TITLE: **Cross Cultural Sustainability: Managing our "liquid assets"**

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PURPOSE: A Technical Presentation for 24th Annual International Irrigation Show, November 18-20, 2003, San Diego, CA.

ABSTRACT: Water conservation is an international issue. According to a report by the United Nations Commission on Sustainable Development, world water use has grown at more than twice the rate of the population increase during the past century. International collaborations between landscape architects and irrigation consultants optimize the application of sustainability best practices.

INTRODUCTION

Proactive members of the irrigation industry are beginning to recognize that they need to rethink or revise the methods by which water is used in their irrigation designs. Their thinking is being stretched throughout a site's water resource map from the water source(s) to the root zone. Water resource awareness has begun to require involvement in issues far beyond the individual site including river catchments, aquifer replenishment, and drainage, especially in urban areas. Increased density of the population and unreliable water sources conspire to bring attention to ways to mitigate the impact of contaminated water run-off and alternative sources for irrigation in cities. Sustainability awareness has become an active issue through forces as critical as the increasing cost and decreasing availability of water sources for irrigation world wide and external criteria such as LEED[1] building criteria. Place-specific, problem-specific solutions using collaborative processes involving landowners, developers, municipalities, water suppliers, architects, landscape architects, civil engineers, contractors and irrigation engineers from around the world need to be developed and implemented to meet the increased demand for irrigation by a growing world population.

The latest statistics report a projected worldwide population of over 9 billion by 2050.[2] With already intense strains on water resources to meet current needs for food and potable water, the call for innovation is tremendous. Two-thirds of the world's fresh water withdrawn for human use goes toward irrigation.[3] Therefore, the ways in which the irrigation industry manages water has a huge impact on how well it is conserved worldwide. Many Best Management Practices have been adopted by the industry to conserve water. Quality design is promoted to ensure efficient pump operation and high distribution uniformity. Instead of flooding crops, point-source drip irrigation systems are installed. Weather stations incorporated into a system measure daily rainfall and evapotranspiration (ET) rates. However, the limits of these methods are that they still exhaust a finite water supply. Are there ways to irrigate without drawing down water resources, albeit slowly?

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[1] The U.S. Green Building Council's Leadership in Energy and Environmental Design Green Building Rating System: http://www.usgbc.org
[2] Sustainable Development International: www.sustdev.org/industry.news/042000/0062.shtml
[3] Scientific American: www.sciam.com Feb 2001 article "Growing More Food with Less Water"

This presentation aims to highlight several cross-cultural examples of irrigation and drainage techniques that can be categorized as "sustainable". Thus, a definition of sustainable design is necessary. The concept of sustainable design holds that technologies must maintain environmental integrity, contribute to the quality of the water, and reduce the impact of human use.[4] So the goal becomes to reuse water, not deplete it. Already in several parts of the world, projects have been designed to reflect the principles of sustainable drainage. We will address these issues through our work in England and the United States using a variety of sites to illustrate the issues outlined above.

WORLD CLIMATE CHANGE

The world's climate is changing, and combined with rises in sea level and an average temperature increase of 3°C [37.4°F] by the year 2100, the current trend points towards a 10% increase in annual rainfall in the UK by 2080.[5] Although annual rainfall is increasing, it is the change in rainfall patterns that are of most concern. 80% of all rainfall in the UK is now received in autumn and winter, resulting in regular annual flooding of low-lying areas. The drier and hotter summer months result in a higher seasonal demand for water, which relies on the extraction of groundwater for potable water. The increase of built development on river catchments is also having an effect on the volume and quality of surface water runoff reaching groundwater aquifers. On top of this, the British continental shelf is sinking in the south, and rising in the north, with the result that London is under constant threat of both tidal and storm water surges.

THE EMERGENCE OF A SUSTAINABLE APPROACH

Figure 1: The increased capacity to remove rainwater from our streets and towns compounds flooding problems and removes the potential for groundwater recharge. Image Atelier Dreiseitl

AGENDA 21

At the Rio Earth Summit in 1992, Governments of the world were encouraged to 'Think globally and act locally' to preserve the world's resources for future generations. One of the agreements signed at The Rio Conference was Agenda 21, an agenda to take us into the 21st Century. It is a 40-chapter document that examines the interconnectedness of social, economic and environmental issues and addresses the problems of today while considering the needs of the future. Agenda 21 outlines objectives and actions that can be taken at local, national and international levels and provides a comprehensive blueprint for nations throughout the world who are starting to make the transition to sustainability. Chapter 28 of the Agenda 21 document calls on local authorities to work with their local communities to achieve a local action plan, a 'Local Agenda 21.' One of the key objectives of Local Agenda 21 was the prudent use of natural resources and the preservation of the environment for enjoyment by future generations. Fresh water has long been recognized as one of the world's most precious resources, and one that is in steady decline through the effects of climate change and through man's destruction of natural ecosystems. In the context of sustainable development, water has been recognized as an important and renewable resource that needs to be carefully managed if we are to meet the needs of the next generation. According to worldwide conservation bodies, water is a good indication of how far we have come in attaining some level of sustainable living.[6]

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[4] National Parks Service, Denver Service Center www.nps.gov/dsc "Guiding Principles of Sustainable Design" Chapter 1
[5] Source: DEFRA, *Impacts of Climate Change, Implications for DETR, 14.12.01*
[6] Fottrell Q 'On the Waterfront' *Landscape Design* September 1995 p10

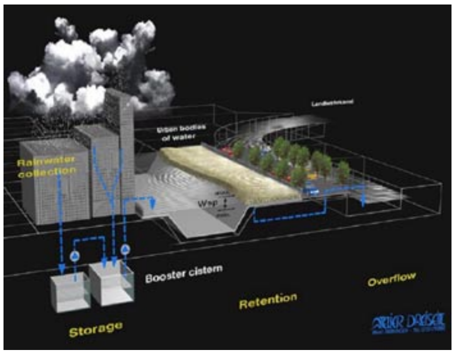
SUSTAINABLE URBAN DRAINAGE SYSTEMS

From as early as the 1970's, studies in Europe began to assess the effects of urban development on river catchments. The increased efficiency at which engineered drainage systems remove water from our cities and channel it into already overloaded river corridors has resulted in severe downstream flooding, especially in low lying countries. In the Netherlands, which receives some of the major rivers in Europe including the Rhine and the Meuse, the Dutch must contend not only with the changing characteristics of their own land, but those of France, Germany and Switzerland. The response to this increase in floodwater has been to construct raised riverbanks, canals, dikes and channels and the Rhine alone has had 70 kilometres [43.5 miles] of meanders and bends straightened out.[7] This means that the rivers flow fuller and faster into the Netherlands, thus compounding the problem.

Figure 2: Increasing urbanisation of river catchments force stormawater runoff into ever constricted chanels. Image Atelier Dreiseitl

Sustainable urban drainage systems or SUDS were developed as an alternative to the engineered drainage response to flooding. SUDS sought to balance the effects of increased runoff from hard surfaces by slowing down the rate at which water is channelled into river catchments, and to allow time for rainwater to infiltrate back into the ground to recharge subterranean aquifers. Typically the solution was to increase on site attenuation and filtration of rainwater runoff in order to balance out the peak flows and reduce the incidence of silt and pollution migration into stream systems. Although initially concerned with the quality and quantity of discharge from urban developments, SUDS have become widely adopted as best practice for developments regardless of their location. The creation of open ditches, attenuation ponds and storm water wetlands not only improves the quality of water systems downstream, but also improves the quality of the environment within a site whether it is urban or rural. We have recently used sustainable drainage systems on colliery regeneration schemes to trap and filter and attenuate runoff containing potentially damaging levels of nitrates and phosphates before it is discharged into sensitive wetlands and adjoining watercourses.

TOTAL CATCHMENT PLANNING



The term "total catchment planning" came about through an understanding that the prevention of flooding, the preservation of the environment and protection of water quality were dependent on the responsible management of development within entire river systems. Total catchment planning depends on government policy to provide guidance and control over the way in which development is allowed to proceed, and the standards of design and implementation that are required. An overall stewardship of the landscape in which government agencies, developers, designers and the community are involved in the decision making process has led to a remarkable change in environmental standards and development approach.

[7]Vidal J; 'So Who's to Blame Then' *The Guardian* 3 February 1995 p4

In cities such as Berlin, which sits on a high water table and deep deposits of glacial sand, a mandate was passed which prevented new developments from discharging rainfall into the sewage system. Instead new developments had to attenuate rainfall on site until it could be discharged on site either through soil infiltration or through evapotranspiration. This prompted a huge increase in the number of roof gardens being built in the city as a means of attenuating rainfall on the rooftops of buildings and as a primary point of off site discharge through evapotranspiration. The Debis building on Pottsdamer Platz is a superb example of water management on confined urban sites. The entire site is built over transport and service infrastructure, so there is no possibility for soil infiltration. Rainwater that falls on the site is collected and stored in large underground cisterns and used to supply irrigation systems for the roof gardens and toilet flushing. Grey water from washbasins and cleaning is stored in a large attenuation pond where it is passed through a reed bed filtration system before being discharged into the adjoining Land-wehrkanal[8]. The scheme is the brainchild of Atelier Dreisetl in Germany who has also designed drainage systems for large housing schemes that not only have a decorative and aesthetic character, but also have little or no impact on surrounding watercourses. In their most ambitious scheme, they are developing the drainage concept for a new town in Austria that will co-exist with an existing wetland. Rather than sweeping water away into underground systems, a new generation of designers is integrating drainage design into the site character in order to enhance the quality of the water catchment.

Figure 3: Rainwater and grey water recycling, Potsdamer Platz Berlin. Images Atelier Dreiseitl

A NEW APPROACH

EMERGING EU LEGISLATION

Legislation has always played a large role in the development of sustainable development policies. In December 2000 the Water Framework Directive was introduced to all EU member states. The WFD requires all inland and coastal waters to reach 'good status' by 2015. It will establish a river basin district structure within which demanding environmental objectives will be set, including ecological targets for surface waters. The first objective of the WFD states that 'Water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such.' The directive identifies water as a community resource that transcends the boundaries of nations and must be protected on a total catchment basis that may extend outside of the territories of the EU.

Figure 4: Grass swale in housing estate, Hannover Germany. Image Atelier Dreiseitl

This is the first piece of legislation to recognise the principles of Total Catchment Planning and to implement policies for the protection of watercourses, which not only flow through but also originate or terminate outside of the jurisdiction of member states. One of the most powerful objectives is the power granted to member states under the directive to prosecute polluters in order to provide funding for the environmental regeneration of surface waters. This lays down a responsibility for developers to not only prevent pollution from occurring, but to prevent existing pollution from escaping into river catchments.

[8] Waterscapes – Planning, Building and Designing with water. H Dreiseitl, 2001, Birkhauser

ZERO HYDROLOGICAL IMPACT DESIGN

A sustainable design approach which involves a much more holistic appraisal of the site has been developed within our practice ahead of a growing trend towards total catchment planning. We call our approach Zero Hydrological Impact (ZHI) design. In assessing the brief for a site we will assess the site characteristics, including the physical, geotechnical, cultural, and economical assets, and explore ways in which the brief for the site can be achieved while maximising the ecological amenity value that the landscape contributes the surrounding community. This means that the site must integrate with its surroundings, without any adverse effect on visual appearance, land use, water quality, wildlife habitat or cultural value of surrounding sites. In all cases it is preferable to involve the local community, use local materials, and employ local industry to develop a scheme that has a local identity. The issues that we are dealing with however have received international interest.

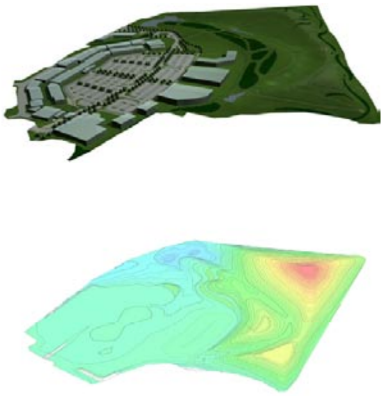


Figure 5: Terrain Modelling Dalton Park

A recent scheme in County Durham, near Newcastle, involved the moving of over 600,000m^3 [784,770yd^3] of colliery shale to create the footprint for a retail outlet centre in an economically deprived community. A culvert that carried a stream beneath the site was subject to collapse and therefore could not be further surcharged with site spoil. The removal of the site spoil was not viable from an economic and logistical point of view, and while the material was inert, it was unable to sustain vegetation. Using digital terrain modelling software we were able to determine cut and fill quantities for the site that gave us gradients of less than 1:3, as well as being able to determine the watershed characteristics of the new landform. We were able to determine where slope stabilisation would be required, and the direction and velocity of site runoff. By commissioning a soil scientist we were able to determine the likelihood of pollution migration from the colliery shale, and to identify locally available soil ameliorants (dried sewage sludge) that would enable us to establish a variety of vegetation habitats on the site. This meant that we were able to use waste products to sustain vegetation on the site rather than stripping another site of its topsoil in order to remediate this one.

Figure 6: Dalton Park Ephemeral stream and Balancing Pond

During the site excavations deposits of sand and clay were found on site, and carefully stockpiled. The clay was later used to line the stream and lake areas, while the sand was used to create growing media for the wetland planting zones where the sewage sludge was not permitted to be used. Over seven different habitat zones were created from material that was once considered waste, and two balancing ponds, a filtration pond, three wetland filter zones, an ephemeral streambed and numerous silt trapping plant colonies were created. The resulting landscape of sculpted earth, woodlands, wetlands, lakes and meadows is now a park which forms an educational facility for local school children and to visitors alike.

ZHI design assesses the potential for existing or new pollutants to become mobile on site and the level of filtration and attenuation required on site to prevent escape. It also ensures that increases in hard surfaces are balanced by on site attenuation to ensure that discharge from the site remains consistent with the coefficient of a greenfield site.

Sometimes our work involves planning for developments within river floodplains. Although buildings are often protected from flood damage by being constructed on raised plateaus or piers, the river is often not protected from oil or pollutants associated with car parking in areas below the flood level. We have recently devised strategies that ensure that the first flush of runoff from sites subject to flooding is directed into water storage cisterns below ground. Although silt traps are effective in removing suspended solids from rainwater runoff, once breached by floods, petrol and oil interceptors often release their captive pollutants into the watercourse. By collecting site runoff in underground cisterns, pollutants can be slowly released through storm water wetlands for treatment when floodwaters have abated. Petrol and oil can be stored in sealed compartments that shut off when floodwaters rise, to be pumped out from their underground storage at intervals. This proposal has enable developments such as Skew Bridge in Rushden to gain planning permission even when they exist close to sensitive landscapes such as a neighbouring SSSI.

Figure 6: Skew Birdge Rushden Masterplan

INTEGRATED WATER MANAGEMENT

Recent schemes have called for closer work with other disciplines on the integration of design skills. The Lower Lea Valley in London is the birthplace of post industrialism. This was the place where industry first learned that it no longer needed to locate next to primary resources, but that raw materials could be transported to where power and labour were most abundant. Today the area is a declining industrial zone in the midst of two expanding London boroughs. The 660-hectare [1,630.9 acre] site has been designated for urban regeneration and the location of the 2012 Olympics if London’s bid is successful. On the agenda for the team were the issues of transportation, infrastructure, spatial quality, flood protection, sustainable drainage, ecology, environmental impact, and pollution. In a bold attempt to reunite the tidal rivers of the Lea Valley with their landscapes, some of the flood defence walls would be taken down and replaced with Flood Buffer Zones.

Within these zones there would be sub zones:

1. Tidal expansion zone.
   These would be areas immediately adjacent to tidal rivers that offered a potential for vegetation that grows in salt marshes to colonise the embankments of the river that had been obliterated by flood defence barriers.
2. Flood alleviation zone.
   These would areas above the mean high tide mark that rose to a height of projected surge tide levels which would allow the swollen river to expand into the surrounding landscape and absorb the shock wave of storm water surges meeting tidal surges during peak flooding events.
3. Storm water wetland.
   Located behind the flood protection bunds these areas would attenuate both storm water and grey water from the urban development. They would have a sufficient expansion capacity to retain storm water for a period of several days in order to retain runoff from development zones until tidal floods recede and water can be release through flow control valves into the flood alleviation zone.
4. Filter zone.
   Effectively large grass swales, this zone would act as pre-filter to the storm water wetlands, and as metropolitan open land for recreation and linear corridors connecting communities.

Flood Buffer Zones are not intended as a replacement to engineered protection for flooding in lowland river catchments, but as a shock absorber to the collision of tidal and fluvial systems. They can also act a as transition zone between tidal and urban drainage systems, allowing space for filtration and discharge of runoff from hard surfaces into sensitive ecological systems such as salt water marshes. The creation of these spaces in derelict industrial land in the Lower Lea Valley would offer the chance to re-establish rich and diverse plant and wildlife communities with an intrinsic value to the urban communities which will grow up around them. Their creation would involve inter-disciplinary work between drainage engineers, sewage engineers, ecologists, soil consultants, landscape architects and irrigation engineers.

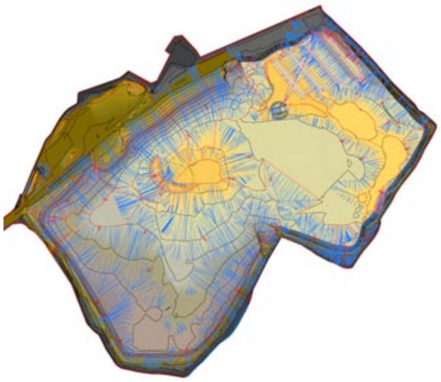


Figure 7: Hydrological Mapping of Betteshanger Colliery near Dover in Kent. Image Lovejoy.

It is ironic that the Lower Lea Valley should be the location of Joseph Bazalgettes famous interceptory sewer system, the device which sealed the fate of so many of London's streams, and turned them into underground systems to remove the stench of raw sewage that once plagued the city. Although we still rely on modern sewage removal and treatment systems we have come to understand the importance of space and time. Water needs space to move if we are to live with it, and time to restore itself when it is used to carry away the pollutants that we subject it to. History has taught us that if we take any shortcuts in our treatment of water, the problem is only compounded elsewhere.

IMPLICATIONS FOR THE IRRIGATION INDUSTRY

In order to realise our greatest potential we, as irrigation engineering consultants need to reconsider our position as end users of water. With our engineering knowledge of hydrological principles, water storage, pumping systems, soil-water-plant relationships and climate, we are truly becoming Water Resource Consultants. By being involved as early as possible in the design stage of projects, we can provide "water utilization maps" for potable and non-potable systems using a combination of on and off site water resources, distributed processing

for pollutants, grey water re-use and other dual use systems, catchment planning and remote sensors and control systems to optimise irrigation water use.
Combining principles of sustainability with our technical background in irrigation engineering and a corporate perspective as water managers, we have applied these principles with clients as diverse as the Sonoran Desert in Arizona and the front range of the Rockies. In arid climates, we design systems that make the best use of water in order to green the desert.

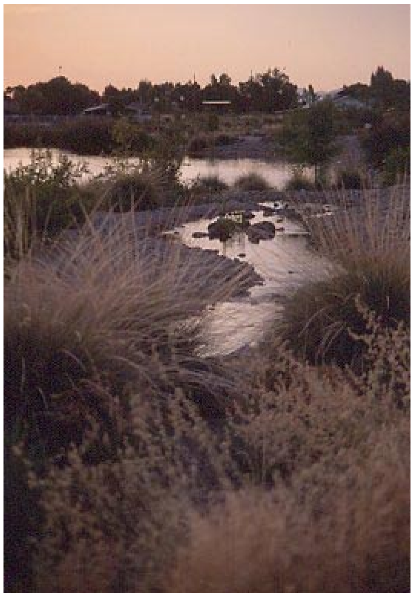


Figure 8: The Riparian Preserve. *Hines*

The Town of Gilbert, Arizona wanted to dispose of excess treated wastewater effluent in high production/low demand periods during winter as groundwater recharge, while providing sustainable wildlife habitat, public recreation, and educational venues year round. They brought together a team of landscape architects and engineers including irrigation engineers to solve the combined needs of the 48.6-hectare [120 acre] site. The resulting Riparian Preserve provides representation of the 17 lower elevation riparian and upland plant communities found in Arizona. Water sources as diverse as in situ shallow aquifer wells, raw water from the Central Arizona Project and a variable source up to 15.1 million litres [four million gallons] of effluent water per day have been combined to serve a fishing lake and 28.3-hectares [70 acres] of aquifer recharge in seven basins. Both the landscape features and mechanical systems on the site are interpreted so the public can see how the water is being recycled, where it is being used, and how the application of high efficiency irrigation equipment is minimizing water waste.

Irrigation engineering took into account the rich diversity of plant ecosystems represented. From lawn to marsh, and desert to lake, each vegetation system required a specific and controlled amount of water. Additionally, the irrigation system was designed to handle seasonal fluctuations in available water. Regulations concerning the sources or water were a factor in the design process as well. Computer generated hydraulic modelling of mainline piping aided in the selection of optimum pipe sizes. A raw water pumping station was designed and aeration and water circulation systems were necessary in order to maintain a high degree of water quality for the plant and animal habitat. A central control system was designed and specified to assist in optimizing system operational efficiency and to maintain the health of over 18,000 native trees and shrubs within the park. In addition to the state-of-the-art control system, high efficiency spray sprinkler equipment was specified in order to maximize overall system efficiency.

Figure 9: Interlocken – Golf Course. *Hines*

We also develop systems and components that can deal with the variable nature of treated waste water effluent and raw (surface/untreated) water to minimize the use of potable water for irrigation and water features. By working with clients and affiliated disciplines as strategic partners, we master plan projects such as Interlocken in Broomfield, Colorado. This 404.7-hectare [1,000 acre] advanced technology commercial office and mixed use development in the Front Range of the Rocky Mountains included a 121.4-hectare [300 acre], 27 hole executive golf course, community parks, athletic fields, landscaped roadways and numerous tenant sites. Sustainability goals for this project included the utilization of runoff water for propagation of wetland and natural areas and development of dual-use water systems for potable and non-potable water distribution.

Irrigation engineering at Interlocken needed to take into consideration significant changes of elevation on the site and the extreme weather conditions of it's location along the eastern slope of the Rockies. Engineering tasks included computer hydraulic modelling of the complete irrigation water delivery system including pipe sizing from 150mm [6in] to 600mm [24in] in diameter, analysis of system pressures at selected locations with varying demands to optimize the piping network, design and installation of a 1,700m³h [7,500gpm] central pump station operation with multiple booster pump stations and on-site water storage facilities. Each sprinkler hydro zone from arterial roadways, golf course, athletic fields, community parks, open space and wildlife habitats required individual assessment to consider terrain slope, aspect, soil type and infiltration rate, plant material type, sprinkler precipitation rate and distribution uniformity. Because of the variable terrain on site, sprinkler check valves were specified at each head to prevent low head drain down. And, pressure regulation was designed into the system to control water droplet size at the sprinkler nozzle to minimize evaporation, reduce "wind drift" of spray and optimize distribution uniformity on the wind-prone, mile-high site. A separate, potable water system for the golf greens was required to leach out salts present in the sewage effluent water source. Finally, a complex central control system including multiple weather station locations to track and respond to daily/real-time evapotranspiration data was designed and installed.

Figure 10: Interlocken – Walkway. *Hines*

In urban schemes we can do all of the above and encourage schemes that involve roof gardens to lower the core temperature of buildings, improve the environment for tenants and optimise evapotranspiration. In one urban "brown-field" scheme, we are recommending the utilization of both roof gardens and the re-use of grey-water from high-rise mixed commercial/residential buildings. In this setting rainfall is unpredictable, the city uses surface drainage to carry run-off away from the civic centre, and flooding frequently occurs during heavy rains. Sources of water for the centralized potable water source are being challenged by high rates of suburban growth and the city sits in a desert environment where temperatures soar to over 46.1°C [115°F] in the summer. Capturing and re-using grey-water would allow for a reduction of up to sixty percent of the potable water use for the site and roof gardens could lower the heat map of the site by as much as 15°C [5°F] saving on electrical costs for air conditioning as well.

Our challenge to the industry is to develop partnerships with clients who are developing schemes with sustainability as a prerequisite. As irrigation engineers we have broadened our perspective to include best practices from other continents to provide a cross-cultural approach to our problem solutions. We encourage others in the industry to join us as we find new ways to manage our limited but most precious "liquid asset."

NOTES ON AUTHORS

Sharon C. Hines is a graduate civil engineer and Senior Engineering Designer for Hines Irrigation Consultants, Inc. currently assigned to their UK subsidiary located in Oxford, England. Sharon has distinguished herself in the engineering skills necessary to excel in this design environment. She has served as a Consulting Engineering Intern, Engineering Research Assistant, and Field Surveying Technician developing skills necessary in design solution development. Sharon's irrigation design experience encompasses project work in the Rock Mountain Region, the Desert South West, California, Wyoming and Afghanistan.

Peter Wilder Cert. Hort. BA(Hons) Dip LA MLI. Peter is an experienced conceptual and technical designer and an Associate with Derek Lovejoy Partnership in London, England. He has worked on large-scale projects from urban and brownfield regeneration through to roof gardens and private estates in throughout Europe. His current work focuses on the development of sustainable design principles for large scale regeneration, and his work has been published in *RIBA Journal*, the official monthly magazine of the Royal Institute of British Architects, and, *AJ Focus*, the product guide for designers published by The Architects' Journal in the UK.

NOTES ON THE COMPANIES THAT SUPPORTED THIS PRESENTATION

HINES™ Irrigation Consultants, Inc.

Hines Irrigation Consultants, Inc. is a Colorado based company with offices in Fort Collins, Denver and through its subsidiary, Hines Irrigation Consultants, Ltd. in Oxford, England. Hines provides design, construction observation, maintenance, and management services to clients internationally, focusing on projects requiring a high level of sensitivity to water source modelling and sustainability. The engineering and design staff create computer generated hydraulic modelling, full dual-use water delivery systems, distributed water processing systems, water features, pump-station design, irrigation system design and specification and central control system design and management. www.hinesirrigation.com

LOVEJOY

Derek Lovejoy Partnership, plc, is one of the largest international land planning and design practices based in the UK. The practice has three offices in London, Edinburgh and Birmingham employing a dedicated staff of planners, landscape architects, and urban designers. The practice invests substantially and consistently in IT ensuring they remain at the forefront of the application of computer technology for the generation, analysis and presentation of information. DLP's philosophy is based on enabling sustainable and environmentally responsible development. They have found that their 'land planning' approach which brings a profound understanding of landscape and planning issues and particularly the interaction between open space and built form can enable innovative even ground-breaking thinking. www.dlp-plc.co.uk

SELECTED INTERNET RESOURCES

UK

http://www.defra.gov.uk

UK Department for environment, food and rural affairs

http://www.silsoe.cranfield.ac.uk/iwe/irrigres.htm

Cranfield University site for water resources – UK

http://www.bbc.co.uk/weather/features/climate_change4.shtml

BBC news report on climate change in UK

http://www.tyndall.ac.uk

The Tyndall Centre focuses on climate change.

US

http://www.rmi.org

Excellent resource for research on sustainability in US

http://www.climatehotmap.org/impacts/water.html

US impact of global warming

http://www.ogp.noaa.gov/library/rtnw91.htm

General discussion of climate and change

http://www.sustainabledesignguide.umn.edu/MSDG/water_pi.html

Design guides developed in Minnesota…see water section especially

http://www.sustainable.doe.gov/efficiency/weinfo.shtml

Wide variety of information for "Smart Communities Network"

http://www.globalchange.org/impactal/96nov1d.htm

Good internationalisation of water issue into the US

OTHER/INTERNATIONAL

http://www.csiro.au

This organization in Australia is focused on conservation.

http://europa.eu.int/comm/research/water-initiative

Excellent resource for EU perspective

http://www.worldbank.org/wbi/sdwater/irrigation.html

Brief list of issues facing developing countries… irrigation initiatives

http://www.tec.org/tec/tec/terms2.html

Excellent resource/dictionary of water terms