

MODULE CODE: M2X9623
TITLE: Environmental Monitoring & Remediation

DATED: 22/09/2019
LEVEL: 5
CREDITS: 20

JACS CODE: D447
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Date: 01.10.2019

Sources: Sergio Garate & Various

The Environment

- Global
- Local
- Boundaries
- Resources

Environmental engineering has been defined as the branch of engineering that is concerned with protecting the environment from the potentially deleterious effects of human activity, protecting human populations from the effect of adverse environmental factors, thereby improving environmental quality for human health and well-being. “Engineering” and “Technology” infer a different degree of mathematical and science knowledge and rigour.

The environment globally consists of the **atmosphere**, **hydrosphere** and **lithosphere**, in which the life-sustaining resources of the earth are contained. The **biosphere**, a thin shell that encapsulates the earth is made up of the atmosphere and lithosphere both adjacent to the surface of the earth, together with the hydrosphere. From the beginning of time it is the biosphere that has received and assimilated the wastes generated by plant and animal life. However, in recent times it has become apparent that the sustaining and **assimilative capacity** of the biosphere is not infinite.

Impact of Humans on the Environment

For some time anthropogenic pollutants have, to a greater or lesser extent, overloaded the system since people began to gather together in stable groupings. This **overloading** was initially caused in simply meeting their needs for **air**, **water**, **food** and **shelter**, however, attention was soon directed to other needs beyond those associated with **survival**. These **acquired needs** are met by the various industries and these **residuals** are likely to be less compatible with the environment and less likely to be assimilated into the biosphere. As societies ascent the socio-economic ladder, the list of acquired needs or luxuries increase.

Impact of the Environment upon Humans

Though rivers stink as do dumping grounds, and skies become **smoggy**, populations generally manage to ignore their impact on the environment until they become aware of the ill-effects upon their health. It has only been in the last century that the correlation between **waterborne** biological agents and human diseases has been proved and effective preventative measures undertaken to limit consequences through immunisation and environmental control.

Pollution of the atmosphere has also caused deaths. Monitoring of sulphur dioxide, lead and carbon monoxide levels in cities have revealed that the high levels of these and other contaminants are at worrying levels. Other environmentally related health problems also concern the environmental engineer/technologist. The widespread use of chemicals in agriculture and industry has introduced dangerous compounds into the environment. The formation of **dioxin** is a by-product of a manufacturing process used with **herbicides** and wood preserving compounds and is extremely toxic.

Our cultural as well as our aesthetic heritage is being lost to pollution; the Parthenon in Athens, the Statue of Liberty in New York are increasingly in danger of being destroyed.

Role of the Environmental Engineer

As pollutants enter air, water or soil, natural processes such as **dilution**, biological and chemical reactions convert waste material to more acceptable forms. The treatment facilities designed by the environmental engineer are based on the principles of **self-cleansing** observed in nature but the engineered processes optimise the operations observed in nature to handle larger volumes of pollutants. An understanding of natural and engineered **purification** processes requires an understanding of the biological and chemical reactions involved in these processes. The environmental engineer/technologist unique role is to build a bridge between biology and technology by applying all the techniques made available by modern engineering technology to the job of cleaning up the debris left in the indiscriminate use of that technology. It is essential to adopt a “**systems approach**”; that is looking at all the interrelated parts and consider their effects on one another.

Engineering/environmental ethics

Ethos, the Greek word from which ‘**ethic**’ is derived means the character of a person as described by their actions. We should treat all of the earth as a sacred trust to be used so that its content is neither diminished nor permanently changed. The recognition of the need for such adaptation has developed into what is now called the environmental ethic.

Some engineers are unhappy about the negative long-term impacts of engineering projects on the natural environment, and no longer can the profession not share responsibility for the ethical dilemmas consequent to their projects. The ethical question requests that we also put aside nationalist views for the long-term greater benefit of the global population and **ecology**.

As environmental engineers we need to believe in our projects as ecologically and humanely desirable. We need to be more adaptable and flexible and collaborate with environmental and community groups from project inception.

Environmental changes and threats to the environment

Over **geological time**, the temperature of earth has naturally changed causing climatic changes, continental plates have moved around the surface of the globe and the topography of the land has changed. This has led to changes in the extent and distribution of various **biomes** on a global scale. Gradual changes in the environment over long time periods do not seriously damage the ecosystem processed as species are able to track the change by either physically moving or adapting.

Resources

- Water - hydrosphere
- Air - atmosphere
- Land - lithosphere

Scarcity of Water

Storage component	Volume of water (10^{12} m^3)	Volume (% approx.)
Oceans	1 350 400	97.6
Ice caps and glaciers	26 000	1.9
Groundwater and soil moisture	7150	0.5
Freshwater lakes	125	0.009
Saline lakes	105	0.008
Rivers	1.7	0.0001
Atmosphere	13	0.001

Note: To highlight the problem only. Not the most up-to-date figures

Distribution of Water

Continent	Proportion of world's human population (%)	Proportion of world's available freshwater (%)
North and Central America	8	15
South America	6	26
Europe	13	8
Africa	13	11
Asia	60	36
Australia and Oceania	1	5

Note: To highlight the problem only. Not the most up-to-date figures

Usage of Water

- Food production (Irrigation, beef? palm oil?)

Hydrology

- **Hydrology:** is the study of water and its movement in the atmosphere, rivers and seas, and in soils and rocks.
- **Evaporation:**
- **Condensation:**
- **Precipitation:**
- **Percolation:**
- **Infiltration:**
- **Absorption:**
- **Transpiration:**
- **Evapotranspiration:**
- **Surface run-off:**
- **Interflow:**
- **Aquifer:**

Hydrological Cycle

Water evaporates from the Earth's oceans and to a lesser extent from the land surfaces. The evaporated water, as vapour, rises into the atmosphere until it condenses and precipitates. Some of this water may become overland flow and eventually reach a stream or river and be discharged as surface run-off or just run-off. It may infiltrate into the soil and either flow horizontally as **interflow** or percolate through the soil into the groundwater zone and recharge the waters in the **aquifers**. A significant volume of precipitation may be returned directly to the atmosphere through evaporation from water surfaces or evapotranspiration from vegetation. Evaporation and evapotranspiration together are often referred to as total evaporation or interception.

If a land use change is proposed for a **catchment** e.g. if a grassland catchment is converted to forestry, an appreciable increase in total evaporation would result due to the increased transpiration rate of trees over grassland.

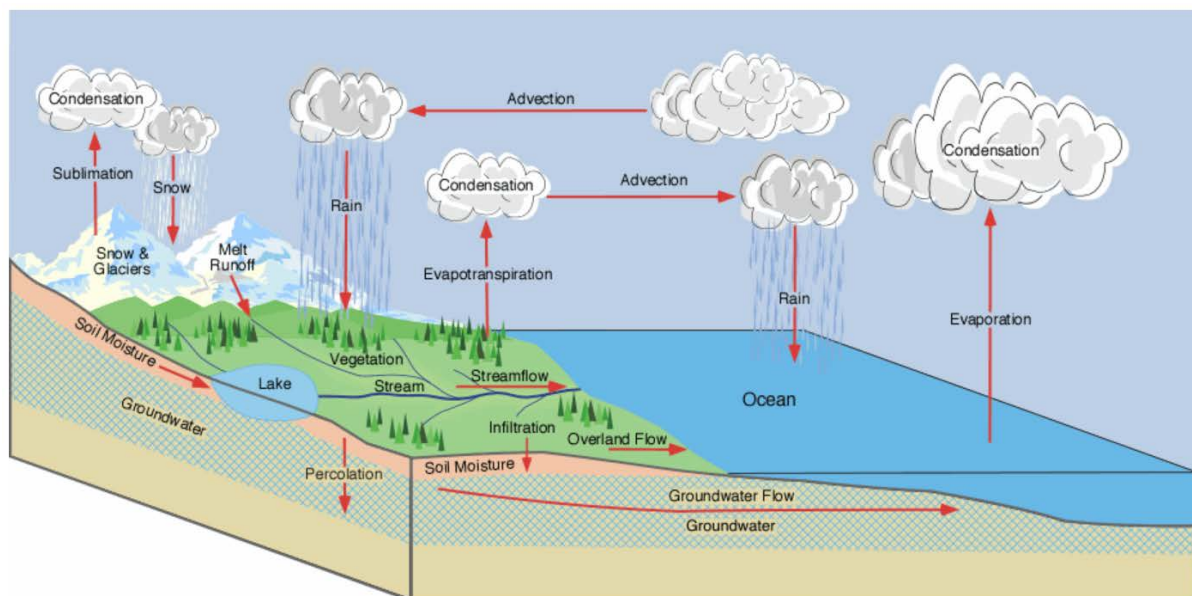


Fig: Hydrological Cycle (PhysicalGeography.Net)

Precipitation

The three means of determining the magnitude of rainfall are precipitation gauges, radar and satellite remote sensing. The traditional means of measurement was to use a network of gauges which were read manually on a daily basis. Today **rain gauges** are predominantly continuous rainfall recorders with attached electronic data recorders.

Infiltration

Infiltration is the movement of water from the soil surface into the soil. A proportion of the water may remain above the water table until it reappears in **channels** by interflow or may percolate below the water table to become groundwater. 30% of the Earth's freshwater is stored in the groundwater although this represents less than 1% of the total water.

Soil Moisture Deficit (SMD)

When the soil moisture is below field capacity it is said to have a soil moisture deficit. A catchment loses water at rates equal or less than potential evapotranspiration depending on whether the soil moisture is at or below field capacity.

In spring when evapotranspiration is greater than the precipitation, the soil enters SMD, first at the surface layers. In the autumn, the precipitation is higher than the evapotranspiration, and the upper layers become replenished with water whilst the lower layers are still in SMD.

Rainfall / Run-off Relationships

When rainfall occurs the proportion of run-off to infiltration depends on land slope and infiltration capacity. The water flowing in streams and rivers is derived, from run-off, and a proportion of the water that infiltrates being the interflow element, and a proportion of the water that has percolated into the groundwater resurfacing, known as the **baseflow**.

The catchment area, **watershed** or **basin** is defined by the surrounding topography.

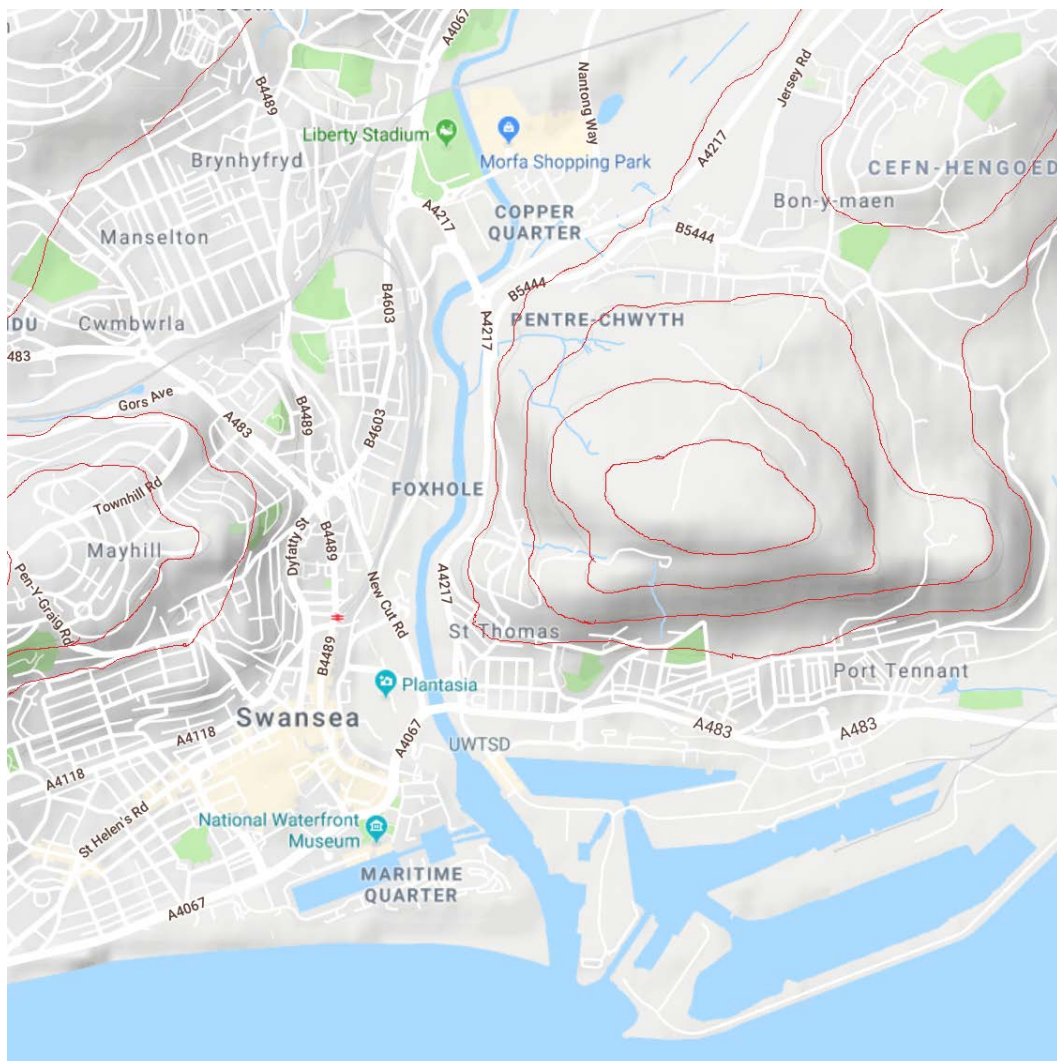


Fig: River Tawe Catchment around Swansea (Google Maps)

The perimeter of the watershed is called a **divide** and is the highest **elevation** surrounding the watershed. Water falling outside of the divide is shed to another basin. The **hydrograph** is a plot of **stream discharge** versus time. Baseflow is that component of the flow which is supplied by groundwater. Interflow is that supplied by subsurface flow within the unsaturated soil matrix. The shape of the hydrograph depends on an overland flow, subsurface flow, groundwater flow, land slope, stream slope, land and channel roughness and rainfall pattern, intensity and duration. Elements of interest for the hydrograph include the “peak magnitude”, the time to peak, the hydrograph duration and the separation of baseflow, interflow and surface run-off.

Time of Concentration

The time of concentration (t_c) is the time required for the direct run-off to flow from the hydraulically most remote part of the catchment to the outlet. The following equation may be used for estimating t_c in minutes.

$$t_c = \frac{1.8 (1.1 - C) \sqrt{3.28D}}{S^{\frac{1}{3}}}$$

Where;

“ t_c ” is in minutes

“ C ” is the run-off coefficient (coefficient: do not have units. 0 is no run-Off, 1 is all rainfall becomes run-off. See table below)

“ D ” is the overland distance in metres

“ S ” is the percentage (%) slope

C – Run-off Coefficients

Type of drainage area	Run-off coefficient
Sandy soil, up to 2% gradient	0.05 – 0.10
Sandy soil, average gradient 2-7%	0.10 – 0.15
Sandy soil, steep	0.15 – 0.20
Urban areas	0.70 – 0.95
Suburban areas	0.25 – 0.40
Industrial (light)	0.50 – 0.80
Industrial (heavy)	0.60 – 0.90
Parks etc.	0.10 – 0.25
Streets (Asphalt)	0.70 – 0.95
Streets (Concrete)	0.80 – 0.95

Slopes as Percentages

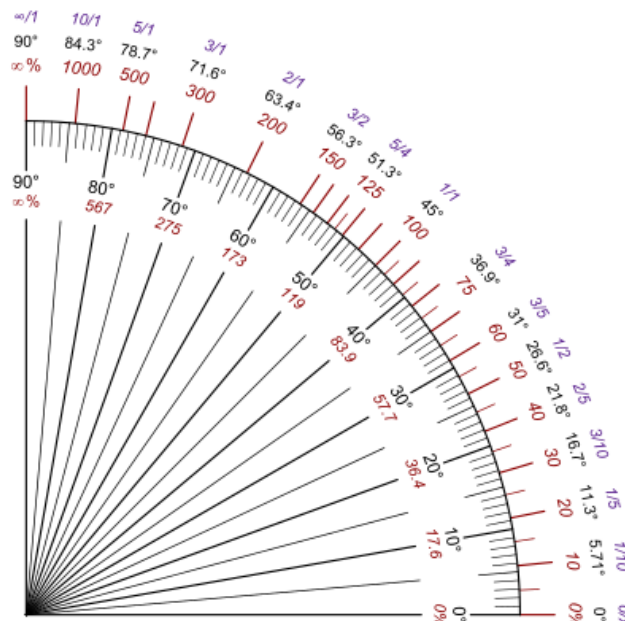


Fig: Gradients as angles and percentages (Wikipedia)

Example:

Estimate the time of concentration for a school playground of 6% slope if the overland flow distance is 300m. Run-off coefficient is to be taken as 0.20.

$$t_c = \frac{1.8 \times (1.1 - 0.20) \times \sqrt{3.28 \times 300}}{6^{\frac{1}{3}}}$$

$$t_c = \frac{1.8 \times (0.9) \times \sqrt{984}}{1.817}$$

$$t_c = \frac{1.8 \times 0.9 \times 30.369}{1.817}$$

$$t_c = \frac{1.8 \times 0.9 \times 30.369}{1.817}$$

$$tc = \frac{49.19}{1.817}$$

$$t_c = 27.076 \text{ Minutes}$$

Note: As this equation is derived from experimental data (Federal Aviation Agency, USA, developed from airfield drainage data in 1970), there are many other similar looking equations that are also available (based on different research on other catchment types etc.) For example;

- Carter lag equation (1961) - $t_c = 100L_m^{0.6}S_m^{-0.3}$
- Eagleson lag model (1962) - $t_c = 0.01111L_f n R_h^{-2/3} S_f^{-1/2}$
- Kerby-Hathaway formula (1959) - $t_c = 0.83 \left(\frac{nL}{S^{0.5}} \right)^{0.47}$

Estimate of the peak run-off rate

The Rational Method, also known as Lloyd-Davies method, is documented to have been used in the 1800s and remains one of the popular methods in calculating peak run-off rate in urban storm water design.

$$q_p = 0.278CiA$$

Where;

“ q_p ” is the peak run-off rate in cubic metres per second (m^3/s)

“ C ” is the run-off coefficient (based on the land use)

“ i ” is the rainfall intensity in mm/hr over a period equal to the time of concentration “ t_c ”. So, select rainfall data matching the t_c

“ A ” is the catchment area in km^2

Swansea Weather Data

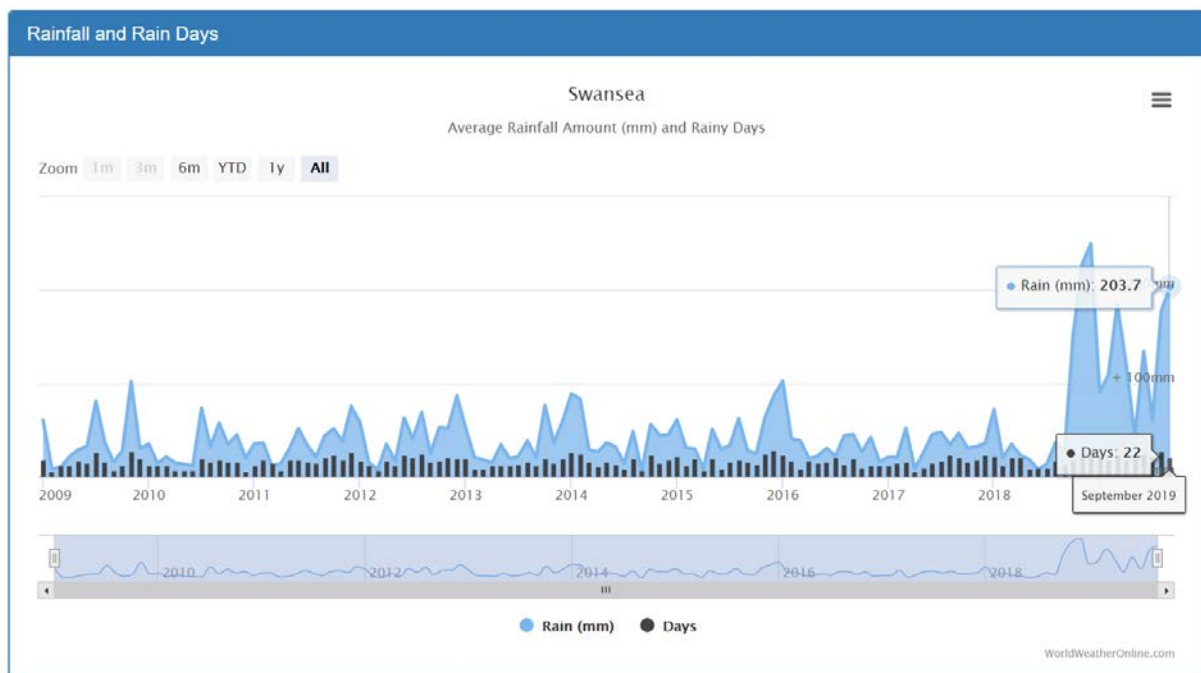


Fig: Average Rainfall Data for Swansea (WorldWeatherOnline)

Mumbles Head (Nearest climate station to Swansea)
Climate period: 1981-2010

Station: Mumbles Head		District: England SW & Wales S		Region: Wales		UK	
Month	Max. temp (°C)	Min. temp (°C)	Days of air frost (days)	Sunshine (hours)	Rainfall (mm)	Days of rainfall ≥ 1 mm (days)	Monthly mean wind speed at 10m (knots)
Jan	8.0	4.0	3.0	n/a	95.5	15.0	15.5
Feb	7.8	3.6	3.3	n/a	67.0	11.0	14.3
Mar	9.5	4.8	0.7	n/a	72.9	13.5	13.9
Apr	11.9	6.3	0.1	n/a	58.5	10.6	12.2
May	15.0	9.2	0.0	n/a	62.8	10.3	12.4
Jun	17.7	11.8	0.0	n/a	63.8	9.9	10.8
Jul	19.6	13.9	0.0	n/a	71.9	10.1	11.7
Aug	19.7	14.0	0.0	n/a	83.9	11.2	11.8
Sep	17.8	12.4	0.0	n/a	77.4	11.4	12.9
Oct	14.4	9.9	0.0	n/a	123.1	15.4	15.1
Nov	11.1	6.9	0.3	n/a	112.1	15.0	14.3
Dec	8.7	4.7	2.3	n/a	110.3	14.4	15.4
Annual	13.5	8.5	9.7	n/a	999.2	147.9	13.3

Climate period:

1981-2010

Please note that station averages are only available for 1981-2010.

Averages are available for official Met Office stations only.

All values are given to one decimal place. For 'Days of' elements, 0.1 equates to one day every ten years, 0.5 to one day every two years, 2.5 to five days every two years, and so on.

Please note that units of measurement shown may not reflect those chosen in customise settings e.g. Temperature is given in °C.

Sunshine and wind averages are not available for all stations.

[More about analysis methods](#)

Swansea site information:

Location: 51.621, -3.942
Altitude: 10.0 m above mean sea level

Mumbles Head site information:

Location: 51.565, -3.981
Altitude: 32.0 m above mean sea level
Distance: 6.8 km from Swansea

Fig: Rainfall Data for Swansea (The Met Office)

<https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcjm7j5g>

Hourly forecast for

Swansea, Wales (United Kingdom)

Updated at 7:36.

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[Forecast as PDF](#)

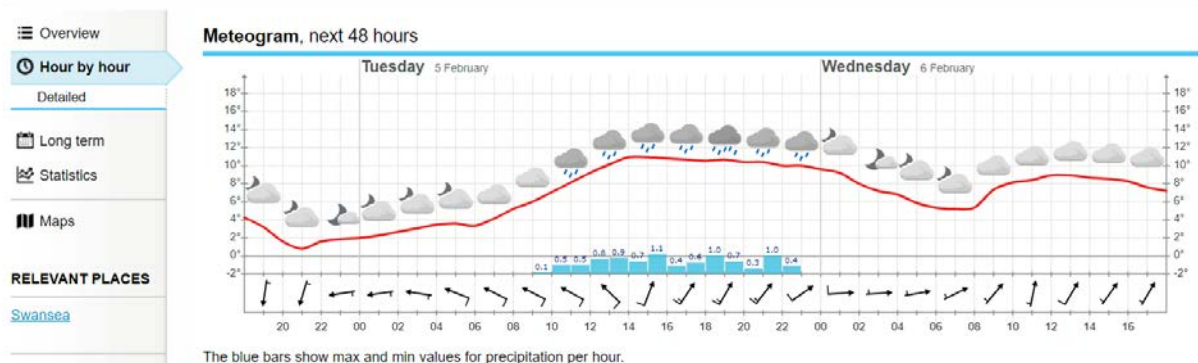


Fig: Hourly Rainfall Forecast for Swansea

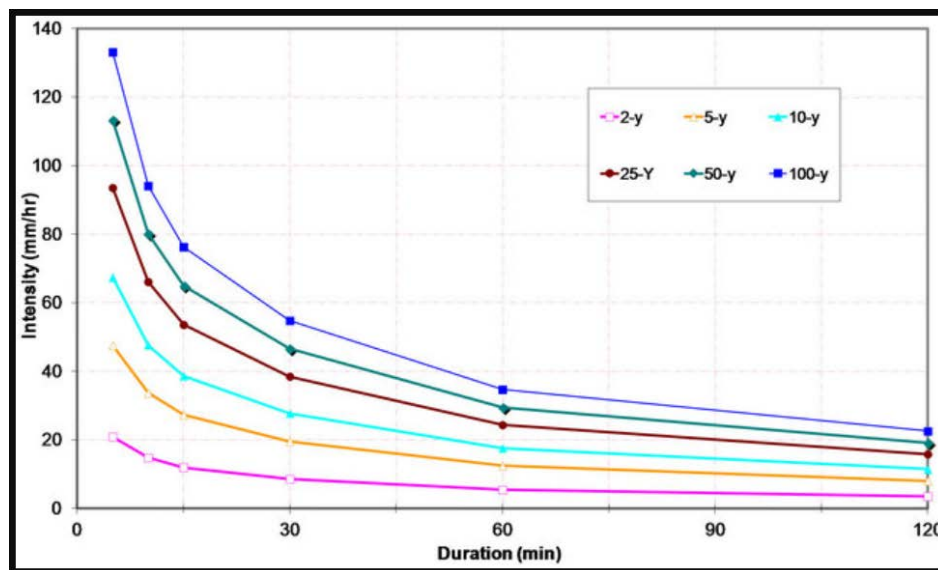


Fig: Intensity-Duration-Frequency (IDF) Curves for Rainfall Data

Example:

What is the peak discharge (=run-off) from a catchment area during a 5 year storm if the average time of concentration t_c is 53 minutes. The composition of the ground is as follows:

Character of surface	Area (m ²)	Run-off Coefficient
Parking area	11,150	0.85
Building	10,800	0.75
Lawns 2% slope	35,000	0.17
Lawns 6% slope	105,050	0.20

The intensity - duration - frequency curve for the site is as shown above.

$$q_p = 0.278CiA$$

$$q_p = 0.278CAi$$

$$CA = (0.85 \times 11,150) + (0.75 \times 10,800) + (0.17 \times 35,000) + (0.20 \times 105,050)$$

$$CA = 44,538m^2$$

$$1 m^2 = \frac{1}{1000 \times 1000} km^2$$

$$CA = 44,538m^2 \times \frac{1}{1000 \times 1000} = 0.044538km^2$$

$$i = 15 mm/hr \text{ from the graph above}$$

$$q_p = 0.278CAi = 0.278 \times 0.044538 \times 15 = 0.185 m^3/s$$