J. W. Gottstein Memorial Trust Fund

The National Educational Trust of the Australian Forest Products Industries

PAYMENTS FOR WATERSHED SERVICES AND OTHER MARKET-BASED APPROACHES TO FOREST MANAGEMENT

ASHLEY A. WEBB

2011 GOTTSTEIN FELLOWSHIP REPORT

JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to,

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About the Author

Ashley Webb is a research scientist with Forests NSW where he has been employed since 2001. After attending James Ruse Agricultural High School he completed a Bachelor of Science (Hons 1) degree at the University of NSW, a PhD in Science at the University of Sydney and more recently a Bachelor of Laws (Hons 1) degree at the University of New England. Ashley has lectured in hydrology and fluvial geomorphology at the universities of Sydney and NSW on a contract basis and worked on environmental consulting projects prior to joining Forests NSW. He has worked in Forests NSW' Environmental Management and Forest Practices Directorate, Research and Development Division, Forest Management Unit, and Land Management and Forestry Services branch. His current duties include undertaking applied research in forest hydrology, managing Forests NSW water quality monitoring program for regulatory compliance, and contributing to forest-water policy development and review within the NSW government. Ashley collaborates on research projects with five Australian universities, is the Secretary of Research Working Group 3 (Land and Water Resources), and to date has authored more than 25 refereed publications. He is passionate about sustainable forest management practices, particularly as they relate to watersheds, and has a keen interest in the use of market-based mechanisms to achieve positive environmental outcomes across all land tenures. Ashley lives in Coffs Harbour with his wife Katrina and their sons Angus and Thomas.

Executive Summary

Forests provide a myriad of hydrological services for the benefit of human societies. It is for this reason that, wherever possible, forests are maintained in drinking water catchments. However, usually these services are not paid for and are taken for granted. They tend to be valued only when an infrequent event such as a wildfire or a logging operation threatens to interrupt this steady, free provision of benefits. The aim of this fellowship was to explore examples in the United States of America where 'watershed services' are valued and investments made in forest management to improve or maintain these services paid for by downstream water users.

In the US compelling evidence demonstrates that water treatment costs decline significantly with increasing forest cover. Compared to a watershed with 60% forest cover the cost of water treatment in a watershed with only 10% forest cover will exceed the former by greater than 200%. Investing in forest health is much cheaper and more efficient than letting catchments become degraded and having to rely on expensive filtration plants to treat the water. Prevention is better than cure. Investing in "Green" infrastructure is cheaper than investing in "Grey" infrastructure. Examples such as Quabbin, New York, Portland (Maine) and Seattle demonstrate this argument in very clear economic terms that support building catchment resilience through forest land purchases, conservation easements, restoration thinning and sound riparian buffer and road management practices. A key to the success of these programs is community education and linking people with the forests that provide their drinking water; a hallmark of the Forest-to-Faucet partnerships. When people realise they are a "forest dependent species" they are more than willing to pay for forest management to safeguard their health. Forest management can also be an insurance policy against the threat of catastrophic damage that could be caused for example by wildfires or insect attack. Examples cited from Denver and Santa Fe again show that water users are very willing to pay to see forests thinned and hazard reduction burning undertaken in their watersheds.

Forests can also play a role in point-nonpoint water quality trading programs. Forest landowners can be paid for offsetting nutrient loadings caused by point source polluters or landowners paid for planting trees to shade streams and offset thermal pollution from wastewater treatment plants. Credit is given where credit is due. The key to most of these solutions; solutions that can be profitable for forest owners and managers, is the development of markets in ecosystem services or

more specifically in watershed services. Typically, Payments for Watershed Services (PWS) schemes involve exchanges of money or credits for activities that effect improvements in watershed values. There needs to be demand for the services, i.e. buyers; a supply of service-providers, i.e. willing sellers; and a well-designed trading scheme supported by appropriate infrastructure and institutional frameworks, preferably utilising existing structures. Regulation often triggers a market but this need not always be the case. The US Government is committed to the further development of environmental markets as evidenced by the establishment of the US Department of Agriculture (USDA) Office of Environmental Markets. The USDA along with a number of Non-Government Organisations (NGOs) are working on metrics, protocols and pilot schemes that use market instruments to tackle environmental problems. Knowing where to invest is being helped by the development of tools such as the Conservation Priority Index (CPI) and the InVEST suite of models.

In Australia, given our reliance upon forests for drinking water supplies it makes sense to invest in these forests. PWS schemes could easily be used in catchments such as those supplying Sydney's drinking water, which are 60% privately owned, to purchase easements (or covenants) to protect and enhance the watershed services supplied. Point sources in the catchments, such as sewage treatment plants (STPs), rather than paying to pollute through an Environment Protection Licence, could be required to offset their pollution by trading in non-point pollution credits. Given the scale of the wildfires that have occurred in recent times in Victoria and near Canberra a shift towards more active management of forests, particularly in a changing climate, deserves further consideration. Singling out plantations as "users" of water in the Murray Darling Basin and elsewhere should be viewed through the broader lens of an ecosystem services model that recognises the salinity, soil conservation, water quality and other benefits that forests can provide. This will level the playing field with competing land uses that under an ecosystem services approach are less profitable.

While there may be hurdles to jump along the way, Australia is ripe for the introduction of PWS schemes. This report demonstrates that under the right conditions they can definitely be a win-win for forest managers and downstream water users and represent a fertile business opportunity in an industry that in the main has relied on timber as its predominant source of revenue. In many ways that we are yet to realise it is water that is the most valuable commodity that flows from our forests.

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1. Introduction

> *Water, in all its uses and permutations, is by far the most valuable commodity that comes from the forest land that we manage, assist others to manage, and/or regulate.*

This quote, reported by Barten (2006), is a policy statement made by the US National Association of State Foresters in 2004. It embodies what many of us may believe or understand but to date in Australia the inherent value of the water that flows from our forests is not recognised in economic terms. Instead, timber products and to a lesser extent carbon sequestration are the economic mainstays of multiple-use forest management. Regarding water, on the contrary, it seems that the role of forests is taken for granted until there is an infrequent and arguably low-risk threat to water supplies due to logging or wildfires (e.g. Webb, 2012). Furthermore, in the context of the Murray Darling Basin, Australian water policies afoot view plantation forests as water users that should be charged for the water they "intercept" rather than paid for the many positive watershed services they provide (e.g. Webb, 2009; Webb and Kathuria, 2012).

This report aims to show, using examples from the USA, that paying forest owners and managers for the water these forests provide actually happens and can be profitable. The schemes involved are generally termed Payments for Watershed Services (PWS) and in 2008 transactions in the USA exceeded $1.3 billion and operated across 16.4 million hectares of forest (Stanton *et al.*, 2010). Evidence from a number of US water supplies indicates that the best drinking water is usually sourced from either forests or natural grasslands (Dissmeyer, 2000). Furthermore, it is clear that the greater the level of forest cover in a given watershed, the better the quality of water provided for downstream use (Barten and Ernst, 2004; Ernst *et al.*, 2004). This is reflected in the increasing cost of water treatment required as the proportion of forest cover in a watershed declines (Figure 1). Compared to a watershed with 60% forest cover the cost of water treatment in a watershed with only 10% forest cover will exceed the former by greater than 200% (Ernst, 2004; Postel and Thompson, 2005). Logically, aside from being environmentally responsible, investing in forests is more efficient than investing in water treatment.

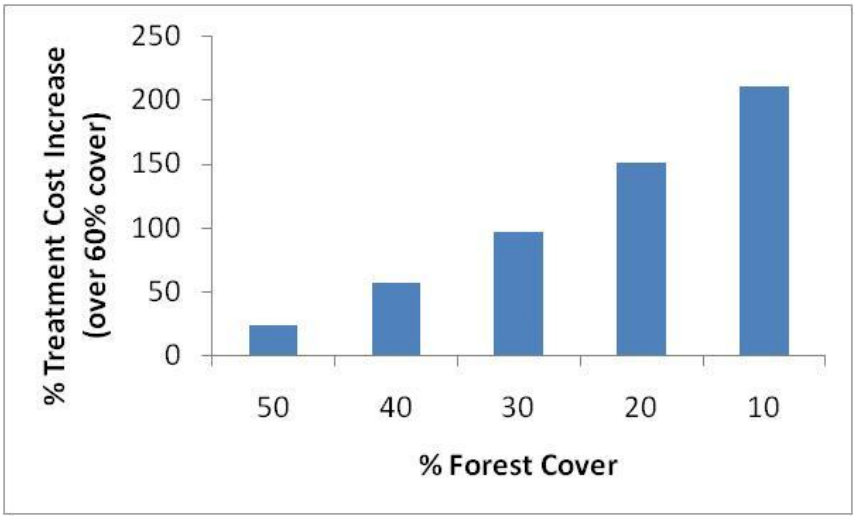

Figure 1. The relative increase in water treatment costs with decreasing forest cover compared to a 60% forested watershed. Data are sourced from 27 US water supplies, as reported by Ernst (2004); Ernst *et al.* (2004) and Postel and Thompson (2005).

The report is divided into sections that variously provide background information, detail discussions held with numerous people in the USA involved with PWS schemes, and summarise the operation of the case study schemes visited during the course of this fellowship in April 2011. The remainder of this chapter introduces some of the key concepts of ecosystem services and more specifically watershed services and PWS schemes. Chapter 2 is devoted to the many programs in which the US Forest Service and US Department of Agriculture are involved. Chapter 3 describes the role of non-government organisations (NGOs) in Payments for Ecosystem Services (PES) and PWS schemes while Chapter 4 summarises initiatives to better link people with the forests that provide their drinking water. Chapter 5 outlines the case studies visited on the fellowship while Chapter 6 explains some of the economic and legal barriers to implementation of PWS schemes. Chapter 7 concludes by outlining some of the key factors to success of PWS schemes and their possible application to Australian forest and water management. Full details of the author's itinerary including entities visited and persons consulted or interviewed are documented in Appendix 1 while Appendix 2 lists the various seminars given to agencies visited.

1.1 Ecosystem Services

Ecosystem services, their nature and value are the subject of a rapidly expanding literature (Salzman, 2011). In essence ecosystem services are those goods and services that humans derive from ecosystem functions, many of which are interdependent (Daily, 1997). Ecosystem goods may include such products as food or timber whereas ecosystem services flow from ecosystem functions and include such services as nutrient cycling and water regulation (Costanza *et al.*, 1997). By convention it is usual to refer to both ecosystem goods and services under the combined term, 'ecosystem services' (Daily and Ellison, 2002).

As Costanza *et al.* (1997) explain 'capital' refers to stocks of materials or information that are finite at any point in time. These stocks of capital, either alone or in conjunction with other stocks, generate flows of services that enhance the welfare of humans. Capital can be divided into various groupings such as 'Natural Capital' which includes physical stocks such as trees, minerals, ecosystems or intangible stocks such as the information stored within ecosystems or species; 'Manufactured Capital' which includes items such as buildings or machines; and 'Human Capital' which refers to physical human bodies or the information 'stored' within the human brain. Indeed the use of capital stocks or the flow of services from them by humans may not leave the original capital stock intact and arguably it is these changes in capital and services that are in turn most important for human welfare. In theory 'Ecosystem Services', the flows of material, energy and information from natural capital combine with manufactured and human services to produce 'human welfare'(Costanza *et al.*, 1997).

Various categories of ecosystem services have been defined in the literature but at present those of the Millennium Ecosystem Assessment (MEA) are considered to be the most appropriate (Kroeger and Casey, 2007). The MEA (2005) defined four broad types of ecosystem services:

(i) supportive,

(ii) provisioning,

(iii) regulating, and

(iv) cultural.

Supportive services lead to the maintenance of the conditions necessary for life to exist, such as nutrient cycling. Provisioning services provide direct inputs into the human economy, such as food and water. Regulating services include such services as the regulation of floods or storm hydrograph peaks by the maintenance of appropriate land cover (Ennaanay *et al.*, 2011), or disease control (Kroeger and Casey, 2007). Finally, cultural services provide opportunities such as recreation or the use of ecosystems for historical or spiritual purposes (MEA, 2005).

1.2 Watershed Services

A specific category of ecosystem service that relates purely to catchments or watersheds[1] has been termed 'watershed services' (Stanton *et al.*, 2010). In the main these are services provided for human benefit but can include services to aquatic ecosystems that in turn benefit humans and comprise a mix of provisioning, regulating, supportive and cultural services (Brauman *et al.*, 2007). These include but are not limited to the provision of water for domestic, agricultural, commercial, industrial and hydro-electric power generation purposes; the supply of fish and other freshwater products; reduction of flood damage; mitigation of dryland salinity impacts; prevention of soil erosion and sedimentation of waterways and reservoirs; water purification; provision of environmental flows; use of rivers for transport; and recreation and aesthetic values (Brauman *et al.*, 2007).

Without being too narrow or restrictive a category, watershed services are appropriate as the focus of this report as it deals with the implications of land cover management on catchment and downstream water values.

[1] The term 'catchment' is used interchangeably with the term 'watershed'. British and Australian custom is to use the term catchment, whereas watershed is the preferred term in North America.

1.3 Valuing Ecosystem Services/Watershed Services

A forerunner to any scheme trading in ecosystem services or watershed services is the concept of placing a value on such services. Quantifying and putting a price on ecosystem services is, however, probably best summarised by the following quote from Professor Geoffrey Heal of Columbia University: "Economics cannot estimate the importance of natural environments to society: only biology can do that" (Heal, 2000). Some argue that despite often being taken for granted, the value of ecosystem services to man-kind is infinite (Kroeger and Casey, 2007). Another way to think about the value of ecosystem services is to consider what it would cost to reproduce them in an artificial environment (Costanza *et al.*, 1997). As Salzman (2006) explains this is exactly what happened during the complex and expensive 'Biosphere II' project in Arizona where researchers sought to recreate a $200 million miniature self-sustaining environment to be populated by eight human 'bionauts'. Unfortunately the experiment was abandoned after just 16 months as oxygen levels had fallen 33%, nitrous oxide levels had increased 160-fold to the point where the 'bionauts' were at risk of brain damage, 19 of the 25 vertebrate species were extinct, as were all of the pollinators, and the vegetation was overrun by ants and vines (Salzman, 2006). Despite being seen as a failure the Biosphere II experiment reinforced the importance of Earth's ecosystem services to man-kind as absolutely essential, infinitely valuable and irreplaceable.

Critical though ecosystem services are they are seldom included in markets and hence are what economists term 'externalities' (Goulder and Kennedy, 2011). In other words because services such as the water quality or water purification services of forests are usually provided for free, they are taken for granted and not internalised into markets (Powell *et al.*, 2002). The focus of this report is not an analysis of economic theory; suffice to say that there are many established methods of valuing ecosystem services as outlined by Williams *et al.* (2010). These include travel cost and hedonic methods, contingent methods (Heal, 2000), social science approaches (Williams *et al.*, 2010), and indeed the replacement-cost method widely touted to favour investment in ecosystem services in situations such as New York's water supply as opposed to the costly alternative of a filtration plant (Postel and Thompson, 2005). See later case studies for more on the New York example.

Again though, regarding the value and pricing of ecosystem services, perhaps it is worth considering the opinion of Professor Heal. Notably that "Valuation is neither necessary nor sufficient for conservation" and "we conserve much that we do not value, and do not conserve much that we value" (Heal, 2000). He further argues that environmental outcomes are the key and that ensuring these outcomes is not contingent upon valuation. The focus should first be on incentives as they are "critical for conservation", whereas "valuation is not necessary for establishing the correct incentives" (Heal, 2000). From this it seems that placing an exact dollar value on an ecosystem service is inherently difficult and getting it exactly right is not necessary to achieving trade, the right environmental outcomes as well as benefits to society.

1.4 Market Approaches to Forest and Water Management

Arguably the current regulatory frameworks utilised in Australia are inadequate in delivering forest management approaches that ensure the best outcomes for downstream water users. Furthermore, few incentives exist to encourage private landowners to improve practices on agricultural land for watershed values despite some 60% of natural resources in Australia being on private land (Williams and Martin, 2009). So, the challenge is to explore other mechanisms that better value forests within a catchment context.

In terms of methods or frameworks for managing ecosystems, there are a multitude of choices concerning different market instruments with various degrees of government intervention. As Martin *et al.* (2007) outlined in their business model it is often necessary to combine elements of several different mechanisms or instruments such as philanthropy, taxation and commercial markets that fit within the relevant economic context. Salzman (2005) considers that ultimately governments also play a role as it is all too easy to rely on the public benefit of goods and services that have typically been provided free of charge. Further, he considers that to complement government involvement, the 'five Ps' are available as options. These include prescription, penalties, persuasion, property rights and payment. The latter two are the general focus of market instruments but it is worth considering each 'P' in turn.

- *Prescription* - Salzman (2005) is referring to command and control regulation that typically has been strictly applied to non-point source pollution (e.g. Environment Protection Licences for forestry activities) and he argues largely unsuccessfully.

- *Penalties* - refers to taxes and penalties that do not preclude an activity but make it more expensive.

- *Persuasion* - refers to the process of education or information exchange to encourage certain activities or discourage others. The example Salzman (2005) uses is that of the US Soil Conservation Service. Similar persuasion services in NSW could be the extension services provided by the Department of Primary Industries, Soil Conservation Service or Catchment Management Authorities.

- *Property rights* - refers to the privatisation of resources or at least access to them. This is the forerunner to a trading scheme whereby entitlements to a given resource may be openly traded (Shortle and Horan, 2008).

- *Payment* - a direct subsidy or an indirect tax break (Salzman, 2005).

Ultimately, as Martin and Verbeek (2006) explain, "each instrument is useful in different circumstances, and depends on others to be effective". The challenge lies in determining which instruments best complement the existing regulatory and institutional frameworks (Daily *et al.*, 2009), and furthermore reduce transaction costs as much as possible to prevent market failure (Martin *et al.*, 2008; Ghosh *et al.*, 2011). Some of these issues are further discussed in Chapter 6.

1.5 Payments for Watershed Services

Broadly defined Payments for Watershed Services (PWS) are "a payment or exchange of credits between a *buyer* and a *seller* to effect some improvement of a watershed service" (Stanton *et al.*, 2010). PWS schemes come in a range of shapes and sizes but essentially can be classified into three broad categories:

(i) Government PWS – these are the most common and involve a government agency as the 'buyer' of watershed services, sometimes on behalf of others, from upstream land owners. Payments take many forms including economic incentives to change land use practices, subsidies, cost-sharing arrangements, tax relief, land purchase deals and purchasing conservation easements.

(ii) Private PWS – these are less common but involve payments wholly by a private entity to upstream land owners to protect a watershed service for either business reasons or philanthropic interests. A good example is the Vittel bottled water company (owned by Nestle) in France that pays 26 large upstream farm operations to abide by environmental management plans to reduce nitrogen loads in the spring water.

(iii) Water Quality Trading – these involve an offset framework whereby a cap on pollution loads is set by regulation and the regulated entities purchase and trade in offset credits to meet their obligations (Stanton *et al.*, 2010).

While these schemes operate by exchanging payments or credits for watershed services in one way or another, as will be discussed in the following chapters, there is often a driver leading to their existence and ultimate success or failure. Typically the drivers are regulatory and/or economic.

2. The US Forest Service (USDA) and Ecosystem Service Payments

2.1 Introduction

Having arrived in Washington DC very late on Saturday 9 April 2011, my first visit was to the US Department of Agriculture Forest Service (USFS) Research and Development headquarters in Arlington, Virginia on Monday 11 April. The R&D office, while across the Potomac River from Washington DC is well connected with the DC office via a shuttle bus system operated by USFS every 30 minutes. I was fortunate enough to be able to take advantage of this service.

Figure 2. The White House was open for Spring Garden Tours on Sunday 10 April.

My visit to the USDA coincided with the proposed shutdown of the US Government due to budget issues, so after a last-minute deal while I was in transit from Australia, thankfully the office doors were open when I arrived at 8 am. A busy schedule had been arranged for me by Dr Katherine Smith who performs the role of National Program Coordinator, Fish and Aquatic Ecology. I obtained Katherine's contact details from Glen Contreras who has retired from that position and whom I had met at a conference in 2000. Glen also kindly distributed my contact details amongst his colleagues.

2.2 The US Forest Service

Most readers will know what the US Forest Service is so this is a brief introduction to the massive Federal government agency that employs approximately 30,000 people. It forms part of the US Department of Agriculture (USDA) and manages 193 million acres (78 million ha) of public land comprising 155 National forests and 20 National grasslands (Figure 3). These lands make up around 8.5% of the total land area of the USA. The agency has various divisions including the National Forest System, Research & Development, and State and Private Forestry. The Research & Development division employs more than 500 researchers and purports to be the largest forest research organisation in the World.

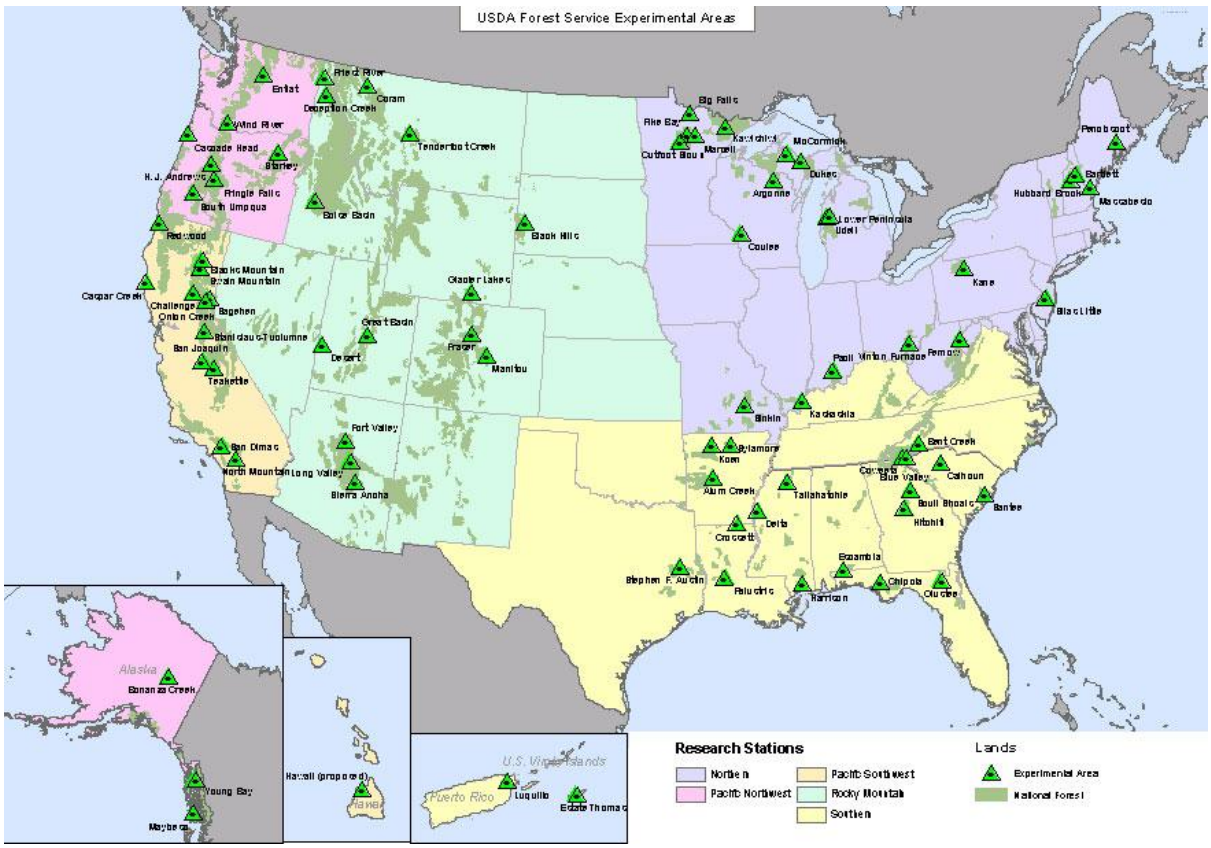

Figure 3. Map of the USA showing the location of National forests, grasslands, experimental areas and research stations of the US Forest Service. (source: http://www.fs.fed.us/research/efr/efr-sites/index.shtml)

The USFS has become a major player in the advancement of markets in ecosystem services (see Box 1) so it was my intention to find out more by meeting some of the research and management staff involved. Accounts of discussions with various Washington DC employees follow.

Ecosystem Services

Ecosystem services are goods and services that we derive from forests and grasslands that are often not valued in the marketplace. Forests and grasslands are valued for basic goods, such as food and wood fiber. But these ecosystems also deliver important services that are often perceived to be free and limitless—air and water purification, flood and climate regulation, biodiversity, and scenic landscapes, for example.

According to one international study, 60 percent of the worldwide ecosystem services evaluated in the study are being degraded or used unsustainably.

The Forest Service is working to advance market-based approaches to conservation and stewardship. Agency research programs provide information on the measurement, monitoring, and valuation of ecosystem services. The National Forest System (NFS) delivers multiple ecosystem services and can serve as a natural laboratory for informing scientific knowledge and policy. State and Private Forestry encourages market-based approaches through public outreach and education, technical assistance to private forest landowners and forestry professionals, and innovative partnerships.

Source: Forest Service Strategic Plan 2007-2012 (USFS, 2007)

Box 1. The USFS and Ecosystem Services.

2.3 Discussion: Beth Larry

Beth is the National Coordinator – Urban Research and has a thorough knowledge of environmental markets and ecosystem services (Collins and Larry, 2007). and we engaged in a rich discussion regarding ecosystem services and their role in forest planning and management, as well as payment schemes and other environmental markets, including some notable success stories and views as to what makes PES or PWS schemes work (or not). To date it seems that in the US an overarching national level policy is missing, though one may argue that such schemes really operate best at the local or specific issue level. In terms of investments in environmental markets, Beth explained that much of the effort to date has occurred on private land particularly in the northeast where there has been a concerted effort by the USFS to promote continued forestland ownership and management in the face of development pressures. On the issue of urban encroachment it was Beth's view that

“that land use change and the loss of agriculture and forestland to development serves as a powerful incentive to advance markets for ecosystem services. Private working lands that are valued beyond traditional commercial uses (valued for carbon, water, and biodiversity values, for example, in addition to timber and food crops) may compete better with HBU (highest and best use) real estate, which is commonly land for development. The aim of environmental markets and payments from our FS perspective is to make continued forestland ownership and management a more attractive investment position than selling this land for development uses.”

The USFS focus in the northeast on private land is not to detract from the fact that the agency is beginning to explore the role of PES schemes that operate on National forest land; the showcase examples being the Denver and Santa Fe watersheds (sections 5.6, 5.7). Some successful examples of other PES schemes include biodiversity banking and wetland and stream mitigation, both of which have evolved into established markets. Most biodiversity banking occurs in California, Texas, and the southeast for species such as Fairy shrimp, San Joaquin kit fox, Gopher tortoise, and wildlife habitat such as vernal pools. In the case of threatened species the federal *Endangered Species Act* helps drive the market.

In terms of water and water values the *Clean Water Act* has been a key driver requiring for example no net loss of wetlands which has facilitated wetland banking schemes. In most cases Beth was of the opinion that for markets to succeed there needs to be some kind of regulatory driver, otherwise buyers would be acting voluntarily. Certain voluntary markets have been successful, such as markets for sustainable wood products. Price premiums for certified products served as a motivation for many producers and retailers entering the marketplace; price premiums are nominal, however. Instead, producers and retailers find that certifying their products grants them more market share and relieves boycotting pressures from consumers and environmental organizations.

Beth mentioned a book she had read by Michael Pollan called “Omnivore’s Dilemma”. In any case we discussed the fact that people might be more willing to pay a price premium for “sustainable” foods that are certified, such as free-range eggs, where there is a direct human health link. The challenge is to outline to society the benefits we derive from the many other ecosystem services that working lands provide, such as carbon sequestration and water purification that are just as critical to human health and well-being. In urban environments the USFS has been engaged in

research that has linked human health benefits to the presence of trees. For example, Beth explained that a correlation has been found whereby patients in hospitals recover quicker from illness when trees are planted outside. Similarly, there is less crime in urban areas where trees are planted (Donovan and Prestemon, 2011). Not to question the integrity of this research but as with any association there are obviously a number of speculated reasons why such trends appear. As the authors suggest, one reason for the lower crime rates might be that trees signal to criminals that an area is better cared for (the "leafy" suburbs) and therefore possibly subject to better security protection measures. Nonetheless, the point being made is that trees and forests benefit society in a multitude of ways that often are taken for granted.

The challenge then is to somehow make the general public aware of the linkages between forests and their own welfare. In this respect Beth (and many others) is a champion of the "Forest to Faucet" partnerships that were established by Professor Paul Barten and colleagues at the University of Massachusetts in collaboration with the USFS (see Chapter 4). The clear message is that the best quality water comes from forests, hence the concept of the forest to the faucet. It is a catchy phrase in the US but unlikely to mean as much in Australia as the term faucet is not widely used – 'tap' being the preferred noun. The way Beth sees it this is just the beginning and what needs to happen is that all tiers of government have to be onside with common goals. The media could also play a key role in convincing the public that forest watershed management is vital and if not safeguarded there are obvious health risks. At the catchment scale when implementing PWS or WQT schemes Beth underscored the importance of people who actively engage with individual landowners "to provide the technical assistance they need to manage their lands for ecosystem services and participate in emerging markets". Finally, Beth pointed to 10 things the USFS can do (or is doing) with respect to ecosystem services:

1. Bring certainty to the ecosystem marketplace. Uniform standards, established baselines, risk mitigation, and early demonstration can accelerate and lend credibility to emerging ecosystem service markets. Our effort to help shape the 2007 Farm Bill to facilitate market-based conservation is one step in this direction.
2. Provide the most reliable and trusted information on forests for all audiences. We are helping to reconnect children to nature through education and involvement; at the same time we're informing policymakers of the positive role that forestry can play in a climate change strategy.

3. Experiment on and learn from the national forests. National forest land serves as a natural laboratory for testing ideas. Demonstration projects can serve as a resource as we help private landowners benefit from market-based conservation.
4. Become market savvy. New markets for ecosystem services require an understanding of how natural assets can be enhanced through forest management. We also need to know how the demand side works–how we can attract investments in conservation and connect conservation buyers to land stewards.
5. Reduce our environmental footprint and be the environmental leader we expect others to be.
6. Lead in research that can answer critical questions about climate change and about carbon sequestration and other ecosystem services.
7. Refresh our language. Much of our vocabulary came from the production forestry era; our words often reinforce practices and a mindset that might need to evolve.
8. Rethink forest plans—what goes into them and how we consider them. Do we need to build climate change scenarios? How can we incorporate a management approach that sustains the flow of ecosystem services across the landscape?
9. Resist the impulse to jump on the ecosystem services "bandwagon" without some thinking–and resist the impulse to dismiss the ecosystem services concept as the latest in a series of attempts to redefine forestry. At the very least, we can appreciate the dialogue that the concept is stimulating.
10. Learn as much as we can. Read, share, and connect with the issues in forestry today, and consider how they relate to the agency's mission and each of our own individual programs. Learning is a key part of our work–and we have important work to do (Collins and Larry, 2007).

2.4 Discussion: Greg Arthaud

Dr Greg Arthaud is a Research Social Scientist and has an interesting background; one which resonated a little with me having not come strictly from a forestry background. He is a social geographer and formerly taught forest policy at the University of Georgia. These days he is most concerned with the question of forest optimisation and broader issues that feed markets of various kinds. Part of that question involves the value and maintenance of ecosystem services. Greg works on cross-agency programs and committees on ecological systems that deal not only with National forest lands but across other tenures with the USDA and National Science Foundation for example.

One thing Greg has been working on is the National Forests Planning Rule. The previous version did not mention 'ecosystem services' at all; however, the term has been used at least 25 times in the latest draft that has been on public exhibition (www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5270250.pdf). Essentially, as Greg explained, all activities on National forest lands have repercussions for ecosystem services, whether this be fuel reduction burning or infestations of pine bark beetles. The Planning Rule represents a shift in the management of NF land in that all decisions used to be made

by a given forest supervisor whereas the new planning rule uses collaborative processes and seeks public participation. There are substantial differences in the way that National forests were created and the rationale for their existence in the eastern versus the western parts of the USA. For example, the majority of National forests in the west were created during the late 1800s and early 1900s in response to strip-cutting of land and as shown in Figure 3 today the majority of National forests are located in the western half of the country. In the east on the other hand most forests were dedicated in the 1920s or 30s in response to urban expansion pressures. However, in most cases (east or west) these forests are seen as the "headwaters" where protection of watershed values is a key reason for their existence.

Aside from working on the planning rule Greg has also been instrumental in bridging the gap between researchers and on-ground managers, something that is not always well achieved. In this regard he has been involved in setting up and running the ACES conferences (A Community on Ecosystem Services), the last of which was held in Arizona from 6-9 December 2010. According to the ACES 2010 website (www.conference.ifas.ufl.edu/aces/) the conferences:

> bring together government, non-governmental organization, academia, tribal, and private sector leaders to advance the use of ecosystem services and related science in conservation, restoration, resource management, and development decisions. The primary objective of ACES is to provide an open forum to discuss the latest and most innovative methods, tools, and processes for assessing ecosystem services while facilitating their effective use in planning and decision making. Individuals and stakeholders interested in resource management, restoration, conservation, and urban and non-urban development are encouraged to attend ACES.

The ACES conferences are a valuable initiative and are sponsored by agencies such as the US Geological Survey (USGS), US Environmental Protection Authority (USEPA), USDA Office of Environmental Markets and the USFS. A further initiative that Greg and colleagues are working on is the development of a web-based portal where those involved in ecosystem markets can participate, exchange ideas and post taped or panel sessions.

2.5 Discussion: Amy Daniels

Dr Amy Daniels is currently a Climate Change Specialist and Presidential Management Fellow in the R&D Division of the USFS. However, she has previously worked on PES schemes and has considerable

knowledge of the success or otherwise of PES in Costa Rica (Daniels *et al.*, 2010). It was useful to discuss the Costa Rica experience with Amy and to learn what she believed were some of the keys to success of PES and potential PWS schemes. In terms of the Costa Rican experience it is obviously somewhat different to that of the USA or Australia given that it is a developing country. However, being located in tropical Central America the conservation of forests is of vital importance as despite being relatively small in land area the country supports a high degree of biodiversity.

Costa Rica has experienced high levels of forest loss in the past with an average loss of 4.2% per year to deforestation recorded between 1986 and 1991 (Daniels *et al.*, 2010). The Costa Rican government intervened in the late 1970s to establish a number of National parks and private forest reserves and during the 1980s and 1990s implemented tax credit and other extension services to encourage reforestation programs. In 1996 the Costa Rican government authorised Payments for Ecosystem Services (PES) and to date some 700,000 ha of land have been enrolled in the program with a cumulative investment in excess of $150 million (Daniels *et al.*, 2010). Initially the main pressure on forest conservation was that the competing land use of cattle ranching was considered profitable and hence promoted deforestation of private lands. The PES scheme essentially recognises four broad environmental services:

(i) Biodiversity

(ii) Watershed function

(iii) Scenic beauty

(iv) Greenhouse gas mitigation (carbon sequestration/storage)

Landowners can participate in the scheme through reforestation (plantations), by protecting existing forests, by promoting natural forest regeneration, or via agro-forestry programs. In the case of agro-forestry systems payments are currently made per tree and such payments are approximately $1.30 per tree over a 3-year period. For natural forest regeneration landowners are paid $41/ha per year for 5-year renewable periods; for forest protection landowners are paid $64/ha per year for 5-year renewable periods; and finally for reforestation programs landowners are paid $816/ha over a ten year period (Daniels *et al.*, 2010). In each case there are minimum requirements that have to be met such as land area or priority indices. The success of the PES scheme Amy argues is somewhat

debatable. A significant amount of land has been involved in the program though notably some 89% has been enrolled via 'forest protection', which is an order of magnitude greater than the amount of land enrolled for example in reforestation.

The research that Amy was involved in pointed to the fact that there were regional differences in the success of the scheme. While the program has unquestionably protected a lot of land this has been occurring in some regions but has not stopped deforestation in others. Deforestation still occurs in areas where opportunity costs are greatest. In other words, if more money can be made from clearing land to enable an activity than can be earned for preserving forest under the PES scheme then logically a landowner may choose the former. According to Amy the PES scheme appears to have worked best in places where people are not dependent upon the land for their income. In other words the lesson that could be learned from the Costa Rican experience is that hobby farmers are a prime candidate for inclusion in PES/PWS schemes. However, she also cautions that more evaluation of the actual on-ground benefits of PES in an environmental context needs to be undertaken. Furthermore, the Costa Rican example highlights another impediment to PES and that is that the context of land use and development is likely to change over time.

2.6 Discussion: Al Todd and Nicole Balloffet

I met with Albert Todd - Chesapeake Bay Team Leader with the USDA Office of Environmental Markets, and Nicole Balloffet - Natural Resources Specialist with the USFS State and Private Forestry division, in the Sidney R. Yates building that is one of the oldest buildings in the USDA complex in Washington DC (Figure 4). Al originally trained in hydrology and previously worked in the USFS in various roles before moving into the USDA Office of Environmental Markets. According to the USDA (www.fs.fed.us/ecosystemservices/OEM/index.shtml):

> The Office of Environmental Markets (OEM) is a new office created within the U.S. Department of Agriculture to catalyze the development of markets for ecosystem services. OEM has a unique role in the federal government's efforts to develop uniform standards and market infrastructure that will facilitate market-based approaches to agriculture, forest, and rangeland conservation. OEM is bringing experts and stakeholders together with government agencies to build a robust, accessible, and scientifically credible market system that will protect and enhance America's natural capital into the future.

The office, formerly called Office of Ecosystem Services and Markets, was established in December 2008 to provide administrative and technical assistance to the Secretary in implementing Section 2709 of the Farm Bill.

Figure 4. US Forest Service Headquarters, Sidney R. Yates Building, 1400 Independence Ave, Washington DC – built in 1879.

One of the first issues we discussed was that of the relative merits of establishing PWS schemes or water quality trading (WQT) on Public versus Private land. Al did not discount the possibility of including public forests but expressed the view that any improvement made would be incremental. In other words he suggested it would be the equivalent of improving land that was in 'B+' condition to an 'A'. This of course takes nothing from the fact that public land in watersheds is extremely important for maintaining good quality drinking water (see Box 2). With regard to the Carbon market for example, Al expressed there was little role for public land to be included apart from perhaps as a backup or reserve pool. In terms of public forest management he also expressed, as Greg Arthaud did, that local members of the public were increasingly being involved in "collaborative forest management" as they were "right there locally". Some examples in the USA show some potential, however, for National forests to be incorporated in PWS schemes. These are most likely in the west where threats are clear, such as wildfires, and ratepayers can be convinced that contributing additional funds towards forest management (e.g. for hazard reduction) is a sage investment. Such examples include Santa Fe and Denver (see Chapter 5) which involve 5-10 year agreements. The

concept as Al put it is akin to investing in insurance against catastrophic threats to the watershed and obvious consequences for drinking water supplies.

In terms of existing and potential PWS/WQT schemes there are regional differences in terms of the potential focus. In the east where population density is generally higher and estuaries are affected by nutrient enrichment the focus is very much on chemical water quality. Mostly the trading schemes operating are motivated by compliance with legislation. For example the Chesapeake Bay scheme is all about regulating water quality. Conversely in the west the majority of markets are concerned with water quantity. This is largely due climate differences and to the operation of the Doctrine of Prior Appropriation that operates throughout much of the western USA. The doctrine has its roots in the 1800s and is based on the premises of 'first in time, first in right' and 'use it or lose it'. What this means in simple terms is that those who first established a right to access a water resource have priority over any subsequent person(s) to be granted a right of access. It is very different to the riparian system that operates in the east (and many other common law countries) and where water access rights are attached to land title. Under prior appropriation in the western USA the Federal government theoretically has 'reserve rights' to access water on public lands, though some states do not acknowledge this. According to a United States Supreme Court ruling in 1963 the federal government has reserve rights that date back to the time when federal reservations (National forests, National parks, Indian reservations etc) were designated and therefore, often these reserve rights pre-date and have priority over many existing private water rights (Postel and Richter, 2003). Environmental markets can operate to allow trading of such reserved water for purposes including the maintenance of fisheries or to supply water downstream for environmental benefit.

Forest ecosystems play a critical role in delivering clean water to the public.

Forests are a source of drinking water for over 180 million people in the United States.

Forests and street trees provide a number of ecosystem services that are essential to water quality and overall watershed health. Most importantly:

- Forests protect and enhance our water supplies.
- Forests absorb rainfall and snow melt, helping to minimizing floods.
- Forests slow storm runoff, reducing soil erosion and improving water infiltration rates and recharge to aquifers.
- Streamside forests filter pollutants, such as sediments, fertilizers, and pesticides, from agricultural and urban runoff.
- Forests provide fish and wildlife habitat and help maintain aquatic diversity.

Box 2. Forests and Watershed Services (USDA, 2007).

The USDA and the USEPA play a significant role in encouraging the use of market instruments such as water quality trading to improve water quality in American streams. The USEPA is a regulating body and can mandate certain levels of water quality. For example, under section 303(d) of the *Clean Water Act* states, territories and certain tribes must develop lists of what are known as 'impaired waters'. These are waters that are highly degraded or polluted and so the EPA mandates that the relevant state or similar authority develops what is known as a Total Maximum Daily Load (TMDL) for each impaired system. The TMDL essentially is a calculation of the maximum level of a given pollutant that can safely be discharged into receiving waters to meet water quality standards. Examples that exist and that have led to water quality trading include the Chesapeake Bay TMDLs for pollutants such as nitrogen, phosphorus and sediment; and the Willamette River (Oregon) TMDLs for temperature, mercury and bacteria. Another method that can be used relates specifically to drinking water systems and is known as a Filtration Avoidance Determination (FAD). Under the Surface Water Treatment Rule (SWTR) a drinking water system can qualify for filtration avoidance if it meets a number of criteria such as water quality limits for coliforms and turbidity, has not experienced a waterborne disease outbreak, and has an established watershed control program implemented to minimise microbial contamination. There is often a large economic incentive for water authorities to maintain FAD status and avoid the cost of filtration. Significant examples of FAD status include

watersheds contributing to water supplies in cities including New York, Boston, Portland (Maine and Oregon) and Seattle (see Chapter 5).

While the EPA can regulate point sources under the Clean Water Act via the National Pollutant Discharge Elimination System (NPDES) permit program, it is unable to regulate non-point source (NPS) pollution. This is where the USDA plays a role in encouraging private landowners to improve their management practices and hence reduce their NPS pollution footprint. I liked Al's description of the USDA – "Incentives R Us" - which reinforces that government incentives are basically a "carrot" for landowners such as farmers. Despite the Federal government being unable to regulate NPS pollution the states are able in some cases to regulate NPS pollution – as Al put it "the States can regulate anything". Therefore there is in many watersheds a threat, however real or otherwise, that states could turn to regulating NPS pollution activities. This in itself provides an incentive or driver for market-based instruments. The USDA administers a number of large subsidies and incentive programs such as funded under the *Farm Bill* and *Clean Water Act* (CWA) section 319 programs. In 2008 alone Farm Bill and CWA conservation program subsidies were estimated at $1.35 billion in total covering an area of 16.3 million hectares. If this is broken down further the Wetlands Reserve program (WRP) made payments of $149 million in 2008 while exclusive PWS schemes for drinking water were funded to the tune of $236 million (Stanton *et al.*, 2010).

Despite the market activity in WQT all over the country (mostly based on government funding) Al advised that there really are very few robust examples beyond those for P and N in the mid-west and the Willamette temperature trading program for TMDL compliance. The Chesapeake Bay TMDL requires a strategy to reduce N, P and sediment by up to 40% compared to current levels and this cap has been set for the States to implement. Al advised that there is a lot of work to be done but that one aspect of trading will be that all new development within the Bay's watershed will be required to offset nutrient and sediment loads, perhaps at a ratio of 2:1.

Finally we discussed key considerations that lead to the development of market-based programs (see Box 3 for a USDA guide to WQT). Al broke these down into 3 areas:

(i) Demand – where is it? Mostly a regulatory driver will be needed, so it is important to work with agencies such as the EPA to develop appropriate rules;

(ii) Supply – the main issue here is encouraging landowners to be involved in the program. It is essential to develop a strategy for certainty; and

(iii) Infrastructure – to make market instruments work there needs to be solid supporting infrastructure. This includes regulatory development, metrics (i.e. what is the unit of exchange?), protocols, education services, environmental assurance programs, advisory boards, registries and the like.

Evidently (iii) is the focus of a lot of the work Al and others are doing in the Office of Environmental Markets (OEM). Indeed the USDA has been generous in funding pilot trading programs and in some cases like the Willamette valley has provided loan guarantees. OEM is keenly involved with education of landowners and has been instrumental in the organisation of ACES conferences, as discussed in 2.4 above.

Key Elements of Water Quality Trading

Water quality trading takes place on a watershed basis to address local water quality issues. Most trading programs incorporate the following steps:

- Assess the potential for a trading program to meet watershed conservation objectives.
- Determine the pollutant reduction a landowner or seller can trade.
- Identify a trading partner or multiple buyers.
- Involve stakeholders in developing the program design and trading agreement.
- Verify and certify the implementation of necessary conservation practices.
- Track and report pollutant reductions and trades.

Box 3. Water Quality Trading (USDA, 2007)

2.7 Discussion: Nikola Smith

Nikola Smith works jointly with the Pacific Northwest Region (Region 6) of the National Forest System and the Pacific Northwest Research Station based in Oregon. When I visited there later in the trip she was unavailable to meet with me so we arranged a phone conference for the morning of

Wednesday 27 April (I called in from Denver). It is logical to report our discussion here in the context of USFS programs.

As discussed above, explicit mention of ecosystem services in the recently proposed Forest Service Planning Rule is very new, so application of ecosystem service concepts to National Forest management is still in development. The Deschutes and Willamette National Forests in Oregon are partnering with the Pacific Northwest Research Station to pilot use of an ecosystem service framework in a forest management context. Nikola's role really is a cross-over role jointly funded by the PNW research station and also Region 6. One thing that has interested her and others in the region is that a functional approach to ecosystem services could be utilised in USFS reporting and inform management decision-making. For example Congress requires the USFS to report on improvements in forest management or land management and this typically involves simple metrics such as the length of streams restored (e.g. in miles). This reporting mechanism could be enhanced by articulation of the connection between National Forest management and ecosystem services benefits that are provided to the public. Nikola has also been involved in the Willamette partnership (see Chapter 5) with respect to the development of protocols and metrics. She agreed that PWS schemes are easier to justify when a cost-benefit analysis supports forest treatments over water treatment infrastructure in water supply catchments (e.g. New York, Denver, Santa Fe) but also expressed that the Pacific Southwest Region of the Forest Service (serving California and the Pacific Islands) is also looking to incorporate ecosystem services in their planning processes.

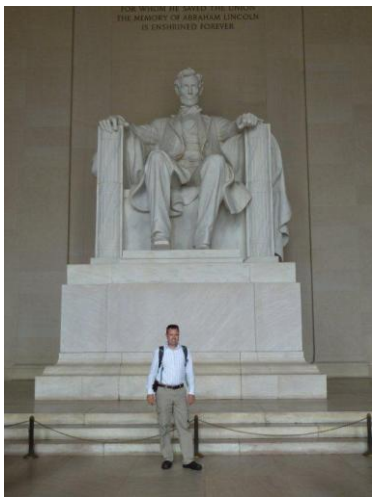

Figure 5. The author at the Lincoln Memorial, Washington DC

3. Non-Government Organisations (NGOs) and PWS schemes

One clear difference between Australia and the USA that became increasingly apparent on this fellowship was the much greater role played by NGOs in conservation programs in the US. The reason is not entirely obvious but it may be related to the greater degree of philanthropy in the US when compared to the very low rates exhibited by big business and the wealthy in Australia (Steffens, 2011). Nonetheless in the USA there are a number of very large environmental NGOs and land trusts involved in an array of programs including PWS and PES schemes. During this fellowship I caught up with some of the players in NGOs starting with the World Resources Institute and Forest Trends in Washington DC.

3.1 Discussion: Todd Gartner (World Resources Institute) and Kate Hamilton (Ecosystem Marketplace)

I met with Todd Gartner and Kate Hamilton jointly on Tuesday 12 April in Washington DC for a fruitful discussion of PES, PWS and WQT schemes. We met at Kramer's Books and Cafe (www.kramers.com), a central location off DuPont Circle. Todd works as a Senior Associate, Conservation Incentives & Markets for the World Resources Institute (WRI) while Kate is the Director of Ecosystem Marketplace. Both are environmental/forestry graduates of Yale University and over the course of this fellowship I learned that many of the people I met involved with PES/PWS were also graduates of Yale, one of whom described themselves affectionately as the "green mafia".

The WRI was established in 1982 and promotes itself as "a global environmental think tank that goes beyond research to put ideas into action" (www.wri.org/). Todd works within WRI's People and Ecosystems program and he is involved in finding ways to fund conservation efforts primarily through the use of incentives and market-based strategies. He has experience working with government agencies, landowners, local community groups and large corporations on projects involving biodiversity offsets, carbon markets and PWS schemes. One of his interests is also looking at ways to either "layer" markets or "stack" them so that the one piece of land could potentially be involved in a PES scheme that allowed several ecosystem services to be traded. In my view this is akin to the separation of property rights such as has occurred in the carbon market, i.e. the carbon

sequestration rights can be traded separate from the land title. In Australia similar changes have been made under the *Water Management Act 2000* (NSW) and similar legislation in other jurisdictions to enable water trading. The idea of stacking would enable these various services to be traded separately and potentially in different markets.

Ecosystem Marketplace is an offshoot of Forest Trends, itself a non-profit organisation with the following aims (www.forest-trends.org/):

(i) to expand the value of forests to society;

(ii) to promote sustainable forest management and conservation by creating and capturing market values for ecosystem services;

(iii) to support innovative projects and companies that are developing these markets; and

(iv) to enhance the livelihoods of local communities living in and around those forests.

The aim of Ecosystem Marketplace (www.ecosystemmarketplace.com) is to provide an information service that covers news, data and analysis of markets and payments for ecosystem services including those for water, carbon and biodiversity. According to their philosophy:

> We believe that by making accessible information on policy, finance, regulation, science, business, and other market-relevant factors, markets for ecosystem services will one day become a fundamental part of our economic system, helping give value to environmental services that, for too long, have been taken for granted. In providing free reliable market information, we hope not only to facilitate transactions (thereby lowering transaction costs), but also to catalyze new thinking, spur the development of new markets and the infrastructure that supports them, and achieve effective and equitable nature conservation.

In our discussions we discussed several examples of trading that Todd and/or Kate were aware of and they each provided me with contacts I could approach in the various places I visited after leaving Washington DC. The issue of investing in projects on public versus private forests or other land uses came up and, as with Al Todd (section 2.6), they each felt that the best “bang for your buck” could be found by investing in private lands; the rationale being that public lands should already be managed appropriately (in theory) though public forests could indeed provide a reserve pool such as

for the carbon market. In terms of the carbon market, though not the focus of my fellowship, mention was made of some innovative projects such as a carbon offset program in riparian areas near Portland, Maine, and the possibility that the Blue Marble moving company would be introducing carbon offsets to its customers' removals.

We discussed some of the reasons that trading schemes fail and one of the reasons identified is excessive transaction costs. Part of the problem seems to stem from the fact that governments have invested significantly in pilot programs that have perhaps enabled some trade but later collapse. Todd suggested that part of the reason for this may well be that often scientists obtain grants to set up and run the pilot projects but for whatever reasons the costs can blowout and unfortunately it is beyond the expertise of the scientists involved to control this. To me this underscores the need to have an interdisciplinary team involved to ensure that all aspects of the scheme are as efficient as possible and managed in a robust fashion from the scientists developing metrics, to the economists devising the trading systems, the lawyers defining or redefining property rights and various accountants and auditors balancing the books and ensuring compliance.

In some cases, however, it seems that trading can be maintained even in the face of excessively high transaction costs. The gopher tortoise is evidently a case in point. It is a large land-based burrowing tortoise whose burrows provide habitat for a number of other species. It has become threatened in the southern states due to pressures such as army base expansion and urban development. Under a WRI initiative 3 years of baseline monitoring have been undertaken and trading has occurred as part of an offset scheme whereby developers can pay to restore, establish or preserve gopher tortoise habitat to compensate for the loss of habitat that their land use activities may cause. Despite very high transaction costs the project is still viewed as a success.

In the water field WRI is involved in both PWS schemes and WQT schemes. On the PWS front its largest initiative is the Northern Watershed Incentives project. This project is being run in collaboration with the American Forest Foundation (AFF) and key partners including the Western Foothills Land Trust, Manomet Center for Conservation Sciences, Hubbard Brook Research Foundation and the White River Partnership. WRI and AFF secured a $500,000 Conservation Innovation Grant from the Natural Resources Conservation Service (NRCS) and this has been

matched by funding of $500,000 from the key project partners. The project is currently running two pilot PWS programs on:

(i) Crooked River Watershed – largely supplying water to the 200,000 residents of Portland, Maine; and

(ii) Upper Connecticut River Watershed – a largely rural groundwater system that is utilised for flood protection and recreational purposes.

In each case the pilots aim to invest proactively in managing forests for watershed protection by providing economic incentives to forest landowners along with technical assistance. Conservation easements are a large component of the investment in the watersheds and to date only 4.7% and 23% of the Crooked River and Connecticut River watersheds are permanently protected by such easements. The Crooked River project is discussed further in Chapter 5 but more reading is provided on the WRI website at www.wri.org/stories/2011/01/using-economic-incentives-connect-us-forests-water-and-communities .

In addition WRI is actively involved in WQT and offers the following services:

- Performing financial analyses of nutrient trading – such as forecasting potential revenue for farmers and cost-savings to municipal authorities in the Chesapeake Bay watershed;
- Designing market-based pollution reduction programs, e.g. for nutrients;
- Developing tools used in trading, such as NutrientNet (http://nutrientnet.org); and
- Performing analyses to determine the feasibility of implementing nutrient trading schemes.

Figure 6. Spring flowers and cherry blossoms adjacent to the Capitol Building, Washington DC

Figure 7. The Smithsonian Castle and gardens, Washington DC

3.2 Discussion: Tracy Stanton and Hannah Kett (Ecosystem Marketplace)

I was very keen to meet with Tracy and Hannah as the Stanton *et al.* (2010) report was integral to my growing interest in PWS schemes and their potential application in Australia. I met with Tracy and Hannah in Caffé Vita, Seattle (Queen Anne) on Wednesday 20 April 2011 not far from the Space Needle tower. A side note is that many NGOs allow employees to work from home so meeting in a cafe is fairly commonplace. Tracy Stanton is the Water Programs Manager for Ecosystem Marketplace and has a background in public and environmental policy. Hannah Kett is an Editorial Assistant with Ecosystem Marketplace and also works as a freelance journalist writing news articles related to the non-profit sector. Many of her news articles can be found on the news section of the website: www.ecosystemmarketplace.com/pages/dynamic/news_articles.landing_page.php.

Meeting with Tracy and Hannah was a great opportunity to exchange ideas and to consolidate what I had learned to that point regarding PWS and WQT schemes. Again the key driver of market-based schemes was discussed as regulation. In other words rather than merely replacing regulations, PWS and similar schemes ideally complement a regulatory approach. On the subject of PWS schemes and filtration avoidance Tracy relayed that a number of water authorities, despite seeing the clear economic benefit, still believe that not filtering water is a "risky business". It would take just one unforeseen event, such as the *Cryptosporidium* epidemic that occurred in Milwaukee, Wisconsin (a filtered system) in 1993, to undo all the good work of PWS and the concept of using the 'green' as opposed to the 'grey' infrastructure. Indeed, in the Milwaukee epidemic there were more than 100 deaths (mostly in immune-deficient persons) and 400,000 illnesses, which underlines the potential seriousness of such an outbreak (Daily and Ellison, 2002).

Regarding the implementation of PWS schemes it was discussed that local water authorities are the key and at the core of the transactions. Tracy cautioned that the idea that PWS schemes can potentially lower water rates is a myth that must not be perpetuated. My reading of this is twofold: firstly, the benefit of investing in the catchment via a PWS scheme is not in reducing costs to consumers but in avoiding an additional cost to them in the way of more expensive capital spending; and secondly that the price consumers pay for the water that we drink is grossly undervalued. It truly seems absurd that bottled water sells for sometimes $5 per litre or more, yet clean drinking

water that is available on-tap in our homes costs in the order of $0.002 to $0.003 per litre (AUD). The bottled price equates to at least 1500 times that of the safe drinking water supplied by water authorities. To increase the drinking water price by a small fraction to invest in the improvement of watershed values would hardly be noticeable and water would still be undervalued.

Tracy and Hannah were intrigued by some of the water resource issues we face in Australia, particularly with respect to water trading and forested land management. One of the obvious case studies I raised was that of the Murray Darling Basin (MDB) and reforms that will likely lead to new plantation forests requiring a water access entitlement (Webb, 2009). Despite all of the hydrological issues underpinning some of the debate (Webb and Kathuria, 2012), in terms of ecosystem services at a catchment level I maintain that the debate has unfairly focused on water yield issues to do with plantations at the expense of the myriad of positive externalities that planted forests provide and which will not be counted. This is disappointing as many of the reforms being implemented, including the National Water Initiative (NWI) and MDB Plan, followed the Wentworth Group's Blueprints for a Living Continent (Wentworth Group, 2002) and for a National Water Plan (Wentworth Group, 2003). The 'Wentworth Group of Concerned Scientists' went to pains in the 2002 report to advocate a shift to "Improving market signals and paying farmers for environmental services". They made the point that in some cases the economic benefits of agriculture can be less than the value of ecosystem services lost due to these practices. They advocated that "less intensive farm practices may be required, *additional trees may need to be planted*, land may need to be taken out of production and returned to bush, and river setbacks established" (emphasis added). These are all laudable aims and certainly point to the introduction of MBIs and strategic tree planting to achieve positive environmental outcomes.

All of this seems to have been lost in the 2003 report which did not once mention ecosystem services or environmental services and instead pointed to the need to account for water used by all forms of changing land use including "forestry enterprises and other forms of vegetation, which reduce the volume of water reaching rivers and recharging groundwater systems" (Wentworth Group, 2003). The 2008 report on "Accounting for Nature" (Wentworth Group, 2008a) talked at length about the need to report on Australia's environmental assets and their condition in areas such as native vegetation, soil condition and water quality. However, in later submissions on

securing water for the MDB (Wentworth Group, 2008b; 2010) commercial forestry was again targeted as a land use change "intercepting" water. The implication here appears to be that trees should be planted to improve catchment condition through provision of salinity and soil erosion control with consequences for water quality; however, if the trees are planted as part of a commercial forestry operation then we should ignore these positive environmental services and instead view them through the narrow lens of the water they will "intercept". All of this is of course enshrined in the NWI (COAG, 2004) and proposed MDB plan (MDBA, 2010) with the exception of paragraph 73(ii) of the NWI which states that the States and Territories agree to:

> *continue to examine the feasibility of using market based mechanisms such as pricing to account for positive and negative environmental externalities associated with water use.*

We discussed that this clause provides some scope for optimism that water policy makers will "see the light" of an ecosystem services approach to forest and catchment management, but at present the light seems rather dim. One thing that Tracy wondered was whether there is scope to use salinity in the MDB as a driver of a WQT scheme or similar. Indeed some modelling undertaken in sub-catchments suggests that hardwood plantations could be used strategically to reduce salt loads in the receiving waters (e.g. Nordblom *et al.*, 2010). The challenge faced, however, is that unless these externalities are in some way incorporated into the economics of water, the quantity of water intercepted by plantations must be purchased so the Net Present Value of growing trees will be less than that of continuing with existing practices.

Finally, we discussed some tools that have been developed that might be of some use in assessing the value of ecosystem services at a landscape level. There are a number of models and indices being developed and these include:

- the InVEST model (www.naturalcapitalproject.org/InVEST.html),
- the AIRES model (www.ariesonline.org/),
- the Ecometrix model (www.parametrix.com/cap/nat/_ecosystems_ecometrix.html), and
- the Watershed Forest Management Information System (Zhang and Barten, 2009; www.forest-to-faucet.org/software_downloads1.html).

Tracy followed up with further correspondence by email, including providing contact details of people she knew were actively involved in PWS and WQT schemes in the Pacific Northwest and Pacific Southwest.

3.3 Discussion: Dan Nees (Chesapeake Fund)

Dan Nees is the Director of the Chesapeake Fund (www.chesapeakefund.org), another arm of Forest Trends. Dan was attending a conference when I was in Washington DC so I arranged to speak with him by telephone upon my return to Australia. We had a discussion on Tuesday 31 May (10pm AEST). In addition to public WQT schemes in the Chesapeake the aim of the Chesapeake Fund program was to try and incentivise private investment in a voluntary offset program for nutrients. The Fund is a partnership between Forests Trends, the Chesapeake Bay Foundation and the World Resources Institute.

Essentially, according to Dan the project did not quite achieve what Forest Trends would have liked. There appear to be many barriers to trying to make a voluntary offset scheme work on a regional basis. One of the obvious issues is that the Chesapeake watershed crosses several geopolitical boundaries. This creates tension as, for example, upstream landowners in one jurisdiction are reluctant to invest in a program for the benefit of downstream water users and the public based in another jurisdiction. This tension also creates a competitive disadvantage for businesses that operate within the program as opposed to those who choose not to. This of course takes nothing away from the fact that nitrogen loadings continue to be a problem in the Chesapeake and that with increasing population and pressures on food production the issue will be exacerbated. The question though is at what point will these water quality problems impact upon investment in the Bay and importantly what is the best way to leverage investment by large companies?

The program that was established by the Chesapeake Fund is based on the concept of nitrogen offsets. For individuals and/or companies an opportunity exists to calculate their nitrogen "footprint". The footprint of an individual is calculated based on a series of factors including:

- number of residents in a home

- the type of sewer system
- electricity usage
- lawn size and frequency of fertiliser application
- percentage of forest on land lot
- the type, year model and average yearly mileage of automobiles.

Calculation of the nitrogen footprint of businesses is the subject of research being undertaken by scientists, industry, government and non-government organisations. Once a footprint is calculated, participants are invited to purchase an offset equivalent to the size of their footprint. The average household in the Bay area has an annual nitrogen footprint of approximately 14 lb. Under the Chesapeake Fund offset credits are sold for $10/lb meaning the average household is asked to contribute $140/year to offset their nitrogen. A further aim of the project is to better educate households on ways they can reduce their own nitrogen footprint. However, proceeds from the Fund are to be used to offset footprints by undertaking on-ground restoration projects. The aim of the Fund and education is to reduce the average household footprint to around 8 lb/year.

Despite the voluntary scheme not thus far being a major success story the Chesapeake Fund has proven how such an offset scheme could work. Notwithstanding that significant state-based programs and regulations have largely solved point source pollution problems in the Bay such as wastewater treatment and air pollution and urban sources of nitrogen the challenge remains to incorporate farming and other non-point source pollution land uses. As with others I met Dan agrees that transaction costs can cause markets to fail. He also cites a general public mistrust in the use of market instruments to solve environmental issues that has led to various lawsuits and polarised communities. However, he sees government incentives as being part of the solution. Furthermore, we discussed the possibility that certification schemes could be a useful way to encourage sustainable farming practices with the reward being a price premium consumers are willing to pay for such products.

4. Linking People with Forests and Catchments

In this section an outline is provided of projects being undertaken to better educate water consumers of the benefits of forested watersheds as well as methods and tools being developed to quantify these watershed services with a view to prioritising land to protect or improve in order to secure such benefits.

4.1 Forest to Faucet Partnership – University of Massachusetts

Having read news articles on the Ecosystem Marketplace website I was highly motivated to find out more about the 'Forest to Faucet' partnership between the University of Massachusetts and the US Forest Service (see Box 4 for further details). Professor Paul Barten from the University of Massachusetts was kind enough to host me for the day on Thursday 14 April and invited along a number of his postgraduate students as well as several project partners from the Portland Water District, Harvard Forest, Manomet Center and Western Foothills Land Trust.

> The Forest-to-Faucet Partnership is a joint venture of the University of Massachusetts Amherst and the U.S. Forest Service Northeastern Area (State and Private Forestry) Watershed Program. It was established in 2001 by Paul Barten and Marcus Phelps (...as the Watershed Exchange and Technology Partnership) to enhance the awareness, understanding and management of forests and water. The conservation of forests to simultaneously protect aquatic ecosystems and public water supplies is the primary focus of our work. The central goal of our research and development work—disseminated through this website, the peer-reviewed literature, presentations, and workshops—is to interpret and adapt scientific information to better meet the needs of watershed managers, foresters, environmental regulators, policy makers, non-governmental organizations, and community leaders

Box 4. The Forest to Faucet Partnership (Source: www.forest-to-faucet.org/).

According to the Forest to Faucet partnership website “People are a Forest Dependent Species”. This is a reference to the fact that in New England, New York and New Jersey more than 1000 reservoirs and river intakes supply drinking water to 25 million people. In almost every case ultimately the source of that water is a forest. In fact in the Northeast and Midwest of the USA it is estimated that more than 52 million people rely largely on forested lands to supply their clean drinking water (Barnes *et al.*, 2009). Professor Barten has an exceptional understanding of the interactions between forests and water, not only in terms of the history (see Box 5) and science of forest hydrology, but arguably more importantly in terms of the linkages between forest management, eco- and hydro-logical processes, urban development pressures and the public health benefits of “protecting the source” (Ernst *et al.*, 2004). Paul’s applied research work has operated at a number of scales and has involved the use of GIS technology and the development of meaningful indices to prioritise watershed forest protection, as follows.

Forests and Water …not exactly breaking news

1342
The first written record of a "protection forest" being established in Switzerland; there were 322 by 1777.

1897 Organic Act
"Public forest reservations are established to protect and improve the forests for the purpose of securing a permanent supply of timber for the people and insuring conditions favorable to continuous water flow."

1903 Gifford Pinchot, *Primer of Forestry*
“A forest, large or small, may render its service in many ways. It may reach its highest usefulness by standing as a safeguard against floods, winds, snow slides, moving sands, or especially against the dearth of water in streams.”

1954 Kenneth Davis, *American Forest Management*
"The public is vitally concerned with water and will pay a survival price to ensure adequate supply."

"Fortunately …watershed protection requirements are rather generally susceptible to harmonization with other uses."

Box 5. Historical perspectives on water and forests. Reproduced from Barten (2006)

4.1.1 Forests, Water and People in the Northeast and Midwest USA

With research partners in the US Forest Service (State and Private Forestry) and Trust for Public Land Paul and his group at U.Mass-Amherst were involved in assessing the importance of forests for water supplies in the Northeast and Midwest of the USA. This area covers 20 States and the District of Columbia and supports a population of 52 million people (Barnes *et al.*, 2009). To summarise this work it involved four steps (Figure 8), as follows:

(i) Step 1 – Ability to produce clean water (APCW)

The entire area was divided into watersheds and data collected on a 30 metre resolution spatial grid. Using a scoring system of Very High (4 points), High (3 points), Moderate (2 points) or Low (1 point) each pixel was assessed and scored for various attributes including 'Percent Forest Land' (F), 'Percent Agricultural Land' (A), 'Percent Riparian Land' (R), 'Road Density' (D), 'Soil Erodibility' (S), and 'Housing Density' (H). Composite scores for the ability to produce clean drinking water therefore range from 6 to 24. The resultant scores are shown in Figure 9 and clearly demonstrate significant spatial variability. Areas that ranked the highest for APCW included northern Minnesota, northern Wisconsin, northern New Hampshire, central Pennsylvania, the Adirondack region of northern New York, the Upper Peninsula of Michigan and the majority of the state of Maine (Barnes *et al.*, 2009). Areas that ranked the lowest tended be where forest and grassland ecosystems have been converted to intensive agriculture leading to poor water quality, and/or adjacent to cities with high population densities, low percentage of forests, high soil erodibility and high percentage of agriculture such as Columbus, Cincinnati, Chicago, Indianapolis and St Paul – Minneapolis (Barnes *et al.*, 2009).

(ii) Step 2 – Add data on Drinking Water Consumers

This step drew upon water use data compiled by the US EPA in its Surface Drinking Water Information System (SDWIS) and incorporated only surface water users (reservoirs and streams) to the exclusion of groundwater users. Data were summed for each watershed and divided by the

watershed area. The results were then divided into 10 quantiles and combined with the Step 1 results to yield composite scores between 2 and 20.

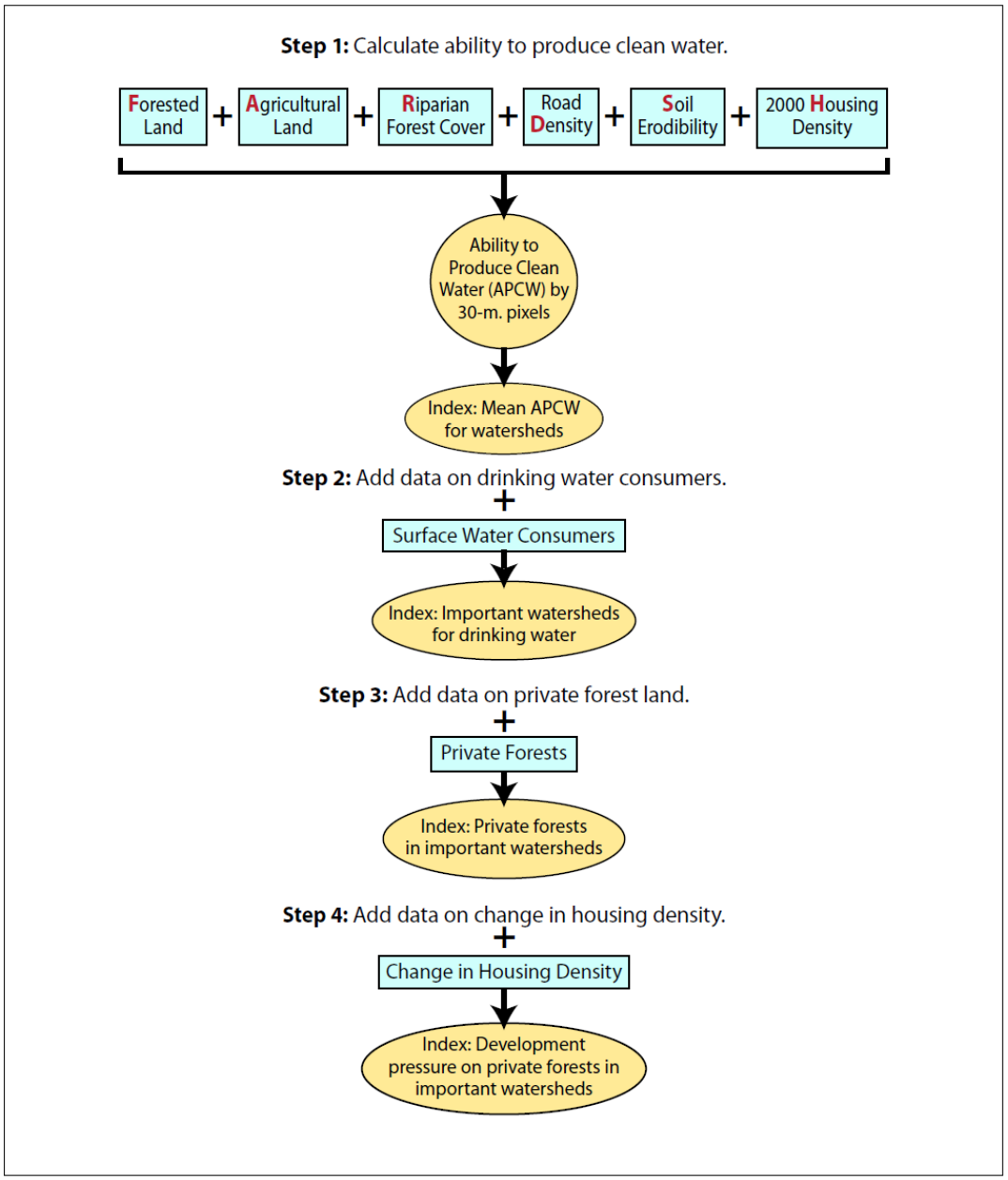

Figure 8. A schematic showing the step-wise process undertaken to produce indices of watershed importance for water supplies and the protection priority required for each supply. Source: Barnes *et al.* (2009).

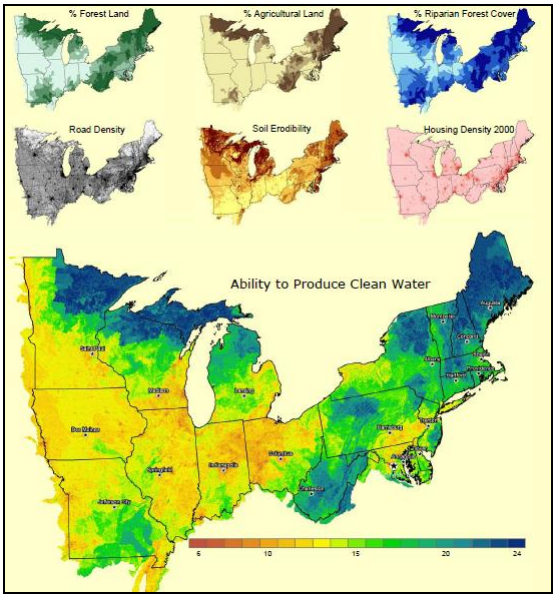

Figure 9. GIS outputs in the NE USA for the various individual attributes (F, A, R, D, S, H) and resultant composite scores for the Ability to Produce Clean Water (APCW). Source: Gregory and Barten (2008).

(iii) Step 3 – Add data on Private Forest Land

The results of steps 1 and 2 were then combined with data on private forest land. This step accounted for private forest land that was potentially available for development and thus public forests and private forests protected by conservation easements were not counted. The percent private forest land results by watershed were again divided into 10 quantiles and when combined with Step 2 results yielded composite cores with a potential value between 3 and 30.

(iv) Step 4 – Add data on Change in Housing Density

The fourth and final step essentially adds in a 'development pressure' factor by calculating the projected increase in housing density expected between 2000 and 2030 (Barnes *et al.*, 2009). This includes various conversions from suburban to urban, rural to suburban/urban, rural to exurban, and exurban to suburban/urban land use (Gregory and Barten, 2008). For each watershed the total area of development pressure was divided by the total watershed area which in turn was again divided into 10 quantiles. When these data were combined with the results of Step 3 this yielded an overall total score potentially ranging from 4 to 40 (Barnes *et al.*, 2009).

This process has resulted in identification of the areas at a watershed scale where forests are depended upon for clean drinking water, where privately owned forests are a major proportion of the forest area, and where these forests (and watershed services) are at greatest threat from development pressures (Figure 10). The studies highlight the fact that watersheds relying upon private forests for clean drinking water are at greatest threat in the NE USA in watersheds around rapidly growing cities such as Portland, Maine and in the areas of watersheds such as the Nashua and Merrimack which are expanding to accommodate communities of people who commute to the city of Boston, Massachusetts (Barnes *et al.*, 2009). In the study these watersheds achieved composite scores of 36 – 37 out of a possible 40. Many other watersheds ranked highly, particularly in areas of "suburban sprawl" along the interstate highway 95 that connects many of the major cities including Portland, Boston, New Haven, New York, Philadelphia and Baltimore. This landscape and watershed level tool is invaluable certainly for Public Land Trusts and others looking to invest in forest management and protection to achieve maximal watershed outcomes.

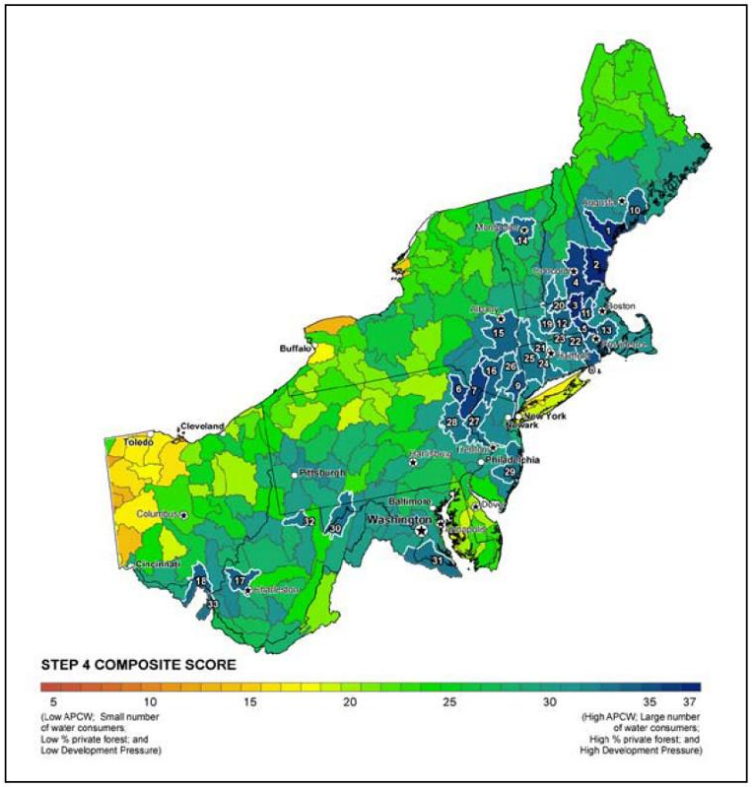

Figure 10. Composite scores of development pressure on private forests relied upon for clean drinking water supplies in the NE states. Source: Barnes *et al.* (2009)

4.1.2 Conservation Priority Index

Professor Paul Barten and his research team have been busy developing further indices and GIS-based tools that can be used in forest and watershed management. These tools are particularly helpful for ranking the importance of various parcels of forested land for water supply protection. One of the tools developed in collaboration with Dr Yanli Zhang (Zhang and Barten, 2009), is the Conservation Priority Index (CPI). The CPI is "an intuitive, scientifically-based method for scoring and ranking the importance of land for water supply protection" (Barten *et al.*, 2010). Similar to the landscape scale methods described in section 4.1.1 the watershed is assessed based on 30 metre pixels via a number of attributes. These are summarised in Table 1. Effectively a given grid cell could be allocated a combined CPI score as low as 5 or as high as 18 based on the summation of 6 attribute scores out of 3 (excluding land uses other than forest).

According to the methods that have been developed, individual parcels of land are then ranked on the basis of a variety of calculated metrics. Clearly the size of a given parcel is important in terms of conservation value as it is more efficient to work with few owners of large parcels than it is to work with many owners of small parcels (Barten *et al.*, 2010). The researchers have identified that there is a strong linear relationship between the raw CPI score (CPI_{raw}) and parcel area (R^2 = 0.96) so they developed other measures such as the CPI_{80} which equates to the sum of the 80^{th} percentile (top 20%) grid cells located within a given parcel. Another metric utilised is termed CPI_{resid} and equates to the residual of the CPI_{raw} score in relation to the least squares regression derived between CPI_{raw} and watershed area. This gives a relative indication of a parcel's conservation value with respect to similarly sized parcels in the watershed. A more recent metric is termed the $CPI_{normalised}$ and is calculated by dividing the CPI_{resid} score for each parcel by its total CPI_{raw} score (VanDoren, 2010).

Each of the scoring metrics can be used independently to rank given parcels of land within a watershed in terms of their conservation value. However, to further refine the choices Barten *et al.* (2010) have developed a parcel prioritisation algorithm. In the example they used parcels greater than 20 acres (8 ha) were scored 10 if they were in the top 20% for 2 or more metrics, 8 if they were in the top 20% for at least one metric and 20-50% for at least another metric, 7 if in the top 20% for only one metric and not in the top 50% for any others, 5 if they ranked 20-50% for multiple metrics, 3 if they ranked 20-50% on only one metric, and 0 if they were not in the top 50% for any metrics. It

is noted that the scoring algorithm can be modified to suit local conditions (VanDoren, 2010). The overall ranking of each parcel can then be assessed relative to adjacent and other parcels.

The CPI is one of several modules developed as part of the Watershed Forest Management Information System (WFMIS) described by Gregory *et al.* (2008). Other modules described by Barten and Ernst (2004) include the Restoration Priority Index (RPI) and the Stormwater Management Priority Index (SMPI). The WFMIS also has the capacity to incorporate the watershed impacts and management of a variety of other forest management activities and incorporates a Forest Road Evaluation System (FRES) and a Harvest Schedule Review System (HSRS) (Zhang and Barten, 2009). An example output from the cross-state boundary Barkhamsted Reservoir watershed supplying water to Hartford, Connecticut is shown in Figure 11.

The WFMIS is freely available for download from the Forest to Faucet website at www.forest-to-faucet.org/software_downloads1.html and is an extension for ArcGIS that comes with a user guide.

Table 1. The scoring strategy and description of GIS layers used in the Conservation Priority Index (CPI). Source: Barten *et al.* (2010)

	Landscape characteristic	Why is it important?	Increasing importance 3	2	1	Decreasing importance 0
	Land use	Forests provides the best protection of water resources of any land cover.	Forest/wetland	—	—	All others
	Distance to streams (meters)	Forests provide shade, organic matter, and woody material while they absorb nutrients and trap sediment. The "riparian forest buffer" has a major influence on streamflow and water quality.	0 to 30	30 to 60	60 to 900	> 90
	Distance to ponds/wetlands (meters)		0 to 30	30 to 60	60 to 90	> 90
Soils (1/2 weight)	Depth to water table	If forests are removed more water enters the soil. If the shallow water table reaches the surface it can lead to overland flow and erosion.	shallow; 0-0.48 m	intermediate; 0.49 – 1.22 m	deep > 1.22 m	—
	Permeability	This is the rate at which water flows into *and* through soils. Poorly drained soils can lead to overland flow and erosion.	poorly drained; hydrologic group D, K_{sat} < 5.66µm/mm	intermediate; K_{sat} 5.85-83.52 µm/mm	well drained; K_{sat} > 83.52 µm/mm	—
	Slope	The rate of water flow is directly related to land slope. Steep slopes also may be less stable and more prone to erosion.	steep (> 15%)	intermediate (5 – 15%)	gentle (< 5%)	—
	Water – Forest – Roads	The narrow strips of forest between roads and streams are especially important for water quality protection.	yes	no	no	no

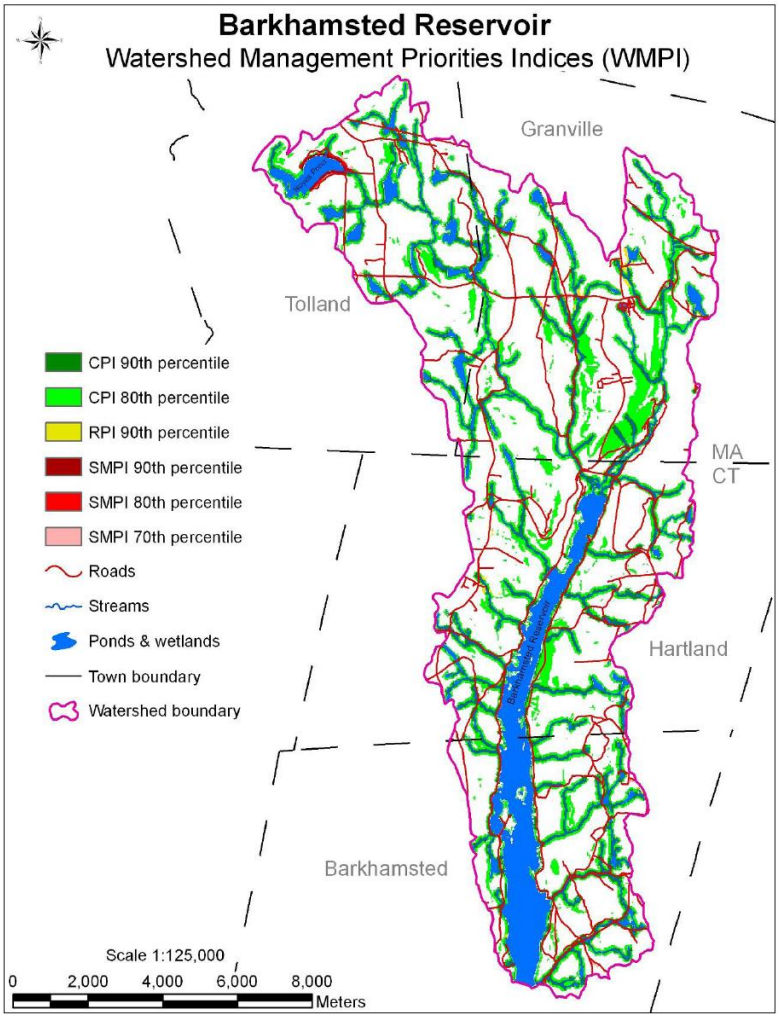

Figure 11. Example output from the Watershed Forest Management Information System showing the highest value CPI and SMPI lands within the Barkhamsted Reservoir watershed, Connecticut and Massachusetts. Source: Gregory *et al.* (2008)

4.1.3 The CPI and Watershed Services in the Crooked River Watershed

Professor Paul Barten arranged for a meeting, lunch and discussion with several project partners who have been working on a project in the Crooked River Watershed that supplies water to the city of Portland, Maine. In addition to Paul the discussion involved the following people who travelled to the University of Massachusetts, Amherst on the day I visited:

- Paul Hunt, Environmental Manager – Portland Water District (www.pwd.org/home.php)
- Dr John Gunn, Senior Program Leader – Manomet Center for Conservation Sciences (www.manomet.org/)
- Lee Dassler, Director – Western Foothills Land Trust (http://wfltmaine.org/)
- Stephen Johnson, Harvard Bullard Fellow – Harvard Forest (harvardforest.fas.harvard.edu/index.html)
- Bill VanDoren , postgraduate student – University of Massachusetts, Amherst (www.umass.edu/)
- Dr Craig Nicolson, Research Assistant Professor, University of Massachusetts, Amherst

The Crooked River watershed is approximately 50 miles in length and has a total area of 275 square miles (71,225 ha). It is the largest tributary flowing into Sebago Lake which is utilised by the Portland Water District (PWD) to supply water to some 200,000 customers in 20 communities including Portland, Maine. Approximately 86% of the Crooked River watershed is forested though only 5-10% is protected land comprising public land and several privately owned parcels either owned by land trusts or encumbered by conservation easements that prevent development. Aside from a 2 mile "no bodily contact" zone on Sebago Lake near the water supply intakes recreation and usage of the watershed for fishing and other pursuits is allowed. With the development pressures that exist in that part of the US (Barnes *et al.*, 2009) many of the privately owned forest parcels could be subject to urban development in the future with consequences for the PWD water supply. At present the Sebago Lake water source has FAD exemption as the water quality is high but there is evidence to suggest that further watershed protection measures are required. To that end a group of four land trusts including the Western Foothills Land Trust, Greater Lovell Land Trust and Loon Echo Land Trust formed the Upland Headwaters Alliance to come together to prioritise and protect forested parcels. The Portland Water District has joined the group and enhanced the focus of preserving the Crooked River watershed for the betterment of the water supply.

Lee Dassler is heavily involved in the project and has been guided by Stephen Johnson who has formerly held positions in land trusts and acts as an adviser to the Greater Lovell Land Trust. John Gunn from the Manomet Center has successfully obtained Federal grant money to implement a pilot program in the watershed utilising the concepts of ecosystem services. The project also involves the World Resources Institute (section 3.1) and American Forest Foundation. While the PWD is

supportive of the project and described as “an enlightened partner”, Paul Hunt explained that at this stage there is no plan to provide financial support to the project. In fact, despite having a filtration avoidance determination (FAD), it may well be that Portland installs a filtration plant in any case particularly as the capital costs are not as great as they were previously but Paul Hunt advised this may not be for at least another 20 years. Nonetheless, PWD still would advocate for better watershed protection as it is clearly demonstrated that treatment costs are greatly reduced when forest cover exceeds 60% (Ernst *et al.*, 2004). Indeed the Upland Headwaters Alliance aims to protect 70% of forest in the Crooked River watershed.

In terms of watershed protection land trusts typically employ one of two means. They either firstly purchase forest parcels outright or secondly purchase a conservation easement over such parcels. A conservation easement operates like a ‘restrictive covenant’ in Australian jurisdictions whereby it restricts the activities that a landowner may undertake on all or part of a parcel of land. The easement is recorded on the land title and binds the owner’s “successors and assigns”. In other words the easement “runs with the land”. I was provided with examples of conservation easements or “Conservation Restrictions” which are rather involved deeds outlining the uses of land that are permitted and restricted. Land trusts use funds obtained from donations and/or government grants to effect forest conservation on private property and again the level of activity of these NGOs surprised me (see Box 6). The quandary they face though is that given limited available funds, where are they best to invest for the greatest watershed improvement or protection? In other words, in the Crooked River catchment for example, out of 7000 parcels which 50 should be targeted? To answer this question the land trusts have turned to the Forest to Faucet partnership and its various tools and indices including the Conservation Priority Index (CPI).

> “Relegating conservation to government is like relegating virtue to the Sabbath. Turns over to professionals what should be the daily work of amateurs.”
>
> Aldo Leopold, 1935

Box 6. Underscoring the importance of NGOs and volunteers in conservation efforts

Bill VanDoren gave an informative presentation on the background and mechanics of the CPI and went on to explain how it had been utilised in the Crooked River watershed to identify parcels of land most suitable for outright purchase or conservation easements (VanDoren, 2010). The results have been used by the land trusts to identify potential candidate parcels and evidently the top 50 prioritised landowners were mailed an invitation to attend an information session. The sessions were used in part also to determine whether any adjacent high priority properties could be pooled to maximise conservation outcomes. A key question in this scenario is how much information should be divulged to landowners? There appears at least some concern that knowledge of the conservation value could drive prices higher and this would not be desirable as the protected value should reflect the replacement cost of the current land use rather than an artificially inflated price. There is also concern that some property owners would object to the idea that "outsiders" are evaluating and targeting their land. The land trusts usually obtain fair market appraisals of properties they wish to purchase or covenant.

The land trusts report that the CPI is an objective and replicable indicator for prioritising the watershed conservation value of private forests. The groups appear to have made significant headway in a short period of time but as yet have not enabled trade in watershed services within the catchment. Ecosystem services have typically been provided to the public for free so perhaps there needs to be a driver, either regulatory or related to public health, to initiate public support for a PWS scheme. It is early days and from the perspective of an outsider "looking in" the alliance partners appear to have done the ground work and are very close to succeeding.

Figure 12. The University of Massachusetts, Amherst

4.2 Natural Capital Project

I did not spend a lot of time meeting with those involved in the Natural Capital project (www.naturalcapitalproject.org) but no report on ecosystem services or watershed services would be complete without making some mention of the efforts of this group. The NC project is a joint venture between Stanford University's Woods Institute for the Environment, University of Minnesota's Institute on the Environment, The Nature Conservancy and the World Wildlife Fund. The project began in 2006 and I was fortunate enough to be able to meet and discuss watershed services with one of its Directors Professor Gretchen Daily of Stanford University (south of San Francisco) on Monday 25 April. I also met with Dr Marc Conte, a post-doctoral economist working on the NC project at Stanford.

When one thinks of ecosystem services the name Gretchen Daily most likely comes to mind. Professor Daily published one of the earliest books on the topic (Daily, 1997) and has been prolifically writing about and working on the concepts of natural capital and ecosystem services in the interim including the Millennium Ecosystem Assessment (MEA, 2005). Gretchen gave me a copy of her 2002 book "The New Economy of Nature: the Quest to Make Conservation Profitable" (Daily and Ellison, 2002) which is written in a popular non-fiction style and provides a first-hand account of the history behind many of the initiatives in the field of ecosystem services and trade in the past two decades. It covers a range of topics including the first "Katoomba group" meetings in Australia, the Sydney Futures Exchange, New York's water supply, Costa Rica, restoration of the Napa River in California, the Milwaukee *Cryptosporidium* crisis, and even devotes a chapter to the rise and fall of John Wamsley's (the man with the Davey-Crocket style hat made from the carcass of a large feral cat) Earth Sanctuaries Ltd in South Australia.

Talking with Gretchen it became obvious that in the field of ecosystem services, though not necessarily watershed services, Australia has been at the forefront particularly with regard to Carbon markets and biodiversity markets such as Victoria's Bush-Tender reverse auction program. Indeed one of the characters to which much space is devoted in the 2002 book is Dr David Brand, a Canadian forester who was formerly an Executive General Manager of State Forests of NSW (my employer – now Forests NSW). In 2005 David founded the company New Forests Pty Ltd based in Sydney but now also with offices in San Francisco and Singapore (www.newforests.com.au). Another of the

characters discussed is Michael Jenkins, the founder of Forest Trends and its offshoots such as Ecosystem Marketplace and the Chesapeake Fund discussed in sections 3.2 and 3.3.

With regard to watershed services Professor Daily gave me a reprint of a paper by Brauman *et al.* (2007) which provides a neat summary of the types of hydrological services provided by different ecosystems. One of the major stumbling blocks appears to be the method of valuation of watershed services. I admitted to Gretchen that initially I had simplistically envisioned that a watershed service was valued, e.g. a dollar amount per ML or per tonne of a nutrient, and downstream users paid for these services on a unit basis but in reality that is not the case. In most of the case studies I visited (chapter 5) the value was either an avoided cost, such as for filtration, or more grossly the aggregated cost of land purchase, conservation easements, restoration thinning and the like in a given catchment. The bottom line is that the "generic value of hydrologic services is apparent, but the functionality and value of an ecosystem service is likely to be highly variable, so site-specific assessment remains important" (Brauman *et al.*, 2007).

4.2.1 InVEST decision-making tools

A large part of the work that researchers like Dr Marc Conte are involved with is the development of tools to help communities with decision making about investment in ecosystem services. One of the tools being developed is InVEST which stands for 'Integrated Valuation of Ecosystem Services and Tradeoffs' (www.naturalcapitalproject.org/InVEST.html). It is a "family" of tools that land managers and other decision makers can use to quantify the importance of natural capital and ecosystem services and then use to assess tradeoffs between various alternative land use choices. InVEST version 2.1 is a freely available software package that runs in either ArcGIS 9.3 or ArcGIS 10 if the Spatial Analyst extension is installed and activated. It can be downloaded from http://invest.ecoinformatics.org/. One of the advantages of InVEST that both Marc and Gretchen mentioned was that it is fully flexible and can be tailored by the individual user to apply region-specific parameters and/or add in the user's own models. Gretchen further explained the intent to partner with Google to utilise the Google Earth Engine platform and NASA's satellite imagery in the near future.

Much of the theory behind the InVEST models has recently been detailed in a new book by Kareiva *et al.* (2011) with chapters devoted to water supplies and ecosystem services for hydropower and

irrigation (Mendoza *et al.*, 2011), land cover impacts on storm peaks (Ennaanay *et al.*, 2011), using vegetation buffers to retain sediment and nutrients (Conte *et al.*, 2011) and the provisioning value of timber and non-timber forest products (Nelson *et al.*, 2011). With regard to water yields Marc revealed that to date the models mostly deal with mean annual flows, while with respect to sediment erosion and retention the models employ modified forms of the Universal Soil Loss Equation (USLE) applied at a landscape scale ignoring forms of erosion such as gully and streambank erosion. However, given the flexibility of the InVEST tools there would seem no reason why it could not incorporate in future iterations a physically-based distributed model such as SedNet (Wilkinson, 2008) that is able to account for such processes.

In summary, the Natural Capital project is progressive and, aside from undertaking research to better understand ecosystem processes, is actively developing practical tools such as InVEST to assist in decision-making regarding ecosystem service provision. Furthermore, the team is engaged in a number of demonstration projects in various parts of the world including China, Colombia, Canada, Indonesia, Ecuador, Tanzania and the US states of California, Oregon, Washington and Hawaii (Daily *et al.*, 2009).

Figure 13. Stanford University, California.

Figure 14. California Redwoods (*Sequoia sempervirens*), Muir Woods National Monument, Marin County CA

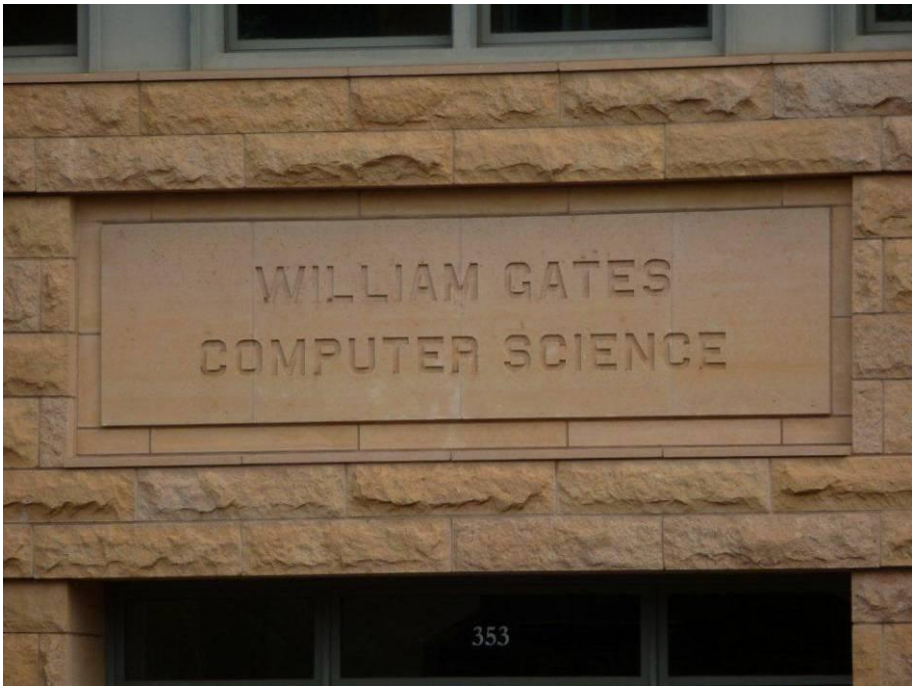

Figure 15. A familiar name in Computing, Stanford University

5. Case Studies of Payments for Watershed Services Schemes

This chapter is devoted to detailing the various PWS schemes I visited in the USA during the fellowship. There are of course many more examples that I would gladly have visited if time permitted, including the Bull Run Watershed (Portland, Oregon), Hetch Hetchy (California), the South River Nation project (Ontario, Canada), the Little Miami River trading project (Ohio), PennVest (Pennsylvania), and the list goes on. The following examples, however, provide a taste of PWS schemes operating in the USA.

5.1 Quabbin Reservoir – Boston, Massachusetts

On Wednesday 13 April I drove from Boston to the Quabbin Reservoir Information Center, an approximately two hour drive to the west, and was warmly greeted by members of the Division of Water Supply Protection (DWSP), Massachusetts Department of Conservation and Recreation (DCR):

- Jonathan Yeo, Director DWSP
- Bill Pula, Regional Director, Quabbin/Ware Section
- Thom Kyker-Snowman, Environmental Analyst
- Herm Eck, Chief Forester
- Dave Small, Assistant Regional Director, Quabbin

Quabbin Reservoir is the largest watershed providing water to the city of Boston. Between the Sudbury Reservoir, Wachusett Reservoir, Ware River and Quabbin Reservoir (Figure 16) DWSP supplies water to the Massachusetts Water Resources Authority (MWRA) which redistributes it to approximately 2.2 million customers in the metropolitan Boston area. Boston is one of the oldest cities in the New England region so the development of water resources has a long and interesting history. The first Water Works Company was incorporated to bring water to Boston in 1652 (Friends of Quabbin, 1996) and as is typical of water supply development around cities as the population grew water was progressively sourced from further afield. When the Wachusett Reservoir was

completed in 1908 it was the largest reservoir in the World (234 GL capacity) but as Boston's population continued to expand the demand on water was so great that additional measures were required (Kyker-Snowman, 2000). Firstly the Ware River was tapped and connected to the Wachusett Reservoir via an aqueduct before the massive Quabbin Reservoir (Figure 17), with a capacity of 1500 GL, was built in 1939.

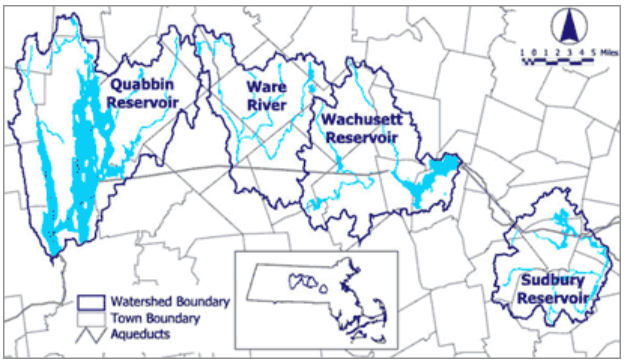

Figure 16. Schematic map of the DWSP watershed system. Source: www.mass.gov/dcr/watersupply/watershed/shed.htm

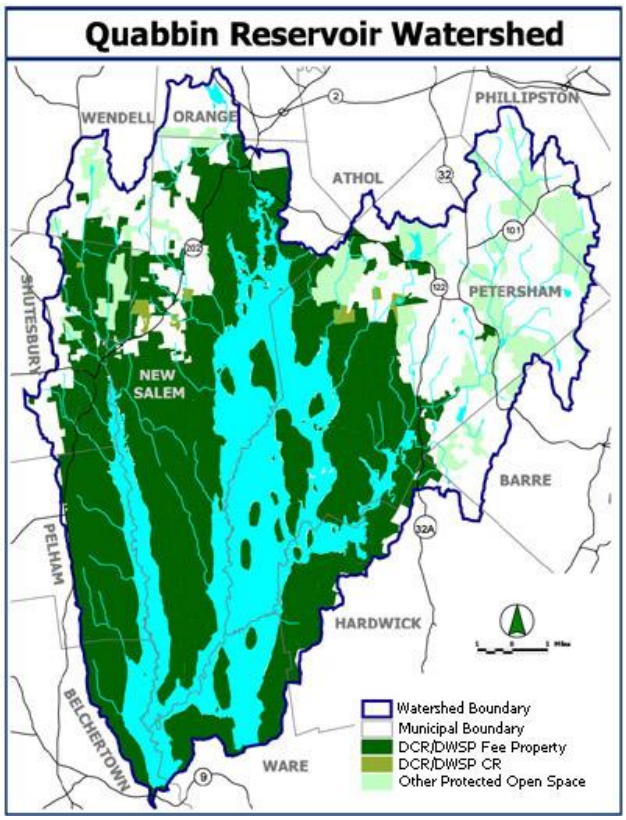

Figure 17. Quabbin reservoir and watershed. Source: www.mass.gov/dcr/watersupply/watershed/quabbinshed.htm

The Quabbin Reservoir filled to capacity by 1947 but by 1967 a severe drought caused water levels to drop to 45% of capacity sparking lengthy debates in the 1970s about how best to manage the watershed with some suggestion that either the Connecticut or Millers Rivers should be diverted to the reservoirs to augment supplies (Kyker-Snowman, 2000). The Massachusetts government decided not to divert the rivers but instead mandated that 2000 acres (800 ha) of the Quabbin watershed comprising Red Pine (*Pinus resinosa*) be clearfelled and converted to grassland to supply an additional 1.1 GL of annual inflows (Kyker-Snowman, 2000). Another severe drought in 1989 caused water levels in Quabbin to drop to a 17-year low which triggered a "water emergency" that saw public education campaigns result in a 20% reduced consumption of water by Boston residents in 1990 (Friends of Quabbin, 1996). A leak detection and repair program undertaken on the city's ageing supply system combined with a stable or declining population has meant that today the draw on the supply system is well below its safe yield.

The total watershed area at Quabbin is 96,000 acres (38,400 ha) and today some 66% of this land is owned and controlled by the Massachusetts DCR. Mean annual precipitation in the watershed since 1955 has been 45 inches (1125 mm). The least precipitation falls in February while the greatest falls in September. DCR reports that on average 50% of precipitation yields water in the reservoir and much of the precipitation over winter falls as snow. Judging by the temperature on 13 April and the fact that the lake was covered in ice until the week before I visited I had no trouble believing this. Water quality in the Quabbin and Wachusett reservoirs is high and accordingly DCR does not filter the water supply and merely treats water with chlorine and chloramines for disinfection, fluoride for dental reasons, and soda ash and carbon dioxide to prevent corrosion of pipes (Kyker-Snowman, 2000). Under the *Safe Drinking Water Act 1974* the US EPA introduced the Surface Water Treatment Rule (SWTR) of 1989 which established a priority for using filtration unless a water authority could prove that its water was of a high enough standard that it could be issued with a Filtration Avoidance Determination (FAD). The Quabbin/Wachusett systems are one of few serving large cities in the USA that have been granted a FAD since 1989 and continue to avoid the need to build a filtration plant. The cost of building a filtration plant for the Boston water supply has been estimated at $200 million with significant on-going costs so there is a large incentive for DCR to manage its forests for water supply protection (Kyker-Snowman, 2000).

The PWS scheme that operates at Quabbin/Wachusetts is largely driven by the SWTR and FAD; in other words avoiding the cost of filtration. Water users pay an additional water rate to MWRA to cover the cost of watershed management for water quality protection. According to Jonathan Yeo the price paid for water is one of the highest in the USA but still equates to less than 1 cent per gallon (<0.26 cents/L) which is comparable to the price paid in most Australian cities. Funds generated from the scheme are provided to DWSP and total approximately $30 million per year. In addition to this annual operating budget, approximately $200 million of Commonwealth environmental bond money has been provided and used to purchase land parcels and/or conservation easements within the watersheds that were prioritized on the basis of the services provided. DCR developed its own system of objectively ranking parcels of land which seems similar to the CPI methods discussed in section 4.1. An interesting aspect of the scheme is called the Payment in Lieu of Taxes (PILOT) which refers to payments made by DCR to local councils on the land that it acquires. Often when land is owned or resumed by the State there is a concern that local towns and municipalities (councils) will lose some of their rate base (or land tax base). However under Massachusetts general law the PILOT scheme operates to ensure that when land is purchased by DCR it continues to pay rates to the local town or municipality. This benefits local communities as they are able to continue investing in schools, roads and other community services.

In addition to purchasing land/easements, DCR has invested in wastewater treatment plant upgrades within the watershed and has a program of active forest management. This of course is backed by a very comprehensive 350+ page Land Management Plan for the period 2007-2017 (DCR, 2007). To summarise the plan it is underpinned by an objective to deliberately manage forest cover within the watershed to promote a diverse mix of age-classes and species as this is believed to result in the greatest “resilience” of the forest against potential large-scale disturbances such as hurricanes, ice, insect attack or disease. This approach is believed to provide the greatest security for the protection of water quality in the long-term and has been devised in consultation with a Science and Technical Committee chaired by Professor Paul Barten from the University of Massachusetts, Amherst (section 4.1). The Quabbin forest comprises approximately 66% deciduous hardwoods such as red oaks (Figure 18) and white oaks, with the remaining 34% being conifers dominated by white pines (Figure 19) and plantations of red pine.

Figure 18. A stand of Red Oaks, Quabbin forest

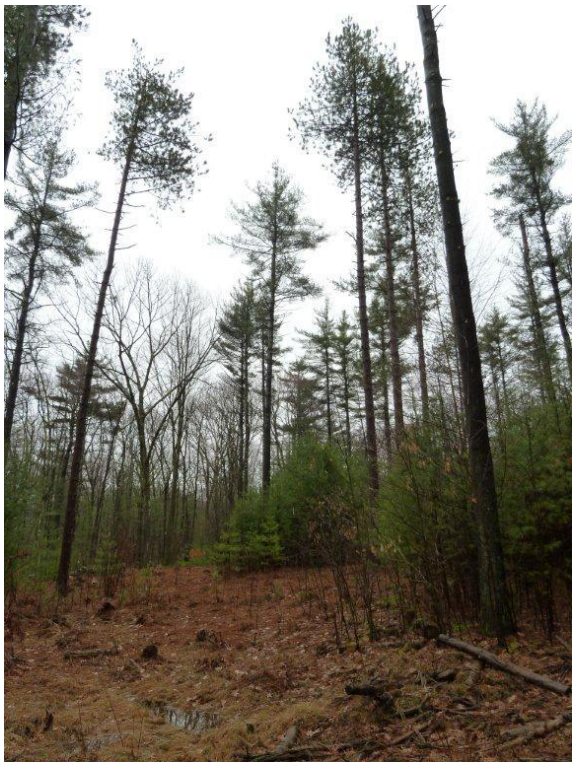

Figure 19. A recently thinned stand of White pines, Quabbin forest

The silvicultural objective of the forest management is to convert the forest to a mix of species and ages which at present is dominated by two age-classes: stands that regrew after farm abandonment at the beginning of the 20th century (Foster and O'Keefe, 2000), and stands that either regrew following the 1938 hurricane or were planted at around that time (Kyker-Snowman, 2000).Red oak and white pine are the two most commercially valuable species growing within the watershed and the aim is to sustainably harvest less than 1% of the forest in any given year, which equates to around 400 acres. Depending on markets the harvesting operations provide annual revenues of up to $1 million. Small openings are made that meet objectives and the total volume of the annual harvest remains less than 50% of the total annual growth of the watershed forest. Guided by the extensive paired catchment experiments at Hubbard Brook and throughout the New England area (e.g. Hornbeck *et al.*, 1987; 1993; 1997) harvesting is limited to no more than 25% of any given sub-watershed in a 10-year period. It is also worth noting that catchment experiments were previously maintained within Quabbin watershed in the Dickey Brook study area to assess the effect of thinning pine plantations on water yield, and in the Cadwell Creek study area to assess the effects of killing riparian trees with herbicides on water yield (Bent, 2001). In addition to the basal area restrictions harvesting operations utilise a combination of a zoning system which precludes harvesting from approximately 20% of the hydrologically sensitive areas of the watershed, and mandates the use of filter/buffer strips near the reservoir, wetlands and tributary streams.

I was taken on a tour of parts of the watershed which included some recent harvesting near Gate 8 along the southwestern boundary of the watershed. At the time of my visit the snowmelt was considerable which contributed to significant flows within ephemeral, unmapped channels (Brooks and Colburn, 2011; Figure 20). The forest operations are small scale and managed so as to mitigate any potential impacts upon water quality. Additionally, considerable work is being done to improve road drainage, including the installation of detention basins at the end of mitre drains (Figure 21). Aside from managing forest-related water quality the DWSP staff are engaged in wildlife management, such as "gull harassment" which keeps seagulls away from the supply intakes, and programs to control populations of white-tailed deer which browse on regenerating trees, and beavers from within the "pathogen control zone". Finally, while recreation is encouraged at Quabbin, strict rules are in place to avoid the introduction of pests such as zebra mussels which can be transported on fishing boats (Figures 22, 23).

Figure 20. Snowmelt contributed to substantial flow in unmapped ephemeral channels, 13/4/11

Figure 21. Detention basins are utilised at the end of mitre drains in Quabbin forest to reduce the likelihood of suspended sediment pollution

Figure 22. Fishing and other forms of recreation are encouraged at Quabbin Reservoir. DCR makes boats available for hire for around $20/day

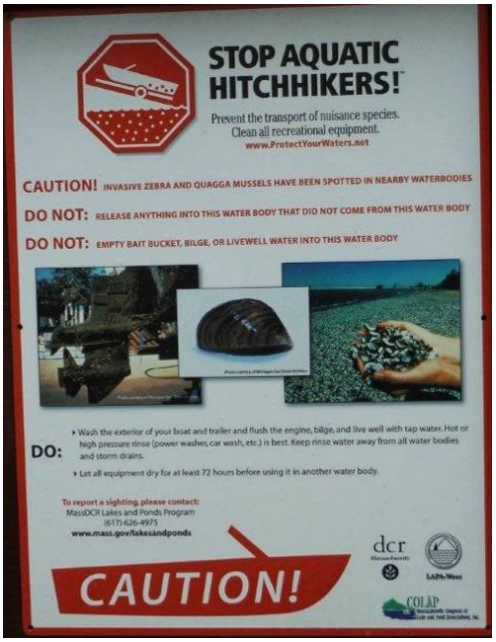

Figure 23. Strict rules are in place to avoid zebra mussel infestation including cleaning boats twice with hot water or a pressure cleaner prior to entering the reservoir

5.2 Catskills/Delaware systems – New York City

The New York City example is held out as the "Poster Child" of PWS schemes. Make no mistake; the economic argument is pretty water-tight. In a nutshell, faced with potentially declining water quality in its watersheds, under the Surface Water Treatment Rule (SWTR) the New York City (NYC) Department of Environmental Protection (DEP) was on the brink of having to invest in a massive filtration plant at a cost in the early 1990s in excess of $6 billion with on-going maintenance costs of approximately $300 million per year. The alternative was to invest in protecting the watersheds to improve water quality and to date some $1.5 billion has been so invested via the PWS scheme that taxes the approximately 10 million New Yorkers that drink the water. By all accounts and judging by the published literature replete with praise for the scheme (e.g. Chichilnisky and Heal, 1998; Heal, 2000; Daily and Ellison, 2002; Postel and Thompson, 2005; Salzman, 2011) it has been a resounding success story. However, I wanted to find out more as, though fewer in number, there are some who question the story (e.g. Sagoff, 2002).

While I was able to visit New York City itself I did not have time to tour the Catskills/Delaware watersheds which are located some 135 miles to the west of downtown New York (Figure 24). However, I was fortunate enough to be able to engage in a lengthy teleconference with NYC DEP staff while visiting Brad Gentry at Yale University to discuss legal and institutional aspects of PWS schemes on Friday 15 April. Much of what I will report has arisen from the teleconference hosted by DEP involving staff from various offices, as well as information subsequently provided by email. Participants in the teleconference included:

- David Warne, Assistant Commissioner, DEP Bureau of Water Supply
- Brad Gentry, Director, Centre for Business and the Environment at Yale
- Jenn Hoyle, postgraduate student, Yale School of Forestry & Environmental Studies
- Deb Layton, Forest Scientist, DEP
- Jeff Graf, Watershed Lands and Community Planning, DEP
- Paul Lenz, NRM program, DEP

- Fred Gliesing, Forester, DEP
- John Schwartz, Working Lands, DEP
- Larry Beckhardt, Chief of Strategic Planning, DEP
- Mike Usai, Ecological Research and Assessment, DEP

Figure 24. Schematic diagram of the New York City water supply system. Source: www.nyc.gov/html/dep/html/drinking_water/wsmaps_wide.shtml

As a Government PWS scheme the NYC scheme is as complex and multi-layered as it is arguably successful. Evidently, as Salzman (2011) explains, much of the credit for the Catskills/Delaware PWS scheme is attributed to Albert Appleton who served as Commissioner of the NYC DEP during the early 1990s. When the city was told that it needed to build a filtration plant under the SWTR DEP estimated it would cost some $6 billion, as commonly quoted. Interestingly, the EPA said “this was ridiculous because it would only cost $3 billion to build”. Mr Appleton then, while New York was “fretting over the cost”, is described by Salzman (2011) as a “very clever city official” as he “took a close look at the law and realized that there was a waiver provision”. Having made the decision to

apply for FAD status for the Catskills/Delaware systems the first time in 1991 and been granted several interim waivers it was not until 1997 that a 5-year waiver was secured on the strength of a Memorandum of Agreement (MOA) between the City; the State; EPA; environmental groups; and representatives of the counties, towns and residents of the watershed in upstate New York. The MOA integrated the existing watershed protection program with additional funding for economic-environmental partnership programs, a water quality investment program, a regional economic development fund, and a regional advisory forum for water quality initiatives and watershed concerns (NYC DEP, 2011). Each of the main aspects of the program is described below:

5.2.1 Land Acquisition

The entire Catskill/Delaware watersheds cover an area, excluding the reservoirs, of 1,023,496 acres (409,400 ha). In 1997 New York City owned just 3.5% of the watershed lands. However, 21.1% of the area is owned by other public agencies or land trusts meaning that in 1997 some 24.6% of the watershed was afforded a strong level of protection. Under the Land Acquisition Program (LAP) the City has secured, as of 31 December 2010, 92,139 acres of land by outright purchase in fee simple or conservation easements, with an additional 21,236 acres of easements on farms secured though an agreement with the Watershed Agricultural Council (NYC DEP, 2011). The program has effectively increased the lands under the City's control by 319% to the point where it now manages some 14.55% of the watershed. Importantly, much of the effort has focused on purchasing riparian buffers within the watershed such that the City has increased its control of 100-foot buffers from 2.6% in 1997 to >16% in 2010. The City, State and land trusts now collectively control some 32.7% of the riparian buffers in the watershed (NYC DEP, 2011).

During the teleconference I asked David Warne about the prioritisation scheme used by DEP in determining which land parcels to purchase. As with Quabbin the City devised its own scheme of prioritising land parcels based on criteria such as distance from the reservoir, likely transit time of pollutants to the intakes (60 day travel time) and so on. The scheme evidently has evolved and changed over time but aims to give the City the "greatest bang for its bucks". Since 1997 the City has operated a 'willing buyer, willing seller' program where land owners can offer their property to the DEP. However, DEP staff reported that a barrier is that people are not always willing to sell which can affect the program outcomes. Nevertheless, the LAP appears to be meeting its objectives and

further targets have been set for the period until 2017 which is part of a 10-year FAD agreement issued by the EPA in July 2007.

5.2.2 Land Management

Given that the amount of land owned by the City has increased, it has in place a significant program to improve the management of lands under its control. This focuses on four main areas: property management, forestry management, natural resources, and the use of City lands. The property management program largely involves monitoring, auditing and awareness. In other words the areas acquired by the city are monitored and issues such as encroachments and trespass are policed, while boundary fences are regularly inspected and signs displayed identifying land as under DEP control. With regard to natural resources management much effort is devoted to identifying and controlling invasive plant species within the watershed. The use of City Lands program involves assessment and control of the use of watershed lands by the public for such uses as hunting, fishing, hiking and limited agricultural pursuits (NYC DEP, 2011).

Forest management is also important as the forests, while steeper than at Quabbin, are dominated by stands 65-100 years old with relatively few younger trees which the DEP believes are needed to increase the nutrient uptake potential of the watershed forests. A complete inventory of the watershed forests has been undertaken and a comprehensive forest management plan has been developed. Similar to Quabbin the aim of forest management is to establish a “continuous, healthy, and vigorous forest cover over time” to maximise soil protection, filtration of water and buffering of nutrients (NYC DEP, 2011). Under the plan forest harvesting is therefore promoted and includes the incorporation of Best Management Practices (BMPs). Fred Gliesing explained that riparian buffers or Special Management Zones (SMZs) are an important component of the BMPs but perhaps differ from those used in Australia as they allow for up to 35% basal area removal within the SMZ. The goal of DEP’s SMZs is to consider the needs of the co-occurring resource (forest and wetlands, streams, etc.) and manage the forest component while minimize the harvest impact on streams, wetlands and other resources.

5.2.3 Watershed Agricultural Program

This is administered locally in the watershed by the Watershed Agricultural Council (WAC) and is a collection of voluntary pollution prevention partnerships that engage private farm owners in cooperation with various Federal, State and Local government agencies. The program has been very successful in enrolling large and small farms in the watershed in a variety of initiatives to reduce agricultural pollution. The main initiatives are the development of Whole Farm Plans and the implementation of BMPs. At the end of 2010 the WAC had enrolled 254 out of the known 265 large farms (96%) in the watershed agricultural program; 248 of which have developed Whole Farm Plans with the remaining 6 in the process of developing them. This level of involvement exceeds the 90% target set in the FAD. Additionally, some 27% of small farms (earning $1000-10000 per year) have developed Whole Farm Plans (NYC DEP, 2011).

Additional measures have included direct investment in some 5416 BMPs on farms involving such measures as the development of nutrient management plans, purchasing manure spreading equipment, barnyard water management systems and livestock fencing. Since 2002 the program has also involved farmer education with some 2860 participants including farmers, students, agri-service professionals and agency staff (NYC DEP, 2011). An innovative initiative sponsored by the WAC is the 'Pure Catskills' trademark (http://buypurecatskills.com/) which is assigned to food products from eligible farms in the watershed. It is an effective marketing campaign that promotes the sale of 'watershed friendly' produce that is locally grown and has been a success with many restaurants, farmers markets and other food business in New York City.

5.2.4 Watershed Forestry Program

The Watershed Forestry Program, also administered by WAC and funded by the DEP and USFS, aims to promote well-managed private working forests as a preferred land use for watershed protection. It provides financial incentives and technical assistance to foresters, logging contractors and forest landowners with a particular view to protecting and/or restoring riparian buffer zones. Forest owners are provided assistance with the development of forest management plans and to date some 914 landowners have completed forest management plans covering an area of approximately 163,513 acres or 16% of the watershed.

Best management practices (BMPs) are a key component of the forestry program and the WAC has actively supported initiatives such as the installation of portable bridges, construction and/or appropriate remediation of forest roads, the use of geotextile fabric for erosion control, and the use of temporary plastic arch culverts in stream crossings during timber haulage (NYC DEP, 2011). Additionally the WAC conducts training programs and has established "Model Forests" as part of its education and outreach initiatives. Furthermore, since 2005 under a new Management Assistance Program (MAP) the WAC supports practices such as timber stand improvement, tree planting, riparian zone rehabilitation, habitat improvement and invasive species control projects (NYC DEP, 2011).

In 2007 the WAC watershed forestry program launched the Catskill WoodNet marketing campaign (http://www.catskillwoodnet.org/) which is closely aligned with the 'Pure Catskills' food campaign. The campaign aims to promote the sale and use of timber products sourced from local forests in the Catskill region.

5.2.5 Other Environmental Programs

PWS funds are used for a variety of environmental projects such as to develop and implement plans and projects to effect water quality improvement through the better management of streams and riparian zones. Projects funded to date include works to reduce bed and bank erosion, full channel restoration works, streambank stabilisation, riparian vegetation rehabilitation and stormwater management works. Additionally the PWS scheme has involved a significant investment in infrastructure projects, such as the upgrading of all non-City-owned wastewater treatment plants (WWTPs) in the watershed, upgrading or replacement of deficient septic systems and/or regular inspections and "pump-outs", the construction of new sewage treatment facilities in targeted communities, an extension of the sewerage system to areas where on-site septic systems are either failing or likely to, upgrades to stormwater systems to reduce their impact on water quality, and the management of waterfowl and other potential carriers of faecal coliforms and bacteria that could contaminate the water supply prior to disinfection (NYC DEP, 2011).

Arguably water quality in the Catskills/Delaware systems has always been high (Sagoff, 2002) but monitoring results by NYC DEP (2011) clearly show that loads of many pollutants such as phosphorus

have declined as a result of the PWS scheme. The economic argument that is regularly explained in the literature regarding the New York water supply is indeed very convincing: a $6 billion investment in 'grey' infrastructure versus to date a $1.5 billion investment in the 'green' infrastructure of the watershed. DEP staff during the teleconference pondered that the analysis has more recently been revised and while the costs of filtration operation and maintenance appear to have reduced in comparison to the original estimates, the city is still way in front of where it would have been if the decision to apply for the FAD waiver were not taken. David Warne advised that at some point in the future, as filtration costs become comparatively cheaper and as investment in the catchment continues to increase, the 'grey' versus the 'green' "lines may cross". However, he believed that "at every point the comparison is properly *at the margin*, and we are confident that continuing the path of filtration avoidance makes sense in the long term". In any case, in economic terms, as an example of linking downstream water users with upstream land owners, and in terms of environmental outcomes my personal view is that despite its scale, complexity and the need to "learn as they went" the NYC DEP and partners have made the PWS scheme succeed perhaps beyond their own original expectations.

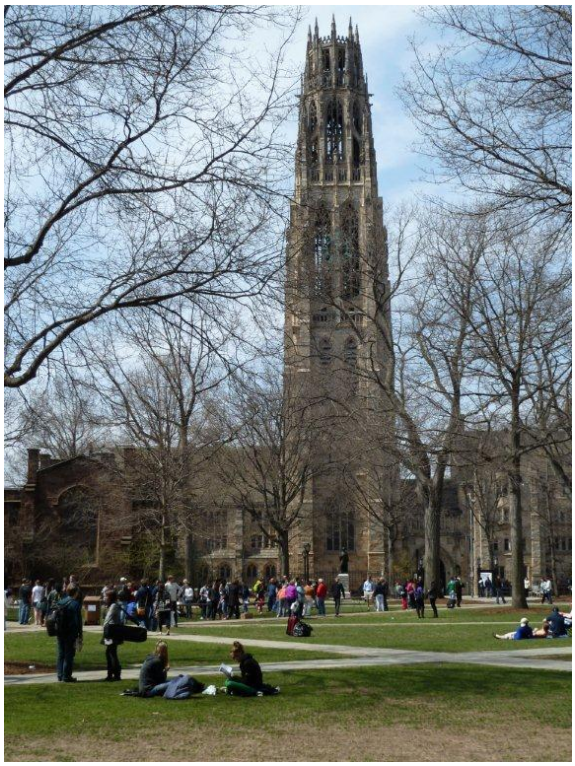

Figure 25. The Memorial Quadrangle and Harkness Tower - Yale University, New Haven, Connecticut

Figure 26. Brooklyn Bridge, New York City

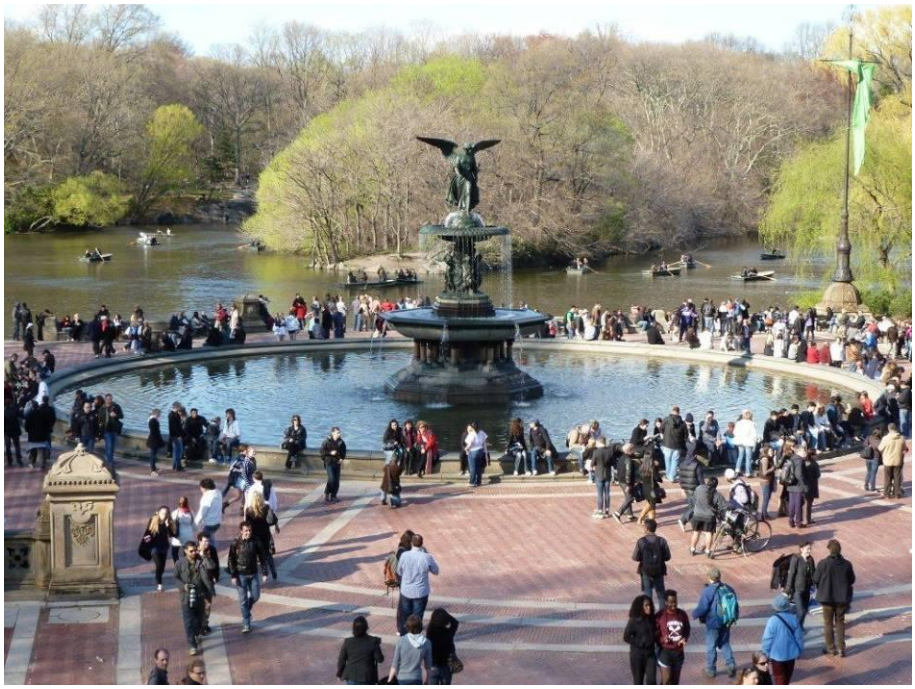

Figure 27. Bethesda Fountain in Central Park, Sunday 17 April

5.3 Cedar River – Seattle, Washington

Seattle Public Utilities (SPU) owns and operates the water supply system that delivers drinking water to approximately 1.4 million people in the Seattle area (Figures 28, 29). Seattle's water is sourced from two main watersheds: the Cedar River watershed (70%) and the South Fork of the Tolt River watershed (30%). The Cedar River watershed supply (Figure 30) is unfiltered and SPU has a FAD waiver for it. A PWS scheme has been in operation since 1992 so I travelled there on Tuesday 19 April to learn more. I was hosted for a most enjoyable day by Dr Dwayne Paige, Supervisor – Fish and Wildlife Unit who has been conducting research in the watershed since 1976 and has been employed by SPU since 1988. I also had the opportunity to meet a number of other SPU staff during the day and received follow-up information from Dr David Chapin, Aquatic and Riparian Ecologist.

The Cedar River watershed is located at North Bend, Washington around 30 miles to the East-Southeast of the city of Seattle (Figure 28). The total watershed area is 90,579 acres (36,230 ha); it is mostly forested and extends from the Cascade Mountain crest along the eastern boundary to gentler undulating hills along the western boundary. The watershed is approximately 25 miles long, 4 - 5 miles wide and today it is 99.9% owned and managed by the City of Seattle. Box 7 provides a description of the supply system that operates at Cedar River.

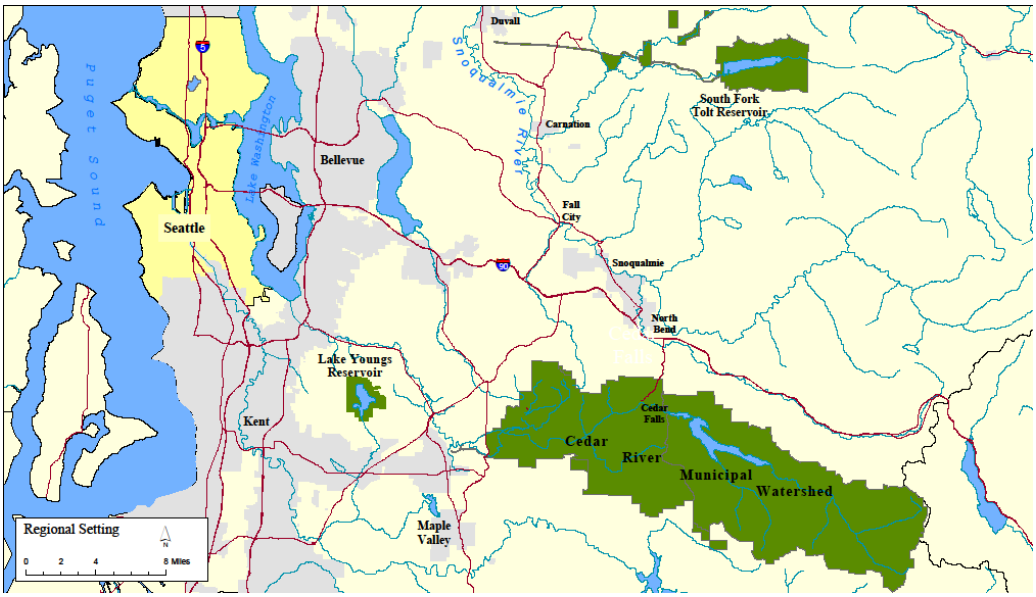

Figure 28. Location map of the Cedar River watershed, Washington.
Source: http://www.seattle.gov/util/groups/public/@spu/@ssw/documents/webcontent/spu02_015249.pdf

Figure 29. View of the Space Needle from Carey Park, Seattle

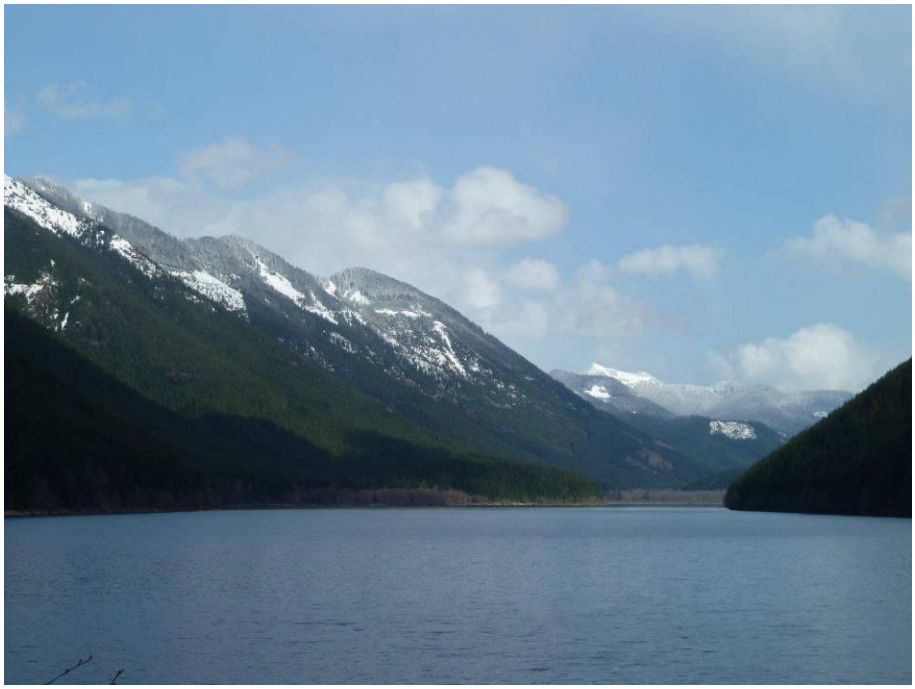

Figure 30. Chester Morse Lake, Cedar River watershed

From Mountain Forests to Faucet

Melting snow and rain are gathered and stored in two reservoirs -- Chester Morse Lake and the Masonry Pool created by the Masonry Dam. Built in 1914, the dam diverts the water into two large 78 inch penstocks. The penstocks drop water 620 feet to the hydroelectric powerplant at Cedar Falls, the birthplace of Seattle City Light.

The water is released back into the river, and continues flowing 12 more miles to Landsburg diversion dam. At Landsburg, on average 22% of the river becomes drinking water and it is screened, chlorinated and fluoridated before being sent to Lake Youngs. At Lake Youngs it is ozonated, exposed to ultraviolet light and lime and additional chlorine are added.

78% of the Cedar River's annual flow continues past Landsburg down the Cedar River into Maple Valley through Lake Washington, Lake Union and out through the Chittenden Locks in Ballard to the Puget Sound.

Box 7. The Cedar River supply system. Source: www.seattle.gov/util/About_SPU/Water_System/Water_Sources_&_Treatment/Cedar_River_Watershed/WaterSupplyTreatment/index.htm

The watershed has not always been owned by the City and previously the US Forest Service, Weyerhaeuser and the Chicago, Milwaukee and St. Paul Railway (Milwaukee) Company owned proportions in a checkerboard fashion. There is a long history of logging in the watershed with clear-cutting dating back to the late 1800s. Principal species logged included Western Red Cedar, Spruce, Hemlock, Pacific silver fir and Douglas fir. Logging camps were set up throughout the watershed and a large proportion of the mature stands (dating to the fires of around 1650) in the watershed was cut over by 1924 when the City appointed its first forester to manage forestry operations. While a small amount of “old growth” forest remains on high elevation ridges (Figure 31), the majority of the watershed is stocked with 80-year old or younger regrowth forests (Figure 32). Logging of the City’s land in the watershed was more controlled after 1924 but it continued until the 1990s. The USFS also controlled approximately 12% of the watershed and logged much of its land. Logging began in the lower west of the watershed and by the 1940s had moved east and into higher elevations. With the introduction of “truck logging” in the 1960s and 1970s the rate of logging accelerated.

Figure 31. Small patches of “old growth” remain in very high elevation areas

Figure 32. Even-aged stands of regrowth Douglas fir are common at lower elevations in the watershed

In the early days of Cedar River's management there were a number of private homesteads in the watershed, as well as small towns that supported the mining of coal and clay. Buildings were razed and all residents had vacated the watershed by 1945. The Milwaukee Railway Company operated the Cedar Falls Depot and a branch line through the watershed that between the 1910s and 1940s supported up to four passenger and eight freight trains per day. Some restrictions were in place to reduce water quality impacts, such as the practice of locking the train rest rooms while travelling through the watershed. Nonetheless the Milwaukee Company operated in the watershed until 1962 while AMTRAK ran passenger services until 1977. An agreement was signed in 1962 with all landowners in the watershed that would see all land transferred to the City such that it would control the entire watershed. The aim was to better control logging and fires and eventually prevent unsupervised public access to the watershed. The final transfer occurred in 1996 when the USFS ceded the National forest lands in the watershed to the City.

5.3.1 PWS and the Habitat Conservation Plan

Having achieved 99.9% ownership of the watershed SPU had largely guaranteed that it could continue operating the Cedar River water supply with fewer concerns about water quality. However, the system and prior management were seen as potentially threatening a number of fish and other wildlife species under the Federal *Endangered Species Act 1973*. In total 14 species were identified as being of "Greatest Concern" with a further 69 species identified as being "Other Species of Concern", that is known to be in decline (City of Seattle, 2000). The 14 species of "Greatest Concern" include six birds, six fish and two mammal species. The birds are the Bald Eagle, Common Loon, Marbled Murrelet, Northern Goshawk, Northern Spotted Owl and Peregrine Falcon. The fish species are Bull Trout, Chinook Salmon, Coho Salmon, Pygmy Whitefish, Sockeye Salmon and Steelhead Trout. The two mammals are the Grizzly Bear and Gray Wolf.

To enable the continuance of the water supply operations SPU was required to formulate a Habitat Conservation Plan (HCP) for the various species and their habitat and in return was granted an Incidental Take Permit that effectively allowed any impacts of the operations to be offset by protection measures and restoration works in the watershed. The HCP was signed in April 2000 and is an agreement for a duration of 50 years. The HCP and related works are funded by a levy on water rates and this forms the basis of the PWS scheme.

The HCP comprises three main areas of focus. These are:

(i) Managing Fish Passage above the Landsburg Diversion Dam;

(ii) Managing the Regulation of Streamflows; and

(iii) Managing the Watershed.

Further details can be found on the SPU website at:
http://www.seattle.gov/util/About_SPU/Water_System/Habitat_Conservation_Plan/AbouttheHCP/Documents/index.htm

Regarding management of fish passage for anadromous species the major issue to be overcome was the barrier created by the Landsburg Diversion Dam which was built in 1901. Fish passage to the 12.5 miles of river above the Dam to the base of Cedar Falls (Figure 33) was blocked for over 100 years. To overcome this and allow certain endangered fish species to migrate up- and down-stream, the HCP mandated that a fish ladder (Figure 34) be installed on the dam, along with a sorting facility and other apparatus to reduce the impacts of the water supply operation on fish species (Figure 35). In addition to the capital works program the HCP has mandated that a comprehensive research and monitoring program be implemented to assess the efficacy of the works. As such some 6000 fish have been captured and either micro-chipped or acoustically tagged. Some 22 hydrophone receivers and 70 data loggers have been deployed at strategic locations in Chester Morse Lake and these monitor the presence of any acoustically tagged fish that approach receivers as data loggers record water temperature at various depths (Figure 36). Some 22 buoys have been deployed at strategic locations in Chester Morse Lake and these monitor water quality and temperature at various depths as well as the presence of any micro-chipped fish that swim by. One can only imagine the vast volumes of data that are being collected throughout the watershed on fish habitat and migration.

Managing regulation of streamflows is also closely aligned with the HCP requirements for fish passage. The basic principle is that the HCP sets levels of flow that must be released from the system to the river downstream under a range of flow conditions. The aim is to ensure that beneficial flows are maintained to benefit all life stages of salmon and steelhead fish species.

Figure 33. Upper Cedar Falls is a natural barrier to fish migration, though Lower Cedar Falls located ¾ mile downstream is the barrier that blocks upstream migration by anadromous species

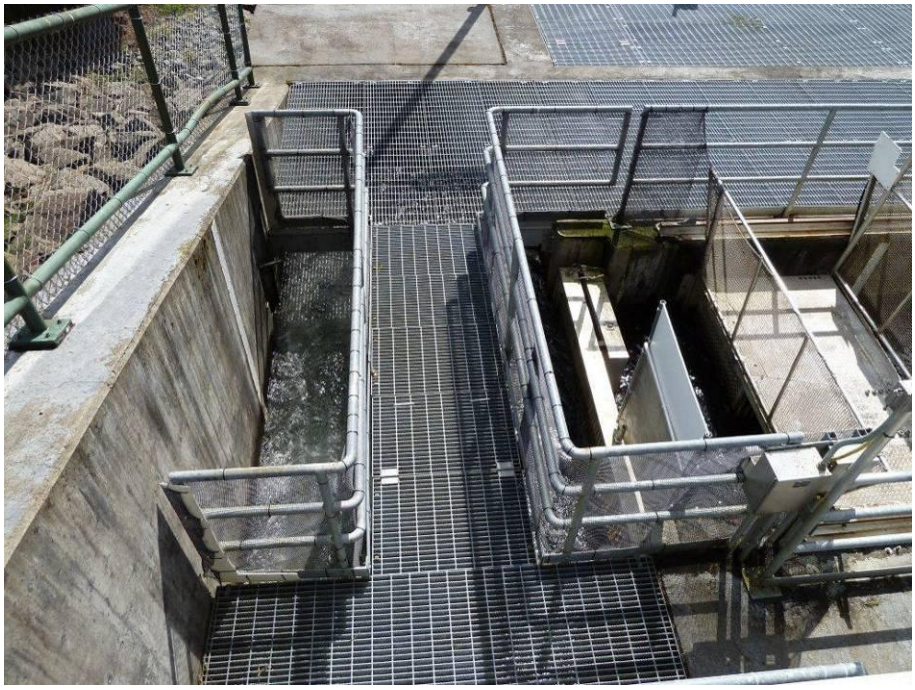

Figure 34. A fish ladder and sorting facility have been installed on the Landsburg Diversion Dam

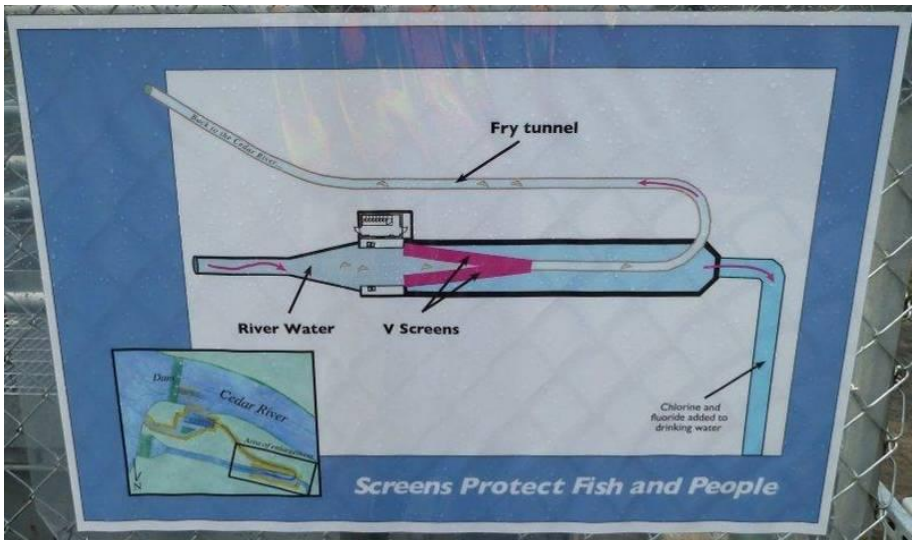

Figure 35. V-Screens have been installed at Landsburg Dam. These act to prevent fish being drawn into the water supply and instead they are diverted back to the Cedar River

Figure 36. A device used to monitor and log the movement of fish that have been micro-chipped

With regard to forest and watershed management, according to SPU, under the HCP the city has agreed to meet the following commitments:

(i) Eliminate timber harvest for commercial purposes to effectively create a watershed ecological reserve, providing long-term, comprehensive protection of the watershed ecosystem.

(ii) Provide a comprehensive program to restore fish and wildlife habitats that have been degraded by past activities such as logging and road construction.

(iii) Remove approximately 38% of the forest roads within the watershed by 2020.

(iv) Employ restoration thinning, planting, and other approaches to restore the natural forest processes and functions that create and maintain habitats for at-risk species.

(v) Design and conduct projects to restore habitat in streams and streamside areas and to improve water quality over the long term.

(vi) Design and conduct comprehensive research and monitoring studies that will provide the information needed to achieve the conservation objectives of the HCP over the long term.

Dr Paige kindly showed me a collection of various projects throughout the watershed that have been implemented to meet the HCP requirements. One of the main contributors to sediment in the watershed has been the roading network that was established mostly to access timber. As Dwayne explained, and as was apparent upon inspection, the north- and south-facing slopes and streams "behave" differently. The north facing slopes tend to be characterised by higher soil moisture and the streams are wetland-fed resulting in sustained baseflows. On the other hand the south-facing slopes are steeper and tend to support intermittent streams. It is on these slopes that a number of landslides have been triggered, often associated with roads high in the watershed. An example of

this is the “perpetual landslide” that occurred in 1990 and has continued to contribute significant volumes of sediment (Figure 37).

Figure 37. Roads are being decommissioned on unstable slopes to reduce the risk of mass movement and subsequent water quality impacts. Pictured is the “perpetual landslide” that began in 1990

During the 50 year life of the HCP there is a plan to decommission approximately two-thirds of the roads in the watershed that totalled some 650 miles (1040 km) prior to the HCP. In the short-term there is a commitment to remove 38% of the roads by 2020. A number of crossings have been rehabilitated and crossing approaches realigned to reduce their impact on water quality. With reference to intact riparian zones (Figure 38) stream rehabilitation works, including the reintroduction of large wood to improve fish habitat, have been undertaken (Figure 39). Considerable attention is paid to road maintenance and the installation of appropriate drainage, as well as research and monitoring projects to assess the type and amount of sediment being produced by different road surfaces (Figures 40, 41). Given the saturated nature of the cut batters and table drains the drainage structures seem entirely appropriate and it was useful for me to view these situations I had read about (e.g. Wemple *et al.*, 2001; Wemple and Jones, 2003).

Figure 38. Dr Dwayne Paige alongside the Cedar River in a natural riparian zone

Figure 39. Road realignment and rehabilitation of the riparian zone, including large wood reintroduction

Figure 40. Roads within the Cedar River watershed are well gravelled and drained. Pictured is a temporary rubber flap drainage device being used in a sediment monitoring project

Figure 41. Road drainage is diverted into detention drums to allow measurement of the amount and type of sediment being produced by different road surfaces

Restoration of the forests is also occurring throughout parts of the watershed that were previously harvested by clearcutting. The previous harvesting has resulted in dense (high stem density), even-aged stands with dense crowns (Figure 42) where little light reaches the forest floor and where little downed wood is present on the ground. These conditions do not support an understory and thus have reduced plant species diversity, providing little good quality habitat for wildlife species. The aim of forest restoration is to promote a diversity of tree species and ages as well as to promote forest health and enhance structural diversity. In the younger forests (<30-40 years old) the term 'restoration thinning' is used. However, in older stands (>30-80 years old) SPU uses the term 'ecological thinning'. Thinning treatments in both forest age ranges are focused on accelerating development of late-successional forest stand conditions (e.g., species diversity, multiple layers, downed wood, etc).

Figure 42. Restoration thinning is being undertaken in overstocked high elevation conifer stands

Several main approaches are employed:

(a) Maintaining existing biodiversity – the aim being to retain tree species diversity (e.g., retain deciduous species, retain all trees greater than a certain diameter, e.g. > 20 inches, promote multi-layered vegetation community structure, retain "biological legacies" such as downed wood, snags, cavity trees, etc.), protect/enhance riparian and wetland-associated habitats.

(b) Variable density thinning – the aims being to create forest stands with variable tree-to-tree spacing (density), variability across size and age classes within and between species, and diverse light conditions.

(c) Skip and gap creation – this aims to promote structural diversity (niches) across a forest stand by maintaining some denser forest patches (skips) that possess a particular set of conditions (e.g., shade, dense canopy, slower rate of growth) that favour shade tolerant tree/plant species (e.g., vine and big leaf maple, hemlock) and provide habitat and cover for certain wildlife species, as well as small canopy openings (gaps – Figure 42) that provide more light to the forest floor, promoting herbaceous ground cover species and shade intolerant tree species such as Douglas fir. These openings can also be used to provide down wood (logs) and snags, adding additional niche diversity for benefit of wildlife.

(d) Restoration planting – this aims to increase species diversity of both native deciduous and coniferous tree species, as well as understory shrubs.

A number of permanent sample plots have been established throughout the forests of the watershed to track changes in forest density, structure and species diversity over the course of the HCP. Wildlife monitoring is also being undertaken on various species in the watershed to assess the efficacy of forest restoration activities. A number of animals, including Black-tailed deer and Rocky Mountain elk (Figure 43) have been caught and collared as part of projects to track their movement and usage of various habitats (Figure 44).

In summary, the Cedar River watershed supplies high quality unfiltered drinking water to much of Seattle's population. Aside from avoiding the cost of filtration (up to $200 million) SPU has managed to secure 99.9% ownership of the spectacular watershed (Figure 45) and via the 50-year HCP it has put in place a remarkable program, funded by a PWS arrangement, that should ensure water quality is maintained or improved at the same time as enhancing the forests to provide habitat for a number of fish and wildlife species.

Figure 43. A Rocky Mountain elk that has been collared for tracking

Figure 44. Meadows in the upper watershed provide herbaceous feed for elk and other mammals

Figure 45. The Cedar River gorge viewed from an overhead pipeline

5.4 Water Restoration Certificates – Bonneville Environmental Foundation

On Thursday 21 April I visited the Bonneville Environmental Foundation (BEF) based in Portland, Oregon to find out about the emergence of trade in "Water Restoration Certificates™". I was able to meet a number of people from BEF but in particular was hosted for a discussion with Todd Reeve – Vice President, Watershed Programs, and Kendra Smith, Willamette Model Watershed Program Director regarding water programs. BEF is a non-profit organisation that was founded by Angus Duncan in 1998. It made its mark early on in the renewable energy credit market and prior to moving into water projects it had established a reputation and the ability to manage trading schemes with experience in sales, marketing, inventories and the like. While many other schemes focus on delivery of outcomes set by regulation BEF focuses on voluntary markets.

Underpinning the concept of Water Restoration Certificates™ (WRCs) is the prior appropriation doctrine. As mentioned in section 2.6 the prior appropriation doctrine dates to the 1800s and is based on the premises of "first in time, first in right", and "use it or lose it". Under the doctrine unfortunately a number of river systems have been over-appropriated, not unlike the situation in many Australian rivers that have been over-allocated. For instance, Todd mentioned that approximately 4000 miles of streams in the state of Montana have been over-appropriated. This essentially means that little water is available in such systems for the environment, often with alarming consequences for aquatic ecosystems. Fortunately in some states (it is still illegal in Wyoming) it is possible for water rights that are unused to be on-sold and used for the benefit of instream flows and fisheries. The concept of WRCs is actually rather simple which could in fact be its best selling point. Many schemes falter in that they require the determination of complex metrics. WRCs on the other hand offset personal or company water use at a simple 1:1 ratio. Individuals and businesses are invited to calculate their water "footprint" and then purchase an equivalent amount of water (each WRC is equivalent to 1000 gallons) that is used in turn to strategically purchase water from Senior Water Rights holders at a critical time of year in streams requiring rehabilitation. The WRC program can also support half season leases, full season leases, permanent transfers, point of diversion changes and efficiency upgrades. The process is neatly explained in a short video on BEF's website: http://www.b-e-f.org/water/cert .

The market is shaping up well and while the transactions and current negotiations with various companies are confidential, it is fair to say that trade is occurring with purchases to date largely made by brewing companies, sports stadiums, clothing manufacturers and computing firms with considerable interest being shown by some large soft drink ("soda") companies. One of the stipulations BEF places on customers is that they must first show that they are as water efficient as possible before allowing them to purchase WRCs to offset their water footprint. In other words WRCs are not available to offset inefficient and water wasting activities. Furthermore, the standards and criteria that BEF has in place for each of its WRC projects are certified and endorsed by the National Fish and Wildlife Foundation, giving purchasers confidence that their offsets will be put to making a significant difference.

Pilot streams have been established in a number of states to demonstrate the benefits that WRCs can provide. As Todd and Kendra admitted, they need a "leap of faith" and if they can secure a big-name company then the scheme should really take off. From the companies' perspective WRCs could be a real branding benefit in demonstrating their "green" water-friendly credentials, especially in industries that are high-users of water. Similarly, if large proportions of individuals in cities like Los Angeles were to sign up BEF believes great things could be possible. Imagine the irony of Los Angeles or Las Vegas residents purchasing WRCs to restore some flows back in the Colorado River hundreds of kilometres away. This could be a stumbling block for the scheme as indeed people may be willing to purchase water offsets but may have a problem say with their water use in California being offset in Colorado or Montana.

Nonetheless, I came away from BEF impressed by the concepts of WRCs and the enthusiasm and know-how of the staff involved. This endorsement is shared by Robert F. Kennedy Jr, who BEF quotes in its pamphlets as having stated:

> A true free market requires us to properly value natural resources. These Water Restoration Certificates are another great example of how BEF uses its integrity and innovation to create a market-based solution to an environmental issue.

Finally, another quote from BEF's material: "Blue is the New Green. Just Add Water", which neatly captures their philosophy.

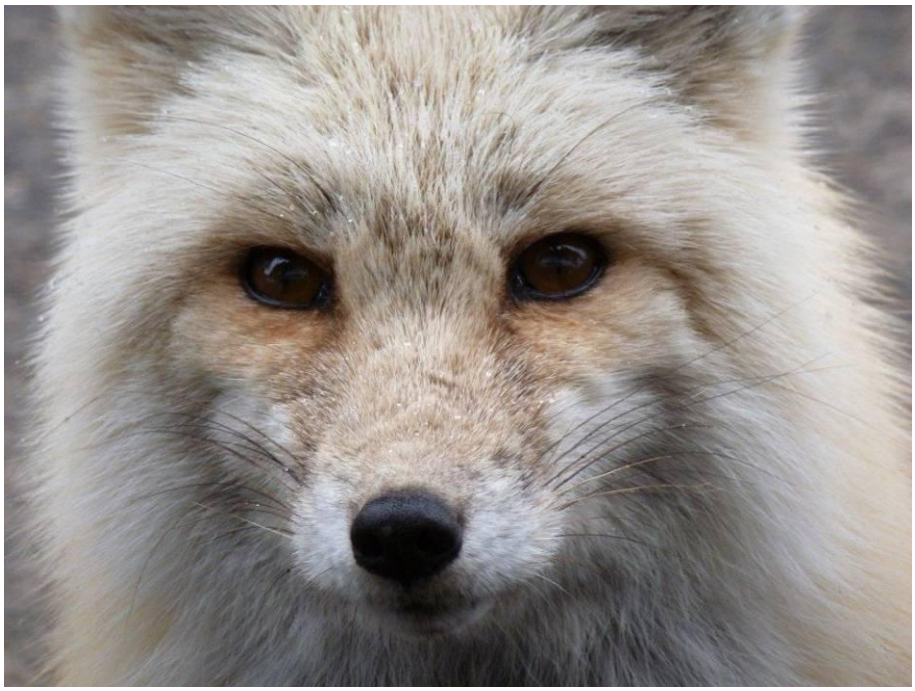

Figure 46. A Red Fox, Mount Rainier National Park, Washington spotted on a detour from the highway on the trip between Seattle and Portland

Figure 47. A ‘Silver phase’ Red Fox, Mount Rainier National Park, Washington

5.5 Willamette Valley projects

While in Oregon I was fortunate to be able to connect with representatives of two projects focusing on the Willamette Valley.

5.5.1 Willamette Partnership

On Thursday 21 April I met in Portland with Devin Judge-Lord from Willamette Partnership (http://willamettepartnership.org/), a non-profit organisation that administers portions of the emerging markets for ecosystem services in the Willamette Basin, Oregon. He has recently been involved in expanding a water quality trading scheme in the Tualatin River basin that was first developed in partnership with Clean Water Services (www.cleanwaterservices.org), Willamette Partnership and The Freshwater Trust (www.thefreshwatertrust.org/). The organisations are building from this example to create other markets throughout the Northwest United States. I met with Devin to discuss the Tualatin project and some of the metrics involved.

The Tualatin River basin in northwestern Oregon to the west of Portland has an area of 712 square miles and flows easterly from the Coast Range to the Willamette plains. The basic pollutant that the environmental market aims to address is 'temperature'. Specifically, this relates to the temperature of water released into rivers from wastewater treatment plants operated by Clean Water Services, the local water utility. While these plants are able to release clean water unfortunately it is warm water and this is neither beneficial for aquatic life including endangered coldwater salmonids, nor was it going to be compliant with the US EPA's new TMDL requirements which are regulated by the Oregon Department of Environmental Quality (DEQ). To meet the TMDL wastewater treatment plants often install cooling structures that act like a giant refrigerator to cool the treated water before its release. Devin explained that these structures could cost up to $60 million to construct. Therefore, economically it seems sensible that if other ways could be found to offset the water temperature effects at a lower cost, then these should be explored.

Tree planting along streamsides is offered as a way of wastewater treatment plants offsetting their temperature pollution. The simple rationale is that shading lowers stream temperature so if the river and its tributaries can be shaded by riparian trees then this will reduce the overall stream

temperature and make up for the thermal pollution of the treatment plants. Thermal effluent load was measured at the points of discharge. Modelling of shade impacts by DEQ is then undertaken using the 'Shade-a-Lator' tool to determine the benefits of tree planting in riparian zones based on the HeatSource model. To comply with the TMDL each wastewater facility is required to offset its temperature emissions at a ratio of 2:1. There is some acknowledgement in the system that there will be a lag time (approximately 10 years) between tree planting and the benefits of shading. Under the WQT scheme Clean Water Services funds tree planting by using revenue raised from ratepayers. It then enters into either 20 year contracts with farmers or purchases conservation easements. Farmers who participate are paid a sign-in bonus (for the contract or easement) and an annual payment for maintaining the revegetated riparian zone. Clean Water Services undertakes the planting or pays a contractor to do so. A summary of the scheme is provided by Cochran and Logue (2011).

Willamette Partnership's role in the scheme has been to facilitate stakeholders in developing policies and protocols for trading. Several large federal grants enabled the scheme to be setup. The Freshwater Trust, another non-profit, is now brokering deals for temperature and nutrient trading in other watersheds in the Northwest using Willamette Partnership's protocols. Judging by the fact that there is a waiting list of farmers wishing to be a part of the Tualatin scheme it appears to be successful. Comprehensive monitoring programs have been established to ensure that this is the case.

5.5.2 Willamette Water 2100 project

On Friday 22 April I visited Professor Jeff McDonnell and water colleagues at Oregon State University (OSU), Corvallis (http://water.oregonstate.edu/). Aside from being world-renowned for his work on water transit times using oxygen isotopes (e.g. McDonnell *et al.*, 2010; Brooks *et al.*, 2010), Jeff is leading a multidisciplinary project called 'Willamette Water 2100' that is a collaboration between scientists at OSU, University of Oregon and Portland State University. The project only began this year and is funded by a $4.3 million grant from the National Science Foundation. It will use the Willamette basin as a test case to predict the future impacts of climate change and human activity on water supplies within the basin under various scenarios (http://water.oregonstate.edu/ww2100/). The project will explore where human activity and climate change will most likely create water scarcity; where such scarcity

will exert the greatest impact on ecosystems and communities; and what strategies communities could use to mitigate or adapt most successfully to water scarcity. The results should be highly valuable and hopefully applicable to other river basins.

Figure 48. Crater Lake National Park, Oregon, Saturday 23 April

Figure 49. A bumper snow season kept the snow ploughs busy near Crater Lake

5.6 Santa Fe, New Mexico: Wildfire 'Insurance'

Santa Fe, New Mexico in the southwest of the USA is very different to the forested regions visited earlier in the fellowship. It experiences a cool semi-arid climate where wildfires are not uncommon. The city itself has a long history beginning with occupation of the area by Pueblo Indians around 1100 AD. It was later to be founded as a city of the province of New Spain in 1608 before becoming the capital of the Mexican Territory of Santa Fé de Nuevo México in 1824 following the Mexican War of Independence. A number of battles ensued and it was not until 1912 that New Mexico became the 47th state of the USA with Santa Fe as its capital. The city lies at an elevation of 7000 feet (2130 m) at the foot of the Sangre de Cristo Mountains and today has a population of approximately 75,000.

On Tuesday 26 April I met with Sandy Hurlocker, USFS District Ranger, Española Ranger District - Santa Fe National Forest to discuss the new PWS scheme that the city has entered into for the period 2010-2029. We toured the watershed and met Felicity Broennan, Executive Director of the Santa Fe Watershed Association (www.santafewatershed.org/). Felicity kindly followed up with some information via email. The Santa Fe Municipal watershed supplies up to 50% of the water used by Santa Fe residents and businesses; the remainder coming from groundwater wells. The watershed is 17,384 acres (6954 ha) in area, of which the City owns and manages around 1000 acres near the dams and riparian zones. The rest of the watershed comprises the Santa Fe National Forest in the lower watershed and the Pecos Wilderness Area (10,000 acres) in higher parts of the watershed. Lake Peak in the Sangre de Cristo Mountains is the high point of the watershed at an elevation of 12,408 feet (3782 m) and annual precipitation of 35 inches (875 mm). This is compared to just 14 inches (350 mm) at the city of Santa Fe. The majority of precipitation falls as snow (as it did on the day I visited); however rainstorms are not uncommon during the July-August monsoon season. The Santa Fe River is dammed firstly at high elevation at McClure Reservoir (Figure 50) to capture streamflow and also to prevent evaporation losses; and secondly at Nichols Reservoir at lower elevation from where it is distributed by the Sangre de Cristo Water Division (http://www.santafenm.gov/index.aspx?nid=269). The watershed has been closed to the public since 1932 to prevent contamination of the water supply (Figure 51). Since the September 11 terrorist attacks in 2001 the watershed has also routinely been patrolled by security guards, as was the case the day I visited with Sandy.

Figure 50. The higher elevation McClure Reservoir, Santa Fe watershed

Figure 51. The Santa Fe Watershed has been closed to the public since 1932. Since the 9/11 terrorist attacks in 2001 it has also been routinely patrolled by security guards

For more than 100 years the Santa Fe watershed forests have been managed with a philosophy of complete fire suppression and this has led to the stands becoming overstocked, vulnerable to pest or insect attack, and highly prone to intense "stand-replacement" fires with drastic consequences for soil erosion and contamination of the water supply. Having witnessed the effects of the Hayman and Buffalo Creek fires on water supplies in Denver, Colorado (section 5.7), as well as the 2000 Cerro Grande fire that resulted in a 140-fold increase in sedimentation of the Los Alamos reservoir, a consensus decision was made that Santa Fe needed to act. Discussions began around 2007 and culminated in the production of the Santa Fe Municipal Watershed 20 Year Protection Plan 2010-2029 (Santa Fe, 2009). The plan is unique in that it "seeks to fund forest restoration activities using the Payments for Ecosystem Services model as an insurance policy against future threats, particularly of catastrophic fire, to the municipal water supply" (Santa Fe, 2009). The major signatories to the Plan are the USFS, Santa Fe Watershed Association, the Nature Conservancy, City of Santa Fe Water Division and the City of Santa Fe Fire Department. The cost of the Plan is estimated to be $4.3 million over 20 years. By comparison investing in the catchment would avoid an estimated repair bill of $22 million if 7000 acres of the watershed were to burn. If left unrestored the likelihood of such a fire was estimated to be 1 in 5 in any given year (Santa Fe, 2009).

The four critical components of the Plan are:

(i) vegetation management and fire use;

(ii) water management;

(iii) public awareness and outreach; and

(iv) financial management based on "Payment for Ecosystem Services", i.e. a PWS scheme.

Between 2003 and 2006 mechanical treatments were carried out across 5,285 acres of forests in the areas dominated by Ponderosa Pines (<10,000 feet). The pines were thinned (Figure 52) using a "mastication" method (Figure 53) that essentially reduces trees to large strips or chunks of wood that can more easily be burnt as part of hazard reduction. The aim of the thinning and mechanical treatments is to separate the crowns (Figure 54) to reduce the risk of crown fires. Additionally under the Plan some additional mechanical works have been outlined which includes the targeted reduction of undergrowth to reduce the density of piñon-juniper woodland (Figure 55).

Figure 52. A stand of Ponderosa Pine that has been thinned to separate the crowns

Figure 53. Ponderosa Pine stump remaining following “mastication”

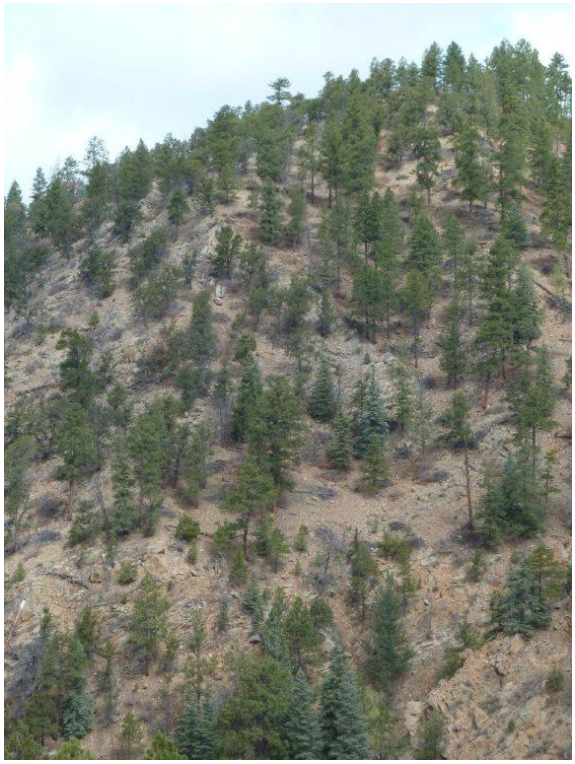

Figure 54. Hillslope of thinned Ponderosa Pines showing separation between the crowns

Figure 55. Piñon-Juniper undergrowth recently cleared and piled ready for burning to reduce wildfire risk

In the Santa Fe National Forest there is a plan to regularly undertake prescribed burning across the already treated areas. The aim is to burn approximately 1000 acres per year with the entire area of the lower watershed being burned once every 7 years. In the Pecos Wilderness Area which covers predominantly the highest elevation areas in the watershed, Federal regulations preclude any mechanical thinning or similar interventions. However, prescribed burning can be undertaken. The wilderness area at lower elevations comprises mixed conifer forests, including Ponderosa pines, Piñon pines and Gambel Oak. At these elevations there are plans to undertake prescribed burns to reduce fuel loads. Under the regulations it is also possible to undertake strategic "hand thinning" to break up fuels and this will be considered. To somewhat 'protect' the wilderness area mechanical thinning will be undertaken on ridges adjacent to its borders. At higher elevations (>10,000 feet) in the wilderness area the predominant forests are Spruce and Fir forests and at this stage there is no plan to undertake any active management activities within these forests (Santa Fe, 2009).

With regard to water management, the Plan has three main aims: to regularly monitor streamflow, precipitation, reservoir levels and bathymetry; to regularly monitor water quality; and to regularly assess riparian habitat with a view to its enhancement. The enhancement of downstream flows and habitat is seen as a priority as the system has long been degraded as a result of the impacts of the reservoirs and significant channelization within and around the city of Santa Fe (Figure 56). The Santa Fe River, prior to the dams, was the "lifeblood" of a number of small Spanish communities that trace their origins to the 1600s. However, the river has not experienced a fully natural flow since 1881 when the city's first dam was built. This and the declining aquatic habitat in the stream led to American Rivers (2007) naming Santa Fe River the most endangered US river in 2007. Evidence suggests that with more flow made available to the river populations of river-dependent species such as the beaver (Figure 57) will begin to increase.

The Plan is at first being funded by federal funds obtained from Congress allocations. However, from 2014 it is anticipated that the USFS's work in the watershed will need to be funded by cost-sharing arrangements. To that end the plan is to establish a PWS scheme that leverages $0.65 per month from water users in the city as part of their service rate charges. Underpinning much of the "selling" of the scheme to the public is the public education and outreach program. This is being handled by the Santa Fe Watershed Association and includes a number of initiatives including taking the general

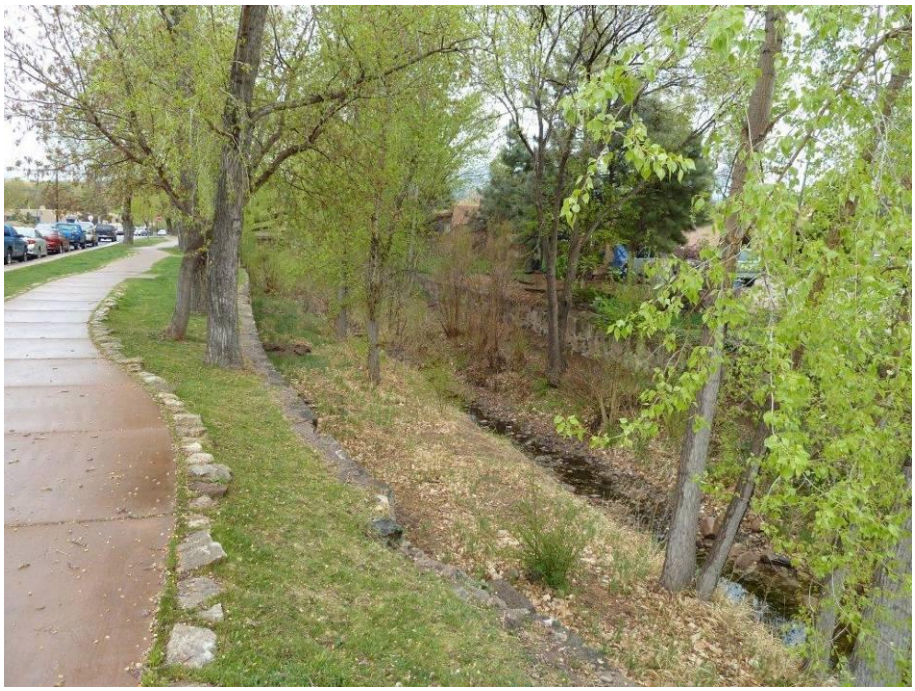

Figure 56. The Santa Fe River as it flows through the city of Santa. The river was recently voted number 1 on a list of America's most endangered rivers (American Rivers, 2007)

Figure 57. A beaver dam on the Santa Fe River within the watershed

public on supervised educational hikes through the watershed, conducting field days with school groups in the watershed, presentations to primary school classes, involving high school students in water monitoring activities, staffing educational tables in the city, distribution of newsletters, placing an information page in the telephone book and developing 30-second television advertisements (Santa Fe, 2009).

A further initiative of the Santa Fe Watershed Association that I received correspondence on from Felicity Broennan is the conduct of surveys to gauge the attitude of residents to the watershed management plans and also the proposed PWS scheme. Two surveys have been conducted to date: the first was a National level survey of 802 people conducted for the Nature Conservancy by Fairbank, Maslin, Maulin and Associates (FM3) in conjunction with Public Opinion Strategies in 2010. The second survey polled 402 Santa Fe residents in March 2011. The results included the following:

- 90% of Americans believe that the services "nature provides" to humans are either "extremely important" (55%) or "very important" (35%).
- 97% of Americans ranked nature's provision of "clean water for drinking and irrigation" as either "extremely important" (62%) or "very important" (35%).
- Americans do not relate to the term "ecosystem services". With regard to alternatives, "Nature's Value" (61%), "Earth's Benefits" (55%) and "Nature's Benefits" (53%) were regarded as "Very Appealing" by the majority surveyed whereas "Ecosystem Services" (31%) was not so recognised.
- The proposed PWS scheme in Santa Fe has the support of 76% of residents surveyed which included 78% of Democrats, 72% of Republicans and 71% of independents.
- 82% of residents are either "Very Willing" (66%) or "Somewhat Willing" (16%) to pay $0.65 per month to the Water Source Protection Fund.
- 64% of residents would be "Very Willing" (42%) or "Somewhat Willing" (22%) to pay $2.00 per month to the scheme.

Based on this level of support the PWS scheme is likely to be a success. One danger that hopefully does not play out is that despite the investment and work undertaken, no doubt the risks are greatly reduced, but there can be no "guarantee" that a wildfire will not occur. If it does the city is surely hoping that the "insurance" work will greatly mitigate its impact upon the water supply.

5.7 Denver, Colorado: 'Forest to Faucet' partnership

The US Forest Service Rocky Mountain Region on 29 July 2010 signed a 5-year Memorandum of Understanding with Denver Water titled "Restoring forest and watershed health to protect the City and County of Denver's municipal water supplies and infrastructure". The deal will see Denver Water and the USFS each contribute $16.5 million towards restoring various watersheds through 11 August 2015. The PWS scheme will be funded in part by payments of $27/household in total over 5 years by Denver Water's customers. I visited both the USFS Rocky Mountain region office and Denver Water in the city of Denver on Thursday 28 April, followed by a tour of some of the watersheds on Friday 29 April. My time in Denver was coordinated by Claire Harper of the USFS, which included meetings and discussions with:

- Claire Harper, USFS Water Partnerships Coordinator
- Polly Hays, USFS Water Program Manager
- Tommy John, USFS Regional Soil Scientist
- Susie Weingardt, USFS Partnership Liaison
- Joan Carlson, USFS Water Quality Hydrologist
- Rick Cables, USFS Regional Forester
- Marc Waage, Manager – Water Resources Planning, Denver Water

Firstly, it must be stated that Colorado water management is complex as not only are the Colorado Rocky Mountains the headwaters of major inter-state rivers including the Colorado, Rio Grande, Arkansas and South Platte that provide water to states as far afield as California and Mississippi, but water laws are based on the "Prior Appropriation Doctrine". Evidently, due to the complexity of water laws and management, Colorado has its own water court system and employs a disproportionately large number of lawyers. A common saying is that "whisky's for drinking; water's for fighting over". Another important fact is that much of the streamflow is generated in headwaters that are forested and the majority of forests are on public land, i.e. National Forests managed by the

USFS. So, forest management is central to the health of many Colorado watersheds. Herein lies part of the problem and also part of the solution.

Denver Water is a non-profit public utility, established in 1918, that supplies drinking water to around 1.3 million people. Its watersheds total 2.5 million acres (1 million ha) in area across four river basins and deliver water to 15 major reservoirs, the largest of which are Dillon (Figure 58), Eleven Mile, Williams Fork and Cheesman Reservoirs (Figure 59). The highest yielding watersheds are those located on the western side of the Rocky Mountains from where water is transferred to the city via a system of tunnels. Denver Water has been proactive in promoting conservation of water by Denver residents and has been running a "Use Only What You Need" campaign for the past five years. This has achieved 90% recognition amongst residents and resulted in water usage dropping to 19% below pre-drought levels. A component of this has been the promotion of "Xeriscapes" or water-conserving gardens (Figure 60). Further, Denver Water promotes recycling of water for industrial purposes and for watering in parks and golf courses.

Figure 58. The lake behind Dillon Reservoir was still frozen over on Friday 29 April, Rocky Mountains, Colorado

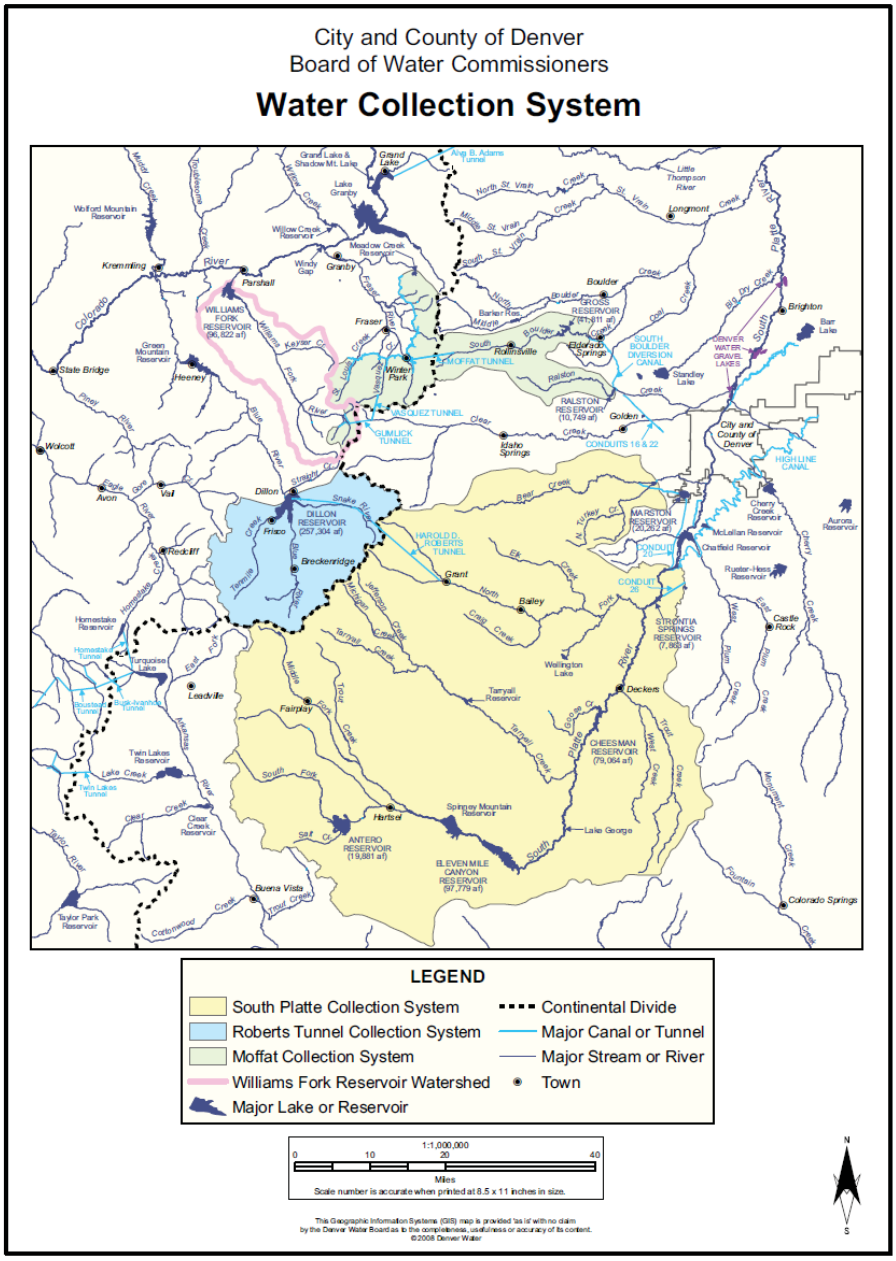

Figure 59. The Denver Water Collection System. Source: www.denverwater.org/SupplyPlanning/WaterSupply/CollectionSystem/

Colorado, like many states in the US, had a long history of wildfire suppression and in recent times the consequences of this approach have become a stark reality for water supply managers like Denver Water. In 1996 the Buffalo Creek fire burned 11,900 acres of forest (Moody and Martin, 2001), much of which was in Denver Water's watersheds. The fire was followed by a 50 mm rainstorm that contributed to debris flows, accelerated soil erosion and the accumulation of 15

surface acres of debris in the Strontia Springs Reservoir. Denver Water, in order to restore the reservoirs function, dredged some 625,000 m^3 of sediment from the reservoir at a cost of $30 million. This precipitated some protection and rehabilitation forest treatments being investigated by Denver Water and the USFS and by 2002 some thinning projects had begun. However, in June 2002 the Hayman fire burned a further 138,000 acres (Robichaud *et al.*, 2008) above the Cheesman Reservoir. The fire suppression costs alone were $42 million while the fire destroyed 600 structures including 132 residences. The private property insurance costs from the Hayman fire exceeded $38 million. The USFS has developed a number of emergency response treatments that are applied to catchments post-wildfires to limit soil erosion (e.g. Napper, 2006; Parsons *et al.*, 2010; Robichaud *et al.*, 2010) as explained by Tommy Johns and Polly Hays. Following the Hayman fire the USFS spent $37 million on treatment and rehabilitation measures while Denver Water spent a further $11 million on reclamation projects and additional water treatment. The picture being built here is that high intensity catastrophic wildfires are extremely costly to fight, can cause significant property damage, require expensive remediation, and are extremely 'bad news' for water supply authorities like Denver Water. The costs of loss of aesthetics, wildlife, tourism and recreation values are additional but unknown.

Figure 60. Denver Water has actively encouraged households to plant water conserving gardens

In 2003 Rocky Mountain Regional Forester Rick Cables, backed by advice from his hydrologists, approached the then Chief of Denver Water Chips Barry with an idea to invest in managing the forests in the watersheds to increase their resilience to fires for the benefit of Denver Water's customers. According to Rick he nudged Chips Barry and said "Hey Chips, wouldn't it be cool if we could somehow connect your water users to their watersheds in a manner that would allow them to invest in the watershed and allow us to maintain it in a healthy state?" Rick Cables reminded me that the 1897 Organic Act that established the aims of the USFS included not only sustainable timber production but "securing favourable flows of water" as one of the drivers for the establishment of National Forests. Rick is a firm believer in the Organic Act and also the concept of 'Forest to Faucet' partnerships. However, in 2003 he received little interest from Denver Water.

In the interim the USFS Rocky Mountain region has worked with a number of partners to fund all manner of projects including watershed restoration. Susie Weingardt explained that non-profit organisations like the National Forest Foundation (NFF) work together with the USFS to engage communities in projects that enhance the health of forests and watersheds. Indeed the Rocky Mountain region receives approximately $60 million annually through non-profit organisations. One initiative of the NFF has been the 'Ski Conservation Fund' which applies to ski resorts that operate via a special use permit on National Forest land. The fund is an "opt out" program whereby, unless a customer opts not to contribute, $1 per night of hotel costs, ski passes and other activities is contributed to the fund, which is matched dollar for dollar by the NFF. Evidently 96-97% of customers elect not to opt out and so the fund has been very successful, with Vail Resorts being a large player. All funds generated by the scheme are re-invested locally and often on watershed projects.

Much work between 2003 and 2010 has led to the development of the USFS-Denver Water partnership. A review of the impacts of forest management activities on the quantity, quality and timing of streamflow in Colorado was undertaken by MacDonald and Stednick (2003) and summarised much of the experimental catchment work that has been undertaken. Acknowledging that Colorado's population is expanding, the fact that many forest stands are over-stocked and that 3.4 million acres of Lodgepole pine forest has been killed in Colorado by the pine bark beetle, an investigation was commissioned to determine the threat of catastrophic wildfires on nine counties

on the Front Range and Grand County on the West Slope (Le Master *et al.*, 2007). Further work identified and prioritised those watersheds that should be treated to prevent wildfires and restore areas previously burnt (Front Range Watershed Protection Data Refinement Work Group, 2009) though some argue preventative measures will be more effective in some forest types and less so in others (Schoennagel *et al.*, 2004).

The $33 million partnership half funded by Denver Water's customers, like the Santa Fe plan, comes with no guarantees. However, by investing in forest treatments in the designated "areas of concern" for Denver Water's infrastructure and watersheds with the greatest fire risk, the hope is that this initiative will provide valuable insurance and greatly reduce the costs of post-fire rehabilitation in future. If the effects of a fire the size of Hayman can be avoided in future, surely Denver Water will be way in front.

Figure 61. An estimated 3.4 million hectares of Lodgepole Pines have been killed by the pine bark beetle in Colorado, as pictured here in the Dillon Reservoir watershed

6. What Does and Doesn't Work?

To this point I have reported rather positively about the many PWS and similar schemes I visited in the US. Undoubtedly, given the right conditions, market instruments can work favourably to enhance forests and watershed values for the benefit of downstream users. It is worth considering, however, that some schemes work better than others and in a number of cases they either don't 'get off the ground' or pilot programs are initiated only for the markets to later fail. Not being an economist I was keen to find out a little more about the economics of trade in ecosystem services. To that end I had an invaluable telephone conservation with Dr James Shortle of Penn State University (http://www.aers.psu.edu/faculty/JShortle/default.cfm) on Monday 18 April, along with follow-up emails. Jim is a Distinguished Professor of Agricultural and Environmental Economics whose research has focused on markets and incentives for ecosystem services and he has a principal interest in water quality trading. He generously explained some rather complex economic theory and modelling, including examples, in pragmatic terms that I could understand.

In terms of programs that work well Professor Shortle cited the USDA's Conservation Reserve Program (CRP) which is the largest environmental program in the US in terms of dollars invested. It essentially allows the US government to purchase forest and agricultural land from private landowners and convert the land to less intensive uses. Using a reverse auction system farmers make a bid and the USDA evaluates the ecological benefits of various land parcels on offer. If a contract is entered this is usually for 10-15 years with a negotiated rental price to be paid at a fixed rate. While the program has been successful Jim questioned whether it was efficient and also whether investment is made in the right places. A Senate Agriculture committee determines how funds are allocated across watersheds but the funds appear to often be distributed to small Midwestern states and arguably there are more severe ecological problems to be addressed elsewhere.

In terms of payments there is also an issue of the 'market value' of land versus the 'ecological value' of land. Jim has been undertaking focus group research with farmers and many are offended that under the CRP 'bad' land is sometimes valued more highly than 'good' land. Ecologically this makes sense as the CRP focuses on vulnerability of land to disturbance but to a farmer the degraded land is less productive and therefore less valuable from their perspective. On the question of prioritising

land for purchase the USDA has scoring rules that typically are kept secret by the agency as research indicates farmers will seek higher prices if they know their land is of high ecological value. The USDA, however, seeks to buy as much as it can for less. Professor Shortle also believes the CRP has worked well in that it can still reward a farmer who has already voluntarily done work to improve their land. This avoids the perverse outcome of rewarding bad practices over good as the CRP mechanisms are targeted towards the characteristics of a parcel of land rather than either the prior or current activities. However, setting a baseline of work to be done before a landowner can enter the market can also address the issue of fairness but this must be managed carefully as in some instances 'bad' actors may then not be persuaded to undertake the work and enter the market as it is too expensive (Horan and Shortle, 2005; Ghosh *et al.*, 2011).

When it comes to water quality trading the results are very mixed indeed. Interestingly, in Jim's opinion the best functioning water quality trading scheme in the world is the Hunter River salinity scheme (http://www.environment.nsw.gov.au/licensing/hrsts/index.htm) that caps the amount of salt that can be discharged from Coal Mining companies which trade credits, 200 of which are auctioned every two years. The scheme, however, trades only in point sources of pollution. In Pennsylvania, as is the case in the Willamette Valley (section 5.5), point source (PS) polluters such as wastewater treatment plants can purchase offsets in the form of modelled reductions in non-point source (NPS) pollution achieved through BMPs such as tree planting. In these cases the ratio of NPS offsets to PS discharges is usually set at 2:1 presumably as this is seen as doubling the nutrient benefits of the trade. However, from an economist's perspective, Professor Shortle and colleagues believe that such a ratio can sometimes work in a perverse way by actually diminishing overall trade in the market as a result of increasing uncertainty (see, e.g. Shortle and Horan, 2001; Horan *et al.*, 2002a, b; Shortle and Horan, 2006; 2008).

In terms of what is required to make environmental markets work Jim expressed similar views to those explained to me earlier by Al Todd (section 2.6); namely that three key requirements are 'supply', 'demand' and 'infrastructure'. Upfront funding Jim cited as having been essential to the success of the CRP backed by the US government. In other words, there needs to be not only a demand for credits or services but purchasers able to pay. The idea that "if we create a market, people will come" is a myth (Horan and Shortle, 2011). Often, as discussed previously, a regulatory

trigger such as a TMDL or FAD for drinking water is required. Many markets have failed due to a lack of binding regulations. An example where trading has occurred successfully in the absence of binding regulations is the Little Miami River trading project in Ohio. In that case there is no TMDL so demand is difficult to establish but there is some expectation that a TMDL may be in place in future. The aim of the program, therefore, is to encourage nutrient reductions before the TMDL at a low cost. Under the pilot scheme funded partly by municipalities and the USDA and USEPA offset credits are purchased via reverse auctions and the process is managed by the existing 14 Soil and Water Conservation Districts. Jim credits the success of the scheme in the absence of binding regulation to this use of existing mechanisms and relationships. Similar success has been achieved in the South Nation River watershed in Ontario with phosphorus trading (O'Grady, 2011). Focus group research has been insightful regarding what does and does not work as Jim explained, because in general farmers prefer to deal with existing agencies and persons with whom they are familiar and trust; hence the Ohio and Ontario success stories. On the contrary, the PennVest program in Pennsylvania for nutrient trading has all the hallmarks of a proper trading scheme – supply, demand, a solid platform and links to the Chicago exchange – but to date has produced very little trade. The problem is most likely that the new market arrangements do not utilise the existing Soil and Water Conservation Districts that farmers like to deal with; hence their reluctance to become involved.

While the focus of this report has been on PWS schemes relating to forest management in drinking water catchments, as well as WQT schemes involving BMPs such as tree planting to offset point-source pollution, the latter do not control total pollution loads in a given watershed. "Slippage", as Jim described it, can occur where some landholders sell credits for NPS reduction, yet on other land NPS pollution can occur unchecked. In an innovative pilot scheme in the Lake Taupo catchment of New Zealand, a cap will be placed on all sources of pollution, NPS and PS, and credits traded: http://www.motu.org.nz/research/detail/nutrient_trading. The project will be well worth following.

In summary, the key elements of successful schemes are demand (often triggered by regulation), supply (willing sellers) and appropriate infrastructure in the form of trading metrics, infrastructure and minimised transaction costs. However, sociology is equally important in determining the likely success or failure of trading schemes.

7. Conclusions

Forests undoubtedly provide many ecosystem services, including a myriad of watershed services that benefit downstream users and society in general. Unfortunately we take most of these services for granted and really only value them when they are lost or threatened by a disturbance such as logging or wildfires. In Australia we need a paradigm shift in thinking about forests and watershed values. The framers of the Organic Act of 1897 in the USA got it right when they set an objective to manage forests to sustain watershed values. While the focus of the US Forest Service has shifted over time there is a real swing back to actively managing forests for watershed values demonstrating that multiple use forests can be managed for more than just timber production.

In water supply catchments there is ample evidence from the US that investing in forest health to promote watershed protection is much cheaper and more efficient than letting catchments become degraded and having to rely on expensive filtration plants to treat the water. Prevention is better than cure. Examples cited in this report such as Quabbin, New York, Portland and Seattle demonstrate this argument in very clear economic terms that support building catchment resilience through forest land purchases, conservation easements, restoration thinning and sound riparian buffer and road management practices. A key to the success of these programs is community education and linking people with the forests that provide their drinking water; a hallmark of the Forest-to-Faucet partnerships. When people realise they are a “forest dependent species” they are more than willing to pay for forest management to safeguard their health. Forest management can also be an insurance policy against the threat of catastrophic damage that could be caused for example by wildfires or insect attack. Examples cited from Denver and Santa Fe again show that water users are willing to pay to see forests thinned and hazard reduction burning undertaken.

Forests can also play a role in point-nonpoint water quality trading programs. Forest landowners can be paid for offsetting nutrient loadings caused by point source polluters or landowners paid for planting trees to shade streams and offset thermal pollution from wastewater treatment plants. Credit is given where credit is due. The key to most of these solutions, solutions that can be profitable for forest owners and managers, is the development of markets in ecosystem services or more specifically in watershed services. Typically, Payments for Watershed Services (PWS) schemes involve exchanges of money or credits for activities that effect improvements in watershed values.

There needs to be demand for the services, i.e. buyers; a supply of service-providers, i.e. willing sellers; and a well-designed trading scheme supported by appropriate infrastructure and institutional frameworks, preferably utilising existing structures. Regulation often triggers a market but this need not always be the case. The US Government is committed to the further development of environmental markets as evidenced by the establishment of the USDA Office of Environmental Markets. The USDA along with a number of NGOs are working on metrics, protocols and pilot schemes that use market instruments to tackle environmental problems. Knowing where to invest is being helped by the development of tools such as the Conservation Priority Index (CPI) under the USFS-University of Massachusetts Forest-to-Faucet partnership, and the InVEST models developed as part of the Natural Capital project.

In Australia, given our reliance upon forests for drinking water supplies it makes sense to invest in these forests. PWS schemes could easily be used in catchments such as those supplying Sydney's drinking water, which are 60% privately owned, to purchase easements (or covenants) to protect and enhance the watershed services supplied. Point sources in the catchments, such as sewage treatment plants (STPs), rather than paying to pollute through an Environment Protection Licence, could be required to offset their pollution by trading in non-point pollution credits. Given the scale of the wildfires that have occurred in recent times in Victoria (Smith *et al.*, 2011) and near Canberra (White *et al.*, 2006) a shift towards more active management of forests, particularly in a changing climate, deserves further consideration. Singling out plantations as "users" of water in the Murray Darling Basin and elsewhere should be viewed through the broader lens of an ecosystem services model that recognises the salinity, soil conservation, water quality and other benefits that forests can provide. This will level the playing field with competing land uses that under an ecosystem services approach are less profitable. A recent assessment in Western Australia demonstrates with regard to salinity that this can certainly be the case (Townsend *et al.*, 2011).

While there will be hurdles to jump along the way, Australia is ripe for the introduction of PWS schemes. This report demonstrates that under the right conditions they can definitely be a win-win for forest managers and downstream water users.

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References

Barnes, M.C., Todd, A.H., Whitney Lilja, R. and Barten, P.K., 2009. Forests, Water and People: Drinking water supply and forest lands in the Northeast and Midwest United States, United States Department of Agriculture Forest Service, Newtown Square, PA.

Barten, P.K., 2006. Overview of forest hydrology and forest management effects, Sustainable Forest Management (SFM) Network - Hydro-Ecological Landscapes Project Workshop, University of Western Ontario.

Barten, P.K. and Ernst, C.E., 2004. Land conservation and watershed management for source protection. Journal of the American Water Works Association, 96(4): 121-136.

Barten, P.K., Nicolson, C. and VanDoren, W., 2010. Prioritizing land to protect drinking water supplies, University of Massachusetts, Forest to Faucet Partnership, Amherst.

Bent, G.C., 2001. Effects of forest management activities on runoff components and ground-water recharge to Quabbin Reservoir, central Massachusetts. Forest Ecology and Management, 143: 115-129.

Brauman, K.A., Daily, G.C., Ka'eo Duarte, T. and Mooney, H.A., 2007. The nature and value of ecosystem services: an overview highlighting hydrologic services. Annual Review of Environment and Resources, 32: 67-98.

Brooks, J.R., Barnard, H.R., Coulombe, R. and McDonnell, J.J., 2010. Ecohydrologic separation of water between trees and streams in a Mediterranean climate. Nature Geoscience, 3: 100-104.

Brooks, R.T. and Colburn, E.A., 2011. Extent and channel morphology of unmapped headwater stream segments of the Quabbin Watershed, Massachusetts. Journal of the American Water Resources Association, 47(1): 158-168.

Chichilnisky, G. and Heal, G., 1998. Economic returns from the biosphere. Nature, 391: 629-630.

City of Seattle, 2000. Final Cedar River Watershed Habitat Conservation Plan For the Issuance of a Permit to Allow Incidental Take of Threatened and Endangered Species, City of Seattle, Seattle.

Cochran, B. and Logue, C., 2011. A watershed approach to improve water quality: case study of Clean Water Services' Tualatin River program. Journal of the American Water Resources Association, 47(1): 29-38.

Collins, S. and Larry, E., 2007. Caring for our natural assets: An ecosystem services perspective, USDA Forest Service Pacific Northwest Research Station, Portland, Oregon.

Council of Australian Governments (COAG), 2004. Intergovernmental Agreement on a National Water Initiative, Council of Australian Governments, Canberra.

Conte, M., Ennaanay, D., Mendoza, G., Walter, M.T., Wolny, S., Freyberg, D., Nelson, E. and Solorzano, L., 2011. Retention of nutrients and sediment by vegetation. In: P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky (Eds), Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, pp. 89-110.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature, 387: 253-260.

Daily, G.C. (Ed.), 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington DC.

Daily, G.C. and Ellison, K., 2002. The New Economy of Nature: The Quest to Make Conservation Profitable. Island Press, Washington DC.

Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J. and Shallenberger, R., 2009. Ecosystem services in decision making: time to deliver. Frontiers in Ecology and the Environment, 7(1): 21-28.

Daniels, A.E., Bagstad, K., Esposito, V., Moulaert, A. and Rodriguez, C.M., 2010. Understanding the impacts of Costa Rica's PES: Are we asking the right questions? Ecological Economics, 69: 2116-2126.

Department of Conservation and Recreation (DCR), 2007. Quabbin Reservoir Watershed System: Land Management Plan 2007-2017, Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection, Office of Watershed Management.

Dissmeyer, G.E. (Ed.), 2000. Drinking Water from Forests and Grasslands: A Synthesis of the Scientific Literature, General Technical Report SRS-39. USDA Forest Service Southern Research Station, Asheville, North Carolina.

Donovan, G.H. and Prestemon, J.P., 2011. The effect of trees on crime in Portland, Oregon. Environment and Behaviour, in press.

Ennaanay, D., Conte, M., Brooks, K., Nieber, J., Sharma, M., Wolny, S. and Mendoza, G., 2011. Valuing land cover impact on storm peak mitigation. In: P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky (Eds), Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, pp. 73-88.

Ernst, C., 2004. Protecting the Source: Land Conservation and the Future of America's Drinking Water, The Trust for Public Land and American Water Works Association, Washington DC.

Ernst, C.E., Gullick, R. and Nixon, K., 2004. Protecting the Source: Conserving Forests to Protect Water. Opflow, 30(5): 3-7.

Foster, D.R. and O'Keefe, J.F., 2000. New England Forests Through Time: Insights from the Harvard Forest Dioramas. Harvard University Press, Cambridge, Massachusetts.

Friends of Quabbin, 1996. Quabbin Facts and Figures. Friends of Quabbin Inc & Metropolitan District, Commission Division of Watershed Management, Quabbin Section, Amherst, Massachusetts.

Front Range Watershed Protection Data Refinement Work Group, 2009. Protecting critical watersheds in Colorado from wildfire: A technical approach to watershed assessment and prioritization, Denver, CO.

Ghosh, G., Ribaudo, M. and Shortle, J., 2011. Baseline requirements can hinder trades in water quality trading programs: Evidence from the Conestoga watershed. Journal of Environmental Management, 92(8): 2076-2084.

Goulder, L.H. and Kennedy, D., 2011. Interpreting and estimating the value of ecosystem services. In: P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky (Eds), Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, pp. 15-33.

Gregory, P.E. and Barten, P.K., 2008. Public and private forests, drinking water supplies, and population growth in the eastern United States, University of Massachusetts, Forest to Faucet Partnership, Amherst.

Gregory, P.E., Zhang, Y. and Barten, P.K., 2008. Watershed Forest Management Information System (WFMIS) User's Guide Version 1.0, University of Massachusetts, Forest to Faucet Partnership, Amherst.

Heal, G., 2000. Valuing ecosystem services. Ecosystems, 3: 24-30.

Horan, R.D., Abler, D.G., Shortle, J.S. and Carmichael, J., 2002a. Cost-effective point-nonpoint trading: An application to the Susquehanna River basin. Journal of the American Water Resources Association, 38(2): 467-477.

Horan, R.D. and Shortle, J.S., 2005. When two wrongs make a right: second-best point-nonpoint trading ratios. American Journal of Agricultural Economics, 87(2): 340-352.

Horan, R.D. and Shortle, J.S., 2011. Economic and ecological rules for water quality trading. Journal of the American Water Resources Association, 47(1): 59-69.

Horan, R.D., Shortle, J.S. and Abler, D.G., 2002b. Point-nonpoint nutrient trading in the Susquehanna River basin. Water Resources Research, 38(5): 8-1 - 8-13.

Hornbeck, J.W., Adams, M.B., Corbett, E.S., Verry, E.S. and Lynch, J.A., 1993. Long-term impacts of forest treatments on water yield: a summary for northeastern USA. Journal of Hydrology, 150: 323-344.

Hornbeck, J.W., Martin, C.W. and Eagar, C., 1997. Summary of water yield experiments at Hubbard Brook Experimental Forest, New Hampshire. Canadian Journal of Forest Research, 27(12): 2043-2052.

Hornbeck, J.W., Martin, C.W., Pierce, R.S., Bormann, F.H., Likens, G.E. and Eaton, J.S., 1987. Northern hardwood forest ecosystem: ten years of recovery from clearcutting. NE-RP-596, USDA Forest Service Northeastern Forest Experiment Station, Broomall, PA.

Kareiva, P., Tallis, H., Ricketts, T.H., Daily, G.C. and Polasky, S. (Eds), 2011. Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford.

Kroeger, T. and Casey, F., 2007. An assessment of market-based approaches to providing ecosystem services on agricultural lands. Ecological Economics, 64: 321-332.

Kyker-Snowman, T., 2000. Managing the shift from water yield to water quality on Boston's water supply watersheds. In: G.E. Dissmeyer (Ed.), Drinking Water from Forests and Grasslands: A Synthesis of the Scientific Literature. USDA Forest Service, Asheville, North Carolina, pp. 212-214.

Le Master, D.C., Shao, G. and Donnay, J., 2007. Protecting Front Range Watersheds from High-Severity Wildfires, Pinchot Institute for Conservation, Washington DC.

MacDonald, L.H. and Stednick, J.D., 2003. Forests and Water: A State-of-the-Art Review for Colorado. CWRRI Completion Report No. 196, Colorado State University, Fort Collins, CO.

Martin, P. and Verbeek, M., 2006. Sustainability Strategy. The Federation Press, Sydney.

Martin, P., Werren, K. and Shearing, S., 2007. Concepts for private sector funded conservation using tax effective instruments, Land and Water Australia, Canberra.

Martin, P., Williams, J. and Stone, C., 2008. Transaction costs and water reform: the devils hiding in the details. Technical Report 08/08, CRC for Irrigation Futures, Armidale.

McDonnell, J.J., McGuire, K., Aggarwal, P., Beven, K.J., Biondi, D., Destouni, G., Dunn, S., James, A., Kirchner, J., Kraft, P., Lyon, S., Maloszewski, P., Newman, B., Pfister, L., Rinaldo, A., Rodhe, A., Sayama, T., Seibert, J., Solomon, K., Soulsby, C., Stewart, M., Tetzlaff, D., Tobin, C., Troch, P., Weiler, M., Western, A., Worman, A. and Wrede, S., 2010. How old is streamwater? Open questions in catchment transit time conceptualisation, modelling and analysis. Hydrological Processes, 24: 1745-1754

Murray Darling Basin Authority (MDBA), 2010. Guide to the proposed Basin Plan: overview, Canberra.

Millenium Ecosystem Assessment (MEA), 2005. Ecosystems and human well-being: synthesis. Island Press, Washington DC.

Mendoza, G., Ennaanay, D., Conte, M., Walter, M.T., Freyberg, D., Wolny, S., Hay, L., White, S., Nelson, E. and Solorzano, L., 2011. Water supply as an ecosystem service for hydropower and irrigation. In: P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky (Eds), Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, pp. 53-72.

Moody, J.A. and Martin, D.A., 2001. Initial hydrologic and geomorphic response following a wildfire in the Colorado Front Range. Earth Surface Processes & Landforms, 26: 1049-1070.

Napper, C., 2006. Burned Area Emergency Response Treatments Catalog, USDA Forest Service, Washington DC.

Nelson, E., Montgomery, C., Conte, M. and Polasky, S., 2011. The provisioning value of timber and non-timber forest products. In: P. Kareiva, H. Tallis, T.H. Ricketts, G.C. Daily and S. Polasky (Eds), Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, Oxford, pp. 129-149.

Nordblom, T.L., Christy, B.P., Finlayson, J.D., Roberts, A.M. and Kelly, J.A., 2010. Least cost land-use changes for targeted catchment salt load and water yield impacts in south eastern Australia. Agricultural Water Management, 97: 811-823.

NYC DEP, 2011. 2011 Watershed Protection Program Summary and Assessment, New York City Department of Environmental Protection, New York.

O'Grady, D., 2011. Sociopolitical conditions for successful water quality trading in the South Nation River watershed, Ontario, Canada. Journal of the American Water Resources Association, 47(1): 39-51.

Parsons, A., Robichaud, P.R., Lewis, S.A., Napper, C. and Clark, J.T., 2010. Field Guide for Mapping Post-Fire Soil Burn Severity. General Technical Report RMRS-GTR-243, USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Postel, S. and Richter, B., 2003. Rivers for Life: Managing Water for People and Nature.

Postel, S.L. and Thompson, B.H.J., 2005. Watershed protection: Capturing the benefits of nature's water supply services. Natural Resources Forum, 29: 98-108.

Powell, I., White, A. and Landell-Mills, N., 2002. Developing Markets for the Ecosystem Services of Forests, Forest Trends, Washington DC.

Robichaud, P.R., Ashmun, L.E. and Sims, B.D., 2010. Post-Fire Treatment Effectiveness for Hillslope Stabilization. General Technical Report RMRS-GTR-240, USDA Forest Service Rocky Mountain Research Station, Fort Collins, CO.

Robichaud, P.R., Wagenbrenner, J.W., Brown, R.E., Wohlgemuth, P.M. and Beyers, J.L., 2008. Evaluating the effectiveness of contour-felled log erosion barriers as a post-fire runoff and erosion mitigation treatment in the western United States. International Journal of Wildland Fire, 17: 255-273.

Sagoff, M., 2002. On the value of natural ecosystems: The Catskills parable. Politics and the Life Sciences, 21(1): 16-21.

Salzman, J., 2005. Creating markets for ecosystem services: notes from the field. New York University Law Review, 80: 870-961.

Salzman, J., 2006. A field of green? The past and future of ecosystem services. Journal of Land Use & Environmental Law, 21: 133-151.

Salzman, J., 2011. What is the emperor wearing? The secret lives of ecosystem services. Pace Environmental Law Review, 28(2): 591-613.

Santa Fe, 2009. Santa Fe Municipal Watershed Plan 2010-2029, Santa Fe, New Mexico.

Schoennagel, T., Veblen, T.T. and Romme, W.H., 2004. The interaction of fire, fuels, and climate across Rocky Mountain forests. Bioscience, 54(7): 661-676.

Shortle, J.S. and Horan, R.D., 2001. The economics of nonpoint pollution control. Journal of Economic Surveys, 15(3): 255-289.

Shortle, J.S. and Horan, R.D., 2006. Water quality trading. Penn State Environmental Law Review, 14: 231-249.

Shortle, J. and Horan, R.D., 2008. The economics of water quality trading. International Review of Environmental and Resource Economics, 2: 101-133.

Smith, H.G., Sheridan, G.J., Lane, P.N.J., Nyman, P. and Haydon, S., 2011. Wildfire effects on water quality in forest catchments: A review with implications for water supply. Journal of Hydrology, 396: 170-192.

Stanton, T., Echavarria, M., Hamilton, K. and Ott, C., 2010. State of Watershed Payments: An Emerging Marketplace, Forest Trends, Ecosystem Marketplace, Washington DC.

Steffens, M., 2011. Philanthropy is big business - except in corporate Australia, Sydney Morning Herald, Sydney. www.smh.com.au/business/philanthropy-is-big-business--except-in-corporate-australia-20110603-1fktm.html

Townsend, P.V., Harper, R.J., Brennan, P.D., Dean, C., Wu, S., Smettem, K.R.J. and Cook, S.E., 2011. Assessment of multiple environmental services as an opportunity for watershed restoration in south-western Australia. Forest Policy and Economics, in press.

USDA, 2007. Watershed Services: The important link between forests and water, United States Department of Agriculture, Washington DC.

USFS, 2007. USDA Forest Service Strategic Plan FY 2007-2012, United States Department of Agriculture Forest Service, Washington DC.

VanDoren, W., 2010. Prioritizing land to protect drinking water supplies, University of Massachusetts, Forest to Faucet Partnership, Amherst.

Webb, A.A., 2009. Streamflow response to *Pinus* plantation harvesting: Canobolas State forest, southeastern Australia. Hydrological Processes, 23: 1679-1689.

Webb, A.A., 2012. Can timber and water resources be sustainably co-developed in southeastern New South Wales, Australia? Environment, Development and Sustainability, 14: 233-252.

Webb, A.A. and Kathuria, A., 2012. Response of streamflow to afforestation and thinning at Red Hill, Murray Darling Basin, Australia. Journal of Hydrology, 412-413: 133-140.

Wemple, B.C. and Jones, J.A., 2003. Runoff production on forest roads in a steep, mountain catchment. Water Resources Research, 39(8): 1-17.

Wemple, B.C., Swanson, F.J. and Jones, J.A., 2001. Forest roads and geomorphic process interactions, Cascade Range, Oregon. Earth Surface Processes & Landforms, 26: 191-204.

Wentworth Group of Concerned Scientists, 2002. Blueprint for a Living Continent, WWF Australia, Sydney.

Wentworth Group of Concerned Scientists, 2003. Blueprint for a National Water Plan, WWF Australia, Sydney.

Wentworth Group of Concerned Scientists, 2008a. Accounting for Nature: A Model for Building the National Environmental Accounts of Australia, WWF Australia, Sydney.

Wentworth Group of Concerned Scientists, 2008b. Senate Submission: The Urgent Provision of Water to the Coorong and Lower Lakes, WWF Australia, Sydney.

Wentworth Group of Concerned Scientists, 2010. Sustainable Diversions in the Murray-Darling Basin: An Analysis of the Options for Achieving a Sustainable Diversion Limit in the Murray-Darling Basin, WWF Australia, Sydney.

White, I., Wade, A., Worthy, M., Mueller, N., Daniell, T.M. and Wasson, R., 2006. The vulnerability of water supply catchments to bushfires: impacts of the January 2003 wildfires on the Australian Capital Territory. Australian Journal of Water Resources, 10(2): 179-194.

Wilkinson, S.N., 2008. Testing the capability of a sediment budget model for targeting remediation measures to reduce suspended-sediment yield. In: J. Schmidt, T. Cochrane, C. Phillips, S. Elliott and L. Basher (Eds), Sediment Dynamics in Changing Environments. IAHS Publication 325, Wallingford, pp. 559-566.

Williams, J. and Martin, P., 2009. Ecosystem services: a means to diffuse political land use decisions in peri-urban regions. WIT Transactions on Ecology and the Environment, 122: 279-291.

Williams, J., Martin, P. and Stone, C., 2010. Using Ecosystem Services as a Means to Diffuse Political Land Use Decisions in Peri-Urban Areas. Technical Report 06/10, CRC for Irrigation Futures, Armidale.

Zhang, Y. and Barten, P.K., 2009. Watershed Forest Management Information System (WFMIS). Environmental Modelling & Software, 24: 569-575.

Appendix 1: Travel details, institutions and persons visited and/or consulted

Date	Travel/Location	Venue	Persons
Sat 9 April	Coffs Harbour to Washington DC (plane)		
Mon 11 April	Washington DC	US Forest Service + USDA	Kathryn Smith, Beth Larry, Greg Arthaud, Amy Daniels, Al Todd, Nicole Balloffet, Deb Hayes, Glen Contreras
Tues 12 April	AM – Washington DC PM – Washington DC to Boston (plane)	World Resources Institute + Forest Trends	Todd Gartner (WRI), Kate Hamilton (FT)
Wed 13 April	AM – Boston to Quabbin Reservoir (car) PM – Quabbin to Amherst, MA (car)	Massachusetts Department of Conservation and Recreation	Jonathan Yeo, Thom Kyker-Snowman, Bill Pula, Herm Eck, Dave Small
Thur 14 April	AM – Amherst PM – Amherst to West Suffield, CT (car)	University of Massachusetts	Paul Barten, Bill VanDoren, Craig Nicolson, Paul Hunt (Portland Water District), John Gunn (Manomet Center), Lee Dassler (Western Foothills Land Trust), Stephen Johnson (Harvard Forest)
Fri 15 April	AM – West Suffield to New Haven, CT (car)	Yale University	Brad Gentry, Jen Hoyle, Tim Hawley (South Central CT Regional Water Authority), Dianne Tompkins (SCCRWA)
Fri 15 April		Teleconference	Brad Gentry, Jenn Hoyle, Dave Warne (New York DEP), Deb Layton (DEP), Jeff Graf (DEP), Paul Lenz (DEP), Fred Gleising (DEP), John Schwartz (DEP),

Date	Travel/Location	Venue	Persons
			Larry Beckhardt (DEP), Mike Usai (DEP)
Sat 16 April	New Haven to New York City (car)		
Mon 18 April	PM – New York to Seattle (plane)	Phone conversation	Jim Shortle, Penn State University
Tues 19 April	Cedar River Watershed	Seattle Public Utilities	Dwayne Paige, David Chapin and Fish & Wildlife Unit staff
Wed 20 April	AM – Seattle	Ecosystem Marketplace	Tracy Stanton, Hannah Kett
	PM – Seattle to Portland (car)		
Thur 21 April	AM – Portland	Willamette Partnership (AM)	Devin Judge-Lord (WP)
	PM – Portland to Corvallis (car)	Bonneville Environmental Foundation (PM)	Todd Reeve, Kendra Smith (BEF)
Fri 22 April	Corvallis	Oregon State University	Jeff McDonnell, postdocs and postgraduate students
Sat-Sun 23-24 April	Corvallis to San Francisco (car)		
Mon 25 April	AM – San Francisco	Stanford University	Gretchen Daily, Marc Conte
	PM – San Francisco to Albuquerque, NM (plane)		

Date	Travel/Location	Venue	Persons
Tues 26 April	Santa Fe, NM	US Forest Service + Santa Fe Watershed Association	Sandy Hurlocker (USFS), Felicity Broennan (SFWA)
Wed 27 April	Santa Fe to Denver, CO (car)	Phone conversation	Nikola Smith, USFS Pacific Northwest
Thur 28 April	Denver (Golden)	US Forest Service + Denver Water	Claire Harper, Polly Hays, Tommy John, Joan Carlson, Susie Weingardt, Rick Cables (USFS), Marc Waage + staff (DW)
Fri 29 April	Denver Water reservoirs + watersheds (car)	Self-guided	
Sat 30 April – Mon 2 May	Denver to Coffs Harbour (plane)		
Tue 31 May	Telephone conversation (10pm)	Chesapeake Fund, Washington DC	Dan Nees

Appendix 2 – Seminars given in the US

An hour long seminar titled "Forests, water management and research in New South Wales, Australia", varied depending on the audience, was given at the following locations:

1. US Forest Service, Washington DC (11/4/11)

2. Massachusetts Department of Conservation and Recreation, Quabbin Reservoir (13/4/11)

3. University of Massachusetts, Amherst (14/4/11)

4. Yale University (15/4/11), including a second abbreviated presentation on the teleconference with New York City DEP personnel

5. Seattle Public Utilities, Cedar River watershed (19/4/11)

6. Bonneville Environmental Foundation, Portland (21/4/11)

7. Oregon State University, Corvallis (22/4/11)

8. Denver Water, Denver (28/4/11)