The benefit of dams to society

C.J.A. BINNIE, Independent Consultant

SYNOPSIS. Dams have been constructed from historical times to provide the needs of many civilisations. Focussing primarily on the UK, the paper sets out the benefits of improved health and life from the provision of a clean water supply from reservoirs, protection from drowning and damage from floods, the provision of power from hydro schemes, water for irrigation, as well as the recreation and environmental benefits of the reservoirs.

INTRODUCTION

At the launch of the World Commission on Dams Report, Nelson Mandela said that for all the problems around some dams; "the problem is not the dams. It is the hunger, It is the thirst. It is the darkness of a township. It is the townships and rural huts without running water, lights, or sanitation." (Bridle 2003). How true. This paper looks at the benefits of dams, and the problems that society would face without them, concentrating primarily on the UK but with illustrations from other countries.

Dams provide water for society to drink and use, protection from both river and marine floods, hydro electric power, irrigation water to grow food, a pleasant recreation area, and enhanced environment. Dams have been constructed during different periods depending on the needs of society at the time.

EARLY DAMS

Dams have been reported from earliest historical times such as the Maan Dam which provided water for irrigation and water supply for the Queen of Sheba's people.

Some of the oldest small reservoirs in UK were constructed by the medieval monasteries to provide supplies of fish, generally carp. The provision of fresh food over a longer season must have been of nutritional benefit in those times.

Long-term benefits and performance of dams. Thomas Telford, London, 2004

LONG-TERM BENEFITS AND PERFORMANCE OF DAMS

MILL DAMS

The Doomsday Book, compiled in 1086, included some 7,000 mills in Britain,(Binnie G.M.1987) Many of these would have used a low dam to control water flow in the mill leat and the stream. During medieval times these were used to generate power for flour milling and later for fulling wool. Few mill dams survive today.

The Wealden iron industry, boomed between about 1540 and 1640 using water power to drive bellows to generate heat, to drive the hammer mills that were used to form the iron and to bore cannon (Binnie G.M. 1987). A few hammer ponds survive today.

From about 1750 blast furnaces powered by coal along with water powered hammer mills were developed in Shropshire. Water power was also used to power the spinning and textile mills. Because of the high rainfall these were located on each side of the Pennines (Binnie G.M.1987).

Thus water power from dams and rivers provided the beginnings of manufacturing that led to the industrial revolution and Britain becoming a major exporting nation and the ensuing wealth.

ORNAMENTAL LAKES

The industrial revolution resulted in uncontrolled development, often with unsanitary housing conditions, so the wealthy classes sought separation by constructing large houses and elaborate gardens, often with ornamental lakes. The leading exponent of this was Lancelot "Capability" Brown. Examples today include Stowe, Sheffield Park in Sussex and Stourhead created by Henry Hoare (Binnie G.M. 1987). Many of these are now run by the National Trust and give pleasure to hundreds of thousands of visitors each year.

CANAL DAMS

With the start of the industrial era, based initially on water power, and the opening of the coal mines, a means of transport for coal, iron ore and heavy goods was required. The roads were frequently poorly maintained, rutted tracks and not suitable for transporting heavy loads, particularly coal. Between 1770 and 1830 over 2,000 km of canals were constructed. Water is required for locking and so reservoirs were constructed to provide water to the summit pounds of almost all canals.

As an example of the benefit that canals and their reservoirs can bring, Birmingham, while near to coal and iron mines, was too far from them to be served by the then roads. A ring of canals was constructed both to bring in

raw materials and also to carry manufactured products to London and other ports. This enabled Birmingham industry to flourish.

Without reservoirs canals could only have been built in the lower reaches of a valley where the natural flow in the river was sufficiently in excess of that needed by the mill owners and other users to allow enough for canal locking. Without reservoirs the canal network would have been inadequate for more than local transport, there would have been no link between Yorkshire industry and the important port of Liverpool, Birmingham would have been virtually land locked, and there would have been no inland route to deliver coal to London: see Figure 1 (Dutton 2003). This would have seriously restricted and delayed the industrial revolution on which the wealth of our country was based.

Figure 1: Canal system with no reservoirs.

The canals are now used mainly for recreation with many canal barges being used for sedate leisure, and canal banks providing solitude for anglers often close to urban environments.

In addition water side property in urban areas now provides desirable views and features so these canal areas have attracted redevelopment in such places as Birmingham, Manchester, the Little Venice area of London, and in Leeds.

Thus, over 200 years after their construction, the reservoirs that enabled the canals to be viable continue to serve society.

Dams and reservoirs also support canals in other countries. Probably of most note are the dams at the south end of the Panama Canal which stored water and raised the canal to the extent that its construction could eventually be completed. Without them it would not have been, certainly for many decades later, thus restricting the development and naval defence of the Unites States.

DOMESTIC WATER SUPPLY

As the industrial revolution developed it resulted in much overcrowding and squalor in the expanding industrial cities. Reformers, in particular Edwin Chadwick, realised that conditions, and therefore the health of the people, would be improved by the provision of a clean water supply and the disposal of sewage (Binnie GM 1981). Following Chadwick's report in 1842 (Chadwick 1842), the Public Health Act of 1848 provided, through the Central Board of Health, the means to support towns and cities in providing water supply and sewerage. The health benefits of the wholesome, generally upland, water supplies are illustrated by cholera statistics. In 1832 there were 30,000 deaths from cholera and in 1849 60,000. Deaths continued in the large cities. In 1857 John Snow published his paper on the Broad Street pump episode, demonstrating that infection occurred not from the supposed miasma in the air but from sewage contaminated well water. It was then realised that almost all the rivers in and downstream of urban areas were also polluted both from the sewers and from the filth from the generally unpaved streets.

Steam pumping was expensive so most new water supplies were provided by gravity from reservoirs constructed in upland areas. Because the need for clean water was understood but the methods of water treatment were known to have little effect, most reservoirs had any sources of pollution, such as people and cattle, removed from the catchment area (Binnie C 1995).

The City fathers were not entirely altruistic in improving the health of the industrial workers. Their output increased as well.

The large towns then started to construct upstream reservoirs, Manchester in 1848, Liverpool in 1852 and London in about 1870. The benefit of clean water supplies can be seen in the graph of Enteric deaths in Figure 2, (Binnie C 1995).

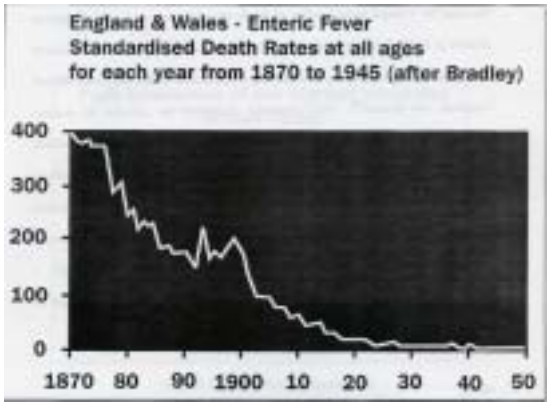

Figure 2: Enteric Fever standardised death rates

There were factories driven by water power downstream of many of the new reservoirs. The mill owners were powerful and demanded that a steady release of water be made, generally amounting to one third of the yield of the reservoir. Today the mills are long closed but this compensation water flow continues providing the benefit of a healthy river environment all year.

It is interesting to consider what the sustainable population would have been without reservoirs. We today use much more water per person than people did in the late Victorian era when reservoirs were first being built. However steam pumping then was both inefficient and costly so long distance transfer of water then would have been impractical.

Taking the instance of Greater London the population in 1870 when reservoirs started to be built was about 4 million. Today the water supplied to Greater London is about 2,200 Mld (Arkell 2003). The river Thames already goes below its minimum environmental flow and the amount available from groundwater is about 200 Mld. Allowing conjunctive use to double this amount would mean, without reservoirs, a population limitation of about 20 percent of the current, or about one and a half million. My great grandfather submitted a Bill to Parliament to bring water by gravity pipeline from Llangorst in Wales to London. However without the benefit of storage the sustainable dry weather flow of the Welsh uplands would have been

low. Until the development of desalination plants during the 1960's London's population would have been severely constrained.

Looking at England and Wales as a whole, the total water supplied today is about 15,000 Mld (Water Facts 2000). The total groundwater abstraction licensed is 8,476 Mld. The Environment Agency consider that about 1,000 Mld of this is over licensed and unsustainable. On the other hand it considers that about 1,000 Mld of river flow could be abstracted during dry weather (Watts 2003). Conjunctive use could increase the amount of water available. However, it can be seen that, without reservoirs, the total population of the country would have been appreciably constrained until the first economic electric pumps became available for long distance transfer, and then the advent of desalination systems.

HYDRO AND TIDAL POWER

After the 1939 – 1945 War the nationalisation of the power industry facilitated a major initiative to develop the hydropower potential offered by the terrain and water in the Highlands of Scotland (Bridle and Sims 1999). Governments throughout the world have used hydropower development to create employment, not only on the project itself, but through a Keynesian multiplier affecting other industries attracted by the energy. The British Government is no exception and the development of hydropower in Scotland was motivated to some extent in this way. By 1980 the hydropower installed in the North of Scotland was 1756MW with an annual output of over 3,000 GWh.

In the North of Scotland over 2,400 km of transmission circuits were constructed. The development of hydropower opened up the Highlands. The construction of a wide transmission system enabled industries to prosper and provide skilled jobs, thereby retaining young people in the Highlands and sustaining a society there with a complete cross section of jobs and income levels. Hydro-production funded the spread of transmission capacity into the glens and farms started to be connected to electricity for the first time. This brought them electric lighting, a fundamental improvement in a region where the winter nights are long, and once the farmers became familiar with the benefits of electricity, they started to use it for milking and to develop their output in other ways. By 1980, 94% of all farms in the neighbourhood were connected and were using a total of 241 MWh. The construction of the dams and power stations also required the construction of new high quality access roads which in turn provided much improved access and in turn brought in tourism.

The problem with nuclear and coal fired power stations was that they were unable to respond to rapid fluctuations of power demand such as when a

system tripped as occurred in 2003 in the eastern United States or when popular sporting events had half time or finished such as the 2003 Rugby World Cup. To respond to this pumped storage schemes were constructed in Wales with a high and low reservoir. The first, the 360MW Ffestiniog scheme was completed in 1964 and the second, the 1800 MW Dinorwig scheme, in 1981. Dinorwig can be brought to full generating load in 12 seconds and is also used to control the frequency of the national grid system. Constructing dams, particularly the 70m high Marchlyn Dam within the Snowdonia National Park, was a challenge but the schemes are now major tourist attractions.

Dams can also be formed in the sea where the tidal range is high and thus generate tidal power. There are several tide mills dating from medieval times and the Carew mill in Pembrokeshire is still in operation today. The 230MW La Rance scheme in Brittany was constructed in the mid 1960s and is the largest in operation.

The English Stones Barrage near the Severn Bridge could develop about 970 MW. (Binnie C.J.A. and Roe 1986) The Severn Barrage lower down the Bristol Channel between Lavenock Point and Brean Down could have an installed power of 7,2000MW, and annual energy output of 14.4 TWh. (STPG 1986). Taylor (1998) estimated this could provide up to 7% of the demand of England and Wales without the emission of polluting gases or the generation of toxic waste products.

Hydropower could contribute much to the UK's efforts in meeting the objectives of the Rio and Kyoto Conferences in reducing green house gas emissions to minimise the impact of climate change. Each kilowatt-hour generated by hydropower saves about 900 grams of carbon dioxide when compared to coal generated power. The hydropower generated between 1947 and 1980 therefore saved a total of 62 million tonnes of carbon dioxide in the atmosphere. (Bridle and Sims 1999)

Internationally hydropower is the world's main source of renewable energy providing about 20% of the world's energy generation. (British Hydropower Association 2003.) Installed capacity is 674,000MW with a further 103,000MW under construction. Dams are required to provide almost all of this.

FLOOD PROTECTION FROM RIVER FLOODING

Dams provide the benefit of protection from flooding from rivers in two ways, either by direct protection or by routing the flood through a reservoir provided for other means thus reducing the peak flow in the river downstream of it.

Examples of the former include many of the dykes through Holland. A good example of the latter in this country is the Leigh Barrier which protects Tonbridge. Without the benefit of the barrier, Tonbridge would have suffered severely in the Autumn 2000 floods.

Nowadays the Environment Agency insist that new development does not increase flooding downstream and that storage be provided. This can either be achieved by excavation of compensation storage but more often by the construction of a dam and empty reservoir. Flood defence reservoirs are often used as amenity areas or used for grazing or other agricultural purposes. Thus dams provide the benefit of being able to carry out development without the risk of increased flooding downstream.

The experience of Dublin described by Mangan (1996) is typical of the contribution by dams to flood relief in the British Isles. Huarricane Charlie produced intense rainfall and flooding on 25th and 26th August 1986. Twenty four hour rainfall in excess of 200 mm was recorded in the Dublin Mountains. The peak inflow to the Pollaphuca Reservoir, at the top of the cascade of the dams in the Liffey valley was 445m^3/s. No flooding was experienced in Dublin. A hydrological model simulating the flow in the Liffey at Dublin without the retention provided by the reservoirs suggests a flow there of 380m^3/s, which would have caused considerable damage in the city.

Severn Trent Water have formalised its agreements with the Environment Agency to hold its Derwent Valley reservoirs at 80% of capacity from October to the end of January better to provide flood reduction downstream. This is typical of arrangements made by other owners of large reservoirs (Bridle and Sims 1999).

Similar features occur overseas. The Yangtze River in China has drowned about 300,000 people in the last century, displaced several million and in 1954 alone inundated 3 million hectares. The Three Gorges Dam will provide flood protection to the 15 million people who now live in the flood plain, converting what used to be a flood every 10 years into one in one hundred years, and to 1 in 1000 years when the Dongting Lakes downstream have been rehabilitated to store flood waters.

SEA DEFENCE

Whilst almost all of Britain is above sea level, there are areas along the coast which have been reclaimed from the sea to provide agricultural or development land. This has been achieved by constructing dams, called sea defences, to keep out the sea. A good example is the sea defences in the Wash to protect the highly productive Fens from being inundated. These sea

defences have resulted in a significant increase in national agricultural output. Some of these are now several metres below high water. A good example of the protection of development is Canvey Island. These sea defences have provided extra land for housing and industrial development particularly for installations needing connection to the sea such as refineries.

Several of the estuaries were developed as ports and centres of commerce. With the south east of England falling relative to sea levels, several of these estuaries here are at risk of higher relative tidal levels. In 1953 a surge tide came down the North Sea and breached the sea defences. This caused 300 deaths in East Anglia but 3000 deaths in Holland. In England this resulted in the raising of the tidal defences and the construction of the Thames Barrier (Gilbert and Horner 1985). Figure 3 shows the area of London provided with protection by these dams (NCE 2003). About one and a half million people work in this area. The 1953 event was lucky for central London in one aspect, at the last moment the extreme meteorological condition curved away and struck Holland instead. Had it not parts of London would have flooded. The benefit of raised river walls and a new barrage provides protection for London against a one in 1,000 year marine flooding event. In 2002 the barrier was shut for 30 tides to prevent either marine or fluvial flooding demonstrating the increasing benefit obtained by this dam system.

Figure 3: Thames flood zone

IRRIGATION

Most supermarkets have strict requirements for quality and size of vegetables and generally require any producer from whom they buy to have irrigation to ensure uniform quality and security of supply.

LONG-TERM BENEFITS AND PERFORMANCE OF DAMS

Since the Environment Agency no longer allow new summer water abstraction in most of the south, east and Midlands of England, farmers have had to construct on farm storage reservoirs. Thus much of the commercial vegetable crops produced in Britain rely on irrigation water from farm reservoirs.

Overseas weather requirements are often more extreme. Irrigation water is often required to cover an entire dry season. In 1877 when a low Nile flood failed to irrigate adequately, there was famine and death among the six and a half million Egyptian population. In 1902 the Aswan Dam was constructed to provide two crops a year and the Aswan High Dam constructed in the 1960s extended this to provide perennial irrigation for a much larger area and a much larger population as well as 12,000 MW of hydropower. Now Egypt supports a population of over 70 million. Without these dams Egypt's population would have been much smaller than it is today.

RECREATION, CONSERVATION AND ENVIRONMENT

When Victorians built reservoirs they knew they could not treat the water so access to the reservoir, and often to the whole catchment, was often severely restricted. Now many reservoirs are recognised for their recreation, conservation and environmental benefits

On the environment, almost all reservoirs release water downstream thus ensuring the downstream environment is maintained even in a drought. At Roadford freshets are released to mimic the natural river and bring salmon up to the spawning beds. That facility would have been most welcome on many rivers during the drought of 2003.

Many reservoirs constructed on ordinary farmland are now Sites of Special Scientific Interest. Nine reservoirs are now internationally registered under the Ramsar Convention (1971) as "Wetlands of International Importance especially as Waterfowl Habitats (Ramsar Convention Bureau 1999). One of them (Abberton) is cited as *"…a roost for the local estuarine population of wildfowl. It is outstandingly important as an autumn arrival point, moulting and wintering locality for wildfowl. Thirteen species of waterfowl occur in nationally important numbers, including Widgeon, whose winter numbers are of international significance, Mute Swan, Gadwall, Shoveler, Pochard, Tufted Duck, Goldeneye, Goosander and Coot"*.

All new reservoirs are landscaped. This includes forming fillets and adjusting the slopes of the dams to minimise its apparent height, forming artificial islands so that birds can nest free from the predation of foxes, and forming lagoons along the foreshore to maintain shallow wetlands for

wildfowl even during drawdown. Many now have woodland plantations near the margin. Extensive planting often screens car parks and facilities.

Rutland Water, one of the largest reservoirs in the Britain, is, in the words of Sir David Attenborough, *"one of the finest examples of creative conservation in Great Britain"* (Anglian Water, 1995).

Like most reservoirs it is now stocked with fish. As a result otters and ospreys have been encouraged to breed there, increasing the bio-diversity.

Reservoirs are now extensively utilised for recreation. Most have fishing. Many have sailing clubs. Several have peripheral paths for walkers, bicyclists, and sometimes horse riders. Many have quiet environmental areas where bird watching hides allow visitors to watch many species of birds. Rutland Water attracts 50,000 birdwatchers a year.

Some reservoirs such as Kielder and Carsington commercialise these features with large carparking areas, a large visitor centre, and even caravan parks and chalets. Visitors to Carsington each year are about 1.2 million, to Kielder 1 million, and to Rutland between ¾ and 1 million.

Thus our reservoirs now provide the benefit of good, albeit changed, environment, and extensive recreation facilities.

SUMMARY

In summary, dams and the reservoirs they form, have provided considerable benefit to society from early times providing water for drinking, growing food, and power when it would not otherwise be available. They also provide an enhanced environment and recreation for many. Without dams and reservoirs the industrial revolution on which our wealth was based would have been much delayed. The population of our major towns would have been curtailed. Without hydropower green house gas emissions would have been greater, and hence climate change would have increased. Without reservoirs providing irrigation water more of our food would be imported. However society will only support more reservoirs provided the benefits they can bring are both provided to the full and publicised.

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