White Cart Water Flood Prevention Scheme

a holistic catchment scale solution to reduce the risk of flooding that has blighted the south side of Glasgow for decades

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The White Cart Water Flood Prevention Scheme protects 1,750 properties and businesses in the south of Glasgow from the risk of fluvial and pluvial flooding and over £100m flood damages. The White Cart Water is a shallow, fast flowing river which is prone to flash-flooding and water levels can rise by 6m after only 12 hours of rain. Since 1908 more than 20 serious floods have affected properties throughout Glasgow's south side. In January 1984 more than 500 homes were devastated by flooding. In 2002 the development of a flood alleviation scheme commenced, based on a holistic catchment management principle looking for a solution that stretched beyond the city boundaries. In addition to protecting houses and businesses in the area from flooding associated with a 1 in 200 year event, the scheme protects, complements and enhances the natural environment.

The Grade A listed Millbrae Crescent was frequently inundated - Courtesy of Glasgow City Council

Introduction

Constructing flood storage areas in rural areas upstream to hold back the water during storm events would enable downstream flood defences along the river in the urban areas to be reduced in height and length. This reduction in height and length has significant benefits not only in engineering terms but more importantly in the associated visual and environmental impact. High walls would have been undesirable as they would have created a barrier between the river and its wildlife and those that live and work alongside it.

Site selection

Initial attention focused on identifying potential sites for flood storage areas in the upper parts of the catchment. In all, 33 sites were considered for size, topography, geotechnical suitability to allow a dam up to sixteen metres in height to be constructed and the associated environmental impacts. It was established that to constrain the flow sufficiently to have a significant impact on the lengths and heights of flood defences downstream would require at least one flood storage area on the White Cart Water and its two major tributaries the Earn Water and Kittoch Water. Several of the sites considered were discounted due to significant environmental and geotechnical concerns.

Consultation

The development of engineering designs for the scheme were complemented by the creation of an environmental working group (EWG) comprising stakeholders from the Scottish Environment Protection Agency, Scottish Natural Heritage, Scottish Water, local angling/fisheries groups and the Royal Society for the Protection of Birds as well as environmental professionals from the three local authorities involved.

The work of the EWG helped to minimise the environmental impact of the scheme, and, where possible, to enhance the natural environment and assist in developing a sustainable flood prevention scheme.

Consultation was a key aspect of the scheme development and the selection of the final three flood storage areas. Through one-to-one discussions and an extensive public exhibition, the views and opinions of affected parties were obtained and, where possible, incorporated within the design. The public were kept fully informed of the development and progress of the project through the distribution of regular newsletters and the creation of a dedicated website. Despite the size and scope of the project, only

limited objections were received, all of which were subsequently resolved through discussion without the need for a Public Local Inquiry, a first for a flood prevention scheme of this size. A full time liaison officer was appointed early in the project and remained involved through to the completion of the construction works. The cooperation and collaboration with surrounding local authorities and the project team was critical to ensuring the smooth passage of the project through the statutory approval processes.

Dam alignment

The alignment of the dams used existing topography where possible to minimise their height and length. All of the dams have been designed to overtop to accommodate floods significantly larger than the 1 in 200 year event and require concrete channels and blockwork protection to ensure their stability during these enormous floods. Rather than leave these concrete structures exposed and potentially unlikely to be used for decades or probably even longer, they were infilled with sacrificial material and grass cover was established to ensure the dams blend in with the existing landscape.

The dams and culverts have been designed to ensure they do not prevent the movement of fish and mammals upstream and downstream. The base of the culverts incorporates baffles and boulders to ensure a varied flow pattern and to retain a minimum depth of water for fish passage in low flows. In addition there are no hydraulic drops, with the base of the culvert laid at the same gradient as the original river bed. Mammal ledges have also been provided throughout the length of the culvert and ongoing monitoring has shown these are being used by otters at all three sites.

The flood storage areas were seen as an opportunity to enhance biodiversity through the creation of artificial wildlife habitats, the creation of woodland, scrub, and over 90,000m^2 of species-rich wet grasslands, shallow scrapes and ponds.

Together the three flood storage areas, located at Blackhouse (Earn Water) in East Renfrewshire, Kirkland Bridge (White Cart Water) and Kittoch Bridge (Kittoch Water) in East Renfrewshire and South Lanarkshire have the capability to hold back over 2.6 million cubic metres of flood water and reduce peak river flows by up to 45%.

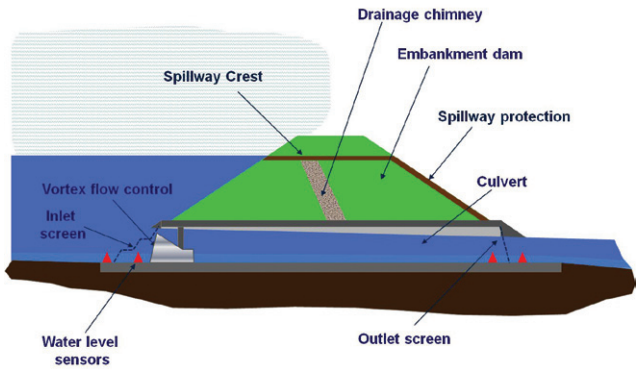
Hydro-Brake

Central to the successful operation of the storage areas was the installation of the world's largest Hydro-Brake vortex flow controls which required new manufacturing and installation techniques to be developed. The Hydro-Brakes internal geometry enables water to flow through unrestricted for as long as possible. A self-activating vortex is created when the water reaches a pre-determined height in a flood situation, holding back the water, and releasing it at a controlled rate. Hydro-Brake flow controls enable the storage capacity within the attenuation area to be used most effectively, because flows can pass unheeded through them for longer than other flow control devices.

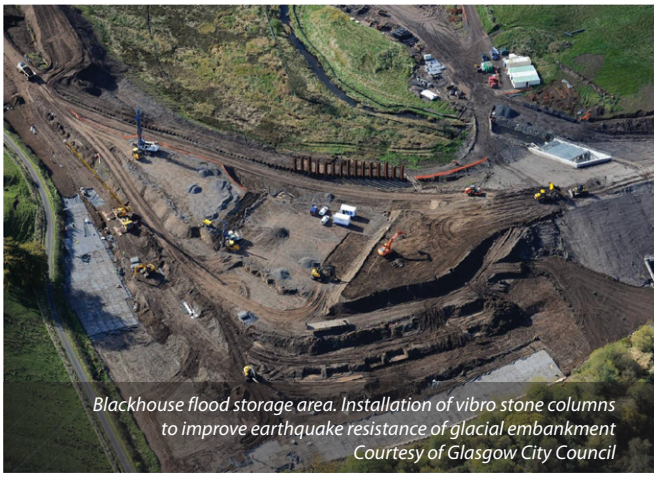
Alternatives such as orifice plates, weirs or gates for example, would start to hold back the water at a much earlier stage and require more flood storage capacity. The Hydro-Brakes reduce the frequency and duration of flooding of the storage area, which is important given that most of the land upstream returns to agricultural use. The Hydro-Brakes offer an efficient fail-safe, passive method of flow control. They do not need power to operate, and once installed, they can be left alone to do their job with minimal maintenance for the foreseeable future.

Construction

The flow controls are installed in earth embankment dams constructed at each of the storage areas. Each dam is capable of storing over 0.7M cubic metres of water, with the largest storing

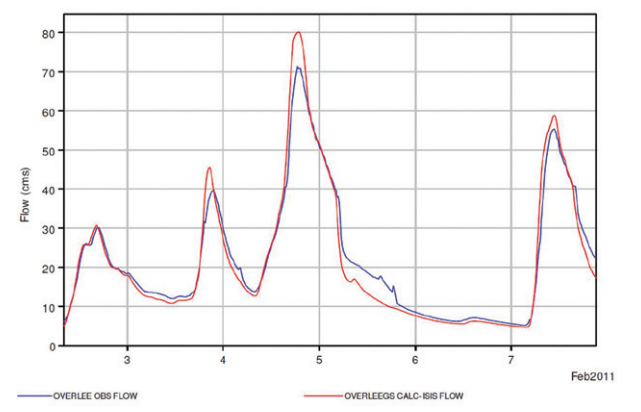


Typical cross section through dam and flow control structure
Courtesy of CH2M HILL



Blackhouse flood storage area. Installation of vibro stone columns to improve earthquake resistance of glacial embankment
Courtesy of Glasgow City Council

Kirkland Bridge Hydro-Brake
Courtesy of Hydro International



Flood event on 4 February 2011. Observed flow (blue) compared to model predictions (red) at Overlee Gauging Station - Courtesy of CH2M Hill

1.1M cubic metres. At two out of the three sites the vast majority of material used to construct the earth dams was won from on-site borrow pits with earthworks designs and specifications tailored to suit the material available in the borrow pits. At the third site an existing glacial deposit was incorporated into the dam following its strengthening by the installation of 4,500 vibro-compacted stone columns with the remaining fill being imported from a local source.

The second element of the project involves the construction of flood defences downstream in the city. This has involved the design and construction of 4.5km of walls in selected reaches of the river corridor downstream, the raising of two footbridges and the construction of six surface water pumping stations.

The presence of many underground services, the close proximity of existing buildings, invasive species including Japanese knotweed and giant hogweed and limited access made the design and subsequent construction of the urban flood defences a significant challenge. The form of construction adopted considered these and other constraints and sought to achieve the most appropriate solution. The wall construction varied from in situ reinforced concrete, sheet piles installed using both vibratory and non-vibratory (silent) piling techniques and rotary bored secant piling.

The design philosophy was to make sure that high defence walls never severed community accessibility to the river and with an average height of 0.85m above ground level, this has been comfortably achieved. Particular attention was paid to the alignment of the flood defence wall and where possible the alignment sought to maximise the retention of the natural flood plain and follow existing boundary walls and features to avoid the reduction in size of private gardens.

In many areas the only access to construct the flood defences was from within the river channel. Where this was required temporary rock haul roads and working platforms were constructed in the river channel. If necessary, temporary flood defences were put in place or made available to be deployed during a flood event. On removal of the haul roads some of the material was recycled and used as scour protection to the toe of the river bank or in some places to form mammal ledges where there had originally been no river bank due to high river training walls.

Scheme in action

In early 2011 when construction was ongoing the scheme was put to its first test. On 4 February 2011 a one in ten year flood event (10% annual exceedance probability) was significantly reduced in impact, principally as a result of the flood storage areas being hydraulically complete, and it is estimated that between £1m and £3m of damage was averted.

On 29 November 2011 an even larger flood event occurred. This event occurred shortly after completion of the scheme and some 231 properties avoided flooding at a cost of £12m. Post-event analysis has shown the scheme to be performing as expected with model predictions closely matching observed data, giving confidence in the hydraulic output of the Hydro-Brake flow controls.

Key participants	
Client	Glasgow City Council
Principal Designer	CH2M HILL (formerly Halcrow)
Principal contractor	Carillion and VolkerStevin
Contract value	£49m

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The world's largest Hydro-Brake is installed at Blackhouse
Courtesy of Hydro International

Kirkland Bridge flood storage area with extensive wetland creation
Courtesy of Glasgow City Council