runoff Management
<u>Increase Water Supply</u> Conjunctive Management and Groundwater Storage Desalination – Brackish and Seawater Precipitation Enhancement Recycled Municipal Water Surface Storage – CALFED Surface Storage – Regional/Local	<u>Practice Resource Stewardship</u> Agricultural Lands Stewardship Economic Incentives (Loans, Grants, and Water Pricing) Ecosystem Restoration Floodplain Management Recharge Areas Protection Urban Land Use Management Water-Dependent Recreation Watershed Management

(Source: California Water Plan Highlights: A framework for action. Department of Water Resources Bulletin 160-05 December 2005)

Table B2: Strategy summary table

Resource Management Strategies	Water Management Objectives									Cumulative Cost of Option by 2030 ($ Billions)
	Provide Water Supply Benefit	Improve Drought Preparedness	Improve Water Quality	Operational Flex & Efficient	Reduce Flood Impacts	Environmental Benefits	Energy Benefits	Recreational Opportunities	Reduce Ground Water Overdraft	
Reduce Water Demand										
Agricultural Water Use	*	*	*	*		*	*		*	0.3 – 4.0
Urban Water Use Efficiency	*	*	*	*		*	*			2.5 – 6.0
Improve Operational Efficiency and Transfers										
Conveyance	*	*	*	*	*	*	*	*	*	0.2 -2.4
System Reoperation	*	*	*	*	*	*		*		
Water Transfers		*	*	*		*				
Increase Water Supply										
Conjunctive Management & Groundwater Storage	*	*	*	*	*	*			*	1.5 – 5.0
Desalination - Brackish	*	*	*	*					*	0.2 – 1.6
Desalination - Seawater	*	*	*	*					*	0.7 – 1.3
Precipitation Enhancement	*	*					*			0.2
Recycled Municipal Water	*	*	*	*		*	*	*	*	6.0 – 9.0
Surface Storage – CALFED	*	*	*	*	*	*	*	*	*	0.2 – 5.6
Surface Storage –	*	*	*	*	*	*		*	*	
Improve Water Quality										
Drinking Water Treatment and Distribution			*							17.0 – 21.0
Groundwater/Aquifer Reclamation	*	*	*						*	20.0
Matching Quality to Use	*	*	*							0.1
Pollution Prevention			*			*		*		15.0
Urban Runoff Management	*	*	*		*	*		*	*	
Practice Resource Stewardship										
Agricultural Lands Stewardship	*	*	*	*	*	*	*	*	*	5.3
Economic Incentives (Loans, Grants, and Water Pricing)	*	*	*	*		*			*	
Ecosystem Restoration	*			*	*	*		*		7.5 – 11.3
Floodplain Management				*	*	*		*		0.5
Recharging Areas Protection	*	*	*		*				*	
Urban Land Use Management	*		*		*	*		*	*	
Water-Dependent Recreation								*		3 - 6% of total
Watershed Management	*	*	*		*	*			*	0.5 – 3.6

(Source: California Water Plan Highlights: A framework for action. Department of Water Resources Bulletin 160-05 December 2005)

Table B3: Agricultural land stewardship practices

Agricultural land stewardship practices
• Wetland Restoration, riparian buffers and shallow water wildlife areas including feeding grounds for wild birds; • Irrigation tailwater recovery i.e. reuse of irrigation run-off; • Restricting or controlling livestock access to surface water; • Erosion control such as filter strips, grassed waterways and contour buffer strips; • Conservation tillage; • Windbreaks; and • Noxious weed control.

(Source: California Water Plan Highlights: A framework for action. Department of Water Resources Bulletin 160-05 December 2005)

- Water management issues including pricing incentives and water trading, river basin and catchment management plans and improved water use efficiency;
- Water quality management including livestock, crop and irrigation management; and
- Water quantity management addressing volume, flow rates, and water balance management.

A sustainable water plan needs to identify the maximum capability of a region based on the resources that are available. Historically, development has often occurred before effective water planning policy and this has ultimately led to unsustainable water use.

Appendix 3: Principles of integrated regional water management

(Source: California Water Plan Highlights: A framework for action. Department of Water Resources Bulletin 160-05 December 2005)

The principles of integrated regional water management include:

- Developing a long term perspective for water management that supports a strong economy and is routinely evaluated to ensure that it will meet future water needs;
- Identifying national and local roles and responsibilities;
- Developing a funding strategy and clarifying the roles of public and private investment;
- Effectively managing and improving operational efficiency of water conveyance, transfer and delivery systems;
- Determining the market mechanism for water management i.e. the benefits, costs and tradeoffs;
- Promoting coordination and collaboration among local agencies and governments;
- Ensuring that regional water management is based on sound science, best data and analysis of that data, and local knowledge;
- Enhancing of groundwater storage activities and development of water technologies to address water problems such as salinity;
- Promoting sustainable resource management and stewardship through agricultural land stewardship schemes, ecosystem restoration projects including recharging of aquifers, economic incentives such as loans, grants and water pricing mechanisms, floodplain and watershed management urban land use management and development of water dependent recreation;
- Increasing regional self-sufficiency in water and identifying new sources of water supply;
- Developing water quality plans to address drinking water treatment and distribution, balancing water quality to use, preventing pollution and managing urban runoff as well as remediation of ground water aquifers;
- Increasing regional drought and regional flooding preparedness; and
- Developing mechanisms for communication to all groups that have an interest in regional water management and developing awareness programmes to promote water conservation and water recycling at personal, organisational and regional levels. This will include the development and implementation of both agricultural and urban water use efficiency plans.

Appendix 4: Chesapeake Bay: Development of best management practices

(Sources : Agricultural Non-Point Source Pollution Control – Good Management Practices – The Chesapeake Bay Experience Cestti et al., World Bank Working Paper No.7 and USEPA Chesapeake Bay Program Nutrient Reduction Strategy Re-evaluation. Report No *. EPA-903-R-005. Washington, D.C).

Figure D1 defines the strategies that the sources suggest should be developed in a best management practice system. Table D1 defines the best management practices and their functions in terms of the individual strategy elements.

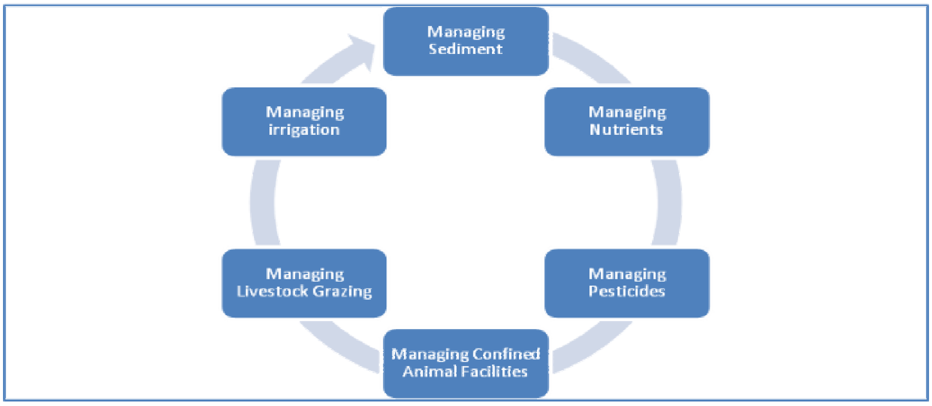

Figure D1: Best management practice strategy

Table D1: The elements of a best management practice strategy

Best Management Practice	Managing Sediment	Managing Nutrients	Managing Pesticides	Managing Confined Animal	Managing Livestock Grazing
Permanent vegetative cover	×	×			×
Animal waste management system		×		×	
Strip cropping systems	×	×	×		
Terrace system	×	×	×		
Diversion system	×				×
Grazing land protection system	×	×			×
Waterway system	×				×
Cropland protection system	×	×			
Conservation tillage system	×	×			×
Stream protection system	×				×
Sediment retention and erosion	×				
Tree planting	×	×			×
Fertiliser management		×			
Pesticide management			×		