Imperial College London

Detecting Flood Embankment Deterioration and Future Projection

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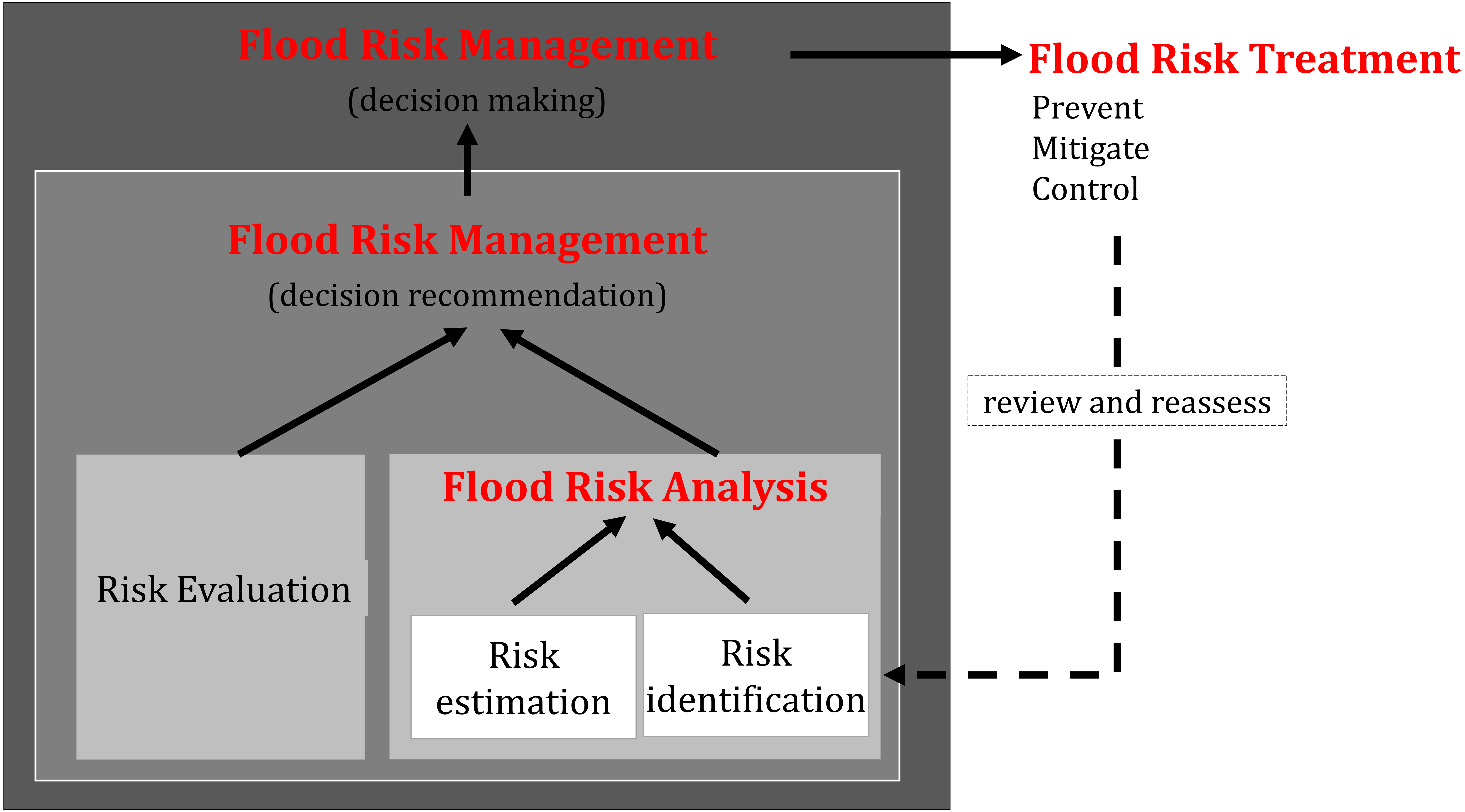
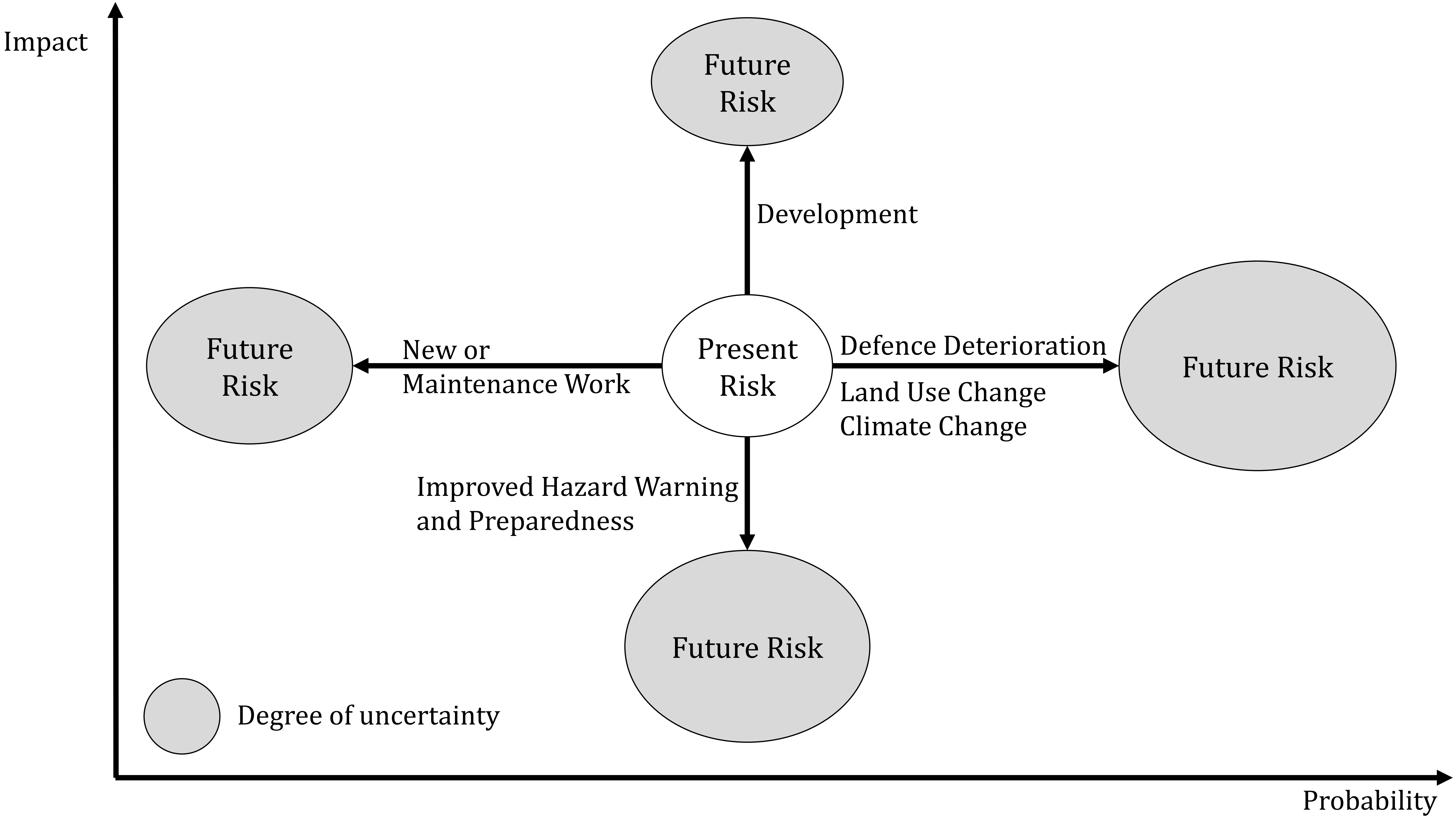
Outline



Flood Risk Management
(decision making)
Flood Risk Treatment
Prevent
Mitigate
Control
Flood Risk Management
(decision recommendation)
review and reassess
Flood Risk Analysis
Risk Evaluation
Risk
estimation
Risk
identification

Outline


Impact
Future
Risk
Development
Future
Risk
New or
Maintenance Work
Present
Risk
Defence Deterioration
Land Use Change
Climate Change
Future Risk
Improved Hazard Warning
and Preparedness
Future Risk
Degree of uncertainty
Probability

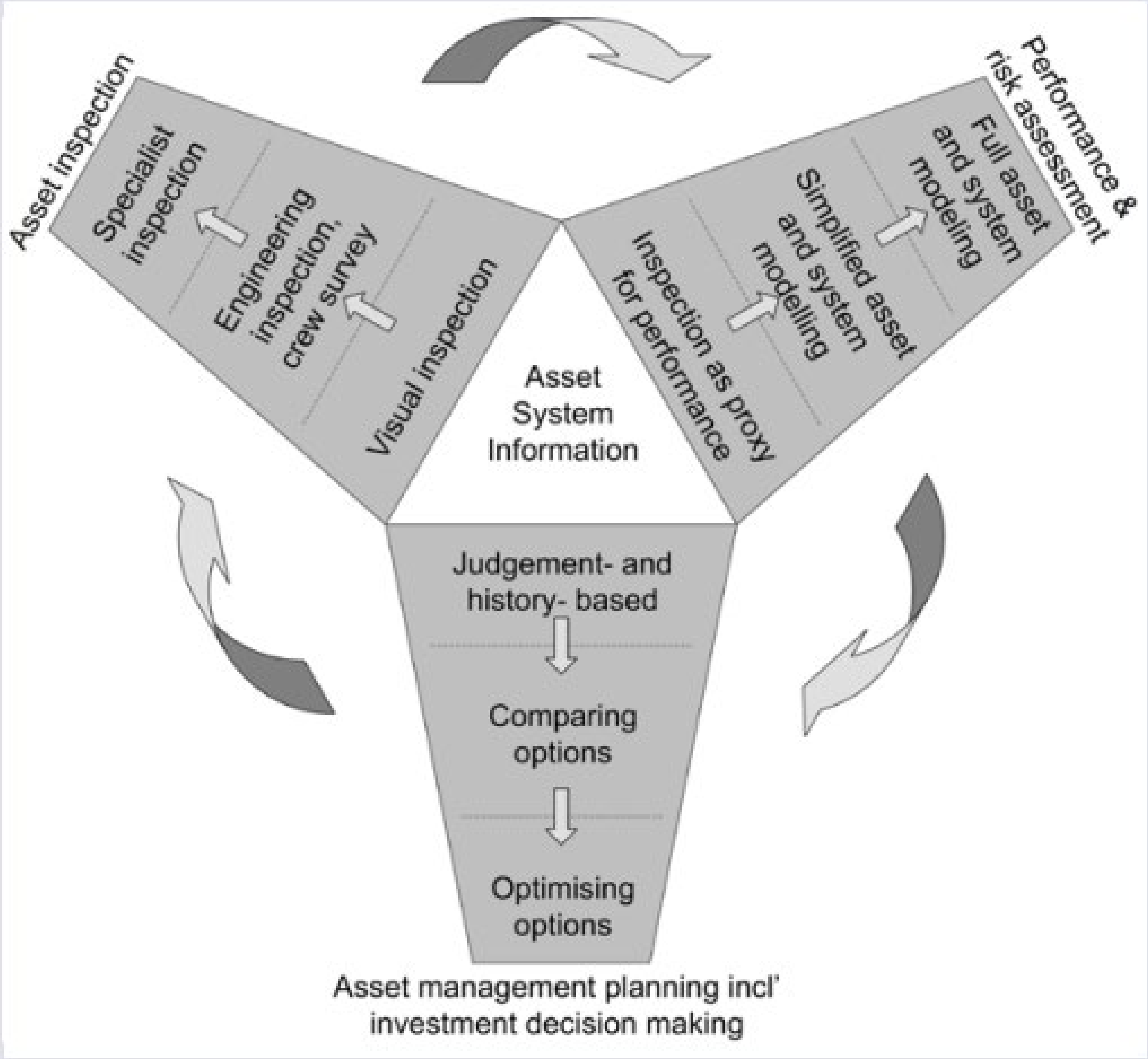


Figure 2.15 ***Asset performance tools propeller (from Environment Agency, 2011)***

Flood Disaster

Key Point

*"Globally, during 2000 – 2019, **rapid urbanisation** increased potential of disaster susceptibility, and extreme weather events have caused thousands reported disasters, **many of fatalities**, and continue to cause billions of dollars of direct **economic loss**. And under the background of global warming, such losses will continue to increase in the future."*

Flooding is defined as the temporary presence of surface water, on or near an embankment, and as the most frequent and widespread natural disaster in the world and typically destructive (1).

Flood Data (2000 – 2019) compared to other types of disasters

1st — Floods are the most common type of disasters, accounted for around 3254 (44%) of total events.

1st — The type of disasters that affecting 1.6 billion people worldwide or around 41% of total affected population.

3rd — It accounted around 636 billion US$ (21%) economic losses.

4th — One of the deadliest disasters with at around 104.614 fatalities.

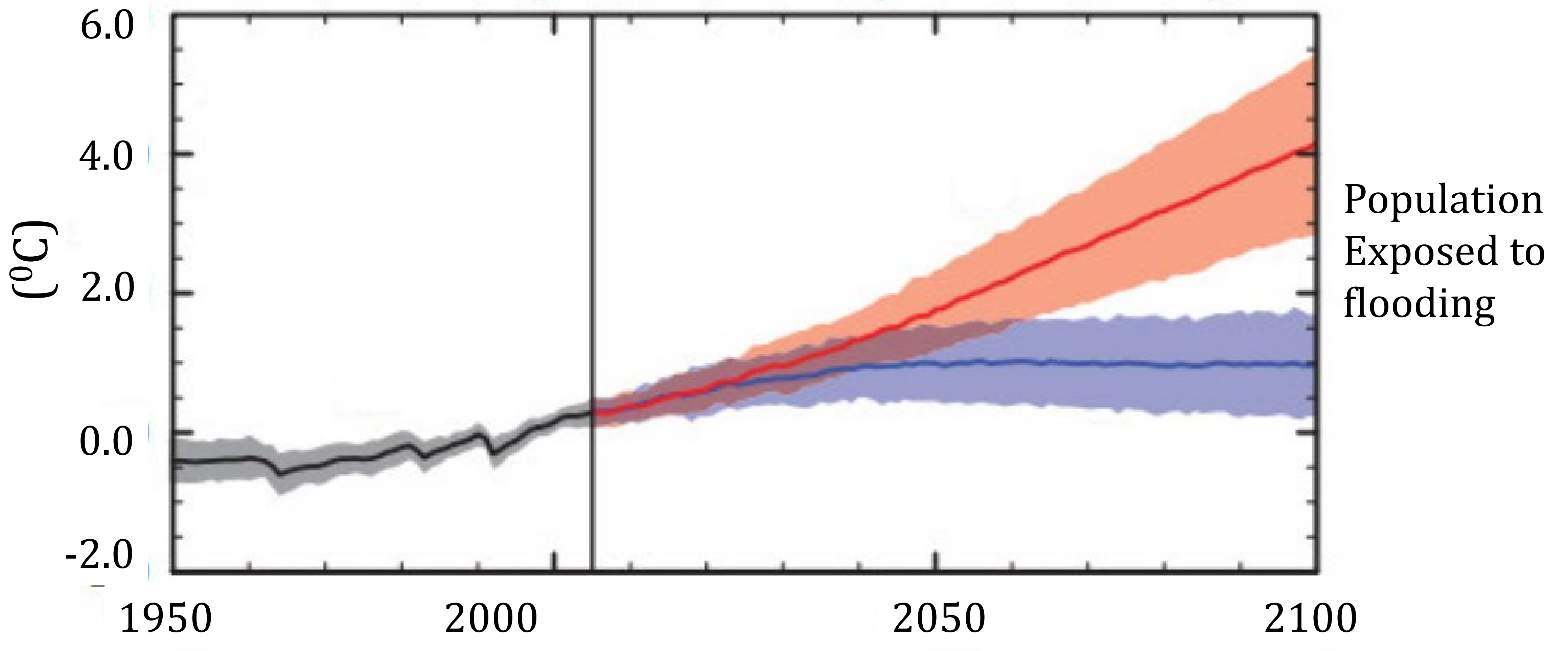
Source:
[1] Iqbal et al. (2021), [2] Centre for Research on the Epidemiology of Disasters (CRED), United Nations Office for Disaster Risk Reduction

Flood under Climate Scenario

Key Point

Better flood control, including prediction and monitoring, *is one of the possible solutions in DRR policy terms since affordable and effective technologies already exist.*
The priority should be given to ***cost-effective measures*** *in poor regions at high risk of recurrent flooding.*

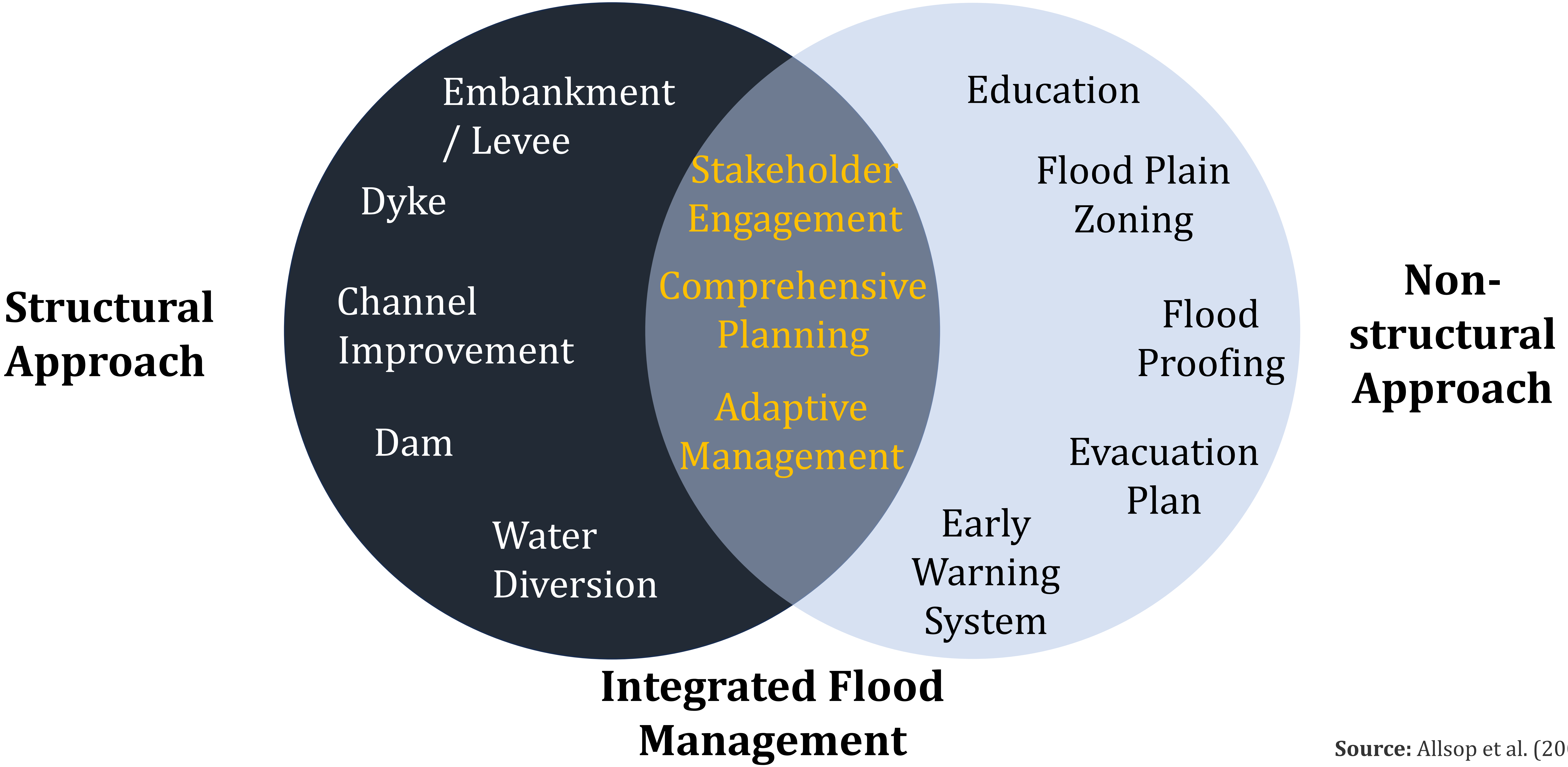
Global average surface temperature change



- People living in **coastal cities and riverine areas** are considered among the most vulnerable to sea level rise, storm surges, and coastal flooding.
- **Global warming** is estimated to increase the frequency of potentially high impact natural hazard events across the world.

Source: Centre for Research on the Epidemiology of Disasters (CRED), United Nations Office for Disaster Risk Reduction

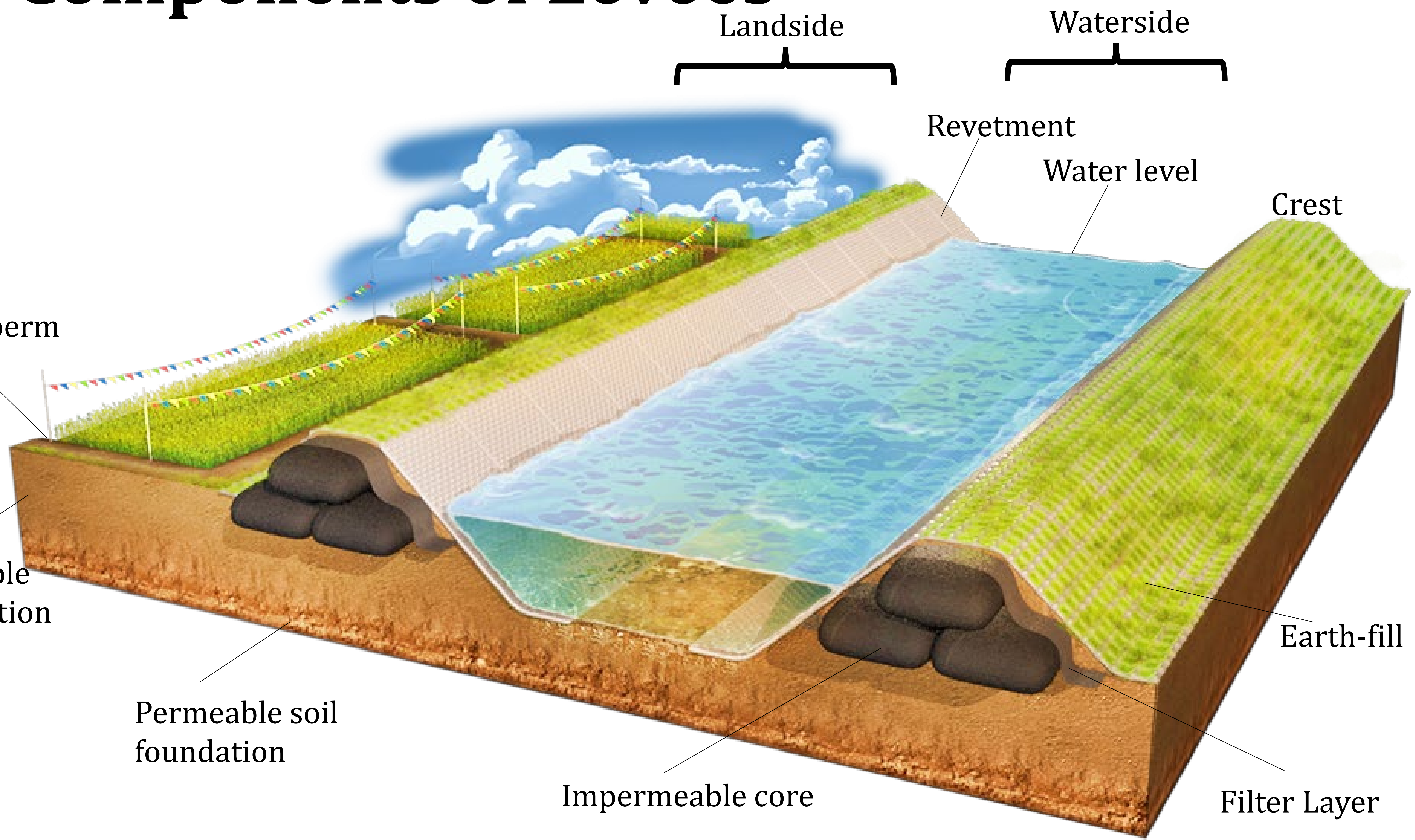
Flood Management Approach



Source: Allsop et al. (2009)

Structural Approach : Levee / Embankment

Main Components of Levees

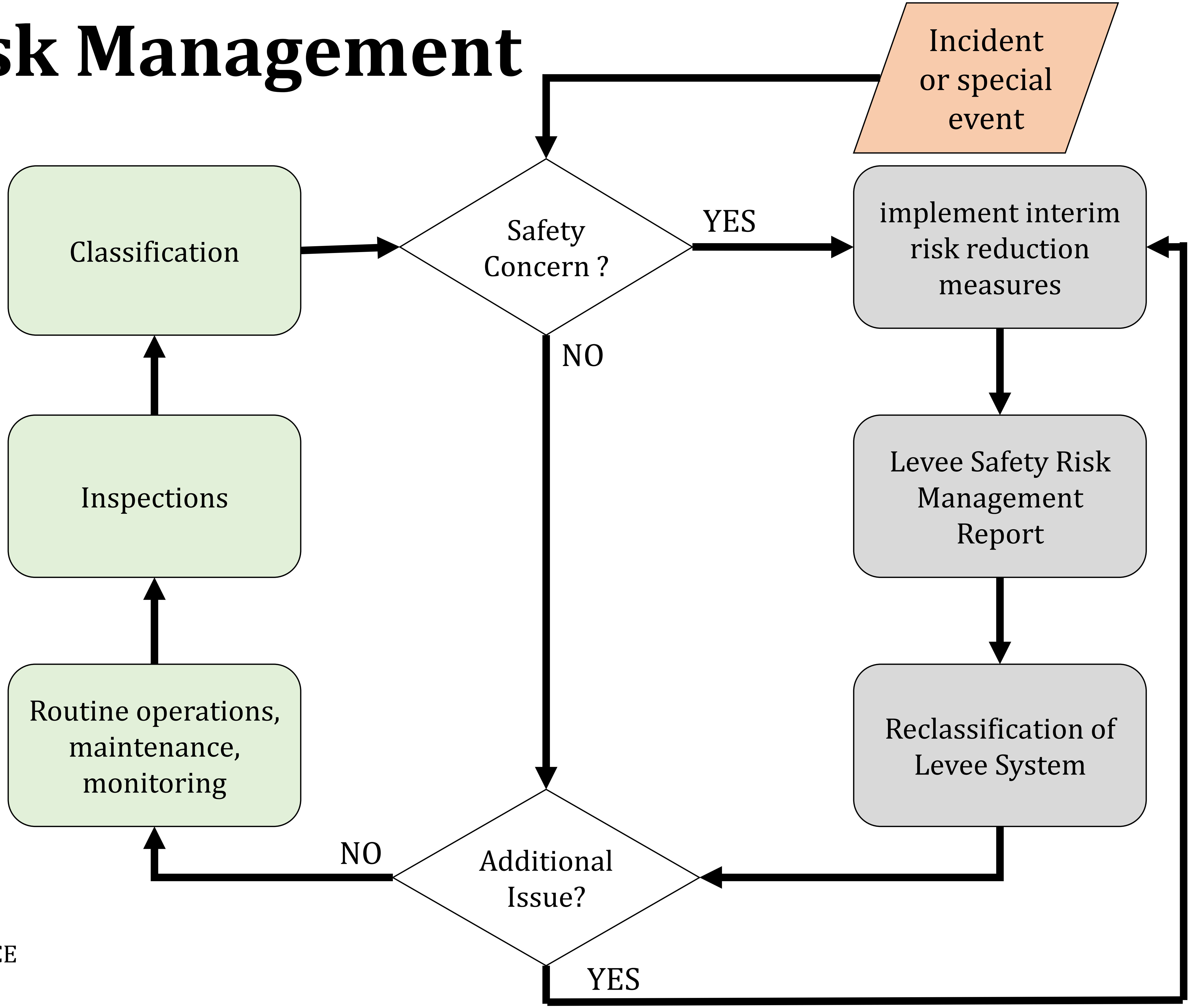


Source: adapted from https://www.geoace.com/app/Riverbank-and-Channel-Protection/Levees-and-Dikes

Levee Safety Risk Management

Key Point

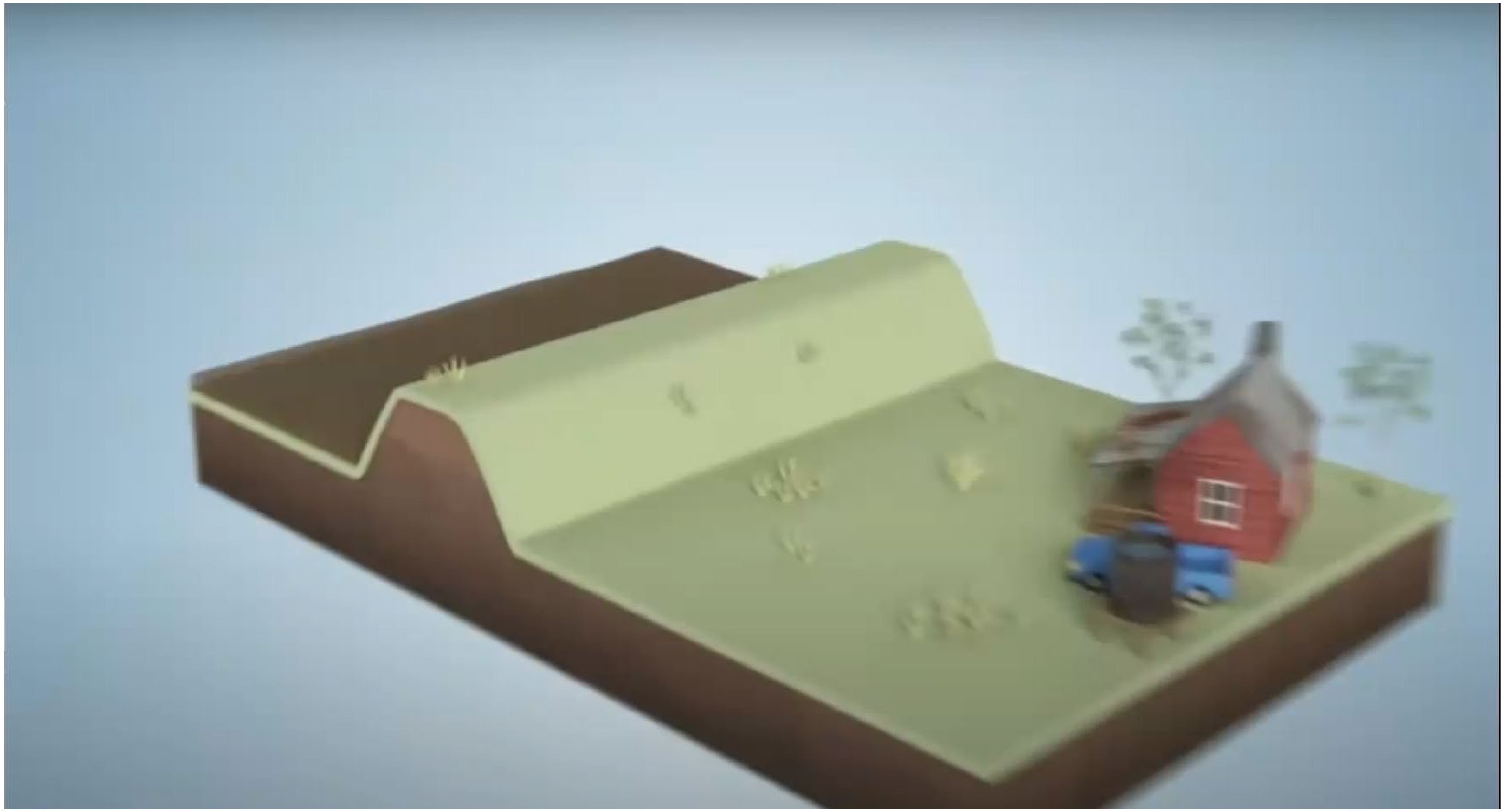
*Typical routine activities are combination between **field inspections** and **screenings**. It must be remembered that although **flood risk may be reduced** by such an approach, **it can never be removed completely**.*



Source: Recommended framework adapted from USACE (The International Levee Handbook)

Disaster Potential of Embankment System

1. Overtopping
2. Cracking
3. Piping, Tree, Weather, and Animal/Human Activities



Courtesy : YouTube NSW SES accessed at 14/03/2023

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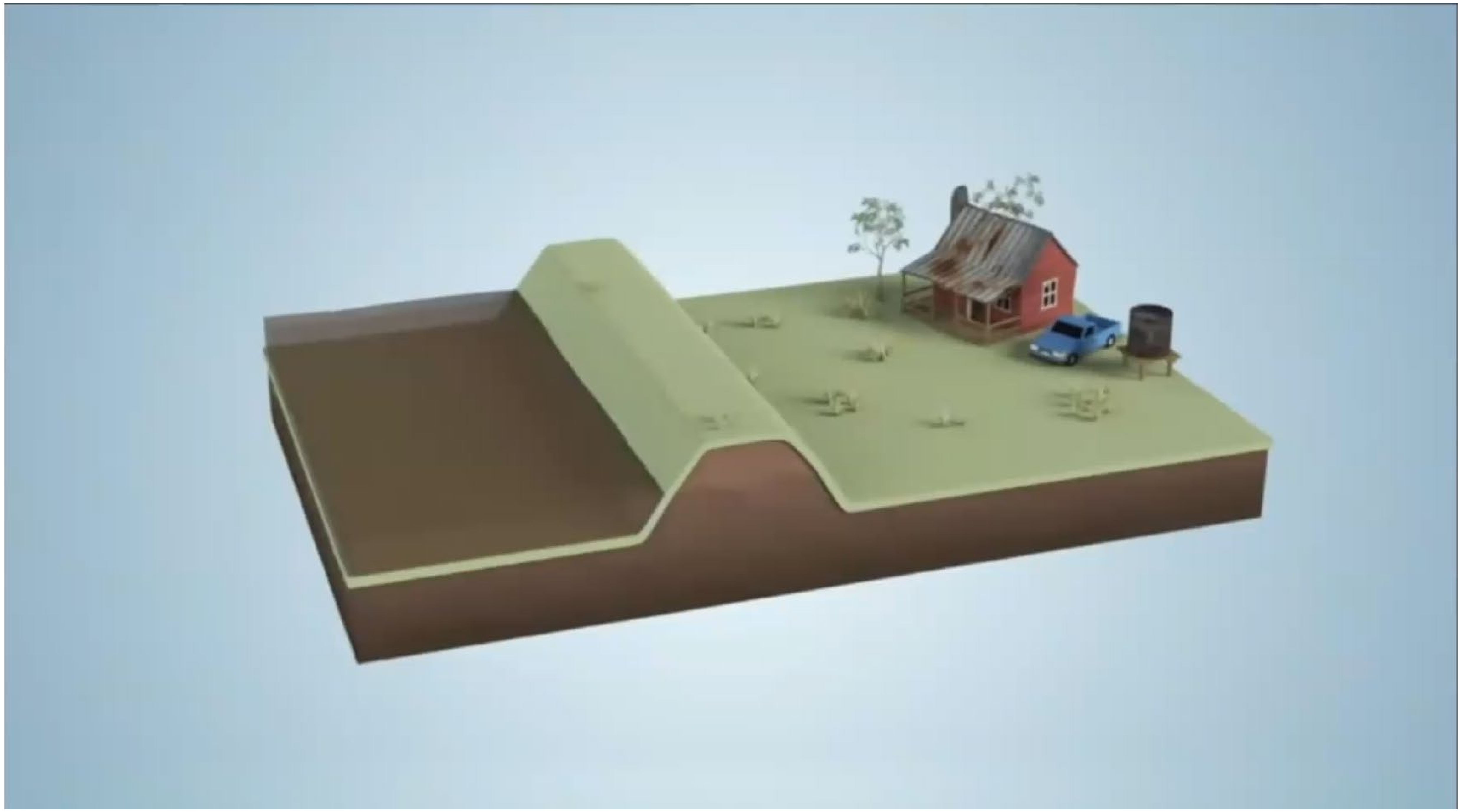

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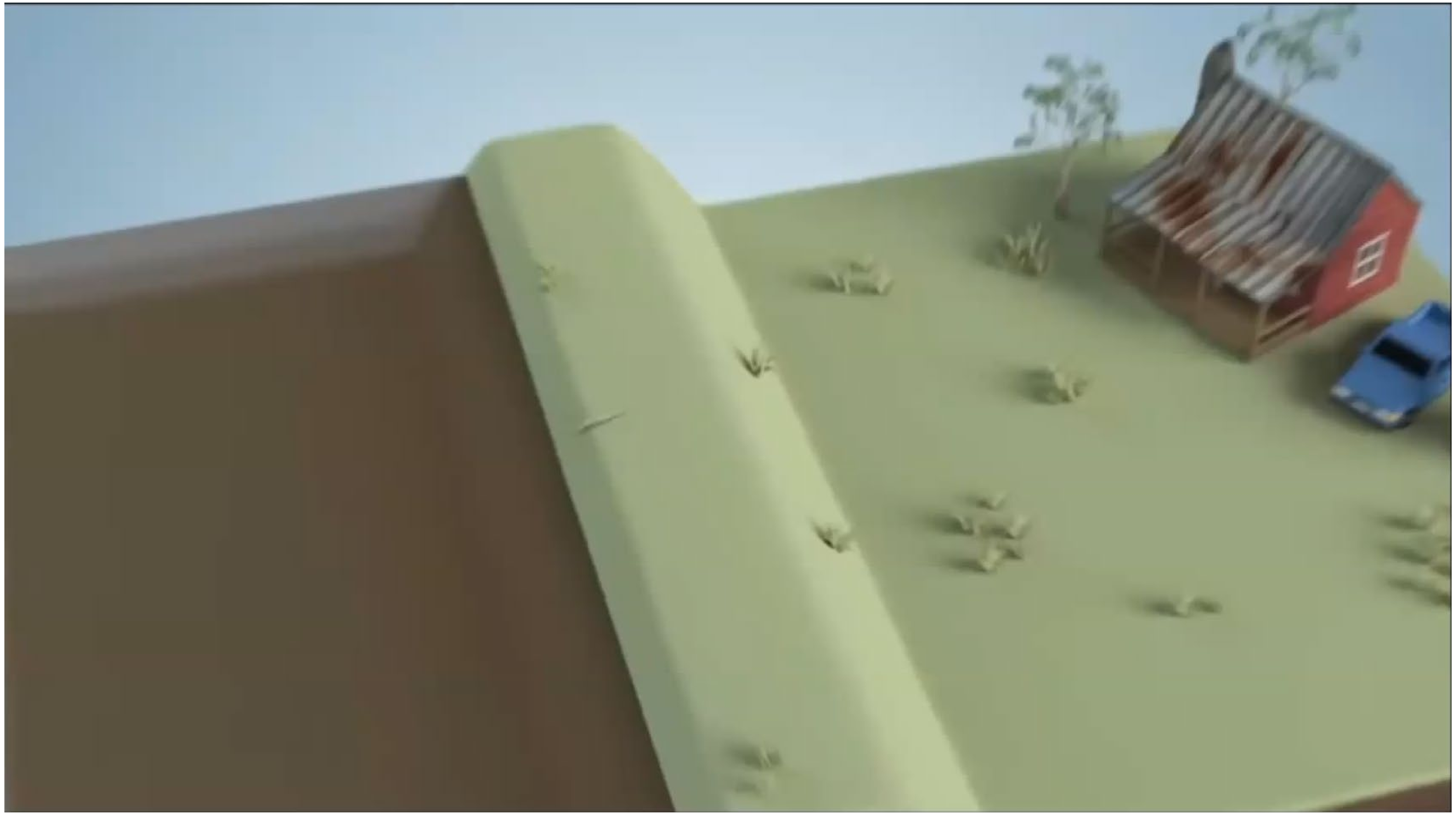

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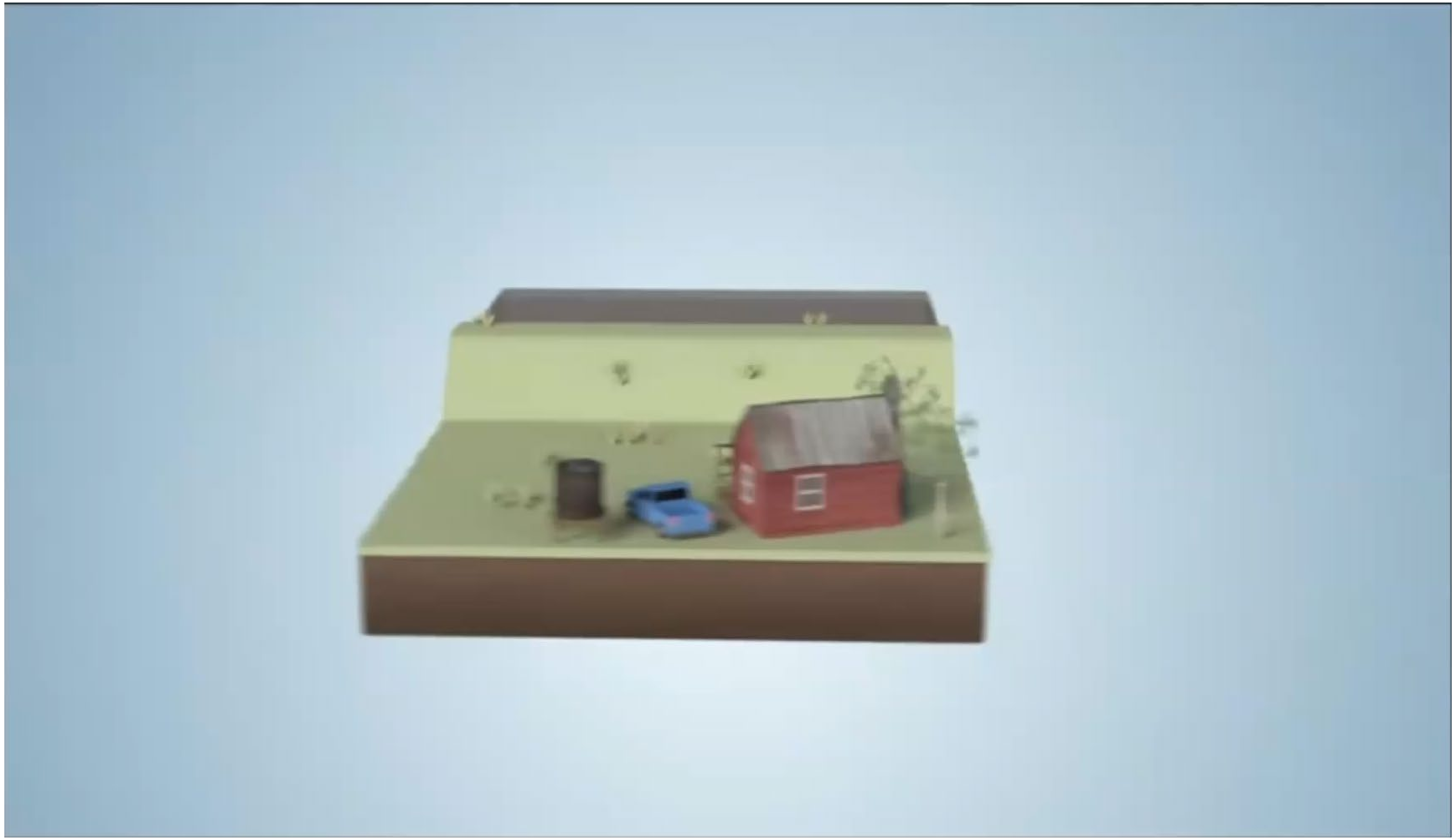


Courtesy : YouTube NSW SES accessed at 14/03/2023

Main Challenge in the Embankment System

Key Point

It is essential for mitigating flood embankment before extreme flood events and ensuring sustainable flood and coastal defence [1].

The rate of deterioration can be detected in high accuracy through long-term observation and inspection.

The traditional inspection methods by visual monitoring are inefficient and inaccurate.

The use of algorithms and techniques based on remote sensing can help local government to identify vulnerable levee sections and repair them rapidly with lower costs [2].

Source: Morris et al., 2007 (1), Mahrooghy et al., 2015 (2)

Key Point

"The structure and components of the embankment should be in a ***sustainable design****, consider the effect of* ***water loading****, and understanding* ***climate variability****."*

Goal

This research aims to calculate the robust deterioration rate of soil embankment, particularly along the Thames and Humber Rivers, and predict future potential failure.

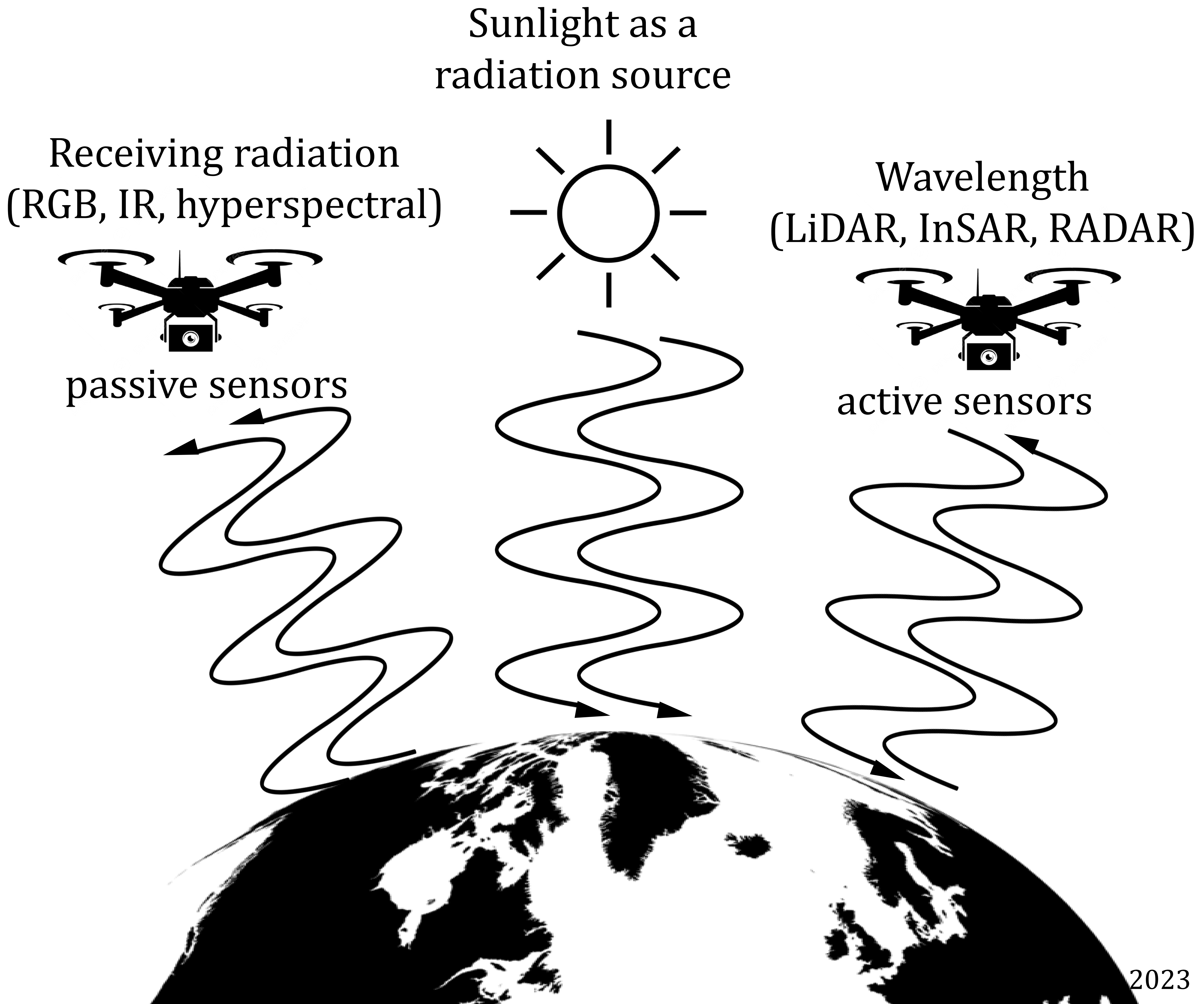
Objective

- To calculate deterioration rate of the embankment
- To project future potential of the embankment structure considering climate change approach

Unmanned Aerial Vehicle (UAV)

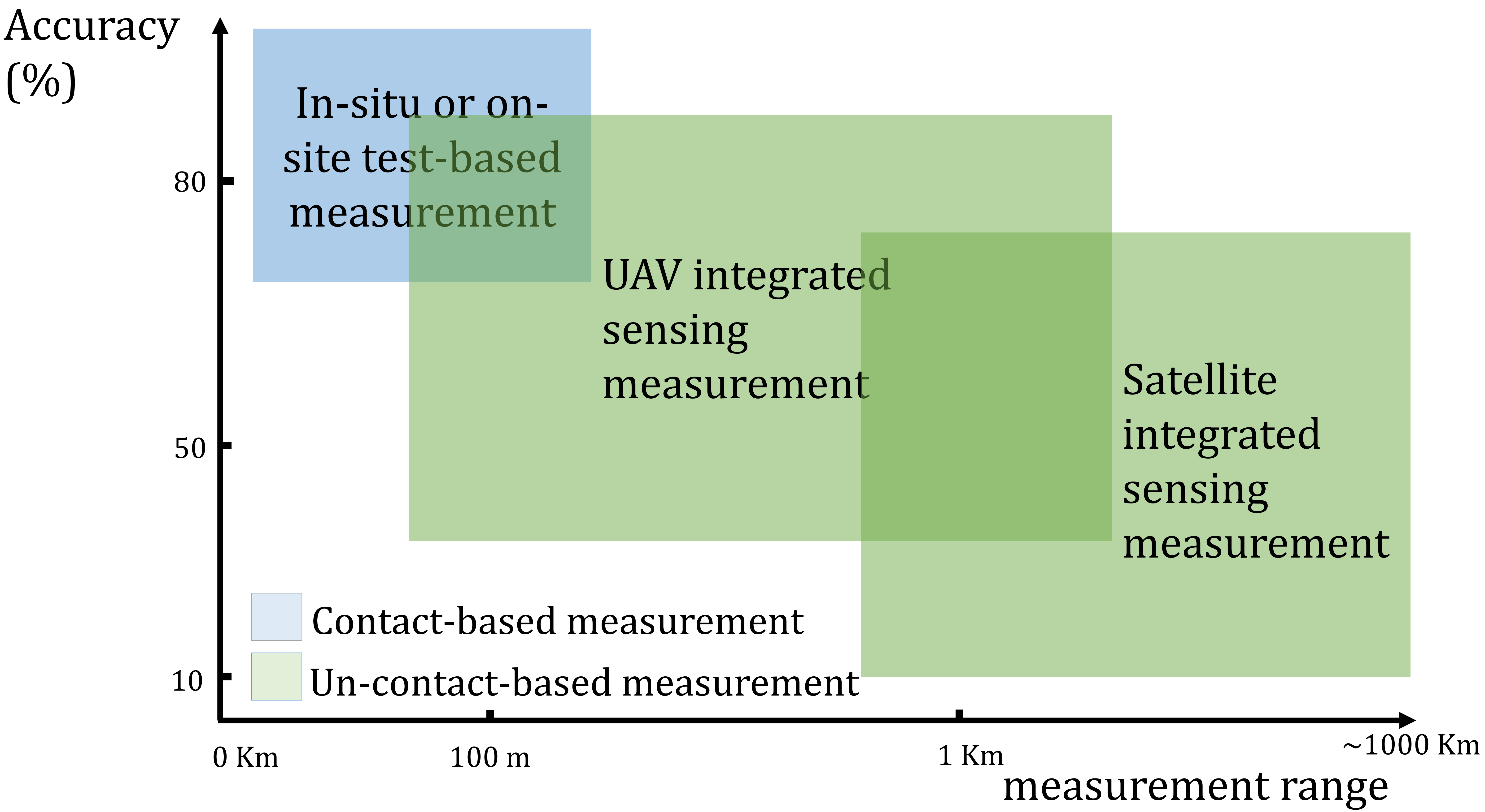
Advancements in sensor and UAV technologies have facilitated :

- more **intelligent monitoring** and inspection of sites prone to failure.
- provide both **in situ and satellite measurements** with sufficient accuracy.
- **fewer spatiotemporal constraints** and **offer superior resolution** with reduced data gaps compared to satellite-based measurements.



Source: Mahrooghy et al., 2015

Comparison of UAVs Sensing Measurement



Source: Kim et al., 2023, Colomina et al., 2014 (UAV), Lillesand et al., 2015 (On-site Test), Congalton et al., 2009 (Satellite)

Previous Research

LiDAR can be used to monitor landslides, rockfalls, and debris flows by generating an accurate slope map [1], calculating instability signs of landslide [2], and understanding the landslide processes and reducing related losses [3]

Key Point

Utilising deep learning approach to calculate probability deterioration rate of the embankment system.

Note

Main factor of the quality of the application results of the LiDAR is **spatial resolution**, including sensor equipment performance, measurement distance, vegetation canopy density, and the **filtering algorithm** effect of the point cloud.

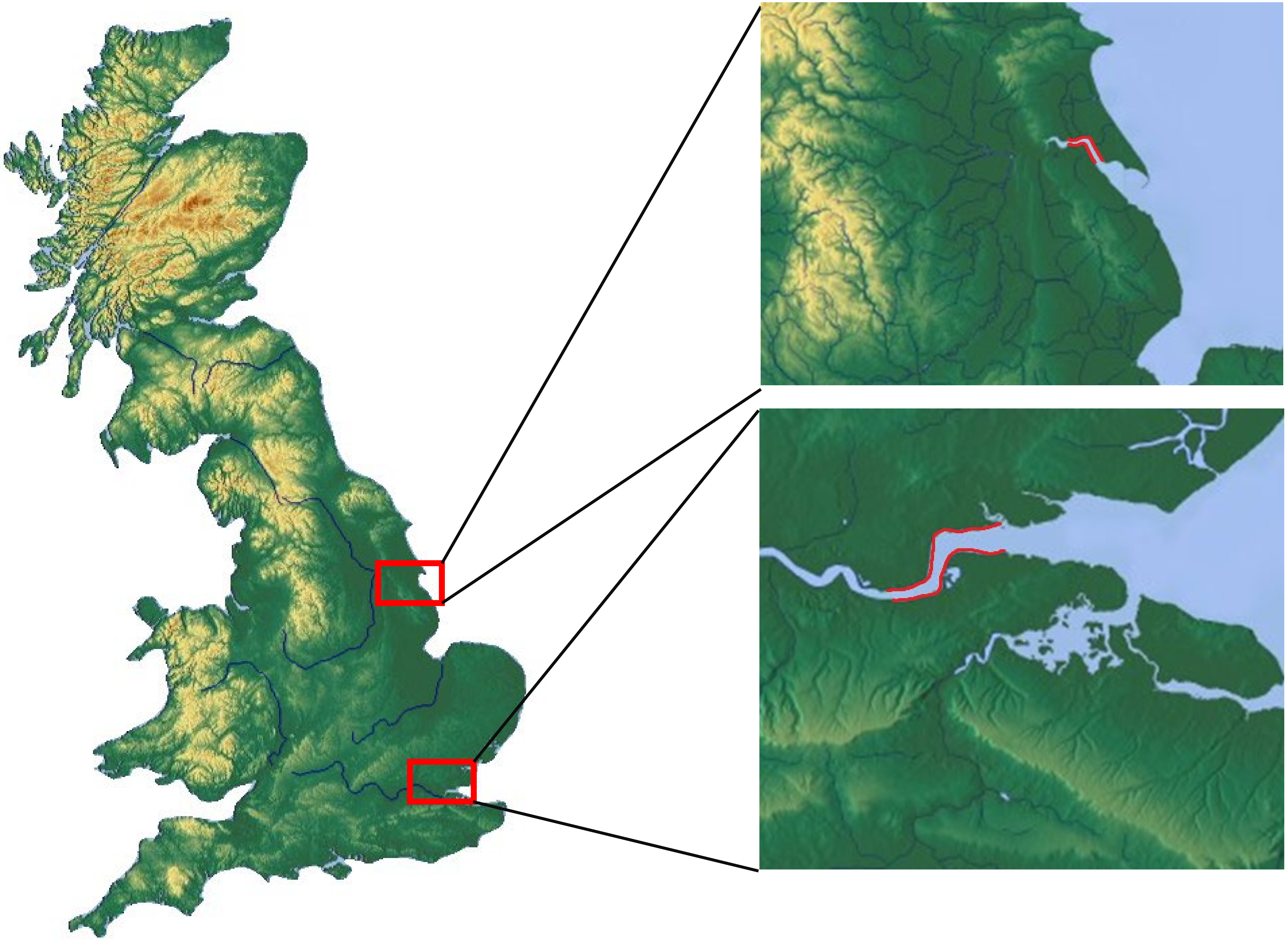
Solution

- Develop mathematical calculation as an input in computational methods that enable to identify potential failure on embankment system
- Develop a statistical approach to project future potential disaster under climate change consideration

Previous Research

Previous Research

Study Area



River Humber

The Humber is about 64 km long, the River is lined by the major ports of Kingston upon Hull, Grimsby, and Immingham.

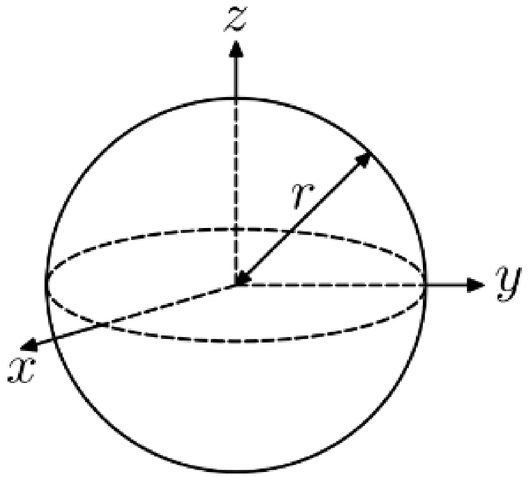
River Thames

The Thames is the largest river in England, with a total length of 354km, housing a fifth of the UK population, including London.

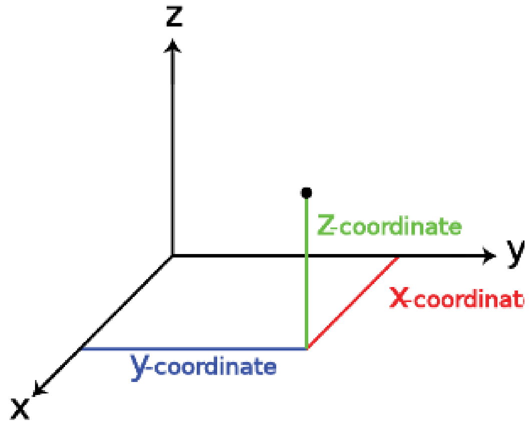
LiDAR

Key Point

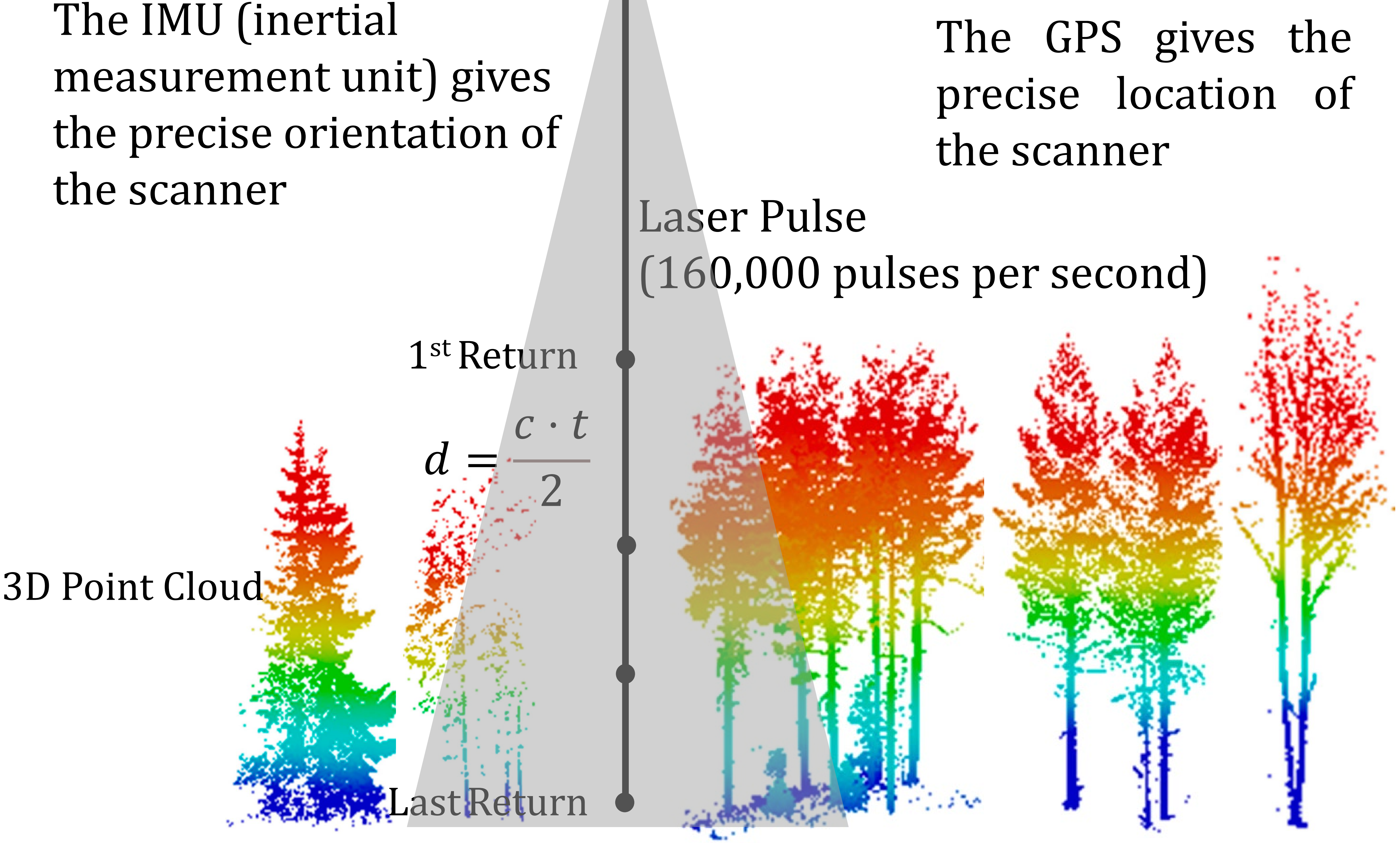
LiDAR excels in capturing data with both **high spatial** and **spectral resolutions**, facilitating the generation of **precise classifications**, detection of surface alterations, environmental monitoring, and various other applications.



The IMU (inertial measurement unit) gives the precise orientation of the scanner



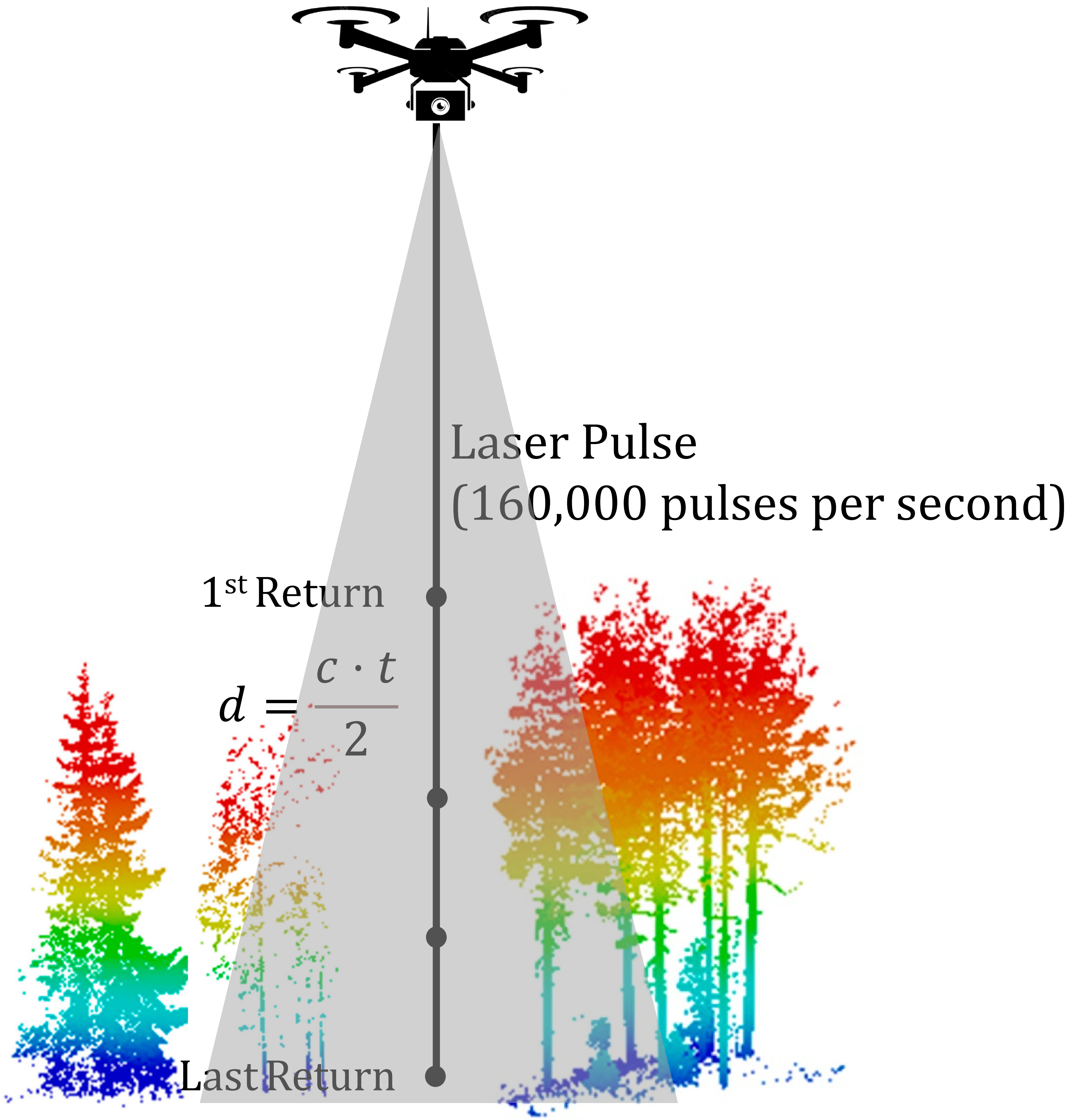
The GPS gives the precise location of the scanner



Source: Kahraman et al., 2021

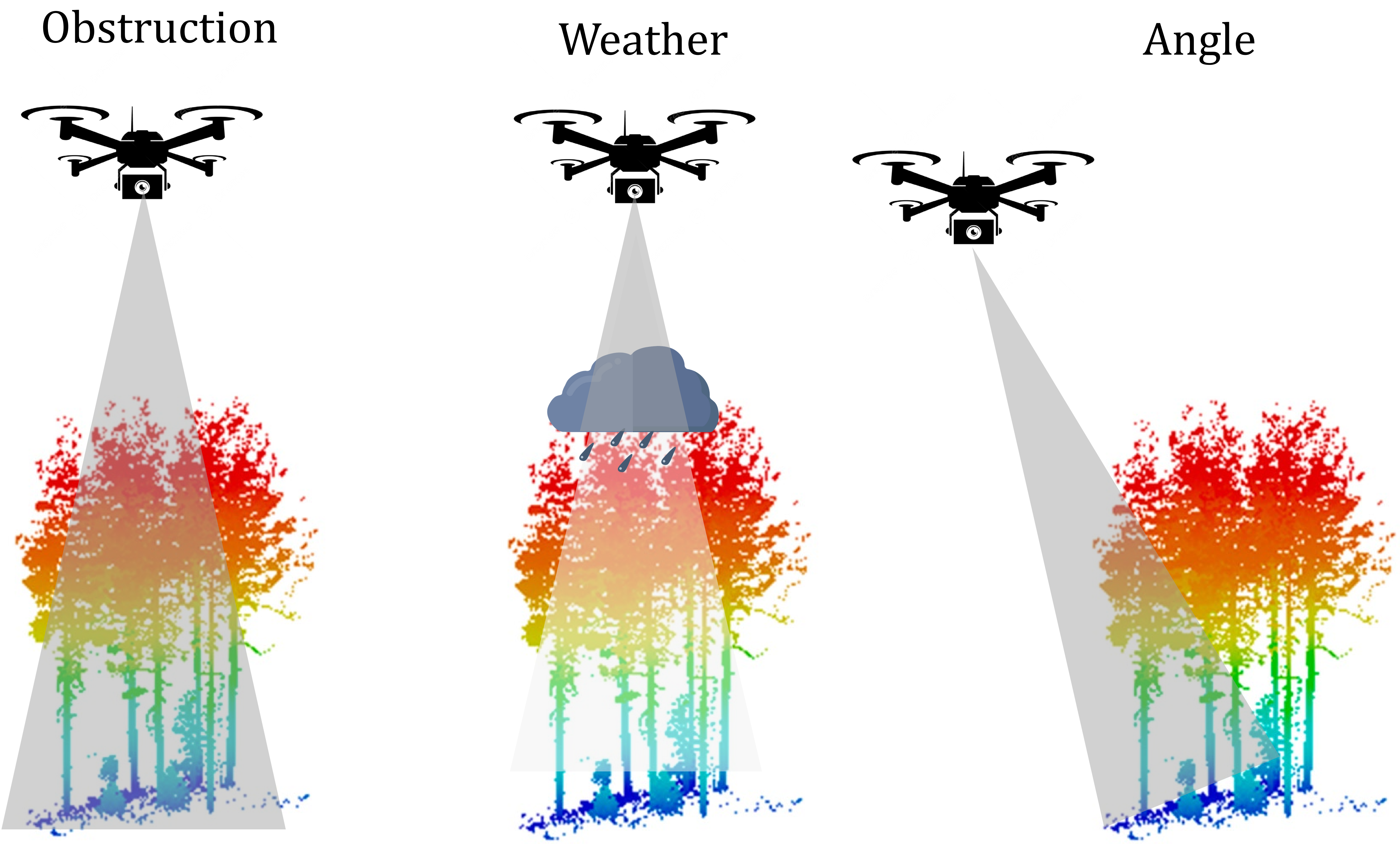
LiDAR

- One pulse may record 1-5 return pulses
- The returned pulses is classified into one or more discrete returns X, Y, Z intensity
- Optical frequency is between Green and near Infra-Red (wavelengths from 532 to 1064 nm)
- Can operate both day and night, some limitations may occur



Source: Kahraman et al., 2021

LiDAR Limitation

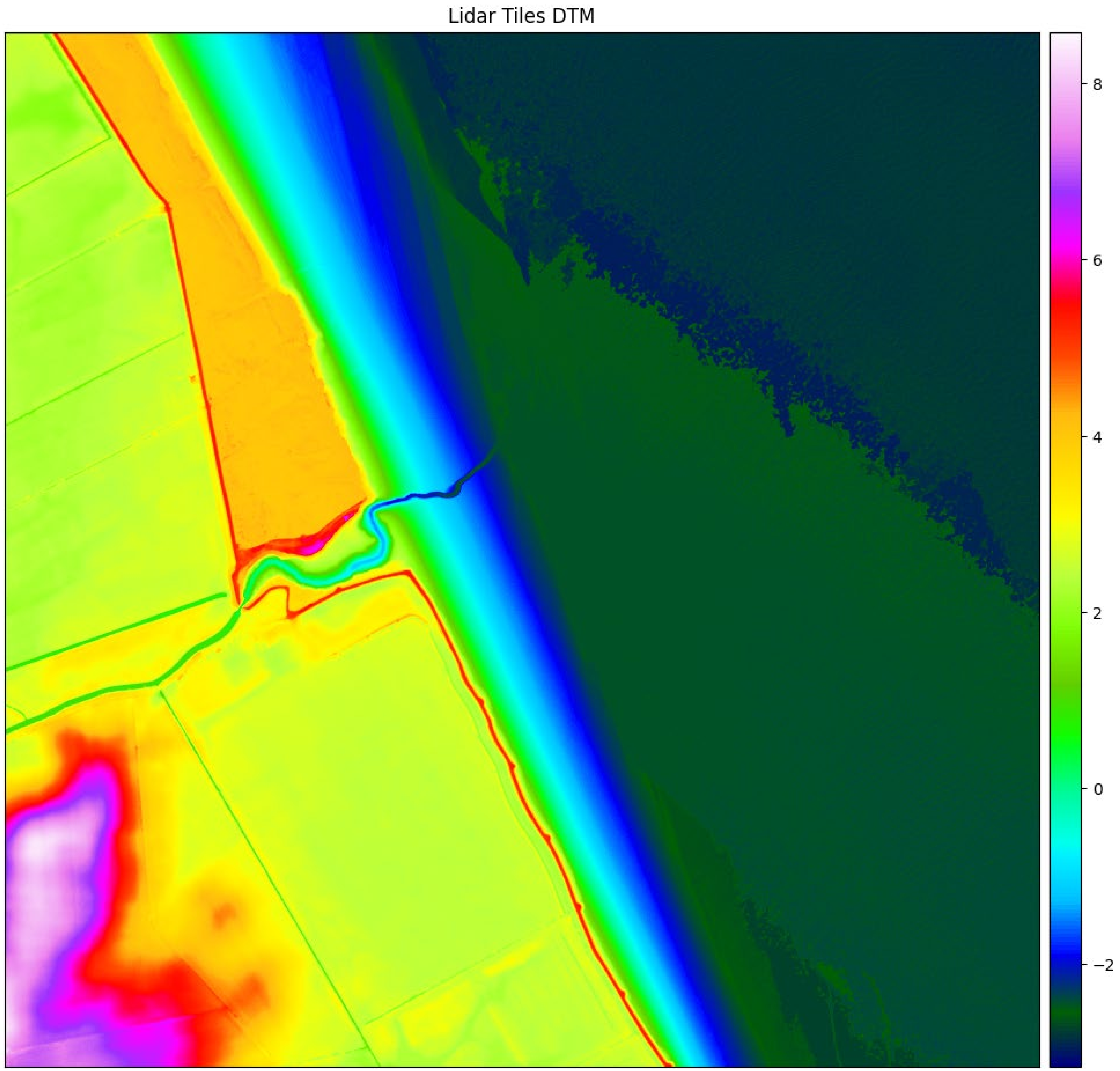


LiDAR Output

1. LiDAR DTM

2. LiDAR DSM

3. LiDAR Point Cloud



Source Data : DEFRA
Location : East Halton Skitter - Immingham
Tool : Google Colab - Python

LiDAR Output

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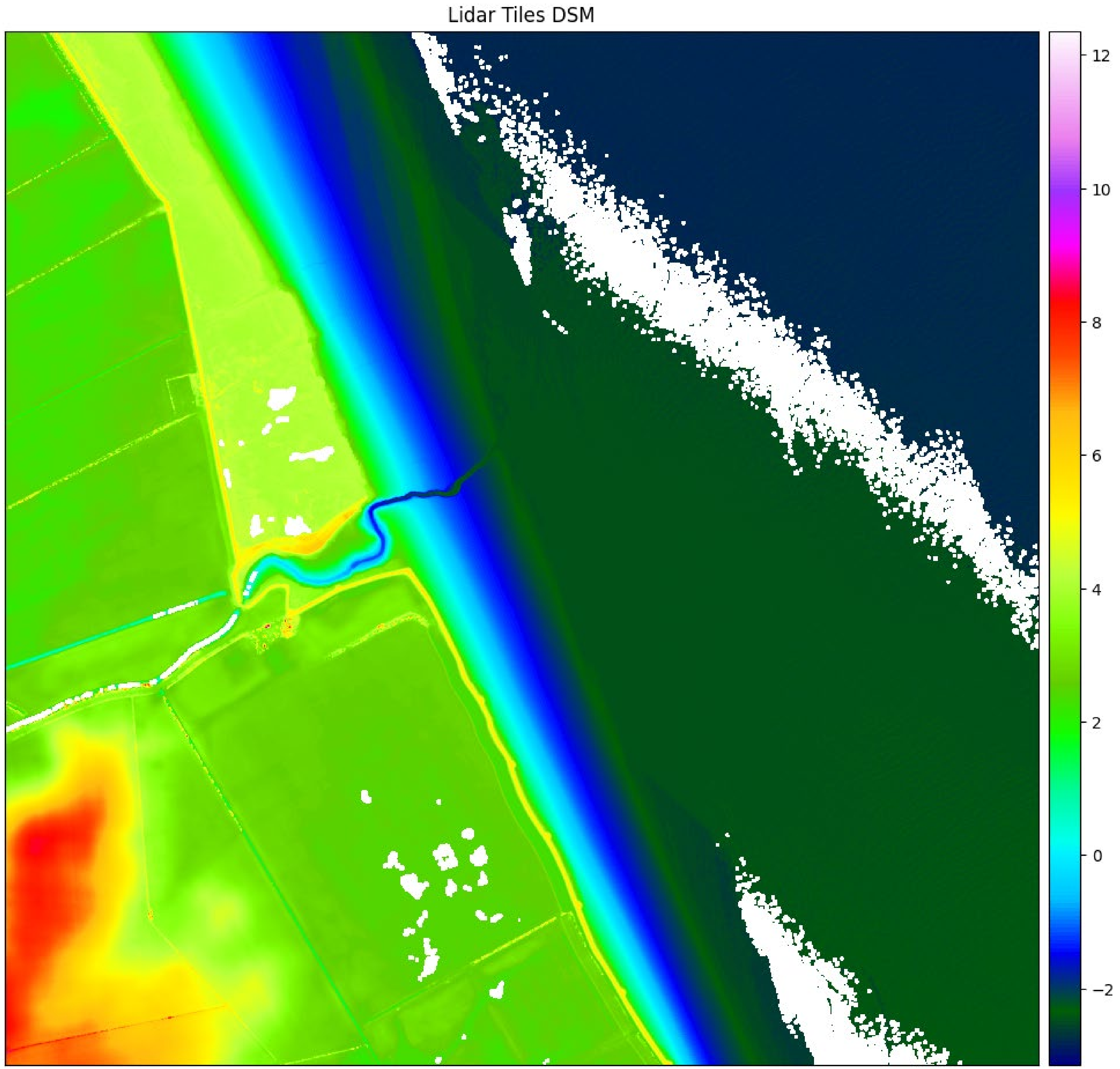
2. **LiDAR DSM**
3. LiDAR Point Cloud



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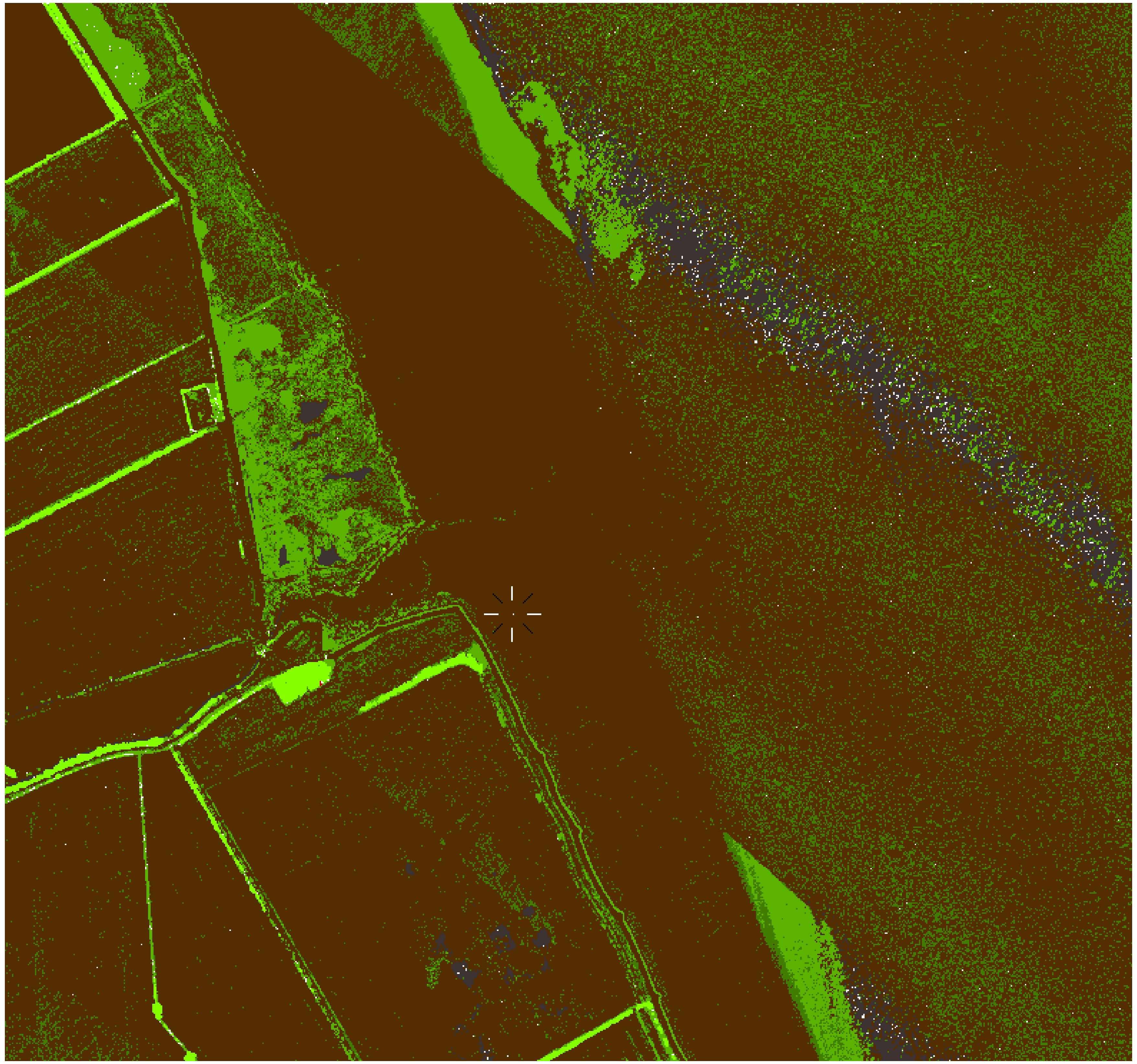
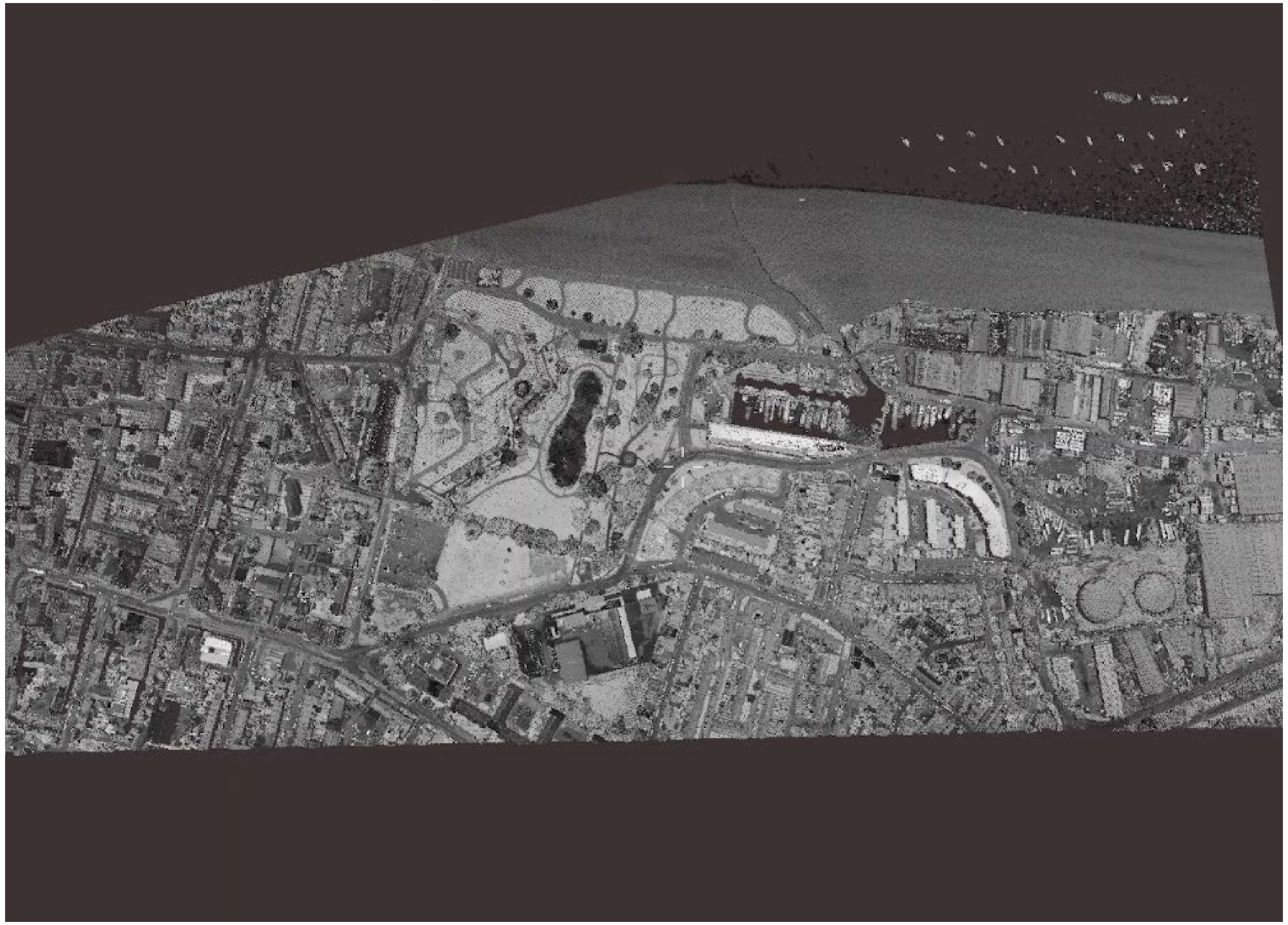
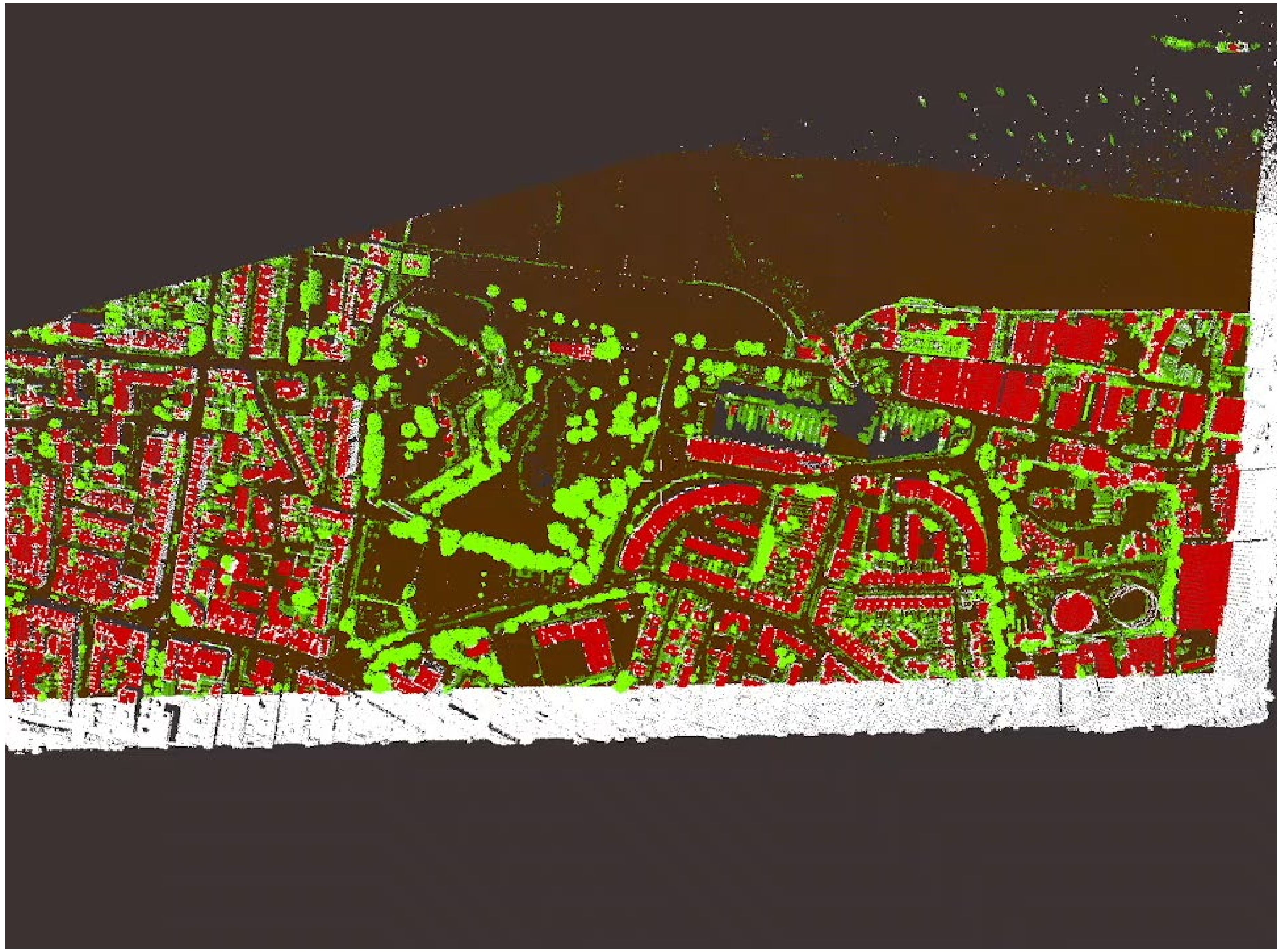


Source Data	:	DEFRA
Location	:	East Halton Skitter - Immingham
Tool	:	Displaz

LiDAR Intensity Data



LiDAR Classification



Source Data	:	DEFRA
Location	:	Residential Area in East Tilburn
Tool	:	Displaz, CloudCompare

LiDAR 3D Visualization

Milestone of Methodology

Lidar Data Acquisition and Pre-processing

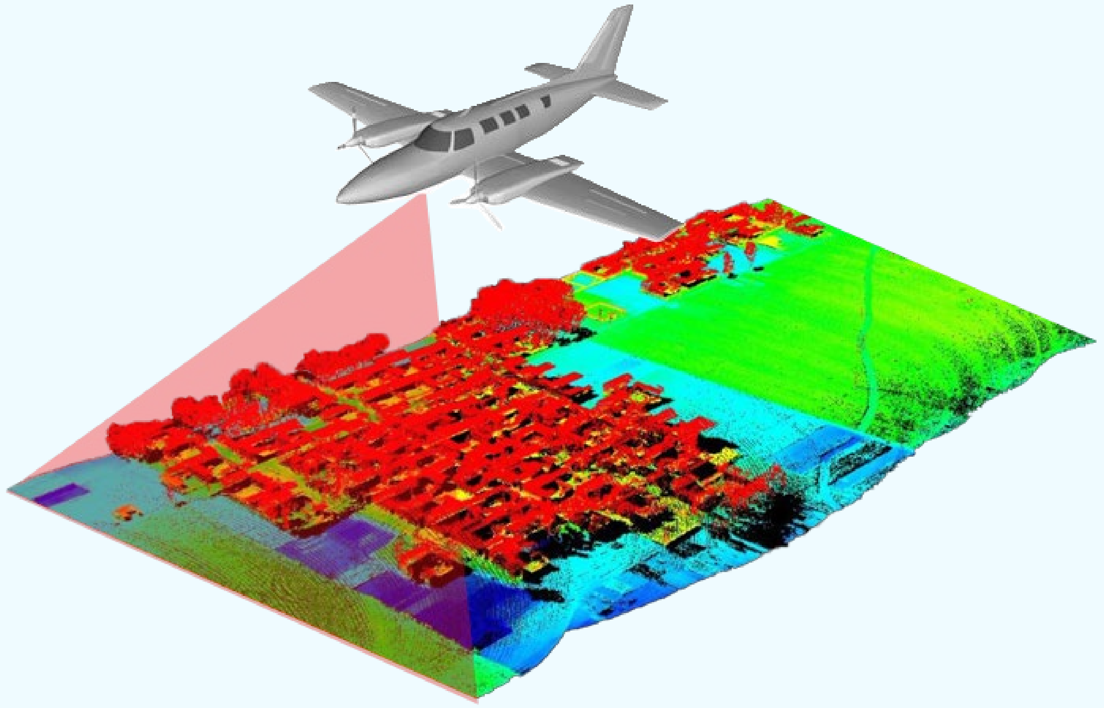
Gathering the data sources and comprehend the data typology.

Segmentation and deterioration analysis

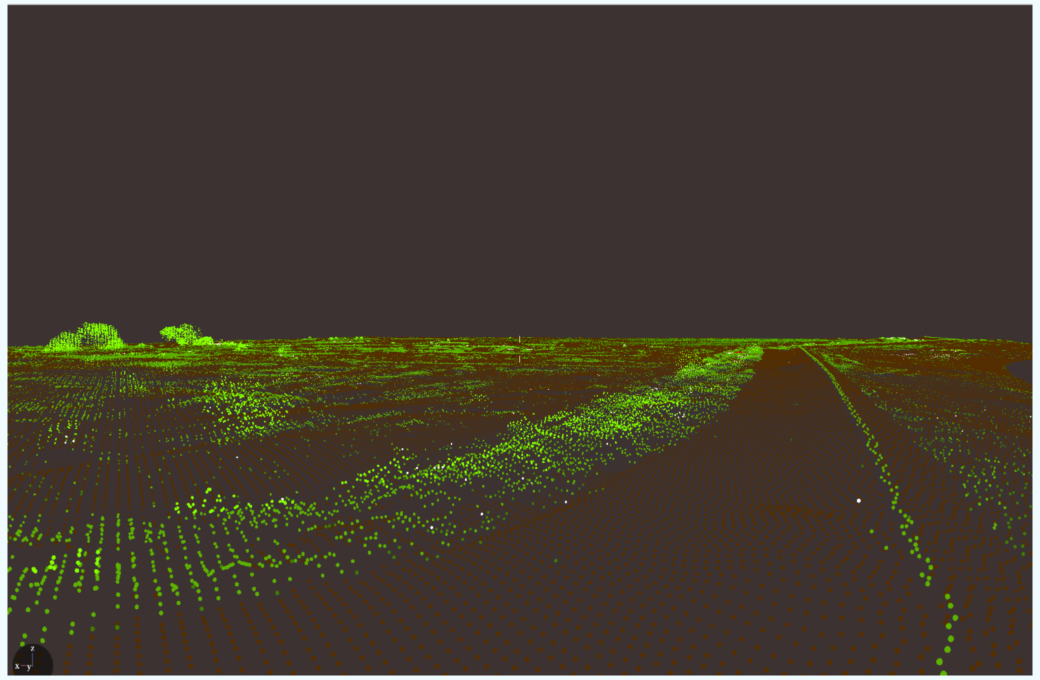
To isolate specific research areas and identify key features from the segmented data relevant to assessing the health and stability of flood embankments.

Predicting and Analysing Future Potential

To project the embankment deterioration rate by applying real-world scenarios to inform decision-making processes in civil engineering.



Source: LIDAR - lidar.co.id



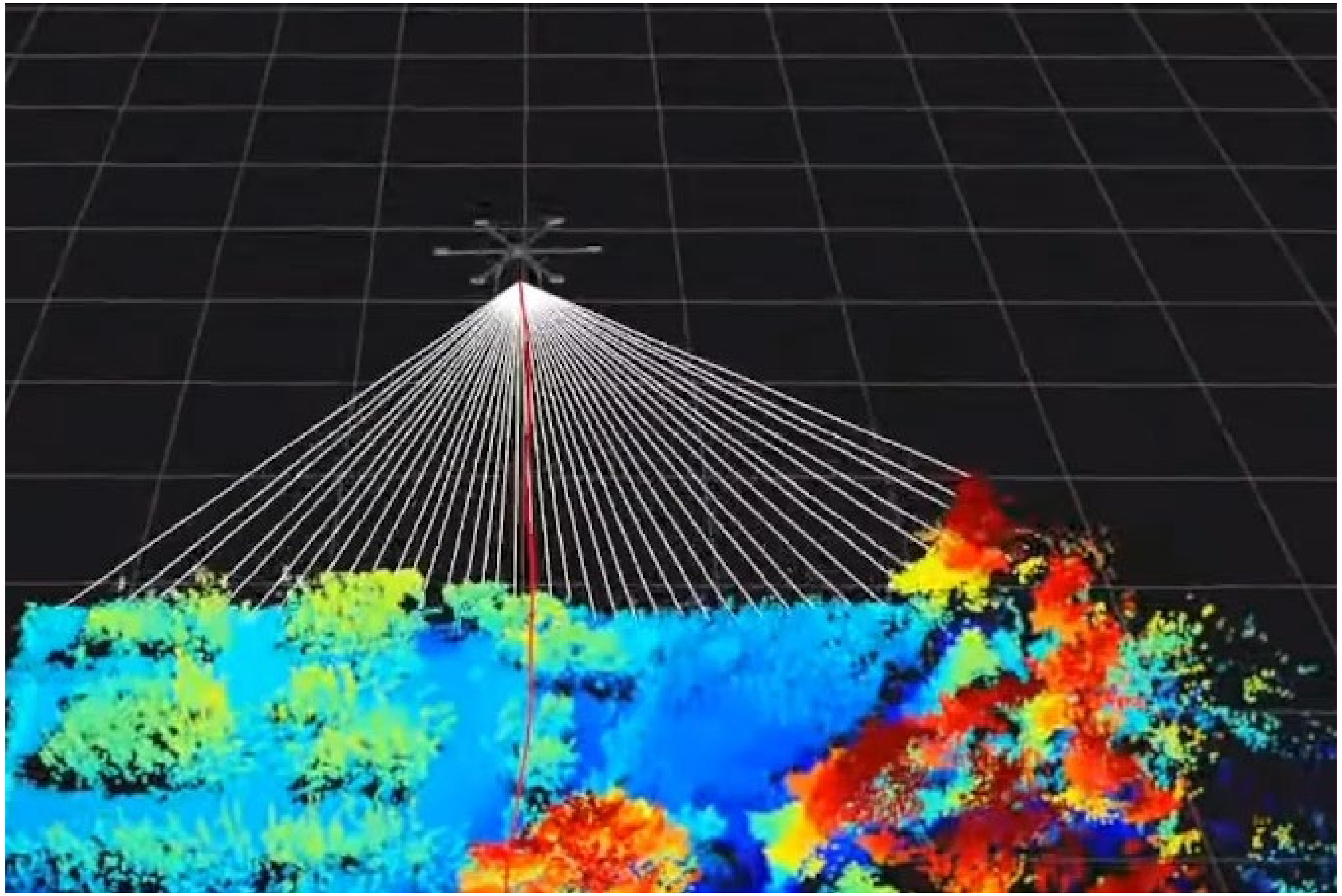
Source : LiDAR Data DEFRA
Tool : Displaz
Location : Lower Hope Point - Rochester

Source : Google Street View
Location : Lower Hope Point - Rochester

Lidar Data Acquisition and Pre-processing

Steps:

1. Project Planning and Preparation
2. Sensor selection and configuration
3. Platform deployment (aircraft / ground vehicle / tripod-mounted, or else)
4. Data acquisition
5. Quality control and assurance
6. Data processing



Segmentation and Deterioration Analysis

Key Point

A segment-based approach offers a systematic and effective methodology for analysing scalar field data representing surface features to detect embankment cracks

NOTE

Divided into segments or regions of interest based on geometric properties, such as curvature, normal vectors, or point density.

Application

Identifying and analysing specific object recognition, scene understanding, and semantic segmentation.

Advantage

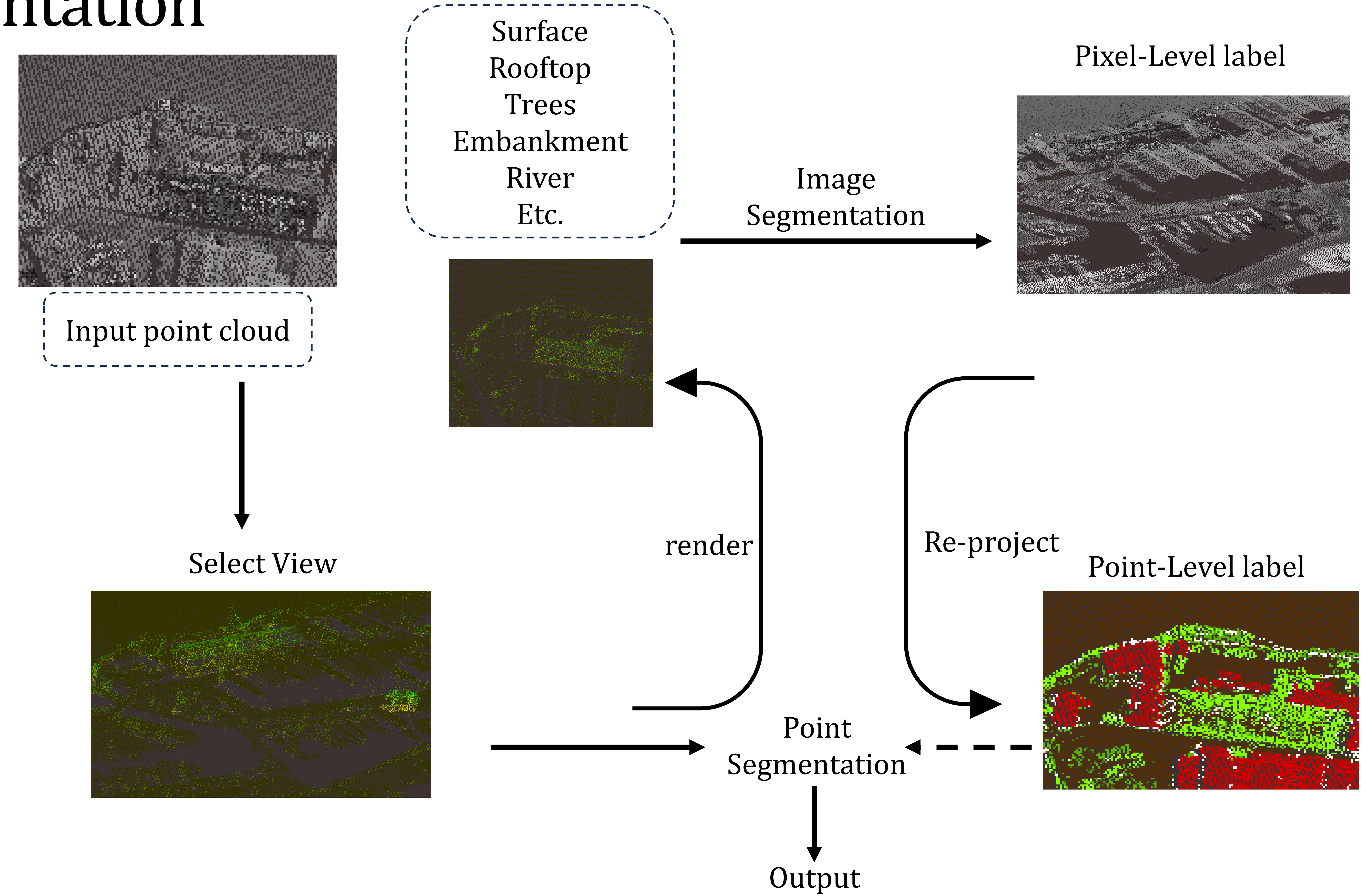
Localised analysis, flexible, and interpretable

Drawback

Segmentation sensitivity, over-segmentation, and computational complexity

Source: Cheng et al., 2018

Segmentation



Climate Projection

Key Point

3D point cloud data provided by a terrestrial laser scanner could play an interesting role for flood mapping.

Challenge

No one single dataset in the public domain is properly detailed to describe for primary research.

Water loss from subgrade soil subjected to dry weather is possible to cause soil cracking. On the contrary, intruded water will cause failures because of the wetting swelling or collapsing of the subgrade soils.

Solution

Currently, the risk of floods is mapped on a global scale using technology like satellite imagery and remote sensing. LiDAR derived flood inundation model can be used to simulate flood hazard estimation using probability analysis and flood scenario.

Source: Johnston et al., 2021

Reference

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Reference

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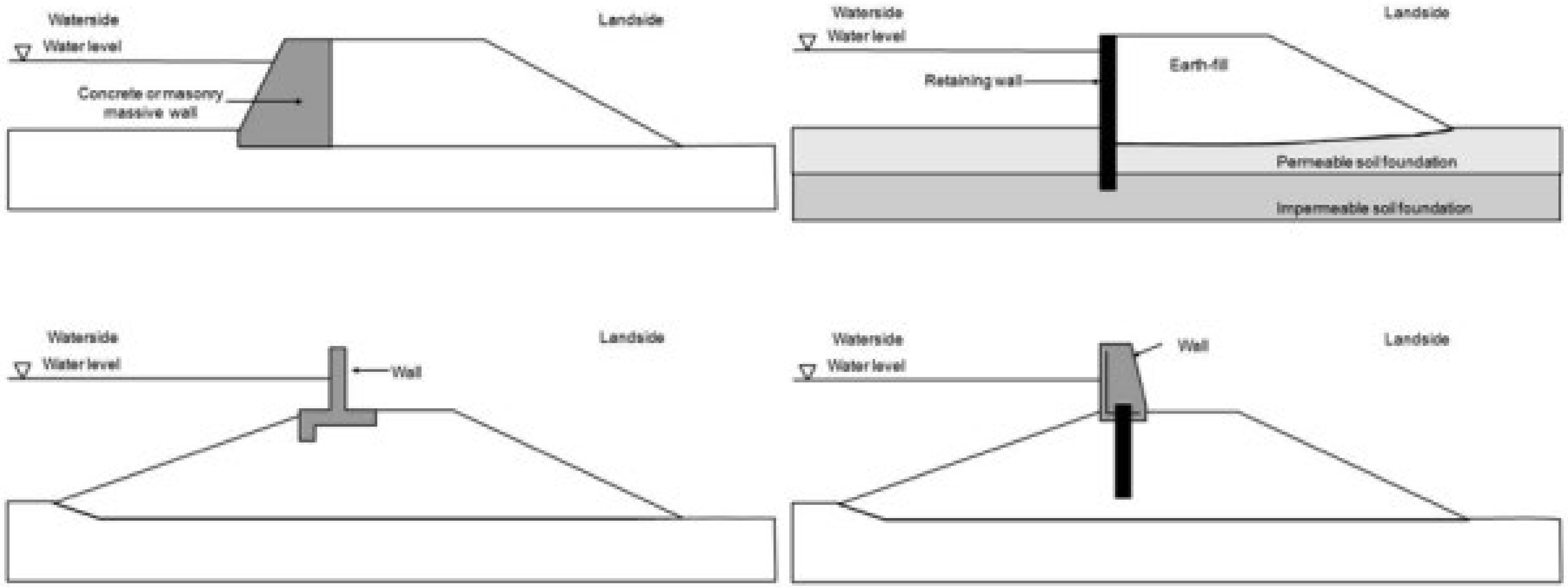
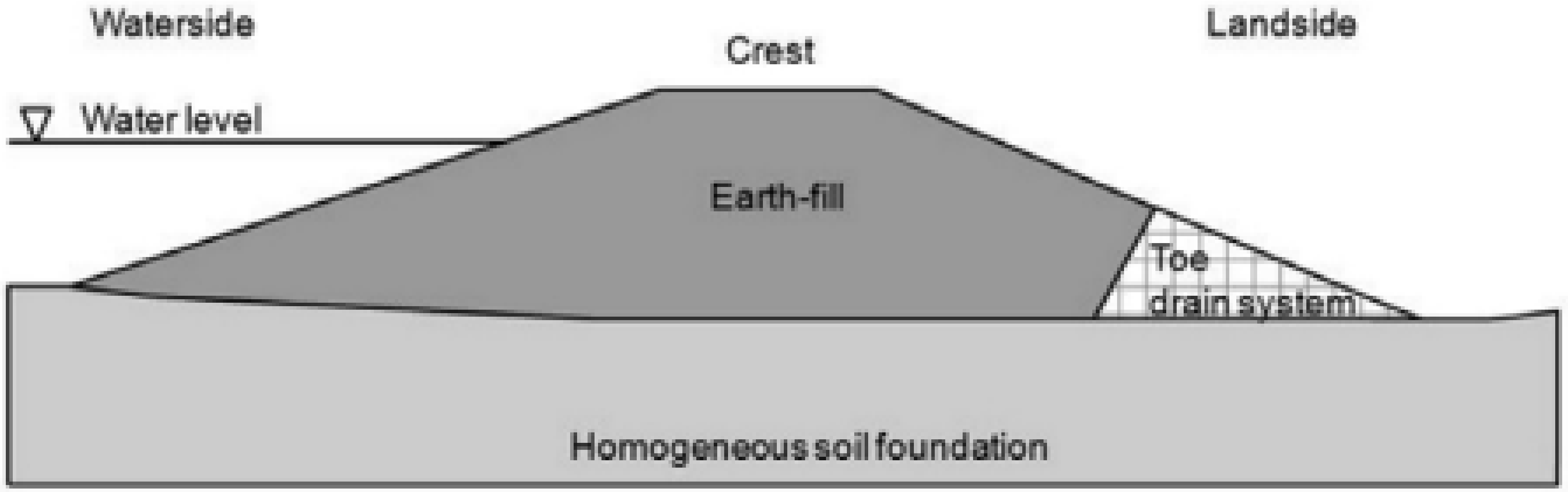
Question ?



Types of walls



Homogeneous levee on homogeneous soil foundation