Assessing the Quality of Greenspaces in Edinburgh Using Vegetation, Connectivity, and Existing Flood Defence Infrastructure as Indicators of Flood Risk

Capital Greenspace Project 2024

Group 6 – Flood Management

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Abstract

The aim of this study is to assess the quality of Edinburgh's greenspaces through their relationship to environmental deprivation and flood management. Data sources include Scottish Index of Multiple Deprivation, the British Geological Survey, and the Ordnance Survey. The study selected 30 greenspaces in Edinburgh with the highest and lowest levels of deprivation and flood risk areas, in order to assess their quality. Six metrics are evaluated to determine greenspace quality: land cover, flood infrastructure, presence of water, slope, elevation, and connectivity. Then investigate the correlation between total score and SIMD and flood risk. In addition, the study introduces 4 different weightings allocation methods, recalculates the total score by adjusting the weightings of 6 variables, and further conducts correlation analysis.

The results show that the correlation between the initial score and the deprivation coefficient is positive and the correlation between the initial score and the flood risk coefficient is negative, but the result is not significant ($p>0.05$). However, the correlation still suggests that the improvement of greenspace quality has the possibility of inhibiting the degree of deprivation and flood risk. The future research direction may need to make the following improvements: increase the sample size of greenspace in Edinburgh and select cities with less greenspace in the same region for additional analysis (Glasgow, Dundee, etc.), and compare them with Edinburgh.

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1. Introduction

In collaboration with the Central Scotland Green Network (CSGN) and the City of Edinburgh Council, this study aims to comprehensively assess the value of greenspaces within Edinburgh city limits. Environmental deprivation in relation to greenspace refers to the unequal distribution of access to recreational areas or green infrastructure and their benefits that disproportionately affect marginalised communities (Pearce *et al.*, 2011). Deprivation can manifest in many ways, such as poor air quality and pollution, higher flood risk, limited opportunities for outdoor access that contributes to health disparities among various socio-economic levels (Hazell, 2020; Pearce *et al.*, 2011). By identifying and characterising greenspaces based on their connectivity and infiltration capacity, this report aims to address environmental quality and accessibility in terms of flood risk with the following research questions:

- What is the quality of greenspaces using vegetation, connectivity, and existing flood defence infrastructure as indicators of flood management?
- Is there a difference in how effectively greenspaces mitigate flood events in areas with high deprivation compared to areas with low deprivation?

The role of vegetation cover in flood management and risk reduction is critical (Milazzo *et al.*, 2023). Vegetation cover in greenspaces absorbs rainfall and reduces surface runoff, a vital element in preventing urban flooding (Milazzo *et al*., 2023). Further, connectivity of greenspace has the potential to create integrated drainage systems that contribute to mitigating flood events (Staccione *et al*., 2024). Such analysis garners insights into the quality and extent of greenspaces, the populations they serve, and the areas in most need of intervention. Ultimately, this report seeks to inform funding and policy decisions that increase equity and environmental sustainability throughout Edinburgh's diverse communities.

2. Literature Review

The relationship between environmental deprivation and natural flood management is a complex and multi-faceted issue. Much research has been done into environmental deprivation, which is typically defined as the lack of access to physical environmental conditions that can positively contribute to health and well-being, or high-quality greenspaces (Centre for Research on Environment, Society and Health, 2024). The benefits of greenspaces for flood management are only beginning to be acknowledged, but their accurate assessment is crucial towards understanding their role in this area (Schuch *et al.*, 2017). Studies show that enhancing green infrastructure makes a significant contribution to urban flood management by increasing vegetation cover and groundwater storage (Zimmermann *et al*., 2016). Vegetation significantly mitigates flood risks by enhancing water absorption and reducing surface runoff. Trees improve soil structure through their root systems, promoting infiltration and minimising runoff, while grass areas slow down water flow, allowing for greater absorption (Archer *et al.*, 2015; Regüés *et al.*, 2017). Greenspaces have previously been evaluated to determine their overall quality via the use of aerial imagery (Wang *et al*., 2021; Baka and Mabon, 2022). Though these studies quantified greenspaces for their benefits around mental health, it suggests that this methodology is potentially viable in other contexts. With the use of appropriate metrics, greenspaces should also be evaluated for their benefits in flood management in the same manner. For a more in-depth literature review, please see Appendix G.

3. Methodology

3.1 Data sources

Data from the Scottish Index of Multiple Deprivation (SIMD), the British Geological Survey (BGS), and the Ordnance Survey (OS) were used to select greenspaces at highest flood risk in areas of the 30% highest and lowest environmental deprivation. Data from SIMD is from 2020 and shows the multiple deprivation index in deciles. BGS data from 2010 shows the geological indicators of flooding based on their risk of flooding from fluvial or coastal water, each divided into two categories of lower or higher flooding potential. A map of greenspaces in Edinburgh was used from OS. This data is updated every six months and was downloaded in October 2024.

3.2 Site Selection and Map Digitisation

Using ArcGIS Pro, the greenspace data was clipped to show only those lying within the identified flood risk areas. There is inherently limited overlap between SIMD areas and greenspaces, as SIMD is focused specifically on where people live. The clipped greenspaces were divided into SIMD areas based on intersections of the 30% most deprived and 30% least deprived SIMD zones. The deprivation areas were distinguished at this point in the study to ensure equal inclusion of sites across areas for later analysis. Using the overlap of flood risk areas, a total of 30 greenspaces were selected for this study (Figure 1). The sites chosen were the largest 15 greenspaces in areas of highest and lowest deprivation. Greenspace area ranged from 1,508 to 2,813,517 m^2 with a median of 141,286 m^2.

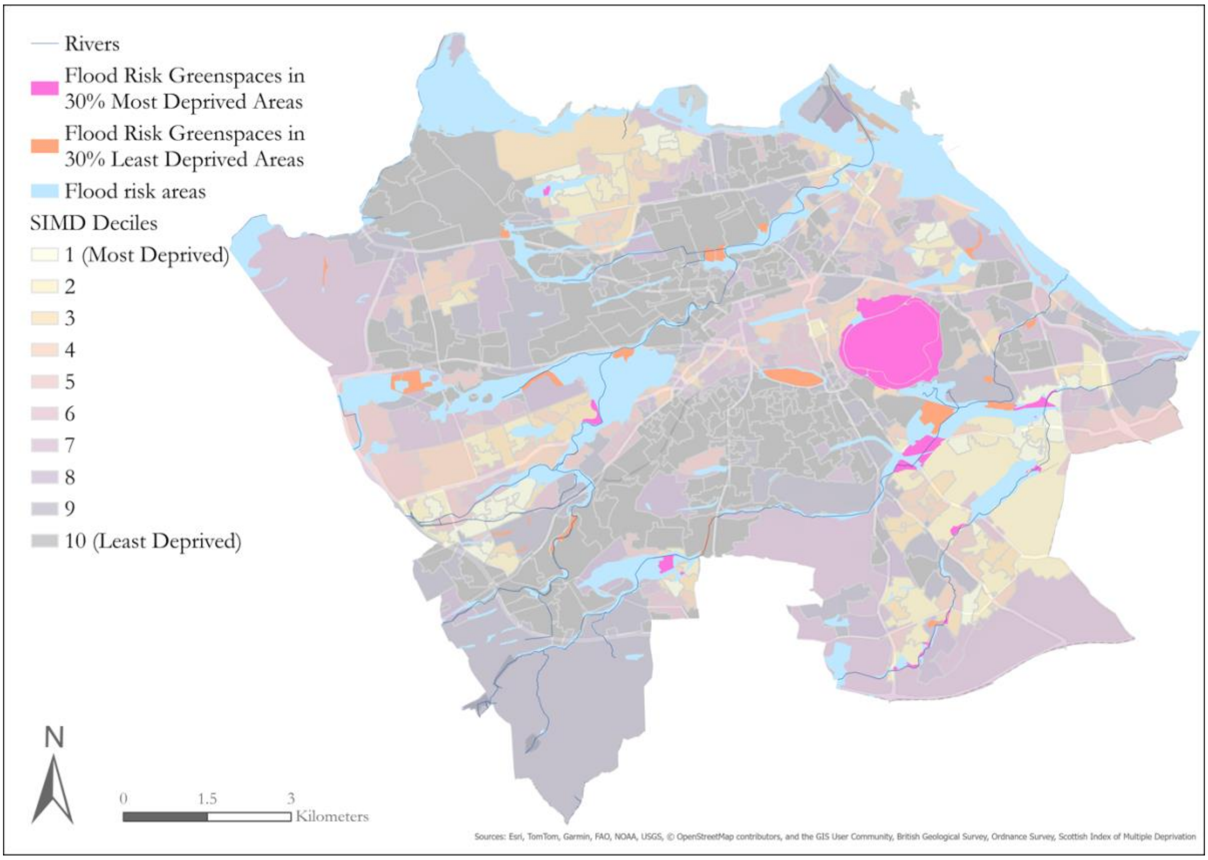

Figure 1: Map of greenspace site selection in the City of Edinburgh using flood risk areas and shown according to intersection with the nearest SIMD area.

The selected greenspaces were digitised based on land cover. Five of these sites were also validated in person to confirm that the satellite imagery was representative, and features could be accurately determined. Digitisation was done using QGIS with Google satellite imagery as a base layer and DTM and DSM layers were created from open-source LiDAR data. Using individual polygons, outlines were drawn around each greenspace, areas of trees, grass, impermeable surfaces, and flood infrastructure (Figure 2). These polygons were used to calculate area, slope, and elevation for each feature of the selected greenspaces. This data was later cleaned and analysed in Microsoft Excel.

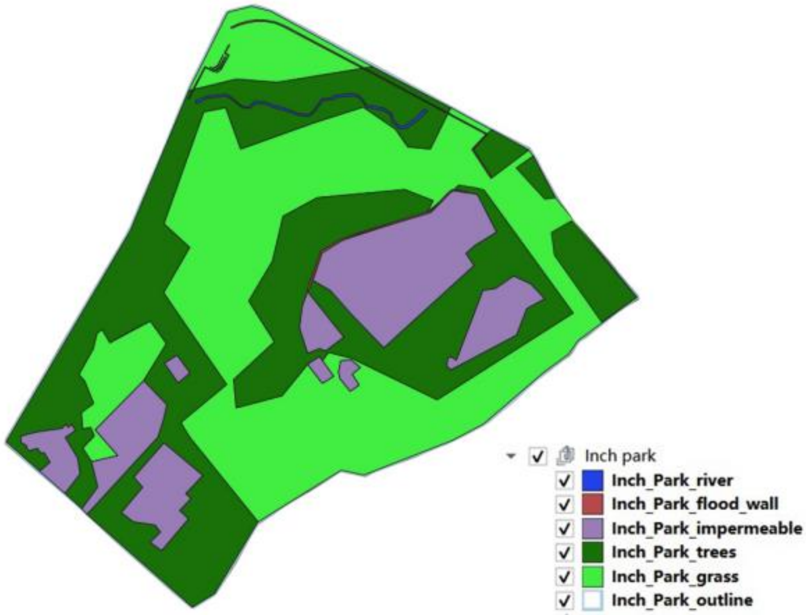

Figure 2: Polygons of Inch Park as an example of greenspace digitisation.

3.3 Scoring system and variable setting

A simple scoring system was designed to assess the quality of greenspaces as objectively as possible. Attributes considered included the presence of flood control infrastructure, the presence of canalisation, the presence of water bodies, area, land cover, slope, elevation and connectivity, which were set as independent variables. The sum of the above attributes is used as the total score and is set as the core argument. SIMD scores and flood risk potential scores are derived from existing data and set as dependent variables (Table 1).

Table 1: Greenspace quality metrics scoring per feature.

Attribute	Scoring rules	Notes	Variable type
Land cover [1]	On a scale of -1 to +1 based on percentage. Upper 10% of component score weighted based on park area	Represents the favourable impact of trees on flood risk mitigation, less the adverse impact of impermeable surfaces, scaled to reflect park area	Independent variable
Flood wall infrastructure	Present +1 Absent and not applicable 0 Absent -1	Flood wall, reservoir, dam, gate	Independent variable
Presence of water	Present +1 Absent 0	Benefit of existing water in syphoning/collecting rainfall	Independent variable
Canalisation	Present -1 Absent and not applicable 0 Absent +1	Canalisation is a potential cause of flood, so it is set as a deduction	Independent variable
Mean slope [2]	Relative slope across parks scaled between 1 and -1	More significant slope is an adverse score due to run-off potential	Independent variable
Mean elevation [2]	Relative elevation across parks scaled between 1 and -1	More significant elevation is also an adverse score due to run-off potential	Independent variable
Connectivity	Present scaled between 0 and 1 depending on number of connections Absent -1	No park connections scored a 0	Independent variable
Total score	Sum	Sum of all the scores of above attributes	Core independent variable
SIMD score	Continuous index	Deprivation index derived from SIMD	Dependent variable
Flood risk potential score	Continuous index from 0% to 100%	Higher flood potential from rivers: the first areas to experience the effects of inland flooding in a river catchment (From BGS).	Dependent variable

[1] Parks have been assigned a weighting between 0 and 1 based on their relative area (*i.e.* the largest park receives a weighting of 1 and the smallest a weighting of 0. The upper 10% of the land cover score is scaled based on this weighting: Land cover score = (% Area trees - % Area impermeable surfaces) * 90% + (Relative area score) * 10%

[2] Mean slope and elevation have been normalized between -1 and 1 as follows:

Normalised score (x) = (mean slope (x) – min(mean slope))/(max(mean slope) – min(mean slope))*2 -1

Normalised score (x) = (mean elevation (x) – min(mean elevation))/(max(mean elevation) – min(mean elevation))*2 -1

3.4 Correlation Analysis

Initial scoring of the 30 greenspaces included no weightings to reflect the relative value of each component of the greenspace quality score (Table 2). The correlation between each component, and the SIMD and flood risk indicators, suggests which variables are driving our scoring. The land cover score is strongly inversely correlated to flood risk potential, reinforcing our approach on scoring this variable. Land cover is also positively correlated to SIMD (23%), which supports our hypothesis that better quality parks are in less deprived areas.

Table 2: Output of initial greenspace scoring with no weightings.

Park Name	(1) Land Cover	(2) Presence of flood defence	(3) Presence of water	(4) Canalisation	(5) Mean Slope	(6) Mean Elevation	(7) Connectivity	(1)+(2)+(3)+(4)+(5)+(6)=(7) Total Score : No weightings
Academical Sport	-0.43				0.94	-0.85	0.43	0.08
Bingham Park	0.44				0.75	-0.42	0.29	1.05
Burdiehouse Burn Valley Park	0.80				-0.03	0.90	0.29	1.96
CammoPark	0.43				0.35	-0.37	0.14	0.55
Carrick Knowe Golf	0.25				0.79	-0.30	0.29	1.02
Chesser Crescent Allotments	-1.00				0.72	-0.21	-1.00	-1.49
Colinton & Craig	1.00	-1.00	1.00	1.00	-0.97	0.49	0.86	2.38
Colinton Mains Park	-0.16				0.96	0.92	0.57	2.29
Craigentinny Golf	0.26				0.75	-0.85	0.57	0.74
Duddingstone Golf	0.44		1.00	1.00	0.65	-0.42	0.43	3.10
Figgate Burn	0.83		1.00		-0.03	-0.85	1.00	1.94
Grange Cricket	0.00				0.97	-0.87	0.71	0.82
Gyle Public Park	-0.30				0.95	-0.33	0.14	0.46
Gyspy Brae	-0.10				0.79	-1.00	-1.00	-1.30
Hays Park	0.37				0.79	-0.44	-1.00	-0.28
Hollyrood Park	0.79		1.00	1.00	-1.00	0.65	0.86	3.29
Hunter's Hall Public Park	0.35				0.81	-0.27	-1.00	-0.12
Inch Park	0.27	1.00	1.00	1.00	0.66	-0.23	0.57	4.26
InverleithPark	0.93		1.00		0.79	-0.72	0.86	2.85
Jack Kane Center	-0.18				0.72	-0.30	-1.00	-0.75
Kingsknowe Golf	0.35				0.28	0.48	0.57	1.68
Liberton Golf Course	0.58				0.40	0.18	0.57	1.73
Meadows	0.20				1.00	0.18	0.71	2.10
Muirhouse Park	-0.61				0.78	-0.32	-1.00	-1.15
peffermill	-0.36	1.00		-1.00	0.66	-0.32	0.57	0.55
PrestonfieldGolf	0.38				0.63	-0.22	-1.00	-0.21
Roseburn	0.04				0.85	-0.39	0.14	0.64
Saughton Rose Gardens	0.14	1.00	1.00	1.00	0.42	-0.27	0.57	3.86
St Marks Roman Catholic Church	-0.71				0.52	1.00	0.14	0.96
Warriston Recreation	0.06				0.69	-0.92	0.29	0.13
Correlation to SIMD	23%	-41%	11%	7%	-4%	-29%	40%	9%
Correlation to Flood Risk Potential	-49%	18%	-27%	-27%	36%	-6%	-1%	-18%

Park Quality Ranking	
Inch Park	1
Saughton Rose Gardens	2
Hollyrood Park	3
Duddingstone Golf	4
InverleithPark	5
Colinton & Craig	6
Colinton Mains Park	7
Meadows	8
Burdiehouse Burn Valley Park	9
Figgate Burn	10
Liberton Golf Course	11
Kingsknowe Golf	12
Bingham Park	13
Carrick Knowe Golf	14
St Marks Roman Catholic Church	15
Grange Cricket	16
Craigentinny Golf	17
Roseburn	18
CammoPark	19
peffermill	20
Gyle Public Park	21
Warriston Recreation	22
Academical Sport	23
Hunter's Hall Public Park	24
PrestonfieldGolf	25
Hays Park	26
Jack Kane Center	27
Muirhouse Park	28
Gyspy Brae	29
Chesser Crescent Allotments	30

The following scenarios were considered to facilitate judgement around the appropriate weighting for each component of the greenspace quality score (Table 3):

- Review of correlation to SIMD and use of regression coefficients as proxy weightings;
- Review of correlation to flood risk and use of regression coefficients as proxy weightings;
- Normalisation of variables such that the sum of all columns (1-7 in Table 2) is equally weighted. This is not true in the initial scoring due to skew of the variables around zero;
- Subjectively selected weightings based on a previous study (Chen, Wang and Wu, 2024) and analysis of the variable correlation to SIMD and flood risk score.

Table 3: Scoring scenarios used for weighting and normalisation of greenspace features.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Scoring Scenarios	Land Cover	Presence of flood defence	Presence of water	Canalisation	Mean Slope	Mean Elevation	Connectivity
SIMD Regression Coefficient (Normalised)	-8%	-100%	-22%	23%	13%	-53%	59%
Flood Risk Potential Regression Coefficient (Normalised)	-100%	-5%	1%	-19%	26%	2%	39%
Normalisation of variable impacts	40%	100%	29%	50%	12%	-33%	44%
Selected Weightings	100%	100%	100%	100%	5%	10%	75%

The unweighted initial scoring shows a 9% correlation to SIMD and a -18% correlation to flood risk potential (inverse of effectiveness for flood mitigation – so a negative correlation to flood risk is good in this case). They are not 100% correlated because the coefficients are used as proxies and are not fit directly to the data. Normalising the variables so they are scaled has an increase for SIMD but a decrease to flood risk, compared to the initial scoring (Table 4). Using weightings based on Chen, Wang and Wu (2024) and on field work carried out by the team, weightings were selected for the coefficients which balance the correlation between SIMD and flood risk potential (15% and -28%).

Table 4: Output of greenspace scoring with normalisation and weightings.

Scoring Scenarios					
Park Name	Initial Scoring	SIMD Regression Coefficient (Normalised)	Flood Risk Potential Regression Coefficient	Normalisation of variable impacts	Selected Weightings
Academical Sport	0.08	0.86	0.83	0.41	-0.15
Bingham Park	1.05	0.46	-0.13	0.53	0.65
Burdiehouse Burn Valley Park	1.96	-0.37	-0.67	0.15	1.11
Cammo Park	0.55	0.31	-0.26	0.42	0.54
Carrick Knowe Golf	1.02	0.43	0.08	0.43	0.49
Chesser Crescent Allotments	-1.49	-0.30	0.79	-0.67	-1.73
Colinton & Craig	2.38	1.05	-1.04	0.29	2.65
Colinton Mains Park	2.29	0.00	0.66	0.00	0.41
Craigentinny Golf	0.74	0.87	0.16	0.74	0.66
Duddingstone Golf	3.10	0.55	-0.28	1.38	2.77
Figgate Burn	1.94	0.75	-0.44	1.33	2.50
Grange Cricket	0.82	1.01	0.53	0.72	0.50
Gyle Public Park	0.46	0.42	0.61	0.17	-0.17
Gyspy Brae	-1.30	0.05	-0.11	-0.05	-0.90
Hays Park	-0.28	-0.28	-0.56	-0.05	-0.38
Holyrood Park	3.29	0.08	-0.79	1.24	3.55
Hunter's Hall Public Park	-0.12	-0.36	-0.53	-0.11	-0.38
Inch Park	4.26	-0.45	-0.09	2.31	3.72
InverleithPark	2.85	0.70	-0.38	1.37	2.55
Jack Kane Center	-0.75	-0.32	-0.03	-0.32	-0.92
Kingsknowe Golf	1.68	0.11	-0.02	0.28	0.85
Liberton Golf Course	1.73	0.26	-0.24	0.48	1.06
Meadows	2.10	0.45	0.36	0.46	0.81
Muirhouse Park	-1.15	-0.26	0.41	-0.48	-1.35
peffermill	0.55	-0.60	0.91	0.80	0.07
PrestonfieldGolf	-0.21	-0.41	-0.60	-0.13	-0.35
Roseburn	0.64	0.40	0.23	0.31	0.16
Saughton Rose Gardens	3.86	-0.46	-0.03	2.23	3.56
St Marks Roman Catholic Church	0.96	-0.31	0.92	-0.48	-0.47
Warriston Recreation	0.13	0.74	0.22	0.54	0.22
Correlation to SIMD	9%	75%	-3%	13%	15%
Correlation to Flood Risk Potential	-18%	-3%	56%	-14%	-28%

3.5 Database Design and Queries

All original data was stored in an Oracle database in four tables based on the attribute categories: Basic_Info, Flood_Info, Geography_Info, and Scoring_Info. SQL statements for table creation and the corresponding ER diagram are shown in Appendix B, C and D. The data loading process involves initially converting the data into a `.dat` format, followed by the creation of a control file (Appendix E). Subsequently, the `sqlldr` command is used to load the data. Finally, queries were designed and executed to extract specific information (Appendix F):

- Greenspaces with flood infrastructure;
- Greenspaces with more than 30% trees and flood infrastructure;
- Greenspaces with a ranking of deprivation.

4. Results

By sequentially introducing the four weighting scenarios in Table 3 and re-ranking the total score, the following results were obtained. The colour of the total score is determined by the Selected Weightings column of Table 5, with scores ranked by colour from highest to lowest in the following order: green, blue, white, yellow, and red. Overall, green and blue labelled greenspaces tend to be ranked higher in the normalised SIMD rankings, suggesting lower levels of environmental deprivation; at the same time, these greenspaces seem to have lower scores for Flood Risk Potential. Comparatively, greenspaces labelled in yellow and orange scored poorly, with the majority being lower in the normalised SIMD rankings and scoring higher for Flood Risk Potential.

Table 5: Final scoring of selected greenspaces based on described scenarios.

	Initial Scoring	SIMD Regression Coefficient (Normalised)	Flood Risk Potential Regression Coefficient	Normalisation of variable impacts	Selected Weightings
1	Inch Park	Colinton & Craig	St Marks Roman Catholic Church	Inch Park	Inch Park
2	Saughton Rose Gardens	Grange Cricket	peffermill	Saughton Rose Gardens	Saughton Rose Gardens
3	Holyrood Park	Craigentinny Golf	Academical Sport	Duddingstone Golf	Holyrood Park
4	Duddingstone Golf	Academical Sport	Chesser Crescent Allotments	InverleithPark	Duddingstone Golf
5	InverleithPark	Figgate Burn	Colinton Mains Park	Figgate Burn	Colinton & Craig
6	Colinton & Craig	Warriston Recreation	Gyle Public Park	Holyrood Park	InverleithPark
7	Colinton Mains Park	InverleithPark	Grange Cricket	peffermill	Figgate Burn
8	Meadows	Duddingstone Golf	Muirhouse Park	Craigentinny Golf	Burdiehouse Burn Valley Park
9	Burdiehouse Burn Valley Park	Bingham Park	Meadows	Grange Cricket	Liberton Golf Course
10	Figgate Burn	Meadows	Roseburn	Warriston Recreation	Kingsknowe Golf
11	Liberton Golf Course	Carrick Knowe Golf	Warriston Recreation	Bingham Park	Meadows
12	Kingsknowe Golf	Gyle Public Park	Craigentinny Golf	Liberton Golf Course	Craigentinny Golf
13	Bingham Park	Roseburn	Carrick Knowe Golf	Meadows	Bingham Park
14	Carrick Knowe Golf	CammoPark	Kingsknowe Golf	Carrick Knowe Golf	CammoPark
15	St Marks Roman Catholic Church	Liberton Golf Course	Jack Kane Center	CammoPark	Grange Cricket
16	Grange Cricket	Kingsknowe Golf	Saughton Rose Gardens	Academical Sport	Carrick Knowe Golf
17	Craigentinny Golf	Holyrood Park	Inch Park	Roseburn	Colinton Mains Park
18	Roseburn	Gyspy Brae	Gyspy Brae	Colinton & Craig	Warriston Recreation
19	CammoPark	Colinton Mains Park	Bingham Park	Kingsknowe Golf	Roseburn
20	peffermill	Muirhouse Park	Liberton Golf Course	Gyle Public Park	peffermill
21	Gyle Public Park	Hays Park	CammoPark	Burdiehouse Burn Valley Park	Academical Sport
22	Warriston Recreation	Chesser Crescent Allotments	Duddingstone Golf	Colinton Mains Park	Gyle Public Park
23	Academical Sport	St Marks Roman Catholic Church	InverleithPark	Gyspy Brae	PrestonfieldGolf
24	Hunter's Hall Public Park	Jack Kane Center	Figgate Burn	Hays Park	Hays Park
25	PrestonfieldGolf	Hunter's Hall Public Park	Hunter's Hall Public Park	Hunter's Hall Public Park	Hunter's Hall Public Park
26	Hays Park	Burdiehouse Burn Valley Park	Hays Park	PrestonfieldGolf	St Marks Roman Catholic Church
27	Jack Kane Center	PrestonfieldGolf	PrestonfieldGolf	Jack Kane Center	Gyspy Brae
28	Muirhouse Park	Inch Park	Burdiehouse Burn Valley Park	Muirhouse Park	Jack Kane Center
29	Gyspy Brae	Saughton Rose Gardens	Holyrood Park	St Marks Roman Catholic Church	Muirhouse Park
30	Chesser Crescent Allotments	peffermill	Colinton & Craig	Chesser Crescent Allotments	Chesser Crescent Allotments

5. Discussion

The analyses conducted in this study yield meaningful correlations. The initial score relationship between greenspace and SIMD was 9%, and the relationship between greenspace and flood risk potential was -18%. After weighting, these scores improved to 15% and -28% respectively. However, the model reveals weak explanatory power for the SIMD as it only explains 7.09% of the variance in the effectiveness of greenspace. Furthermore, the p-value of 0.155 suggests that the results are not statistically significant, implying a 15.5% probability that the observed associations are due to random chance rather than a true relationship. This shows the complexity of the factors involved in flood management and emphasises the need for more thorough study.

The results suggest that greenspaces with higher vegetation cover and better connectivity tend to perform better in reducing flood risks. The linear regression analysis reveals a negative coefficient of -49% between land cover and flood risk potential, which is the only significant variable, indicating that greater vegetation cover leads to lower flood risk.

It is important to note that the analyses found minimal differences in flood risk mitigation between areas with the highest and lowest levels of deprivation. This could be explained by

Edinburgh's profusion of greenspaces, which make up about 49% of the total area in the city (BBC, 2017). A more consistent degree of flood resistance across different socioeconomic strata is likely a result of this vast network of greenspaces. Additionally, the small sample size in this study limits the ability to detect more nuanced variations. Furthermore, Edinburgh is generally less deprived compared to other urban areas, which could account for the limited disparities observed.

Future research should expand the sample size in Edinburgh and conduct similar analyses in cities with less greenspace to further investigate our findings, for instance, Glasgow has about 32% greenspace and Dundee has approximately 41% (BBC, 2017; Dundee City Council, 2024). Looking at different cities in approximate regions can identify effective tactics that can be modified for Edinburgh and encourage cooperation amongst municipalities to tackle common issues. Moreover, collaborating with local communities to monitor and assess the performance of these greenspaces over time will be vital for informing policy decisions and promoting sustainable urban environments.

6. Conclusion

This study has brought attention to the vital role that greenspaces play in flood management, especially considering Edinburgh's environmental deprivation. Through an evaluation of 30 chosen greenspaces according to land cover, connectivity and current flood defence infrastructure, the results show that well-integrated greenspaces can mitigate flood risks. The study emphasises the importance of providing equal access to greenspaces because they are essential parts of urban flood defence systems in addition to offering recreational advantages.

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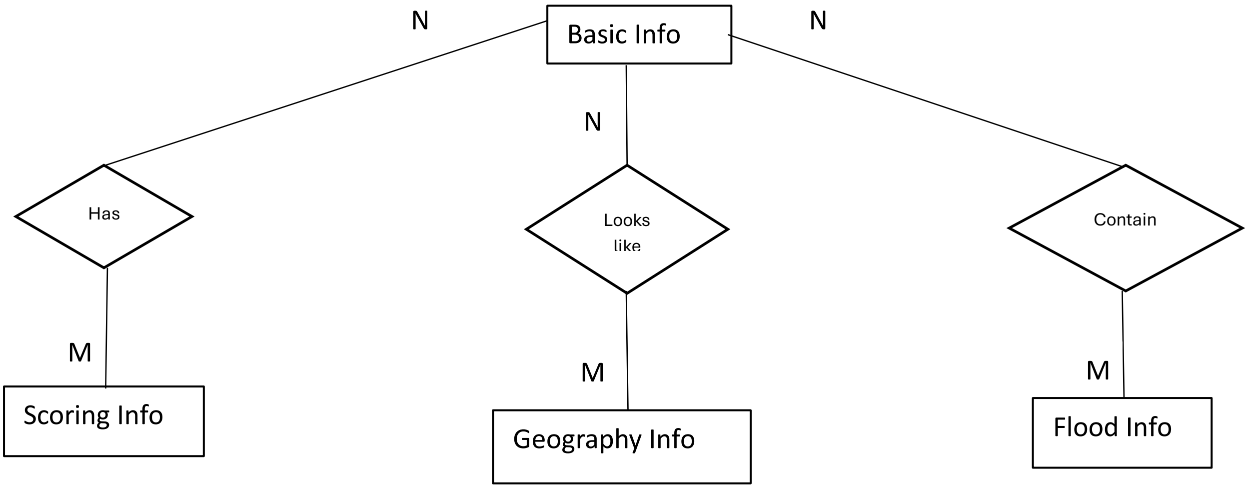
Appendix A: Team Contributions

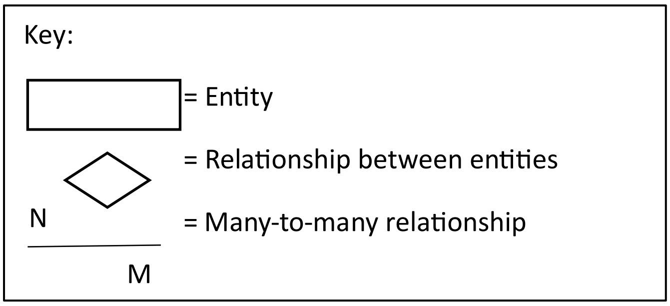
Team organisation was a board-based structure, with all members raising issues and delegating tasks and one chair keeping the group moving when needed during weekly progress meetings. Such a method allowed members to take on tasks according to their skill set while also allowing flexibility in the leadership structure. Members were proactive in asking for help when required or raising issues, instead of waiting until the next team meeting to do so, allowing the group to remain on track with tasks.

Team Member	Contribution
B235562	- Literature review sources - Risk Assessment - Fieldwork - Presentation design and writing - Presentation - Introduction - Report editor
B270531	- Literature review sources - Literature review - Greenspace digitisation - Quantifying greenspaces - Discussion - Conclusion
B269482	- Fieldwork - Mapping - Metrics design - Methodology - Results
B263983	- Literature review sources - Literature review - Fieldwork - SQL E-R Model - Presentation

	- Report editor - Gantt chart reflection - Project Manager/chairperson
B263126	- Fieldwork - Methodology design - Presentation slides - Presentation - Analysis - Results - Report contribution - Gantt chart
B271000	– Fieldwork – Map digitisation – Quantifying greenspaces – Database development and queries – Methodology – Results – Abstract

Appendix B: Oracle E-R Model





Appendix C: SQL Database Design

Three main constraints were applied to the creation of these tables. The first constraint is Primary Key. Each table has a Primary Key, which is used to identify unique rows within a table. Each table uses the Primary Key 'Park ID.' The tables for Flood Info, Geography Info, and Scoring Info additionally all contain a Foreign Key. The Foreign Key is used to reference or link tables together. These tables all use the same Foreign Key, which is 'Park ID.' Finally, the constraint Not Null was applied to each table. The Not Null constraint prevents any empty cells from appearing within the tables. Given the size of the data files that were being used for this project, it would have been difficult to check each cell individually to make sure that all attribute data was included; Not Null has done that work for us.

Key:

Primary Key	Foreign Key

Basic Info table

Park ID	Park Name	Total Area	Grass	Impermeable	Trees	Other

Flood Info table

Park ID	Presence of Flood Defences	Presence of Water	Canalisation	Higher Flood Potential	Lower Flood Potential	Unassessed potential	Trees and Impermeable

Geography Info table

Park ID	Mean Slope	Mean Elevation	Min. Elevation	Max. Elevation	Elevation Range	Connectivity

Scoring Info table

Park ID	Deprivation	Total Score

Appendix D: Oracle Table Creation

```
SQL> CREATE TABLE Basic_Info (
  2  Park_ID NUMBER PRIMARY KEY,
  3  Parkname VARCHAR2(255) NOT NULL,
  4  Total_Area NUMBER,
  5  grass NUMBER,
  6  impermeable NUMBER,
  7  trees NUMBER,
  8  other NUMBER);

Table created.
```

```
SQL> CREATE TABLE Flood_Info (
  2  Park_ID NUMBER PRIMARY KEY,
  3  Presence_of_flood_defence NUMBER,
  4  Presence_of_water NUMBER,
  5  Canalisation NUMBER,
  6  Higher_flood_potential NUMBER,
  7  Lower_flood_potential NUMBER,
  8  Unassessed_Flood_Potential NUMBER,
  9  Trees_impermeable NUMBER,
 10  CONSTRAINT fk_flood_basic FOREIGN KEY (Park_ID) REFERENCES Basic_Info (Park
_ID));

Table created.
```

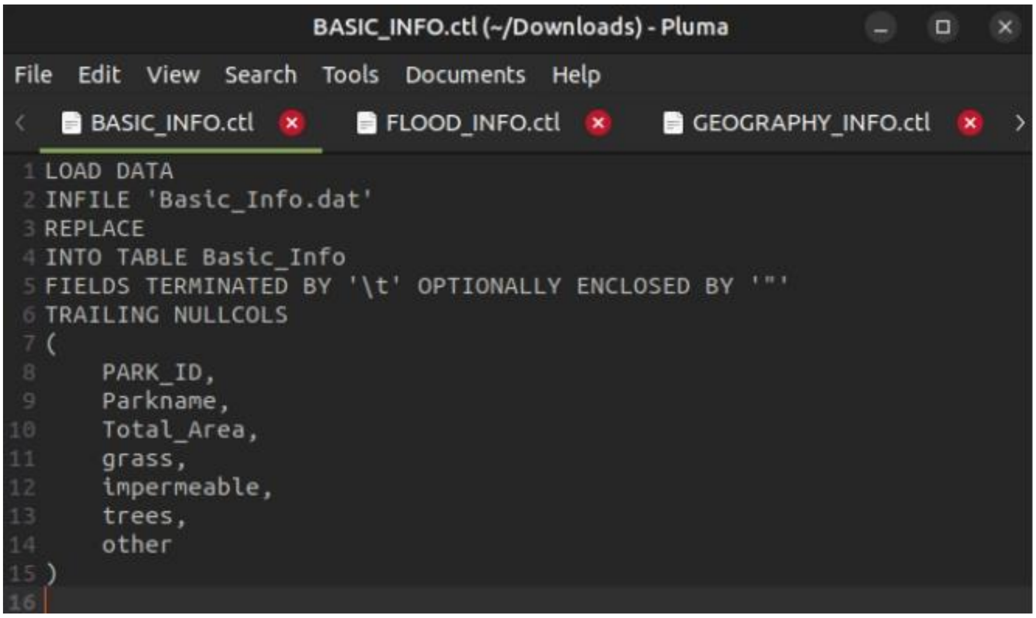
```
SQL> CREATE TABLE Geography_Info (
  2  Park_ID NUMBER PRIMARY KEY,
  3  mean_slope NUMBER,
  4  mean_elevation NUMBER,
  5  min_elev NUMBER,
  6  max_elev NUMBER,
  7  elev_range NUMBER,
  8  Connectivity NUMBER,
  9  CONSTRAINT fk_geography_basic FOREIGN KEY (Park_ID) REFERENCES Basic_Info (
Park_ID));

Table created.
```

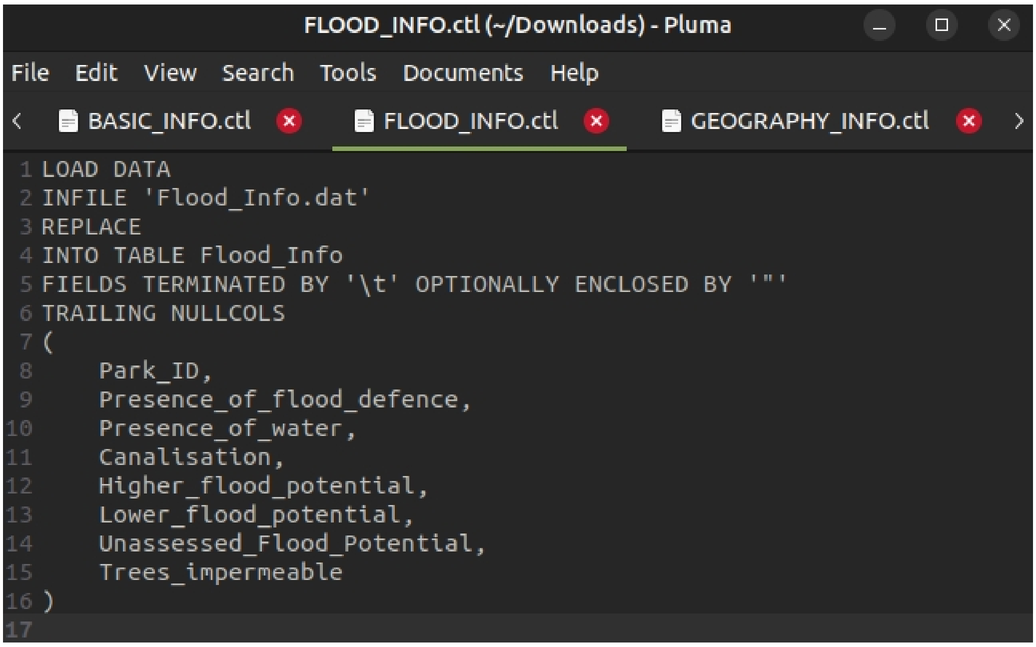
```
SQL> CREATE TABLE Scoring_Info (
  2  Park_ID NUMBER PRIMARY KEY,
  3  Deprivation NUMBER,
  4  Total_score NUMBER,
  5  CONSTRAINT fk_scoring_basic FOREIGN KEY (Park_ID) REFERENCES Basic_Info (Pa
rk_ID));

Table created.
```

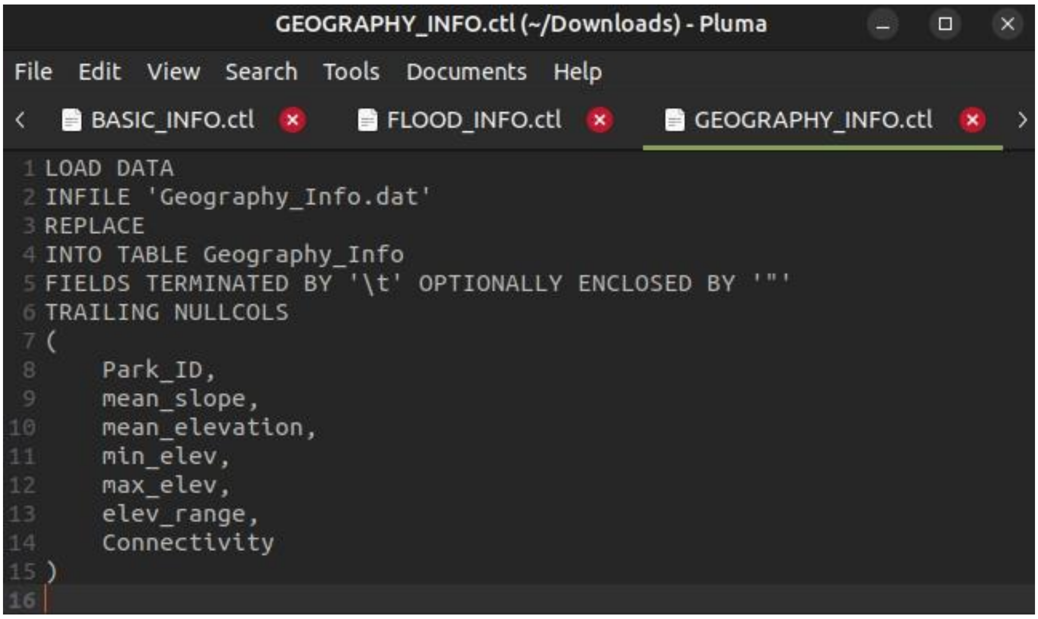
Appendix E: Oracle Control Files for Data Loading



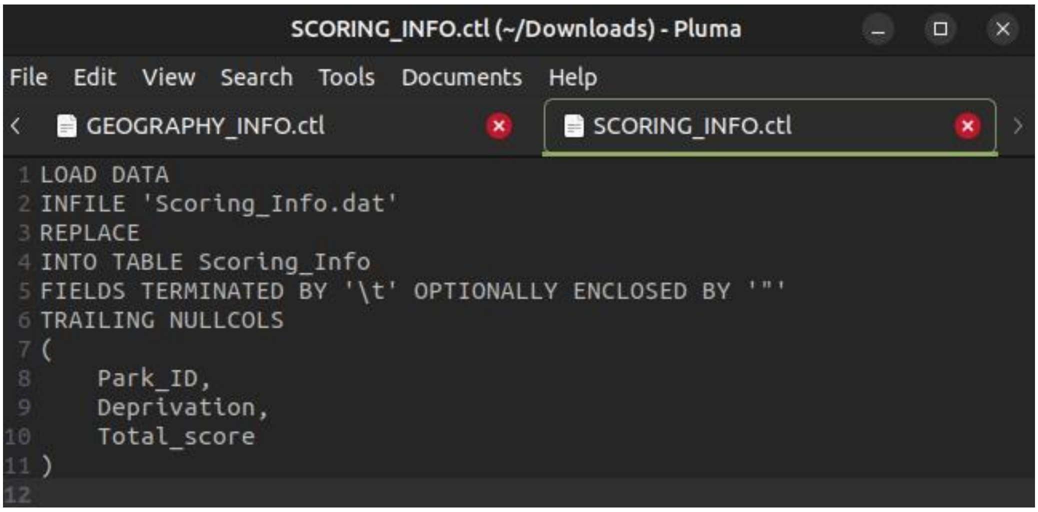

```
LOAD DATA
INFILE 'Basic_Info.dat'
REPLACE
INTO TABLE Basic_Info
FIELDS TERMINATED BY '\t' OPTIONALLY ENCLOSED BY '"'
TRAILING NULLCOLS
(
    PARK_ID,
    Parkname,
    Total_Area,
    grass,
    impermeable,
    trees,
    other
)
```




```
LOAD DATA
INFILE 'Flood_Info.dat'
REPLACE
INTO TABLE Flood_Info
FIELDS TERMINATED BY '\t' OPTIONALLY ENCLOSED BY '"'
TRAILING NULLCOLS
(
    Park_ID,
    Presence_of_flood_defence,
    Presence_of_water,
    Canalisation,
    Higher_flood_potential,
    Lower_flood_potential,
    Unassessed_Flood_Potential,
    Trees_impermeable
)
```




```
LOAD DATA
INFILE 'Geography_Info.dat'
REPLACE
INTO TABLE Geography_Info
FIELDS TERMINATED BY '\t' OPTIONALLY ENCLOSED BY '"'
TRAILING NULLCOLS
(
    Park_ID,
    mean_slope,
    mean_elevation,
    min_elev,
    max_elev,
    elev_range,
    Connectivity
)
```




```
LOAD DATA
INFILE 'Scoring_Info.dat'
REPLACE
INTO TABLE Scoring_Info
FIELDS TERMINATED BY '\t' OPTIONALLY ENCLOSED BY '"'
TRAILING NULLCOLS
(
    Park_ID,
    Deprivation,
    Total_score
)
```

Appendix F: Oracle Queries and Output Format

```
SQL> SET LINESIZE 160;
SQL> SET PAGESIZE 50;
SQL> COLUMN Parkname FORMAT A30;
SQL> COLUMN Presence_of_flood_defence FORMAT 99;
SQL> SELECT Basic_Info.Parkname, Flood_Info.Presence_of_flood_defence
  2  FROM Basic_Info, Flood_Info
  3  WHERE Basic_Info.Park_ID = Flood_Info.Park_ID
  4    AND Flood_Info.Presence_of_flood_defence > 0;

PARKNAME                       PRESENCE_OF_FLOOD_DEFENCE
------------------------------ -------------------------
Inch_Park                                              1
peffermill                                             1
Saughton_Rose_Gardens                                  1
```

```
SQL> SET LINESIZE 160;
SQL> SET PAGESIZE 50;
SQL> COLUMN Parkname FORMAT A30;
SQL> COLUMN trees FORMAT 99.99;
SQL> COLUMN Presence_of_flood_defence FORMAT 99;
SQL> SELECT Basic_Info.Parkname, Basic_Info.trees, Flood_Info.Presence_of_flood_
defence
  2  FROM Basic_Info, Flood_Info
  3  WHERE Basic_Info.Park_ID = Flood_Info.Park_ID
  4  AND Basic_Info.trees > 0.3
  5  AND Flood_Info.Presence_of_flood_defence > 0;

PARKNAME                        TREES PRESENCE_OF_FLOOD_DEFENCE
------------------------------ ------ -------------------------
Inch_Park                         .39                         1
Saughton_Rose_Gardens             .34                         1
```

```
SQL> SET LINESIZE 160;
SQL> SET PAGESIZE 50;
SQL> COLUMN Parkname FORMAT A30;
SQL> COLUMN Deprivation FORMAT 9999.9999;
SQL> SELECT Basic_Info.Parkname, Scoring_Info.Deprivation
  2  FROM Basic_Info, Scoring_Info
  3  WHERE Basic_Info.Park_ID = Scoring_Info.Park_ID
  4  ORDER BY Scoring_Info.Deprivation DESC;

PARKNAME                       DEPRIVATION
------------------------------ -----------
Colinton&Craig                   6910.0000
WarrisonRecreation               6732.2100
Roseburn                         6706.0000
AcademicalSport                  6588.0000
GrangeCricket                    6586.9800
InverleithPark                   6486.0000
Kingsknowe Golf                  6241.0000
DuddingstonGolf                  5729.0000
PrestonfieldGolf                 5565.3500
CarrickKnoweGolf                 5366.0000
CraigentinnyGolf                 5134.0000
FiggateBurn                      5034.1000
Meadows                          4964.0000
GylePublicPark                   4913.0000
Chesser_Crescent_Allotments      4667.4300
CammoPark                        4580.0000
Bingham_Park                     4157.2500
Burdiehouse_Burn_Valley_Park     3662.7500
Hollyrood_Park                   2449.0700
Inch_Park                        2386.7600
Gyspy_Brae                       1999.0000
Colinton_Mains_Park              1654.2400
Muirhouse_Park                   1639.7500
Saughton_Rose_Gardens            1465.0000
Hunter's_Hall_Public_Park        1395.6100
Liberton_Golf_Course             1380.0000
peffermill                       1356.9000
St_Marks_Roman_Catholic_Church   1306.3000
Jack_Kane_Center                  699.8000
Hays_Park                         393.0000

30 rows selected.
```

Appendix G: Literature Review

Much research has been done around environmental deprivation, which is typically defined as the lack of access to physical environmental conditions that can positively contribute to health and well-being (Centre for Research on Environment, Society and Health, 2024). One way to think about access to “physical environmental conditions” would be in terms of access to high quality greenspaces. In general, environmental deprivation in the UK seems to increase as income deprivation also increases. This also seems to correlate with greater social disadvantage (Pearce *et al*., 2011). There is some room here for additional research, however. For example, the benefits of green open spaces for flood management are rarely acknowledged; however, their accurate assessment is crucial towards understanding the role they play in this area (Schuch *et al*., 2017). Studies do show that enhancing green infrastructure such as living roofs, parks, and flood plains, can make a significant contribution to urban flood management by increasing vegetation cover and groundwater storage capacities, ultimately reducing fluvial runoff. These benefits do increase when used in conjunction with traditional grey infrastructure such as storm drains and canalisation (Zimmermann *et al.*, 2016). Issues can also arise when greenspaces and infrastructure used as flood management cross into multiple political jurisdictions. It can also cause issues when a lack of green infrastructure upriver overwhelms flood management infrastructure downstream, especially when these are also in separate political jurisdictions (Carter *et al*., 2018). Additional research on this topic would be timely, given effects due to climate change, as well as research on green infrastructure in areas of deprivation. Interestingly, it also appears as though deprivation, specifically economic deprivation, has a much greater effect on long-term flood resilience, with those who are more economically deprived being less resilient to flooding in the long term (Houston *et al*., 2021).

It appears well researched and understood that soil compaction levels have a definitive effect on infiltration levels (which can contribute to flooding in post-fluvial events), with more compacted soil generally decreasing the infiltration level (Zemke *et al*., 2019; Yang and Zhang, 2011). Causes of soil compaction can include heavy pedestrian traffic, sports fields, compression by construction equipment, and more. The current literature does not appear to have studied whether soil is more likely to be compacted in areas of higher deprivation. Soil infiltration can also be affected by other factors such as pollution, with higher levels of pollution correlated with lower infiltration rates (Fung *et al*., 2022), as well as being affected by distinct types of vegetation. Water infiltration appears to be better under trees and old forests (Archer *et al.*, 2015), and then under scrubland and grasses, with variation in vegetation types being less of a determining factor than anticipated (Regues *et al*., 2017). Finally, soil infiltration appears to be affected by the type of soil, with sandy soils retaining the most water, and clay-based soils retaining the least water (Rawls, Brakensiek and Saxton, 1982; Contreras and Bonilla, 2018); however, much of this is outside the scope of this project.

Several studies have quantified greenspaces for their benefits through the use of satellite imagery and aerial photography, particularly in the area of mental health (Wang *et al*., 2021; Baka and Mabon, 2022). In both studies, greenspaces were assessed using multiple relevant metrics that are observable through satellite imagery and aerial photography, including presence of trees and degree of greenness. Though the purpose of this report is not in relation to mental health, it suggests that with the appropriate metrics, this methodology can be altered to fit other purposes. Ultimately, the use of aerial imagery can potentially be viable in accurately assessing greenspaces for their quality regarding flood management, though it does not appear to have been done before.

Appendix H: Risk Assessment

Travel Fieldwork Risk Assessment – Taught / Independent - UK / International

GEOS-HS-001(v1_April2023)

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Grey fields are mandatory for all trips
****blue fields are additionally required for international trips***

Location(s) to be visited	Inch Park/Peffermill Playfields, Colinton Mains Park, Meadows, Roseburn Public Park			
Duration of Visit	**From:**	10.26.24	**To:**	1100 to 1500
Accommodation Address or Field Camp Site Location	N/A			
Description of activities	An afternoon spent visiting four study sites for validation purposes. Activities will include: walk around park, measurements of relevant areas with participants making their own travel arrangements to relevant areas.			
Drivers - required by all staff driving on University business and student demonstrators where they are driving on school-led fieldtrips.				
Detail drivers' names	NA (public transport)			
Have all drivers been approved and vetted on AA DriveTech?	N/A			
*** Is there FCO advise against or advice against all but essential travel advisory in place for your destination or transit areas?**	N/A			
*** Summarise the current FCO travel advice for areas to be visited incl. pandemic advise** [UK Gov Foreign Travel Advice](#)	N/A			

Is it a Taught Fieldwork? *Delete not applicable*	**NO**
Number of Participants	
Staff names	
Demonstrators' names	
Number of Student	
First Aid Trained number	
Insurance – University travel insurance is strongly recommended for all travel. Available from: [University Insurance Website](#)	
Will you obtain suitable and comprehensive travel insurance for your trip?	
Are any travellers travelling against medical advice?	
*** Will all travellers be able to comply with country specific entry requirements concerning vaccinations?**	N/A
*** Where relevant, have all travellers been advised to consult with a travel health clinic or their GP to verify that they are up to date with the necessary vaccinations required by the destination and have access to any required prophylaxis, for instant - antimalarials etc.?** [UoE Travel Health](#)	N/A

Travel Fieldwork Risk Assessment – Taught / Independent - UK / International

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FIELDWORK CODE OF CONDUCT

All participants, staff, demonstrators, and student should be familiar with the School of Geosciences Fieldwork Code of Conduct: [School of GeoSciences Fieldwork Code of Conduct](#)

EMERGENCY CONTACT

All travellers must ensure that University hold up to date next of kin information. Please confirm that ALL staff and students have verified that the information currently held is correct. *Staff – People & Money System / Students - EUCLID*	Yes
Have all participants left NoK/emergency contact/health declaration with the Teaching Office? *Everyone must submit MS form few days prior the trip*	No
Will Fieldwork Organiser/Lead be carrying a mobile phone with you?	Yes
Fieldwork Organiser/Lead mobile phone number	07551981248
Alternative contact 1 (another participant, accommodation etc.)	
Alternative contact 2 (another participant, accommodation etc.)	

***Nearest UK embassy/consulate** *State address and contact number*	N/A
***Local Emergency Numbers**	N/A
***Medical**	N/A
***Fire Service**	N/A
***Police**	N/A
***Other (specify)**	N/A

EMERGENCY PROCEDURES

Specify arrangement for obtaining medical aid, nearest hospital, quality of medical facilities, emergency evacuation procedures, notification of routes and schedules, remote and lone working, communication, mobile phone reception, Insurance Helpline etc. *University of Edinburgh Security 24h: (+44) 0131 650 2257, security@ed.ac.uk*
Two of the participants are first aid trained. Route finding is easy, we will follow paths. The nearest hospital with A&E is the Royal Infirmary in Edinburgh in Little France. If the person can walk and is not in immediate danger, we will escort to a bus stop. If they cannot walk, we will call the emergency services or call a taxi, however our fieldwork will always be close to roads and public buildings. Good mobile phone reception throughout.

CONTINGENCY PLANS

Consider what actions will be taken following emergency response or interruption to travel plans (e.g. local support, alternative accommodation, flexible travel plans etc.).
If the weather forecast is exceptionally poor, we will cancel and reschedule fieldwork to an alternate date (10.30.24)

ADDITIONAL INFORMATION

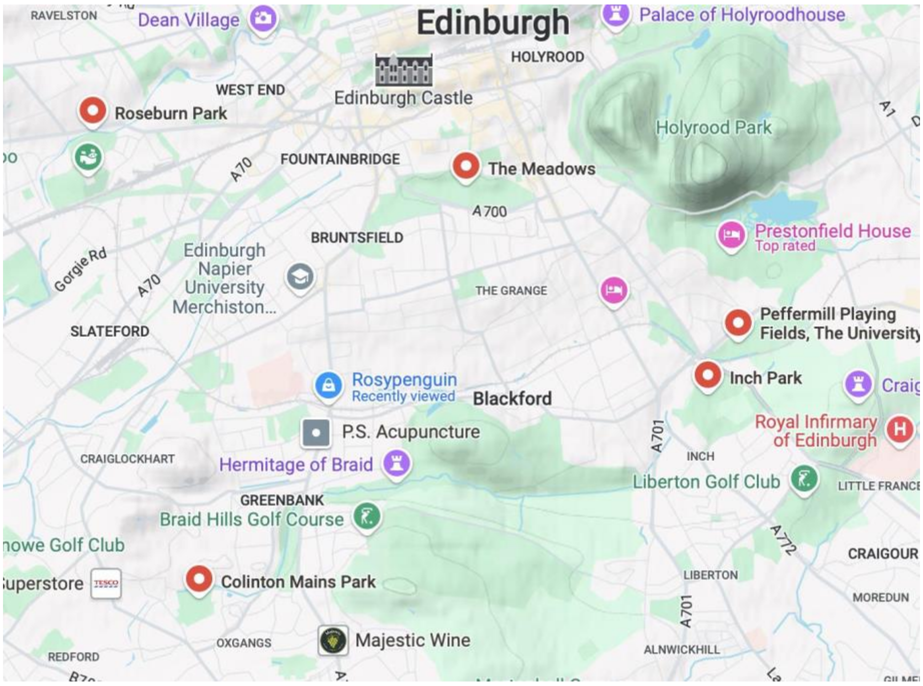
Identify any additional information relevant to your travel or fieldwork activity including pre-trip information and briefings, supervision, training requirements, mandatory kit list, specialist equipment, clothing, whether you have made previous trips to the area etc.
If you have consulted GeoScience Health and Safety Team please add relevant information here

We will wear suitable clothing (i.e. warm and waterproof, not jeans) and footwear (sturdy shoes or trainers as we are not doing any intrepid exploring). We do not require any specialized equipment. We will be using a camera, measuring tape, and GPS.

MAPS AND ITINERARY

Please insert maps and itinerary below *Recommended is a 1:50000 map showing a pencil ring around the site*

Meet 11.00 on Saturday at the Costa in Cameron Toll. We will conduct our data collection in the Inch Park/Peffermill Playfields, Colinton Mains Park, the Meadows, and lastly Roseburn Public Park.
Activities completed by 15.00, but hopefully earlier.



HAZARD IDENTIFICATION / RISK ASSESSMENT
The risk assessment (and contingency plan, where appropriate) should be revised throughout the fieldwork to ensure that it is always up to date and relevant to changing circumstances.
Review the risk assessment in the light of any incidents or near misses and record any recommendations or lessons to be learned (Accident and Incident Reporting (AIR) system). Report of any accident or ill health should be prepared and submitted to the Fieldwork Supervisor and the Head of School.

Hazard – something with the potential to cause harm.
Risk – the likelihood of potential harm from that hazard being realised, in combination with the severity of injury, damage or loss that might foreseeably occur.

Please use for reference list below of Hazards or activities which might lead to hazardous situation and consider whether it refers to your trip. It is inclusive but not exhaustive list of examples. Write in the table hazards that might be applicable and assess the risk for each. *RISK SCORING SYSTEM under the table.*
Risk (IR - Initial Risk or RR – Residual Risk) = Severity (S) × Likelihood (Li)

University Fieldwork Guidance available at UoE Fieldwork Guidance USHA/UCEA guideline available at USHA Safety in Fieldwork Guide

Hazard or dangerous activity, technique	Hazard	Risk Rating IR			Control measures	Risk Rating RR		
		S	Li	Risk		S	Li	Risk
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Human related issues *violence and stress (incl. interaction/communication with team members /contractors /public, civil unrest/war/terrorist/pirates, religion/culture/custom difference, religious police, language barrier, LGBT+ rights, lack of family support), mental ill health, substance misuse,* ***lone and out of hours working, disabled workers, new and expectant mothers****, sub-standard medical care, access to save accommodation/welfare facilities and leisure time*	This is a public area in Edinburgh so there are chances that students will encounter a range of possible interactions with members of the public or dogs. Interactions with wildlife possible though unlikely. Risk of encounter with tics and Lyme disease This is a group activity which may make some students feel uncomfortable.	2 2 1	2 2 2	2 4 1	Remain aware of the surroundings, keep up to date with local media reports and follow the advice of local authorities. Avoid problematic areas; only use safe transport. Keep to the paths and wear long trousers We will stick together as a group. International students know emergency numbers, have the NOK information saved in the system. Avoid carrying valuables on person.	2 2 2	1 1 1	2 2 2
Musculoskeletal *static posture, manual handling, load-handling equipment, back injuries and back pain, work-related upper limb disorders, other chronic soft-tissue injuries*	There are no foreseen "musculoskeletal" risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA

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Safe movement of people *slip, trips, falls on the same/different level, collisions with moving vehicles, being struck by moving, flying of falling object, striking against fixed or stationary objects*	Slips and trips on uneven pavement or path. Some pavements in can be slippery after rain.	2	2	2	We will be aware of our surroundings. Adequate footwear is recommended though the walk is largely on grass, paths and tracks.	1	1	1
Transport *vehicles, driving, traffic, terrain, quality of infrastructure, public transport, planes, boats*	Left hand traffic (international students), traffic accidents	3	2	6	Only travel on regulated public transport and taxis. Wear a seatbelt if travelling in a taxi.	2	1	2
Work at height *excavation, demolition: work at height, falls and falling materials, confined spaces*	There are no foreseen "work at height" risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA
Equipment *hand-held, machinery, being struck by moving, flying of falling object (e.g. drones), striking against fixed or stationary objects, entanglement, drawing-in), breakdown of equipment*	There are no foreseen equipment related risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA
Mechanical *crushing, shearing, cutting or severing, entanglement, drawing in or trapping, impact, stabbing or puncture, friction or abrasion, high-pressure fluid injection*	There are no foreseen mechanical risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA
Physical *noise, vibration, dust, radiation non-ionising (ultraviolet, visible light, infrared, microwaves, radio waves) and ionising (alpha particles incl. radon, beta particles, X-rays, gamma rays, neutrons)*	There are no foreseen physical risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA

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Electrical *electric shock, burns, arcing, fire, explosion*	There are no foreseen electrical risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA
Fire and explosives *burns, fire, explosion* DSEAR	There are no foreseen fire risks associated with the walk in the city.							
Chemical *solid, liquid, dust, fume, mist, vapour, nanoparticles/nanotubes, toxic gases and asphyxiating gases (slurry pit), fibres incl. asbestos; toxic or very toxic, harmful, corrosive, irritant, carcinogenic, mutagenic, reproductive toxin*	There are no foreseen chemical risks associated with planned trip.	NA	NA	NA	NA	NA	NA	NA
Biological *fungi, bacteria, viruses, plants (poisonous, irritating), animals wild/domestic (venomous/toxic/aggressive) Lyme Disease, Leptospirosis - Weil's Disease, Tetanus*	Risk of allergic reaction to flowers, grasses, berries or fruit Risk of viral infection (e.g., flu, COVID)	2 2	2 2	4 4	We will not touch, pick or eat plants. Avoid close contact with visibly ill people. Encourage using facemask indoor, especially if someone has weak immune system.	2 2	1 1	2 2
Environmental *extreme weather conditions, lightning/sea/sand storms, blizzards, tornados, altitude, volcano, seismic area, not even/not stable ground, quicksand, marshes, glaciers, avalanches, landslips, remote localisation, cliffs, pits and quarry faces, caves, mines, tidal/flooding area, periodic river, on/in standing or flowing water (diving, sailing), strong currents, drought area, wild fires, fog, air/water/ground pollution*	There could be quick changes in weather conditions.	1	2	2	We will bring clothing for cold/rainy weather. We have a backup field date in case conditions get too bad.	1	1	1
Environmental impact *refuse, pollution, disturbance of ecosystem*	Refuse, carbon footprint	1	2	2	We will not be in the field long, but if necessary we will bring reusable food/drink containers. Dispose any waste in proper waste/recycling bins. Use public transport.	1	1	1