by Tan Jin Bang, Marco Ursi, Tong Su Ling, Grant Mitchell

RIVER WATER HEALTH

SURFACE WATER POLLUTION

Clyde Estuary- Outer

Water body Identifier code: 200320
Area: 70.74 km2
Water body category: Transitional

	Point source	Morphological Alterations	Diffuse Source Pollution
Types of Pressure			
Causes of Pressure	- Sewage Disposal	- Water transport (sea, coastal or inland water transport) Reinforcement - involved using concrete -Recreational activities -Dredging ,resulting in removal of sediment	- Sewage Disposal - Other manufacturing Industry
Target Actions by SEPA	- Change timing or frequency of discharge - Relocate all or part of discharge	- Improve Modified -Habitat Improvement to sediment management maintenance regime -Improve Modified Habitat	- Reduce at source of disposal

Clyde Estuary - Inner (Inc Cart)

Water body Identifier code: 200510
Area: 4.40 km2
Water body category: Transitional

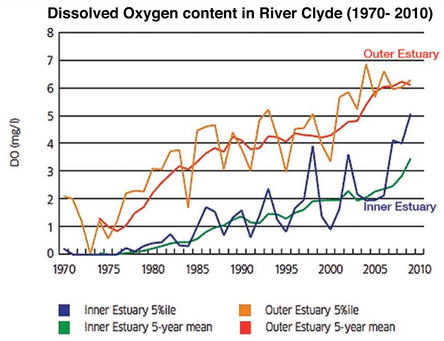
	Point source	Morphological Alterations	Diffuse Source Pollution
Types of Pressure			
Causes of Pressure	-Sewage Disposal -Air Transport (From Airport)	-Channelisation/realignment/ straightening -Recreational activities Impounding - weir / dam	-Sewage Disposal -Organic Disposal
Target Actions by SEPA	-Change timing or frequency of discharge - Reduce Point Source Inputs -Increase treatment	- Improve Modified Habitat	-Reduce Organic waste

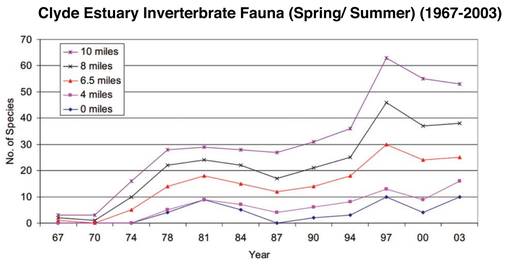
Water Framework Directive set up an analysis to identify the status of all water bodies in Scotland. The recent objective is to achive “Good” status for all water bodies by 2015 while the water bodies fail to achieve “Good” status is identified as “At Risk”. In 2012, River Clyde is analysed and the result for Outer Clyde Estuary is “Moderate” and Inner Clyde Estuary is “Moderate Ecological Potential”.

As Clyde Estuary- Inner is located near Glasgow city and industrial area, the watmain pollution are from Sewage Disposal and urban run off which reduce the water quality.

Glasgow has many Combined Sewage Overflow, an old sewage sewage system. During dry weather (and small storms), all flows are handled by the Wastewater treatment works. During large storms, the relief structure allows some of the combined stormwater and sewage to be discharged untreated to the River Clyde which cause polution.

WATER QUALITY (DISSOLVED QUALITY)



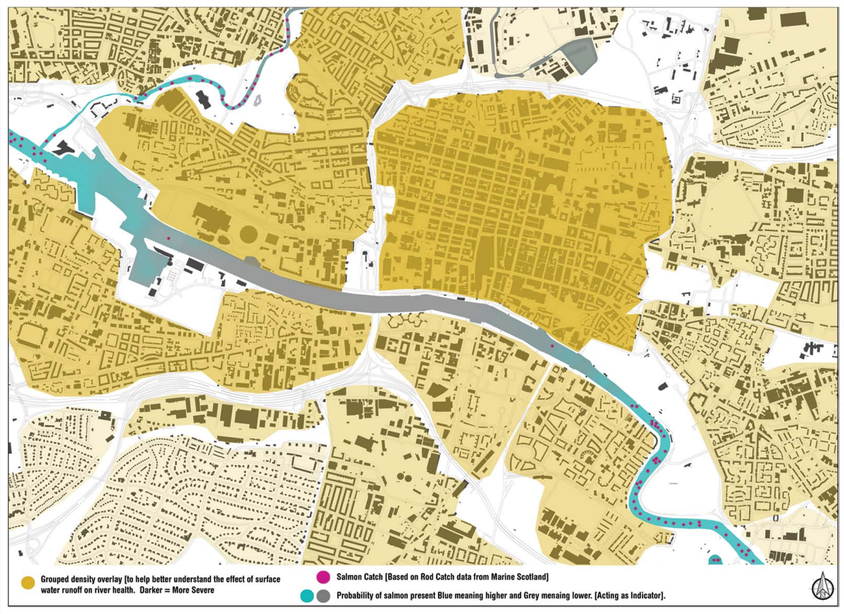


From 1975 to 2010, Dissolved oxygen (DO) concentration 5-year mean has increased from 1mg/l to 6mg/l in Outer Estuary . While in Inner Estuary, DO concentration 5-year mean has increased from 0mg/l to 3mg/l in the year of 1975 to 2010.

Part of the reason the level of DO increased is due to the declined of discharges of organic waste as a result of improvements to effluent treatment. This increase in dissolved oxygen resulted in the reappearance of salmon in 1983 following an absence of over a century.

Land reclamation and dredging such as development of Pacific Quay have made the inner Clyde narrower and deeper than its natural state. These changes have reduced the strength of the tidal currents causing less mixing between freshwater and the incoming seawater, resulting in layering of the water column. This layering inhibits the transfer of oxygen from the surface allowing deeper water to become depleted (used up) in oxygen.

SALMON POPULATION IN RIVER CLYDE

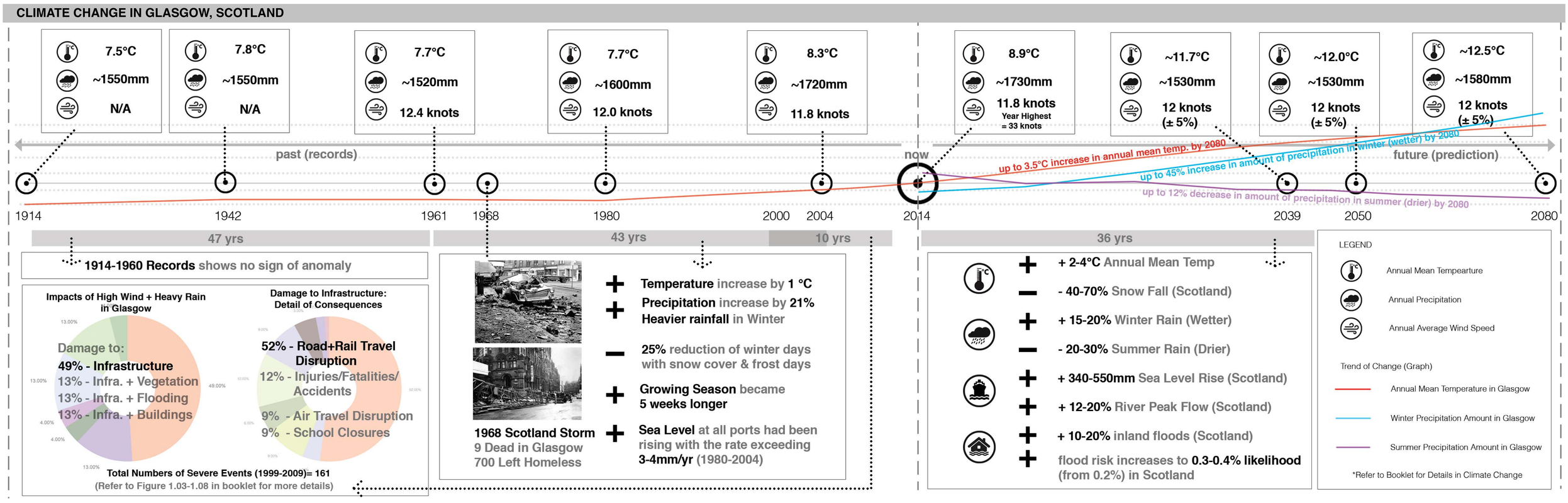


The map illustrates the population of salmon in the river Clyde as it stands today. It shows that the main body of the Clyde flowing through city cts mainly as a transitional point for salmon to travel to the smaller, healthier, subsidiary water bodies such as the Cart and Kelvin.

It is evident that salmon are returning to the Clyde and provided that the current year on year increase in fish sstocks is sustained then there may be potential for salmon within the Clyde to bring multiple benefits to the city.

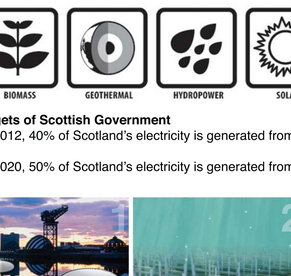
CLIMATE CHANGE OVER 166 YEARS

CLIMATE CHANGE IN GLASGOW, SCOTLAND

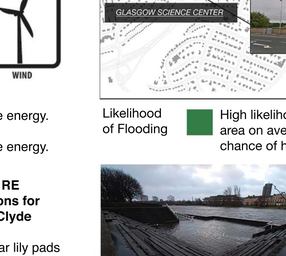


1914-1960 Records shows no sign of anomaly

Impacts of High Wind + Heavy Rain in Glasgow



Damage to Infrastructure: Detail of Consequences



Total Numbers of Severe Events (1999-2009)= 161
(Refer to Figure 1.03-1.08 in booklet for more details)

1968 Scotland Storm
9 Dead in Glasgow
700 Left Homeless

- **Temperature** increase by **1 °C**
- **Precipitation** increase by **21%**
- **Heavier rainfall** in Winter
- **25%** reduction of winter days with snow cover & frost days
- **Growing Season** became **5 weeks longer**
- **Sea Level** at all ports had been rising with the rate exceeding **3-4mm/yr** (1980-2004)

- **+ 2-4°C** Annual Mean Temp
- **- 40-70%** Snow Fall (Scotland)
- **+ 15-20%** Winter Rain (Wetter)
- **- 20-30%** Summer Rain (Drier)
- **+ 340-550mm** Sea Level Rise (Scotland)
- **+ 12-20%** River Peak Flow (Scotland)
- **+ 10-20%** inland floods (Scotland)
- flood risk increases to **0.3-0.4% likelihood** (from 0.2%) in Scotland

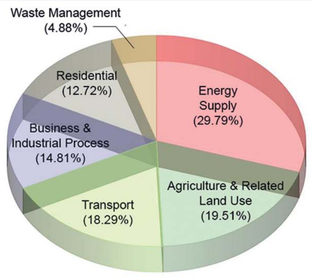
LEGEND
- Annual Mean Tempearture
- Annual Precipitation
- Annual Average Wind Speed

Trend of Change (Graph)
- Annual Mean Temperature in Glasgow
- Winter Precipitation Amount in Glasgow
- Summer Precipitation Amount in Glasgow

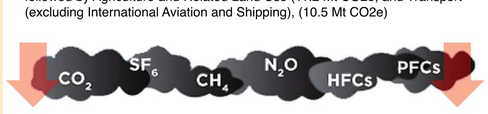
*Refer to Booklet for Details in Climate Change

CONSEQUENCES: CARBON EMISSION AND FLOOD RISK

G.H. GASES EMISSIONS AND R.E. TECHNOLOGY



In 2012, Energy supply was the largest source of net emissions (17.1 Mt CO2e), followed by Agriculture and Related Land Use (11.2 Mt CO2e, and Transport (excluding International Aviation and Shipping), (10.5 Mt CO2e)



Reduce 80% of Greenhouse Gases by 2050

The Scottish Act set a long-term target to reduce emissions of greenhouse gases (GHGs) by 80% in 2050 relative to 1990, with an interim target to reduce emissions by 42% in 2020 relative to 1990.

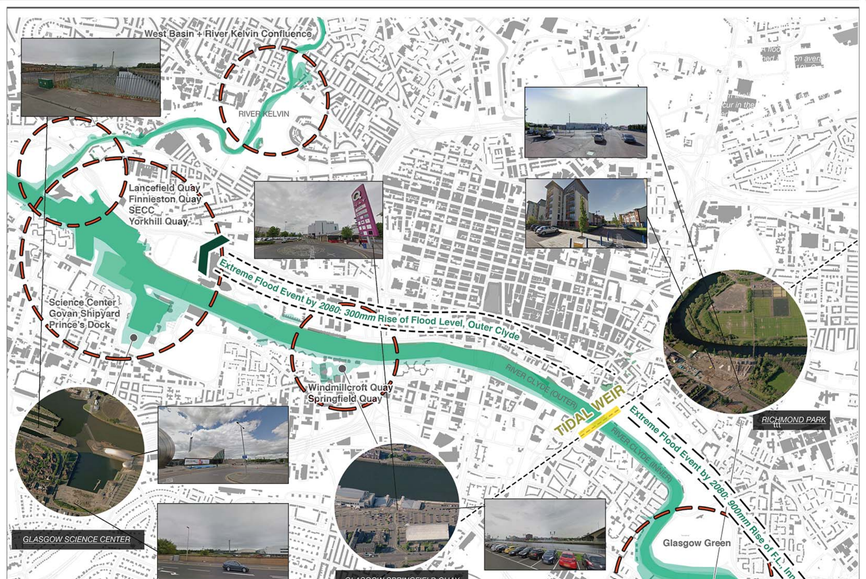
Targets of Scottish Government
By 2012, 40% of Scotland’s electricity is generated from renewable energy.

By 2020, 50% of Scotland’s electricity is generated from renewable energy.

Viable RE Solutions for River Clyde

(1) Solar lily pads (River Clyde) / (2) VIVACE - Turbine (Concept) / (3) Heat Pump (Thames River) / (4) Tidal Barrier (River Clyde)

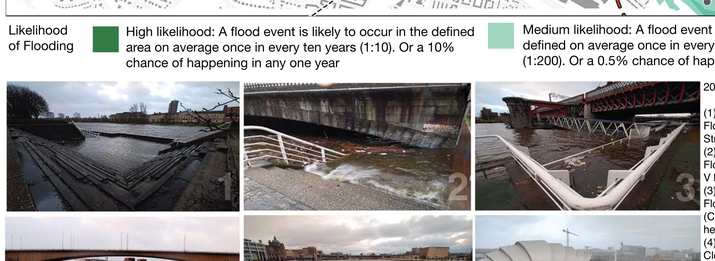
PROJECTION MAP OF FLOOD RISK IN GLASGOW



Likelihood of Flooding

High likelihood: A flood event is likely to occur in the defined area on average once in every ten years (1:10). Or a 10% chance of happening in any one year

Medium likelihood: A flood event is likely to occur in the defined on average once in every two hundred years (1:200). Or a 0.5% chance of happening in any one year



2012 Glasgow Winter Flood

(1) Flooding Clyde Walkway Clyde Street
(2) Flooded Clyde Walkway George V bridge
(3) Flooding River Clyde Glasgow (Clyde Bridge with rail track heading towards Central Station)
(4) Closed Kingston Bridge Note wave Direction
(5) Flooded River from Tradeston Footbridge
(6) Pacific Quay SECC area

ASSESSMENT OF CURRENT FLOOD DEFENCE (QUAY WALL) CONDITION

Flood defences should take the form of permanent structures (e.g walls and earth embankments) which have an insignificant visual impact and do not act as a barrier to the movement of people or vehicles. Soft and hard landscaping can be used to disguise the true function of permanent flood defences. Where their construction would act as a barrier or result in a significant visual impact, demountable flood defences are an alternative. A combination of building design, raised areas and permanent and demountable defences can achieve a satisfactory level of defence.

The City Plan recognises that quay wall maintenance has not been carried out in a consistent manner and thatmany of the quay walls are in a poor condition. In this map, city council had identified the key areas with relatively high flood risk to the development along River Clyde and reflects the assessment of quay wall condition, recommendation to improvement and brief description of the river edge area.

For more information, refer to River Clyde Flood Management document by Glasgow City Council.

VIALBLE SOLUTION: SUSTAINABLE URBAN DRAINAGE SYSTEM (SUDS)

SUSTAINABLE URBAN DRAINAGE SYSTEM (SUDS)

What is the best way of combating flooding? → SuDS?

Move it / Store it

Natural system
There are two options available for dealing with floodwaters: either move it or store it.
In natural, unaltered river systems, both these processes take place. Wetlands and washlands provide areas of flood storage, while water moves quickly through steep-sided areas.

Traditional flood protection
Traditional flood protection has tended to focus on moving water, using expensive hard defences such as flood walls to protect specific areas. This has often only led to problems being transferred further downstream.

- focus only on flood control and protection
- provide protection up to a certain pre-determined safety level
- bad impact on upstream and downstream areas
- planned in a mono-disciplinary manner
- high financial costs
- aim to separate the river and the population

What are SuDS?

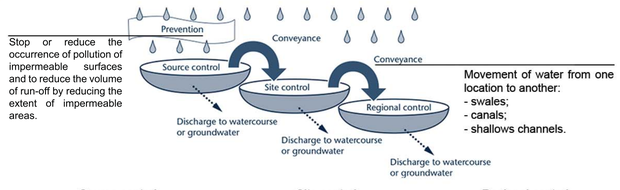
SUDS are a sequence of water management **practices** and **facilities** designed to drain surface water in a manner that will provide a more sustainable approach than what has been the conventional practice of routing run-off through a pipe to a watercourse. The primary purpose of SUDS is to mimic the natural drainage. (SEPA, Scottish Environment Protection Agency)

SuDS benefits:

- preventing water pollution
- slowing down surface water run-off and reducing the risk of flooding
- reducing the risk of sewer flooding during heavy rain
- recharging groundwater to help prevent drought
- providing valuable habitats for wildlife in urban areas
- creating green spaces for people in urban areas

How SuDS work

SuDS capture rainfall, allowing as much as possible to evaporate or soak into the ground close to where it fell, then conveying the rest to the nearest watercourse to be released at the same rate and volumes as prior to development. Along the way any pollutants, such as metals and hydrocarbons from roads and car parks, are reduced.



Stop or reduce the occurrence of pollution of impermeable surfaces and to reduce the volume of run-off by reducing the extent of impermeable areas.

Movement of water from one location to another:
- swales;
- canals;
- shallows channels.

Sourse control
Management close to where rain falls:
- garden roofs;
- rain gardens;
- permeable pavements;
- swales, filter strips;
- bioretention areas.

Site control
Management within site boundary:
- community ponds;
- swales;
- detention basins;
- filter strips.

Regional control
Management serving several sites:
- regional ponds;
- wetlands;
- retentions basins.

Sustainable drainage systems are now the preferred approach to managing rainfall from hard surfaces and can be used on any site.
In a well designed SUDS,these features are provided in sequence, which is known as the **management train.**

The management train

Source control

- **Green roof**: • ideal in high density areas; • slows and reduces run-off; • reduction in noise and the urban heat island effect; • increased visual and physical access to green spaces.
- **Rain gardens**: • slows rainfall run-off and improves water quality; • reduces flooding; • space for relaxation and quiet enjoyment; • mitigates urban heat island effect.
- **Permeable surfaces**: • ideal in urban areas; • reduces run-off; • allows run-off to percolate naturally into ground; • dry surfaces to park and walk on after heavy rain.
- **Swales, filter strips**: • intercept rainfall run-off; • slow water down; • collect and move water; • cleaner run-off ; • can be used anywhere; • remove any silt in the water.
- **Bioretention areas**: • Ideal in high density areas; • reduces run-off; • intercepts and filters pollutants at an early stage.

Site control

- **Detention basins**: • detain water allowing gradual infiltration; • removal of pollutants through bioremediation; • reduces flood risk; • high biodiversity; • multi-functional uses.

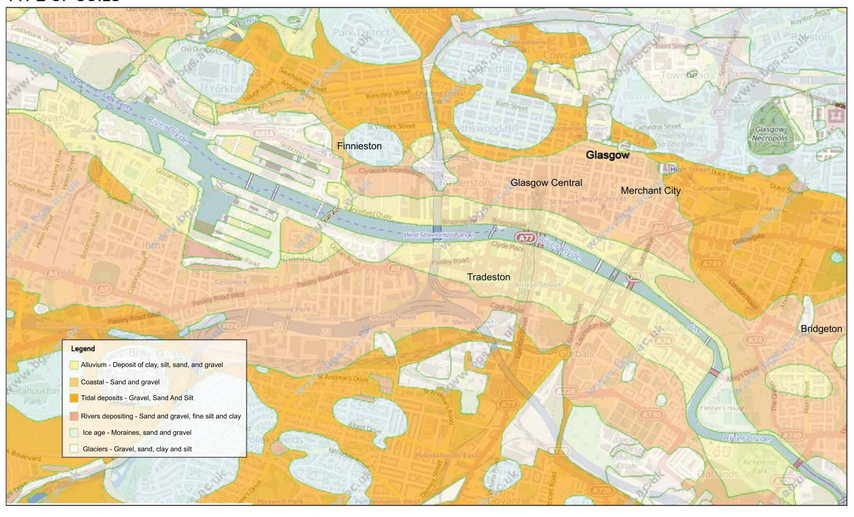
Regional control

- **Ponds and Wetlands**: • storage for excess water; • water flows slowly over an extended period of time; • removal of pollutants; • reduces flooding; • attractive public space; • habitat for wildlife.

Conveyance

- **Swales and canals**: • transport water from one part of the SuDS management to the next; • slows run-off; • allows natural infiltration; • intercepts and filters pollutants.

TYPE OF SOILS



The choice of SUDS system will depend on a number of factors and one of this is infiltration rate of the soil.
Soil permeability can have a significant effect on selecting the right SUDS techniques for a site.
In fact infiltration methods may not be suitable but there are many other methods that can be used in clayey soils, e.g. swales, ponds, wetlands.
So, although clay soils may prevent a complete infiltration solution it will still be possible to use other SUDS features such as ponds, wetlands and swales. It is also possible to allow some water to soak into the ground, even if the drainage design calculations do not allow for it (for example out of the bottom of an unlined swale).
In some areas where there are sand and gravel deposits over the top of the clay soils that may be suitable for infiltration.
Each site should be evaluated on its own merits by undertaking comprehensive soil Standard BS 5930: 1999, Code of practice for site investigations, including infi ltration testing and groundwater level monitoring. This will identify any opportunities for infiltration.
It’s important anyway that ground conditions should not prevent the use of SUDS but may affect the choice of system.

POSSIBLE MANAGEMENT TRAIN FOR SUDS

* where soils are rich of clay and not much permeable, it is possible to resort to **engineered soil**, man-made substrate of soil mixed with materials such as crushed stone, sands and slate to increase porosity and permeabitlity.

Parks, gardens, green spaces and vacant lands where the soils are predominantly **clayey***, so with limited opportunities to use infiltration methods could be used as **swales, ponds, wetlands and retention basins** in order to detain water, reduce rainfall run-off and remove pollutants.

Parkings, especially in urban areas can be built with **permeable pavements** in order to allow water to soak through the surface into the gravel subbase below, controlling the flow of water and removing pollution from it.

Where the soils are predominantly **sandy and gravel**, could be used as **swales, rain gardens, and detention basins** in order to allow gradual infiltration, slow rainfall run-off and remove pollutants.