Impacts of Urban Growth on Surface Water and Groundwater Quality (Proceedings of IUGG 99 Symposium HS5, Birmingham, July 1999). IAHS Publ. no. 259, 1999.

Improving degraded urban water courses in eastern Scotland: a case study

CHRIS JEFFERIES
Wastewater Technology Centre, University of Abertay, Dundee DD1 1HG, UK
e-mail: c.jefferies@abertay-dundee.ac.uk

ANNA GOVIER
ABB Power T&D Ltd, East Kingsway, Dundee DD4 7RP, UK

KATHERINE BRADSHAW
SEPA, Clearwater House, Riccarton, Edinburgh EH14 4AP, UK

Abstract The outcome of a range of studies of the Lyne Burn in eastern Scotland is presented. This is a typical water course which has become degraded in the past from discharges directly related to urban influences. Changes include reduced low flows due to mining and at the same time increased washoff of pollutants from industry and sewerage, a major housing and commercial development and new highways. The drainage improvement actions and initiatives undertaken are also presented. Details of pollution causes and impacts are presented together with the changes in the water course quality mirroring the various initiatives. It is concluded that the index of stream classification has not changed and that a water course of this type can only be improved in the long term if source control measures are implemented in a wide range of areas and continual attention is paid to the causes of pollution.

INTRODUCTION

The Lyne Burn is typical of a water course which has become degraded in the past from discharges directly related to urban influences which have included reduced low flows due to mining and at the same time increased urban runoff and washoff of pollutants from industry and sewerage, general housing development and roads. Changing land use on the drainage basin and encroachment of the stream channel has led to regular flooding which has had to be controlled by implementing flood protection measures principally using raised stream banking.

Considerable pressure has been applied by the Scottish Environment Protection Agency (SEPA) to reduce the numbers and frequency of discharges to the stream and its tributaries, but limited resources permit only infrequent enforcement. Discharges from the majority of the readily identifiable point sources have now been reduced or eliminated. This has led to a noticeable rise in the quality of the water course, indicated by gradually improving chemical and biological values.

However, in spite of this effort, there has been little improvement in the classification of the water course. Furthermore, the drainage basin is in an area of rapid urban expansion and, in spite of the investment in infrastructure, stresses on the water course are likely to increase in future. Alternative strategies are being implemented in

response to the need for further measures to address the diffuse sources of pollution from the expanding urban area which includes one of the largest industrial and housing developments in Scotland.

A CHANGING DRAINAGE BASIN

Water quality has become an increasingly important issue for the Lyne Burn as its drainage basin has been developed; Fig. 1 illustrates the basin and the various causes of water quality degradation which are present.

The drainage basin

Flows in the Lyne Burn and periodic flooding have been affected by a range of urban and industrial influences. There has been a significant reduction of flows in the past due to the mining operations which also causes ferruginous discharges. Formerly there were 32 mines in the area, drained by a network of low level tunnels known as day levels, and seven have been identified in the drainage basin. Several opencast mines have been developed and these may increase surface flows by up to 100% (Jefferies *et al.*, 1986). Construction on the flood plain, made attractive by the low flows in the past has led to obstructions to the water course and loss of flood storage. Finally, and of most importance, increased urbanization including housing, industry and major highway developments would increase peak flow rates if not managed correctly.

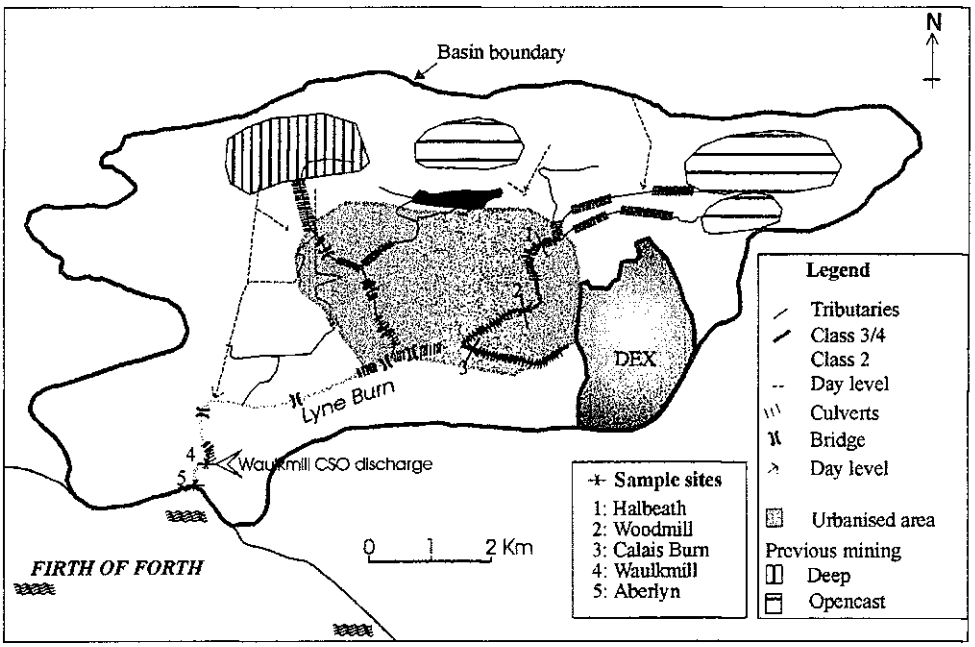

Fig. 1 Map showing key water course features, illustrating the basin and the causes of water quality degradation. The figure also shows approximate locations of day levels, urbanized areas and culverts.

Most urban development within the Lyne Burn drainage basin is at the eastern, or higher part of the basin. This has exaggerated the problems associated with urbanization since the developments tend to have a cumulative effect downstream (CIRIA, 1992). At present, the drainage basin to Liggar's Bridge is approximately 46% urbanized.

Dunfermline eastern expansion area

The development to the east of Dunfermline (known locally as DEX) is one of the largest ventures of its kind in Scotland. Within 20 years, the development will cover approximately 5 km^2 of rural land and will develop it for housing, industry, a leisure park, and a district centre with supermarket and community facilities. Approximately 3 km^2 of DEX lies within the Lyne Burn basin.

In total, 3500 new homes are planned within DEX. The DEX housing located within the Lyne Burn basin, added to those anticipated by the Dunfermline local plan, will bring the total of newly completed and proposed housing in the area to over 5000. The addition of such a large number of houses, in an already highly developed area, would be expected to double surface runoff and add to the pressure on the ageing sewer system and inadequate water courses.

The need for a change in drainage policy

The quality of water in the Lyne Burn and a number of drainage basins in the area of the Forth River Purification Board led to a shift in policy for the drainage of urban areas in Scotland. All newly approved surface water drainage systems should now incorporate source control Best Management Practices (BMPs). These are passive systems intercepting pollutants at source and dispose of incident rainfall close to the point of precipitation. Efforts to promote the use of BMPs included a programme of presentations to all local authorities in the Board's area, and publication of a readily accessible guide to BMPs (FRPB, 1994). This guide has recently been updated (SEPA, 1996).

CHANGES TO THE DRAINAGE INFRASTRUCTURE

Mirroring the various expansion phases, there have been a number of major infrastructural changes, all of which influence the quality of the Lyne Burn water course.

Sewerage improvements

Major sewage contamination in the urban area in the 1950s resulted in the construction of a storm relief sewer (Ashley *et al.*, 1986) to convey storm flows from the town to a remote discharge point (Fig. 1). Although this merely transferred the problem, access is

restricted at the discharge point, and the BMWP scores (Biological Monitoring Working Party scores, Gardiner (1991)) scores improved only slightly from this time forward.

In addition to such major pollution sources, 500 cross connections were discovered in the Calais Burn sub-basin alone leading to a major improvement scheme to rectify the worst manholes. However, in spite of this scheme under which £10 million has been invested since 1982 and 10 000 m^3 of storage has been built, there has been no measurable improvement in the BMWP field scores (see Fig. 3). Upgrading of the sewerage system commenced in 1993 with the construction of three major new combined sewer overflows and tanks. These followed the construction of a small overflow and tank built in 1980 to control chronic pollution in a high amenity tributary area. Salient details of the storm tank programme are shown in Table 1.

Flooding and flood control

Flooding concerns in the Burn led to the promotion of a Flood Prevention Scheme for the town centre. The various measures required to improve the water course are shown in Table 2 and all bankside developments must meet its requirements. Design flow derivation used the UK Floods Studies Report methods (NERC, 1975), considerable care being paid to the effect of the combination of coalfield redevelopment and urbanization. Hydraulic analysis used HEC-RAS to give bank heights and channel widths. Flood protection uses raised banking and the reconstruction of a number of road bridges to give greater waterway clearances. Little attention was given to making the channel environmentally friendly due to the density of building locally.

Sustainable urban drainage

The response to the policy change by SEPA has been the introduction of urban drainage best management practices (BMPs) for all new developments. BMPs can

Table 1 Major sewerage improvements since 1988.

Development	Volume (m^3)	Date	Population	Replacing
Broomhead	400	1988	5000	Surcharging sewers
Tower Burn	2500	1991	16 000	Surcharging sewers and overflow
Rex Park	3000	1993	26 000	Complex overflows
Elliot Street	1400	1998	4500	Several minor one major overflow

Table 2 Water course improvements implemented since 1980.

Development	Date	Problem	Solution
Parknuek FPS*	1980	Water damage due to collapsing mines	Open out channels and strengthen water course
Halbeath Pond	1986	Retail development	On-line flood attenuation
Kiersbeath Lagoons	1987	Open cast mine	Construction of four settlement lagoons
Dunfermline FPS*	1995	Localized flooding	Raised banks, removal of obstructions
DEX	1997–1998	Major development	Drainage includes source control, attenuation and treatment

*FPS = Flood Prevention Scheme.

incorporate flow attenuation and water quality improvements. They also offer the potential for multiple benefits such as local amenity sites and urban biodiversity habitats (D'Arcy, 1997). Source control systems in use in the UK include French drains, grass swales, porous surfaces and some sub-soil soakaways. End-of-pipe soft engineering structures such as ponds and wetlands giving passive treatment have also been constructed. BMP systems which have been implemented at DEX include six treatment ponds and a number of swales.

THE QUALITY OF THE LYNE BURN

Biology of the Lyne Burn

The water quality index used in this study was the Biological Monitoring Working Party (BMWP) score (Gardiner, 1991). Figure 2 illustrates a decade of BMWP field score changes throughout the length of the Lyne Burn. The location of each sample site and the current WQI class of the burn (see below) along its length is shown in Fig. 1 and the average scores from 1988–1996 are illustrated in Fig. 3. This graph illustrates that average biological quality has improved since 1988, but it also highlights that the poorest water quality is in the urban areas.

The Water Quality Index (WQI) is a "mother" classification system which integrates groups of determinands: chemical, biological, nutrient, aesthetic and toxicity levels, into an overall water quality classification scheme. The WQI is applied to the data to produce an index of river quality which may be interpreted by non-specialists.

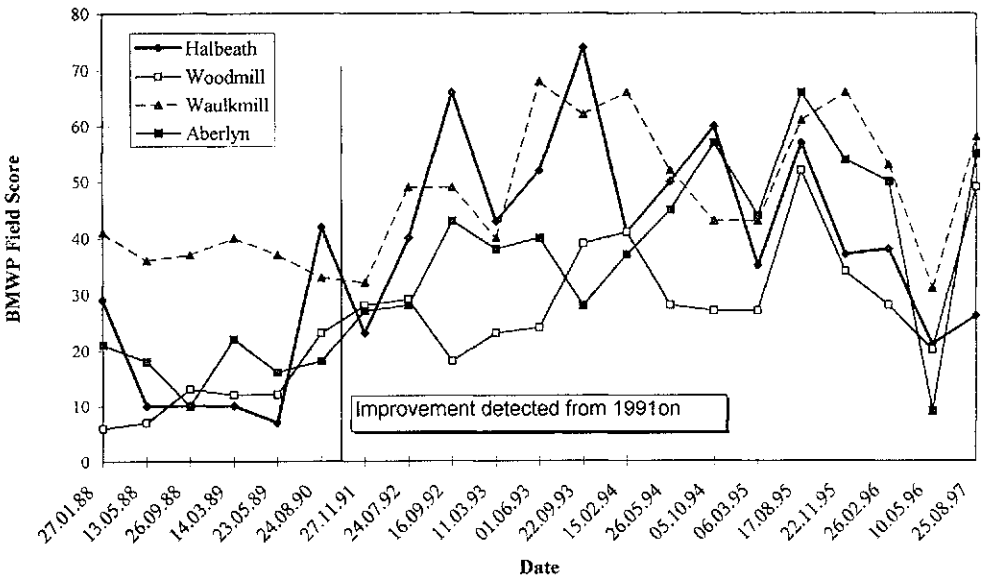

Fig. 2 BMWP scores in the Lyne Burn 1988–1997. (BMWP is a commonly used measure of the biological quality; scores range from <25 (very poor), through 50–99 (moderate) to >150 (very good)). Data source: SEPA.

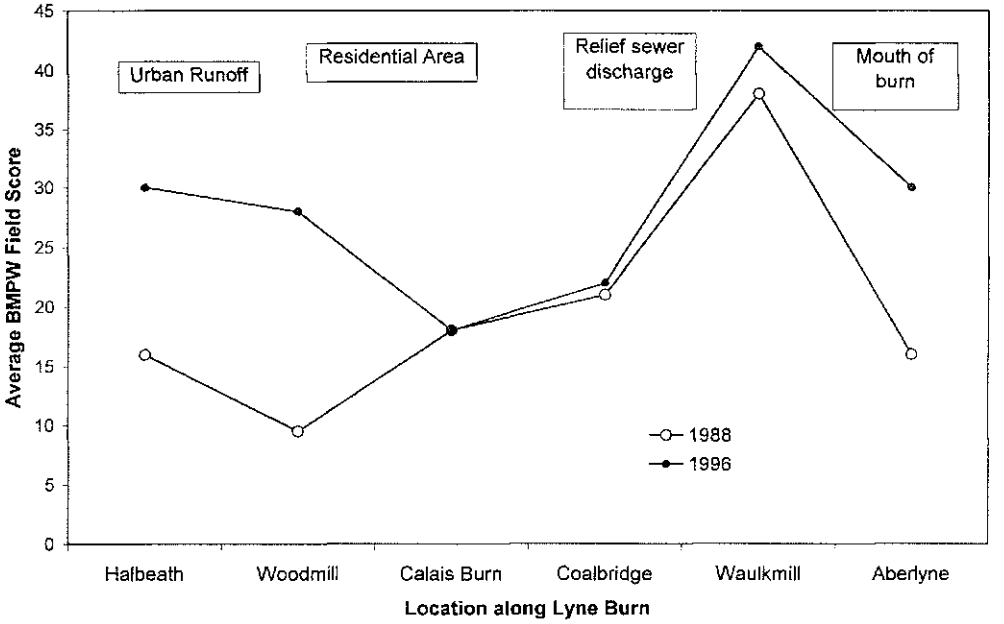

Fig. 3 Average BMWP scores in the Lyne Burn. Data for a nine year period have been averaged to show the general change with time and distance along the water course. Data source: SEPA.

In spite of significant investment in infrastructure, and improvements in BMWP scores, there has been little change in the WQI for the Lyne Burn. The biology remains poor yet the information in Fig. 2 indicates there have been improvements in BMWP scores from 1991 onwards, especially at the more downstream locations.

It would appear that the WQI is not sufficiently sensitive to cope with such poor water quality and does not have enough classification bands to be able to detect the changes in water biology. A fifth band was recently introduced, but it is as yet uncertain whether it will provide an improved classification methodology.

Pollution sources

Along with internal monitoring, information on pollution incidents for selected water courses is collected by SEPA. The incident record for the Lyne Burn and its tributaries included 96 reported pollution incidents for the period July 1989–May 1997. The source of each pollution incident was defined and the results are presented in Table 3.

Table 3 Pollution incidents in the Lyne Burn basin 1989–1997.

Cause	% of total
Vandalism	2
Runoff from housing and industrial areas	43
Pollution escapes from sewerage system	50
Not determined	5

The discharge of sewage effluent remains the single most frequent type of pollution event in the Lyne Burn in spite of the investments made. Storm runoff into the inadequate sewerage system caused some 50% of the total reported pollution incidents which resulted from combined sewer overflows, surface storm water outlets, cross-connections, dual manholes and illegal discharges of sewage effluent.

WATER COURSE UPGRADING – THE LONG TERM STRATEGY

The Lyne Burn is typical of an urban stream which has become downgraded by point sources of effluent and is increasingly affected by diffuse urban pollution. The prospect of further pollution from urban expansion in a drainage basin which is already significantly developed has prompted a radically new approach to drainage and pollution prevention practices. In late 1996 a world expert was appointed to assist in the development of a surface water management policy for the DEX development area. The key issue was flood prevention due to the increase in flows predicted as a result of further development and to ensure that the current level of safety afforded to the communities downstream was not compromised.

The data presented in the paper have shown that, in spite of significant investment in sewerage improvements and flood protection measures, the quality of the water course is little improved. While this does not suggest that the investment has been wasted, it shows that diffuse pollution from urban areas, and industrial dereliction are very pervasive influences on water course quality. The conclusion can be drawn that the introduction of source control systems and other drainage BMPs is the only logical way forward in improving stream quality, but that this is a long term policy which will only show results after decades of attention to detail.

REFERENCES

Ashley, R. A., Jefferies, C. & Stevens, G. S. W. (1986) Overloading of the Dunfermline sewerage system due to peripheral urban expansion. Conf. Infrastructure Renewal & Waste Control, University of Manchester, April 1986.

CIRIA (Construction Industry Research and Information Association) (1992) *Scope for Control of Urban Runoff.* Report no. 124, vols 1, 2, 3, CIRIA, London, UK.

D'Arcy, B. J. (1997) Urban BMPs: New greenspace habitats. *Urban Wildlife News* **14**(3) August 1997.

FRPB (1994) *A Clear Future for Our Waters.* FRPB, Edinburgh, UK.

Gardiner, J. (1991) *River Projects and Conservation: a Manual for Holistic Appraisal.* John Wiley and Son, Chichester, UK.

Jefferies, C., Stevens, G. S. W. & Ashley, R. M. (1986) A Scottish burn. *J. Inst. Wat. Engrs Scient.* **40**(6), 483–500.

NERC (Natural Environment Research Council) (1975) *The UK Flood Studies Report.* Institute of Hydrology, Wallingford, UK.

SEPA (Scottish Environment Protection Agency) (1996) *A Guide to Surface Water Best Management Practices.* Scottish Environment Protection Agency, Edinburgh, UK.