ASSOCIAÇÃO PORTUGUESA DOS RECURSOS HÍDRICOS

APRH

STORMWATER ATTENUATION & ENHANCED INFILTRATION SYSTEM TO MITIGATE FLOOD & DROUGHT CONDITIONS

9th Seminar of the APRH Northern Regional Centre

Extreme hydrological phenomena:
the challenges of the coming decades

OGI

GROUNDWATER SPECIALISTS

Presented at the
Faculdade de Engenharia
da Universidade do Porto

by

Engenheiro Dr Stephen D. Thomas
OGI Groundwater Specialists Ltd
City of Durham, England, UK

16 November 2023

Extreme hydrological phenomena:
the challenges of the coming decades

STORMWATER ATTENUATION & ENHANCED INFILTRATION SYSTEM TO MITIGATE FLOOD & DROUGHT CONDITIONS

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Groundwater Dynamics Ltd, Leamington Spa, UK

9º Seminário do Núcleo Regional do Norte - APRH

Engenheiro Dr Stephen Thomas

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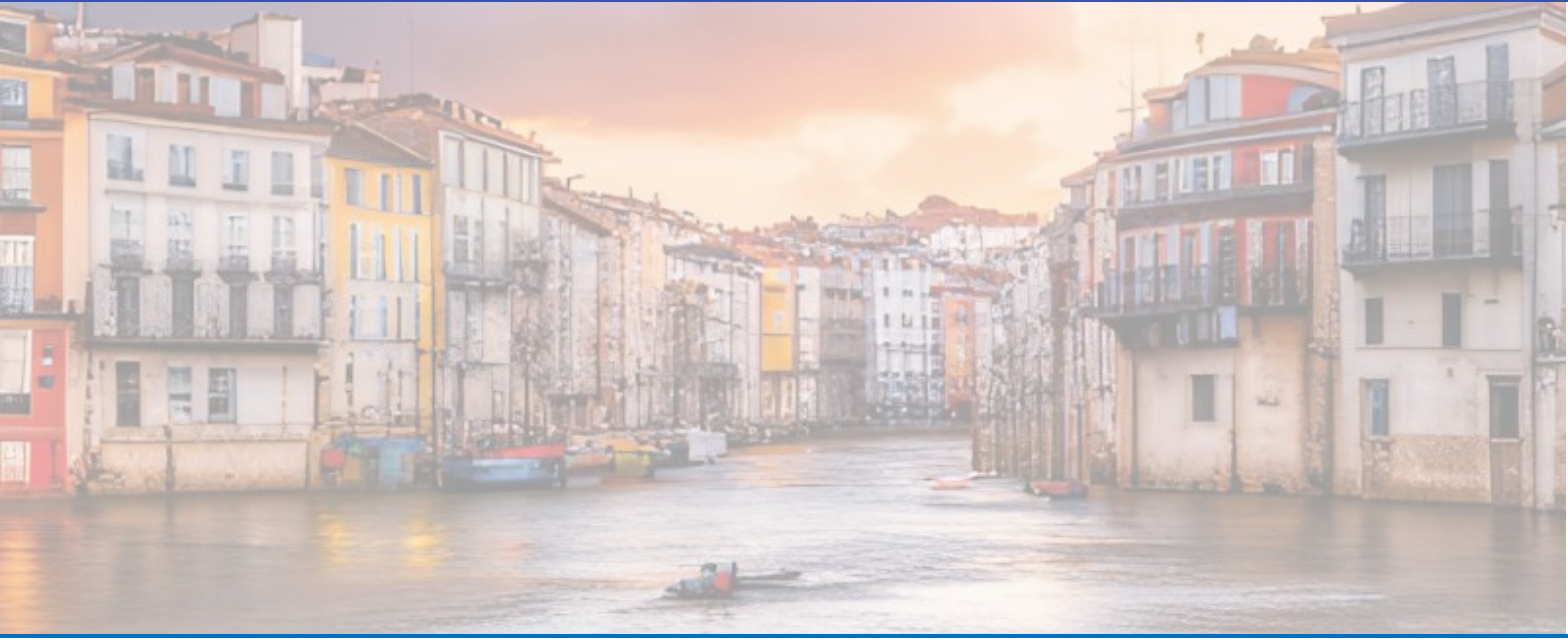
Fellow of the Institution of Civil Engineers, UK
Registered Ground Engineering Adviser, UK
Member of the Chartered Institution of Water & Environmental Management
Membro da Ordem dos Engenheiros, Portugal
Member of the British Geotechnical Association
Membro da Sociedade Portuguesa de Geotecnia
Membro da Associação Portuguesa dos Recursos Hídricos
Sociedad Española de Mecánica del Suelo e Ingeniería Geológica
Worshipful Company of Engineers & Liveryman of London

WE ARE IN A CRISIS



WE ARE IN A CRISIS

Dictionary

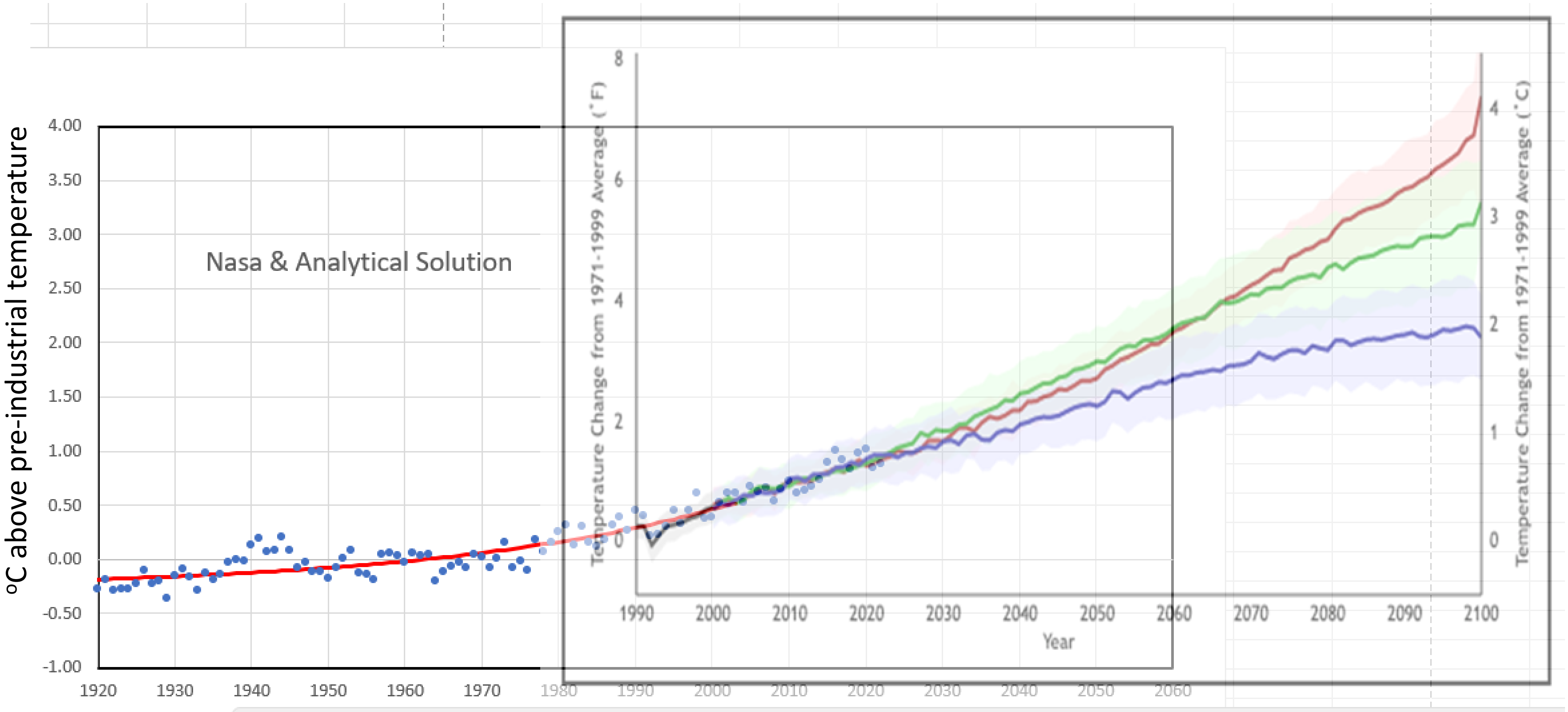
Definitions from Oxford Languages · Learn more

crisis

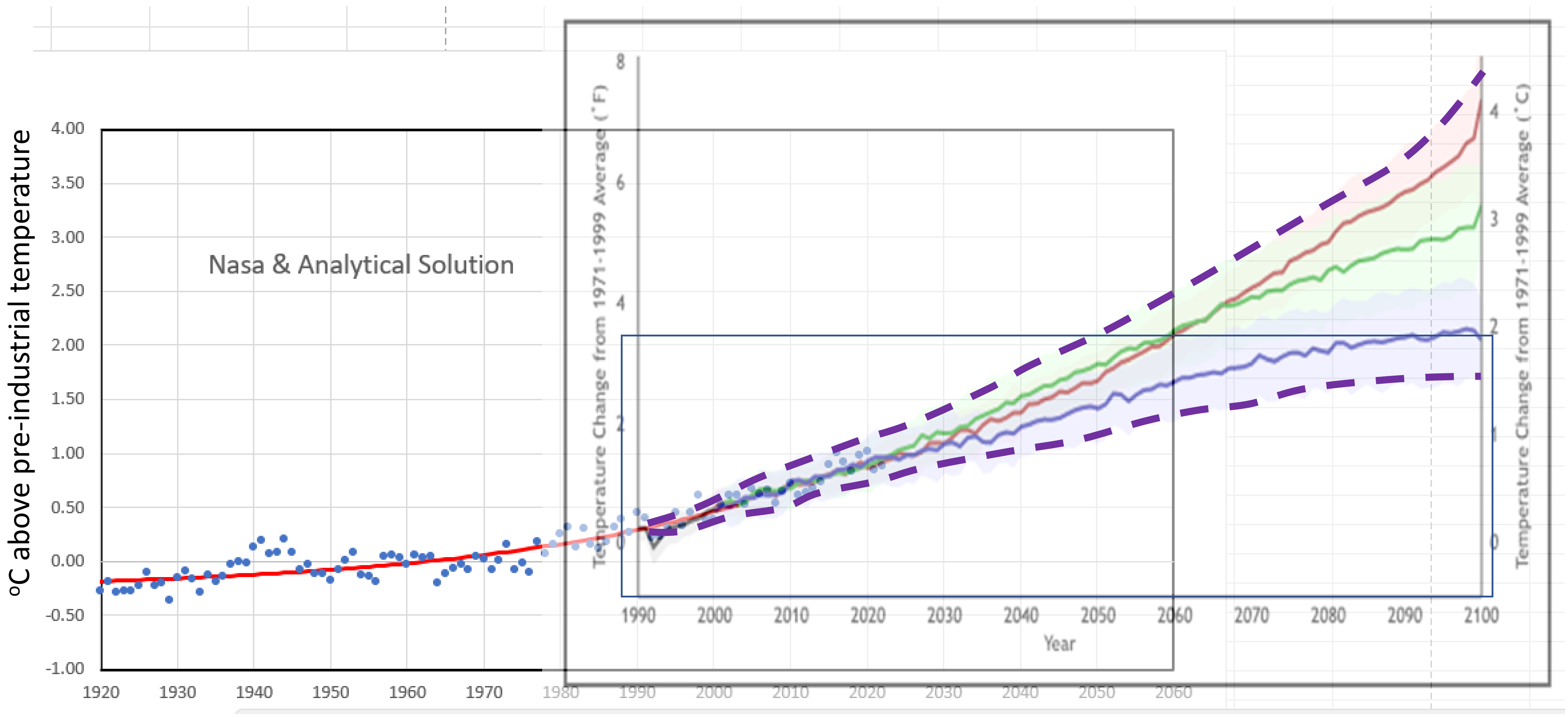
noun

a time of intense difficulty or danger.

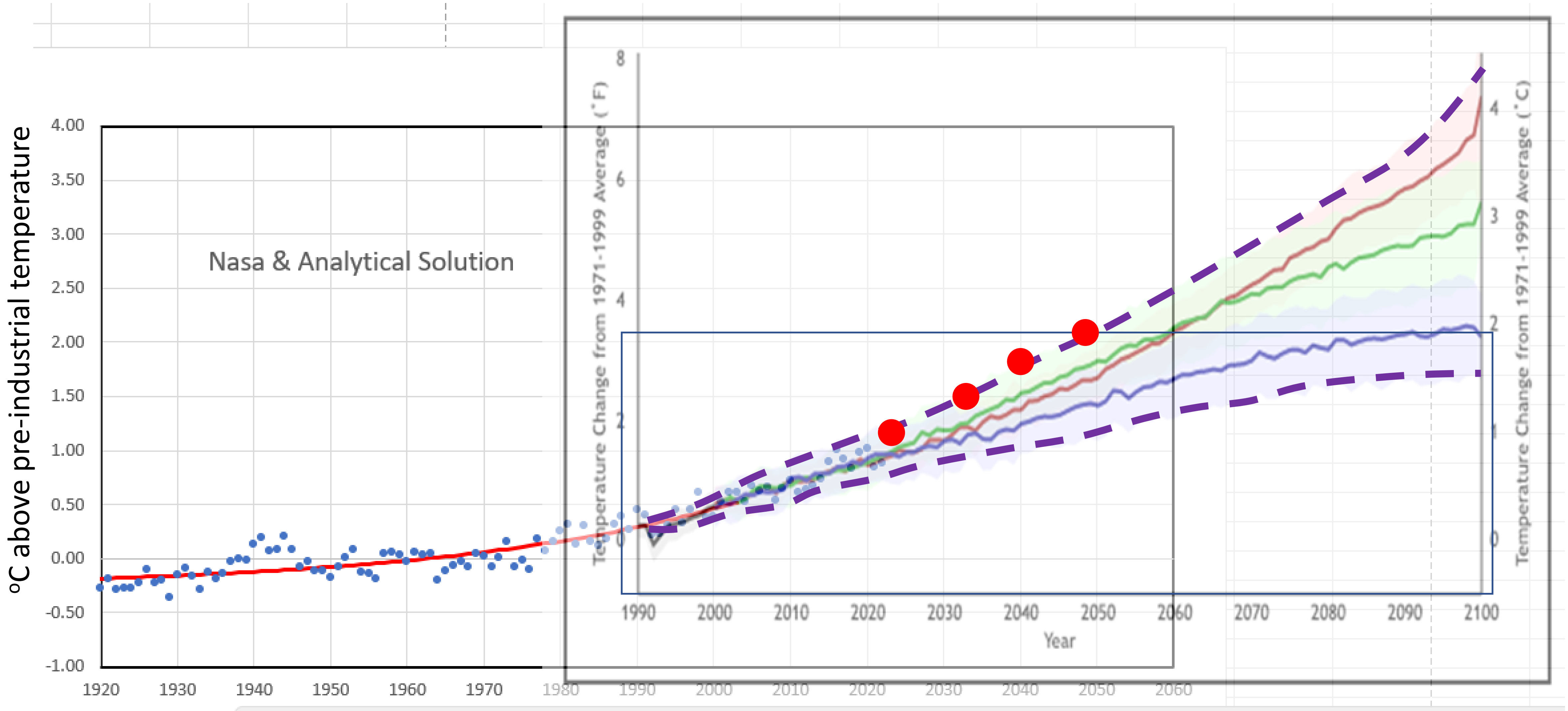
Consequences of Global Warming



Mitigation of Environmental Impact utilising Geotechnology



Mitigation of Environmental Impact utilising Geotechnology



Consequences of Global Atmospheric Warming To Drought Events

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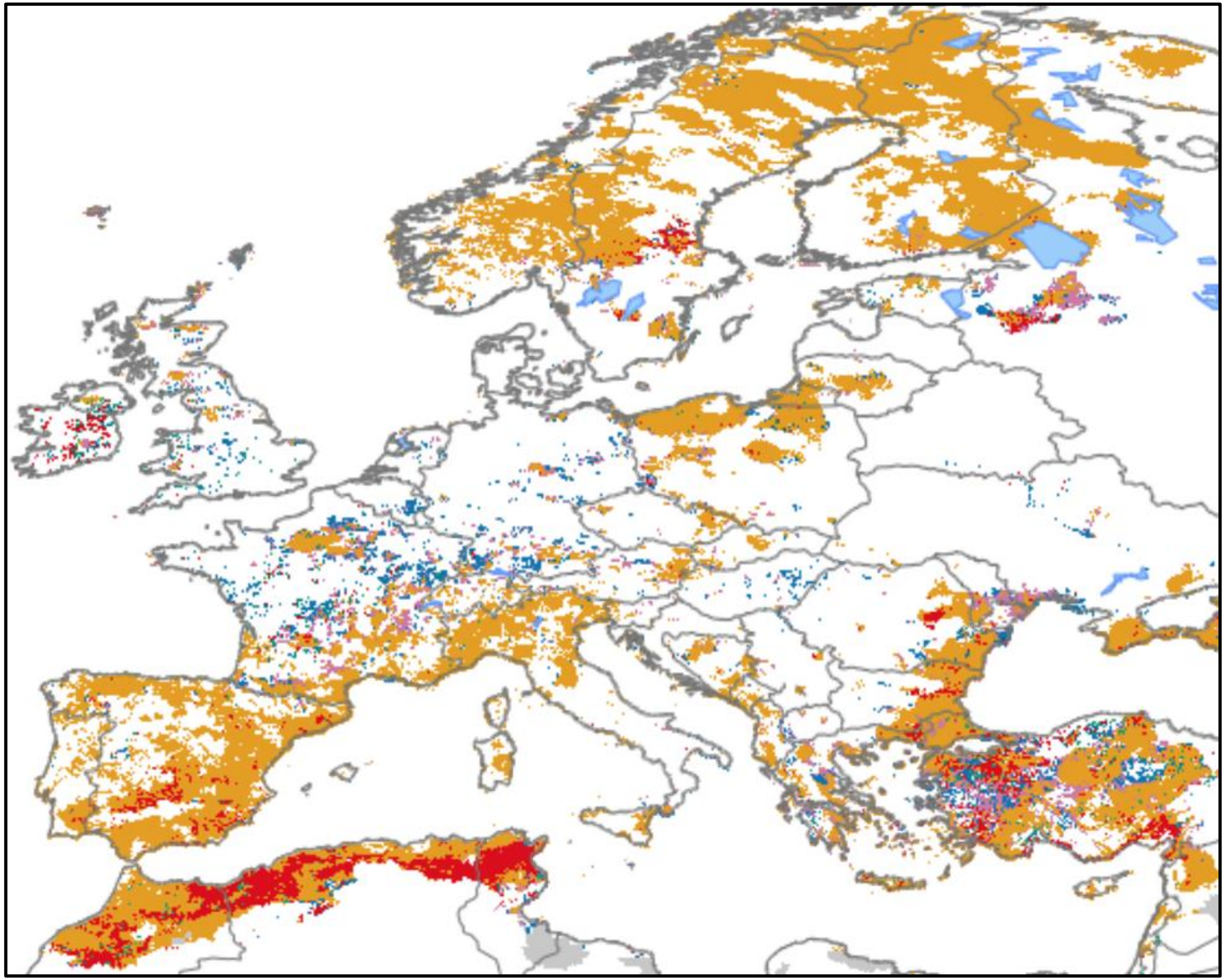

Drought map for the first 10 days of April 2023, showing that much of Europe faces a water problem.

Warning

Alert

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Country:	Portugal (Continental)
Land Area:	89,015 km²
Annual Rainfall (2022):	774 mm
Annual Rainfall Volume:	69 Billion m^3
Population:	9,855,909
Rainfall per person:	6,990 m^3 per Annum
	134 m^3 per Week

Approximate Figures

Drought in England?

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Typical image of English Countryside

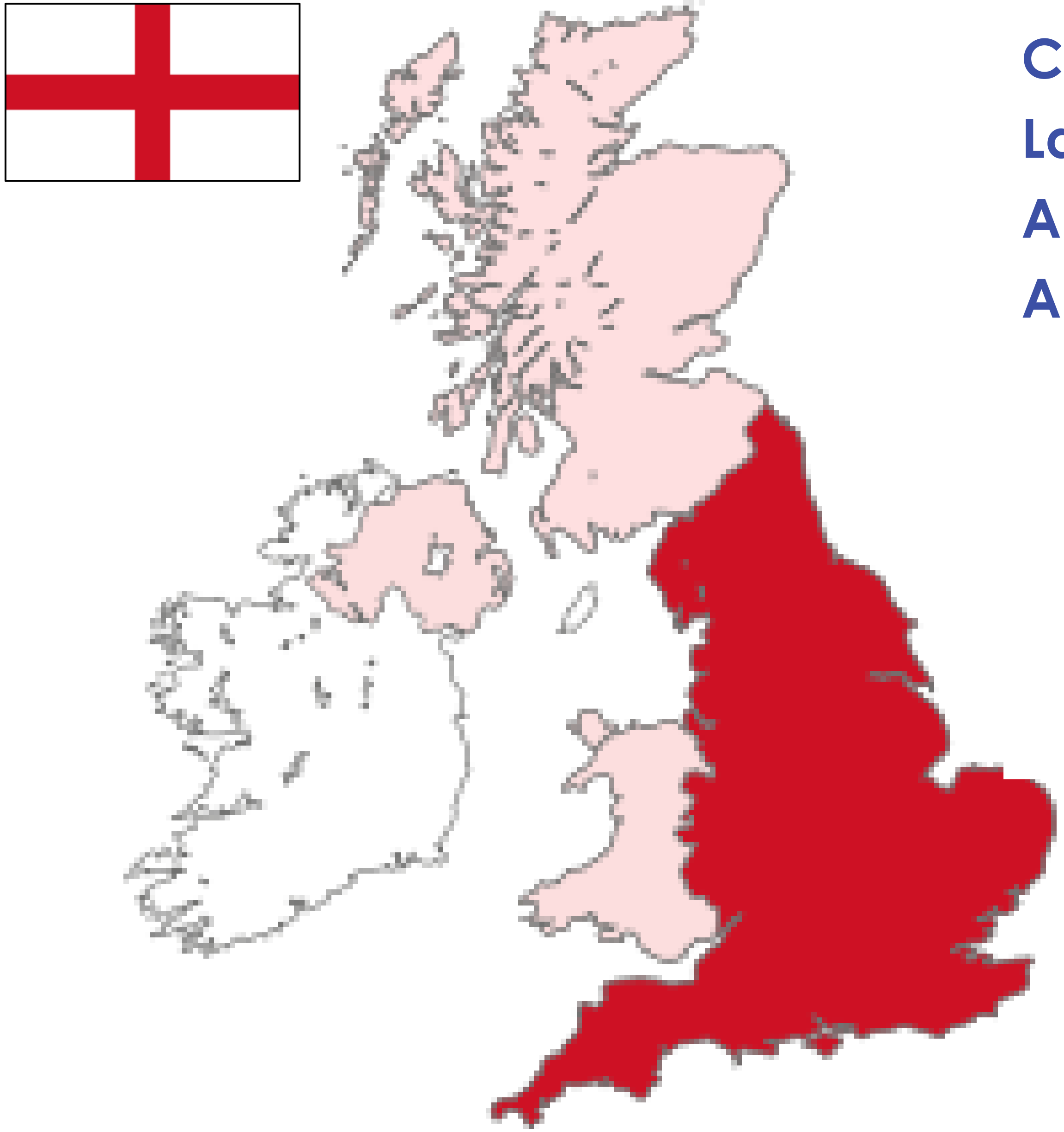
Drought in England?

The effect of Drought on Typical English Countryside

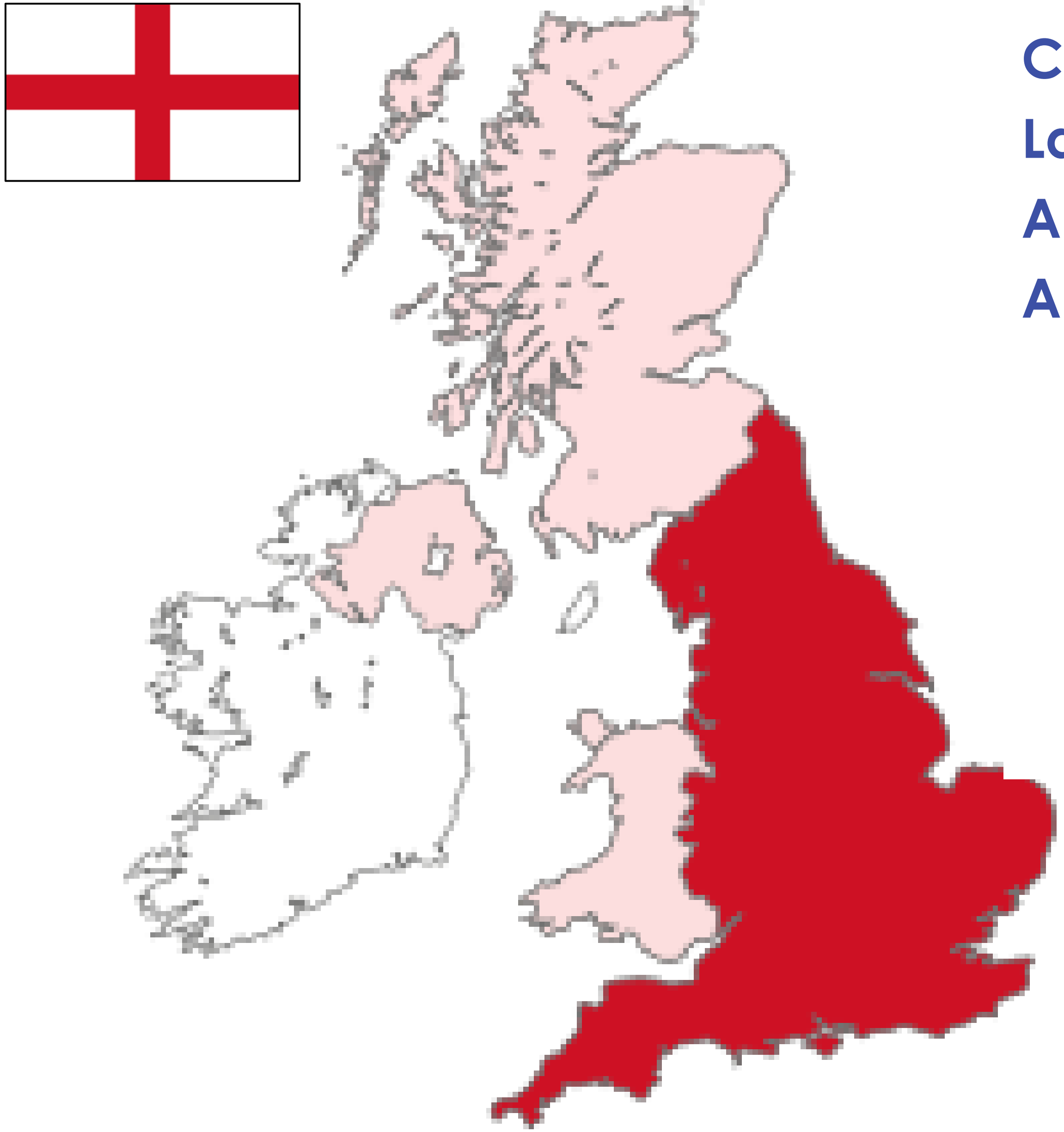
London Hyde Park grass dries up in UK drought following extreme heat

England faces longer and drier summers, Met Office research suggests

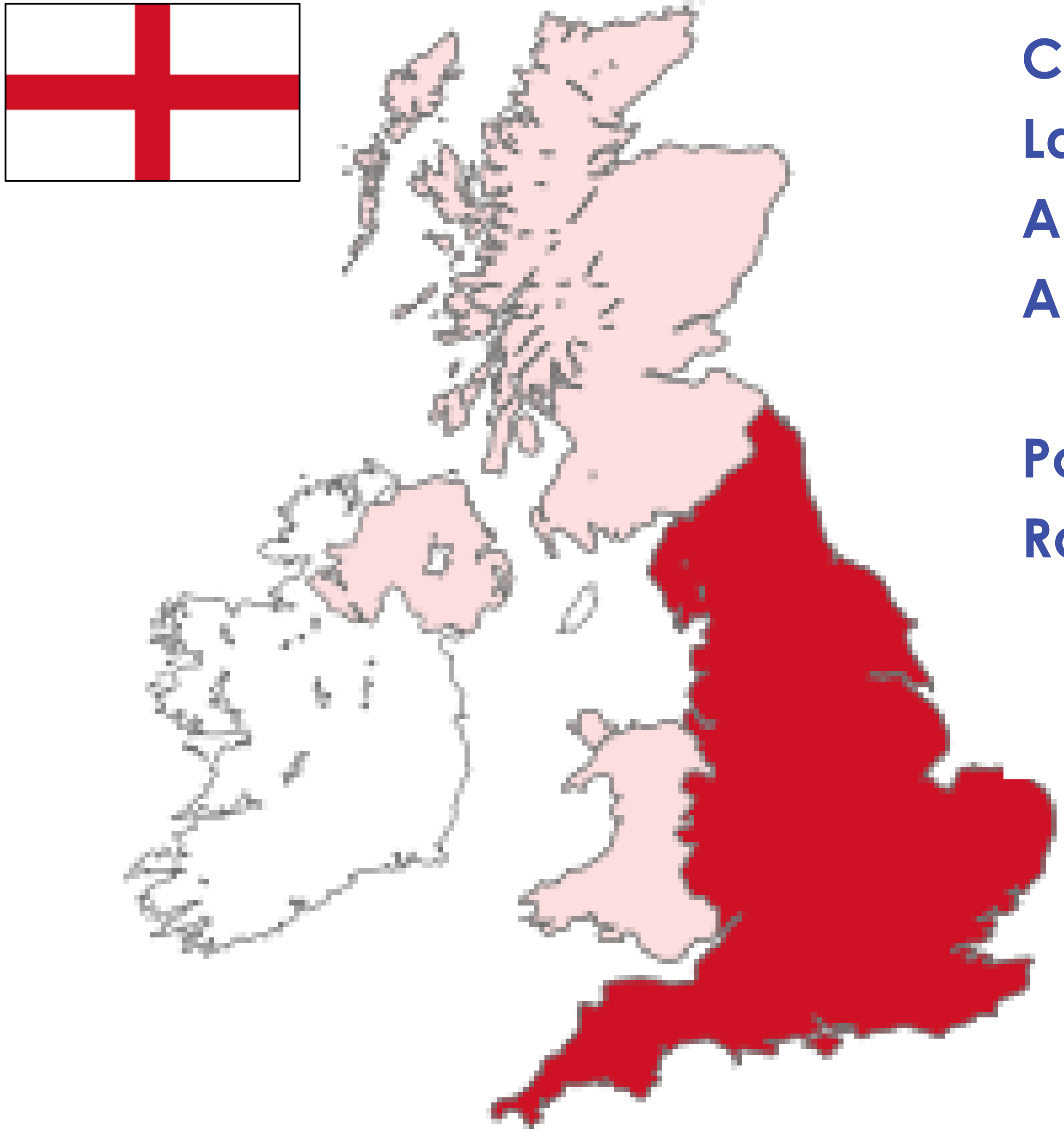
The Met Office said summer-like conditions were expected to last longer and a 4-12% reduction in rainfall in England was likely in the future during the autumn weeks.



Country:	England
Land Area:	130,279 km²
Annual Rainfall (2021):	1104 mm
Annual Rainfall Volume:	144 Billion m^3



Country:	England
Land Area:	130,279 km²
Annual Rainfall (2021):	1104 mm
Annual Rainfall Volume:	144 Billion m^3
	208% of Portugal



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Land Area:	130,279 km²
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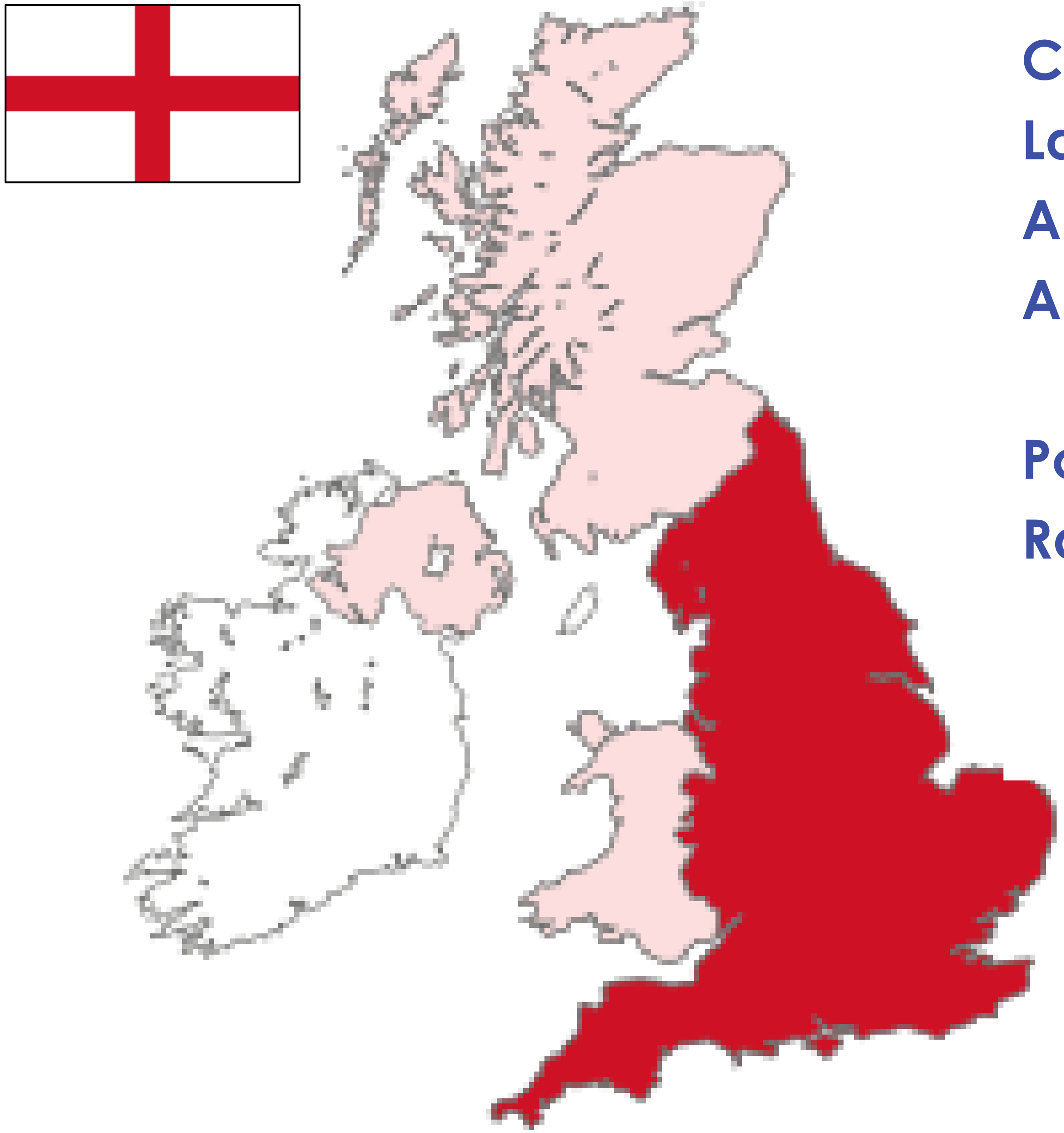
	208% of Portugal
Population (2021):	56,536,000
Rainfall per person:	2,544 m^3 per Annum
	c. 50 m^3 per Week

Drought



Country:	**England**
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Annual Rainfall Volume:	**144 Billion m^3**
	208% of Portugal
Population (2021):	**56,536,000**
Rainfall per person:	**2,544 m^3 per Annum**
	c. 50 m^3 per Week
	<u>36% of Portugal</u>

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Typical annual abstraction of Groundwater in England

c. 2 km^3, or

2 Million MegaLitres, or

2 Billion cubic metres, or

2 Trillion Litres

Drought


BBC
Your account
Home
News
Sport
Weather
iPlayer
NEWS
England drought: Everyone must rethink their water use, experts say

Consequences of Global Atmospheric Warming To Flooding Events

One of many loss events due to water storms.
Cainta, east of Manila, Philippines, in 2009

Consequences of Global Atmospheric Warming

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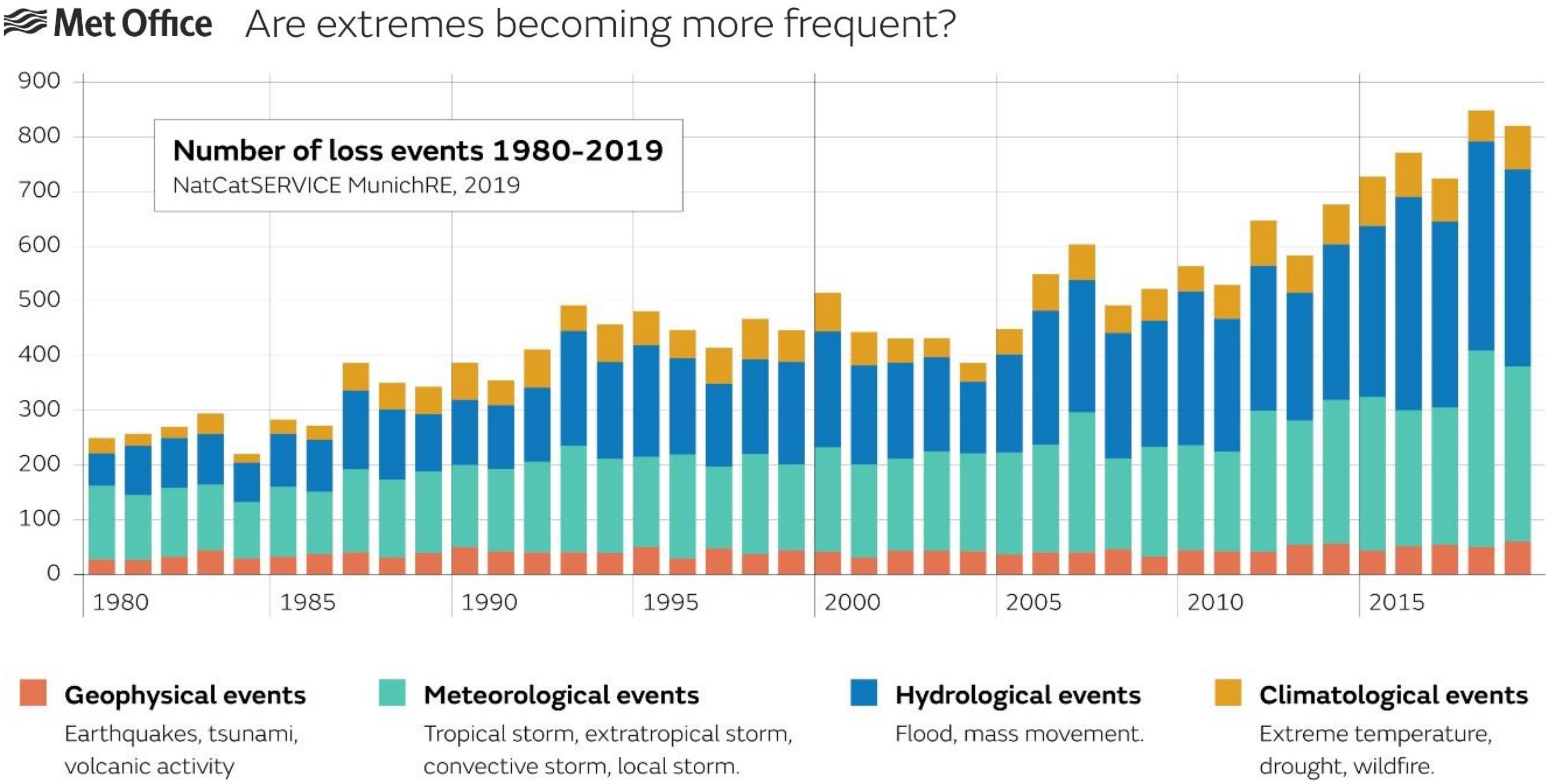
Number of Loss events due to storm or water are doubling every 20 years



Consequences of Global Atmospheric Warming

Montenegro, Faro, Portugal, 2022

Raw sewage Discharged to the natural water environment

Leads to Political pressure and Legislation

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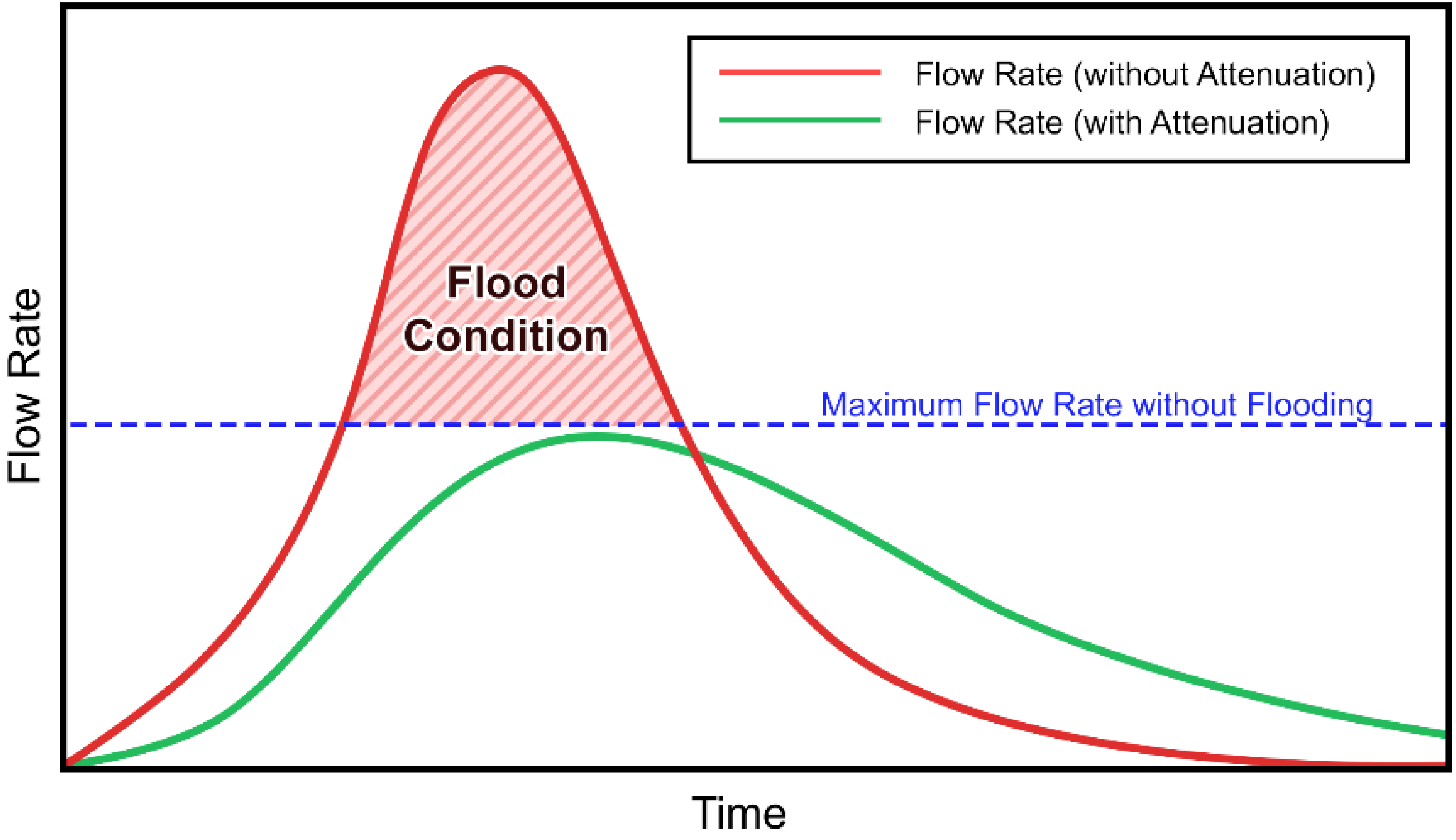
How can we :

1. Mitigate Flooding Events, and
2. Ameliorate Drought Conditions

by using our Engineering Skills

What Causes Flooding Events?

Flood Mitigation



Hydrograph showing the difference between non-attenuated and attenuated flow rate following a storm event.

CASE STUDY

A Stormwater Attenuation & Enhanced Infiltration System

New Car Sales Operation in the Northeast of England

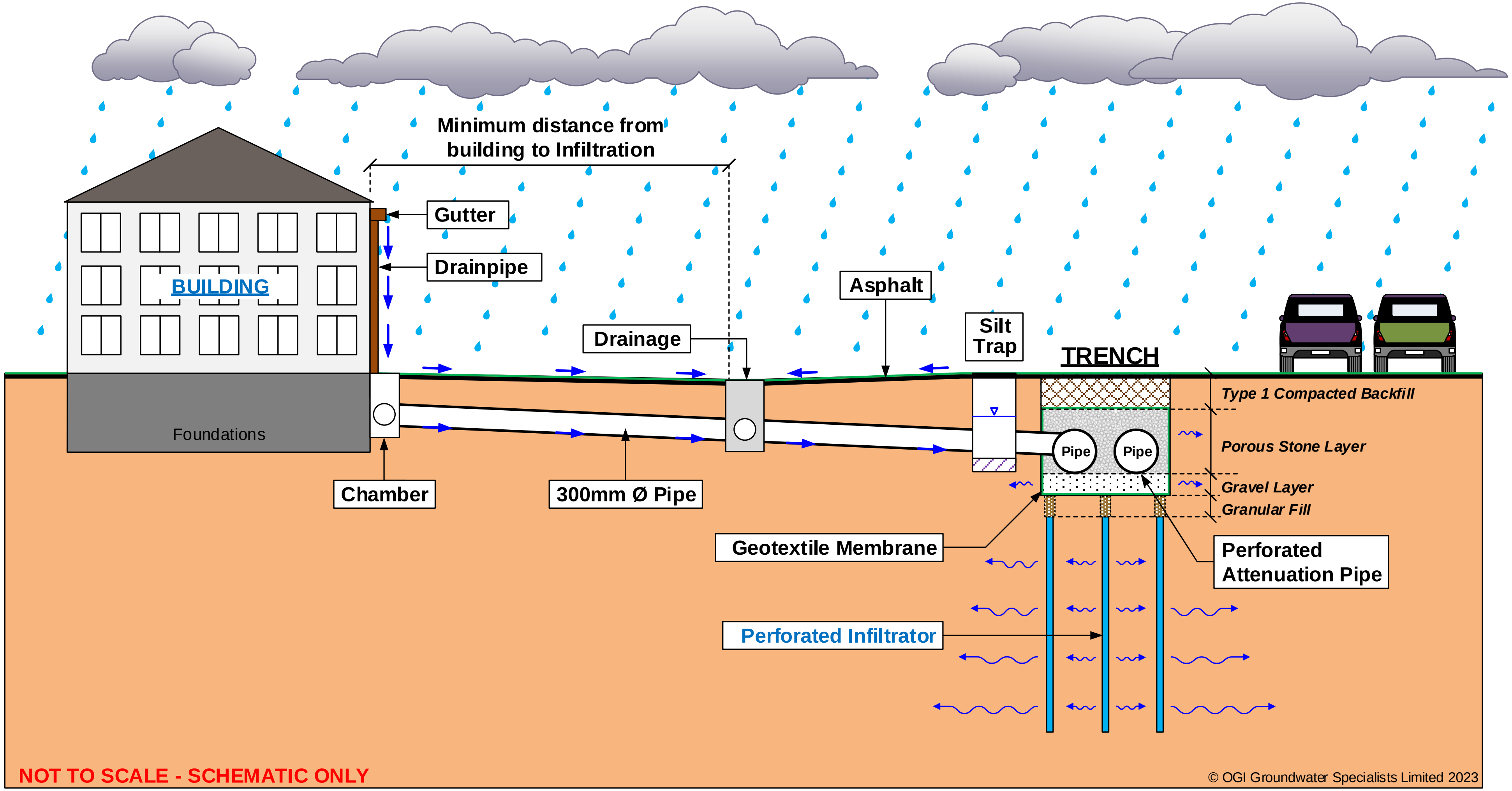
Plan of Building & Carpark (c.1Ha)

Impermeable Site Area = 10,000 m^2

Designed for Rainfall intensity = 60mm in 3 hours

Total 3-hour Rainfall Volume = 300 m^3

Flood Mitigation



Storm Event of Heavy rainfall on Impermeable Roofs and Asphalt.

Flood Mitigation

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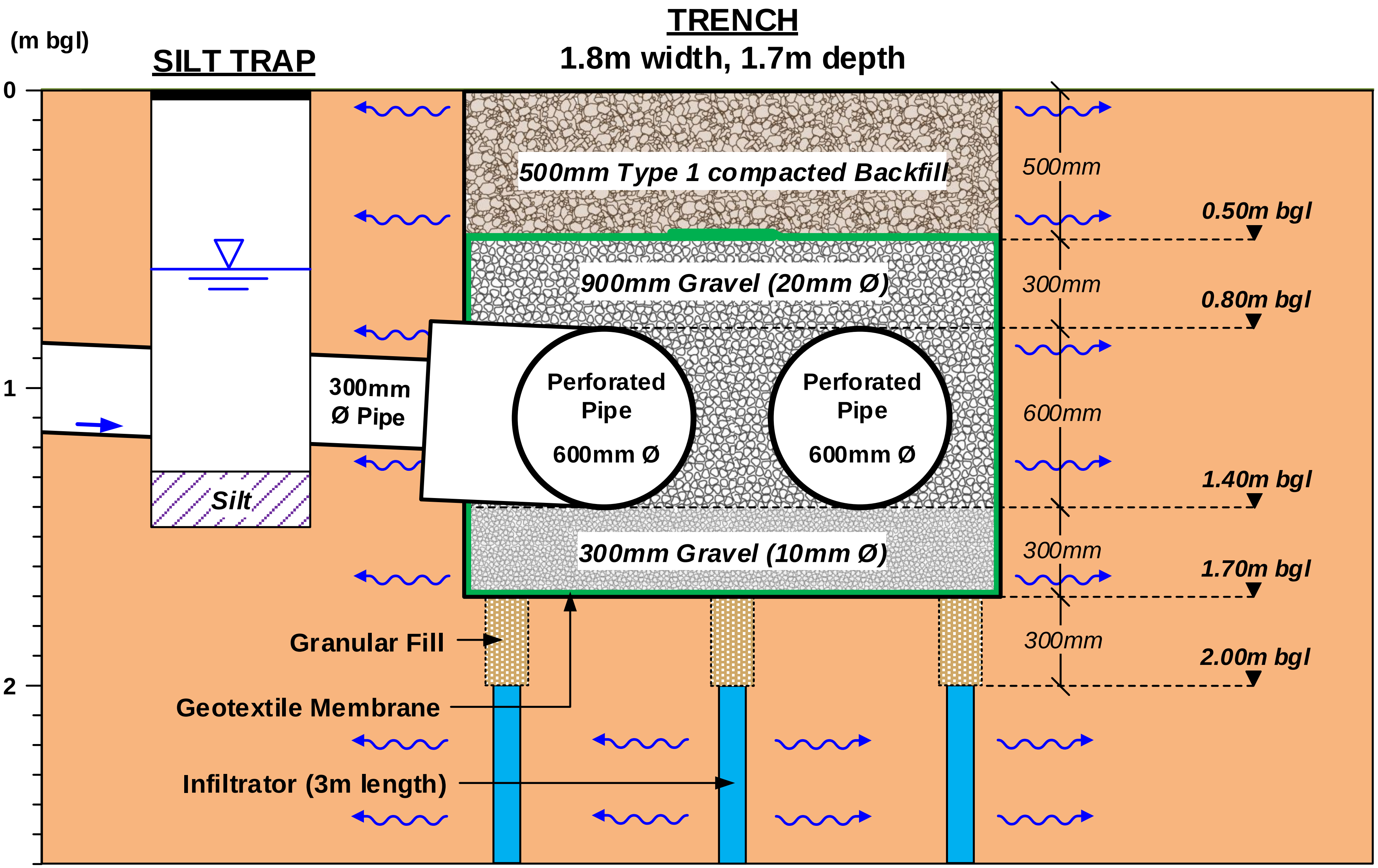

Detail of perforated attenuation pipes, gravel surround and Geotextile biogenic wrap

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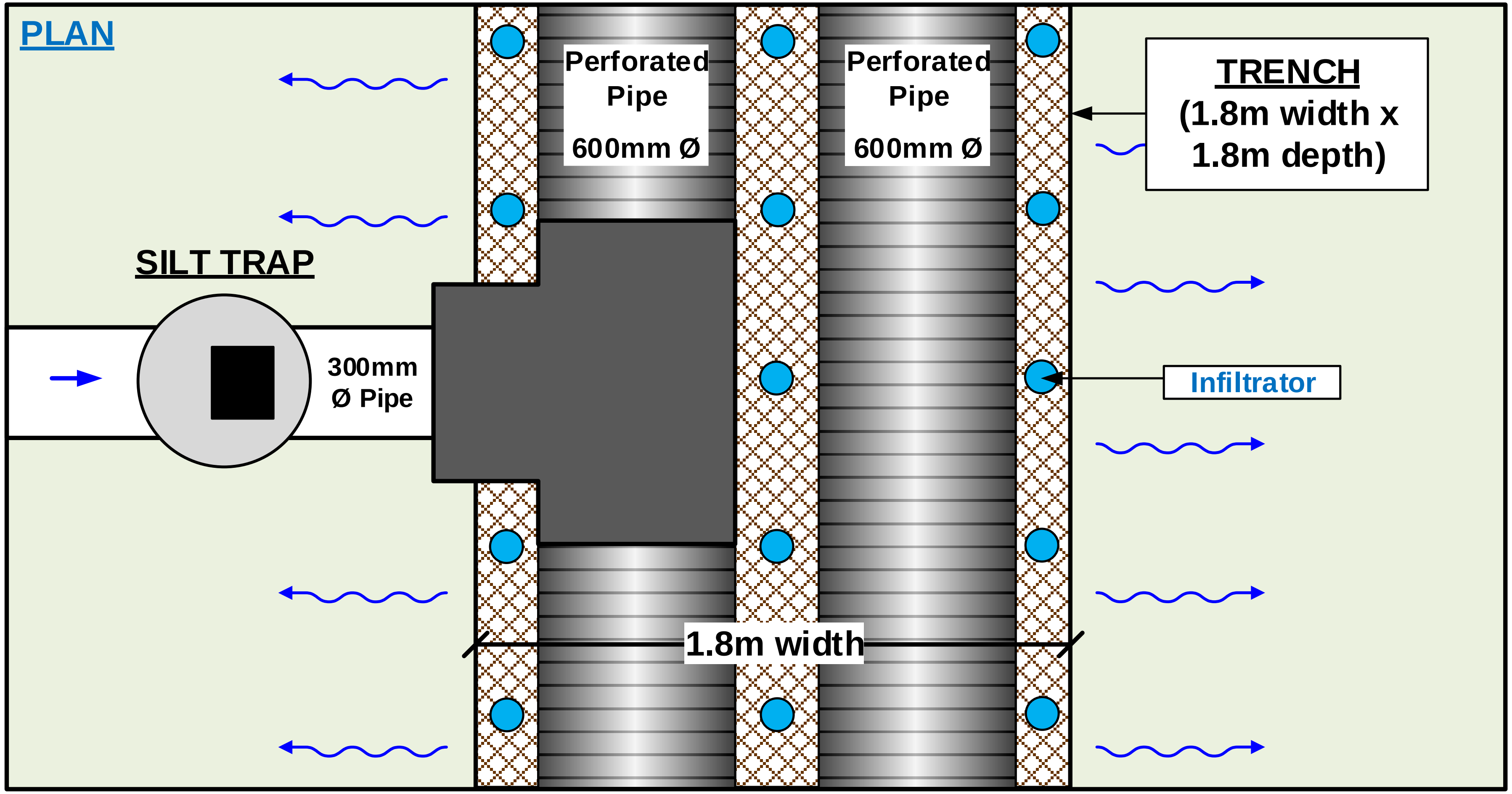
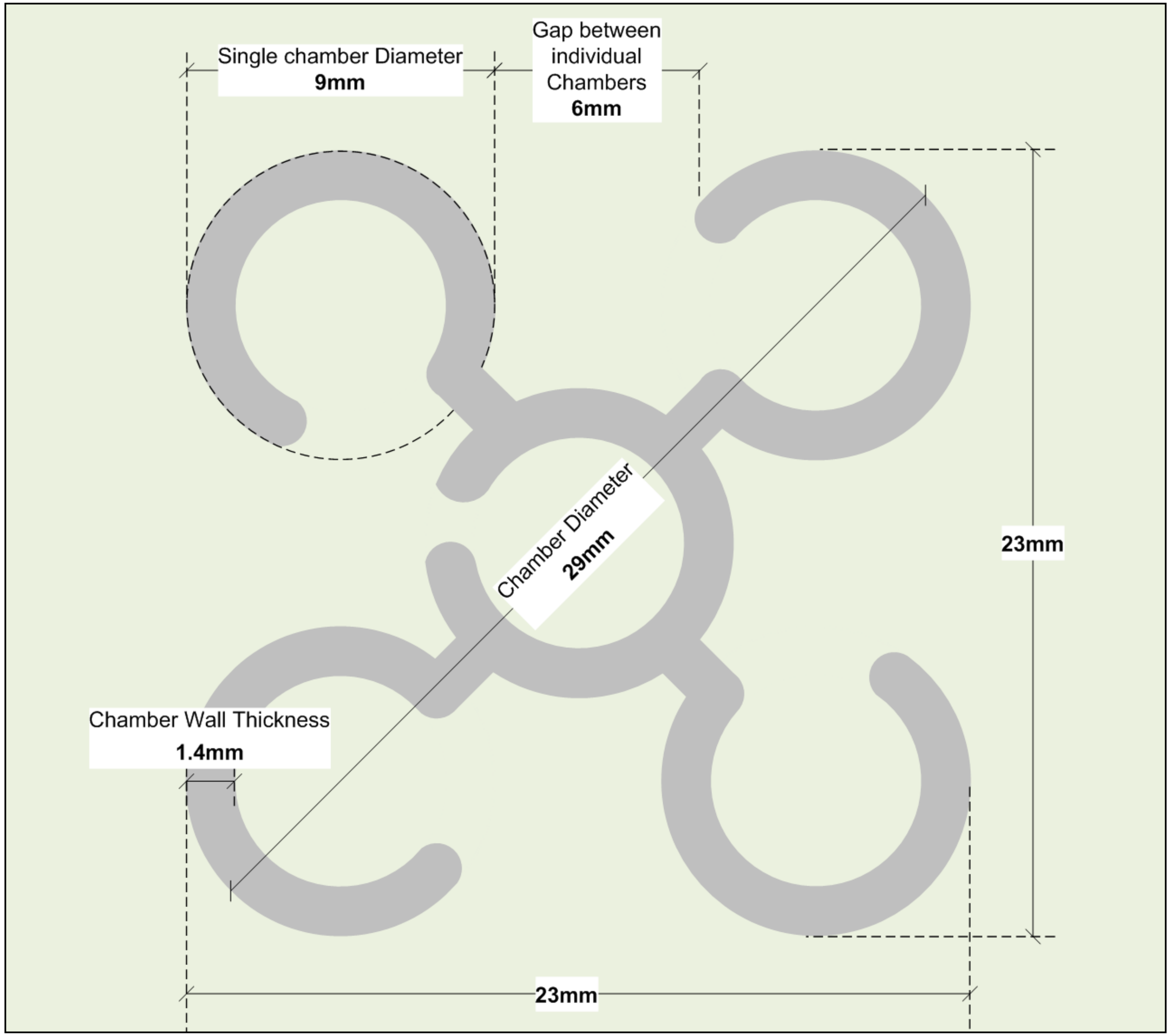
Plan of perforated Attenuation pipes, gravel surround Infiltrators, constructed within a Trench Excavation





ECO-90 Infiltrator Section (Courtesy of Groundwater Dynamics Ltd)

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ECO-90 Infiltrator (Courtesy of Groundwater Dynamics Ltd)

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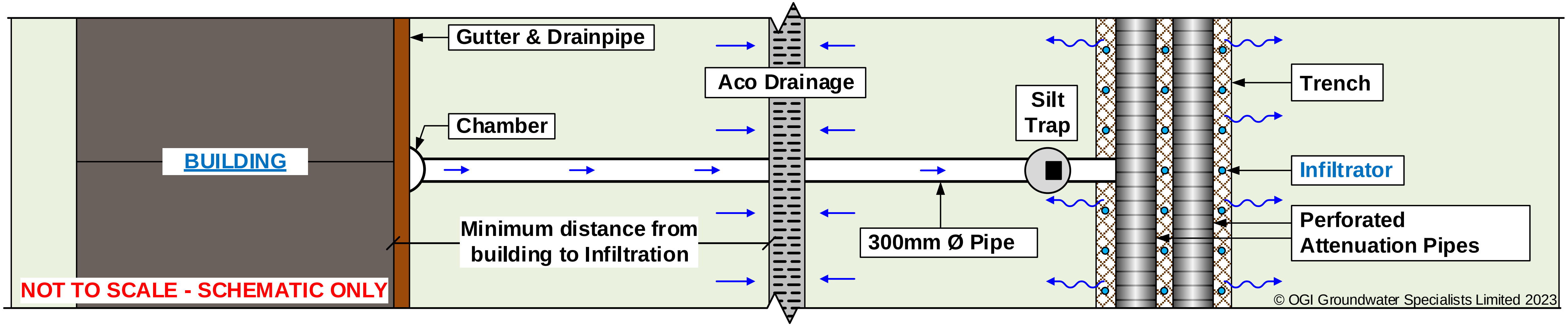
Connection of Roof and Ground drains to the Attenuation & Infiltration System



Flood Mitigation

Placing of perforated attenuation pipes within gravel filled trenches, surrounded with biogenic geotextile wrap.

(Courtesy of Groundwater Dynamics Ltd)

Flood Mitigation

Placing of perforated attenuation pipes within gravel filled trenches, surrounded with biogenic geotextile wrap.

(Courtesy of Groundwater Dynamics Ltd)

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Connection of perforated attenuation pipes within gravel filled trenches with access chamber.

(Courtesy of Groundwater Dynamics Ltd)

Flood Mitigation

Filling of trenches with gravel filled trenches inside biogenic geotextile wrap.

(Courtesy of Groundwater Dynamics Ltd)

Flood Mitigation

Final wrapping of pipe & gravel filled trenches with biogenic geotextile wrap.

(Courtesy of Groundwater Dynamics Ltd)

System Verification using Multi-Dimensional Saturated-Unsaturated Finite Element Modelling

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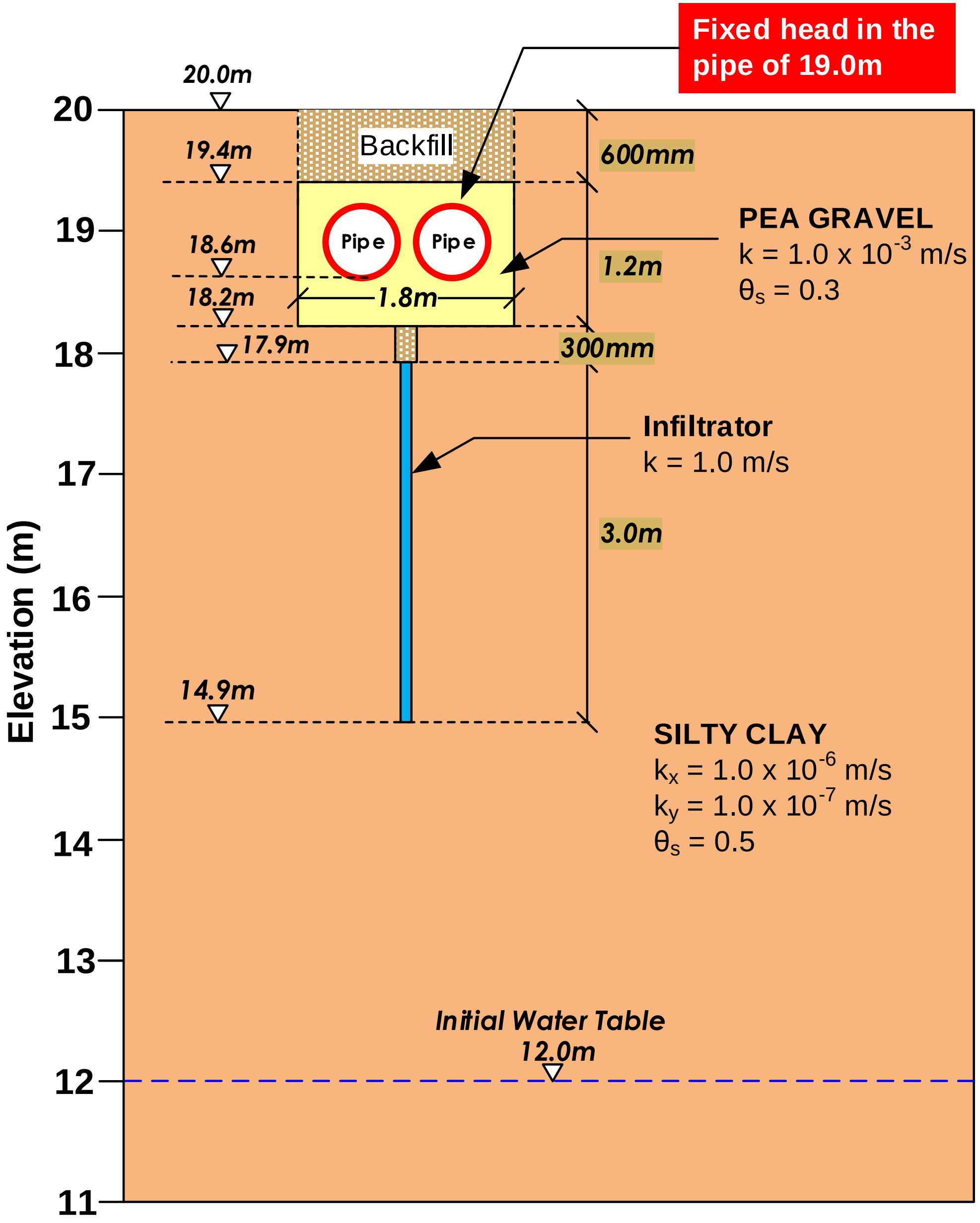
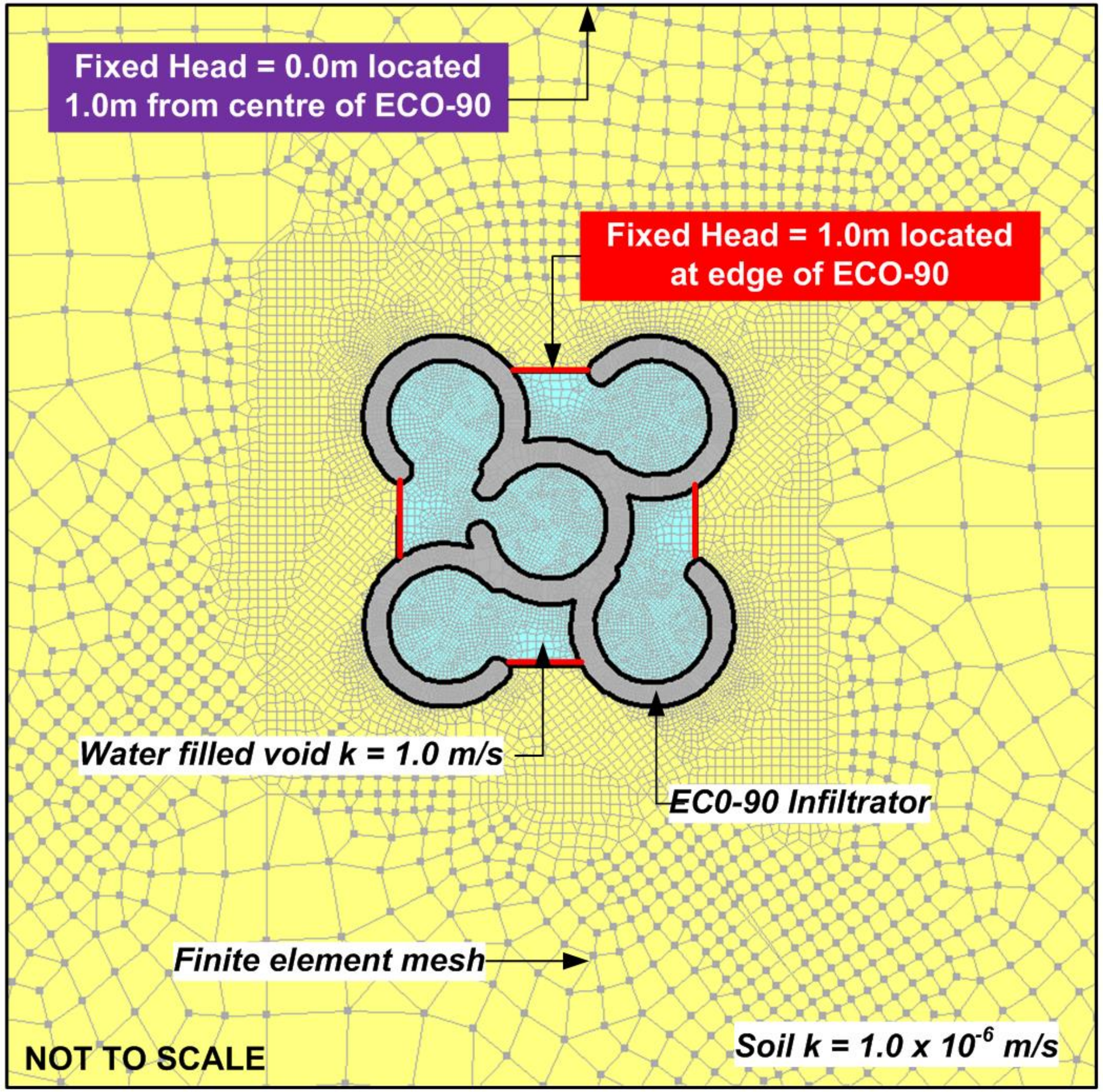
$$\frac{\partial}{\partial x_i}\left(k_{rw}K_{ij}\frac{\partial h}{\partial x_j}\right)=\left(S_wS_s+\varphi\frac{\partial S_w}{\partial \psi}\right)\frac{\partial h}{\partial t}-Q_w$$

Where k_{rw} is relative permeability, K_{ij} is Hydraulic Conductivity Tensor, h is hydraulic head, φ is porosity, S_w is water saturation, S_s is Specific Storage, ψ is pressure head, and Q_w is a point water source.

Flood Mitigation



Conceptual model of a single infiltrator under axisymmetric conditions



Finite Element Mesh of an ECO-90 Infiltrator in silty soil

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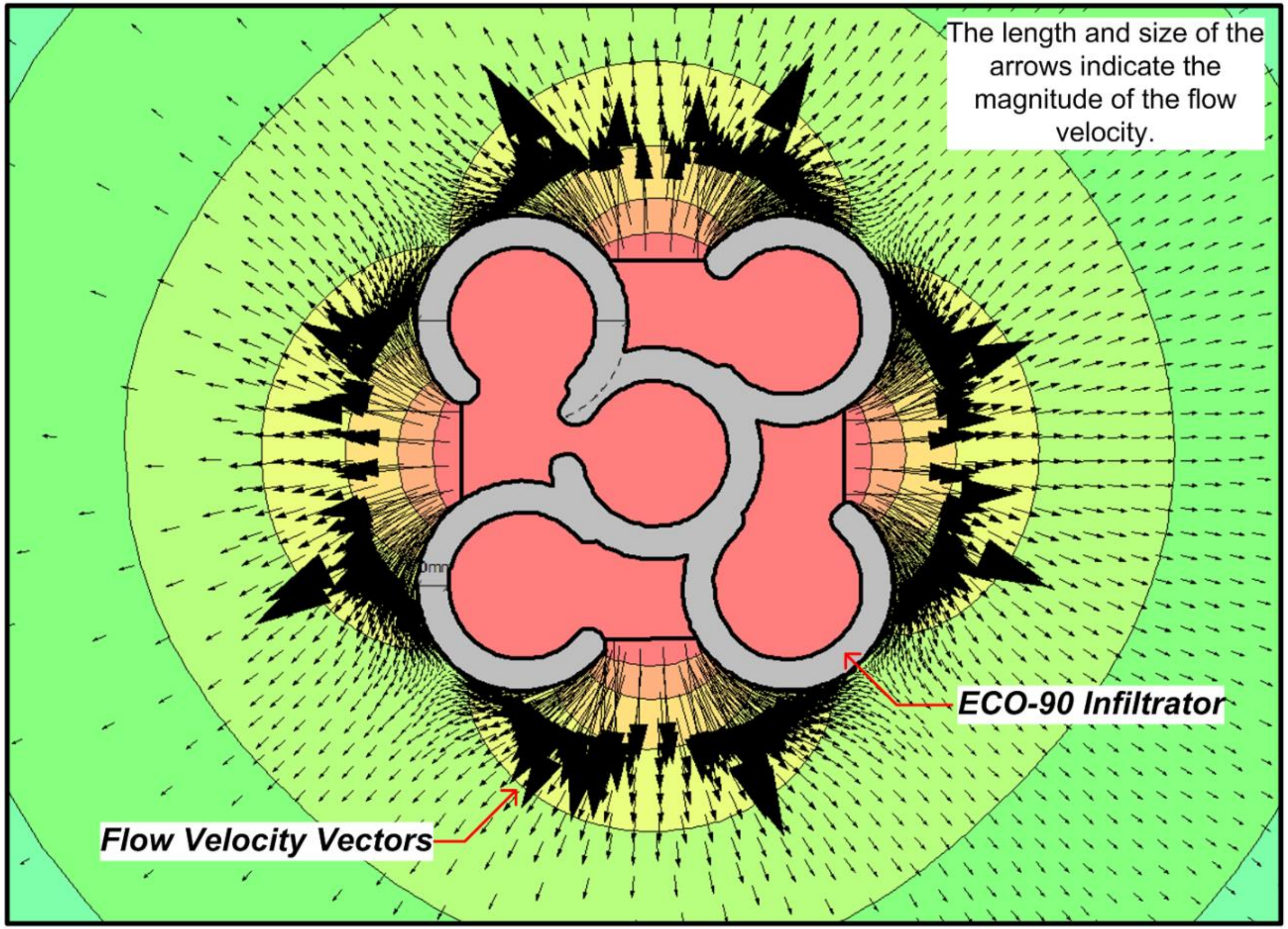

Darcy Velocity Vectors from ECO-90 Infiltrator

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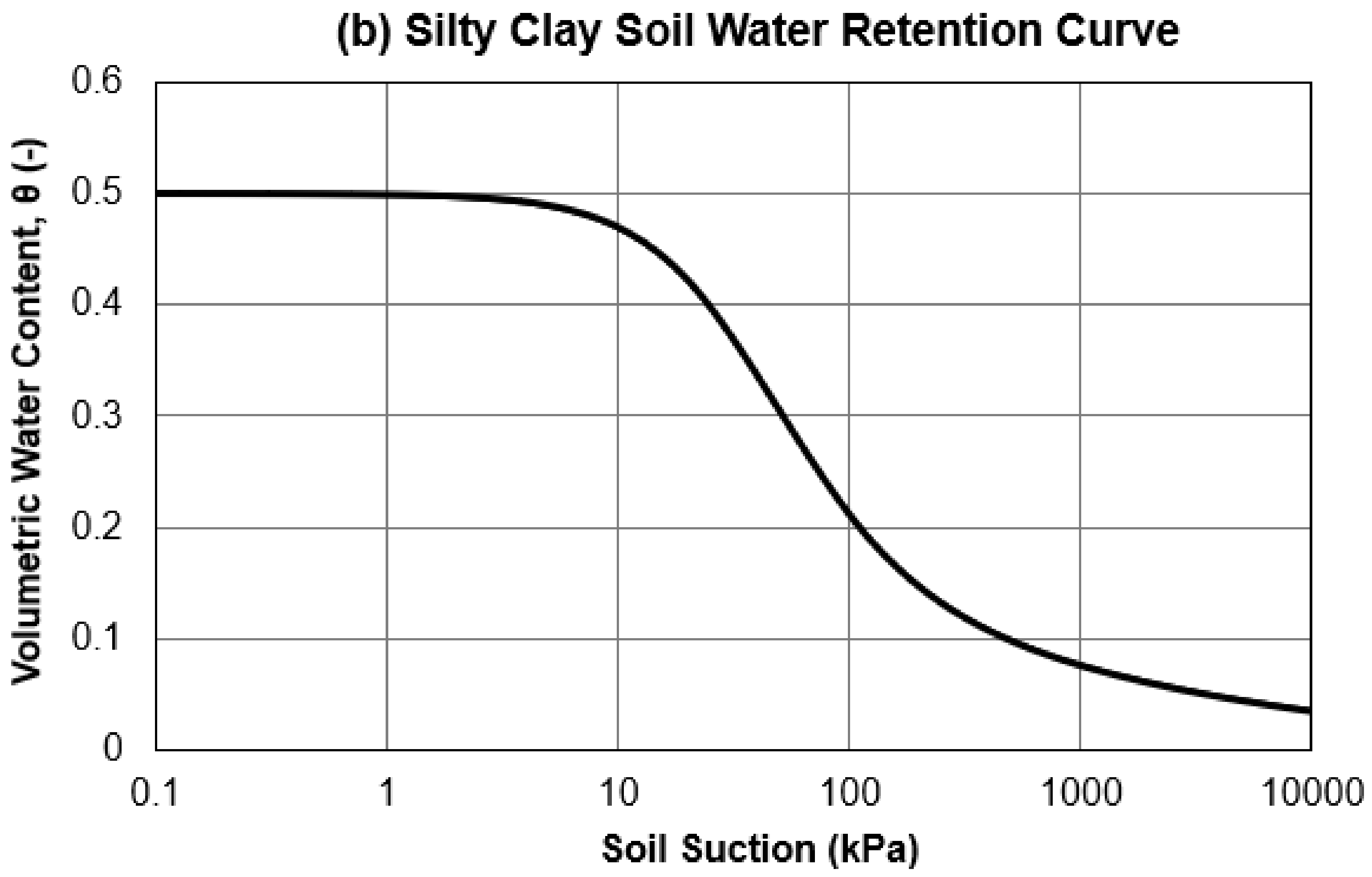
Typical soil-water retention curve function for silty clay



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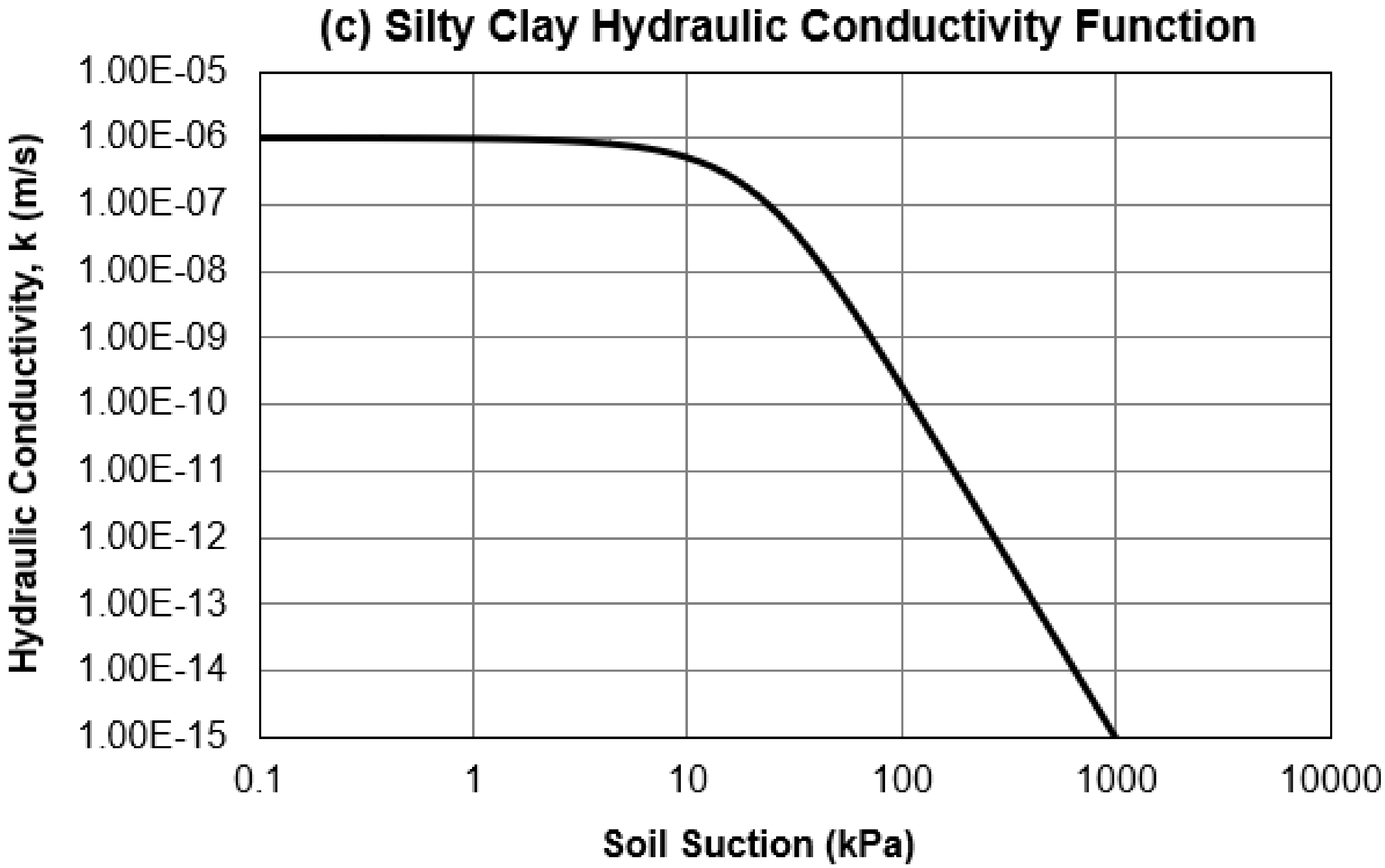
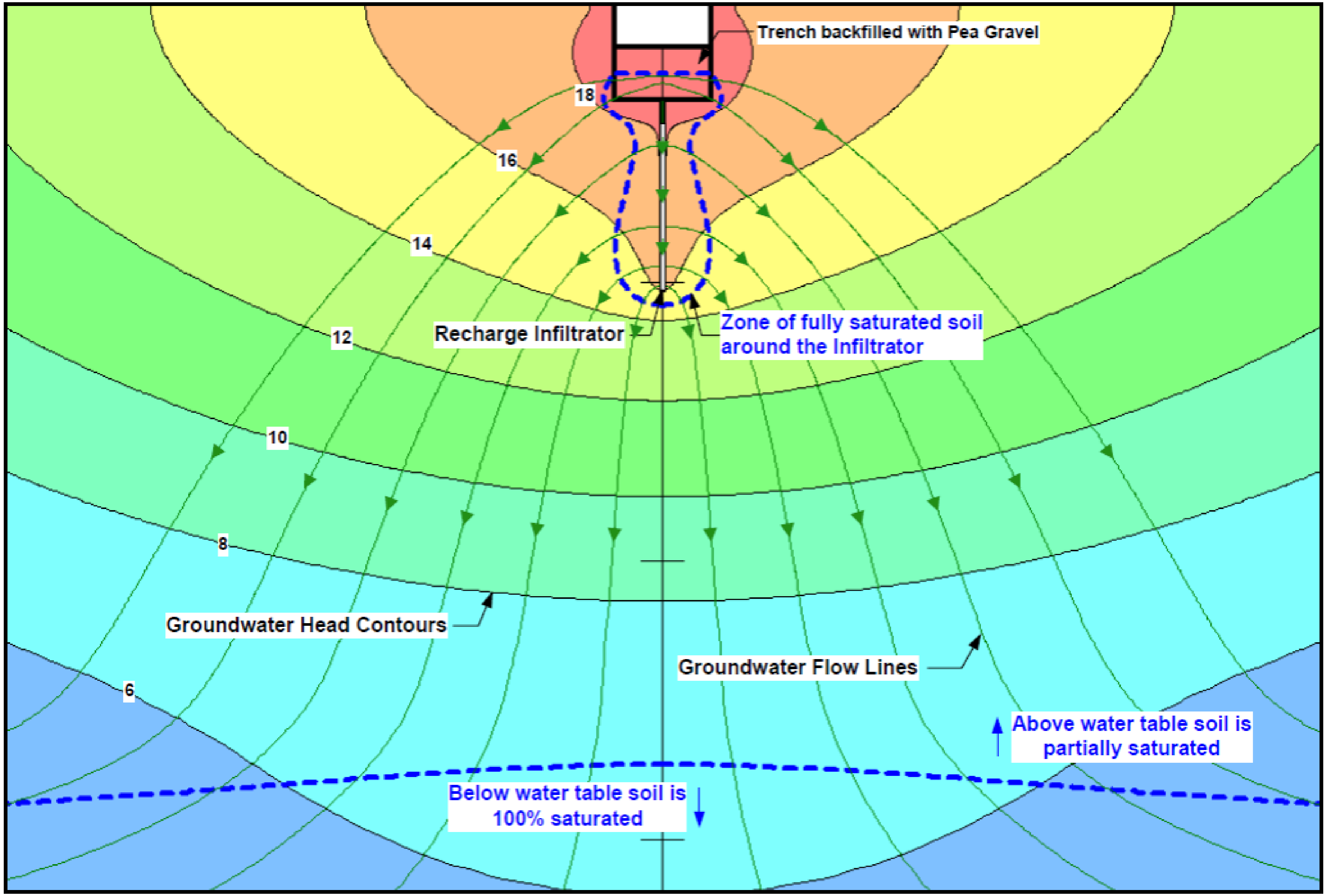
Typical & hydraulic conductivity function for silty clay



Flood Mitigation



Mathematical model of a single infiltrator under axisymmetric conditions

0 Hours – 3 Hours

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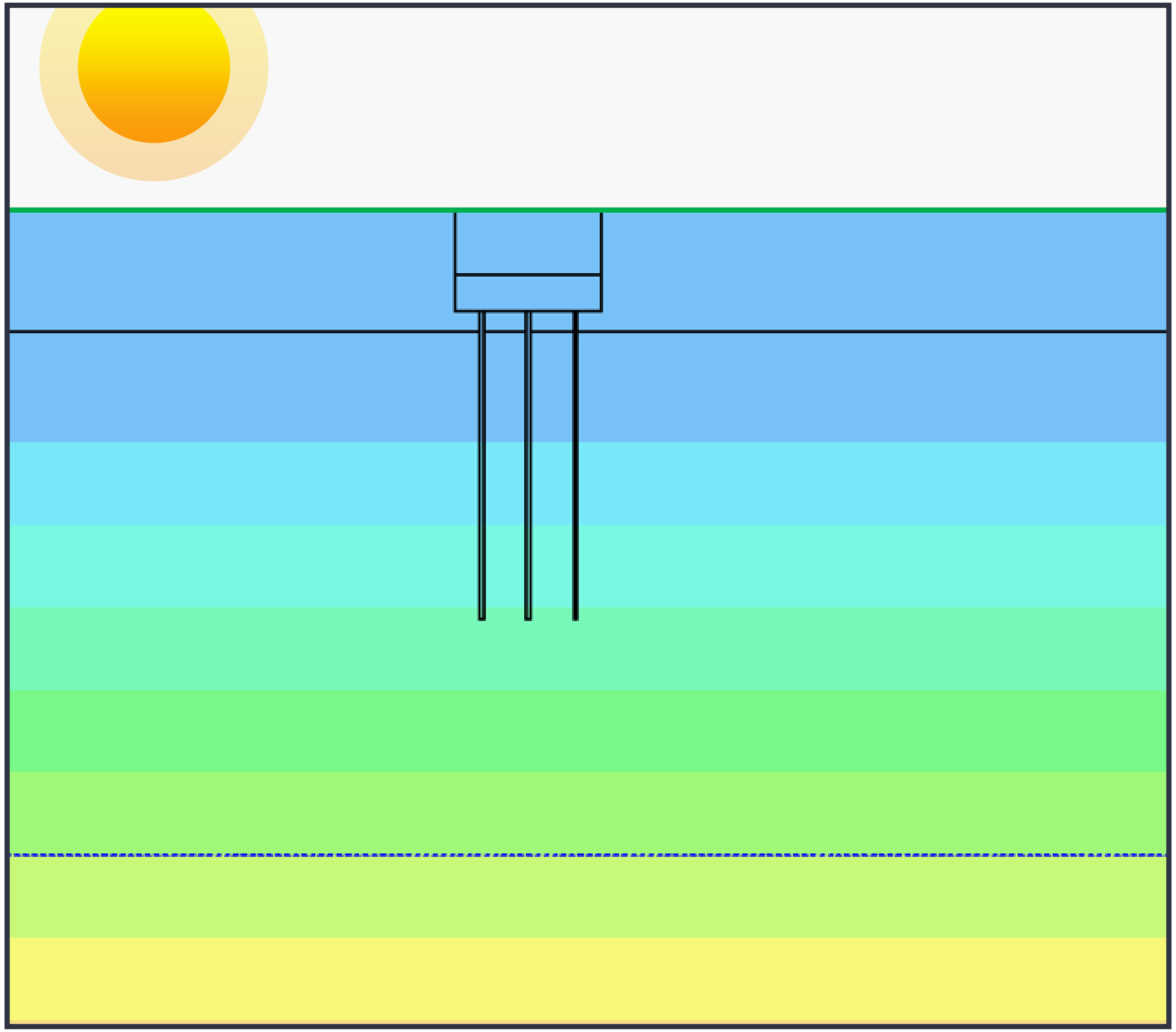
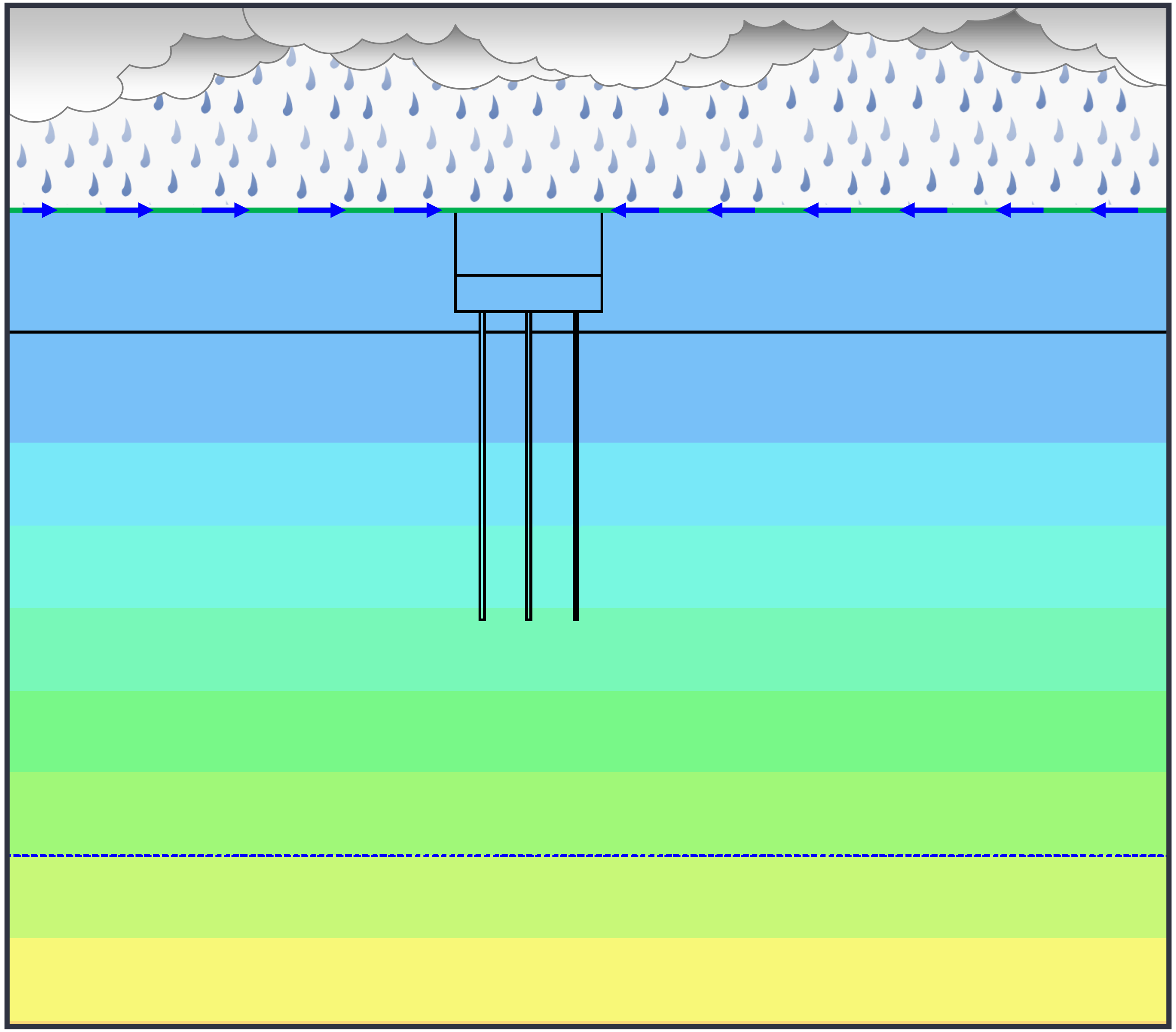


0 Hours – 3 Hours

0 Hours – 3 Hours



0 Hours – 3 Hours

Storm Event

Surface water flowing to Attenuation Trench which results in Enhanced Infiltration into the ground via the Infiltrators

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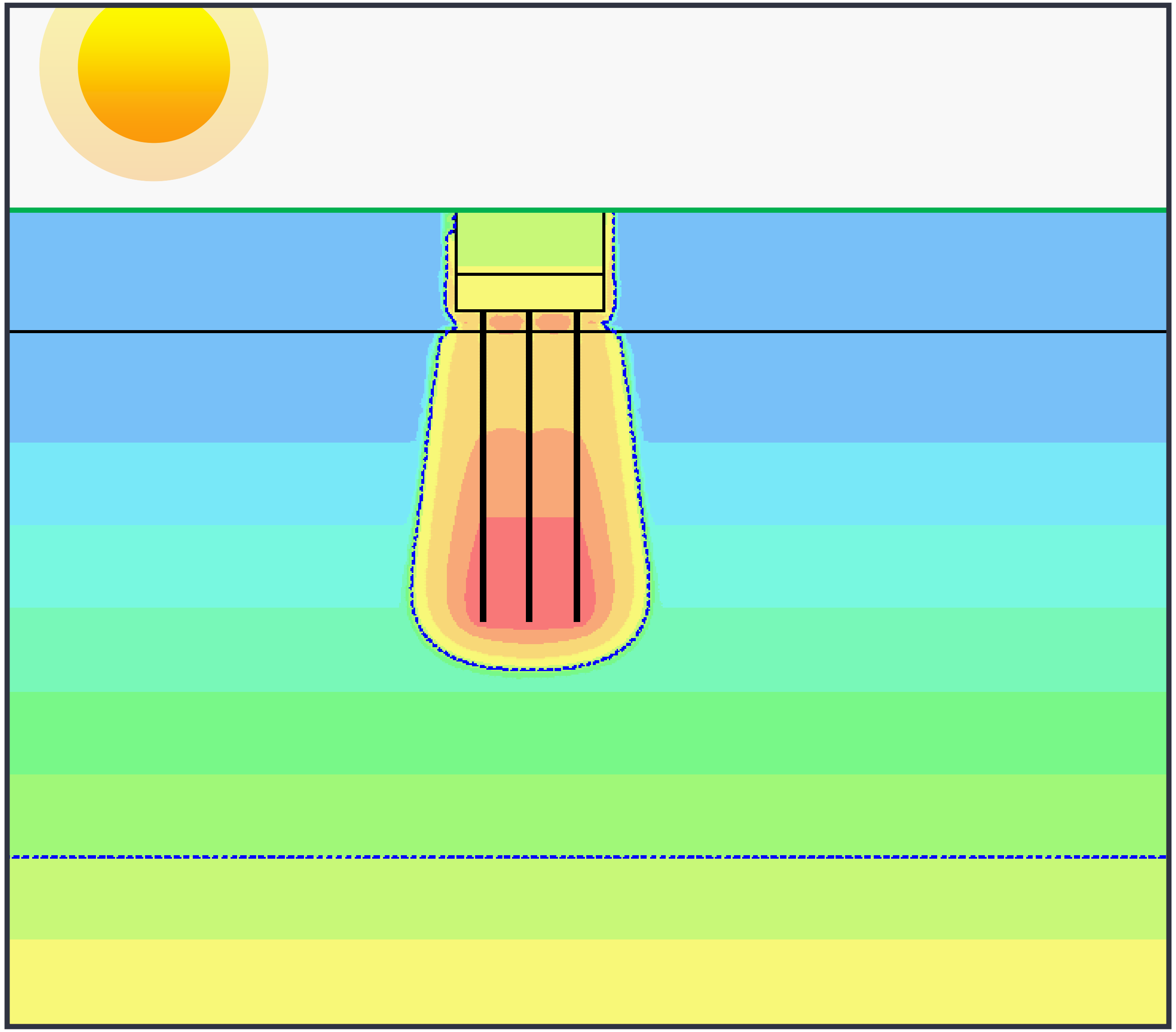
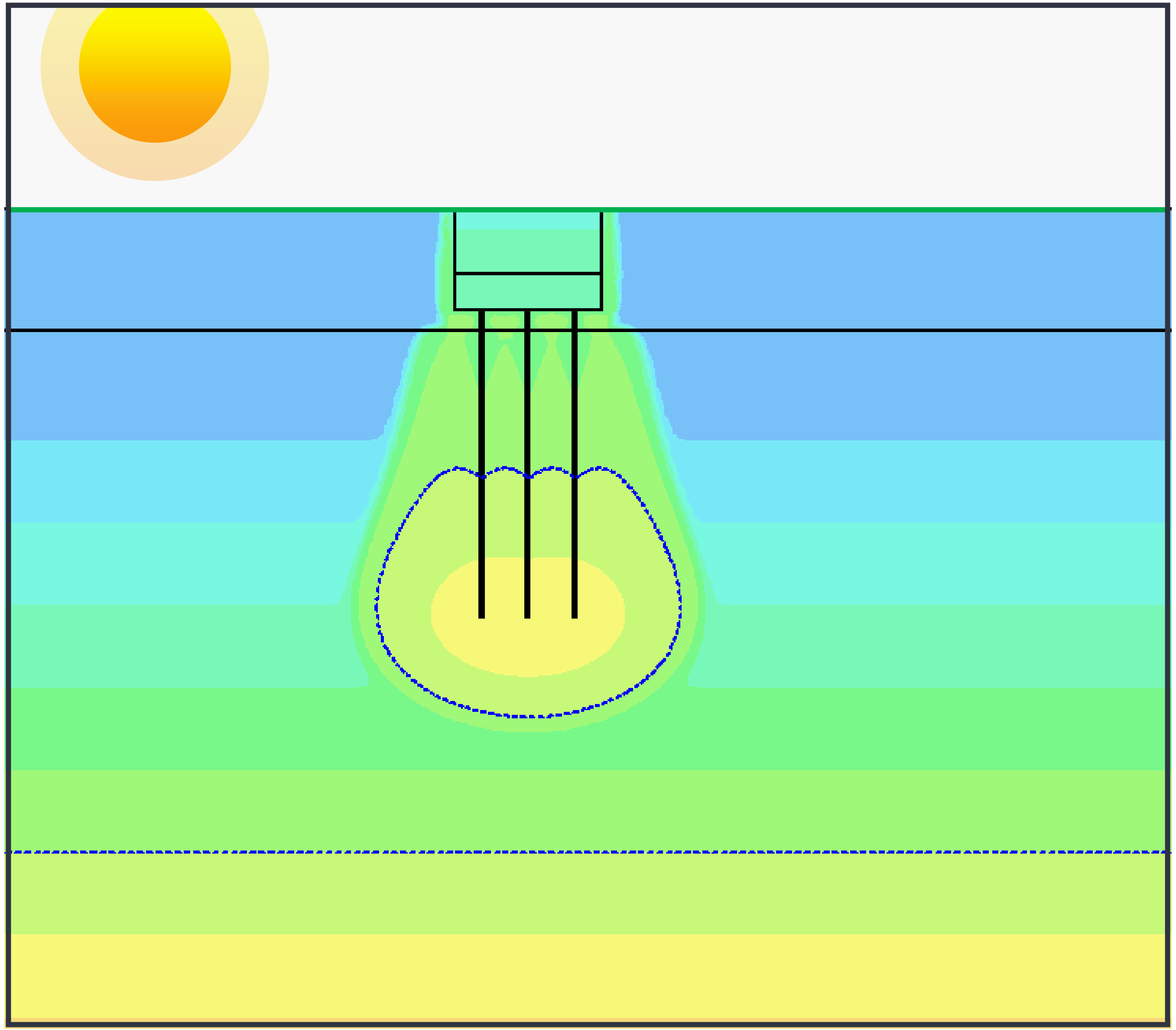


3 Hours – 24 Hours

Post-Storm Event

Attenuated water continues to infiltrate into the ground, until the Attenuation trench is empty.

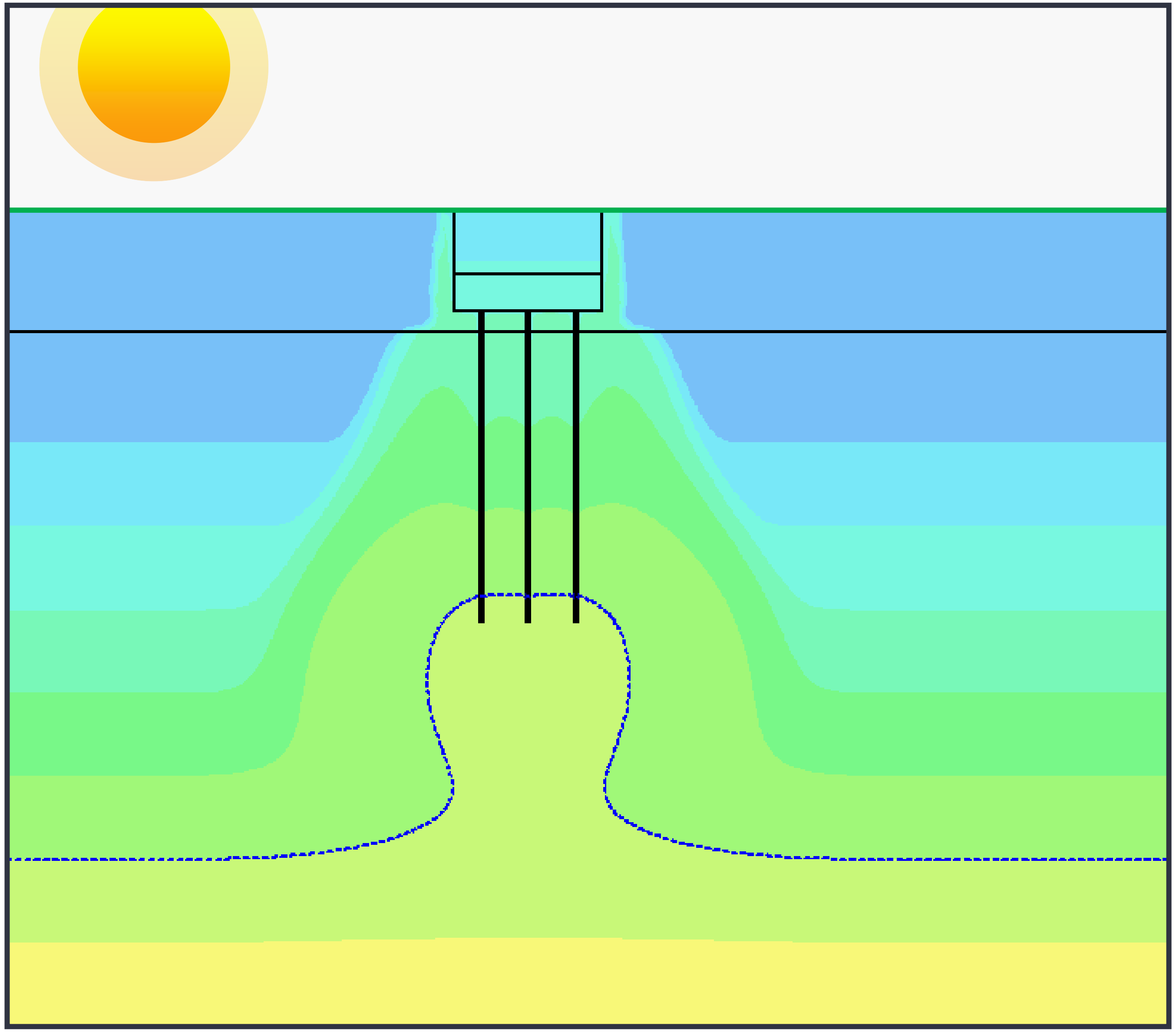


24 Hours – 7 Days

Post-Storm Event

Infiltration continues, with water forming a bulb at the base of the infiltrators, continuing to migrate downwards until interception with the water table.

7 Days – 30 Days



7 Days – 30 Days

Post-Storm Event

The bulb of saturated water finally departs from the interceptors and is amalgamated with the groundwater below water-table.

Impermeable Site Area	= 10,000 m^2
Designed for Rainfall intensity	= 60mm in 3 hours
Length of Trench	= 300 m
Total 3-hour Rainfall Volume	= 600 m^3 = 2m^3/m

Length of Trench	= 300 m
Attenuation Capacity of Trench	= 1.5 m^3/m
Attenuation Capacity of Ground	= 2.0 m^3/m
Total Attenuation Capacity/m	= 3.5 m^3/m

Total Attenuation Capacity of System	= 1050 m^3
Factor of Safety = 1050/600	= 1.75

Robustly Designed and Accurately Tested System by Groundwater Dynamics.

Combined with

Verification and Finite Element Modelling by OGI Groundwater Specialists Ltd

The Head of the City Council Approved the System

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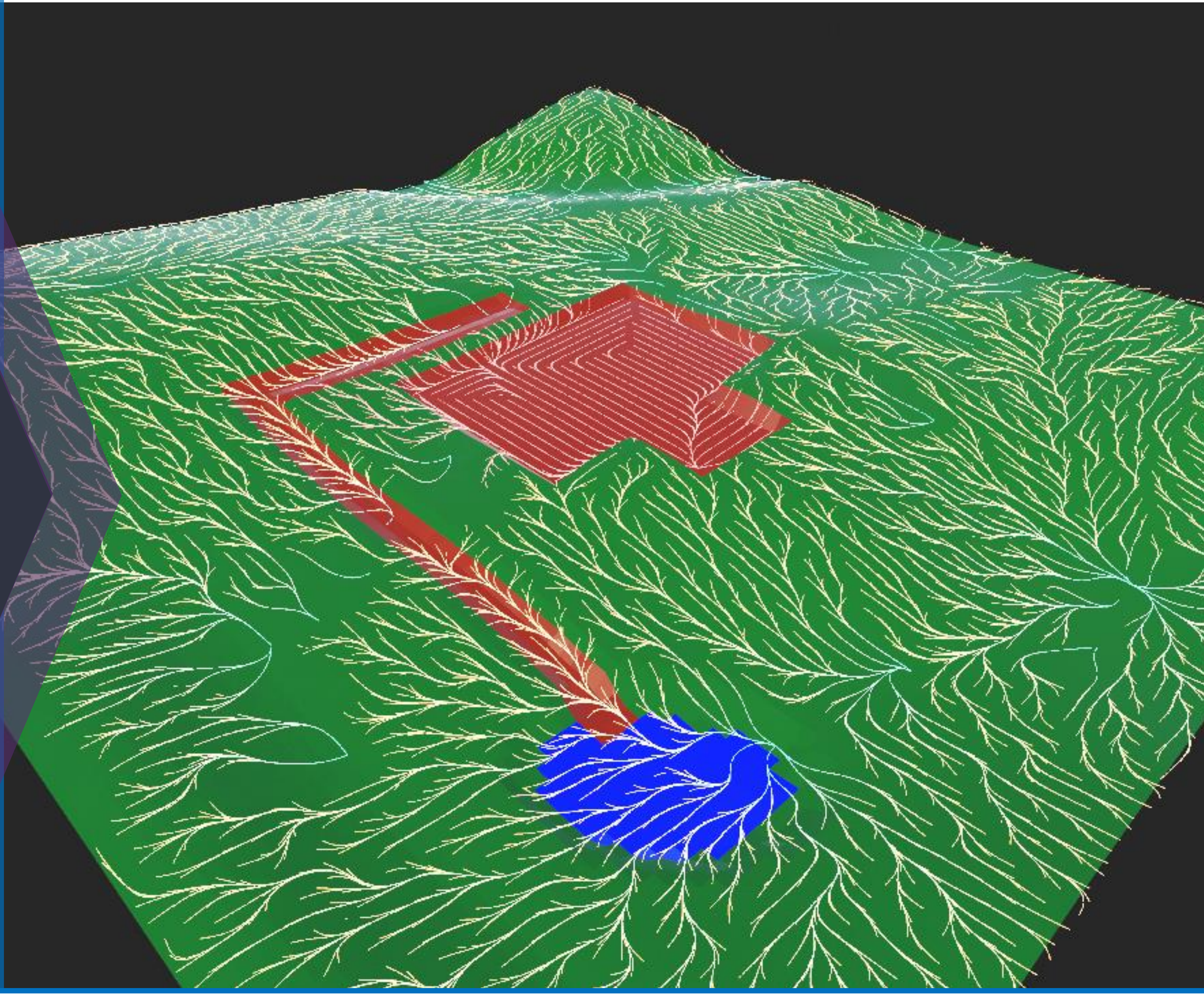
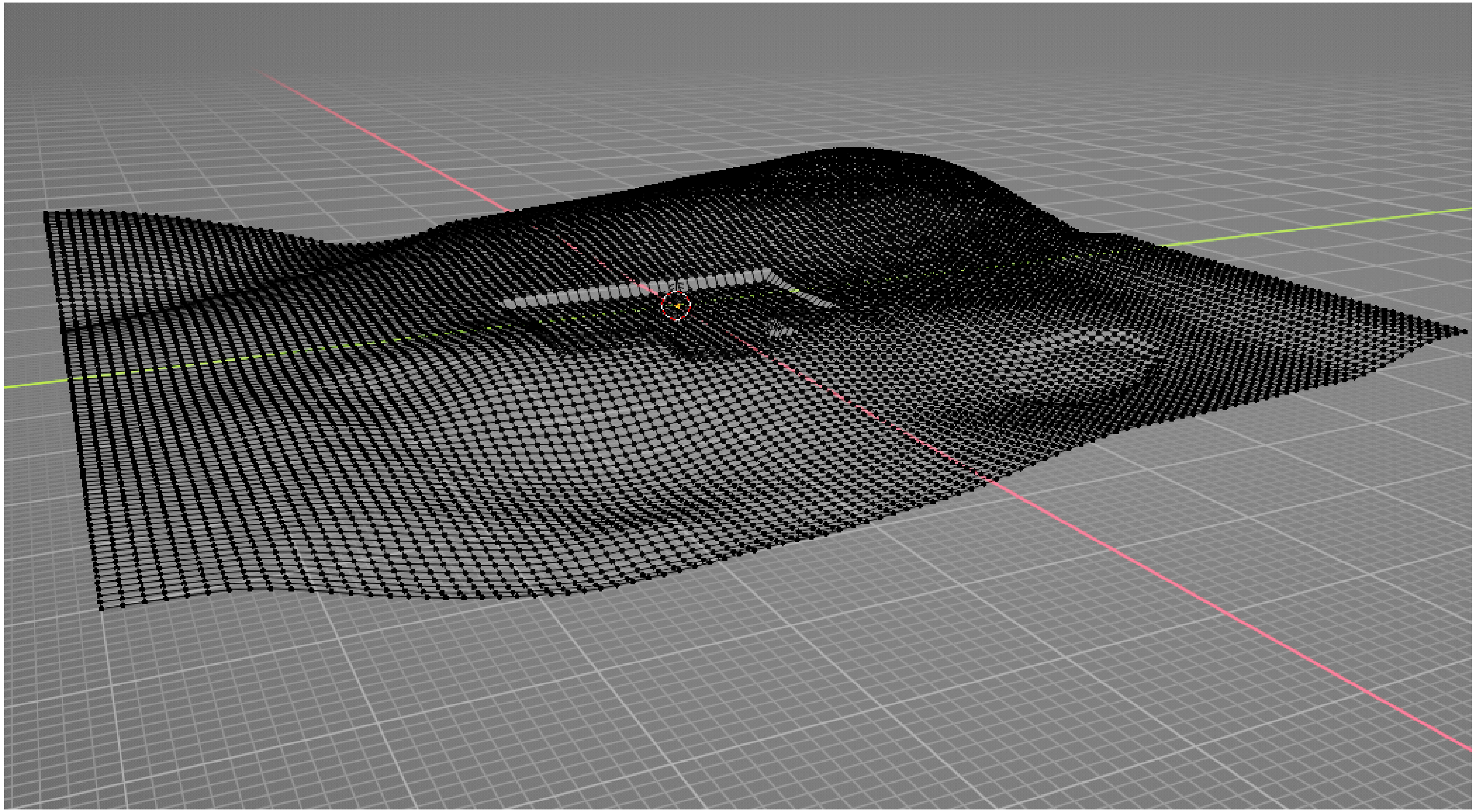
Ongoing Advances



Ongoing Advances



An example 3D mesh generated from topographical data

A 3D mesh of a site may be generated from coordinate data (i.e. eastings, northings, elevations)

This data may be collected via surveying equipment or extracted from drone images using photogrammetry

Ongoing Advances

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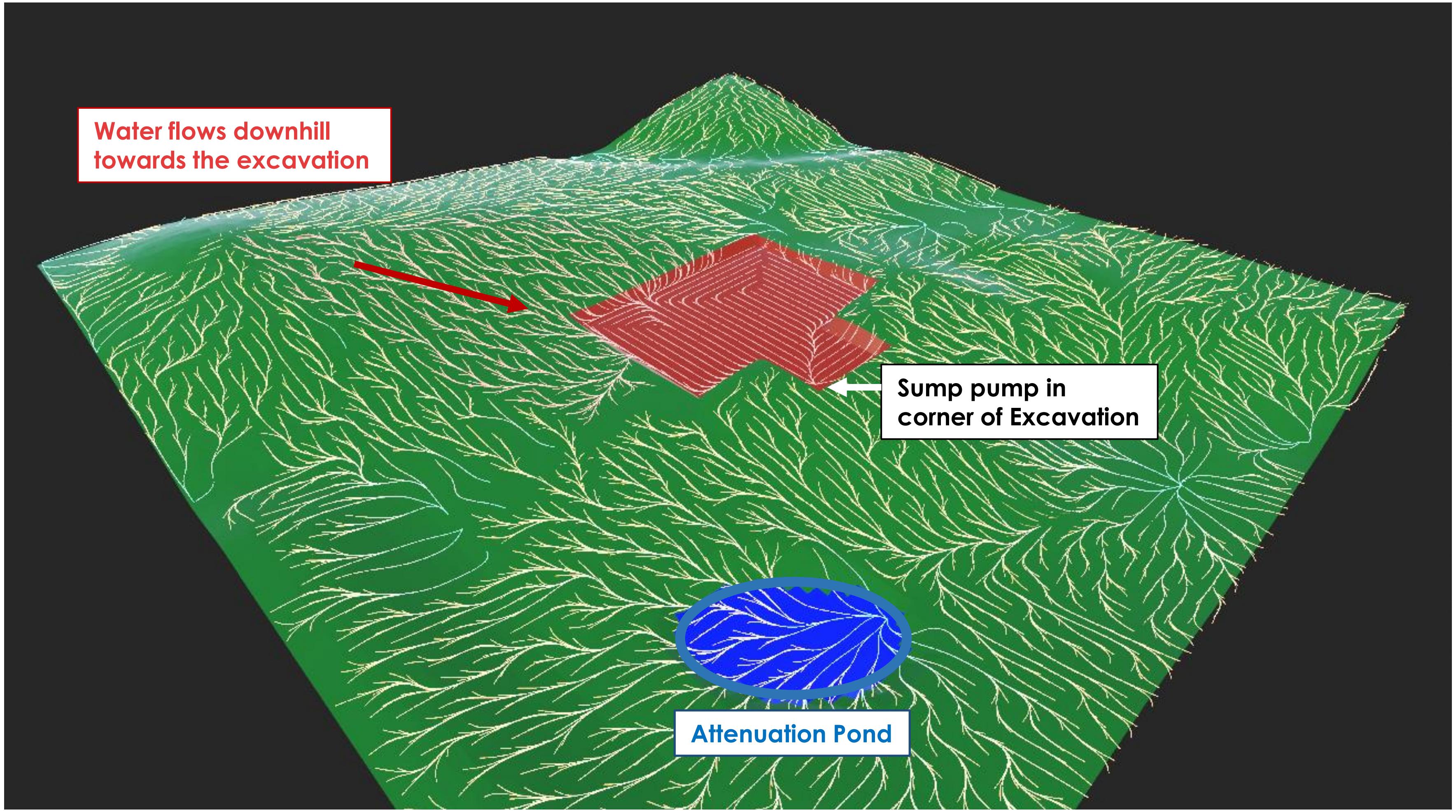

An example site with a battered excavation and an attenuation pond

The direction of flow is influenced by the topography of the site (and surrounding area)

Water flows from orange to blue

Potential surface water flow paths that reach the excavation are highlighted in red

Ongoing Advances

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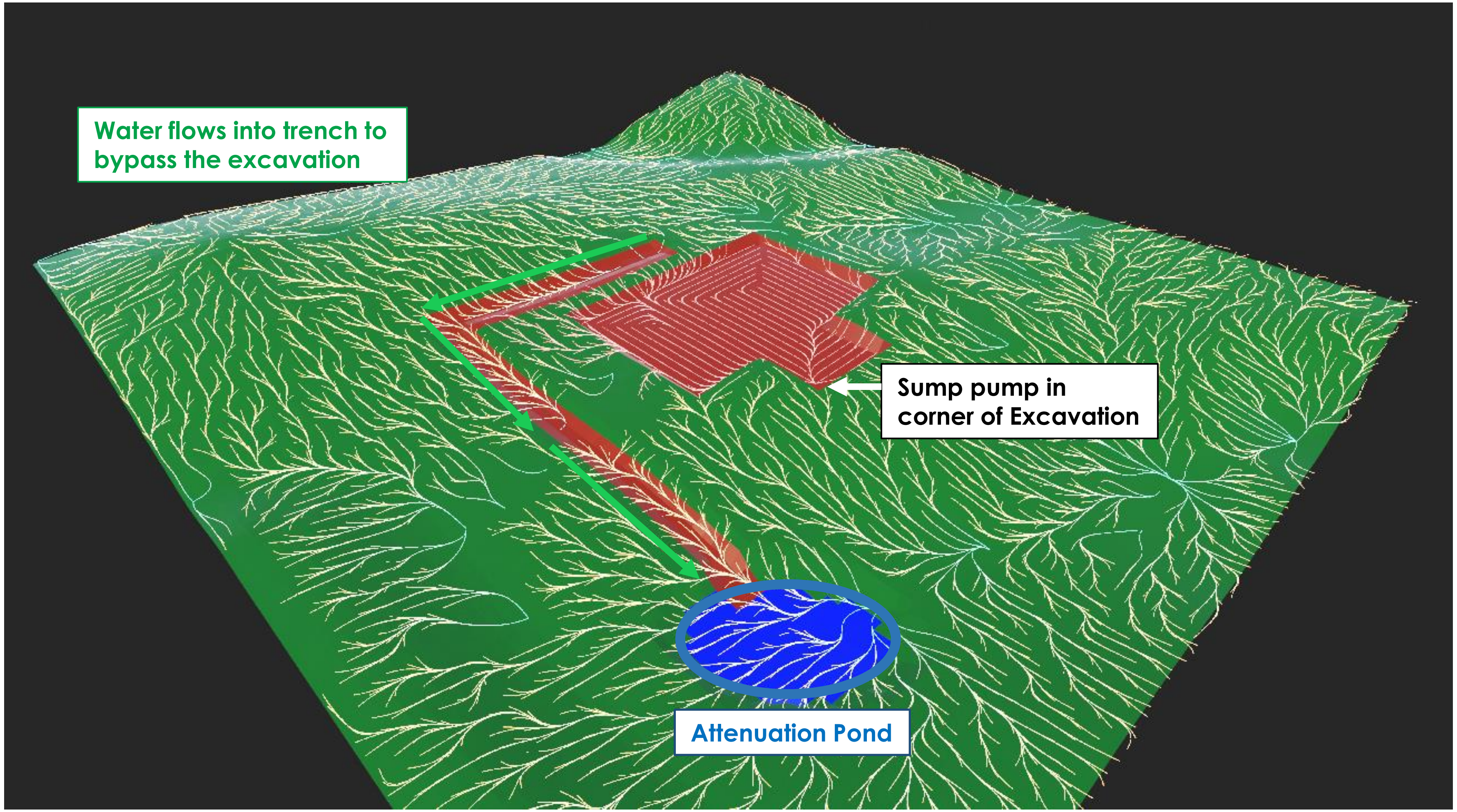

An example site with a battered excavation and an attenuation pond
A trench has been dug to intercept water flowing towards the excavation

Point data may be manipulated to introduce a trench onto the site

By re-running the model, the effectiveness of the trench can be assessed

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