Turquoise Coast Development Plan: Environmental Buffers and Biodiversity Offsets

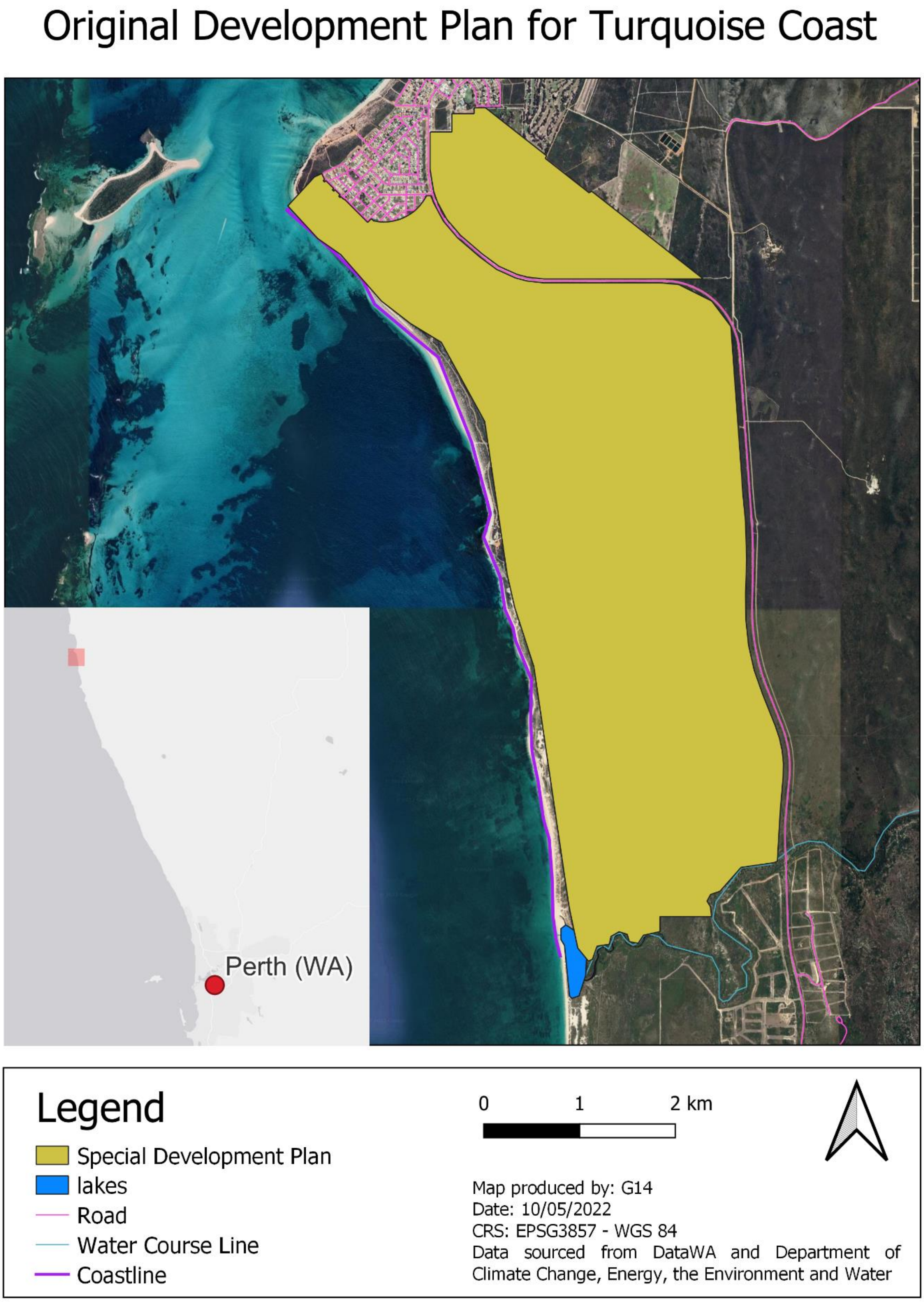
Introduction

Jurien Bay is a small but rapidly growing town located in the Shire of Dandaragan, Western Australia. It is recognized as a “Supertown” for its distinguishing economic features, such as the multi-million-dollar tourism, agricultural and crayfish industries, which give Jurien Bay the potential to become a new regional centre (Department of Regional Development and Lands, n.d.). Due to population growth and economic opportunities in Jurien Bay, the Turquoise Coast Development Plan (TCDP) has been proposed by Ardross Estates for a range of urban land uses, including residential, industrial, and tourist uses (Shire of Dandaragan, 2020).

Map 1 shows the location of the proposed TCDP, which is bound by Jurien Bay town to the north, Indian Ocean coastline to the west, Hill River and Hill River Estuary to the south, and Indian Ocean Drive to the east. The development site has a total area of 2,063 hectares with approximately 1350 hectares of native vegetation. The Environmental Protection Agency (EPA) has identified several significant environmental assets in the area, for instance, the Hill River as the last relatively pristine river in the Mid-west area, the coastline reserves such as Jurien Bay Marine Park, and the large area of native bushland, which holds high biodiversity values (EPA WA, 2001). For the development to take place, the EPA expects the landowner to manage these valuable assets sustainably and adhere to all their guidelines, to ensure that the development has minimal impacts on the environment and biodiversity (EPA WA, 2001). For projects that result in environmental degradation and biodiversity loss such as the TCDP, biodiversity offsets are commonly implemented to compensate for the impacts (Grimm & Köppel, 2019)

Multi-Criteria Analysis (MCA) is a decision-making tool used to evaluate the strengths and weaknesses of different alternatives across criteria, assess trade-offs, and analyze its performance (Adem Esmail & Geneletti, 2018). A major strength of MCA is that it allows the different pathways to be analyzed with preferences of stakeholders considered in a transparent and replicable manner, which makes the MCA being increasingly used in environmental conservation (French et al., 2009). MCA is commonly integrated with factual data from Geographical Information System (GIS) or value-based information from stake holder engagement to derive the most suitable alternative (Mustajoki et al., 2011; Nordström et al., 2011; Strager & Rosenberger, 2006).

This report aims to conduct two MCAs using Quantum Geographical Information System (QGIS) as a tool for spatial analysis. The first MCA will create a new development Plan for Turquoise Coast in such a way that environmental impacts are minimized, and the EPA's requirements are fulfilled. The second MCA will identify areas most suitable for biodiversity offsets within the Shire of Dandaragan. Two environmental offset scenarios will be developed based on the outcome of the second MCA and will be evaluated in terms of their cost-effectiveness. Together, the revised development plan and the recommended offset scenarios will inform stakeholders of how the development plan can proceed while meeting environmental, social, and economic goals.



Map 1: TCDP (JB01) proposed by Ardross Estates Pty Ltd (Source: Dandaragan Regional Land Supply Assessment, 2020)

Methods

Development Plan

The objective of the new development plan is to mitigate potential environmental impacts from the TCDP. *Table 1* summarizes the data that were used in the first MCA for the new development plan. *Figure 2* outlines five criteria to be considered for the objective and the input data that will be utilized in the spatial analysis of each criterion.

Table 1: Summary table of data used in the MCA for Development Plan

Dataset name	**Source**	**URL**
Aboriginal Heritage Places	DataWA	(https://catalogue.data.wa.gov.au/dataset/aboriginal-heritage-places)
Black Cockatoo Breeding Sites	DataWA	(https://catalogue.data.wa.gov.au/dataset/black-cockatoo-breeding-sites-buffered)
Black Cockatoo Roosting Sites	DataWA	(https://catalogue.data.wa.gov.au/dataset/black-cockatoo-roosting-sites-buffered)
Lakes	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Mine Areas	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Native Vegetation Information System (NVIS)	Department of Climate Change, Energy, the Environment and Water	(https://www.dcceew.gov.au/environment/land/native-vegetation/national-vegetation-information-system)
Prohibited Areas	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Reserves	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Road Network	Data.gov	(https://data.gov.au/error?errorCode=404&recordType=Dataset&recordId=%22ds-aurin-aurin%253Adatasource-WA_Govt_MRWA-UoM_AURIN_DB_mrwa_road_network_2018%22)
Threatened Ecological Communities (TECs)	DataWA	(https://catalogue.data.wa.gov.au/dataset/threatened-ecological-communities)
Water Course Lines	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)

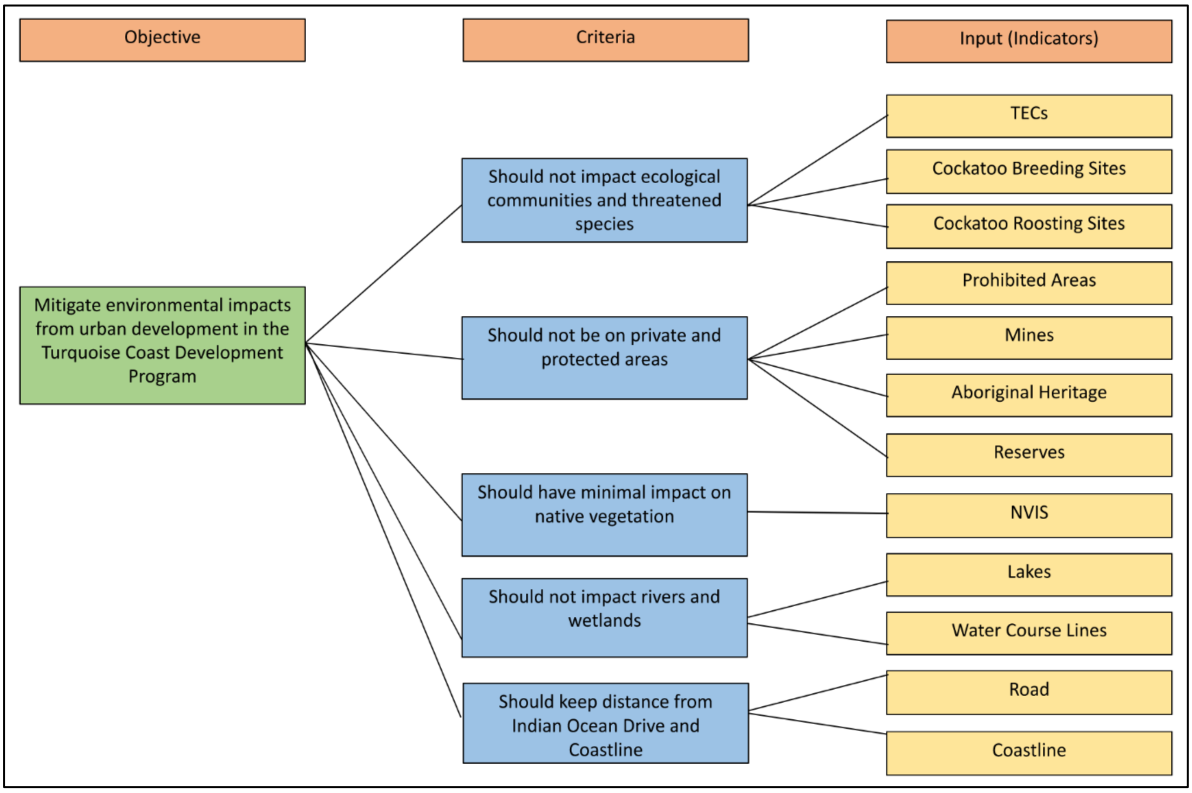


Figure 1: Means-to-an-end diagram for the new development plan

Appendix B shows the workflow diagram of our spatial analysis in QGIS for the development plan. The use of QGIS allowed us to identify any significant ecological sites (TECs, cockatoo breeding and roosting sites) in the area that we should avoid and any unavailable lands (Prohibited areas, mines, aboriginal heritage, and reserves) that we cannot develop on. To ensure that the new development plan has minimal impact on ecosystems and visual amenities, we added buffers of recommended distances around lakes, the Hill River, the Indian Ocean Road, and the coastline. Details on buffers are outlined in *Table 2*.

Table 2: Summary table of environmental buffers

Environmental asset	Buffer distance (m)	Purpose
Lake/wetlands	500	Reduce inputs of nutrients and pollutants, maintain ecological processes, alleviate rising salinity (Water and Rivers Commission, 2000)
Hill River	350	Buffer of 200 meters to support fish and aquatic wildlife, reduce nutrients runoff, increase flood retention, and maintain flow (The Nature Conservancy, 2015). An additional buffer of 150 meters to adequately preserve the lower parts of the Hill River (EPA WA, 2001)
Indian Ocean Drive	500	Preserve visual amenity for road users (EPA WA, 2001)
Coastline	500	Account for projected sea-level rise in 2110 and preserve coastal dunes (Cardno, 2018)

The NVIS data revealed three main types of native vegetation in the area: acacia shrublands, other shrublands, and heathlands. Heathlands were the priority for conservation in our development plan due to their diverse and endemic flora and fauna inhabitants, such as plant families of Proteaceae, Fabaceae, and Restionaceae (Department of the Environment and Energy, 2017). They are also relatively rare along the coastline, as shown by *Appendix C*, making it a locally significant ecological community that demands conservation. Moreover, we will leave portions of native vegetation as wildlife corridors to prevent habitat fragmentation. The corridors will be 500 meters wide to preserve natural patterns of native vegetation and landscape elements (EPA WA, 2001).

Offset planning

The objective of our offset plans is to offset the biodiversity loss from land clearing in the TCDP. We have chosen to offset by revegetation at a ratio 2:1 for the area that will be revegetated compared with the area that will be cleared, as determined by the WA Environmental Offsets Guidelines (EPA WA, 2014). *Table 3* summarizes the data that were used in the second MCA for offset. *Figure 2* outlines three criteria to be considered for the objective and the input data that were utilized for the spatial analysis of each criterion.

Table 3: Summary table of data used in the MCA for the offset plans

Dataset name	**Source**	**URL**
Aboriginal Heritage Places	DataWA	(https://catalogue.data.wa.gov.au/dataset/aboriginal-heritage-places)
Black Cockatoo Breeding Sites	DataWA	(https://catalogue.data.wa.gov.au/dataset/black-cockatoo-breeding-sites-buffered)
Black Cockatoo Roosting Sites	DataWA	(https://catalogue.data.wa.gov.au/dataset/black-cockatoo-roosting-sites-buffered)
Bushfire Prone Areas	DataWA	(https://catalogue.data.wa.gov.au/dataset/bush-fire-prone-areas-2019-no3-obrm-017)
Mine Areas	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Prohibited Areas	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Reserves	Extracted from GEODATA TOPO 250K Series 3	(https://data.gov.au/data/dataset/a0650f18-518a-4b99-a553-44f82f28bb5f)
Surface Acidity	DataWA	(https://catalogue.data.wa.gov.au/dataset/soil-landscape-surface-acidity-current)
Surface Salinity	DataWA	(https://catalogue.data.wa.gov.au/dataset/soil-landscape-surface-salinity-current)
Threatened Ecological Communities (TECs)	DataWA	(https://catalogue.data.wa.gov.au/dataset/threatened-ecological-communities)

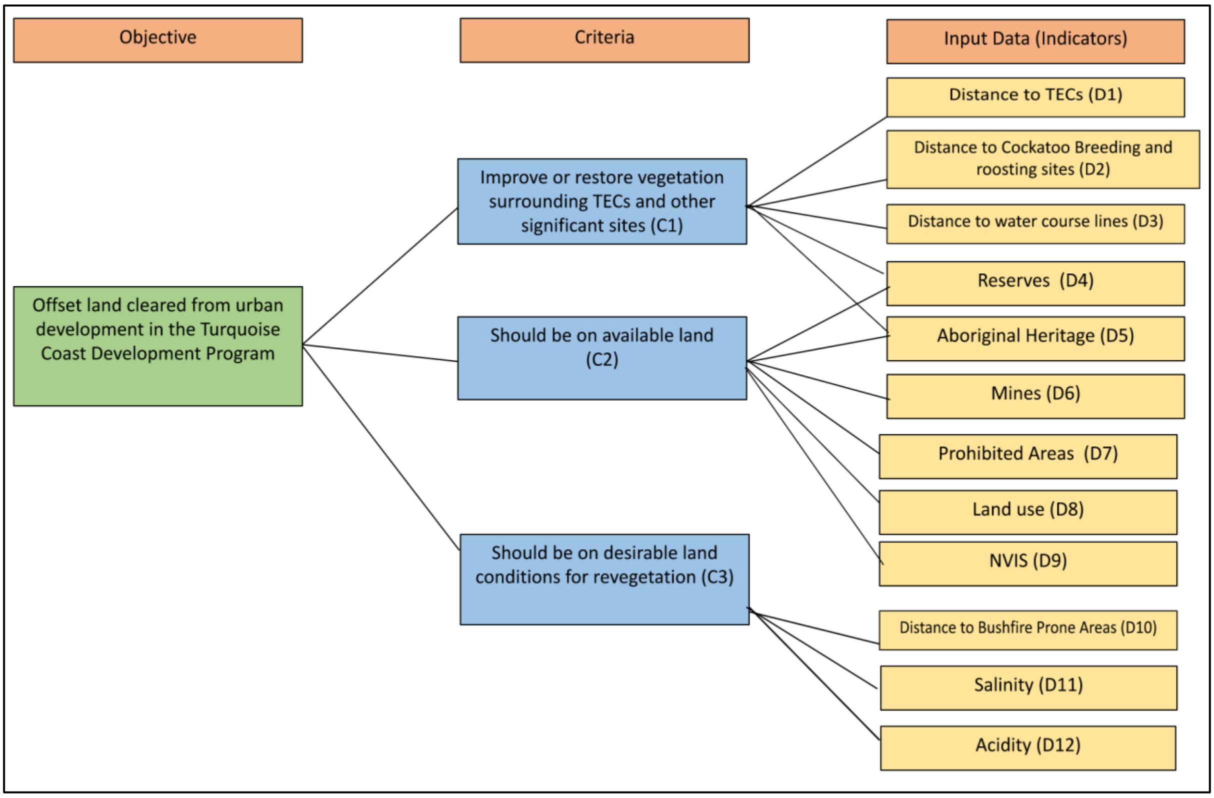


Figure 2: Means-to-an-end diagram for the offset plans with each criterion coded "C" and each input data coded "D"

To identify areas of environmental values (suitable for offset), we used the eight input data from C1 and C3. The proximity to D1, D2, D3, D4, D5, and D10, and the characteristic of D11 and D12 determine the environmental value of each raster grid. These input data were mapped, and their proximity and characteristic values were reclassified into standardized environmental values of 0 to 10 where 0 is the least suitable for offset and 10 is the most suitable for offset. Details on QGIS methods for the offset plans are illustrated in *Appendix D*. *Table 4* explains the reclassification processes. The closer the area is to D1, D2, D3, D4, and D5, the higher the environmental values because nearby vegetation would increase the value and resilience of these environmental assets. Black cockatoos have a maximum range of 12 kilometers for roosting and breeding (Threatened Species Network, 2008); therefore, we set the distance greater than 12 kilometers to 0 environmental value. The further away from D10 an area is, the greater the environmental values because juvenile native vegetation has a higher chance of survival further away from bushfires. We aimed for areas of moderate salinity and acidity risks because we wanted to restore partially degraded lands through revegetation, but also ensure that they are not too degraded that juvenile plants cannot survive on.

Table 4: Reclassification tables of each input data

Input	Environmental values										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
D1	>5km	4-5km	3-4km	2.5-3km	2-2.5km	1.5 – 2km	1– 1.5km	0.5 – 1km	0.25-0.5km	0.05-0.25km	<0.05 km
D2	>12km	10-12km	8-10km	7-8km	6-7km	5-6km	4-5km	3-4km	2-3km	1-2km	<1km
D3	>5km	4-5km	3-4km	2.5-3km	2-2.5km	1.5 – 2km	1– 1.5km	0.5 – 1km	0.25-0.5km	0.05-0.25km	<0.05 km
D4	>5km	4-5km	3-4km	2.5-3km	2-2.5km	1.5 – 2km	1– 1.5km	0.5 – 1km	0.25-0.5km	0.05-0.25km	<0.05 km
D5	>5km	4-5km	3-4km	2.5-3km	2-2.5km	1.5 – 2km	1– 1.5km	0.5 – 1km	0.25-0.5km	0.05-0.25km	<0.05 km
D10	<0.05 km	0.05-0.25km	0.25-0.5km	0.5 – 1km	1– 1.5km	1.5 – 2km	2-2.5km	2.5-3km	3-4km	4-5km	>5km
D11	AR 4	-	-	AR1	-	-	AR 2	-	-	-	AR 3
D12	SR 6	-	SR 5	-	SR 1	-	SR 2	-	SR 3	-	SR 4

*AR = Acidity Risk, SR = Salinity Risk
AR 1,2,3, and 4 = <3%, 3-10%, 10 – 30%, and 30 -50% of area has acidity of less than pH 4.5 respectively.
SR 1,2,3,4,5, and 6 = <3%, 3-10%, 10 -30%, 30 -50%, 50 – 70%, and >70% of area has high SR, respectively

We combined all the inputs in *Table 4* into a single map, showing the environmental values of each raster grid. Because each factor has different degrees of significance, we assigned them different weight coefficients, as shown in *Table 5*. TECs and reserves have the highest weight because our first criterion is to conserve rare, threatened ecosystems. Black cockatoos' factors are weighed the least as there were no roosting or breeding sites in the development plan; therefore, the plan did not have significant impact on the black cockatoos. The overall environmental value was calculated by *equation 1*. Lastly, we met C2 by covering the overall environmental value map with layers of prohibited land (D4, D5, D6, and D7), non-purchasable land (D8 land use, such as roads, conservation, harbours etc.) and existing native vegetation (D9) to show areas that we cannot implement revegetation on.

$$E = \Sigma\, w_i\, x_i \text{ (\textit{Equation 1})}$$

Where E is the total environmental value, w is the weight coefficient, and x is the factor.

Table 5: Weights of each environmental factor (Input data)

Factor	D1	D2	D3	D4	D5	D10	D11	D12
Weight	0.24	0.04	0.05	0.12	0.05	0.14	0.18	0.18

Offset scenarios and costs

From our offset planning map, we developed two offset scenarios. The first scenario consists of a single large high-environmental-value area, whereas the second scenario consists of several small high-environmental-value areas. Both scenarios have approximately the same area, which is double the area to be cleared by the development plan. The QGIS Method for analyzing costs is shown in *Appendix E*. The total costs were calculated using *equation 2*. The land acquisition costs were calculated by hectare and the price per hectare depends on land-use. Fencing costs, planting costs, and effort costs were calculated by *equation 3*, *equation 4* and *equation 5*, respectively.

$$\text{Total cost} = \text{Land acquisition costs} + ((\text{Fencing costs} + \text{Planting costs}) * \text{Effort costs})$$

(*Equation 2*)

Fencing costs = 25 * perimeter (m) (*Equation 3*)

Planting costs = 2,000 * area (ha) (*Equation 4*)

Effort costs = 1 + (Distance from roads (m)/ 50,000) (*Equation 5)*

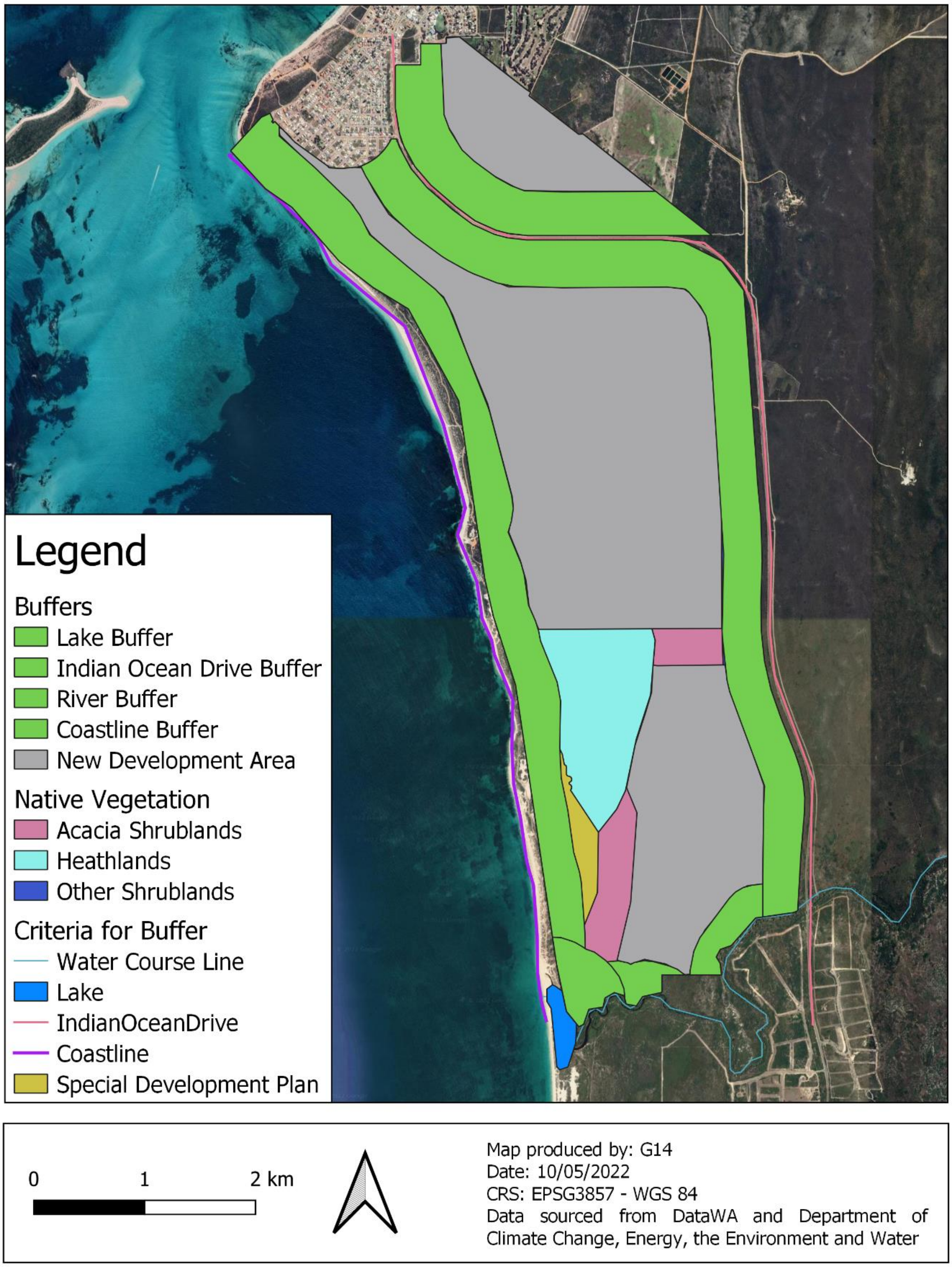
Results

The revised TCDP designates half the area of the original plan for development, which sums to 1,039 hectares. *Map 2* and *Table 6* show that more than half of acacia shrublands are cleared, while more than half of heathlands are conserved, with two habitat corridors connecting the heathlands to the estuary and to the east. Most of the other shrublands are protected by the buffers from the Indian Ocean Drive (*Map 2*).

Table 6: Summary table of the area of native vegetation in hectares that will be cleared or conserved in the new TCDP

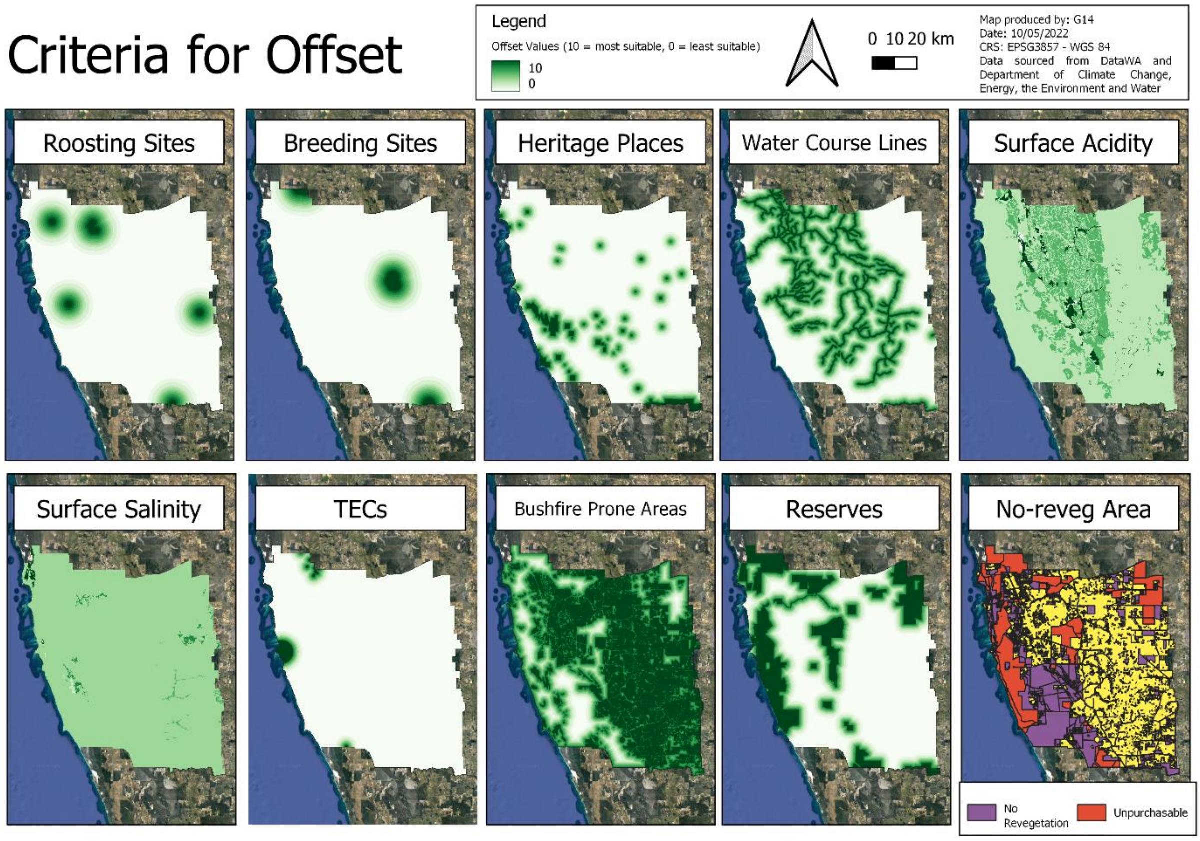
Type of Native vegetation	Total in original TCDP	To be cleared in the new TCDP	Conserved
Acacia Shrublands	827.80	573.47	254.33
Heathlands	279.24	122.94	156.30
Other Shrublands	240.17	47.27	192.90

Revised Development Plan for Turquoise Coast

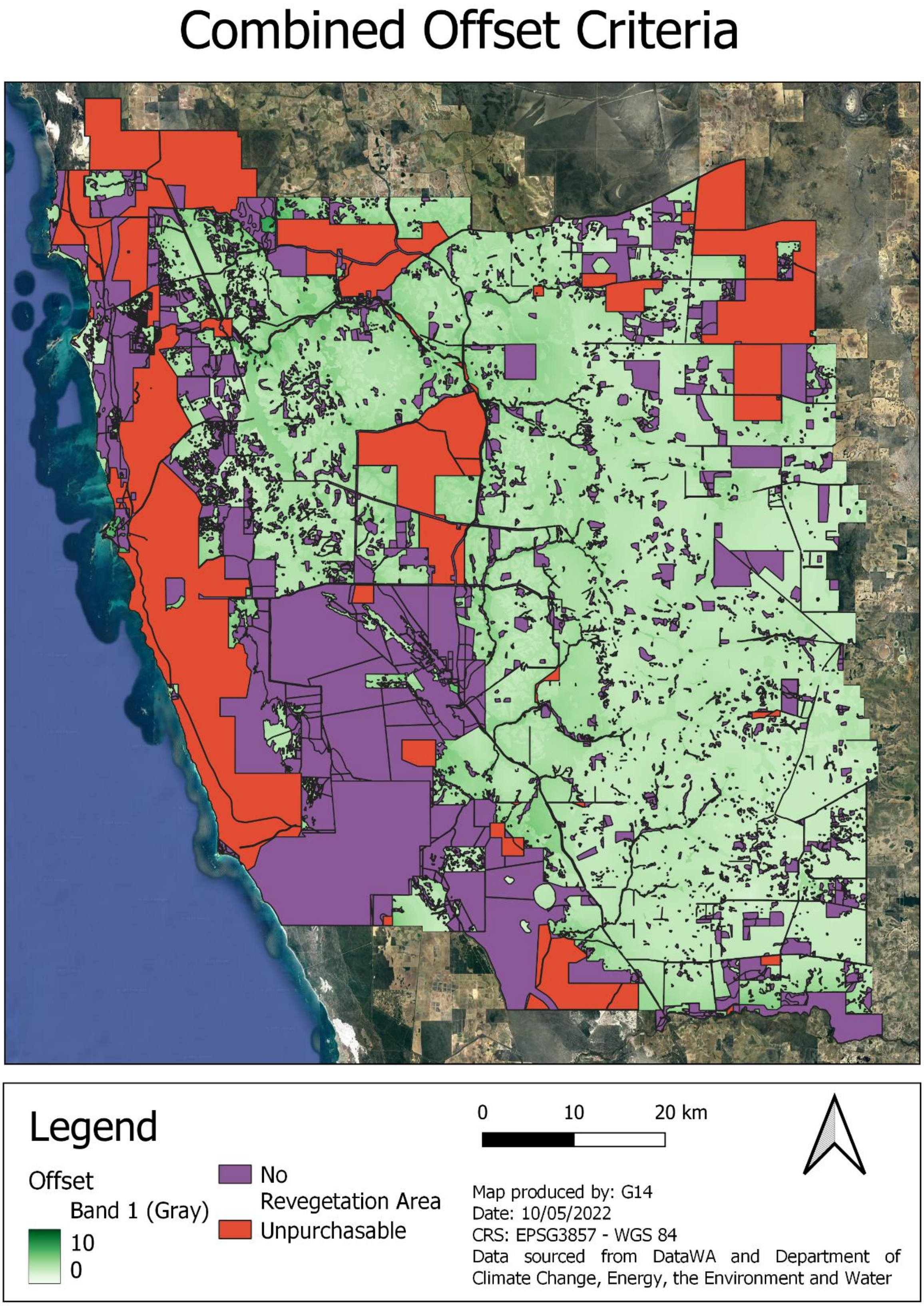


Map 2: Revised TCDP

Map 3 and *Map 4* show the factors that were put into the offset map and the combined output, respectively. Because environmental values are relatively higher in the northwest area, our offset scenarios are situated there, as shown in *Map 5* and *Map 6*. There are 7 portions of land zoned for revegetation in scenario 2 (*Map 6*).

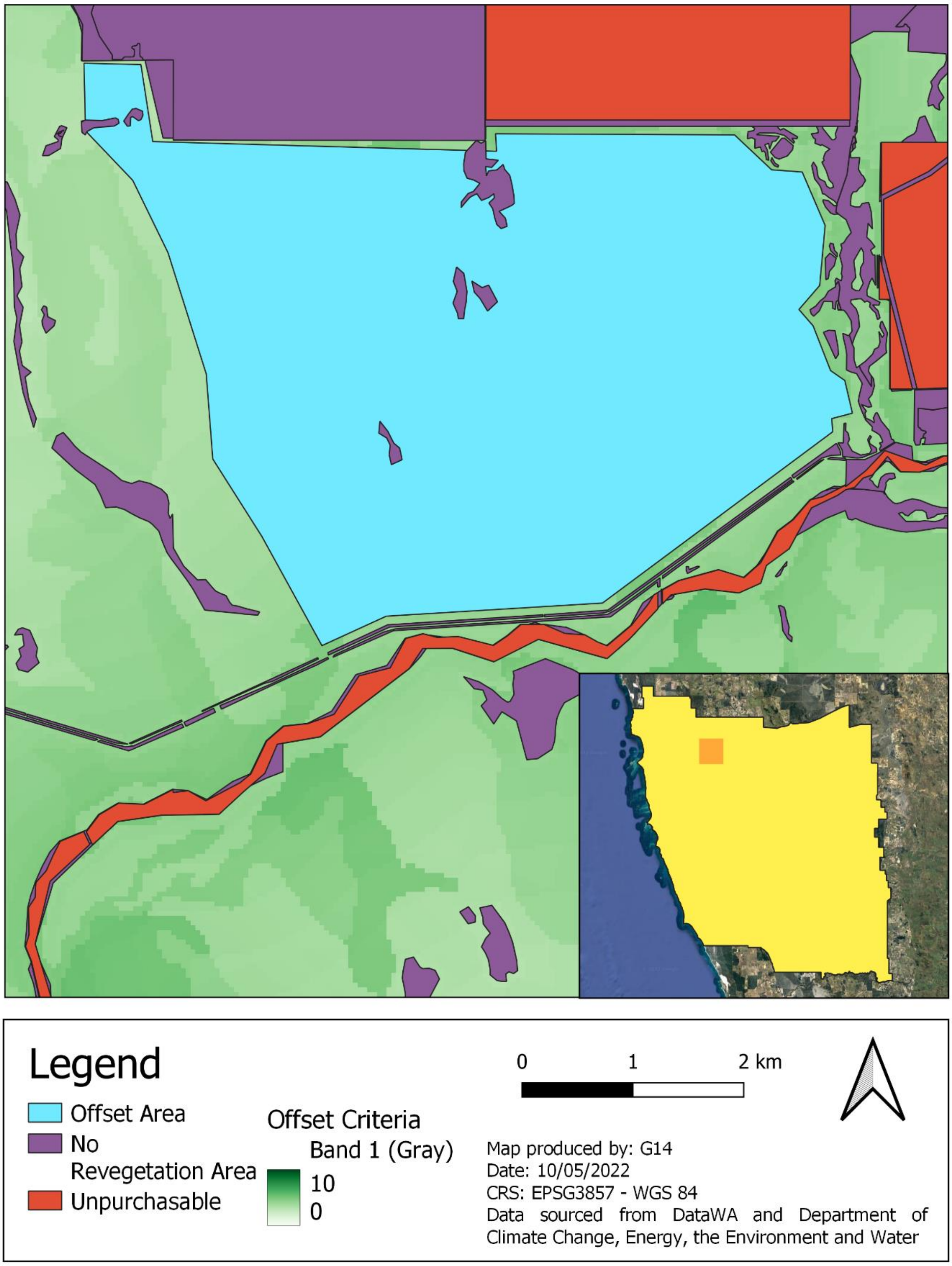


Map 3: Environmental values of each criterion's factors and the no-revegetation area in the Shire of Dandaragan

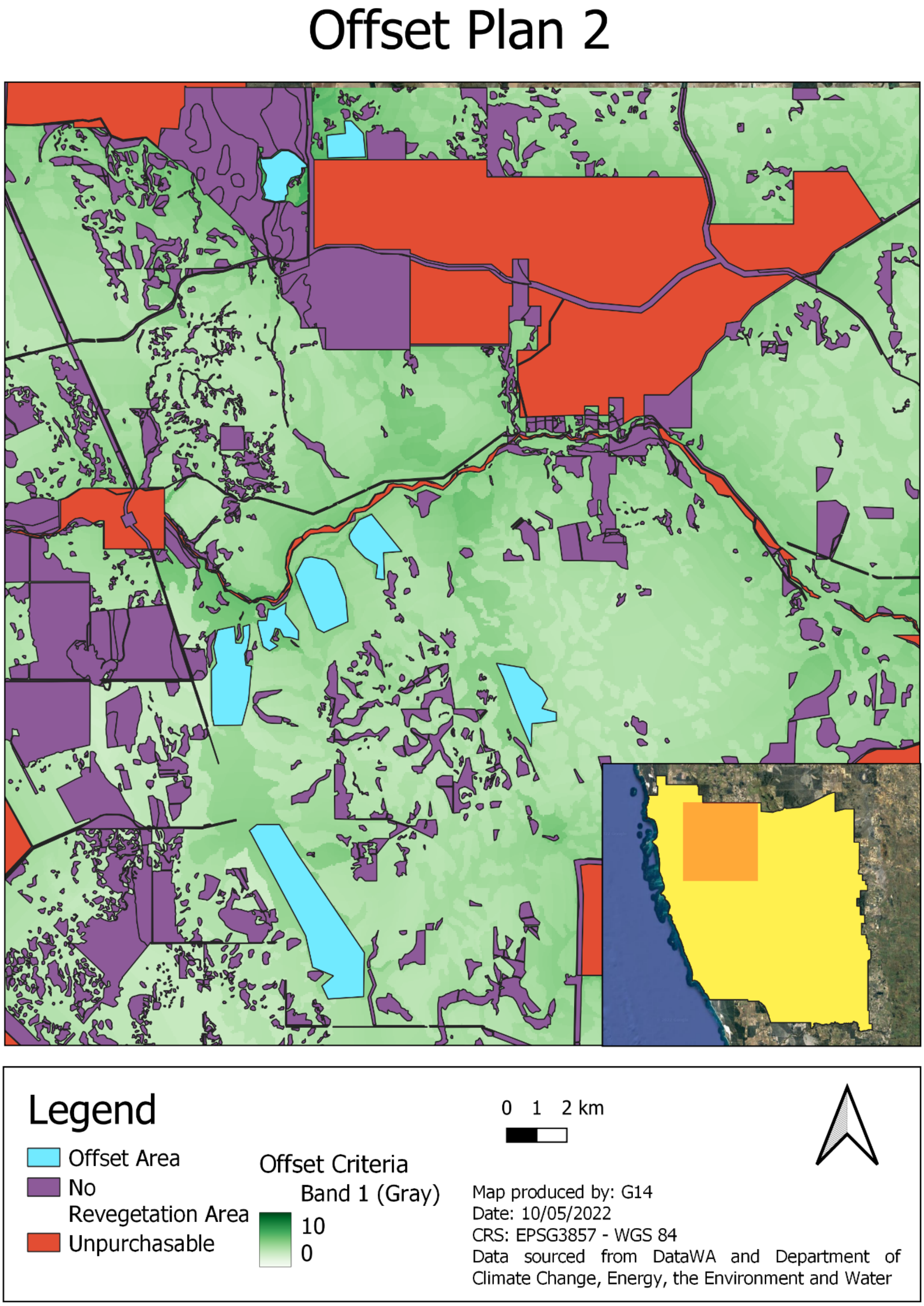


Map 4: Calculated combined offset factors with no-revegetation and unpurchasable layers superimposed

Offset Plan 1



Map 5: Offset scenario 1 (a single large area)



Map 6: Offset scenario 2 (multiple smaller areas)

Table 7 and *Table 8* summarise the costs of offset scenario 1 and 2, respectively. The offset areas of both scenarios are on rural land, which costs $1,200 per hectare. The total perimeter of scenario 2 is about three times greater than the total perimeter of scenario 1, which leads to the fencing costs of scenario 2 being around $1 million higher. Because all other costs are similar, the total cost of scenario 2 is around $1 million more than the total cost of scenario 1.

Table 7: Summary table of costs of implementing offset scenario 1

Area (hectare)	2,205.00
Perimeter (m)	21,103.00
Planting costs ($)	4,411,988.00
Fencing costs ($)	527,585.55
Effort costs ($)	1.06
Land acquisition costs ($)	2,682,201.60
Total cost ($)	7,908,270.41

Table 8: Summary table of costs of implementing offset scenario 2

Area (hectare)	2,205.27
Perimeter (m)	62,763.28
Planting costs ($)	4,410,545.79
Fencing costs ($)	1,569,082.12
Effort costs ($) (average)	1.03
Land acquisition costs ($)	2,646,327.48
Total cost ($)	8,794,748.19

Discussion and Recommendations

Using GIS-integrated MCA, we developed the new development plan, which prevents and reduces various environmental impacts such as degradation of water bodies and habitat fragmentation. *Table* 6 highlights that 56% of the heathlands, our native vegetation prioritized for conservation, are to be conserved by the new TCDP. Nonetheless, biodiversity loss would occur due to clearing of native vegetation, but this issue can be alleviated by the suggested biodiversity offsets. Offsets have a time-lag before reaching their full conservation potential; therefore, they will require long-term maintenance (McKenney & Kiesecker, 2010). The biodiversity loss caused by the temporal lag should also be accounted for in the estimates of offset benefits (McKenney & Kiesecker, 2010). A limitation of this study is that it did not consider time-related factors, such as long-term maintenance costs, time-lag, permanence of benefits, or time discounting (Moilanen & Kotiaho, 2018). A post-implementation evaluation using a robust biodiversity currency is vital to ensure that no net biodiversity loss occurs and our objective of mitigating environmental impacts is truly met (Bull et al., 2013).

In conclusion, although the development area is compromised by 50% with the new TCDP, we can mitigate the environmental impact through buffers and biodiversity offsets. Overall, offset scenario 2 is more costly than scenario 1; however, scenario 2 can target more land of higher environmental value due to its smaller offset land sizes. Nevertheless, a single large area of native vegetation enhances species persistence better than several small areas as it preserves ecological functions, such as natural disturbances (Leroux et al., 2007) and interspecific interactions (Rayfield et al., 2009). This undermines the ecological benefit of small, isolated offset areas; therefore, we recommend offset scenario 1 for its relatively cheaper costs and more beneficial ecological processes. Future studies should evaluate the long-term post-implementation evaluation and maintenance costs of the offset scenarios to better inform stakeholders of their decisions regarding biodiversity offsets.

References

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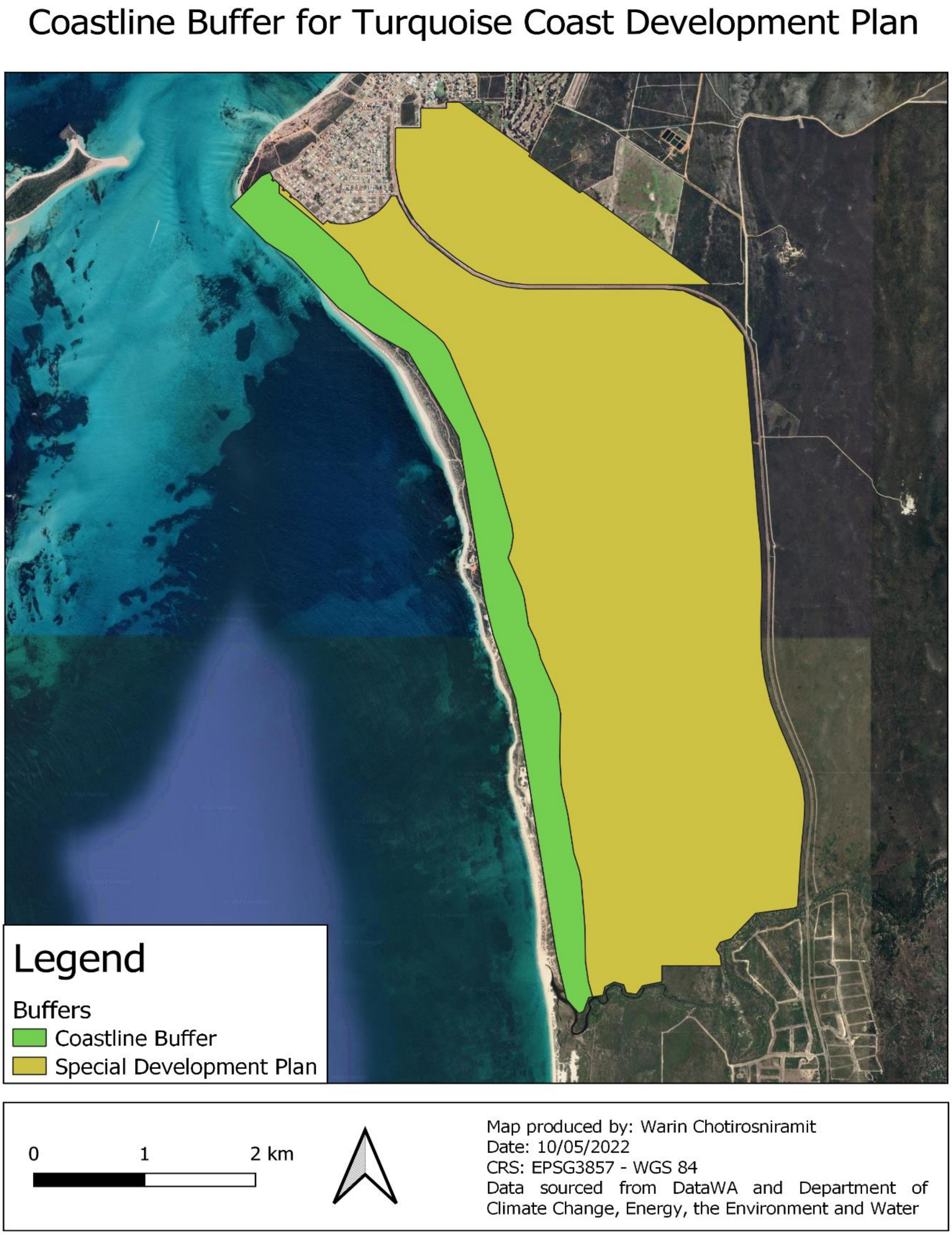
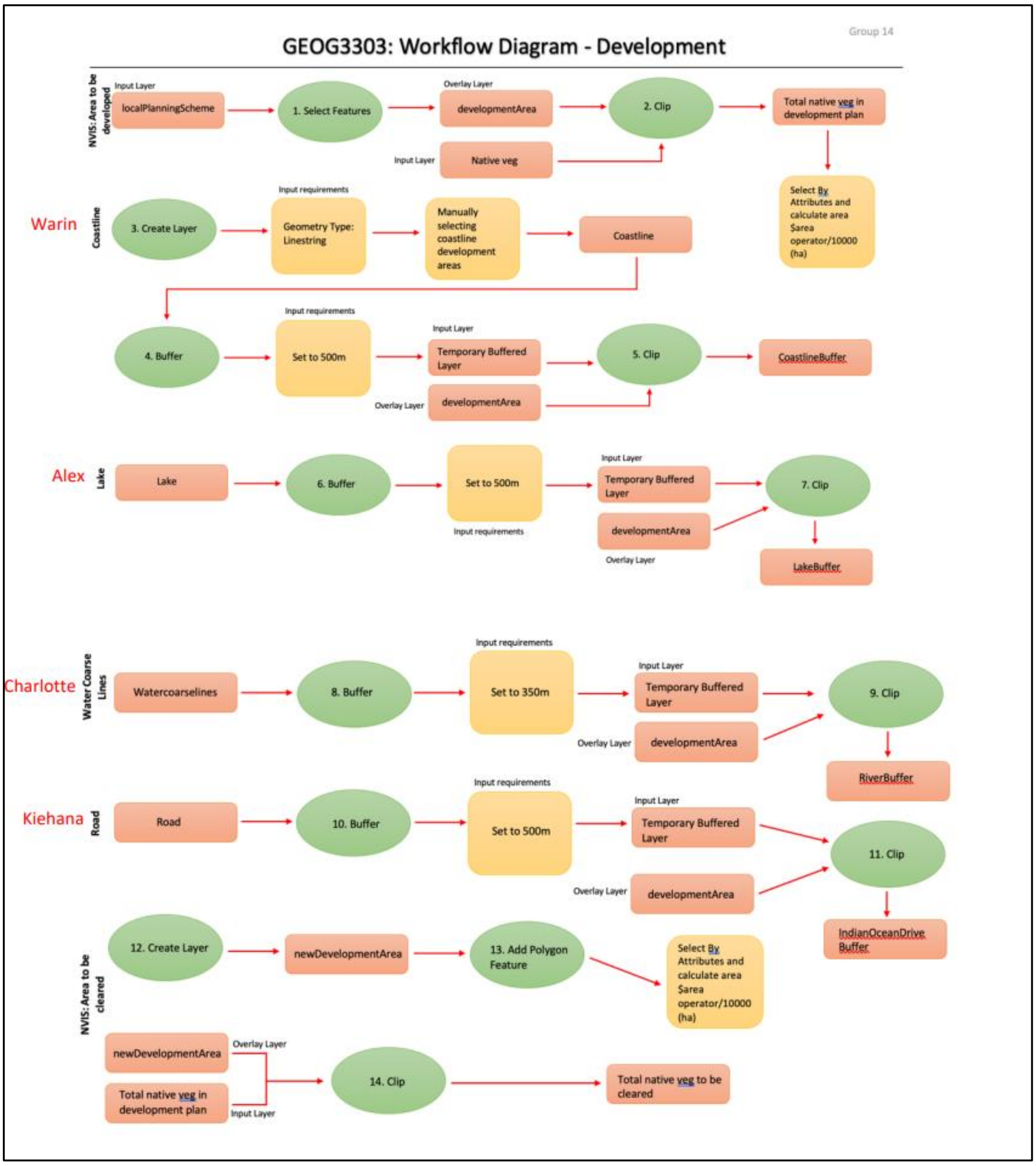
Appendix

Appendix A



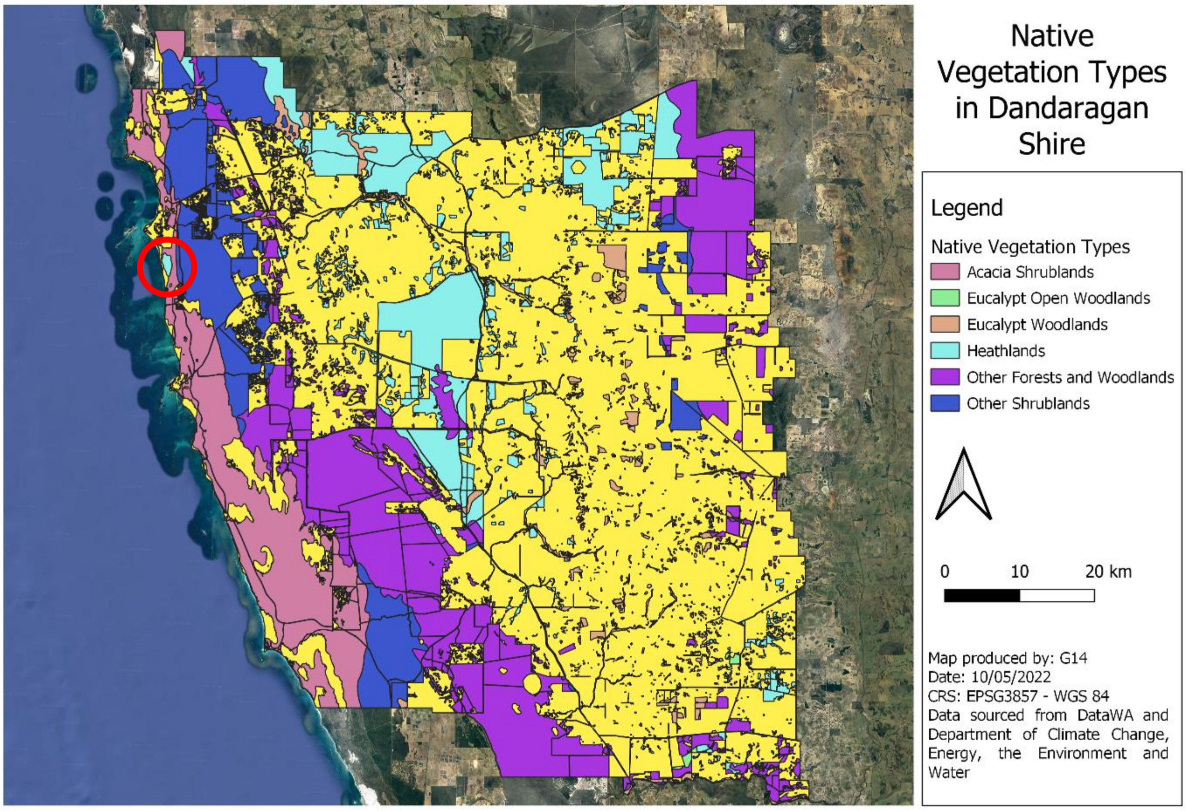
Appendix A: Student's layer of coastline buffer

Appendix B



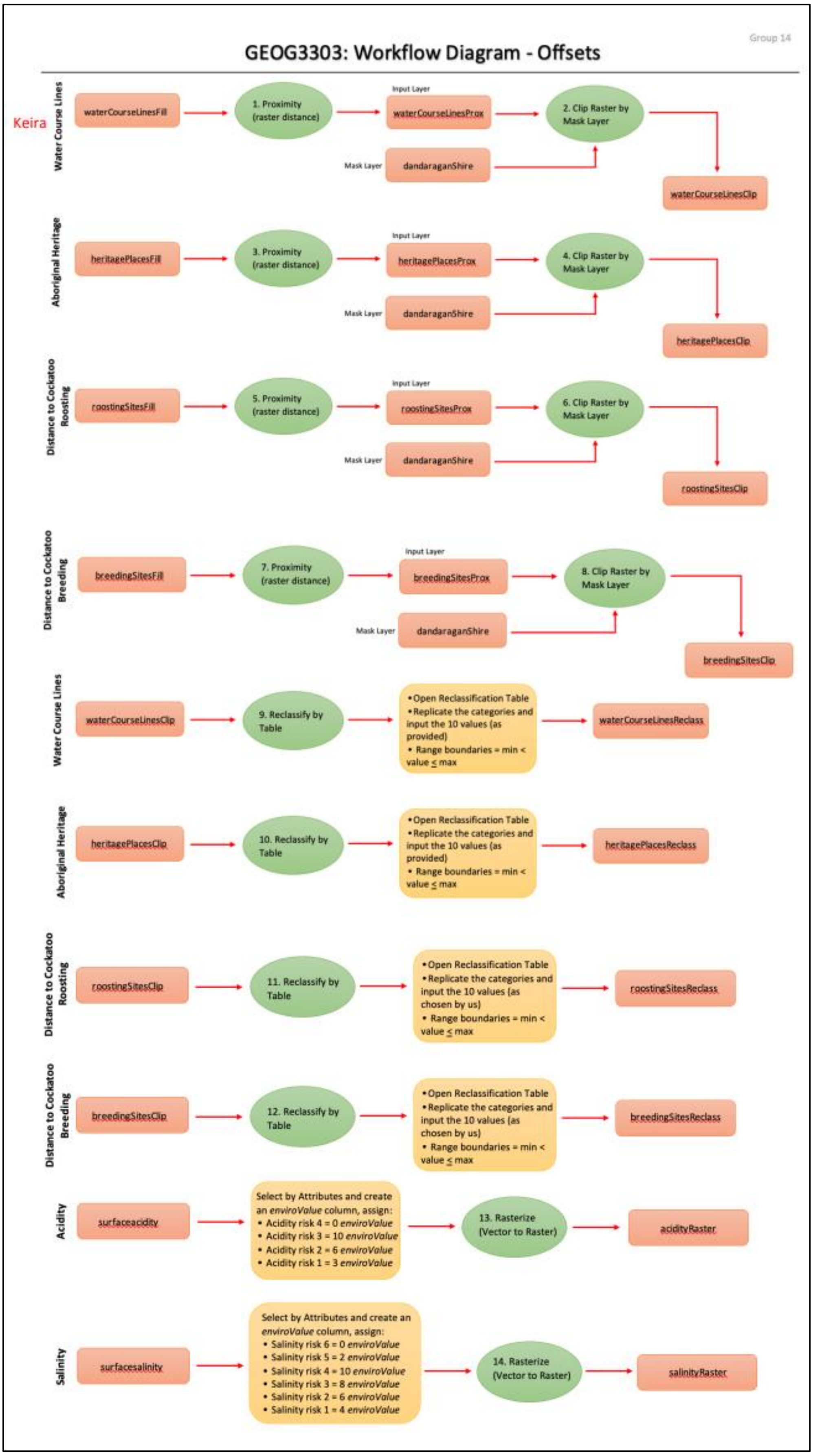
Appendix B: Workflow diagram for development plan

Appendix C

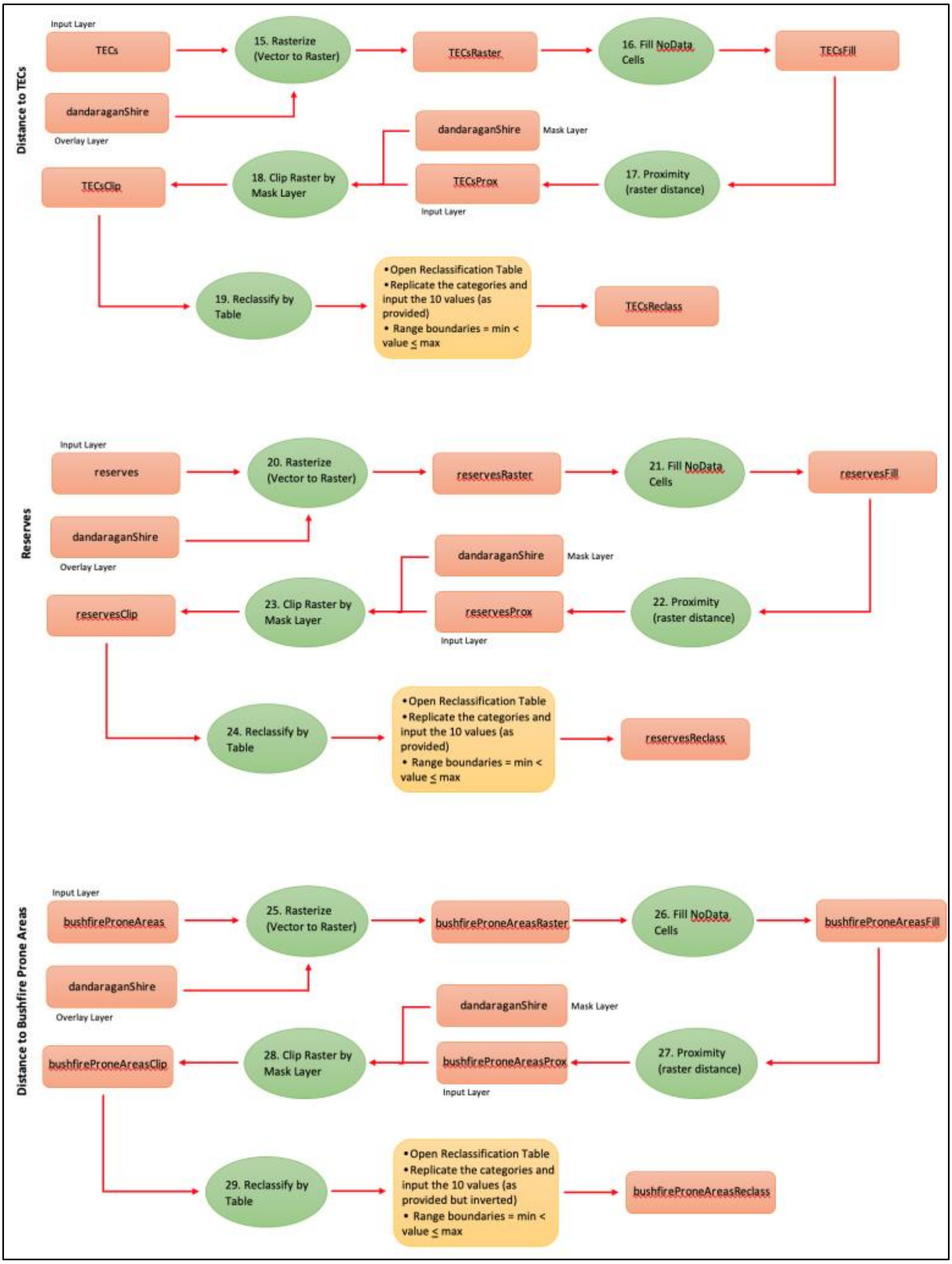


Appendix C: Map of native vegetation in the Shire of Dandaragan (Source: NVIS). The red circle indicates the rare portion of coastal heathland that is in the TCDP.

Appendix D

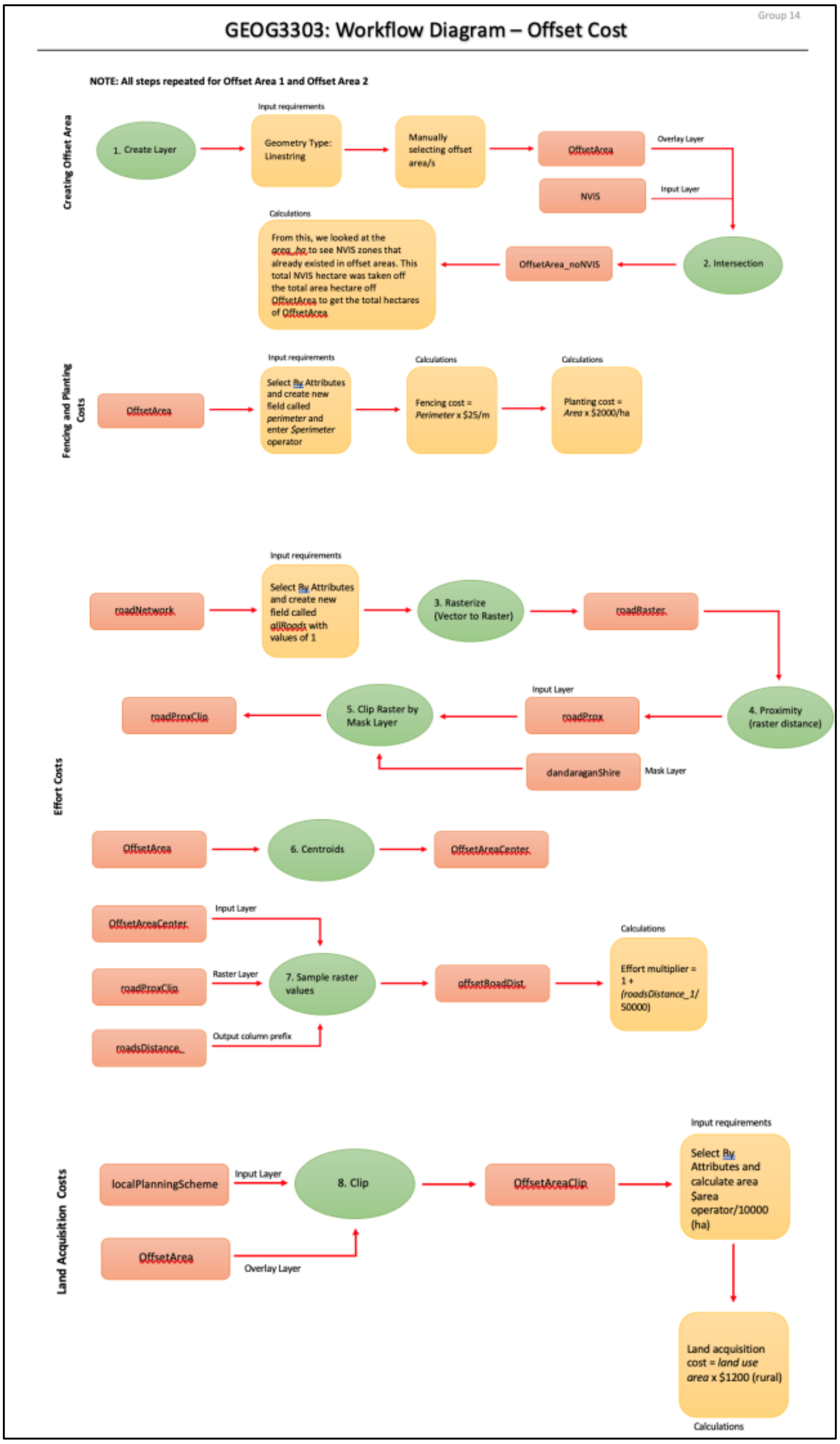


Group 14
GEOG3303: Workflow Diagram - Offsets
Keira
Water Course Lines
waterCourseLinesFill
1. Proximity (raster distance)
Input Layer
waterCourseLinesProx
2. Clip Raster by Mask Layer
Mask Layer
dandaraganShire
waterCourseLinesClip
Aboriginal Heritage
heritagePlacesFill
3. Proximity (raster distance)
Input Layer
heritagePlacesProx
4. Clip Raster by Mask Layer
Mask Layer
dandaraganShire
heritagePlacesClip
Distance to Cockatoo Roosting
roostingSitesFill
5. Proximity (raster distance)
Input Layer
roostingSitesProx
6. Clip Raster by Mask Layer
Mask Layer
dandaraganShire
roostingSitesClip
Distance to Cockatoo Breeding
breedingSitesFill
7. Proximity (raster distance)
Input Layer
breedingSitesProx
8. Clip Raster by Mask Layer
Mask Layer
dandaraganShire
breedingSitesClip
Water Course Lines
waterCourseLinesClip
9. Reclassify by Table
• Open Reclassification Table
• Replicate the categories and input the 10 values (as provided)
• Range boundaries = min < value ≤ max
waterCourseLinesReclass
Aboriginal Heritage
heritagePlacesClip
10. Reclassify by Table
• Open Reclassification Table
• Replicate the categories and input the 10 values (as provided)
• Range boundaries = min < value ≤ max
heritagePlacesReclass
Distance to Cockatoo Roosting
roostingSitesClip
11. Reclassify by Table
• Open Reclassification Table
• Replicate the categories and input the 10 values (as chosen by us)
• Range boundaries = min < value ≤ max
roostingSitesReclass
Distance to Cockatoo Breeding
breedingSitesClip
12. Reclassify by Table
• Open Reclassification Table
• Replicate the categories and input the 10 values (as chosen by us)
• Range boundaries = min < value ≤ max
breedingSitesReclass
Acidity
surfaceacidity
Select by Attributes and create an enviroValue column, assign:
• Acidity risk 4 = 0 enviroValue
• Acidity risk 3 = 10 enviroValue
• Acidity risk 2 = 6 enviroValue
• Acidity risk 1 = 3 enviroValue
13. Rasterize (Vector to Raster)
acidityRaster
Salinity
surfacesalinity
Select by Attributes and create an enviroValue column, assign:
• Salinity risk 6 = 0 enviroValue
• Salinity risk 5 = 2 enviroValue
• Salinity risk 4 = 10 enviroValue
• Salinity risk 3 = 8 enviroValue
• Salinity risk 2 = 6 enviroValue
• Salinity risk 1 = 4 enviroValue
14. Rasterize (Vector to Raster)
salinityRaster



Appendix D: Workflow diagram for offset planning (two images)

Appendix E



Appendix E: Workflow diagram for calculating costs of offset scenarios