TRANSITION ENGINEERING URBAN CANYONS - ROGER STEVENS COOLING POND CASE STUDY LEEDS, UK

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Keywords: Transition Engineering; Urban Heat Island Mitigation; Blue-green infrastructure; Nature-based solutions

Abstract

Our research project focuses on assessing microclimates associated with water features and green infrastructure set among the "Brutalist" concrete canyons developed in late 20th century, and Transition Engineering (identifying pathways) to exploit storm water to mitigate the combined impact of urban heat islands and global warming as far as the end of the 21st century. As a case study we are monitoring the environs circa the Roger Stevens Building (1970) which Heritage England listed at Grade II as a fitting centrepiece to the group of additional buildings on the south of older Red Brick University of Leeds which inspired the "plate glass university" building boom throughout the UK during the 1970. The precinct includes a "Cooling Pond" identified by the Ordinance Survey, which since 1983 reflects upon a flying bronze figure removed from the Midland Bank in London, "keeping a watchful eye out for impromptu swimmers". There is no evidence that the Cooling Pond was ever connected to any mechanical building services by pumps or pipework. We are investigating how the role of this water feature have been evolving over almost time and what role could potentially play today in line with a more contemporary idea of blue/green infrastructure. The pond is currently undergoing redevelopment to allow the previously chlorinated sterile water feature to become a thriving bluegreen ecosystem, as a collaborative living lab involving Estates Services, Sustainability Service, Water@Leeds, School of Geography, School of Biological Sciences and School of Civil Engineering. Within this project we aim at assessing ambient air temperature surrounding the Roger Stevens Building before and after the redevelopment of the Cooling Pond.*

INTRODUCTION

Interdisciplinary transition innovation, management and engineering are the staged components of the 7-step methodology (Krumdieck 2013) for Transition Engineering to overcome wicked problems. The concept of "wicked problems" (Rittel & Webber 1973) has been alluded to in countless examples of land and resource management. Examples of such problems include urban land management (McPhearson et al. 2016), policymaking (Head 2008), climate change (Grundmann 2016), and the conservation of biological diversity (Redford et al. 2013). The specific criteria that apply to true wicked problems have been outlined elsewhere, but, in summary, these are challenges that are highly complex, have many interacting stakeholders, and lack an obvious solution. Wicked problems compound one another when they come into contact. In this paper we outline some wicked problems that exist at the shared borders of different fields of work. Case in point, we are challenged by wicked problems, borne out of mutually-exclusive priorities from different fields, converging within a small pool in a city in the north of the United Kingdom (Figure 1).

Figure 1. Outlook from Waterview Café across the Cooling Pond towards screened temperature sensor on the corner of the Food Science Building.

The Roger Stevens Pond has been identified for development and improvement by Leeds University Estates Services due to ongoing maintenance issues associated with its pumps and fountains. The Pond needs to be drained every time the pumps and fountains need maintenance and this can happen several times a year. When the system isn't working effectively there is commonly a build-up of algae which is unsightly and potentially hazardous to wildlife. A project was therefore set up to identify a more sustainable management method that replaces the need for pumping with a more natural approach. By introducing planting to the pond both the amenity and biodiversity value of the pond will be significantly increased whilst reducing the time and financial costs of maintenance.

The project was identified as an opportunity to take a living lab approach to the development and management of the area. The Leeds Living Lab brings together students, academic and professional staff to co-create innovative and transformational solutions to real-world sustainability challenges, using the University as a testbed. It is interdisciplinary and drives continual, sustainable improvement by tackling global challenges at the local scale. Academics from the Faculties of Biological Sciences, Engineering, and Environment were brought together in a project team with colleagues from Estates Services and the Sustainability Service to co-create an innovative space for research-led teaching. This initially brought the benefit of leading academic expertise into the consultation process and helped the University to identify the most effective solution and approach, such as the types of planting, the species selection, and conclusions on current options for water sources. It is now allowing Schools across the University to identify ways in which they can utilise the pond for teaching assessed student projects. Plans include installation of sensors for environmental monitoring, an online data dashboard, species selection that provides amenity value, biodiversity enhancement and academic interest, and safety and access to allow all ages to utilise the pond for field learning.

The project brings with it an opportunity to better understand the current micro climate of the Pond and its surrounding area, and to monitor how this might change with the introduction of planting. Development plans for adjacent and connecting areas may allow for further water and greenspace landscaping so Estates Services will gain from improved knowledge and awareness of the potential benefits to climate control in terms of buildings efficiency and staff wellbeing.

The University is committed to immediate changes this summer (2018), including removal of the fountains and the installation of a floating 'Biomatrix' to improve natural management of water quality, and to enhance biodiversity and amenity value. The Leeds Living Lab project delivery team are keen to continue to support research-led teaching on campus, and will be guided by academic experts regarding planting regimes as well as design features that support access to both the pond itself, and to monitoring data. The idea is to produce a learning loop to attempt incremental improvement of the pond while maintaining a collaborative safe operating environment for research, teaching, and urban biodiversity. Given the significance opportunity, the micro-climate urban heat island effects will continue to be monitored this summer to observe any detectable impact. So the present paper presents preliminary results of a Transition Engineering analysis of key system dynamics. The authors of this paper came together in discussion over how to implement a programme of enhancement of a fifty-year-old water feature (30m x 30m, depth ca. 0.5m) on the campus of the University of Leeds in the UK shown in Figure 1. A search of archival plans has confirmed that there never was any abstraction of cooling water for any sort of mechanical building services, but it still bears the place-name "Cooling Pond" on the Ordinance Survey presented by Historic England in listing the surrounding buildings. So, it is surmised that the Cooling Pond might have been conceived in the 1960s by Chamberlin, Powell and Bon Architects to mitigate the expected urban heat island effects (Bornstein 1968) of their development plans for the South Campus of the University of Leeds.

The Cooling Pond is interesting from a number of perspectives. First, it has small fountains and lights for aesthetic appeal, although these are in need of replacement. Second, the concrete lining of the pool provides no habitat for the establishment of plants or animals and so the only natural components of the pond are a dense algal community and a pair of mallard ducks that routinely nest in a duck house on the edge of the pool. Those mallards produce 5-7 chicks each year before leaving the site, and are extremely popular with the local students. Third, the Cooling Pond is part of a larger Grade 2* heritage listed building, the Roger Stevens Lecture Theatre Block, which was completed in 1970 – representing a prime example of the brutalist architectural movement that swept across the UK in the following decade. Fourth, there are many ongoing problems with the pond, including the need to completely drain the water several times over the spring and summer period to remove the algal and clean the concrete lining. Because of leaks into laboratories below, the southeast arm of the pond was decommissioned before heritage listing, and now is entirely contained by membrane over concrete slab-on-earth construction. Collaboration between academic and operational teams will now research global challenges and deliver sustainable solutions, using the Cooling Pond as a testbed as long at the architectural container is untouched. Our focal water body, the mirror pool itself generates a cultural ecosystem services associated with the built heritage of the structure and provides evaporative cooling to reduce temperatures in a denselyconstructed city. The question is: can we retain those ecosystem services while enhancing the biodiversity value of the pool? The evidence suggests that biodiversity of standing urban waters is relatively robust (at larger scales) to the impacts of urbanisation, and that biodiversity can co-exist with ecosystem services. The various circumstances of our case study combine to illustrate two related wicked problems.

The Urban-Ecological Problem

Competition for land between nature and human use has dominated the fields of environmental and biological sciences over the past 50 years. Human impacts are the predominant cause of biodiversity decline (Tilman et al. 2017), while biodiversity itself underpins a wide range of processes and services that are essential to the healthy functioning of human societies (Duncan et al. 2015). The relationship between ecosystem services and biodiversity is not linear in all cases (if any). Links between health and biodiversity suggest that a greater number of species is associated with increased health outcomes (Fuller et al. 2007; Hanski et al. 2012), but the same is not true of the relationships between biodiversity and pollination (Kleijn et al. 2015) or carbon sequestration (Sullivan et al. 2017). The challenge, therefore, has been to develop an approach to land management within which natural and human systems coexist in a mutualistic manner. Nowhere is that more challenging than in urban landscapes, due to the intensive use of space for human purposes (Eigenbrod et al. 2011). Studies of the impacts of cities on biodiversity have concluded that urban ecosystems usually act to reduce biodiversity and homogenize biological communities (McKinney 2002; McKinney 2006), as found plants and insects (McKinney 2008). However, fresh waters are a notable exception, where pond biodiversity tends not to show variation in relation to larger scale land use patterns unaffected by surrounding urban landscapes (Hill et al. 2016). This opens up the possibility for urban water sources that can provide their ecosystem services and still serve an important role in wider ecological function. Urban lakes and rivers have been studied from a variety of perspectives and are known to produce health benefits through mitigation of the urban heat island and generation of natural noise (Völker & Kistemann 2011), provide water for drinking and washing (Nagendra & Ostrom 2014), and generate cultural ecosystem services (Kumar 2017). These ecosystem services can co-exist with biodiversity (Hassall & Anderson 2015), although the evidence for such “win-win” scenarios is scarce. The wicked problem from the ecologist’s perspective is how to enhance nature in urban spaces without compromising the function of cities for human purposes.

Engineering-Heritage Problem

Contemporary cities integrate historical urban patterns with new stratifications that in some cases evolve organically, comprising a large diversity of building forms and functions. When local society and culture recognise themselves in specific buildings, which are considered of value, then heritage schemes are set in place to protect them. The schemes also allow promoting the value of the built heritage to local economies (Richards 1996). There is an inherent challenge in updating built heritage for contemporary use without compromising the values of that heritage. In most of the cases, those buildings were built when there was less attention to energy efficiency. Moreover the increasing global temperature is stressing the current built environment. Many recent studies have attempt to develop strategies for the energy retrofitting of heritage buildings while still maintaining the heritage values (Martínez-Molina et al. 2016). However, there is not a one fit-all solution. Therefore, how to reduce the energy demand of buildings protected by heritage restrictions is still an open question. (Mosley 2013).

Path-breaking out of business-as-usual traps

To break out from wicked problems, objective metrics need be established in accordance with the initial steps of the Transition Engineering approach (Krumdieck 2013), following the discipline of Safety Engineering. The process begins by auditing records, monitoring and investigation to understand where sustainability problems arise. This background enables stakeholders to see if established trends will result in an un-sustainable operating environment if business-as-usual continues without timely proactive remedial changes. These metrics are long term key performance indicators of resource availability - such as energy, water, and air quality.

RESEARCH METHODS

In the present paper we describe how we are in the process of employing first three steps for stakeholders to understand the system dynamics of infrastructure such as the pond. The present case study focuses on an isolated water feature that has been maintained with potable water mains, and is not connected by natural water courses. An integrating surrogate for water condition has been assessed by the biodiversity of the pond. It is understood that air quality by way of nitrous oxides in the urban canyons of Leeds is being monitored by others, but in the present circumstance we have found that we can employ urban heat island intensity (UHII) in a hourly comparing of the urban ambient temperature with airport observations from the open lands of the greenbelt, similar to the approach of Levermore and Parkinson (2017). This would have been difficult since the Weather Centre in the Leeds Town Hall closed in 2003, but fortunately the University established a new weather station one km northwest of the City centre, on the roof of the Building that houses the Schools of Maths, and Earth and Environment. The altitude difference between the two meteorological stations was accounted for by assuming the wet adiabatic lapse rate of 7°C per km. Consequently, we observed urban heat island intensity during spring 2018. Using the new on-campus weather station we deployed screened temperature sensors to measure the micro-climatic heat island intensity (µHII) variations between four outdoor areas on the campus of the University of Leeds as illustrated in Figure 3.

Figure 2. Precinct surrounding Waterview Café (upper pane), with four radiation-screened temperature sensors deployed to monitor micro-climate variations (lower panes). In the map please find Chancellor's Court (light green); the Cooling Pond (blue); Cark Park south of the EC Stoner Building (grey); and the Edge on Willow Terrace Road

Both the screen temperature in the Chancellor's Court (lower left of Figure 2) and pond-side (second from the left in Figure 2) were compared with the roof level campus weather station as representatives of green and blue infrastructure.

RESULTS

The ambient temperature of Leeds would be expected to be warmer than the airport moorlands that are located at a higher altitude, yet the urban heat island has increased by an incrementally greater quantum difference. Figure 3 has removed altitude effects, to present the heat island intensity attributable to anthropogenic effect of the urban system – where median (50%) UHII was generally observed to be more than +2°C – except during more settled dry weather in May 2018 the daytime UHII increased to +2°C and dipped at night. We will continue to monitor the hourly profiles of UHII as we progress into the summer months, and use this local baseline to measure the micro heat island intensity (µHII) of various urban canyons surrounding our case study.

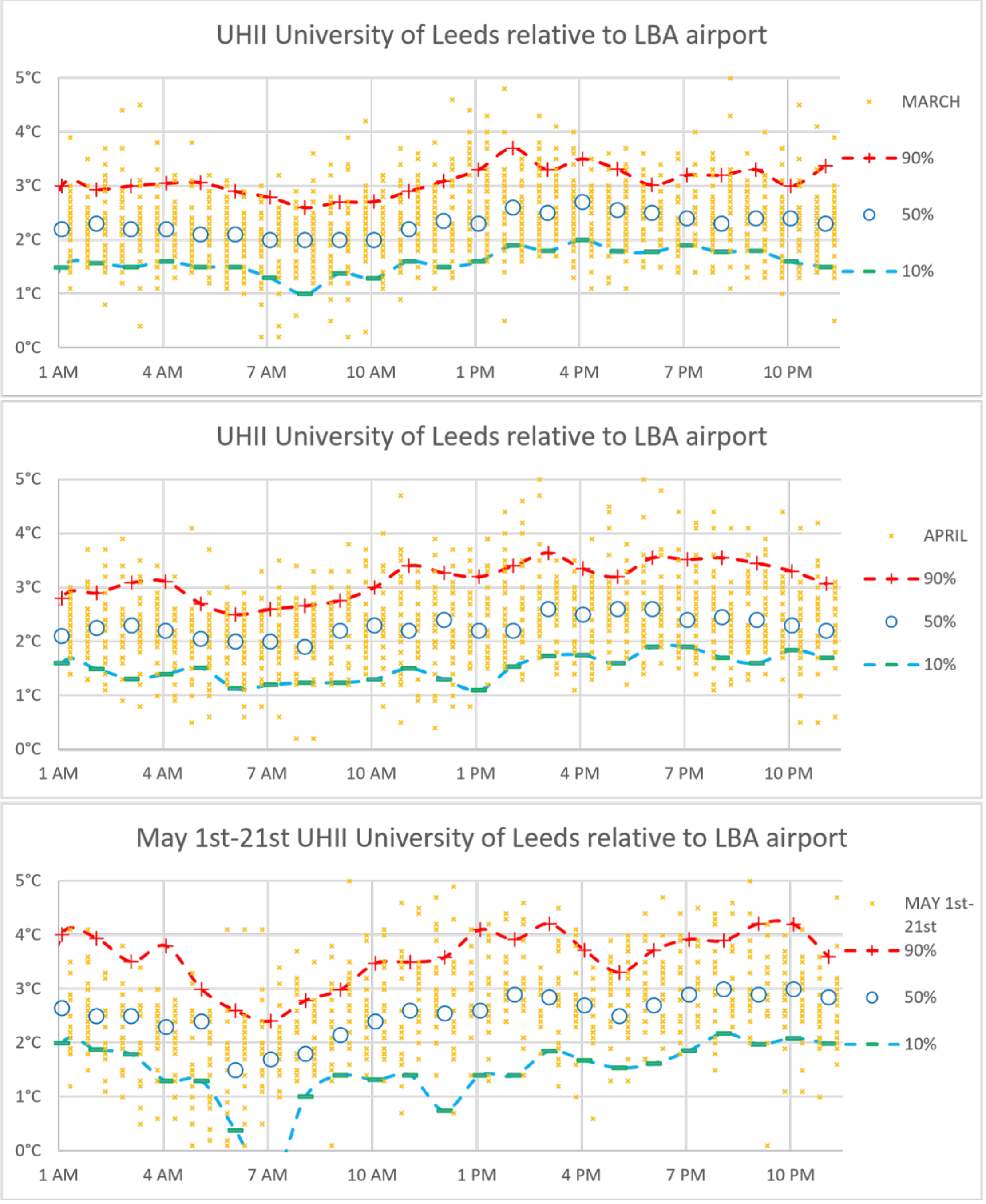
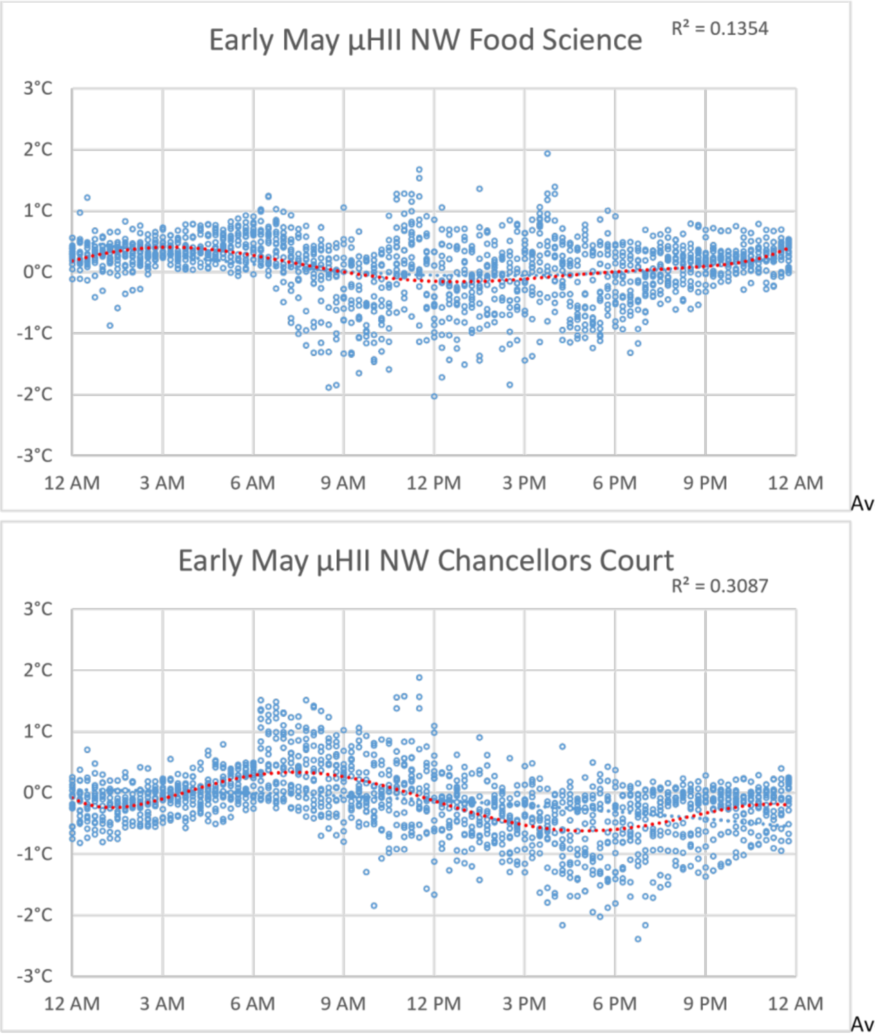


Figure 3: Urban heat island intensity of the University of Leeds weather station relative to Leeds-Bradford International Airport (LBA) Upper pane – March 2018; Centre pane – April 2018; Lower pane – May 2018 (until Monday 21st May)

Micro-climate heat island intensities (µHII) are plotted in Figure 4 for the month of May 2018, with sixth-order polynomial regression R^2 showing 30% and 13% of the variability is associated with the time of day. Chancellor's Court micro urban heat island intensity (µHII) drops during the afternoon as sun is shaded by the Staff Centre Building. The pondside, NW corner of the

School of Food Science Building remains exposed to afternoon sun, directly and reflected by the pond, and so has a fractionally elevated µHII.

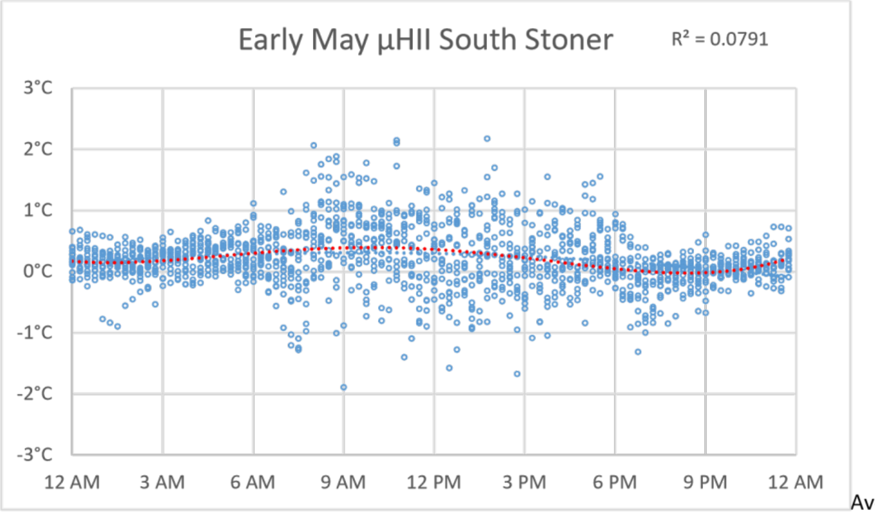


Average +0.2°C ±0.9°σ

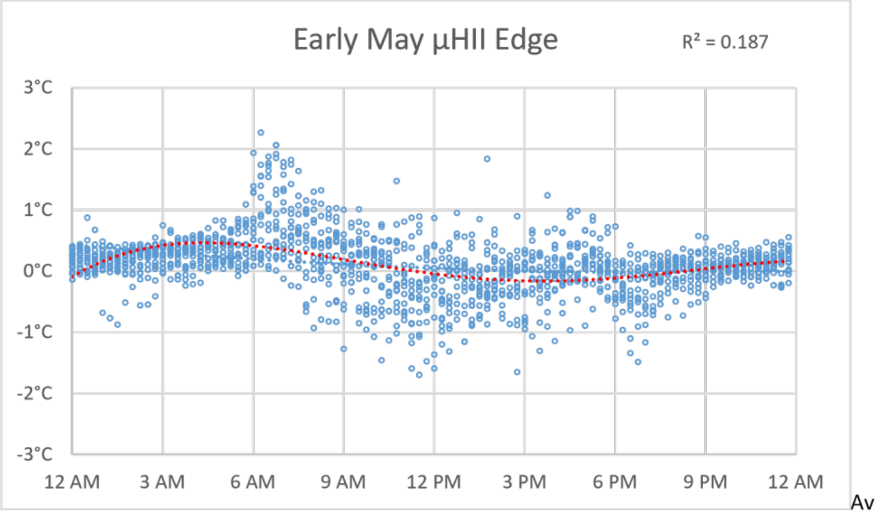
Average 0.0°C ±0.5°σ

Figure 4: Blue and Green micro-climate heat island intensities (µHII relative to the University of Leeds weather station) Upper pane – NW of School of Food Science, NE of the Cooling Pond – example of blue infrastructure Lower pane – NW of Chancellor's Court,
East of Staff Centre – example of green infrastructure

Similarly, two locations further from the pond and gardens are compared with the roof level campus weather station in Figure 5, with R² showing only 8% and 18% of the variability associated with time of day at the parking area south of the Stoner Building and at The Edge on Willow Terrace Street. The Edge appears to benefit from afternoon shading, but not as well as the Chancellor's Court. Micro-climate heat island intensity is generally positive on the south of Stoner Building, and only a small hedge of vegetation is present to mitigate.



Average +0.1°C ±0.9°σ



Average +0.1°C ±0.9°σ

Figure 5: Micro-climate heat island intensities (µHII) relative to University of Leeds weather station Upper pane – Finsbury Road, South of EC Stoner Building – gravelled parking 100 m east of Cooling Pond Lower pane –Willow Terrace Street, NE of The Edge Building – service road below the Cooling Pond

In both figures 4 and 5 the swarm of data is much tighter at night, and scatters markedly during daylight – indicating that thermal radiation is differentially impacting microclimates even though sensors are performing very well to eliminate short wave solar radiation.

CONCLUSIONS

We have not completed the Transition Engineering process of resolving competing wicked problems, looking through two lenses: Urban–ecology, and engineering–heritage. What has been achieved is that we have measured the urban heat island intensity (UHII) of our campus that is located 1 km from Leeds Town Hall, and within one precinct we have investigated variations in the micro-climatic heat island intensity (µHII), finding that green infrastructure that is shaded in the afternoon is cooler than concrete-lined blue infrastructure.

On-going monitoring of the Cooling Pond could help resolve the ongoing trajectory of enhancement efforts. Our consensus is that it is justified to install water-column DO/salinity/temperature logger, and auditing of the occasional refilling events. A chlorophyll logger would be nice-to-have, but is not expected to be funded in the foreseeable future. The School of Biology is equipped to provide regular sampling with specimen storage and cell count estimation using spectrophotometry, but recommends that a “Sustainability Student Champion” be elected among students to provide an annual report card on pond health if a part-time role could be funded by the Sustainability Service as a part of the Leeds Living Lab.

Now there appears to be some consensus on immediate interventions that are recommended to maintain the Cooling Pond in a safe operating environment, as follows.

1. Engineering-Heritage: A sustainable solution to the algal bloom problem is the addition of a more coherent ecosystem, based around macrophytes to oxygenate the water and invertebrates to graze the algae. This would vastly reduce, if not eliminate, the cost of cleaning. However, the addition of such an ecosystem would need to be done in keeping with the heritage listing of the building, presenting a key ecological challenge.
2. Urban-Ecology: The University of Leeds campus lacks freshwater habitats for mallard ducks are likely contributing to the problem, through the excretion of nitrogen into the water which then provides nutrients for the algae. However, those mallards cannot be removed without careful management of the perceptions of the local site users.

The resolution of wicked problems of ensuring the sustainability of the Roger Stevens Cooling Pond may depend on a more complete historical reconstruction of the past halfcentury, complemented with the development of a Living Laboratory Dashboard of real time monitoring such as has been availed with the University of Leeds Weather Station, so that stakeholders are able to project trends into the future. The next step is to consider if incremental changes will ensure that the Cooling Pond can be maintained in a safe operating environment. Transition Engineering suggests that all concerned be prepared for a substantial change in direction over the next half century.

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