# 1.0 lecturer mr. shane newell. from this

1. 0 IntroductionAs part of GMIT’s fourth year Civil Engineering Integrated Projectmodule, each student received a title from our lecturer Mr. Shane Newell. Fromthis title, each student was then required to research and submit a technicalreport based on their given title.

I received the title ‘ Types of hydro-logical investigations inwhich reservoir or lake flow routing could play an important role’ on which Iresearched for this report. Over the past century, flooding has become a major problem on both an inter-national and nationalscale. The impacts of these flooding events on the natural environment andpeople’s livelihood are producing disastrous consequences. These events arecaused by many factors, some of these factors are human influenced while othersare due to the natural environment and the way the it works. Some of thenatural occurring effects consist of Tropical cyclones, Hurricanes, rising sealevels, high tides occurring with high river levels. Hydrologicalinvestigations and Flow routing plays a very important role in mitigating andreducing the effects of these flood events by predicting flooding levels inadvance allowing for flood relief structures to be constructed in areas proneto flooding.

Thesenatural occurring events are factors that man cannot control but work to try lessenthe damages caused by these events. Countries are working both individually andtogether to reduce their impacts on the environment which can significantlyreduce the impacts of these disasters. 2. 0 Types of Flow RoutingInvestigations2. 1 FlowRoutingFlow Routing is a process used to estimate the shape of a hydrograph ata specific location in a reservoir, lake or channel. The shape of thishydrograph usually shows the effects of a predicted or measured flood at aprecise location in the water body, usually upstream.

It can also be used topredict water levels downstream or upstream in tidal locations. A key factor thateffects flow in a stream is the geometry of the flood plain and channel. Floodplains and channels in general consist of two distinct types consisting ofstream A and stream B as shown in figure one below. Figure 0? 1 – Effects of Channel shape on DischargeIf a channel is narrow and trench like similar to channel Awith a small floodplain, a sudden increase in water level may not produce asignificant change in discharge in comparison to channel B. Channel B iscomprised of a shallow channel with a broad flood plain area. If a suddenincrease in water level were to occur in this channel type, there would be alarge rise in volume of discharge due to the spread of water across the floodplain.

(Jones. N 2017)2. 1. 1 Routing ApplicationsTime of flow, flood peaks and water volume are mainly predicted by flowrouting. These predictions are required to determine peak water levelsdownstream which are caused by intensive rainfalls and flooding. From thesepredictions and calculations, the capability of spillways, culverts, dams, reservoirs etc.

can be determined, thus designed. (Jones. N 2017) Flow routing is also used to designreservoirs/dams. These large waters retaining structures withhold excess floodwater during periods of intensive rainfall. With the peak out flow being lowerthan peak inflow, the retained volume of water is released at a controlled rateand duration therefore reducing the peak discharge and flood peak. Other usesof flow routing consist of determining the area of a flood plain that may flooddue to intensive rainfall and in carrying out other design calculations.

(Jones. N 2017)2. 2HydrographsHydrographs are used to assess a drainage basin (i. e. riverrunoff) response to water flow during and after a period of rainfall.

Ahydrograph is a graph showing the rate of flow (discharge) versus time past aspecific point in a river, or other channel or conduit carrying flow (Wikipedia 2018), typically expressed inm3/sec. The theory behind a unit hydrograph is to provide an estimate to flowin a waterbody given the quantity of rainfall that could occur. The graph isused to determine the impact of precipitation on a waterbodies flow.

Given aspecific amount of precipitation, unit hydrograph theory allows us to calculatehow much flow will result over a time period (Wikipedia 2018).
(Jones. N
2017)

Aunit hydrograph is only related to the surface runoff component of a hydrograph(i. e. direct runoff), it does not account for the base flow component. Unit Hydrographs are relative to a particular catchmentand a particular length of time in conjunction to the duration of the effectiverainfall, therefore unit hydrographs are expressed as 1-hour UH, 6-hour UH, 24-hour UH etc. or any other specified lengthof time up until the time of concentration of direct runoff at the catchmentoutlet (Wikipedia

2018). Thus, there may be a several unit hydrographs relatingto the same catchment corresponding to the duration of the effective rainfall.

(Jones. N 2017) 2. 2. 1 Hydro-Graph UsesHydrographcan be used to: To calculate a flood hydrograph from a specified design rainfall for determining: Peak discharge By pass channel Redesign of an existing channel  2. Peakwater level for floor level / road levels 3. Flood volumes for testing/designing reservoir outflows4.

Flood forecasting / warnings.  (Jones. N 2017)   Figure 2 – Typical hydrographdisplaying peak/discharge2. 2. 2 UnitHydrograph DesignWhen designing hydrographs, there are severalfactors (known as drainage basin controls) that need to be incorporated in thedesign to determine the shape of the hydrograph and the way in which a river respondsto precipitation. Some of these factors consist of the shape, size andrelief of the basin. (Jones. N 2017)Wheregradients are steep, water runs off faster, reaches the river more quickly andcauses a steep rising limb.

Prolonged heavy rain causes more overland flow thanlight drizzly rain. Areas of permeable rocks and soil allow more infiltrationand so less surface run off (BBC 2017). (Jones. N2017)Landuse also plays a vital role in the design of hydrographs. Vegetated lands interceptprecipitation, thus allowing evaporation to occur. This reduces the quantity ofwater available to penetrate the ground or flow into nearby waterways. Impermeablesurfaces found in urban and mountainous areas produce run off into nearbydrains or gutters carrying being transported to the nearest waterbody.

(Jones. N 2017) 2. 2. 3 Flaw of Unit Hydrographs The state of the catchment prior to the rainfall event is not accounted for. The second period of rainfall the response of the catchment will depend on the effects of the first input. Seasonal variations –vegetation. Assumption that effective Rainfall is uniform in the time and the catchment.

(Jones. N 2017)2. 2. 3Assumptions/ Weaknesses of Hydrographs Constant rainfall intensity is assumed.

Rainfall is uniformly distributed. Time increment is constant (1mm of rainfall in same amount of time for each storm). Catchment will not change (i. e. no new houses, no new roads etc.).(Jones.

N 2017) 3. 0 Role of Hydrological Investigations3. 1 EU Flood DirectiveThe EU flood directive is a management andassessment of flood risks process 2007/60/EC on which the union requires allmember states to follow. It was transposed into Irish law by the EUROPEANCOMMUNITIES (ASSESSMENT AND MANAGEMENT OF FLOOD RISKS) REGULATIONS 2010 (SI122/2010) (The Office of Public Works 2018). The directive process on whichmember states were required to follow are listed as follows: Undertake a Preliminary Flood Risk Assessment (PFRA) by 22 December 2011 to identify areas of existing or foreseeable future potentially significant flood risk (referred to as ‘ Areas for Further Assessment, or ‘ AFA’s) Prepare flood hazard and risk maps for the AFAs by 22 December 2013, and Prepare flood risk management plans by 22 December 2015, setting objectives for managing the flood risk within the AFAs and setting out a prioritised set of measures for achieving those objectives.(The Office of Public Works 2018)While the Office of Public Works isresponsible for implementing the directive in the Republic of Ireland, theRivers Agency (Dept. of Agriculture and Rural Development) holds theresponsibility for implementing the directive in the North of Ireland.

Theregulations set out in the directive require both authorities to implement, consult, detail and monitor the flood risk management plans in their ownjurisdiction individually.  Wherenecessary, both authorities have committed to working together where riverscross between borders, so an effective management plan is upheld for situationssimilar to this. (The Office of PublicWorks 2018) 3. 2 Flood Risk Assessment Reports required for PlanningThe main aim offlood risk assessments is to provide a sustainable development with a minimumrisk of flooding to people and property. This allows for the avoidance ofconstruction of developments in areas prone to flooding (The Office of Public Works 2009). The key aims of a flood riskassessment report are: Avoid inappropriate development in risk areas.

Avoid new developments increasing flood risk elsewhere. Ensure effective management of residual risks for development permitted in floodplains. Avoid un-necessary restriction of national, regional or local economic & social growth. Improve understanding of flood risk among relevant stakeholders. Ensure requirements of Irish & EU law are complied with.(The Office of Public Works 2009)To prepare a floodrisk report, the site subject to planning must be examined in great detail. Forthis, the source of the flowing river, pathways/tributaries along the river, the people and assets affected by it must be identified and studied.

A surveymust be completed to examine river bed and water levels both upstream anddownstream of the proposed development. The proposed finish floor level of thedevelopment and finish floor levels of nearby properties must also be surveyedand studied. The three main stages of flood risk assessment consist of: Stage 1: Flood risk identification – To identify whether there may be anyfloodingor surface water management issues related to the area. Stage 2: Initial flood risk assessment – To confirm sources of flooding that mayaffecta plan area or proposed development site.   Stage 3: Detailed flood risk assessment – To assess flood risk issues insufficientdetail and to provide a quantitative appraisal of potential flood risk.(The Office of Public Works 2009) The likelihood offlooding occurring in a particular geographical area is displayed by flood zonemaps. Flood zone maps area a key instrument to determine if a flood riskassessment needs to be carried out for a proposed development by identifying ifthe area is prone to flooding. There are three levels of flood zones definedfor the purposes of these Guidelines: Flood Zone A – where the probability of flooding from rivers and the sea is highest.

Flood Zone B – where the probability of flooding from rivers and the sea is moderate. Flood Zone C – where the probability of flooding from rivers and the sea is low. Flood Zone C covers all areas of the plan which are not in zones A or B.(The Office of Public Works 2009)These flood zonesare determined on the basis of the probability of river and coastal floodingonly and should be prepared by suitably qualified experts with hydrologicalexperience (The Office of Public Works 2009). 3. 3 Flooding Prevention Methods Flooding prevention methods are designed to reduce or mitigate the effectscaused by flooding. In studying hydrographs and storm types 1 in 100-yearstorm, 1 in 50-year storm etc.

Meteorologists can warn the public in advance offlooding. This then allows for councils and locals authorities to prepare forflooding by installing temporary flood prevention methods. In locations whereflooding is a frequent problem, permanent flood barriers are installed. Bothpermanent and non-permanent flooding prevention methods used consist of: Dams – Dams are man-made structures constructed to retain water during intense periods of rainfall. As the intense period of rainfall decreases, rain water held by the dam is released at a controlled rate down the river, thus controlling flooding. Diversion canals – Diversion canals divert flooding from populated urban areas.

At times of peak rainfall, these man-made structures re-direct large quantities of water from flooding rivers/lakes to other waterways with a lower water level and larger capacity. Flood plains/man-made lakes – A flood plain can be described as a low-lying area adjacent to a river subject to flooding during occasions of intense rainfall and storms. As a river reaches its full capacity, the river will over spill into the floodplain. River defences – River defences consist of permanent flood walls and banks, demountable river barriers and glass flood walls. Self-closing flood barriers – Self-closing flood barriers are designed to self-rise and act as a flood gate during flooding periods which is automatically activated by rising flood waters. Temporary perimeter barriers – These temporary structures can be set up quickly in the event of a flood occurring. The main types of temporary flood structures available consist of inflatable flood barriers, membrane barriers and modular barriers(O’Malley.

A 2017)In order to design the size and quantity of the above floodprevention methods, flow routing is calculations and predictions need to beassessed to determine the height, strength and area of flood preventionstructures required. With the aid of flow routing predictions, these structurescan prevent and control disastrous flooding consequences in areas of highpopulation density, low lying areas etc.  3. 4 Water Supply Schemes – WeirA weir is a barrier acrossthe horizontal width of a river that alters the flow characteristics of thewater and usually results in a change in the height of the river level(Wikipedia 2018). There are many designs of weir, but commonly water flowsfreely over the top of the weir crest before cascading down to a lower level. Weirs are usually providedfor one of four fundamental reasons: Water level management Flow (discharge) measurement Environmental enhancement Channel stabilisation(Jones. N 2017)The weir is diagonal to the flow to maximisethe crest length and thereby reduce water level variation upstream.

Inengineering terms, the design of a weir must satisfy three fundamentalrequirements Hydraulic performance, Structural integrity and Health and safetyrequirements. With the aid of Flowrouting and Hydrographs, design of weirs can be carried to manage water levelsupstream in a river or lake. Water may be required to be retained to be usedfor human/domestic consumption during periods of little rainfall or periods ofincreased use. (Jones. N 2017) Figure 3 – Purpose ofa Weir – Water Level Raised 3. 5Flood Relief SchemesWith the aid of hydrological investigations and flow routing, floodrelief schemes have been designed to prevent flooding in populated areas. Floodrelief schemes have been carried out in many flood prone areas in Ireland, someof these areas consist of Fermoy, Co. Cork, Clonmel, Co.

Tipperary, Mallow, Co. Cork 3. 5. 1Fermoy, Co. CorkFermoy, Co. cork holds a long history to flooding due to the RiverBlackwater flowing through the town. With the preferred solution of floodmitigation problems being published in an engineering report in 2003, constructionof permanent flood walls, extensive use of temporary demountable floodbarriers, millrace gates and construction of embankments along the banks of theriver, the towns risk of flooding was greatly reduced.

(The Office of Public Works 2018)Figure4 – Flooding in Fermoy Town (1980s)Figure 5 – PermanentFlood Walls and Embankments3. 5. 2 Clonmel, Co. Tipperary Clonmel, Co. Tipperary has suffered nine flooding eventssince 1995 from the River Suir and its tributaries, the Auk and WhiteningStreams.

Designed for a 1 in 100-yearstorm plus a 20% increase in design flow, works along the river commenced whichincluded the construction of reinforced concrete and sheet piled retainingwalls, embankments and pumping stations, improvements and alterations to thedrainage system. Demountable flood barriers were also constructed at publicflood prone areas along the river banks. (The Office of Public Works 2018) Figure 6 – Permanentflood wall and demountable flood barrier constructed along Quay Street, Clonmel3. 5. 3 Mallow, Co. CorkSimilar to Clonmel, Co. Cork, Mallow, Co. Cork has a long history offlooding caused by the River Blackwater which flows through the town and otherminor rivers such as Spa Glen stream and the Bear Forest stream.

Floodingevents have occurred in the town of Mallow since 1853 up to 2009. Designed fora 1 in 100-year storm, the flood relief works compromises of walls andembankments, new culverts, pumping stations, demountable defences and thelowering of ground at Mallow Bridge. To warn the town of a possible flood, aflood warning alarm system was also implemented.

(The Office of Public Works 2018) Figure 7 – Demountable flood barriers Figure 8 – Flooding in Mallow caused by R. Blackwater Incomparing the above three flood relief schemes, Flow routing and Hydrographswould have played a significant role in the design of permanent flood walls andembankments, new culverts, pumping stations, demountable defences, drainagediversions etc. as a 1 in 100-yearflood, 1 in 200-year flood etc.

Flow routing and Hydrographs would have beenmodelled and studied in computer programmes to determine the water height, quantity, force of a flood if to occur. All flood works carried out in theserelief schemes were guided by the OPW and County Councils. All flood measuresdeveloped in these schemes were also designed to include a 20% increase in waterlevels due to climate change. 4. 0 Case Study – Storm EleanorStormEleanor occurred at Galway City, Co.

Galway on 02/01/2018. High tide wasrecorded at 17. 30pm on 02/01/2018 in Galway port by the Marine Institute tidegauge as approximately +3. 77m OD Malin. The storm event was recorded at 17.

45pmon 02/01/2018 at Wolfe Tone Bridge by the EPA gauge as approximately +3. 89m ODMalin. The Catchment Flood Risk Assessment and Management (CFRAM) predicted the flood level at Wolfe Tone Bridge for a 1: 200-yearevent (present day, i. e. excl. Climate Change) to be +3. 89m OD Malin.

The floodmap (figure 9 below) shows the 1: 200-year level as a mid-shade green. The floodmap was found to be almost accurate with what was experienced on the streetsaround the Claddagh, Dominic Street, Flood Street etc. Galway on that night. Figure 9 – Flood map showinga 1: 200 year predicted storm in Galway CityThe coastal (sea only)model value for a 1: 200-year flood (present day, i.

e. excl. Climate Change) in Galway at Mutton Island calculated to be +3. 77m OD Malin. Thiswas the same reading as the tide gauge recordedin Galwayport meaning that the event was a 1: 200-year event, thus the models wereaccurate. However, they didn’t account for overtopping in Salthill.

Also, nowthat this event has occurred, the return period will change for all futureevents, making the CFRAM maps slightly less accurate. Figure 10 – Water levelsmOD (m) recorded at Mutton Island between 28/12/2017-04/04/2018After studying storm Eleanor, it’s clear that the predictedflood levels modelled were correct. Flow routing and hydrographs would haveplayed a significant role in calculating and preparing these models.