A preliminary Mannings-*n* layer to support regional flood modelling in Tasmania

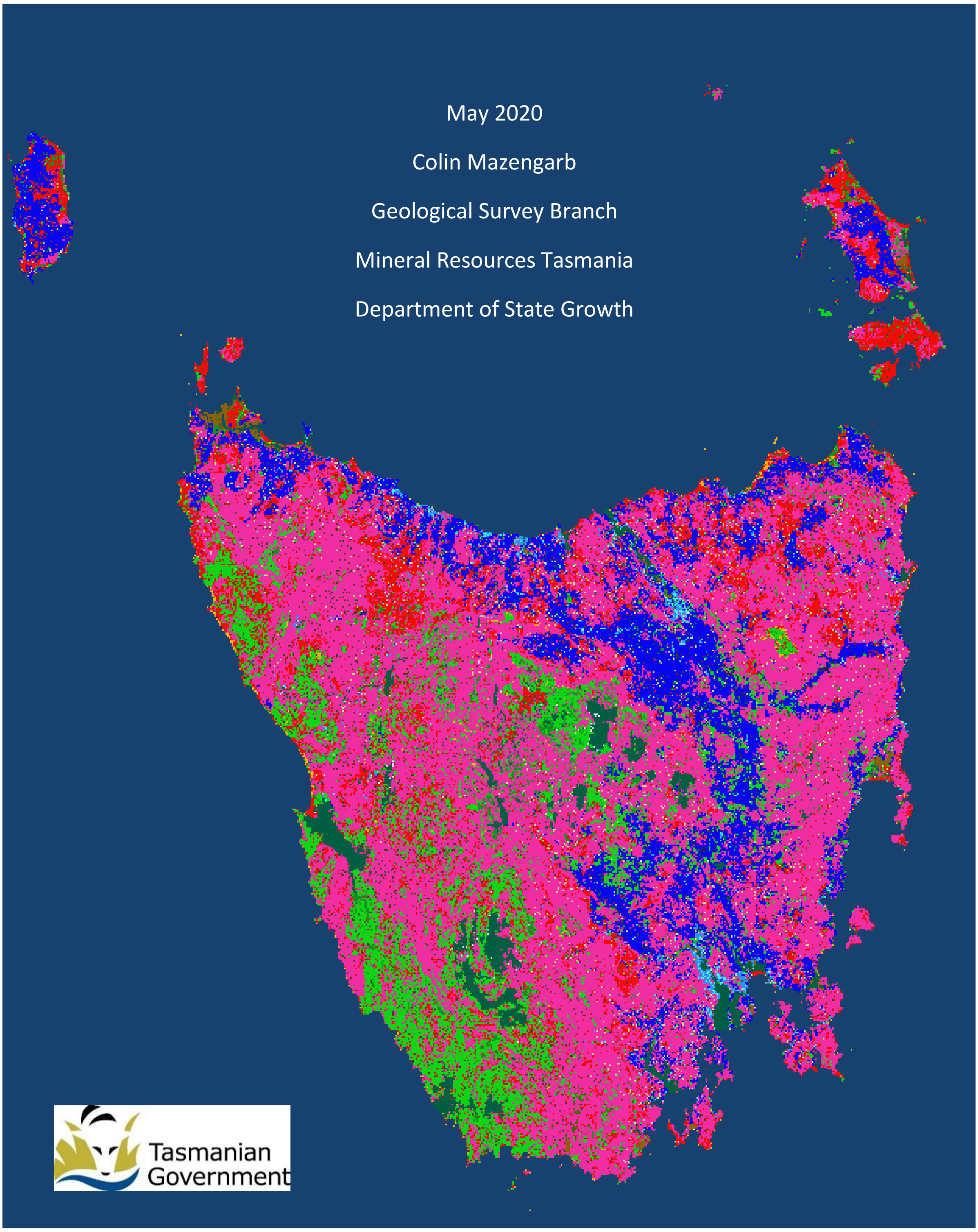
May 2020

Colin Mazengarb

Geological Survey Branch

Mineral Resources Tasmania

Department of State Growth



Tasmanian Government

Table of Contents

Introduction

The Flood Policy Unit of the Tasmanian State Emergency Service have requested Mineral Resources Tasmania to produce two input layers to support their state-wide 2D flood modelling project; a revised DEM (digital elevation model) and a Mannings-n layer. A Mannings-n layer (or a Gauckler–Manning coefficient) is an empirically derived coefficient, which is dependent on many factors, including surface roughness and sinuosity (Wikipedia). It is a second-order input layer used in contemporary flood modelling to account for frictional losses imposed by the surfaces over which water flows. These surfaces include natural and built environments for which reference tables of Mannings-n values exist. In addition, a given surface may have multiple values, to account for water depth.

This document provides the explanation and supporting information to accompany the layer that was constructed.

Method

In typical flood model practice, a Mannings-n layer is constructed by utilising one or more of the following methods; manual digitising from orthophotos, image processing methods and utilising existing GIS layers. The choice of methods employed will often depend on the size of the project area, the budget, the availability of datasets and the skill of the operator. In this study I have developed a preliminary method for the construction of a Mannings-n layer using publicly available vector datasets. It should be stated first up that I have used datasets that were not ever intended for this purpose and should be regarded as proxies of varying reliability (in terms of currency, spatial and attribute accuracies). The method involves assigning standard surface categories to the input features that can then be linked to Mannings-n values. A table of suggested conversion values (Appendix 1) was provided by the technical advisor to the project, Mr E R (Ted) Rigby, but the end user can readily apply other values should they wish.

In the development of the method, an initial directive was provided from the technical advisor that the output be in a vector format and derived from a series of vector operations. The reason for this approach being that flood modelling software would require this format rather than a raster. While an output in this format was eventually achieved, the coding and processing took an enormous amount of time and proved to be problematical. For instance, vector unionisation tools for such a large area were on the edge of computer limitations, plus they introduced topological slivers that could not be effectively removed despite tools being available that claimed to be able to do this. These concerns were conveyed to the advisor and a subsequent directive was given that the format could now be a raster.

The creation of the raster output proved to be substantially easier to implement than the vector method. I have created a series of operations to be run in sequence that creates a single output raster at a nominated cellsize (10 m) and snapped to the associated 10 m statewide DEM. These operations consist of a mixture of python scripts that implement the ESRI *arcpy* module and the use of the ESRI *Model Builder* requiring ArcGIS Desktop 10.6 (basic license) and the Spatial Analyst extension. QGIS 3.10 was also used for a buffering process that could not be done with the ArcGIS Desktop 10.6 basic license level. At the time of writing, these steps are being condensed into a cleaner process to allow transfer to third parties with software described.

In a nutshell, the process I have developed combines a series of selected features from the various inputs in an order of priority. Each of the adopted features has a surface type assigned to it based on the associated reference table (Appendix 1). However, a very small number of cells in the raster escaped the net and a default value of 50 has been assigned.

For those wishing to rerun the supplied algorithms, the authority tables used (see appendices) can be easily updated if the assigned surface values are not as one would wish. These tables are contained in a single Excel spreadsheet file that is read by the program operations. Furthermore, the approach presented here is compatible with the creation of higher resolution rasters to cover smaller areas where greater detail with more accurate data is required.

Input layers

Seven layers were used to construct a Mannings-n layer with priorities indicated (Table 1). All but one of these layers is publicly available. At the time of writing, I am experimenting with the inclusion of a buildings surface type that may impose greater control in the built environment. When this is completed, an update to this documentation will be provided.

Priority	Layer	Comment
1	Buildings	Polygon and Point
1	Water bodies	Polygon
2	Water Courses	Polyline
3	DSG State Roads	Polyline, restricted availability
3	LIST Transport Roads	Polyline
4	Cadastre Roads	Polygon
5	Vegetation (TASVEG3)	Polygon
6a	Interim Planning Scheme	Urban areas only for non-road parcels. Flinders Island was not available at the time of compilation
6b	Sullivans Cove Planning Scheme	The one planning area currently not included in the State layer.

Table 1 Priority order for input layers

Step 1 Roads, tracks and pathways

Script: S1ManningsRoadCalc.py and ModelBuilder (Combine 3 road layers)

Information on referenced Layers:

Three principal inputs have been used for this purpose, cadastral parcels, LIST Transport and the DSG State Roads (with widths) layers. From the outset, this has proved to be a challenging dataset to produce as there are serious integrity issues with two of these!

DSG Trafficable Width (State Roads)

This is a constructed view served internally within the Department of State Growth that is derived from their RIMS system (Road Information Management System). While we are informed by the custodian that there is spatial consistency between this and the LIST Transport layer, there is no common identifier that simply relates the two together.

The DSG layer contains accurate road widths whereas the LIST Transport layer does not have a widths field at all. All of the roads are assumed to be sealed and hence assigned a single surface class. Unfortunately bridges have not been identified as separate features and remain in this layer, as roads. If these were left in the layer, they could create ‘interesting effects’ where they cross waterways. However, I was able to remove them by over-stamping with the water layer (discussed below).

I have use a buffer tool in QGIS (QGIS GDAL buffer, segments= 5, end cap = flat, join style = miter, miter limit = 2) to produce a polygon layer. I could have done this step in ArcGIS but it requires a higher license level to have anything other than rounded ends!

LIST Transport Segments: This dataset contains all transport features in the state including roads, tracks, rail lines, bridges and ferry routes. A description is provided in the following link: http://listdata.thelist.tas.gov.au/public/LIST_Transport_Segments_Information.pdf

Transport segments is a polyline layer that depicts the centre lines of all contained features.

Road widths as mentioned above are not provided and are inferred with reference to contained fields. Details are provided in the python script.

Bridges and culverts have been removed along with rail lines and ferry routes. Two surface types, sealed and unsealed, are assigned.

I have used this layer as a compliment to cadastral road parcels where outside of **urban regions,** such as the Pinnacle Road to Mt Wellington, such features are not in separate parcels.

The processing steps for this preparing this layer before merging with the other two layers are contained in a python script and ModelBuilder (below) and contains a final buffer and rasterization process. The buffer used the rounded ends default process in ArcMap. The polygon to raster process used the Maximum_COMBINED_AREA method and the Priority Field option in order to create connected raster cells but has the effect of slightly exaggerating the road widths. However, after trying several settings this was judged to be the best compromise.

Cadastral Parcels: This is a representation of cadastral parcels for the state (with the exception of Sullivans Cove and the missing Flinders Island schemes) and is visible on LISTmap. I accessed this file as a shapefile loaded on the MRT server that is periodically updated. A description is provided in the following link: http://listdata.thelist.tas.gov.au/public/LIST_Cadastral_Parcels_information.pdf.

Cadastre is a complete polygon layer for the whole State showing property titles. Within this layer it is possible to identify roads and paths based on the field 'CAD_TYPE2' where the word 'road' appears. The features have several recognised limitations:

1. Most notably, the polygon for a typical road will be wider than the actual pavement as it includes nature strips among other things. However, it fills the gaps that can occur between non-road cadastral parcels and transport polygons in many cases.
2. A surface type is not specified in the layer and I have therefore defaulted it to be a paved surface as the majority of roads are paved especially in urban environments. While there will be many country roads that are unsealed, the transport layer will overwrite with the correct surface type in most instances.
3. There will be some instances where cadastral roads and the constructed road do not coincide for whatever reason. Either the road layer may be accurate but constructed in the wrong place, or the cadastre layer is an inaccurate representation of the surveyed feature. I have only recognised this in rural areas so far so it is probably only a minor limitation as I have not identified an automated way to remove these.
4. The layer also does not show driveways or tracks that may exist within titled properties which generally exist outside of urban areas. Within urban areas at regional scale, the presence of driveways within titled properties is incorporated into an overall value.

The final steps for creating a single roads layer were to rasterise each polygon based on the surface-type identifier and combine using the raster calculator in order of priority; State Roads, LIST Transport and Cadastral roads.

Geoprocessing steps:

An overview of the ModelBuilder processing steps is provided as a graphic in Appendix 8.

Step 2 Waterways

Information on referenced layers:

Two inputs are used:

1) Hydrographic lines is a DPIPWE layer of waterway polylines (rivers, streams, etc) and a copy is available on the MRT server as w_course_arc_shp.

2) Hydrological areas is a DPIPWE polygon file representing water bodies and watercourses that is available on the MRT server as HYDAREA.shp.

Information about these layers are contained in the following file:
http://listdata.thelist.tas.gov.au/public/LIST_Hydrographic_Information.pdf

Hydrographic lines are assigned a surface type (see table in appendix).

Hydrological areas are filtered and assigned a range of surface values (see appendix).

Note that there are issues in this layer including some reservoirs (concrete tanks) that are (in my opinion) inconsistently and incorrectly coded. An attempt to filter out concrete tank reservoirs has been done as it was felt they should naturally sit within a buildings layer (see later). The filter query was "HYDARTY2" = 'Reservoir' AND "COMP_AREA" < 2000. This filter is definitely not perfect and as these features are circular it may be worth experimenting with a simple shape analysis where the circumference and the area of each polygon formulas are used to calculate a hypothetical radius. If the ratio of these two calculations are close to 1, it should be a circular structure.

Geoprocessing steps (This is all done in ModelBuilder):

The attribution step is followed by the two inputs being rasterised and then combined using the raster calculator with the Hydrological areas taking priority.

An overview of the ModelBuilder processing steps is provided as a graphic in Appendix 8.

Step 3 Planning Scheme

Script: S2ManningsPlanningScheme.py

This step involves combining the Tasmanian Interim Planning Scheme with the Sullivans Cove planning scheme into a single entity. (As previously mentioned the Flinders Island planning scheme is missing for unknown reasons.) The Sullivans Cove layer is also not freely available but was provided by the Hobart City Council on request. The currency of the layer is unknown.

I have had to do some manual attributing on these layers as there are many inconsistencies between component schemes. The use of Particular Purpose Zones (PPZ) was one of several examples that confounds a rule-based approach as each one is an exception to a standard planning scheme category. PPZs appear to be created for a range of purposes and individually may contain several land uses; a good example being the Cascade Brewery property in Hobart.

The final process was to use the polygon to raster tool (default settings) in ArcMap to create a raster layer.

Geoprocessing steps

The python code is provide in Appendix 6 as a preprocessing step. An overview of the second step, in ModelBuilder, is provided as a graphic in Appendix 8.

Step 4 Vegetation

This step involves manually assigning surface values to certain vegetation classes in an authority table that is then joined to the TASVeg3 dataset.

The final process was to use the default polygon to raster tool in ArcMap using the surface identifier. Note that where certain vegetation classes are not assigned a surface value and this produces a null value in the rasterisation step. In the case of null values, a layer of lower rank/priority is used.

Geoprocessing steps (This is all done in ModelBuilder):

An overview of the ModelBuilder processing steps is provided as a graphic in Appendix 8.

Step 5 Buildings and similar structures

Information on referenced layers:

Three inputs are used; building polygons, building points and concrete reservoirs (extracted from Hydrological areas discussed previously). The building layers are available as a download from the LIST web site and served as a WFS layer. However, my attempt to directly download the entire dataset using the WFS in one operation was unsuccessful as there is a feature limit imposed by Land Tasmania. I had to resort to download the data, divided ‘conveniently’ into the 29 council areas, unzip each one and merge them into a single feature. The merge was performed in QGIS because I did not have a high enough license level in ArcGIS.

1. *Building Polygons* are those man-made structures used for occupation, commercial, service or storage purposes. Any built structure with one side having a length greater than 25 metres. Building types include: Residence, Feature (those shown in red on the Tasmanian Towns Street Atlas), Shed, Ruin, Hothouse, Silo, Commercial, Industrial.
2. *Building points* are buildings with sides less than25m are captured as point features and delivered as the LIST Building Points dataset. Building types include: Residence, Feature (those shown in red on the Tasmanian Towns Street Atlas), Shed, Ruin, Hothouse, Silo, Commercial, Industrial.
3. Concrete reservoirs as previously discussed.

Geoprocessing steps (This is all done in ModelBuilder):

The three layers are mutually exclusive and are simply combined with single surface type identifier by converting each layer to raster then using the raster calculator to merge them.

Geoprocessing steps (This is all done in ModelBuilder):

An overview of the ModelBuilder processing steps is provided as a graphic in Appendix 8.

Step 6 Combining layers

A final step in the process involves using the raster calculator with priority given in the following order: Buildings, Water, Roads, Vegetation and Planning. The priority order is achieved through the use of the IsNull and Con (conditional) functions in ArcMap. In the case where there are gaps (no layers apply) a default value of 50 has been assigned. These are small areas and I have left this to the end-users decide what Mannings value to assign.

Geoprocessing steps (The final step is done in ModelBuilder):

An overview of the ModelBuilder processing steps is provided as a graphic in Appendix 8.

Observations and Conclusions

The modelling process as outlined provides a ready-made state-wide approximation of surface types to which Mannings-n values can be assigned for the purpose of flood modelling. The process is entirely transparent and can be updated using the tools provided. The adoption of the raster processing chain has proved to be significantly easier to code, vastly quicker to process and eliminates topological issues encountered with the vector unionisation method attempted earlier.

The process is non-unique and contains many compromises that could be adjusted/improved if necessary. For instance:

- Some of the layers are outdated, particularly TasVeg, and it is possible that some form of satellite or LiDAR imagery may be better suited to this application.
- I have not considered recently burnt areas that would also impact on the vegetation layer.

With the output format provided, updates can be readily applied by either rerunning the process in its entirety with improved datasets or over-stamping smaller areas as necessary.

While some QA has been performed on the dataset, the sheer size of the area precludes an exhaustive check. I therefore encourage the users of this layer to record any errors/issues they may find so that an update can be produced at a later date. This document is in a draft-for-comment form and the author would appreciate any suggestions for improvement before it becomes a published MRT report.

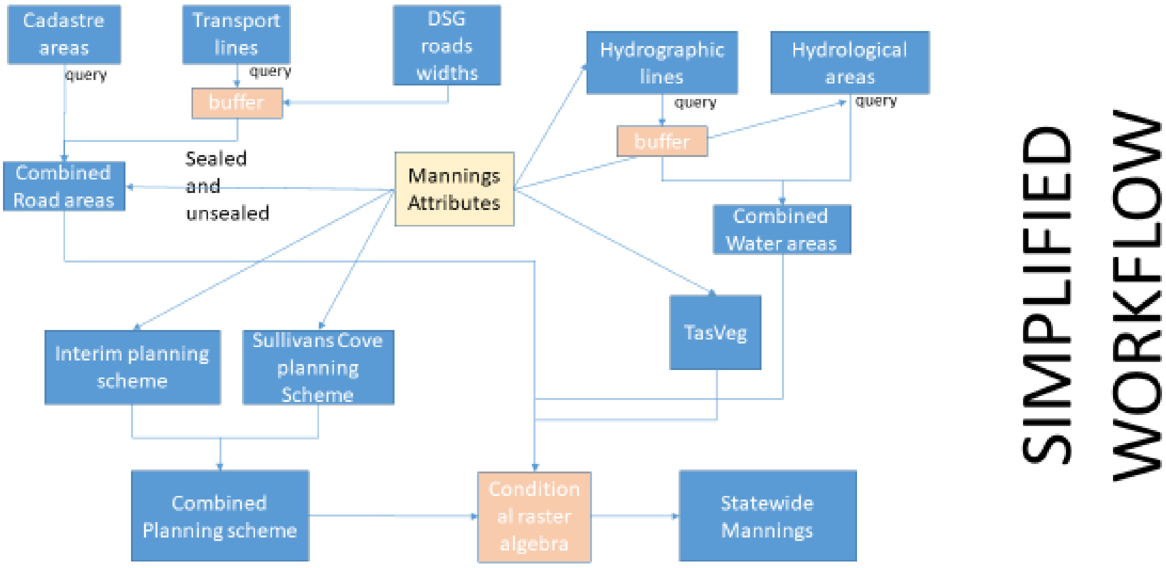


Figure 1 Simplified process model

Figure 2 Example of Manning layer, Hobart area

Appendix 1 Surface-type Authority Table

Surface-type classes with suggested Mannings-n values (based on table provided by Ted Rigby)

ID	Group	MANNNFILE	d1	n1	d2	n2	DESCRIPTION
1	Rural&Forested	Grassed_Low_n.txt	0.05	0.075	0.25	0.02	mown or well grazed 0.05 stubble and low undulations
2	Rural&Forested	Grassed_Mod_n.txt	0.15	0.1	0.75	0.03	mixed areas of slashed/grazed grassland with some shrubs and/or taller grass clumps
3	Rural&Forested	Grassed_High_n.txt	0.5	0.1	2.5	0.04	tall stiff grass with significant areas of clumped shrubs
4	Rural&Forested	Grassed_Swale.txt	0.05	0.075	0.25	0.02	mown or grazed 0.05 stubble (sim Grassed low_n)
5	Rural&Forested	Trees_Low_n.txt	1	0.05	5	0.05	moderate density little underbrush typically easy to walk thru off track
6	Rural&Forested	Trees_Mod_n.txt	1	0.1	5	0.075	moderate density some underbrush occasional fallen limb typically difficult to walk thru off track
7	Rural&Forested	Trees_High_n.txt	1	0.2	5	0.1	High density substantial underbrush and fallen limbs typically cannot walk thru off track
8	Rural&Forested	Landscaping_Low_n.txt	0.5	0.075	2.5	0.05	Low density mod height shrubs foliage from ground some gaps between
9	Rural&Forested	Landscaping_Mod_n.txt	0.5	0.15	2.5	0.075	Mod density mod height shrubs foliage from ground few gaps between
10	Rural&Forested	Landscaping_High_n.txt	0.5	0.2	2.5	0.1	High density mod height shrubs foliage from ground continuous barrier
11	Roads	Sealed_Surf_Low_n.txt	0.05	0.03	0.25	0.02	roads/parking areas - mostly free of parked vehicles
12	Roads	Sealed_Surf_Mod_n.txt	0.05	0.03	0.25	0.035	roads/parking areas - significant number of parked vehicles present
13	Roads	Gravel_Surf_Mod_n.txt	0.15	0.05	0.75	0.035	roads/parking areas - roads with side veg swales - few parked vehicles
14	Roads	Road_With_Barrier.txt	0.7	0.03	3.5	0.02	paved road with armco style barrier perp to flow - mostly free parked cars
15	Roads	Road_With_Barrier.txt	1	0.05	5	0.03	paved road with Armco style barrier perp to flow - significant parked cars at kerb
16	Residential	Res_Low_n.txt	0.3	0.1	1.5	0.05	low density typically large blocks with small dwelling footprint significant grassed yard and open fences

17	Residential	Res_Mod_n.txt	0.9	0.2	4.5	0.1	average density some solid fences
18	Residential	Res_High_n.txt	0.9	0.5	4.5	0.2	typically smaller blocks with large dwelling footprint small yards and frequent solid fences
19	Residential	ResYard_High_n.txt	0.9	0.2	4.5	0.15	where dwelling is modelled as a solid - mostly solid fences perpendicular to flow
20	Residential	ResYard_Mod_n.txt	0.9	0.15	4.5	0.1	where dwelling is modelled as a solid - some solid fences perpendicular to flow
21	Residential	ResYard_Low_n.txt	0.3	0.1	1.5	0.04	where dwelling is modelled as solid - yard mostly free of solid fencing perpendicular to flow
22	Residential	ResSubd_Dev.txt	0.2	0.07	1	0.05	subdivision under construction
23	Commercial	Comm_Low_n.txt	0.3	0.25	1.5	0.1	small building footprint significant paving mostly permeable fences
24	Commercial	Comm_Mod_n.txt	1	0.5	5	0.25	40% footprint some paving and solid fences
25	Commercial	Comm_High_n.txt	1	0.5	5	0.5	80% footprint mostly solid fences
26	Commercial	CommYard_High_n.txt	0.9	0.2	4.5	0.15	where building is modelled as solid - Stored matl/cars and mostly solid fences perp to flow
27	Commercial	CommYard_Low_n.txt	0.3	0.1	1.5	0.04	where building is modelled as solid - mostly free of solid fences and stored matl/cars
28	Industrial	lightInd_Low_n.txt	0.3	0.075	5	0.05	low density small building footprint significant paving and permeable fences
29	Industrial	LightInd_Mod_n.txt	1	0.35	5	0.1	average density 30% footprint some solid fences
30	Industrial	LightInd_High_n.txt	1	0.35	5	0.15	high density 60% footprint some solid fences
31	Industrial	LightIndYard_High_n.txt	1	0.2	5	0.15	where building is modelled as solid - mostly paved significant stored matl/car/trucks with solid fences perp to flow
32	Industrial	LightIndYard_Mod_n.txt	0.3	0.15	1.5	0.075	where building is modelled as solid - mostly paved free of stored matl some cars/trucks with mostly open fences perp to flow
33	Industrial	LightIndYard_Low_n.txt	0.3	0.1	1.5	0.035	where building is modelled as solid - mostly paved free of stored matl few cars/trucks with open fences perp to flow
34	Waterways	ConcChannel.txt	0.02	0.02	0.1	0.011	concrete lined channel

35	Waterways	Estuary.txt	0.05	0.035	0.25	0.013	flat variable grade sandy bed low undulations no instream vegetation - typically estuary and/or lake
36	Waterways	Ocean.txt	0.05	0.035	0.25	0.01	deeper water
37	Waterways	Creek_Low_n.txt	0.3	0.05	1.5	0.035	uniform bed grade and section little instream vegetation
38	Waterways	Creek_Mod_n.txt	0.5	0.1	2.5	0.075	variable bed grade and section moderate instream vegetation
39	Waterways	Creek_High_n.txt	1	0.15	5	0.01	variable bed grade and section substantial instream vegetation (overgrown)
40	Waterways	SurfFlowpath.txt	0.3	0.35	1.5	0.15	ill-defined surface flowpath through otherwise residential area
41	Waterways	StructInvert.txt	0.3	0.05	1.5	0.03	waterway with structure over generally clear of vegetation and flat
42	Waterways	Wetland_Low_n.txt	0.5	0.05	2.5	0.035	some reeds but relatively free of plants with rigid stems
43	Waterways	Wetland_High_n.txt	1	0.1	5	0.05	substantial reed growth including plants with rigid stems
44	Miscellaneous	RailReserve Low_n.txt	0.05	0.05	0.25	0.04	small relative footprint some paving and open fences
45	Miscellaneous	RailReserve High_n.txt	0.5	0.1	2.5	0.07	grassed well maintained light occasional shrub only
46	Miscellaneous	RoadReserve.txt	0.15	0.1	0.75	0.05	irregularly mown or grazed grassland with some paving (footpaths) and shrubs
47	Miscellaneous	SolidBuildings.txt	1	10	5	10	nom 1% permeability modelled as n =100*0.100
50	Unassigned						User to choose default Mannings values

Appendix 2 Planning Schemes

Planning scheme codes with assigned Surface_type identifier. Where an identifier is not assigned other layers are used based on the priority order. See Appendix 3 for values used in the transport layer.

ManID	ZONECODE	Description	Comments (informal by author)
17	10.0	General residential	
18	11.0	Inner residential	
16	12.0	Low Density residential	
5	13.0	Rural living	Lifestyle blocks in bush
5	14.0	Environmental living	Lifestyle blocks in bush
17	15.0	Urban mixed use	
17	16.0	Village	
	17.0	Community purpose	
1	18.0	Recreation	
1	19.0	Open space	Could use TasVeg?
25	20.0	Local business	
25	21.0	General business	
47	22.0	Central business	
25	23.0	Commercial	
29	24.0	Light Industrial	28-30
29	25.0	General Industrial	28-30
	26.0	Rural resource	use tas veg?
	27.0	Significant agricultural	use tas veg?
23	28.0	Utilities	includes roads and utilities
6	29.0	Environmental management	includes estuaries so overprint later
	30.0	Major tourism	
23	31.0	Port and Marine	Inconsistent layer
	32.0	Particular purpose	
	33.0	Particular purpose	
18	34.0	Particular purpose	sandy bay campus - part veg part buildings - problematic
23	35.0	Particular purpose	
25	36.0	Particular purpose	hospital
24	37.0	Particular purpose	Wrest Point Casino
24	38.0	Particular purpose	
24	39.0	Particular purpose	Utas old campus
25	40.0	Particular purpose	Cascades Brewery
25	41.0	Particular purpose	Royal Hobart
18	1.0	Inner City Residential (Wapping)	Sullivans Cove

25	2.0	Sullivans Cove Mixed Use	Sullivans Cove
	2.1	Domain Open Space	Sullivans Cove; use tas veg
	3.0	Sullivans Cove Gateway & Trans.	Sullivans Cove
	4.1	Macquarie Point Wharf	Sullivans Cove
	4.2	Regatta Point	Sullivans Cove
	4.3	Sullivans Cove Working Port	Sullivans Cove

Appendix 3 Transport

The following entries in the cadastral layer field (CAD_TYPE2) were assigned a Surface-type identifier.

ManID	CAD_TYPE2
11	Acquired Road
11	LGA Subdivision Road
11	Reserved Road
11	Road (type unknown)
11	Subdivision Road
11	State Rail Network
11	Footpath
11	Footway
11	Walkway

Appendix 4 Vegetation

List of vegetation types with assigned surface-type. If a ManID identifier is not specified, a no data (null) value is assigned to the raster that allows lower priority layers to be used.

ManID	TasVegID	Definition	Comment
2	FAG	Agricultural land	
	FUM	Extra-urban miscellaneous	Not mapped
3	FMG	Marram grassland	
2	FPE	Permanent easements	
5	FPL	Plantations for silviculture	
7	FPF	Pteridium esculentum fernland	
3	FRG	Regenerating cleared land	
3	FSM	Spartina marshland	
5	FPU	Unverified plantations for silviculture	
	FUR	Urban areas	Not mapped
8	FWU	Weed infestation	
7	DAC	Eucalyptus amygdalina coastal forest and woodland	
7	DAD	Eucalyptus amygdalina forest and woodland on dolerite	
7	DAS	Eucalyptus amygdalina forest and woodland on sandstone	
7	DAM	Eucalyptus amygdalina forest on mudstone	
7	DAZ	Eucalyptus amygdalina inland forest and woodland on Cainozoic deposits	
7	DSC	Eucalyptus amygdalina - Eucalyptus obliqua damp sclerophyll forest	
7	DBA	Eucalyptus barberi forest and woodland	
7	DCO	Eucalyptus coccifera forest and woodland	
7	DCR	Eucalyptus cordata forest	
7	DDP	Eucalyptus dalrympleana - Eucalyptus pauciflora forest and woodland	
7	DDE	Eucalyptus delegatensis dry forest and woodland	
7	DGL	Eucalyptus globulus dry forest and woodland	
7	DGW	Eucalyptus gunnii woodland	
7	DMO	Eucalyptus morrisbyi forest and woodland	
7	DNI	Eucalyptus nitida dry forest and woodland	
7	DNF	Eucalyptus nitida Furneaux forest	
7	DOB	Eucalyptus obliqua dry forest	
7	DOV	Eucalyptus ovata forest and woodland	
7	DOW	Eucalyptus ovata heathy woodland	
7	DPO	Eucalyptus pauciflora forest and woodland not on dolerite	
7	DPD	Eucalyptus pauciflora forest and woodland on dolerite	
7	DPE	Eucalyptus perriniana forest and woodland	
7	DPU	Eucalyptus pulchella forest and woodland	
7	DRI	Eucalyptus risdonii forest and woodland	
7	DRO	Eucalyptus rodwayi forest and woodland	
7	DSO	Eucalyptus sieberi forest and woodland not on granite	
7	DSG	Eucalyptus sieberi forest and woodland on granite	

7	DTD	Eucalyptus tenuiramis forest and woodland on dolerite	
7	DTG	Eucalyptus tenuiramis forest and woodland on granite	
7	DTO	Eucalyptus tenuiramis forest and woodland on sediments	
7	DVF	Eucalyptus viminalis Furneaux forest and woodland	
7	DVG	Eucalyptus viminalis grassy forest and woodland	
7	DVC	Eucalyptus viminalis - Eucalyptus globulus coastal forest and woodland	
7	DKW	King Island eucalypt woodland	
7	DMW	Midlands woodland complex	
3	HCH	Alpine coniferous heathland	
3	HCM	Cushion moorland	
3	HHE	Eastern alpine heathland	
3	HSE	Eastern alpine sedgeland	
3	HUE	Eastern alpine vegetation (undifferentiated)	
3	HHW	Western alpine heathland	
3	HSW	Western alpine sedgeland/herbland	
3	MAP	Alkaline pans	
3	MBU	Buttongrass moorland (undifferentiated)	
3	MBS	Buttongrass moorland with emergent shrubs	
3	MBE	Eastern buttongrass moorland	
3	MGH	Highland grassy sedgeland	
3	MBP	Pure buttongrass moorland	
3	MRR	Restionaceae rushland	
3	MBR	Sparse buttongrass moorland on slopes	
3	MSP	Sphagnum peatland	
3	MDS	Subalpine Diplarrena latifolia rushland	
3	MBW	Western buttongrass moorland	
3	MSW	Western lowland sedgeland	
3	GHC	Coastal grass and herbfield	
3	GPH	Highland Poa grassland	
3	GCL	Lowland grassland complex	
3	GSL	Lowland grassy sedgeland	
3	GPL	Lowland Poa labillardierei grassland	
3	GTL	Lowland Themeda triandra grassland	
3	GRP	Rockplate grassland	
7	NAD	Acacia dealbata forest	
7	NAR	Acacia melanoxylon forest on rises	
7	NAF	Acacia melanoxylon swamp forest	
7	NAL	Allocasuarina littoralis forest	
7	NAV	Allocasuarina verticillata forest	
7	NBS	Banksia serrata woodland	
7	NBA	Bursaria - Acacia woodland and scrub	
7	NCR	Callitris rhomboidea forest	
7	NLE	Leptospermum forest	
7	NLM	Leptospermum lanigerum - Melaleuca squarrosa swamp forest	

7	NLA	Leptospermum scoparium - Acacia mucronata forest	
7	NME	Melaleuca ericifolia swamp forest	
7	NLN	Subalpine Leptospermum nitidum woodland	
	ORO	Lichen lithosere	
	OSM	Sand, mud	
	OAQ	Water, sea	
7	RPF	Athrotaxis cupressoides - Nothofagus gunnii short rainforest	
5	RPW	Athrotaxis cupressoides open woodland	
7	RPP	Athrotaxis cupressoides rainforest	
7	RKF	Athrotaxis selaginoides - Nothofagus gunnii short rainforest	
7	RKP	Athrotaxis selaginoides rainforest	
10	RKS	Athrotaxis selaginoides subalpine scrub	
7	RCO	Coastal rainforest	
7	RSH	Highland low rainforest and scrub	
7	RKX	Highland rainforest scrub with dead Athrotaxis selaginoides	
7	RHP	Lagarostrobos franklinii rainforest and scrub	
7	RMT	Nothofagus - Atherosperma rainforest	
7	RML	Nothofagus - Leptospermum short rainforest	
7	RMS	Nothofagus - Phyllocladus short rainforest	
7	RFS	Nothofagus gunnii rainforest and scrub	
7	RMU	Nothofagus rainforest (undifferentiated)	
7	RFE	Rainforest fernlandAHF Freshwater aquatic herbland	
3	ASF	Freshwater aquatic sedgeland and rushland	
3	AHL	Lacustrine herbland	
3	AHS	Saline aquatic herbland	
3	ARS	Saline sedgeland/rushland	
3	AUS	Saltmarsh (undifferentiated)	
3	ASS	Succulent saline herbland	
3	AWU	Wetland (undifferentiated)	
5	SAL	Acacia longifolia coastal scrub	
5	SBM	Banksia marginata wet scrub	
5	SBR	Broad-leaf scrub	
5	SCH	Coastal heathland	
5	SSC	Coastal scrub	
5	SCA	Coastal scrub on alkaline sands	
5	SRE	Eastern riparian scrub	
5	SED	Eastern scrub on dolerite	
5	SCL	Heathland on calcareous substrates	
5	SKA	Kunzea ambigua regrowth scrub	
5	SLG	Leptospermum glaucescens heathland and scrub	
5	SLL	Leptospermum lanigerum scrub	
5	SLS	Leptospermum scoparium heathland and scrub	
5	SLW	Leptospermum scrub	
5	SRF	Leptospermum with rainforest scrub	

5	SMP	Melaleuca pustulata scrub	
5	SMM	Melaleuca squamea heathland	
5	SMR	Melaleuca squarrosa scrub	
5	SRH	Rookery halophytic herbland	
5	SSK	Scrub complex on King Island	
5	SSZ	Spray zone coastal complex	
5	SHS	Subalpine heathland	
5	SWR	Western regrowth complex	
5	SSW	Western subalpine scrub	
5	SWW	Western wet scrub	
5	SHW	Wet heathland	
7	WBR	Eucalyptus brookeriana wet forest	
7	WDA	Eucalyptus dalrympleana forest	
7	WDL	Eucalyptus delegatensis forest over Leptospermum	
7	WDR	Eucalyptus delegatensis forest over rainforest	
7	WDB	Eucalyptus delegatensis forest with broad-leaf shrubs	
7	WDU	Eucalyptus delegatensis wet forest (undifferentiated)	
7	WGK	Eucalyptus globulus King Island forest	
7	WGL	Eucalyptus globulus wet forest	
7	WNL	Eucalyptus nitida forest over Leptospermum	
7	WNR	Eucalyptus nitida forest over rainforest	
7	WNU	Eucalyptus nitida wet forest (undifferentiated)	
7	WOL	Eucalyptus obliqua forest over Leptospermum	
7	WOR	Eucalyptus obliqua forest over rainforest	
7	WOB	Eucalyptus obliqua forest with broad-leaf shrubs	
7	WOU	Eucalyptus obliqua wet forest (undifferentiated)	
7	WRE	Eucalyptus regnans forest	
7	WSU	Eucalyptus subcrenulata forest and woodland	
7	WVI	Eucalyptus viminalis wet forest	

Appendix 5 Hydrological areas

The following surface-type identifiers were assigned to the HYDARTY2 field of the HYDAREA layer. Note that this layer has a topology that allows overlapping features but

ManID	HYDARTY2	Description
35	Aquacultural Pond	
35	Hydro Storage	
35	Natural or dammed freshwa	
35	Reservoir	
35	Tailings pond	
43	Coastal Flat	
50	Dam	A Mannings value is required for this feature
37	Drain	
42	Lagoon	
35	Other	estuary
35	Sand	
36	Sea	
36	Shoal	reef off coast
35	Stream	all in estuaries
43	Swamp	
42	Unvegetated mudflat	
43	Vegetated mudflat	
41	Water channel	
37	Watercourse	
43	Wet area	

The following Manning identifiers were assigned to the HYDLNTY2 field of the WATER_COURSES layer.

ManID	HYDLNTY2	Description	Comment
34	Drain		
37	Definite		
34	Canal		

Appendix 6 Step 1 Road layer python code

```
# Name: S1ManningsRoadCalc.py

# Description: A process to create a roads layer in polygon vector format

# Import system modules

import arcpy, time, sys

start = time.time()


arcpy.env.overwriteOutput = True


# Set environment settings

arcpy.env.workspace = "E:\StatewideMannings\GIS\RasterMannings\scratch.gdb" #The scratch workspace

fc = "AllRoadsScratch"


AllRoadsLIST = "E:\\StatewideMannings\\Inputs\\Transport.gdb\\AllRoadsLIST" #This was supplied by DSG staff with council, private and state roads combined

Model_extent = "E:\\StatewideMannings\\Inputs\\InputLayers.gdb\\AllTasmania" # extent of clipping

CadRoads = "M:\\vector\\admin_boundaries\\CADASTRE_area.shp"



# Check that these files above exist

if arcpy.Exists(CadRoads):

   print "CadRoads file exists"

else:

   print "CadRoads does not exist"

   sys.exit(0)

if arcpy.Exists(AllRoadsLIST):

   print "AllRoadsLIST file exists"

else:

   print "AllRoadsLIST does not exist"
```

```
    sys.exit(0)


if arcpy.Exists(Model_extent):
    print "Model_extent file exists"
else:
    print "Model_extent does not exist"
    sys.exit(0)
print "All files exist, proceeding to copying road files to scratch"


arcpy.FeatureClassToFeatureClass_conversion(AllRoadsLIST,
"E:\StatewideMannings\GIS\RasterMannings\scratch.gdb","AllRoadsScratch")
arcpy.FeatureClassToFeatureClass_conversion(CadRoads,
"E:\StatewideMannings\GIS\RasterMannings\scratch.gdb","CadRoadsScratch")


print "Adding fields to road layers"
###Process: Add field "ManID", "RoadWidth" to the transport layer
arcpy.AddField_management("AllRoadsScratch", "Man_ID", "LONG", field_length = 10)
arcpy.AddField_management("AllRoadsScratch", "RoadWidth", "FLOAT")



#Process: Add field "ManID" to the cadastral roads
arcpy.AddField_management("CadRoadsScratch", "Man_ID", "LONG", field_length = 10)


#Test to see if the new fields exists
field_names = [f.name for f in arcpy.ListFields(fc)]
#print field_names


for x in field_names:
    if x == "Man_ID":
        print x, ' field exists'
        ManIDField = 1
    elif x == "RoadWidth":
```

```
        RoadWidthField = 1
        print x, ' field exists'

# Process: Assign mannings and road width values
print "Assign mannings and road width values, and delete unwanted records that are not roads"

# Firstly define the fields to interrogate
fields = ['TRANS_TYPE','SURFACE_TY','RoadWidth','Man_ID', 'TSEG_FEAT', 'TRAFF_DIR', 'STATUS']

#Scrolling through the STATUS field
with arcpy.da.UpdateCursor(fc,fields) as cursor:
    for row in cursor:
        if row[-1]<> 'Proposed':
            word = row[-3]
            if word[:2]<> 'Br':
                if row[0] == 'Rail' :
                    cursor.deleteRow()
                elif row[0] == 'Road' and row[1] == 'Sealed':
                    row[3] = 11
                    cursor.updateRow(row)
                elif row[0] == 'Road' and row[1] == 'Unsealed':
                    row[3] = 13
                    cursor.updateRow(row)
                elif row[0] == 'Road' and row[1] == 'Not Applicable':
                    row[3] = 11
                    cursor.updateRow(row)
                elif row[0] == 'Road' and row[1] == '4WD required':
                    cursor.deleteRow()
                elif row[0] == 'Track':
                    if row[1] == 'Sealed':
                        row[3] = 11
```

```
            row[2] = 1.75 #width of track
            cursor.updateRow(row)
          else:
            cursor.deleteRow()
      else:
        cursor.deleteRow() # delete 'bridges'
    else:
      cursor.deleteRow() # delete 'proposed' roads
del cursor

#Scrolling through the TRAFF_DIR field
with arcpy.da.UpdateCursor(fc,fields) as cursor:
  for row in cursor:
    word = row[-2]
    if word == 'Alternating':
      if row[1] <> '4WD required':
        row[2] = 2 #1/2 road width. Buffer will double this
    elif word == 'Both':
      row[2] = 3.5#1/2 road width. Buffer will double this
    elif word == 'One':
      if row[-3] == 'Dual Carriageway':
        row[2] = 4
      else:
        row[2] = 2#1/2 road width. Buffer will double this
    else:
      row[2] = 2 # Ensuring that all rows have a mannings value
    cursor.updateRow(row)
del cursor

# Scrolling through the TRANS_CLASS field to delete Ferry
with arcpy.da.UpdateCursor(fc,['TRAN_CLASS']) as cursor:
```

```
    for row in cursor:
        if row[0] == 'Ferry':
            cursor.deleteRow() # delete ferry
del cursor


# Scrolling through the TSEG_FEAT field to delete culverts (2 types)
with arcpy.da.UpdateCursor(fc,['TSEG_FEAT']) as cursor:
    for row in cursor:
        word = row[0]
        if word[:2] == 'Cul':
            cursor.deleteRow() # delete culvert
        elif word == 'Elevated Way':
            cursor.deleteRow() # delete
        elif word == 'Opening Bridge':
            cursor.deleteRow() # delete
        elif word == 'Undefined Way':
            cursor.deleteRow() # delete
        elif word[:2] == 'Tun':
            cursor.deleteRow() # delete 3 types of tunnels
del cursor




print "Begin buffer process"
# Process: Buffer road value based on the Roadwidth field.
arcpy.Buffer_analysis(fc, "AllRoadsBuff", 'RoadWidth', "FULL", "ROUND", "LIST", "Man_ID", "PLANAR") #Using LIST option as I cannot use the FLAT option because of ESRI license level
print "Buffer completed"
```

Appendix 7 Step 2 Planning scheme python code

```
# Name: S2ManningsPlanningScheme.py

# Description: Combine planning schemes (Interim and Sullivans Cove) into single polygon vector layer.

# Import system modules

import arcpy


arcpy.env.overwriteOutput = True


# Set environment settings

arcpy.env.workspace = "C:\Users\cmazen\Documents\ArcGIS\Default.gdb"


ManningsAuthorityTable_xls = "E:\\StatewideMannings\\AuthorityTable\\ManningsAuthorityTable.xls"

interim_planning_scheme_zoning_statewide = "M:\\vector\\planning\\interim_planning_scheme_zoning_statewide.gdb\\interim_planning_scheme_zoning_statewide"

sullivansCove = "E:\\StatewideMannings\\Inputs\\TasmanianInterimPlanningSchemeZoning1.gdb\\SullivansCovePlanningArea"


Model_extent = "E:\\StatewideMannings\\Inputs\\InputLayers.gdb\\ModelExtentMainIsland"

TablePlanningExcel = "C:\\Users\\cmazen\\Documents\\ArcGIS\\Default.gdb\\ManningsAuthorityTable_PS"

Viewplanningtable = "ManningsAuthorityTable_PS_Vi"

interim_planning_scheme_zoni = "interim_planning_scheme_zoni"

interim_planning_scheme_zoni__3_ = "interim_planning_scheme_zoni"

interim_planning_scheme_PZ = "C:\\Users\\cmazen\\Documents\\ArcGIS\\Default.gdb\\interim_planning_scheme_PZ"


# Check that these files above exist

if arcpy.Exists(ManningsAuthorityTable_xls):

   print "ManningsAuthorityTable_xls exists"
```

```
else:
    print "ManningsAuthorityTable_xls does not exist"


if arcpy.Exists(interim_planning_scheme_zoning_statewide):
    print "interim_planning_scheme_zoning_statewide exists"
else:
    print "interim_planning_scheme_zoning_statewide does not exist"


if arcpy.Exists(sullivansCove):
    print "sullivansCove exists"
else:
    print "sullivansCove does not exist"


if arcpy.Exists(Model_extent):
    print "Model_extent exists"
else:
    print "Model_extent does not exist"


# Process: Make Feature Layer (3)
arcpy.MakeFeatureLayer_management(interim_planning_scheme_zoning_statewide, interim_planning_scheme_zoni, "", "", "OBJECTID OBJECTID VISIBLE NONE;SHAPE SHAPE VISIBLE NONE;ZONECODE ZONECODE VISIBLE NONE;ZONE ZONE VISIBLE NONE;SCHEMECODE SCHEMECODE VISIBLE NONE;PLANSCHEME PLANSCHEME VISIBLE NONE;SCHEMEDATE SCHEMEDATE VISIBLE NONE;COMMENTS COMMENTS VISIBLE NONE;DISCLAIMER DISCLAIMER VISIBLE NONE;LIST_GUID LIST_GUID VISIBLE NONE;SHAPE_Length SHAPE_Length VISIBLE NONE;SHAPE_Area SHAPE_Area VISIBLE NONE")


# Process: Excel To Table (2)
arcpy.ExcelToTable_conversion(ManningsAuthorityTable_xls, TablePlanningExcel, "InterimPlanningScheme")


# Process: Make Table View (3)
arcpy.MakeTableView_management(TablePlanningExcel, Viewplanningtable, "", "", "")
```

```
# Process: Add Join

arcpy.AddJoin_management(interim_planning_scheme_zoni, "ZONECODE", Viewplanningtable,
"ZONECODE", "KEEP_ALL")

print "join completed"

# Process: Clip

arcpy.Clip_analysis(interim_planning_scheme_zoni__3_, Model_extent,
interim_planning_scheme_PZ, "")

print "clip completed"



inFeatures = [[interim_planning_scheme_PZ],[sullivansCove]]

outFeatures = "ManningsPZ"

print outFeatures

# Process: Combine the Sullivans with Interim planning scheme

arcpy.Union_analysis (inFeatures, outFeatures, "ALL", 0.001)

print "union completed"


##fieldList = [f.name for f in arcpy.ListFields(outFeatures)]

##print fieldList

# Process: Update ManID with sullivans cove mannings


with arcpy.da.UpdateCursor(outFeatures, ["ManningsAuthorityTable_PS_ManID", "SC_ManID"] ) as
cursor:

    for row in cursor:

        if row[0] == 0 and row[1] > 0:

            row[0] = row[1]

            cursor.updateRow(row)

del cursor


# Process: Dissolve based on ManID
```

```
arcpy.Dissolve_management(outFeatures, "MannPZdiss", "ManningsAuthorityTable_PS_ManID", "",
"SINGLE_PART", "DISSOLVE_LINES")

print "dissolve completed"


print "stage 3 completed"
```

Appendix 8 Step 3 Combining all the component rasters

This is entirely a ModelBuilder process broken down into several smaller models for clarity.

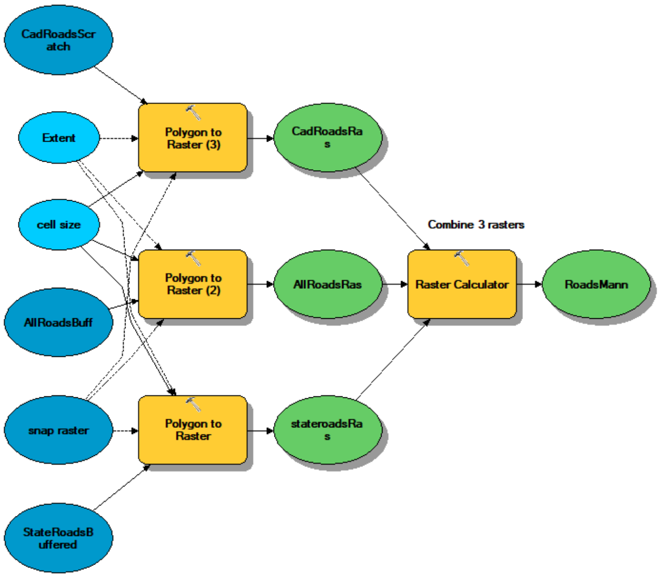


Figure 1 Road layer combining model

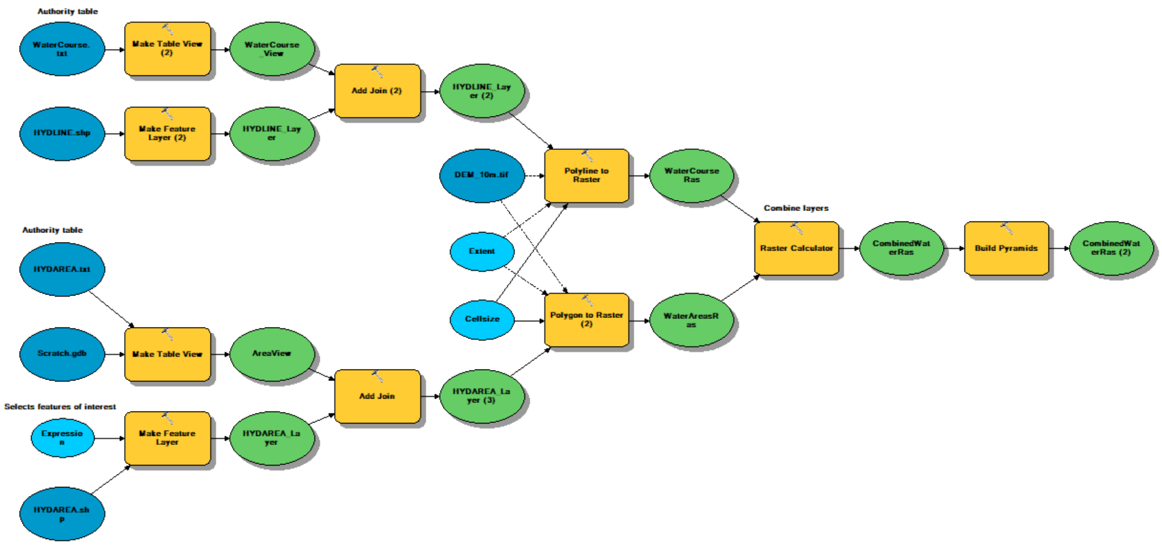


Figure 2 Water layer combining model

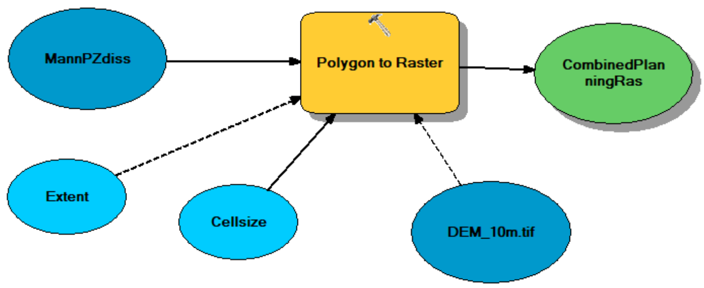


Figure 3 Planning layer preparation

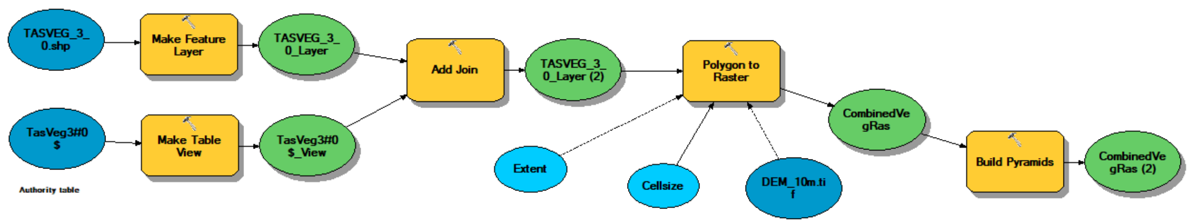


Figure 4 Vegetation layer preparation

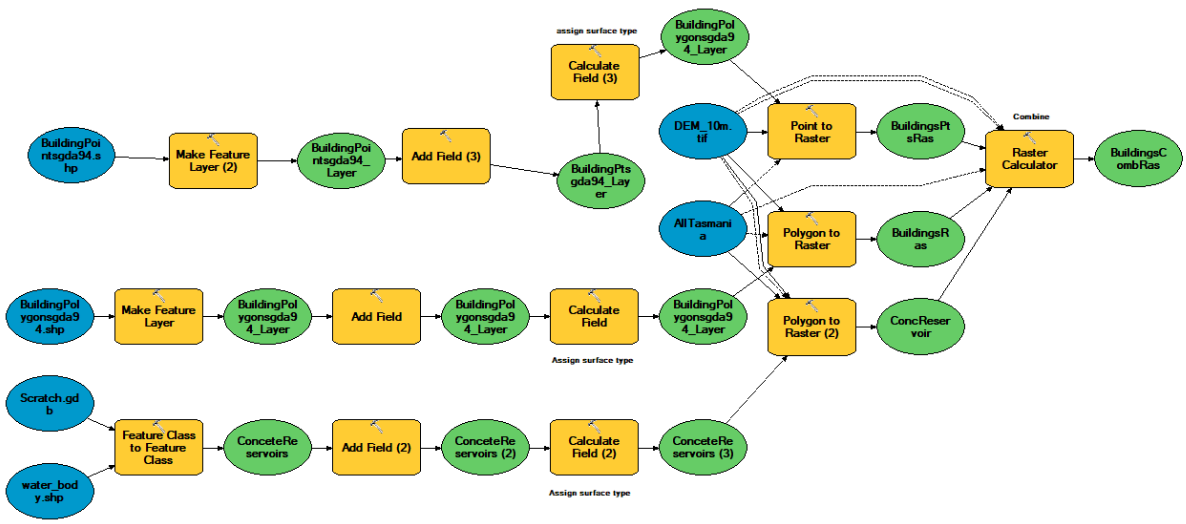


Figure 5 Building layer preparation

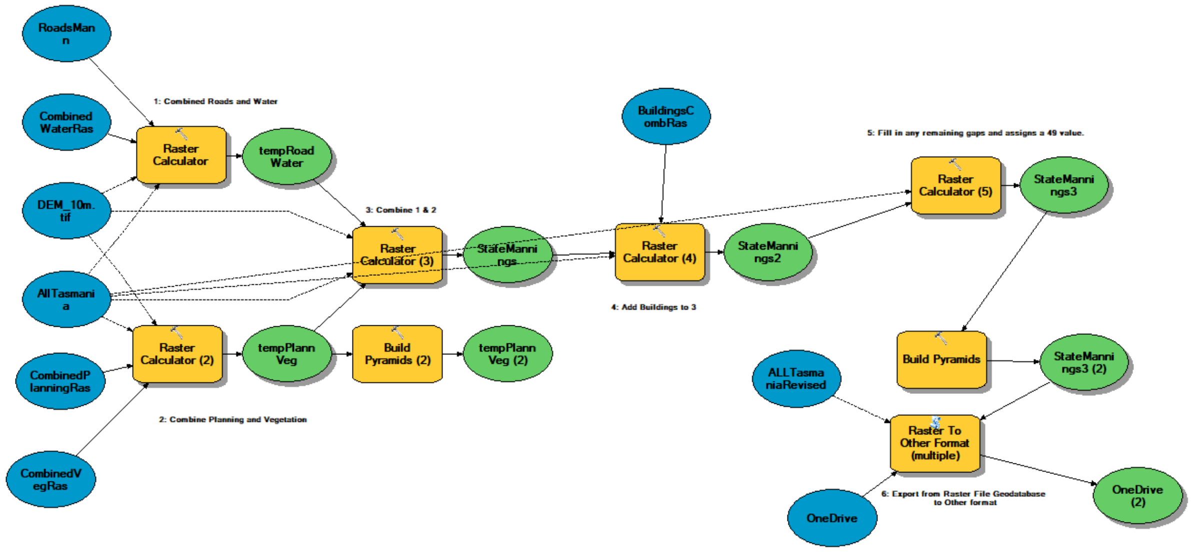


Figure 6 Combining all inputs