agricultural use can dominate. Small reservoirs permit the capture of excess winter flows and therefore ensure summer supply without environmental conflict. The farmer can then plan cropping and product supply with far greater certainty.

- Sustainable drainage systems (SUDS) comprise a variety of localised interventions that mimic natural catchment responses. In order to slow water passage over seasonal time frames to provide benefit for water resources, SUDS that direct runoff into the ground such as permeable paving, should be prioritised.
- Aquifer storage and recovery (ASR) describes the process of pumping excess surface water flows below ground to be utilised in the future, often in response to droughts. Several schemes exist, contributing small additions to the supply resource, although larger schemes are present in the Lee Valley and at Enfield-Harringey in London.

A primary constraint upon the application of supply enhancement measures is the common requirement for high upfront investments that may initially outweigh financial gain. Securing funding is therefore of key importance, and in this respect consideration should be given to the price we assign to water. When compared against the cost of other household outgoings, notably those for energy, water comprises such a small proportion that for all but the poorest, any incentive to reduce usage is small or absent. An increase in annual household bills of £100, whilst pricing water still a long way short of its true economic value, would provide additional potential annual investments to the water industry of £2.4 billion, an amount not inconsistent with infrastructure investments in other sectors. Clearly, the value of safeguarding our future water security is incalculable. However, as an indicator it is estimated that the Environment Agency's regulation of abstraction protects resources worth some £72 billion.

The above discussion demonstrates how consideration of water storage measures provides a viable means of increasing water resource security and resilience to future climate change. Furthermore, by combining intervention measures that act at different geographic scales, alignment can be achieved both with the general concept of slowing down water throughout the catchment, and with the widely prophesised aim of a 'big society' in which integrated communities consider their wider environment. In view of the long time that storage projects take to promote we should be considering options now.

RESEARCH AND TRAINING: UNIVERSITY PARTNERSHIPS FOR A BETTER RAILWAY

John Amoore
R&D Specialist, Network Rail

Britain's railway is a world leader in research and innovation. The company is advancing research and developing engineering talent at all levels – all in the cause of delivering the railway Britain needs.

DEVELOPING A LONG TERM RESEARCH STRATEGY

The railway is an industry where long term forward planning is essential. Short-term, incremental work only gets the industry so far; by investing in longer term research we can deliver a much improved railway in the future.

All Network Rail's research and development and innovation activities address at least one of the major challenges facing the industry, known as the 'four Cs':

- CAPACITY: increasing the capacity of the railway;
- CUSTOMERS: delivering a service to meet the rising expectations of passengers;
- CARBON: improving rail's environmental performance;
- COST: improving the overall cost effectiveness of the railway.

The railway is already much improved on where it was, but keeping up with growing demand for travel and delivering value for money needs us to keep pushing ahead. Rail is carrying record numbers of passengers and freight on a network that is safer and more reliable than ever.

Passenger demand has grown by 40% and freight by 60% over the last decade. Of 1.3 billion annual passenger journeys, 1 billion are by commuters and business travellers, almost all on the key networks vital for the economy and into or between the urban centres in which many of the most productive parts of the economy are located. The rail freight industry supports economic output of £5.9 billion, six times its direct turnover. Commuter demand is expected to increase by at least 22% by 2014 and passenger growth of 39-54% is expected in major northern cities over the next decade. Rail demand is projected to grow by 30% over the next decade and up to 140% over 30 years.

Research helps Network Rail take costs out of the industry by delivering efficiency savings. In the last 5 year regulatory period (2004-9), Network Rail reduced costs by 27%. In the next 5 years up to 2014 we are required to build on this by meeting a 22% efficiency target, which amounts to a saving of £4 billion. Network Rail is committed to driving costs down further, in line with the current Value for Money inquiry by Sir Roy McNulty. Research and

technology will be a key part of this.

RESEARCH PARTNERSHIPS WITH UNIVERSITIES

Network Rail's commitment to research has led us to develop strong links with British universities. This includes funding Professorial chairs at three universities, funding PhD students and leading bids for funding from the Research Councils and the EU. In fact, Britain now receives more EU research funding for rail than any other country, in no small part due to the strength of collaboration between Network Rail and British universities.

Network Rail has established three strategic research chairs at the Universities of Nottingham, Sheffield and Imperial College London, recognising the advantages of longer term relationships and allowing the universities to build a centre of excellence in railway engineering. Each University has a specific theme of specialisation although they may propose a research project on any subject where they have a capability.

From the start of its research programme, Network Rail has collaborated with the University of Birmingham to develop remote monitoring systems for railway track-side assets, such as point machines, level crossing barriers and track circuits. Failure of track circuits and point machines are two of the largest causes of train delay. In partnership with Japan's Central Railways and Deutsche Bahn, Birmingham is also further developing expertise in advanced algorithms for detecting incipient failure as part of Network Rail's Intelligent Infrastructure project.

One of the early themes of our research programme was Rolling Contact Fatigue (RCF), essentially wear and tear caused by vehicles going over rails. This led to a contract with the Rail Technology Unit at Manchester Metropolitan University to produce software capable of replicating the design and track quality of any track route. When used with a detailed computer simulation of train design, it will predict suitability of a train for a specified route. This is used to evaluate all new train designs and determine where vehicles may need to be modified. We are currently funding testing of an innovative suspension spring which is able to provide 'soft' and 'hard' characteristics to both reduce forces on the track and give passengers a comfortable ride at speed.

We have also used our RCF research to develop analysis tools to predict where and when rail failures will occur, reduce their severity and extend track asset lives. Reduced rail degradation means a safer, more reliable and lower cost railway.

We have also supported PhD projects, with some very interesting outputs. One recent thesis on the effects of climate change on the rail network was done at Birmingham. It has informed a lot of our adaptation plans, as well as developing new relationships on this subject with a range of universities. We are currently supporting one of Network Rail's staff in his PhD work on sustainable station building, in the Department for the Built Environment at Nottingham University.

Perhaps more important than directly providing funding, Network Rail is able to use its unique position and expertise to work with universities to leverage large amounts of research funding for rail. The UK is now the largest recipient of EU funding for rail research, in addition to funding from the Engineering and Physical Sciences Research Council.

Future projects include work to increase the resistance of track to loads from vehicles which would reduce maintenance needs, and automating maintenance processes, with significant cost and safety benefits. These two projects have received over €9 million EU funding. We are also hoping to take forward 'On-time', which will explore real-time rescheduling of trains when delays occur. This will start in late 2011 if funding is approved by the European Commission.

TRAINING THE NEXT GENERATION OF ENGINEERS

In addition to our high-level research, Network Rail is one of the country's biggest investors in vocational training and development. This is because we have a continuing need for young rail technicians and engineers to help deliver the schemes and develop the technological advances needed to deliver a high-performing railway safely and efficiently to meet strongly growing demand from passengers and freight.

Our further and higher education programmes range from apprenticeships through to post-graduate qualifications to train the technicians, incorporated and chartered engineers that Network Rail and the broader industry will need in future.

Network Rail's award winning advanced apprenticeship scheme is one of the largest in the country. It is based at a residential facility at HMS Sultan in Gosport, Europe's largest engineering training facility, and combines high quality technical training with personal development. The apprentices specialise in one of track; signalling and telecoms; or electrification and plant.

Network Rail has trained 1,250 skilled maintenance engineering technicians since it launched in 2005. Our scheme will train a further 1,200 apprentices in the next five years and this year's intake of 201 apprentices have just begun their three year programme.

Over the past three years Network Rail has also recruited 469 graduates, 28% in an engineering discipline. Our graduate engineering development programme, with an intake of around 50 per annum, is accredited by leading engineering institutions, IMechE, IET, and ICE.

Network Rail has developed a Foundation Degree and BEng degree in rail engineering in partnership with Sheffield Hallam University and launched an MSc in project management in partnership with University College London and the University of Warwick.

Network Rail also assists universities in running seminars and international conferences on railway engineering. Some also have laboratory facilities specifically for railway engineering. These activities increase student awareness of the challenges and opportunities offered by rail engineering.

Network Rail's research, innovation and education programmes are vital to driving up the safety, performance, efficiency and economic contribution of the railway in this country and abroad. For the wider economy and further/higher education sectors, these schemes are crucial in equipping a new generation of young people with STEM skills and providing and leveraging much needed research funding and expertise for some of Britain's leading universities.