Sheffield's Great Flood of 1864:

Engineering Failure and the Municipalisation of Water[1]

Introduction

At around midnight on the 11th March 1864 the Dale Dyke Reservoir (DDR), eight miles north-west of the thriving industrial town of Sheffield in South Yorkshire, England, burst its banks and sent 650 million gallons of water, or 40,000 cubic feet per second, cascading down the valley at eighteen miles per hour. The flood waters followed the route of the river Loxley before joining with the river Don, smashing through everything in their course into Sheffield: corn and paper mills and their stocks, steel and machine tools manufactories, mill-dams, bridges, livestock, housing and their sleeping inhabitants were swept away. Trees were uprooted and rocks torn up. The villages of Low Bradfield, Damflask and Little Matlock, as well as Malin Bridge, Owlerton and Hillsborough, all part of suburban Sheffield, were flooded. Once the waters reached town, gardens, yards and cellars were submerged, reaching nine feet in places; in the morning Sheffield was left 'covered thick with timber, stones, sand, and mud.'[2] According to the official figures, 250 lives were lost, though a local historian has since calculated the death toll, including deaths through debilitating illnesses caused by deep water immersion, at 306.[3]

The reservoir, having just been completed to supply compensation water to millowners, was the property of the Sheffield Water Works Company. The Company owned another three reservoirs in neighbouring valleys, as well as a service reservoir in town, and hired a resident engineer to manage the works, as well as a consultant engineer who designed and supervised their construction. The flood attracted considerable interest from provincial and national newspapers, and sparked anxieties

about the public safety of large socio-technological ventures as well as the expertise of civil engineers. Unsurprisingly, the Company's directors and engineers defended the flood as an unanticipated accident caused by a land slippage in the valley. For others, including the Sheffield Town Council, as well as a vocal minority of internationally-recognised engineers, the avoidable flood was the result of poor workmanship. Corners were cut during construction, problems were identified but not rectified, and the design specifications were fatally flawed. Whilst engineering disputes were not unheard of, it was rare for one group to publicly blame their colleagues for engineering failures. However, R.A. Buchanan and others have shown that the Victorian engineering profession was increasingly subject to various social, political and cultural divisions, which led to institutional proliferation and served to generate a multiplicity of voices and opinions on major engineering failures like the Sheffield (1864) and Holmfirth (1852) floods and the collapse of the Tay Bridge outside Dundee (1879).[4]

Having been described as 'the greatest single "natural" catastrophe of the [nineteenth-] century' in Britain, an examination of the Sheffield flood highlights the contested nature of disaster investigation.[5] This was particularly pertinent in cases where engineers and other 'disaster experts' (as Scott Gabriel Knowles refers to those insurance officials, government inspectors and researchers who built careers on studying and acquiring knowledge about disasters) disagreed over the causes of socio-technological failure – as was often the case with large urban fires, collapsed bridges, coastal floods and so on – where there existed no straightforward explanation.[6] Victorian engineers, whilst claiming to possess the tools to tame nature for man's benefit, also adroitly disputed their level of control over the natural environment whenever it mattered. Engineers were one of a growing number of elites whose

professional practices and experience were contingent on their access to, and understanding of, an evolving body of scientific and technical knowledge about how best to harness nature to man's control, as well as their confidence and freedom in being able to utilize new technological structures and materials in their works. This has been further borne out in recent research, including a special issue in this journal, which has revealed how modern Western understandings of risk and uncertainty are inextricably linked, and that disasters are taken as unfortunate consequences of societal and technological modernization, rather than the product of natural forces or acts of God.[7] Since professional engineering was founded on an element of risk-taking, engineered landscapes were always subject to uncertainty and failure, and there is little natural about these "engineering-induced disasters".[8]

Drawing on a burgeoning historiography at the intersection of the histories of technology and the environment, this paper will illustrate the interdependence of socio-technological systems and engineering knowledge with the political agendas of municipal governments and private water suppliers. Histories of technology share common ground with urban environmental history because of the way that 'nature and technology – and the way in which we understand the two – have become more and more entangled, blurring boundaries that once seemed so clear.' This is because 'a city is both an environment and a network of technological systems', which blurs the boundaries between what is traditionally seen as "natural" (non-human) and "artificial" (human and cultural) environments.[9] In his study of the evolution of the modern Spanish waterscape, Eric Swyngedouw persuasively argues that '[h]ardly any river basin, hydrological cycle, or water flow has not been subjected to some form of human intervention or use; not a single form of social change can be understood without simultaneously addressing and understanding the transformations of and in

the hydrological process.'[10] It is, therefore, plausible to view "engineering-induced disasters" as the product of 'a network of interwoven processes that are simultaneously human, natural, material, cultural, mechanical, and organic.'[11] By problematising this 'nature/built environment nexus', one can trace the interactions between human technologies and urban political cultures.[12]

As an example of a socio-technological system, which connected the natural and urban environments into a new kind of liminal space, the DDR's failure reverberated politically as much as it had an environmental and social impact locally. It violently shook the Victorian belief in the beneficial relationship between technological innovation and environmental justice, and provided a 'window of opportunity' through which local actors attempted to better regulate and manage the supply of water for industrial and residential consumption. Clare Johnson *et al* and Thomas Birkland have shown how city-based floods and other similar "nature-induced" events act as catalysts for policy change by placing hazard management and prevention onto the political agenda, thereby making technology, engineering and the natural environment matters for state involvement.[13] Learning from disaster takes place across three main stages, from the emergency phase through to the recovery and reconstruction phases, and involves a variety of groups, including engineers, legislators, service providers, and insurers, as well as local communities affected on the ground.[14] Yet lessons themselves are contested by interested parties, and, although policy windows elevate a problem to public attention, it does not automatically translate that those parties will act positively. Nor, as we shall see, does the window remain open for long or guarantee significant change beyond a return to the *status quo*. Lessons can be disputed, repudiated, forgotten, unlearned or even simply ignored.[15]

A Going Concern

Sheffield Water Works Company was incorporated in 1830 with clear expansionist aims. In 1830 and 1845, the Company secured Acts of Parliament to expand its service by constructing a series of impounding and compensation reservoirs in the Redmires and Rivelin valleys. These 'protosystems', as Martin Melosi refers to early urban-industrial waterworks, were completed by 1854 to increase the Company's control over the town's infrastructure, as well as to improve the health of its customers. They did so by supplying an estimated 2.8 million gallons of water daily to the town in addition to 1.5 million gallons as compensation to the millowners on the rivers.[16]

In its ongoing search for improved potable water, the Company established ever larger 'ecological frontiers' for the town.[17] Water was increasingly seen in terms of how it could service urban populations, that is, as a resource 'essential for urban and demographic growth.'[18] As Joel Tarr puts it, water was a pivotal feature of the industrial city's metabolism, providing energy and potable water required by urban populations.[19] The preamble to the Company's 1830 Act reads that the rapid growth in Sheffield's population had left the town 'very inadequately supplied with water' to furnish the 'health, comfort, convenience and security' to its inhabitants, while its 1854 Act viewed water as a resource 'to be taken and diverted' into reservoirs. What the Company's directors, all Sheffield men, wanted was a 'regular and ample supply of pure and wholesome water.' Only then could they furnish the town with that 'bright, and colourless Water' which its customers demanded.[20] Once impounded, water could then be assigned a use. Usage inevitably inscribed water with new meanings and a monetary valuation, which helped transform the 'protosystem' into a

serviceable infrastructure, but also inevitably exacerbated existing social and environmental inequalities between suppliers and consumers.[21]

This tension between nature, technology and the built environment inevitably brought water suppliers into contact with socio-technological experts.[22] Sheffield's directors plugged into an expanding network of professional engineers in their drive to continually expand their waterworks system, and drew their technological inspiration from early canal and railway initiatives. Leeds-based engineer John Towlerton Leather was appointed as Managing Clerk, Resident Agent and Surveyor in 1830, shortly after starting his Sheffield practice, with responsibility for designing and building the works. He had served his apprenticeship with his uncle, George Leather, building the Goole Docks in the East Riding for the Aire and Calder Navigation. When he became Consulting Engineer in 1839, in order to expand his external practice, he was succeeded in residence by John Gunson, a lifelong Company employee.[23]

The Company also consulted with other leading engineers between the 1830s and '50s, including John Frederic La Trobe Bateman, engineer to Manchester Waterworks, and James Simpson, who was engineer to Chelsea Waterworks.[24] Having served his apprenticeship on the canals, Bateman's reputation was forged during an illustrious career in reservoir construction, notably Manchester Corporation's waterworks at Longdendale (1848-77) and its controversial Lake District scheme. He was also engaged with over thirty other urban waterworks systems and was a lifelong member of the Institution of Civil Engineers (ICE), including its President in 1878-79.[25] Simpson, meanwhile, spent most of his career working for the Chelsea and Lambeth water companies, where he designed and installed water filter beds, before turning his attention to gravitational engineering at

Bristol, Aberdeen and Liverpool. He too was President of the ICE, in 1854-55, which illustrates the high regard that water engineers were held in the engineering profession and was, as Christine MacLeod has convincingly elided, part of a wider celebration of heroic invention as engineers tamed nature and became the standard-bearers of the industrial classes.[26]

In addition to externally validating the Company's works, consultation inevitably brought uniformity in reservoir design during the nineteenth-century. In most cases, a trench was dug across the end of the valley to be closed, and a wall of puddled earthen clay (clay mixed with sand, wetted and kneaded into a water-tight amalgam) sunk down to bed-rock and raised in thin layers from its foundation, to settle and harden into a solid barrier against water leakage. A slope of earth was added on each side to further protect the puddle. The dam's water faces were then covered with masonry and sown with grass to give a natural appearance, thereby further blurring the boundaries between "natural" and "artificial" landscapes. By 1840 there were around a dozen such engineered landscapes in Britain, the majority around Yorkshire and Lancashire, as well as the Scottish Lowlands. British engineers preferred this mode of construction simply because it had proven itself to be successful over time, in canal and railway embankments as well as waterworks technology, and they subsequently attempted, with varied success, to build similar systems across the British Empire. Yet, as Harold Platt has argued, this method was largely dependent on a working experience of on-site problems and the collation of reliable data on rainfall and surface water run-off to better plan for changing seasonal conditions.[27]

Sheffield's continued urbanisation during the Company's formative years saw residential demand for water continue to rise. During the 1850s, the town experienced

'a massive demographic surge' (its population rising to 185,172 by 1861) to become the fifth largest in England, which was the result of a major expansion in steel production fuelled by a flood of in-migrant labour. The town expanded in a centrifugal pattern with a mushrooming of working-class terraced housing towards the north-east, while middle-class suburbs developed on the western and south-western fringe.[28] This surge had major implications for the supply of water, especially through the increased pressures on domestic water practices involving cooking, flushing and cleansing. In 1848, there were only 126 indoor water closets in the town. Within five years, the Company had imposed charges on their spiraling use. Similar rates were introduced for bath-tubs, which led to a protracted legal dispute over the Company's rights to charge additional costs for user technologies. In 1853 the Company supplied water to roughly eighty-five per cent of the town's residents, and drew annual revenue of over £13,000. Between 1854 and 1861, the average rental increase from new customers was £852 per annum. During the same period, the Company laid over thirty miles of new pipes.[29]

Extended supply technologies connected the Company's water catchment and storage areas with the town's growing number of outlets for consuming water, creating a vast socio-technological network. Thus, the technologies of service reservoirs, water pipes, mains and flushing systems played increasingly important roles in circulating water throughout the city and its hinterland. Such networks inevitably brought private water suppliers into conflict with public regulatory bodies, notably the Town Council's Water-Works Committee, whose role, since its formation in late 1844, was to supervise the cleanliness of the water that was being privately provided to homes, rather than seek the role of supplier itself. The earliest municipal ethos was, therefore, regulatory in character.[30]

Supply difficulties were exacerbated by delayed land purchases, ongoing repairs, and a drought in 1852, which reduced the daily supply below the Company's statutory guarantees and drew censure from the Water-Works Committee.[31] Engineering provided the solution when, in 1853, the Company secured parliamentary sanction for an expanded source of supply in the Loxley Valley, including powers to construct three new reservoirs, along with connecting aqueducts and tunnels to an enlarged storage reservoir.[32] Loxley offered natural advantages over the Rivelin and Redmires valleys, but only after engineers had mastered gravitational delivery. As a steep and narrow millstone grit valley, water was naturally purified and softened by the grit before being transported along the Loxley into the Don. The three planned reservoirs offered a combined drainage area of 6,978 acres, almost one-and-a-half times greater than the existing watershed, and a capacity of 1,540 million gallons. Engineering practice would again harness the productive forces of nature by extending Sheffield's hinterland and bringing the benefits of an expanded water supply to the town's thirsty residents, thereby producing an expanded waterscape that, to paraphrase Swyngedouw, would weave together nature and society – through the various underground and surface pipes, mains, aqueducts, rivers, streams and their tributaries – to produce what he calls "socionature".[33]

By establishing nature as a serviceable resource for industrialising towns, contemporaries circumvented the tendency to delineate between natural and man-made environments, preferring instead to identify town and countryside as mutually beneficial, 'integral to each other' with their own permanencies, particularly in a commercial and engineering sense.[34] Dale Dyke was the first Loxley works to be built, in a 'hammock of hills close to the picturesque village of Bradfield,' where several small streams converged. Construction work began in January 1859 with a catch-

water reservoir and artificial watercourse to intercept the waters during the building of the embankment, and was completed during the winter of 1863-64, whereupon it was gradually filled until its collapse. Its chief function was to impound the water produced within the gathering grounds to provide compensation to the mill-owners on the river, whilst the neighbouring Strines and Agden reservoirs (both completed in 1869) would service public consumption. With a water area of 78 acres and a capacity of over 700 million gallons, the DDR was a monumental example of mid-Victorian water-works engineering designed to celebrate the Water Company's mastery of its natural environment as well as to fuel future growth in water demand. Its embankment, at 1,254 feet long and 95 feet high, was above average in size to offset future expansion in the Company's interests: its greatest width at the base was upwards of 500 feet; while the puddle wall at the top was four feet thick, increasing to sixteen feet at ground level, and sunk to a depth of 60 feet below the sandstone surface to make it water-tight. Utilising nature's own tools, the sloping walls of the embankment were composed of a mixture of shale and rubble excavated from the reservoir bed, techniques borrowed from the leading water engineers. To maintain river flow, twin 18-inch cast-iron outlet pipes ran through the puddled clay trench in the base of the embankment and ended at the foot of the slope in a valve-house, while a bye-wash provided an outlet for overflow.[35]

The construction process was beset with setbacks from the outset. Delays were occasioned by difficulties in excavating the puddle wall foundations, where leakages from springs in the sandstone bed were recurring problems. The artificial watercourse collapsed under flood waters in 1863, causing the main reservoir to fill fifty feet, which had to be emptied before construction could resume. As a precaution, Gunson moved the dam's centre line upstream onto firmer ground to protect against further

disruptions.[36] Such incidents caused little alarm, however, since, as the disaster studies literature confirms, failures to individual components are considered to be normal within a maturing industry.[37] The growth of mechanical engineering – with the formation of the Institution of Mechanical Engineers (IME) in 1847 to rival the ICC, which had enjoyed a monopoly since its creation in 1818 – introduced new ways of thinking about urban problems. Coupled with increased specialisation in marine, structural and other engineering disciplines, each with their own institutional bodies, there emerged new knowledge, materials and approaches within the nascent field.[38] With professional diversification came competing, and invariably fluid, opinions, as well as evolving knowledge: Platt notes how plans for new water-works were rarely executed as intended and each new project became 'a source of both on-the-job education in hydraulic engineering and influential advances in waterworks technology.'[39]

Reservoir engineers were, however, conscious to protect themselves from blame since the failure of a dam could have devastating repercussions for their reputations. They also severely dented their Water Company's revenue, particularly since, following the collapse of the Bilberry dam outside Holmfirth, West Yorkshire, in 1852, all water companies had to accept liability for losses caused by the failure of any reservoir embankment.[40] John Towlerton Leather was more alert to this than others since his uncle had been consulting engineer at Bilberry. Problems had plagued this project from the outset: the contractors cut corners to complete on budget, and the reservoir, which leaked throughout the 1840s, was patently not water-tight.[41] No-one was really surprised when it collapsed on the 5th February, 1852, releasing 300,000 tons of water into the valley and desolating the manufacturing village of Holmfirth three miles below. Eighty-one people died, while over 6,000 workmen were thrown

out of employment. Following contradictory evidence at the Coroner's inquest, George Leather's reputation was left in tatters.[42]

If the Holmfirth disaster was still fresh in the public mind during the early 1860s, it brought no material benefits; nor did the policy window that emerged in its wake remain open for long. Indeed, the then home secretary, Sir George Grey (who coincidently happened to be back in office when the Sheffield flood occurred), had dismissed calls for state intervention, insisting that 'the Government cannot undertake the inspection of all such Reservoirs at the public expence.'[43] Notwithstanding the real anxieties felt by engineers about the safety of their works, Dale Dyke's collapse came as a major surprise to John Gunson, who could do nothing to prevent a large crack in the outer wall of the embankment giving way in the early hours of the 11th March, 1864.

An estimated 650 million gallons of water were sent rushing without warning down the narrow sloping valley, razing land, buildings, machinery and bridges and drowning hundreds of people and animals. Entire families were killed: Daniel Chapman, a young steel tilter and forger, his wife Ellen, their two sons, a domestic servant and two apprentice lodgers were drowned in their terraced house by the river at Little Matlock. James Trickett, a dairy farmer, died with his wife, Elizabeth, their three children and three servants at their home in Malin Bridge. George Bisby, innkeeper of the Cleakum public house at Malin Bridge, was also killed along with his family, leaving an orphaned daughter. The body of Bisby and his eldest daughter were found four days later in Sheffield. At Owlerton, a suburb to the north of Sheffield, the Loxley joins the river Don and here the waters changed course, running directly through Sheffield. The torrent was eventually halted by the river snaking into a north-easterly direction at Lady's Bridge just outside the town centre, which

escaped damage. The densely populated area of the Wicker was inundated by the flood water instead. The flood waters even managed to reach Rotherham, some eleven miles east of Sheffield. Twenty bridges were either wholly or partially destroyed. Thirty-one factories, mills or workshops were destroyed, a further fifty-five were partially destroyed or damaged, while 237 were flooded. Some 800 houses were destroyed or abandoned and a further 4,357 flooded. Once the waters receded, they left an 'accumulation of mud and decaying matter.'[44]

The flood – which was immediately appropriated as a Sheffield event – elicited intense media interest. Newspapers sent journalists into the 'wrecked and ruined district' where they filed harrowing reports; the national dailies picked up the news through the telegraph wires operated by the editor of the *Sheffield Telegraph*, William Leng. Frequent editions of the two Sheffield dailies, the *Telegraph* (founded in 1855), which represented the predominantly Anglican and Conservative steel manufacturers, and the *Sheffield and Rotherham Independent* (founded in 1819), which was the mouthpiece for the Liberal guard, appeared throughout the day. Leng noted that his publishing office 'was literally besieged throughout Saturday and we scarcely stopped our machines, the demand for news was insatiable. We were always bringing out new editions, and our steam machinery was kept going till close on midnight.' The editor of the *Independent*, Robert Leader, reported that, although he had printed 80,000 copies of his paper on Saturday the 12th and Monday the 14th, 'many thousands of persons' had been left disappointed, so he duly reprinted the detailed account in the Tuesday edition.[45]

Intrigued by the fantastical details of the reports, crowds flocked to the scene. Special trains were laid on from many towns for up to two weeks after the flood. Newspaper reports described 'an unceasing stream of visitors up the valley …, and

the scene of devastation, especially between Owlerton and Malin Bridge, was crowded for many hours.'[46] In his account of the flood, which was based on published reports as well as survivor testimonies, the editor of the weekly-published *The Sheffield Times*, Samuel Harrison, estimated that 150,000 of the inhabitants of Sheffield visited the scene within days of the flood, while 'perhaps an equal number came in from the adjacent villages and towns and from more distant parts.' Many made it by foot as far as the ruined reservoir, effectively treating Bradfield as an extension of suburban Sheffield.[47]

The Politics of Disaster Relief

Even allowing for editorial bias – and Leng was an outspoken critic of the Water Company, which he felt represented the outdated Liberal elite – Sheffield's newspapers fixed on two main narratives which emanated from the disaster. The first of these concerned the organised response to the flood, which drew Sheffield's public bodies firmly into the events; the second dealt with the controversy surrounding the cause of the flood, which masked a wider dispute about the ownership of urban water supplies. Both narratives subsequently reappeared in national newspapers like *The Times*, which illustrates how disasters elicited an increasingly common response.[48] Responses to nature- and engineering-induced disasters were equally cultural and indicate a general willingness to draw practical lessons from such incidents as well as cope with catastrophe. Comparisons were even drawn between recent fires, explosions and floods, which illustrate a concerted interest in improved hazard management.[49]

For once, it emerged that Sheffield's civil bodies responded promptly in a crisis. Faced with a massive clear-up operation, public and private organisations alike

collaborated in an early instance of what would today be called joined-up government. Members of the police force, a municipal body usually subject to ridicule, were lauded for their 'most arduous and praiseworthy' exertions in working throughout the night to rescue residents from their submerged homes and remove dead bodies.[50] The engines belonging to the various fire insurance offices worked day and night to pump out the town's flooded cellars, while the Town Council's Sanitary Committee, another vilified body, ordered a major clean-up of the town to prevent the spread of infection. Lime and chloride of lime were used to decontaminate streets and houses, while sewers were flushed out to avoid cross-contamination of water.[51]

In the morning, the Mayor, Thomas Jessop, and Sheffield's Chief Constable inspected the scene of devastation and promptly issued public notices requesting information of dead bodies found 'so that they may be removed to the Sheffield Union House for Identification,' and imploring the public to assist the police in recovering lost property.[52] On the same day, the Town Clerk, John Yeomans, wrote to the Home Secretary requesting the attendance of a Government Inspector 'to enquire into the Cause of this dreadful Catastrophe.' The Borough Coroner issued a similar request the following day.[53] Such examples of interactive readjustment, in which authority figures participated in information exchanges to accelerate readjustment, indicates an orderly and systematic response to coping with disaster and initiating recovery. It also illustrates how the co-ordination of emergency responses was conducted by municipal officers who had greater access to the resources necessary to aid recovery on a citywide basis without prejudice. The municipal official, according to Barry Doyle and others, was the exemplar of the Victorian transition into a professional and non-partisan approach towards urban governance, whereas private companies, with their responsibilities towards their shareholders, were not trusted to

act fairly in their treatment of such cases. Market failures merely exacerbated the existing social and environmental inequalities in water provision and the municipal authorities, in pursuing an emergency regulatory role, were better placed to offer help to everyone affected.[54]

That the Water Company was not involved in recovery activity at any stage reveals both its unpreparedness to provide equal treatment to everyone and the tentative growing public faith in the quality of care offered by the town's municipal regime, a recurring theme elsewhere.[55] Sheffield's ratepayers had little cause for optimism, however. For years, charges of inaction had been made against the Town Council, particularly its refusal to adopt the Public Health Act, 1848, on the grounds that it threatened 'those principles of free local self-government, so congenial to the spirit and feelings of Englishmen.'[56] The Council preferred to pursue its own course of toothless regulation; its Water-Works Committee had long tried to rein in, and failed, the Company's expansionist schemes. Indeed, the threat of centralisation under the Chadwickian General Board of Health was tangible to a Council presiding over a town with an average life expectancy of twenty-four during the 1840s. A proposed improvement bill was twice defeated, in 1851 and 1858, through petty in-fighting between the Liberals and the radical Chartist-inspired Democrats.[57] The Council only adopted the 1848 Act's successor, the Local Government Office Act, in 1864 because it was a cheap option for implementing essential sanitary reforms.[58] The Council was in the process of restructuring when the flood occurred and had recently urged the Company to provide a constant supply of water to the town.[59]

Sheffield's ratepayers were reluctant to engage with the political process during the mid nineteenth-century and it took systemic shocks to bring to their attention the extent of the inequalities in force in the town. They only accepted

incorporation in 1843 after a proposal that the West Riding magistracy, which sat outside Sheffield, should govern the town's policing. Little changed in the town's complex political landscape, however, since the Church Burgesses and Town Trustees, founded in 1554 and 1681 respectively, retained responsibility for the parish church, street improvements and hospitals, while the Cutlers Company, which was incorporated in 1624, controlled apprenticeship regulations and the award of corporate marks to cutlery manufacturers. Boards of highways surveyors and the police commissioners (formed in 1818) further muddied the political landscape. Manorial authority, vested with the Duke of Norfolk, continued over the town's markets until the end of the century.[60]

Sheffield's political failures, particularly in its inability to limit the pecuniary interests of the Water Company, largely derived from the overlapping membership of the various bodies as well as in-fighting between the multiple interests. The Company's Board of Directors was dominated from the outset by men who also served in public office. These included Samuel Hadfield, the two-time Master Cutler; Samuel Roberts, the silver plate manufacturer and town councillor; and the table knife manufacturer Thomas Asline Ward, who chaired many of the Company's meetings during the 1830s and '40s alongside his other interests, which included the Town Trustees, the Sheffield Political Union and the Litt. and Phil. Society.[61] Frederick Thorpe Mappin, the Managing Director of the file manufacturers Thomas Turton and Sons, was elected Master Cutler and town councillor in 1855, and became a director of the Water Company in 1862 and the Gas Company in 1863. Sheffield, therefore, is a classic example of contradictory interests and political inertia. The town's Liberal elite was unwilling and incapable of regulating itself, not least since the town was governed by a bewildering patchwork of public authorities.

For all its problems, the flood posed an unanticipated window of opportunity for Sheffield's urban elite – which, by the 1860s, was increasingly represented by Conservative steel-making interests who had emerged as the main challenge to Liberal control of the town[62] – to establish the Town Council as more than an arms-length regulator of the environment. In this it was ably assisted by Leng's *Telegraph*, which pushed for a clearer demarcation of responsibilities between the municipal sphere and the marketplace. This was part of a broader transition, evident across the Western world, from overlapping and oligarchic public/private interests to a modern understanding of municipal governance that was openly democratic and accountable.[63] Since the immediate task after collecting the dead was to provide shelter, food and drink and clothing for the hordes of homeless survivors, Jessop quickly convened a meeting, which was attended by the town's leading manufacturers, at the Council Hall to discuss their coordinated response. Another meeting held the next day formally established the Sheffield Inundation Relief Committee (SIRC), which duly raised over £50,000 towards the relief effort.[64] Although not strictly a municipal venture, the SIRC was placed under the management of the town's public servants. Jessop, a senior partner in one of the town's larger steel manufacturers and the presiding Master Cutler, was elected Treasurer, while Yeomans was appointed Honorary Secretary. Other members included the steel manufacturers Edward Vickers, Robert Jackson, John Brown and Robert Thomas Eaton, all of whom were either councillors or aldermen; Henry Vickers, who was Clerk to the Town Trustees; and Michael Ellison, the duke of Norfolk's land agent. Post-disaster recovery was being viewed through a public lens, circumventing many of the traditional tensions between the established Liberal elite and the emerging Conservative steel manufacturers. Political rivalries were temporarily shelved as Sheffield's political classes presented a

united front of resilience, which resonated with the fact that disasters historically reveal the resilience of urban governments, not least by allowing citizens the opportunity to observe how their political leaders respond to a crisis.[65] Sheffield's flood, therefore, marked the beginnings of a sustained shift towards municipal regulation; the market would no longer be left to regulate itself, while concerns about the safety of "socionature" prompted the introduction of new agencies responsible for supervisory control.

Engineering Municipalisation

Sheffield's governing classes capitalised on the flood in their quest to modernise municipal government in the town. Taking control of the emergency response and relief effort was the immediate response, but it masked deeper-rooted tensions between the local state and private enterprise over the delivery of local services. An emerging public service ethos within Britain had started to influence how elected municipalities defined their rights and responsibilities. Albeit a clumsy and occasionally misappropriated term, "gas and water socialism" served as an ideological and political justification for reformist agendas, though the involvement of Conservatives like William Leng at the *Sheffield Telegraph* paints a more varied canvas of support for municipal trading.[66] The battle to seize monopoly control of water supply was a turning-point in the longer-term and more pronounced municipalisation of the urban condition. In the case of Sheffield, public safety rhetoric infused public sector arguments in favour of dismantling the Company's monopoly and taking ownership. Private enterprise could no longer be trusted with managing dangerous socio-technological systems; "focusing events" such as these proved that only public bodies, aided by disaster experts, enjoyed the legal and moral legitimacy

to safely manage such risks, which was never a given outcome of the policy learning process.[67] Municipalisation was duly being defined as a technologically-driven decision as much as a political strategy, involving a complex interaction between, amongst other factors, 'technological development, local politics, public financing, and bureaucratization.'[68]

In order to win the heated public argument about ownership, however, the Town Council first had to prove that the Water Company had been negligent in its legal duty by highlighting the engineers' failures to safely discharge their plans. Consequently, the dispute relied upon technological details concerning the reservoir's design, capacity and safety, and took place in a variety of arenas. Two overlapping enquiries occurred simultaneously: first, the public inquiry was conducted by the Coroner's Court and local newspapers, and involved both expert and lay witness evidence; second, the professional inquiry started in the Coroner's Court, but soon moved on to other institutional locations, including parliament, the town hall and the boardroom.[69] In this inquiry, evidence was sourced from qualified engineers who disputed the reasons for the reservoir's failure. Whereas the public inquiry focused overwhelmingly on apportioning blame for the disaster, the professional inquiry was more interested in addressing the causes of the failure, managing the legal ramifications of the Water Company's liability, and paving the way for the eventual municipalisation of water.

The evidence on the apportioning of blame should be read with an eye on points-scoring by the Conservative press against the Liberal establishment, as well as the motives of an inexperienced, yet ambitious, Town Council. The battle-lines were drawn as early as the 15th March when, in a rasping editorial in the *Telegraph*, Leng declared that 'The Bradfield Dam was a mistake, or if not a mistake we should like to

know what it was. It was made to perform a certain duty, and it has proved itself unequal to the duty.'[70] Leng, a supporter of greater municipal regulation – if not control – of local services, regularly supplemented his editorials with articles from the professional press, and the voluminous correspondence from budding engineers, all of whom had a theory on the cause of the reservoir's collapse.[71] For instance, he praised an article from *The Builder* which criticised the engineers for failing to install sluices to reduce the water level, and for their use of loose and porous materials in the puddle wall.[72] Another article, in *The Engineer*, agreed: 'That the Bradfield dam was lamentably defective no one can doubt.'[73] The Water Company had, according to Leng, failed to guarantee the safety of Sheffield's residents, but the Liberal-controlled Town Council had also failed to adequately supervise the Company's activities. If Leng was taking sides, it was with the growing Conservative influence on the Council, which promised stronger regulation without discouraging enterprise. On the other side, the Liberal *Independent* published similarly lengthy correspondence into the supposed causes of the disaster, but its editor, Robert Leader, refrained from drawing judgment on them until after the outcome of the Coroner's inquiry and the report of the Government inspectors. Even then, he refused to condemn any aspects of the reservoir's construction. Moreover, as a member of the SIRC, Leader was unwilling to publicly criticise his colleagues on the Council. Once the emergency relief effort had been organised, the flood transformed Sheffield into a battle-ground for control of the municipality and other important institutions, and editors like Leng and Leader were key players in this conflict.

Unsurprisingly, the Coroner's inquiry concentrated on the construction of the reservoir. The Water Company's engineers were cross-examined by the Coroner, John Webster, and Sir Robert Rawlinson, the Home Office Inspector, both of whom

pounced upon any inconsistency in either man's evidence. Both Leather and Gunson adhered to the Company's official explanation for the collapse, citing a landslip, of 'some hundred years old,' under the embankment, which undermined the puddle wall and allowed water to seep inside and force the embankment to subside. Leather rejected the theory that the bursting of the reservoir was through 'unsound principles of engineering or … bad workmanship', preferring to emphasise the differences between natural and built environments and the limits to his control over the former:

> I did all that I thought necessary to provide against danger. I know of no means of providing against danger except the pipes and bye wash … There is a possibility of a landslip under the seat of the embankment having produced it, but that I cannot tell. I do not believe the embankment itself has slipped, but the stratification beneath it may have slipped.[74]

Such comments illustrate the inherent appearance of risk and uncertainty within the environment, and chime with the findings of Lübken, Mauch and others.[75] Yet Leather undermined his own argument once he had admitted to having inspected both the puddle trench and wall once only, thereby making no concerted effort to shed light on the uncertain technological elements. He confessed that he had not been present at all during the puddling process, but had faith in Gunson adhering to his plans. Gunson appeared on the defensive, claiming that, having 'acted as engineer for this company for nearly 33 years … there was nothing left undone that could have been done as to safety of construction.'[76] Experience mattered to Gunson who insisted that important lessons would be fed back into the construction of the Company's other dams. Try telling that, an irascible Webster exclaimed, to the families of those killed by 'an accident that ought not to have happened and which might have been avoided.'[77]

The Water Company would not publicly admit to any mistakes. Its directors accepted liability, but to accept blame would be an admission to criminal damages.

Both engineers cited the extended excavation of the puddle-trench and the installation of the bye-wash as evidence that they had taken appropriate remedial safety measures; whilst the delays that these modifications made to the project was proof that the directors had put safety considerations above any pecuniary self-interest. Besides, the Company could handle the angry outbursts of an official, particularly after Leader, a supporter of the political *status quo* and a friend to some of the Company's directors, publicly criticised Webster's 'intemperate language' and 'anti-judicious conduct.'[78]

Greater difficulty was evinced by the measured condemnation of Rawlinson, who, as one of Britain's leading professional engineers, was 'listened to attentively.' As an experienced servant of government – an engineering inspector for the disbanded General Board of Health (1848-54) and, since 1861, Chief Engineering Inspector in the Local Government Act Office[79] – Rawlinson's opinion mattered, however unpopular it could be with practicing engineers who resented government interference in their work. He was accompanied by Nathaniel Beardmore, an expert in hydraulic engineering, who was sent to represent the ICE in the absence of its President, John Hawkshaw.[80] Rawlinson and Beardmore made 'a full and searching examination' of the ruined reservoir, as well as the Company's other works, studied the original plans, and attended meetings of the Water-Works Committee and the SIRC. No stone would be left unturned in their pursuit of the truth.[81]

Rawlinson lent the weight of detached expert evidence to the proceedings, identifying 'Several grave errors … in designing and in executing these works.' First, he insisted that pipes should not have been laid unsupported through the 'dangerous' puddle-trench. These he suspected had slipped into the artificially formed substratum in the trench, leaving a cavity above it for water to seep through, further adding that the absence of valves to turn the water off from the pipes was 'a fatal objection'.[82]

Second, having inspected the Agden construction site, which was modelled on the DDR plans, he criticised the mode of unsystematically tipping wagon-loads of rocks, stones and other materials to build up the embankment as dangerous, rendering it 'as porous as a sieve.'[83] In their haste to exploit the natural environment for their directors' benefits, the engineers had under-estimated the ways in which nature constrained their best efforts to create a safe technology, thereby erecting an 'illusory boundary' between technology and the environment that was misguided at best.[84] By cutting corners on safety, Rawlinson insisted, Leather had failed in his basic duty: 'The engineer should be master of his work; not let it be master of him.'[85] Uncertainties and in-built risks could, with care and responsibility, be rendered knowable and controllable.

Rawlinson's evidence went some way towards alleviating the public's insatiable appetite for explanations. In so doing, his testimony added considerable weight to the jury's decision that 'there has not been that engineering skill and attention in the construction of the works, which their magnitude and importance demanded.'[86] He and Beardmore repeated these criticisms in their joint report to the Home Secretary.[87] The problem, therefore, lay with the reservoir's original design and construction; mistakes had subsequently been made by the Resident Engineer, under pressure from the directors to complete on time, in the absence of adequate supervision from the Consulting Engineer.[88]

Rawlinson's evidence might have assuaged public anxieties, but, as one engineering writer put it, he 'is not an authority above all others in matters of engineering.'[89] The idea that there can be dispassionate and neutral scientific inquiry into the key questions of causality and blame is misleading. A discourse of public responsibility for the safety of private ventures had evolved during the nineteenth-

century to the point that there existed a dense network of investigators each representing conflicting interests and tending to emphasize different aspects of the same disaster, which inevitably made it impossible to assign blame.[90] More generally still, competing discourses of nature and risk emerged through which an understanding of "socionature" could be constructed, represented and challenged in a variety of engineering, scientific and political contexts.[91]

The engineering profession was divided over the likely cause of the accident and the Water Company's directors deftly exploited this split. Timed to coincide with Rawlinson and Beardmore's report, though subsequently delayed, the directors commissioned their own inquiry and hired 'the undoubted leaders of the profession amongst Hydraulic Engineers in England' to conduct it.[92] In addition to Simpson and Bateman, these included Thomas Hawksley, another celebrated water engineer and a member of the ICE's Council since 1853, who had designed a constant water supply for Nottingham, and had recently completed reservoirs for Liverpool and Leicester. John Fowler, a former pupil of Leather at Sheffield and the chief engineer to the Manchester, Sheffield, and Lincolnshire Railway, was a natural ally for the Company; T.E. Harrison, who was most intimately known for his work on the North Eastern Railway, but also had an active interest in water engineering, completed the team.[93]

In their jointly authored report, issued in November 1864, they picked apart each of Rawlinson and Beardmore's points. They were satisfied that the puddle-trench had been sunk to a sufficient depth to make it water-tight and stated that the embankment was made from the 'best material which could be procured,' that is, of material excavated from within the reservoir itself. The discharge pipes had been carefully laid in a trench specially cut out from the solid ground beneath the base of the bank, made watertight with lead and protected by a layer of 'good puddled clay

well rammed together.' By deliberately reducing the capacity of the reservoir from their original plans, and increasing the size of the embankment, the Company's engineers had paid due attention to public safety and 'determined to avoid' any dangers. This led them to conclude that the accident was caused neither by engineering or design fault, but by a landslip, 'which occurred in the ground immediately on the east side of the embankment, and which extended beneath a portion of its outer slope, involving in its consequences the ruin of that portion of the bank, and producing the catastrophe which followed.' The physical evidence of the surrounding landscape – with its tears and fractures signifying land movement – was enough for the engineers to absolve Leather and Gunson from any blame.[94]

Aware of delays facing the Company's inquiry, the Council's Waterworks Committee out-maneuvered the directors for once by commissioning its own report into the cause of the collapse, which it published in June. Unsurprisingly, it included all those reports from qualified engineers, nine in total, which found fault with either the construction or management of the waterworks and favoured public ownership of waterworks. These included the water engineers James Leslie, Chief Engineer to Edinburgh Waterworks, Henry Conybeare, who designed Bombay's waterworks, and David Stevenson, well-known for his works in canal and river engineering, as well as the celebrated railway engineers Sir John Rennie, Charles Blacker Vignoles, John Murray and Peter William Barlow.[95] Much of what they wrote chimed with Rawlinson's criticisms. For example, Leslie, the pioneer of embankment-style storage reservoirs in non-urban settings, found the decision to build one in an area susceptible to slippage 'in the highest degree objectionable,' and, along with Barlow, blamed the lack of 'sufficient and careful supervision' for its collapse. Conybeare cited poor decision-making throughout as the main defect: this included Leather's decision to

site the dam on ‘a line of fault abounding in springs’; the use of pervious materials, unevenly spread, in the embankment, which duly settled and sank ‘to a level dangerously near that of the water’; the ‘injudiciously thin’ puddle trench, deemed too small for such a large reservoir; and inadequate provision of inlet and outlet pipes, goits and channels for regulating the flow of water through the reservoir.[96]

Others, like Rennie, a former ICE President (1845-48), and William Lee, the sanitary engineer, preferred to suggest solutions, identifying municipalisation as the logical option facing the town:

> Considering the size of Sheffield, its growing importance, the general tendency of legislation on the subject, and the reciprocal connection between water supplies and drainage and other sanitary arrangements, it is my opinion that the Corporation ought to have possession of the water works.[97]

Vignoles further fuelled the acrimony by deriding the Company for destroying public confidence in the private management of large engineering works and claiming that it would simply ‘go on repeating the dangerous practises’ if left in charge.[98] Taken by surprise by the Council’s spirited activities and strongly-worded condemnation, the Company’s directors tried to dismiss the report as speculative scaremongering, seeing the exercise as a calculated attempt by the Council to seize control of its property, occurring as it did against a backdrop of recriminatory negotiations to settle the compensation rights of victims.

Apart from the fact that each engineer was commissioned to comment on the DDR’s collapse by a partisan body, the reasons for the division in opinion appeared to boil down to personal loyalties (between Fowler and Leather, or Leslie and Rennie, who were Edinburgh friends, for example), professional rivalries, especially between Bateman, Hawksley and Rawlinson, and personal preferences for public or private

ownership: Hawksley was a staunch advocate of private water supplies, believing that the provision of constant water supplies could only be satisfactorily delivered through competition, whereas Leslie favoured municipal control, not least because of the checks it brought against unnecessary expansionism. Whereas Bateman had worked for the municipal authorities in Manchester and Glasgow, many of his commissions came from private enterprises, so he was unlikely to publicly condemn a major source of income. Lee, who had been paid by Sheffield Town Council in 1847 to report on the sanitary condition of the town, was likewise a safe pair of hands for the municipal cause. Moreover, despite the divisions on this issue, there were no noted institutional splits within the ICE's membership: all the engineers involved in the dispute were long-time members, and some, like Simpson, Fowler, Rennie and Vignoles, enjoyed senior positions. Nor was there any obvious disagreement between the ICE and IME. Indeed some, notably Hawksley, Fowler and Leather, were members of both bodies.[99]

The inconclusiveness of either side's evidence meant that neither inquiry settled the issue of blame. Yet the political ramifications to the engineering impasse were considerable, not least with the Water Company's defiant response. Having admitted liability for the accident, its annual report outlined plans to promote a Bill to raise £400,000, 'to meet all the claims arising out of the late lamentable occurrence,' and to create an 'independent' Commission to administer them. To offset the additional burden on its shareholders, the directors further proposed to make 'a moderate addition' to their water rates. Any defense of the Company's reasonable claims were duly shattered by the revelation in the published Bill that the directors brazenly advocated a twenty-five per-cent hike in their rates in perpetuity; they were, in effect, charging the town's residents for their negligence.[100]

Amidst the inevitable outrage of public meetings and press censuring, the Council opposed the Bill and offered to purchase the Company's concern. Called to debate the finer points before select committees of both Houses of Parliament, the opponents readied themselves to prove that the disaster had been caused by bad engineering, but were headed off by the Company's admission of liability. This meant that the Bill was debated on legal points alone, playing into the hands of the Company's expert legal team, which could boast of the support of Sheffield's large ratepayers. Neither of Sheffield's Members of Parliament, one of whom was a major shareholder in the Company, spoke against the Bill. Both committees unsurprisingly found in favour of the Bill, although the Lords fixed the rate increase to twenty-five years and ordered the Company to give a constant supply to the town within five years and complete its Loxley works by 1873.[101] Defeated and demoralised, the Town Council was railed against publicly for its inept showing, undermining all the effort it had invested into winning the argument in favour of municipalisation. By focusing exclusively on engineering issues, the Council had failed to whet the public and media appetite for reform, which had centered on political and moral arguments against private enterprise rather than the technological details. They had also lost the momentum provided by Leng's open criticism of the Water Company. The window of opportunity, which is always briefly open following "focusing events," had thus closed; the political momentum generated by the disaster had been insufficiently seized.[102] As this case had proven, engineering arguments only went so far in the heated debates over municipalisation.

The passing of the Sheffield (Bradfield Inundation) Act was not the final curtain to the saga. Three Inundation Commissioners were appointed, who, between October 1864 and April 1865, sat in judgment of 6,619 claims for destroyed or

damaged property as well as the claims for deaths and injuries. Claimants ranged from the largest manufacturers in Sheffield's steel and iron industries to individual cutlers and grinders who claimed against loss of employment. They also included shopkeepers, farmers, timber merchants, brickmakers and printers, as well as many hundreds of domestic claims for loss of furniture and household effects. The Commissioners' proceedings meticulously record the priorities of victims who were trying to rebuild their lives, emphasising the calculability of material losses over the human casualties, and illustrating the Water Company's hand over the settlement procedure.[103] The final sum of £276,821 awarded was a welcome figure for the Company, which invested the remainder raised under its Act into its works.[104]

Tensions between the Council and the Company simmered for the next twenty-five years, boiling over on occasions when the former again tried to take-over the waterworks. Whenever the two bodies clashed, the memory of Dale Dyke was invoked and old wounds reopened. After the Company defaulted on its obligation to provide a constant supply in 1869, Sheffield's Mayor brought the disaster up in his written complaints to the Home Office and the Board of Trade.[105] This simmering hostility culminated when, once the Company's rating agreement came up for renewal in 1887, the Council finally succeeded in taking control of the town's water supply. Time was a great healer of wounds. None of the directors in 1887 had been on the board in 1864, as also with the Council. Upon its purchase, all the Company's works were transferred under municipal control, including the reconstructed DDR, which was completed in 1875 one-quarter of a mile higher up the valley from the original site.[106] The Council proceeded to complete the projected Loxley works under the supervision of the Company's Resident Engineer, Michael Edward Eaton, who succeeded Gunson on his death in 1886, and its Consulting Engineer, Thomas

Hawksley, who replaced Leather in 1865 as the inevitable collateral damage after the flood. Together, they finished Damflask Reservoir by sinking a concrete and puddle wing trench as an additional safety measure. Public safety tended to follow municipal control because town councils could fall back on their rates as collateral against the extra capital investment. In his report on the works' completion, the Chairman of Sheffield's Waterworks Committee diplomatically marked the occasion: 'we are at the completion of the extensive scheme of Rivelin and Loxley Waterworks, as system, not only of magnitude…, but one which, for its engineering features, and from the memory which attaches to the Dale Dyke disaster of 1864, is among the most interesting in the country.' There was no opening ceremony; memories of the disaster had not yet sufficiently abated.[107]

Conclusion

Having taken twenty-five years to secure control of the waterworks, it would be easy to conclude that the Sheffield Town Council failed to capitalize on the window of opportunity temporarily opened by the flood of 1864, but this would mask significant historical context. Urban environmental historians have argued that floods and other "nature-induced disasters" act as catalysts for major social and political change: major fires and earthquakes have triggered significant changes to building regulations, insurance codes as well as fire-fighting and other emergency relief services; floods similarly cause fundamental shifts in flood prevention and risk management policy, not least with building-in additional capacity for overflow in reservoirs or in installing sea defences for combating coastal floods.[108] There also remains a society-wide tendency to believe that, in order to be effective, change needs to be immediate

because, as Frank Uekötter writes, 'A natural disaster is like a bee. It stings, and then dies,' presumably to be forgotten by legislators, relief agencies and others.[109]

Such a view understates the longer-term, more piecemeal influence of disasters, particularly in the case of "engineering-induced" incidents. Such events can trigger a strengthening of regulatory control and supervision, particularly from the state: much fire safety legislation in Britain, for example, has been passed in the aftermath of major fires. Yet the majority of these changes – to political structures, social attitudes and technological systems – originated locally and followed years of piecemeal innovation at the municipal level.[110] A disaster may, like a bee, sting and then die, but it is never forgotten; it can leave a scar that long continues to haunt and shape a community's identity, memory and collective attitude towards reform.

The localness of Sheffield's flood limited its wider social and political reverberations, especially since the flood occurred during a time when the central government remained wedded to the philosophy of *laissez-faire*. Such policy windows are hardly unimportant when restricted to the local stage, however, because much of the agitation for the municipalisation of water, gas and other utilities came from the local level and reflected a growing trend for municipal control across the urban-industrial north and midlands. Historians have long agreed that the transformation of Victorian municipal government was achieved primarily by local legislation promoted by local councils and fostered by local pride.[111] In the case of municipal water supplies, over 130 town councils established a presence in the two decades after 1866; in the two decades before 1865 only fifty-one councils did likewise.[112] Although it is unclear how much incidents such as the Sheffield and Holmfirth floods influenced this changed ethos, the Sheffield Town Council's relative immaturity as a regulatory body was evidently not uncommon; neither was the Water

Company's strength to maintain monopoly control in the face of fierce public censure. The Council's representatives obviously lacked the financial, engineering and legal resources necessary to win its argument with the Company's directors and engineers. Yet the political, engineering and legal discourses that were riven with fierce recriminations for both sides invested the Council's officials with crucial experience from which they were able to exert greater regulatory and supervisory control over the Company's works, before inevitably securing ownership in 1887. Municipal intervention in the supply of water was less, as John Hassan has shown, an ideological response to perceived market failures than 'a pragmatic and rather haphazard process' involving a variety of local factors; the Sheffield case proves this.[113]

This paper has also revealed the tensions within the contemporary engineering profession over the alleged causes of technological failure. Whereas some sections of the profession effectively closed rank around troubled engineers, others publicly doubted their ability and questioned the nature of professional practice. Everyone connected with the design, management and use of water supply technologies was invested in the cult of engineering innovation, yet responsibility ultimately rested with the appointed engineers, who derived their power from their specialised knowledge and experience, and answered to this in a variety of public and private arenas. Engineering expertise was, therefore, socially and politically constructed through the working relations forged between consultant engineers, their employers and critics, and was strongly shaped by the contemporary debates over the politics of supply between private water suppliers, their customers and municipal regulators.

Conflicting explanations mattered where non-expert bodies could harness the available evidence and arguments to suit their own pre-determined agendas. Boards of directors for water companies and the waterworks committees of elected municipal

government exploited this engineering impasse, thereby rendering some of the country's leading engineers as pawns in a political game over control of water supplies. Yet for all the infighting, no consensus was ever reached regarding the supposed cause of the Dale Dyke Reservoir's collapse. By resorting to cumbersome arguments that centered on unverifiable technical details, these bodies distanced themselves from the broader public debates about the ownership, delivery and pricing of water. Lay debates, generally the preserve of the contemporary press, tended to focus on moral and ideological arguments that favoured municipalisation, whereas the leaders of Sheffield Town Council allowed themselves to be pulled into a convoluted technical and legalistic debate that they had little chance of winning against the Sheffield Water-Works Company, well endowed as it was with financial, legal and political clout.

All this occurred against the backdrop of an emerging public discourse that broadly favoured the municipalisation of water supplies on grounds of public health and cost, and which undoubtedly influenced some engineers' criticisms of the methods employed by privately-contracted engineers. Municipal authorities were keen to utilize the detached support of professional engineers in their arsenal of arguments in favour of wrestling control of waterworks from private enterprise. Similarly, some engineers, conscious of the threat to their livelihoods by a diminishing number of outlets for contracted work, vocally defended competition in supply. Although historians have tended to focus on more general arguments for municipalisation around themes like public health, social justice and the heavy cost of providing universal access to water, technological, environmental and engineering factors also need to be considered. In particular, historians are beginning to consider the ways in which engineers' projects facilitated greater integration and overlap

between natural and manmade environments, thereby extending a town's hinterland beyond the suburban fringe. It suited the longer-term goals of ambitious municipal governments to own such ventures since municipalisation paved the way for the inevitable extension of the network as well as the town's legal and fiscal borders. Thus, in 1896 Sheffield Council was given authority to extend its waterworks into the Little Don Valley and become a water supplier for the neighbouring South Yorkshire towns of Doncaster and Rotherham, and three years later it entered into an agreement with the authorities of Derby, Leicester and Nottingham to share the upland drainage waters of the Derwent Valley.[114]

Finally, the Sheffield flood occurred within a specific socio-political moment in the town's history. As a rapidly growing industrial town faced with a burgeoning water-supply problem, Sheffield, much like other industrial towns, was governed by an elite that was under pressure to make the transition into a modern form of municipal government. The contested nature in which Sheffield's flood was reported testifies to the contestations prevalent within the town's contemporary governance. Critics like William Leng, the newspaper editor, capitalised on the destructive prowess of the flood waters by attacking the existing Liberal elite that made up a significant proportion of Sheffield's governing classes, effectively using the flood as an opportunity to make political capital. In addition, the Water Company's directors also capitalised on the flood to tighten their grip over the town's supply in the face of an emerging municipal threat in the post-flood arena, deftly exploiting Parliament's proclivity to allow private enterprise to regulate itself. More widely still, professional knowledge about the safety of urban waterworks was produced, consumed and challenged in a variety of public arenas, at both the local and national scales. This brought the organisations that managed urban society into conflict with one another,

broke down existing coalitions of public and private interests, not least between the Water Company and Town Council, and opened up new vistas from which industrial towns would be governed in future.

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[1] I am very grateful to the archivists at Sheffield City Archives and the National Archives for their untiring help during the research process. I am also thankful to the editor, Stephen Mosley, and referees for their helpful comments on an earlier draft.

[2] Parliamentary Papers [hereafter PP], *Report on the Failure and Bursting of a Reservoir Embankment belonging to the Sheffield Waterworks Company, on the Night of Friday, 11th March 1864; by Robert Rawlinson and Nathaniel Beardmore, Civil Engineers* [hereafter *Rawlinson and Beardmore Report*], 20th May 1864, Cmd. 290-I, p.5.

[3] Karen Lightowler, *Sheffield Flood: The Aftermath* (self-published, 2007).

[4] Robert A. Buchanan, *The Engineers: A History of the Engineering Profession in Britain, 1750-1914* (London: Jessica Kingsley Publishers, 1989), chs.3-6; Robert A. Buchanan, 'The Causes of the Great Sheffield Flood of 1864', *History of Technology* **26** (1, 2005): 113-129; G. M. Binnie, 'The Collapse of the Dale Dyke Dam in Retrospect', *Quarterly Journal of Engineering Geology and Hydrogeology* **11** (1978): 305-324; Shin Hirose, 'Two Classes of British Engineers: An Analysis of Their Education and Training, 1880s-1930s', *Technology and Culture* **51** (2, 2010): 388-402; Ian Harlow, *Holmfirth Floods: The Story of the Floods in Holmfirth* (Sheffield: ALD Design & Print, 2004); John Thomas, *The Tay Bridge Disaster* (Newton Abbot: David and Charles, 1970); John Rapley, *Thomas Bouch: The Builder of the Tay Bridge* (Stroud: Tempus, 2007).

[5] James Winter, *Secure from Rash Assault: Sustaining the Victorian Environment* (Berkeley and London, University of California Press, 1999), p.173.

[6] There is a voluminous literature here: Geoffrey Amey, *The Collapse of the Dale Dyke Dam 1864* (London: Cassell, 1974); Christine Meisner Rosen, *The Limits of Power: Great Fires and the Process of City Growth in America* (Cambridge: Cambridge University Press, 1986); Sara E. Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City* (Baltimore: Johns Hopkins University Press, 2000); Mark Tebeau, *Eating Smoke: Fire in Urban America, 1800-1950* (Baltimore: Johns Hopkins University Press, 2003); Joanna Bourke, *Fear: A Cultural History* (London: Virago, 2005); Shane Ewen, *Fighting Fires: Creating the British Fire Service, 1800-1978* (Basingstoke: Palgrave, 2010); Alex Hall, 'The Rise of Blame and Recreancy in the United Kingdom: A Cultural, Political and Scientific Autopsy of the North Sea Flood of 1953', *Environment and History* **17** (3, 2011): 379-408; Scott Gabriel Knowles, *The Disaster Experts: Mastering Risk in Modern America* (Philadelphia: University of Pennsylvania Press, 2011).

[7] Uwe Lübken and Christof Mauch, 'Uncertain Environments: Natural Hazards, Risk and Insurance in Historical Perspective', *Environment and History* **17** (1, 2011): 1-12. See also papers in the same special issue: Sam Temple, 'Forestation and its Discontents: The Invention of an Uncertain Landscape in Southwestern France, 1850-Present', 13-34; Andrea Westermann, 'Disciplining the Earth: Earthquake Observation in Switzerland and Germany at the Turn of the Nineteenth Century', 53-77. See also the chapters on the interconnections between urban growth, risk, conflagration and fire insurance in Greg Bankoff, Uwe Lübken and Jordan Sand, eds.,

Flammable Cities: Urban Conflagration and the Making of the Modern World (Wisconsin: University of Wisconsin Press, 2012).

[8] Christian Pfister prefers to talk about "nature-induced disasters" rather than "natural disasters" since the former evokes the idea of 'catastrophes brought about by natural phenomenon without obscuring their anthropogenic dimension.' Whilst this is a useful concept, this paper is more specifically about man-made disasters, or what I call "engineering-induced disasters." Christian Pfister, 'Learning From Nature-Induced Disasters: Theoretical Considerations and Case Studies from Western Europe', in *Natural Disasters, Cultural Responses: Case Studies Toward a Global Environmental History*, eds., Christof Mauch and Christian Pfister (Lanham et al: Lexington, 2009), 18.

[9] Hugh S. Gorman and Betsy Mendelsohn, 'Where Does Nature End and Culture Begin? Converging Themes in the History of Technology and Environmental History', in *The Illusory Boundary: Environment and Technology in History*, eds., Martin Reuss and Stephen H. Cutcliffe (Charlottesville and London: University of Virginia Press, 2010), 266, 279; Jeffrey K. Stine and Joel A. Tarr, 'At the Intersection of Histories: Technology and the Environment' *Technology and Culture* **39** (4, 1998): 601-640; Martin V. Melosi, 'The Place of the City in Environmental History' *Environmental History Review* **17** (1, 1993): 1-23.

[10] Eric Swyngedouw, 'Modernity and Hybridity: Nature, Regeneracionismo, and the Production of the Spanish Waterscape, 1890-1930' *Annals of the Association of American Geographers* **89 (**3, 1999): 444.

[11] Ibid: 445.

[12] Thomas P. Hughes, 'The Evolution of Large Technological Systems', in *The Social Construction of Technological Systems: New Directions in the Sociology and History*

of Technology, eds. Wiebe E. Bijker, Thomas P. Hughes and Trevor J. Pinch (Cambridge, Massachusetts: MIT Press, 1987), 51-82; Martin V. Melosi, 'Humans, Cities, and Nature: How Do Cities Fit in the Material World?' *Journal of Urban History* **36** (3, 2010): 3-21.

[13] Clare L. Johnson, Sylvia M. Tunstall and Edmund C. Penning-Rowsell, 'Floods as Catalysts for Policy Change: Historical Lessons from England and Wales' *Water Resources Development* **21** (4, 2005): 561-575; Martin Körner, ed., *Destruction and Reconstruction of Towns*, three vols. (Bern: Haupt, 1999-2000); Thomas A. Birkland, *Lessons of Disaster: Policy Change After Catastrophic Events* (Washington, D.C.: University of Georgetown Press, 2006), 103-156.

[14] Pfister, 'Learning from Nature-Induced Disasters', 17-40.

[15] Trevor A. Kletz, *Learning from Accidents*, 3rd edn. (Oxford: Butterworth Heinemann, 2001); Birkland, *Lessons of Disaster*, 182-9.

[16] Sheffield City Archives [hereafter SCA] YWA/2/48, Sheffield Waterworks Acts 1830 and 1845; G. M. Binnie, *Early Victorian Water Engineers* (London: Thomas Telford Ltd., 1981), pp.256-261; Martin V. Melosi, *The Sanitary City: Urban Infrastructure in America from Colonial Times to the Present* (Baltimore: Johns Hopkins University Press, 2000).

[17] See Matthew Gandy, *Concrete and Clay: Reworking Nature in New York City* (Cambridge, Mass., and London: The MIT Press, 2002), 19-40.

[18] Dieter Schott, 'Resources of the City: Towards a European Urban Environmental History', in *Resources of the City: Contributions to an Environmental History of Modern Europe*, eds. Dieter Schott, Bill Luckin and Geneviève Massard-Guilbaud (Aldershot: Ashgate, 2005), 9.

[19] Joel A. Tarr, 'The Metabolism of the Industrial City: the Case of Pittsburgh' *Journal of Urban History* **28 (**5, 2002): 511.

[20] SCA YWA/2/48, Sheffield Waterworks Acts 1830 and 1853; SCA CA/6/1, Sheffield Water Works Company [hereafter SWWC] Report, 1838, p.2.

[21] On the uses and meanings of water see Maria Kaika, *City of Flows: Modernity, Nature, and the City* (London: Routledge, 2005). On the relationship between water and social and environmental justice, see Jonas Hallström, 'Urban or Suburban Water? Working Class Suburbs, Technological Systems and Environmental Justice in Swedish Cities in the Late Nineteenth Century', in *Environmental and Social Justice in the City: Historical Perspectives*, eds., Geneviève Massard-Guilbaud and Richard Rodger (Cambridge: White Horse Press, 2011), 133-154.

[22] This theme is also explored in Joel A. Tarr, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective* (Akron, Ohio: University of Akron Press, 1996).

[23] Leather worked as consultant engineer for various railway and waterway schemes, including a portion of the Midland Railway at Chesterfield, the Tadcaster and York Railway and the Erewash Valley line. He was also engaged with the River Nene improvement works during the mid-1850s and '60s: *Minutes of the Proceedings of the Institute of Civil Engineers* [hereafter *MPICE*] **83** (1886): 433-436.

[24] Binnie, *Water Engineers*, 256-265; SCA CA/6/1, SWWC Reports, 1831, 2; 1850, 2.

[25] *MPICE* **97** (1889): 392-398; Binnie, *Water Engineers*, 157-201; Peter Russell, 'Bateman, John Frederic La Trobe (1810-1889)', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) [http://www.oxforddnb.com/view/article/1668, accessed 22 August 2011]; Harriet

Ritvo, *The Dawn of Green: Manchester, Thirlmere and Modern Environmentalism* (Chicago and London: University of Chicago Press, 2009).

[26] Binnie, *Water Engineers*, 70-94; John Broich, 'Simpson, James (1799-1869)', *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004) [http://www.oxforddnb.com/view/article/95495, accessed 22 August 2011]; Christine MacLeod, *Heroes of Invention: Technology, Liberalism and British Identity, 1750-1914* (Cambridge: Cambridge University Press, 2007).

[27] Norman Smith, *A History of Dams* (London: Peter Davies, 1971), 171-181; John Broich, 'Engineering the Empire: British Water Supply Systems and Colonial Societies, 1850–1900' *Journal of British Studies* **46** (2, 2007): 346–65; Harold L. Platt, *Shock Cities: the Environmental Transformation and Reform of Manchester and Chicago* (University of Chicago Press: Chicago, 2005), 201-207.

[28] Dennis Smith, *Conflict and Compromise: Class Formation in English Society 1830-1914* (London: Routledge & Kegan Paul, 1982), 65-69, 86-87.

[29] SCA YWA/2/48, Sheffield Waterworks Act, 1853, 16 Vict., cap. xxii, sec.82; SCA CA/6/1, SWWC Reports, 1854-61; Vanessa Taylor and Frank Trentmann, 'Liquid Politics: Water and the Politics of Everyday Life in the Modern City', *Past and Present* **211** (1, 2011): 210-213.

[30] SCA CA/436/13/1, Sheffield Water Works Bill, 1844-45, Minutes of Committee; Martin V. Melosi, *Effluent America: Cities, Industry, Energy, and the Environment* (Pittsburgh: University of Pittsburgh Press, 2001), ch.11.

[31] Binnie, *Water Engineers*, 261; SCA CA/6/1, SWWC Report, 1852, 1-2.

[32] SCA CA/6/1, SWWC Reports, 1852, p.2; 1853, pp.1-2; 1854, p.2; Sheffield Central Library and Local Studies [hereafter SCLLS] SCL/SQ. Vol. 12, p.163.

[33] SCA YWA/13/5, J. K. Swales, *The Waterworks of the Corporation of Sheffield* (Sheffield: City of Sheffield, 1932), 2-3; Swyngedouw, 'Modernity and Hybridity': 445-446.

[34] Ibid: 446.

[35] SCA YWA/2/48, Sheffield Waterworks Act, 1853, 16 Vict., cap. xxii, s.53; *Rawlinson and Beardmore Report*, 4-5; Amey, *Collapse*, 7-8; Binnie, *Water Engineers*, 306-08.

[36] SCA CA/436/11, SWWC Reports 1859-63; *Rawlinson and Beardmore Report*, 4-5.

[37] Charles Perrow, *Normal Accidents: Living with High-Risk Technologies*, 2nd ed. (Princeton University Press: Princeton New Jersey, 1999).

[38] Buchanan, *Engineers*, 88-103.

[39] Platt, *Shock Cities*, 205.

[40] cf. SCA YWA/2/48, 1853 Act, 16b Vict., cap xxii, s.68.

[41] West Yorkshire Archives [Huddersfield] KC/6/1/4, Holme Reservoir Order Book, misc. meetings, 1842-49.

[42] Ibid KC/6/1/34, Notes of Evidence on Inquest: Bundle 1, 18 February 1852, 8-12; Binnie, *Water Engineers*, 49-69.

[43] National Archives, Kew [hereafter NA] HO45/4210, Note by Sir George Grey, 17 February 1852.

[44] Ibid, 27-35; SCA SY/295/C1/17, Sheffield Constabulary Memorandum Book, 1864-1874, 7-24.

[45] *Sheffield and Rotherham Independent* [hereafter *Independent*], 14 March 1864, 4, col.2; 16 March 1864, 6, col.1; J. H. Stainton, *The Making of Sheffield 1865-1914* (Sheffield: Weston & Sons, 1924), 23.

[46] *Independent*, 12 March 1864, 8, col.1; 15 March, 5, col.1; 22 March 1864, 8, col.1; 23 March 1864, 3, cols.2-3.

[47] Samuel Harrison, *A Complete History of the Great Flood at Sheffield on March 11 & 12, 1864* (London and Sheffield: Samuel Harrison, 1864), 92.

[48] *The Times* (London, England), 14 March 1864, 9, cols. 3-6 reports on a 'Terrible Calamity at Sheffield', before turning its attention to explanations for the events: 1 April 1864, 8, col. 6. It also reported extensively on the relief effort: e.g. 29 March 1864, 3, cols. 1-6.

[49] Pfister, 'Learning from Nature-Induced Disasters', 22-34; *Independent*, 14 March 1864, 4, cols.1-3. For comprehensive approaches towards disasters, see Ted Steinberg, *Acts of God: The Unnatural History of Disaster in America* (Oxford and New York: Oxford University Press, 2000); Greg Bankoff, *Cultures of Disaster: Society and Natural Hazard in the Philippines* (London: Routledge, 2003).

[50] The Watch Committee minutes record commendations, promotions or gratuities for seventy-seven officers for their work: SCA CA-WAC/1/4, Borough of Sheffield Watch Committee Book No. 4, 31 March 1864, 525-27; 28 April 1864, 536; 12 May 1864, 540-45.

[51] *Independent*, 17 March 1864, 3, cols.1-2.

[52] NA HO/45/7656, First Bundle, 'Public Notice. Great Destruction of Life', 12 March 1864; 'Public Notice. The Great Flood, 12 March 1864'.

[53] Ibid, Second Bundle, Letter, John Yeomans to Sir George Grey, 12 March 1864; John Webster to Grey, 13 March 1864.

[54] Barry M. Doyle, 'The Changing Functions of Urban Government: Councillors, Officials and Pressure Groups', in *The Cambridge Urban History of Britain, Volume III: 1840-1950*, ed. Martin J. Daunton (Cambridge: Cambridge University Press,

2000), 287-314; Irene Maver, 'The Role and Influence of Glasgow's Municipal Managers, 1890s-1930s', in *Urban Governance: Britain and Beyond since 1750,* eds., R. J. Morris and Richard H. Trainor (Aldershot: Ashgate, 2000), 69-85; Michele Dagenais, Irene Maver and Pierre-Yves Saunier, eds., *Municipal Services and Employees in the Modern City* (Aldershot: Ashgate, 2003).

[55] See, for example, the debates that emerged following the collapse of Los Angeles' St. Francis Dam in the Santa Clarita Valley, in March 1928: William L. Kahrl, *Water and Power: The Conflict over Los Angeles' Water Supply in the Owens Valley* (Berkeley, Los Angeles and London: University of California Press, 1982).

[56] Quoted in Derek Fraser, *Power and Authority in the Victorian City* (Oxford: Clarendon), 141.

[57] Brian Barber, 'Sheffield Borough Council 1843-1893', in *The History of the City of Sheffield 1843-1993. Volume I: Politics,* eds., Clyde Binfield *et al* (Sheffield: Sheffield Academic Press, 1993), 36.

[58] Smith, *Conflict and Compromise,* 63-64. For further details on the Act's adoption, see NA MH/13/165, Sheffield Correspondence 1864-1870.

[59] SCA CA-COU/5, 17 February 1864, 440; 9 March 1864, 451.

[60] Fraser, *Power and Authority,* 139-48; Barber, 'Sheffield Borough Council', 25-37.

[61] *The Sheffield Directory and Guide* (Sheffield: John Blackwell, 1828); SCA SLPS/153-186, Thomas Asline Ward's Pocket Diaries.

[62] Smith, *Conflict and Compromise,* 85-7.

[63] Alan DiGaetano, 'The Birth of Modern Urban Governance: A Comparison of Political Modernization in Boston, Massachusetts, and Bristol, England, 1800-1870' *Journal of Urban History* **35** (2, 2009): 259-287.

[64] Having dealt with all cases of urgent relief, the SIRC was left with almost £20,000 in hand, which it returned to donors on the basis of half their subscription. This left a credit of nearly £8,000 which the SIRC disbursed as follows: 50% to the Sheffield Infirmary, 30% to the Public Hospital and Dispensary and 20% to the Hospital for Women. Amey notes that only about two-fifths of the total subscribed was actually spent on relief: Amey, *Collapse*, 197.

[65] *Independent*, 15 March 1864, 5-6; 16 March 1864, 1, col. 2; Lawrence J. Vale and Thomas J. Campanella, 'Conclusion: Axioms of Resilience', in *The Resilient City: How Modern Cities Recover from Disaster*, eds., *idem* (Oxford: Oxford University Press, 2005), 340.

[66] John R. Kellett, 'Municipal Socialism, Enterprise and Trading in the Victorian City' *Urban History Yearbook* (1978): 36-45.

[67] The American literature illustrates how it can never be assumed that interested groups, especially legislative specialists, will act upon lessons from "focusing events" to strengthen prospective disaster relief and preventative policy, e.g. Thomas A. Birkland, 'Natural Disasters as Focusing Events: Policy Communities and Political Response' *International Journal of Mass Emergencies and Disasters* **14** (2, 1996): 221-243; Knowles, *Disaster Experts*, pp.280-86.

[68] John C. Teaford, 'Technology, Expertise, and Municipal Services, 1860-1940' *Journal of Urban History* **X** (3, 1984): 320; Malcolm E. Falkus, 'The Development of Municipal Trading in the Nineteenth Century' *Business History* **19** (2, 1977): 134-155; John Hassan, 'The Growth and Impact of the British Water Industry in the Nineteenth Century' *Economic History Review* new series, **38** (4, 1985): 531-547; Robert Millward, *Private and Public Enterprise in Europe: Energy, Telecommunications and Transport, 1830-1990* (Cambridge: Cambridge University Press, 2005), 33-58; Taylor

and Trentmann, ‘Liquid Politics’, 199-241.

[69] Buchanan, ‘Causes’, 115.

[70] *Sheffield Daily Telegraph*, 15 March 1864, 4, col.4.

[71] As an example, see the letters in Ibid, 17 March 1864, 4, cols.4-5; 19 March 1864, 7, col.5.

[72] Quoted in Ibid, 21 March 1864, 2, col.4.

[73] *The Engineer*, 1 April 1864: 203.

[74] *Independent*, 24 March 1864, 3, cols. 1-2.

[75] Lübken and Mauch, ‘Uncertain Environments’: 2-4; Stephen Pyne, *Fire: A Brief History* (Seattle: University of Washington Press, 2001); Ulrich Beck, *Risk Society: Towards a New Modernity* (London: Sage Publications, 1992).

[76] *Independent*, 24 March 1864, 3, col. 5.

[77] Ibid, 24 March 1864, 3, col.4.

[78] Ibid, 25 March 1864, 2, col.4, 4, col.2.

[79] The LGAO succeeded the General Board of Health in 1858 and was reorganised as the Local Government Board in 1871. Rawlinson continued to work for the Board until his retirement in 1888.

[80] NA HO/45/7656, First Bundle, Robert Rawlinson to Sir George Grey, 18 March 1864; Note by [G.]eorge [G.]rey, 18 March 1864.

[81] Ibid, Rawlinson to Grey, 15, 16, 18 March 1864.

[82] Ibid, Rawlinson to Grey, 18 March 1864; *Independent*, 25 March 1864, 3, col. 4.

[83] *Independent*, 25 March 1864, 3, cols. 3-4.

[84] Martin Reuss and Stephen H. Cutcliffe, ‘Introduction’, in *Illusory Boundary*, eds., idem, 1-2.

[85] *Independent*, 25 March 1864, 3, cols. 3-4.

[86] Ibid, 4, col. 1.

[87] *Rawlinson and Beardmore Report*, 9.

[88] See Rawlinson's report, 'Remarks on Reservoir Making', in Appendix B to Ibid, 11-13.

[89] Quoted in Amey, *Collapse*, 129.

[90] Knowles, 'Lessons in the Rubble', 24; Iain McLean and Martin Johnes, *Aberfan: Government and Disasters* (Cardiff: Welsh Academic Press, 2000).

[91] Swyngedouw, 'Modernity and Hybridity': 447.

[92] PP, *Sheffield Reservoirs. Copies of the Report of the Engineers Employed by the Sheffield Waterworks Company to Report on the Dale Dyke and Agden Reservoirs, which bears date November 1864, and was forwarded to the Home Office on the 29th of the month* (1866), Cmd. 25, 7; SCA CA/436/11, SWWC 1864 Report, 1.

[93] Binnie, *Water Engineers*, 130-156.

[94] PP, *Sheffield Reservoirs*, pp.9-12; SCA CA/436/9, Sheffield Waterworks Bill. Minutes of Evidence, Reports &c..

[95] Binnie, *Water Engineers*, 104-11 records that Leslie also clashed with Hawksley and Bateman over his work in Edinburgh and Dundee.

[96] SCA CA/MIN/1, Minutes of the Proceedings of the Council and Local Board, Minutes of Water Works Company's Bill Committee, 29 July 1864, Appendix, v-xxix.

[97] Ibid, xiv.

[98] Ibid, xv.

[99] Leather became an Honorary Life Member of the IME in 1859; Hawksley was President of the ICE in 1872-73 and the IME in 1876-77.

[100] SCA CA/436/11, SWWC Report 1864, 2.

[101] SCA CA/436/9, Sheffield Waterworks Bill, Minutes of Evidence, Reports &c. &c., House of Lords Select Committee on Private Bills: Sheffield Water Works (Bradfield Inundation) Bill, 19-23 July 1864.

[102] Thomas A. Birkland, 'Learning and Policy Improvement after Disaster: The Case of Aviation Security' *American Behavioral Scientist* **48** (3, 2004): 342.

[103] Sheffield Flood Claims Archive, accessible at http://www2.shu.ac.uk/sfca/. The proceedings of the Commissioners are in SCLLS 352.6 SSTQ.

[104] Jean Cass, 'The Flood Claims: A Postscript to the Sheffield Flood of March 11/12 1864' *Transactions of the Hunter Archaeological Society* **15** (1989): 29-37.

[105] PP, *Sheffield Waterworks. Copy of Correspondence which has passed between the Mayor and the Corporation of Sheffield and the Board of Trade and the Home Office on the subject of the Sheffield Waterworks since 1 January 1869, and all other communications or applications relating thereto*, 1870, Cmd. 111.

[106] SCA CA/619, Sheffield Corporation Town Clerks Files: Sheffield Corporation Water Bill, 1887.

[107] SCA CA-WTE/1/1, Borough of Sheffield Water Committee Minute Book, 5 February 1896, 241.

[108] Pfister, 'Learning from Nature-Induced Disasters', 17-19; Körner, ed., *Destruction and Reconstruction of Towns;* Geneviève Massard-Guilbard, Harold L. Platt and Dieter Schott, eds., *Cities and Catastrophes: Coping with Emergency in European History* (Frankfurt am Main: Peter Lang, 2002).

[109] Quoted in Pfister, 'Learning from Nature-Induced Disasters', 18-19.

[110] Shane Ewen, *Fighting Fires: Creating the British Fire Service, c.1800-1978* (Basingstoke: Palgrave, 2010).

[111] Derek Fraser, *Power and Authority in the Victorian City* (Oxford: Basil Blackwell, 1979), 151; Christopher Hamlin, 'Muddling in Bumbledom: Local Governments and Large Sanitary Improvements: The Case of Four British Towns, 1855-85' *Victorian Studies* **32** (1988): 55-83.

[112] Hassan, 'Growth and Impact of the British Water Industry': 535

[113] Ibid: 537.

[114] SCA CA-WTE/1/1, Borough of Sheffield Water Committee Minute Book, 5 November 1895, 210-11; 2 September 1896, 278; SCA, *Official Handbook of the Sheffield Corporation Water Undertaking* (Sheffield: Waterworks Office, 1948), 23-31.