Adapting the SedNet sediment budget framework to incorporate multiple empirical input data sets; an example from the Normanby catchment

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Sediment Sinks Sources & Drivers in the Normanby Basin

CAPE YORK WATER QUALITY

Reef Rescue Research & Development

Griffith UNIVERSITY

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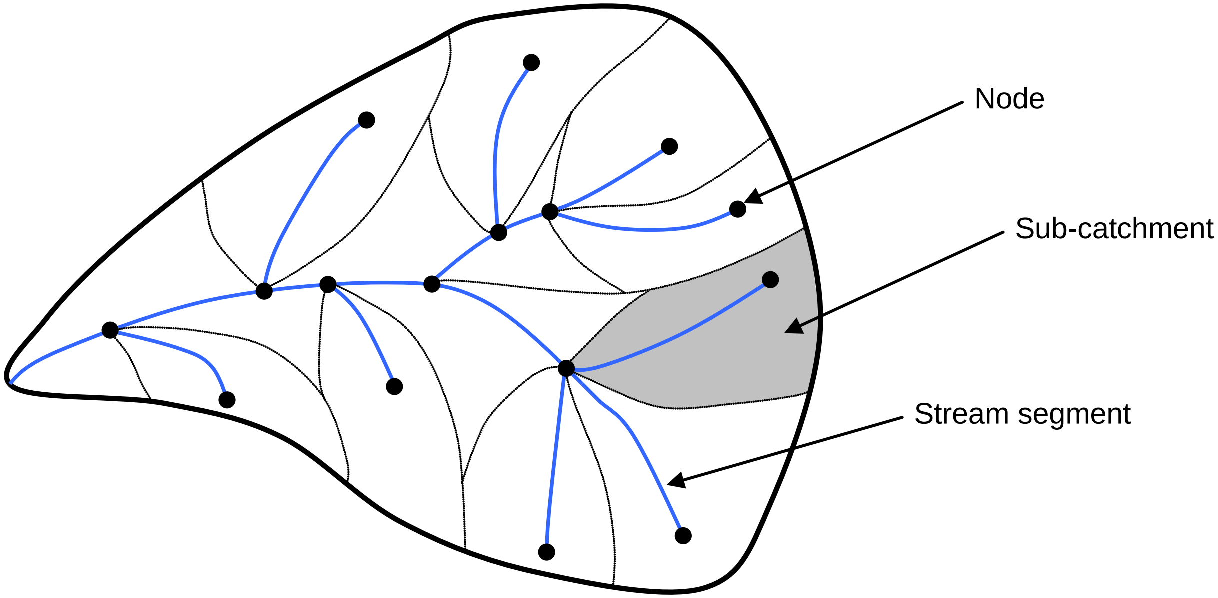
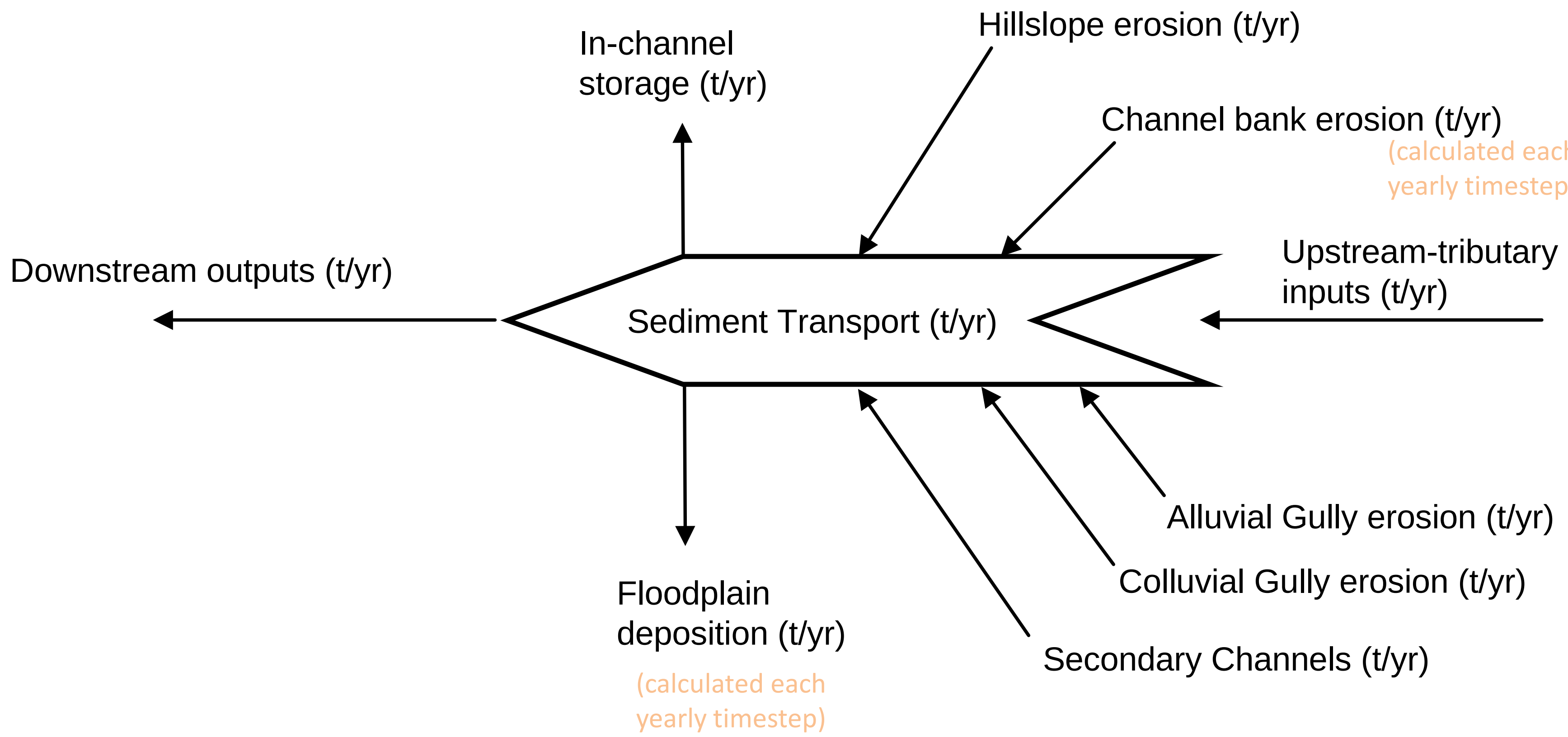
Normanby Model

- The model developed for this project;
  - Uses the stream segment as the primary unit.
  - Is a static model.
  - With a yearly time step.
  - Covers a 24 year (1986-2009) period of synthetic hydrologic data.
  - Calculates suspended sediment inputs and outputs for all stream segments, starting at each headwater and progressing downstream carrying surplus sediment to the next downstream segment.
  - The stream network contains and the model deals with bifurcations and distributaries, partitioning flow and suspended sediment.

- River basin conceptualised as;
  - Sub-Catchments
  - Stream Segments
  - Nodes

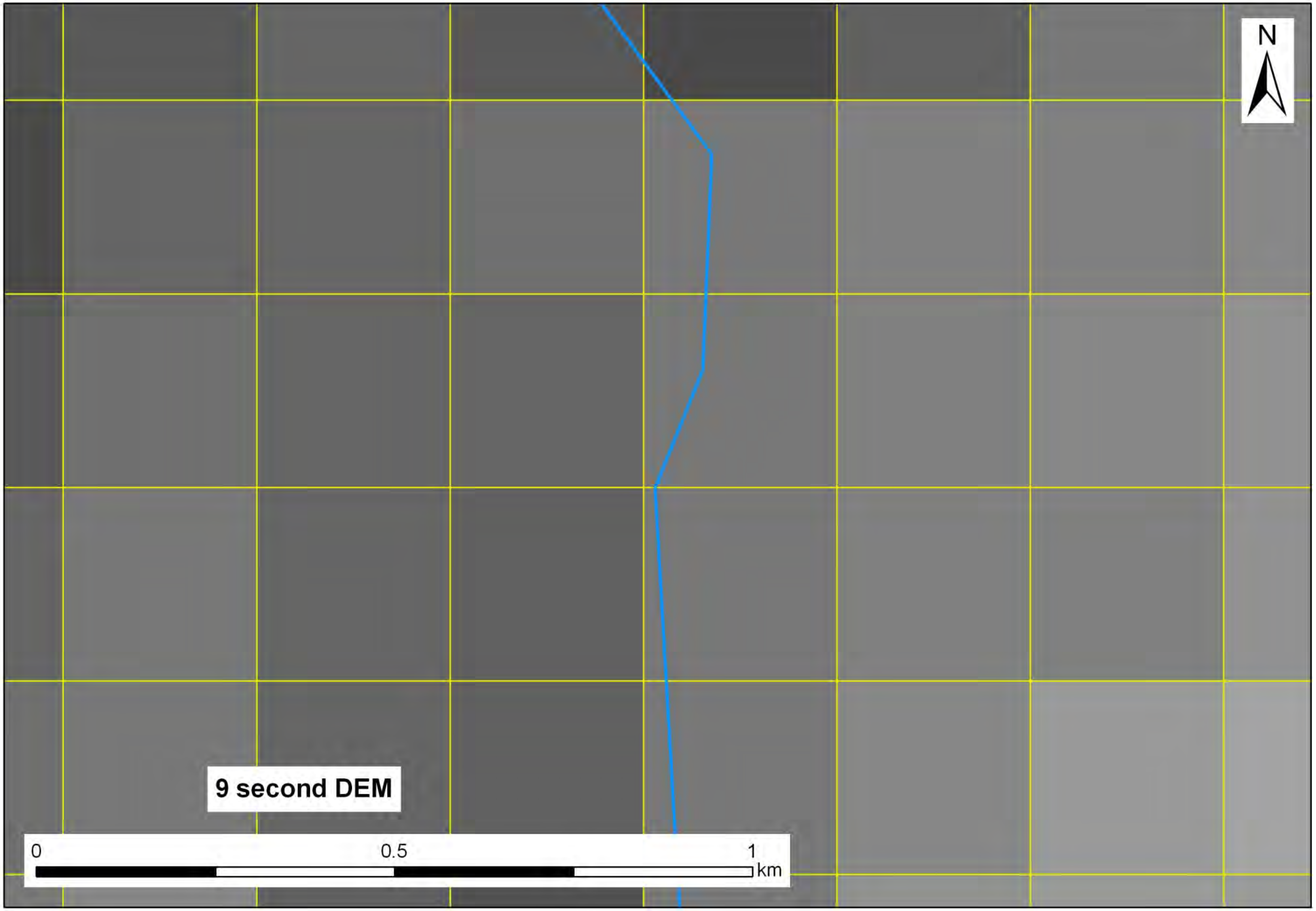


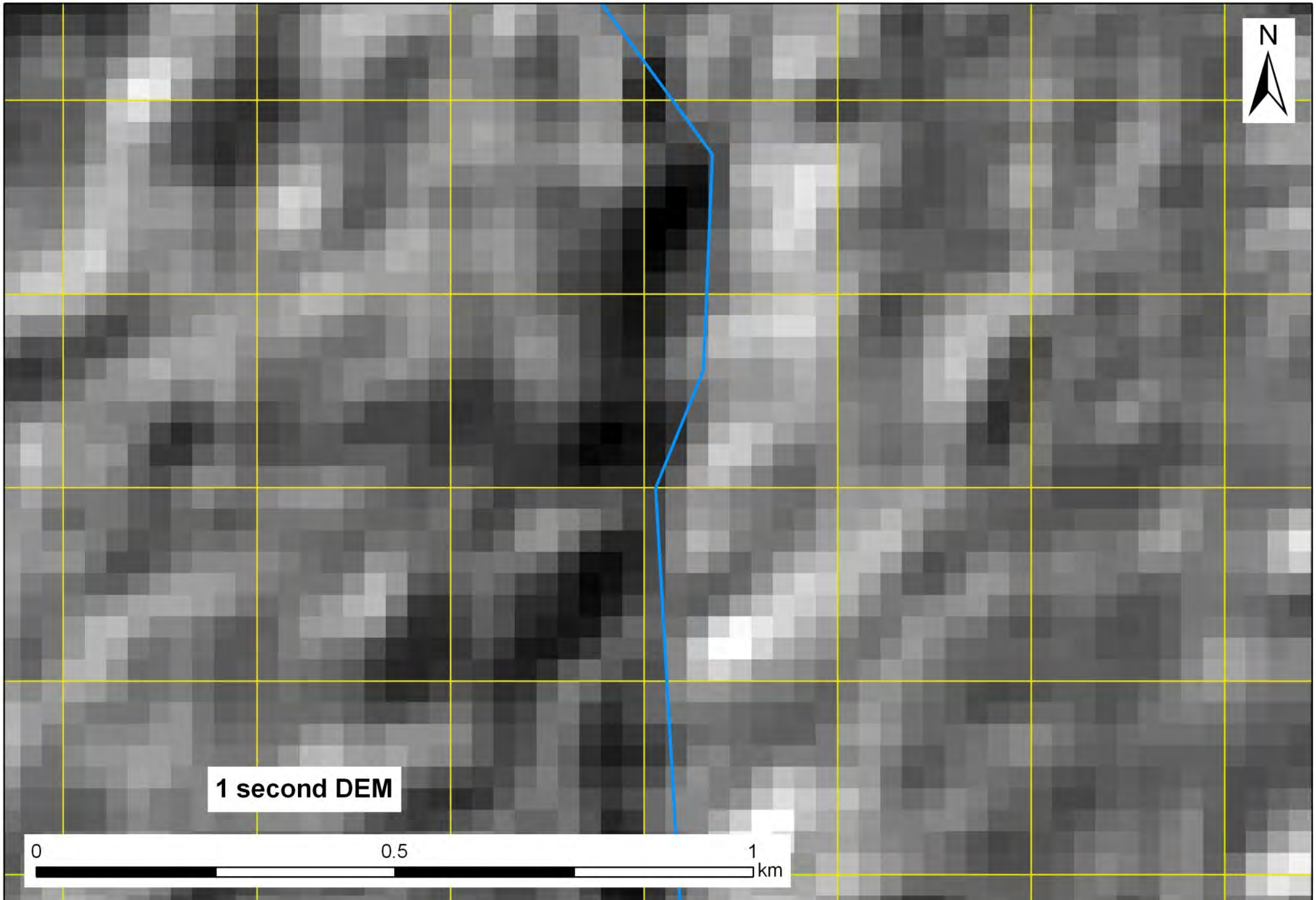
Schematic of suspended sediment input and output for a stream segment



Normanby Model

- Require data and parameters;
  - Stream segment network.
  - Annual discharge for each segment.
  - Annual overbank discharge for each segment.
  - Annual in-channel discharge for each segment.
  - Estimates of channel width and depth for each stream segment.


N
9 second DEM
0
0.5
1
km


N
1 second DEM
0
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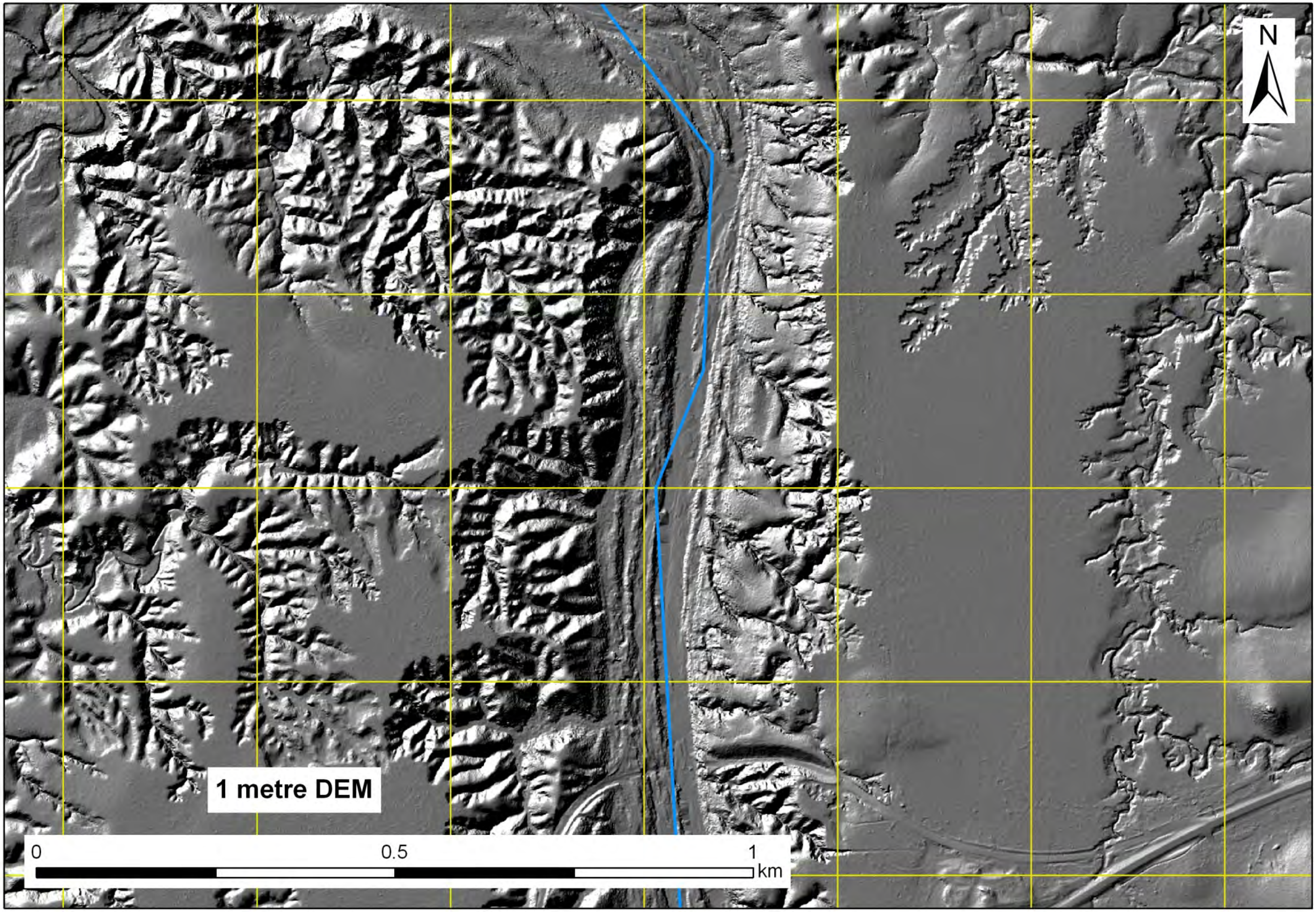
km


N
1 metre DEM
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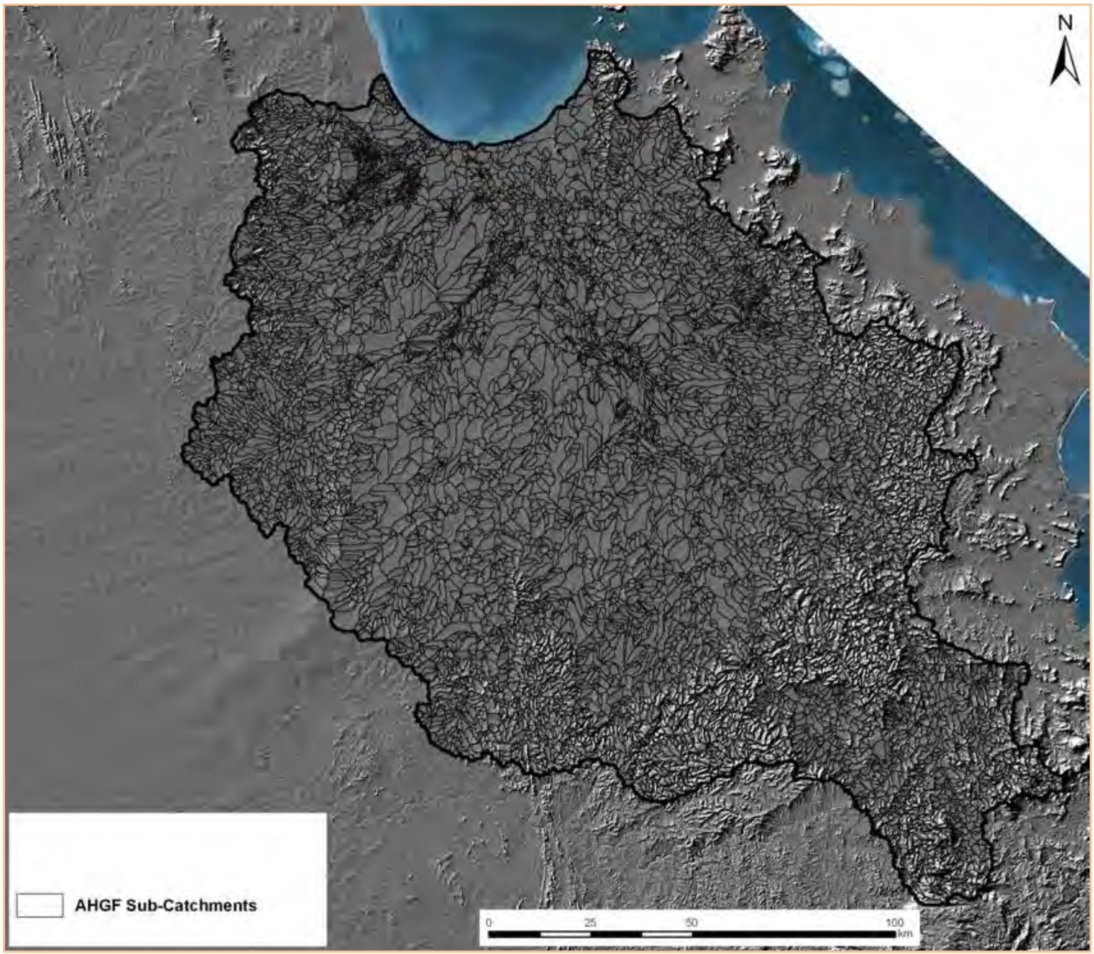
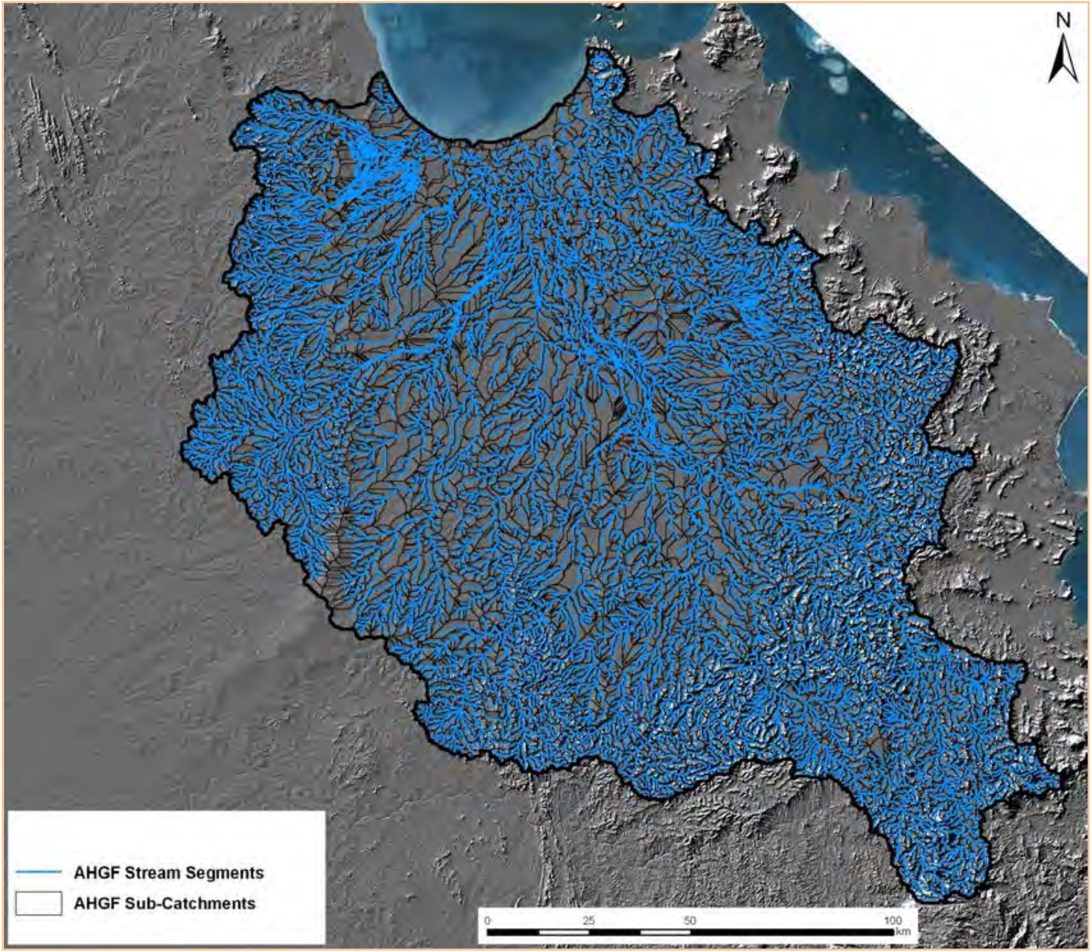
Australian Hydrologic Geospatial Fabric (AHGF)

- Based on the 9 second (~270m) DEM of Australia
- 9621 Sub-Catchments



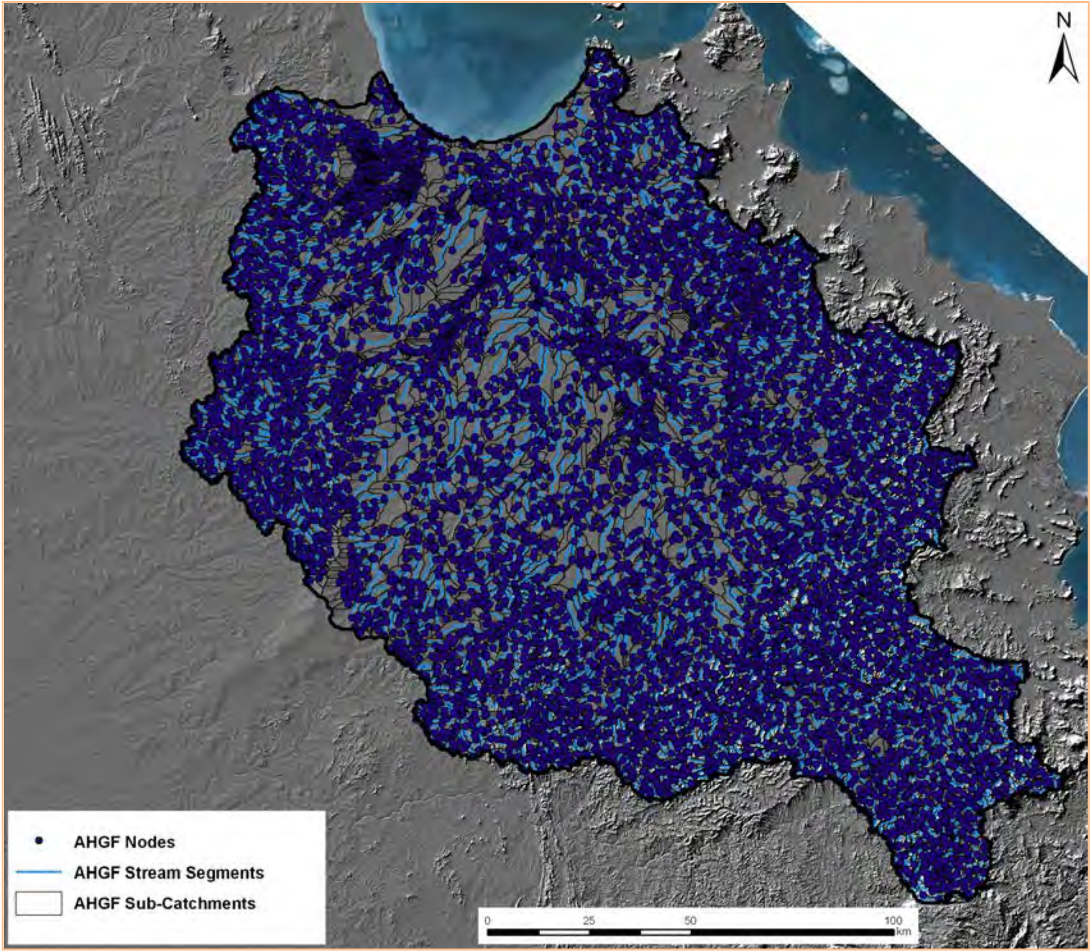
Australian Hydrologic Geospatial Fabric (AHGF)

- 9621 Sub-Catchments
- 9635 Stream Segments



Australian Hydrologic Geospatial Fabric (AHGF)

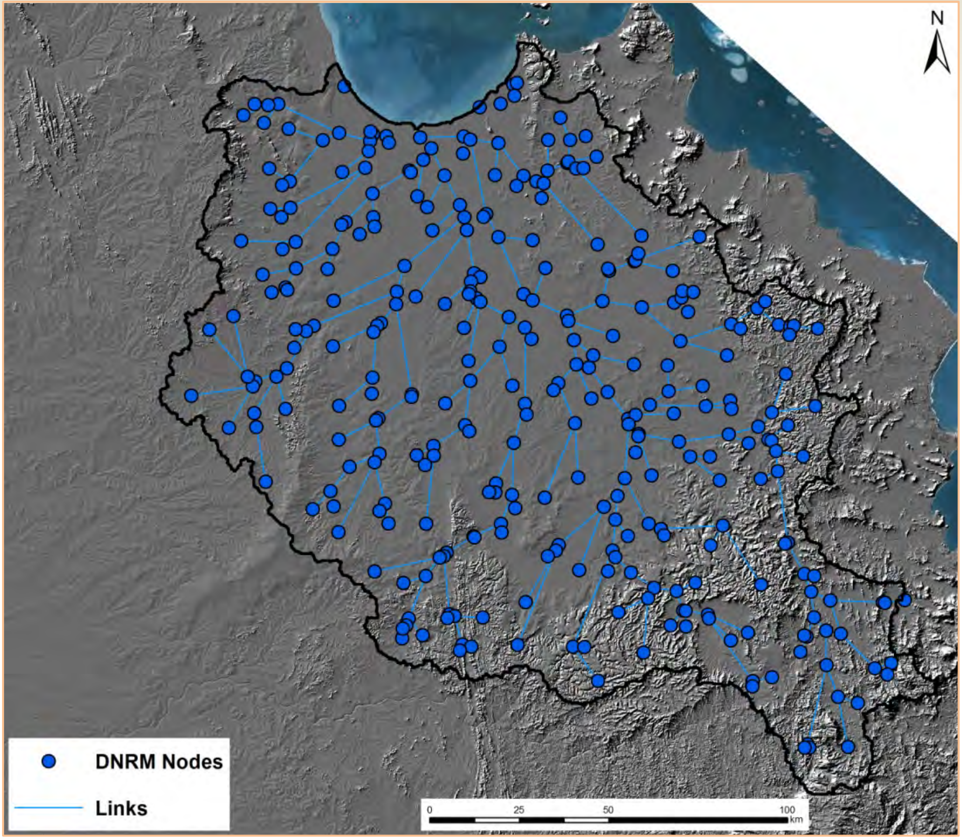
- 9621 Sub-Catchments
- 9635 Stream Segments
- 8782 Nodes



Methods developed for this model

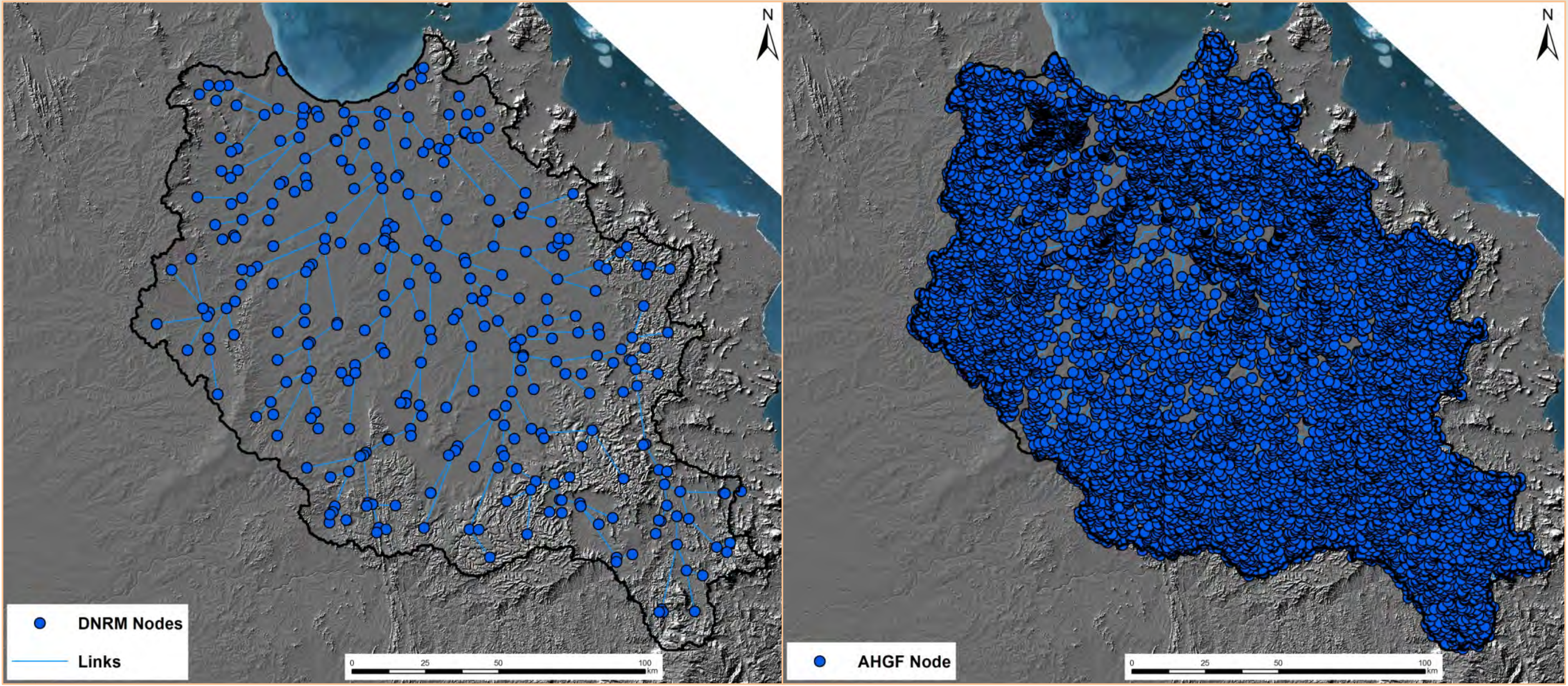
- Interpolation of synthetic hydrograph data.
- Channel width-depth modelling.
- Distributed stream network.
- Floodplain accretion rates.

Hydrograph Interpolation.



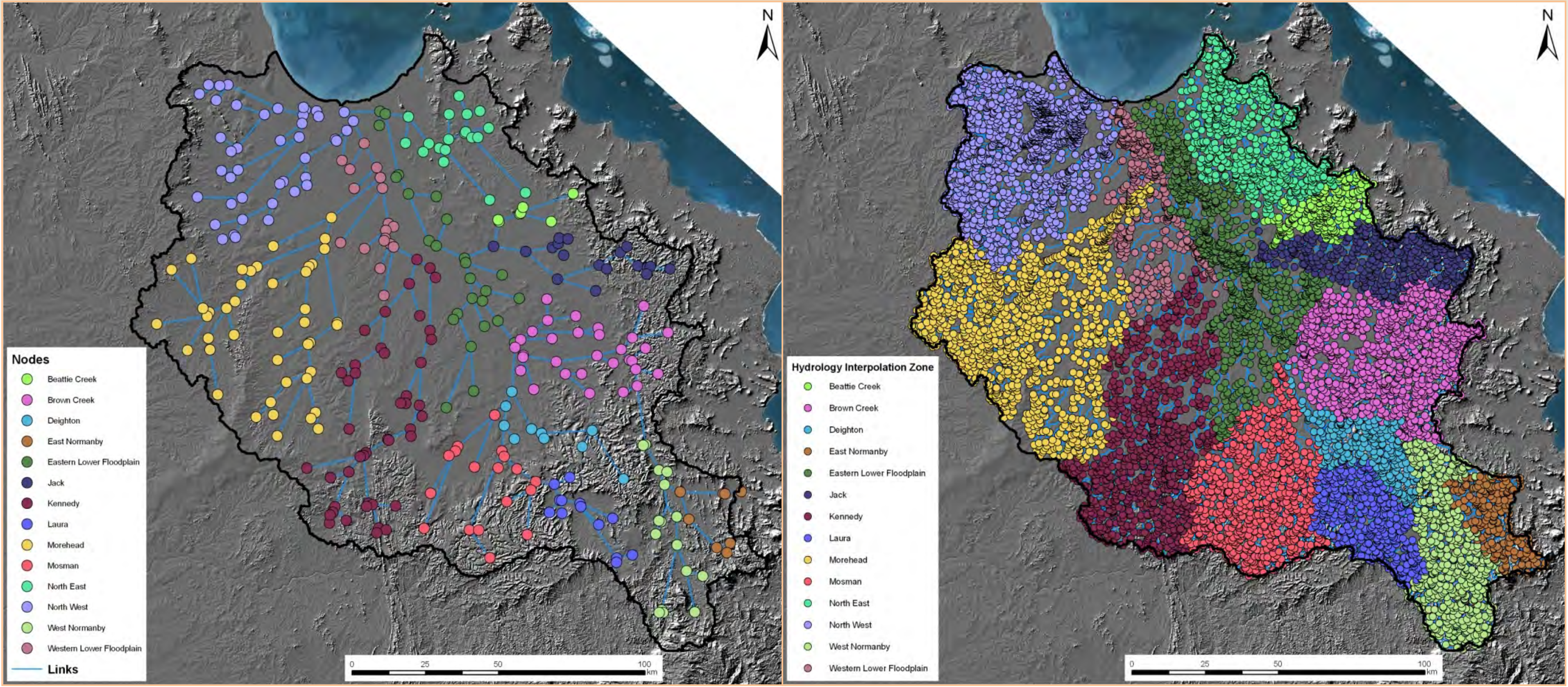
- Queensland DNRM have created a synthetic hydrograph dataset.
  - Average daily discharge for a 24 year period (1986 to 2009).
  - Normanby catchment consists of 361 nodes (24 years of daily data for 361 nodes is over 3 million rows of data).
  - Not based on the AHGF stream network.

Hydrograph Interpolation.



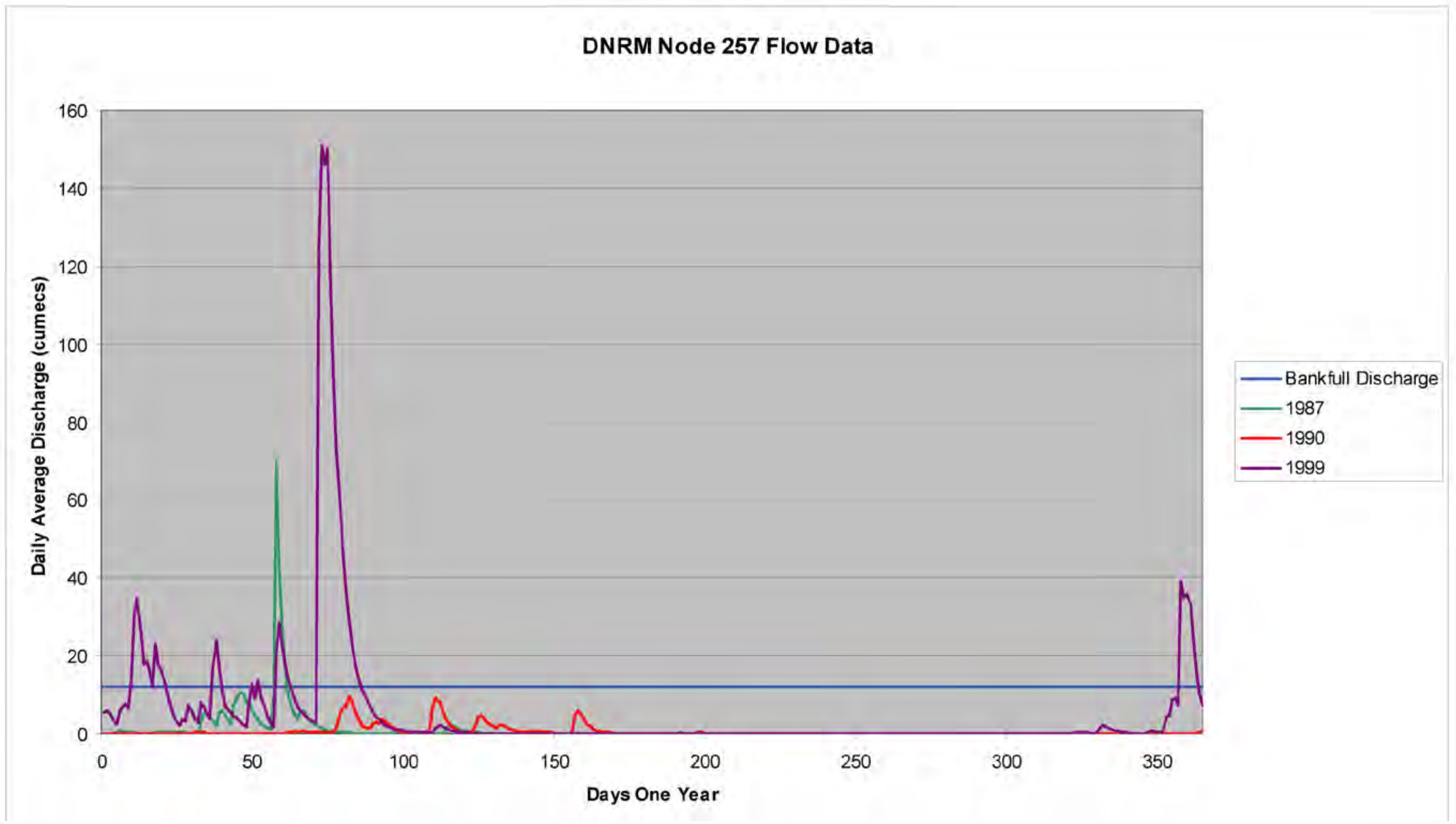
- Needed a method to interpolate from 361 to 8782 nodes.
  - Catchment area – Discharge relationships produce poor R^2 for the whole of catchment.

Hydrograph Interpolation.



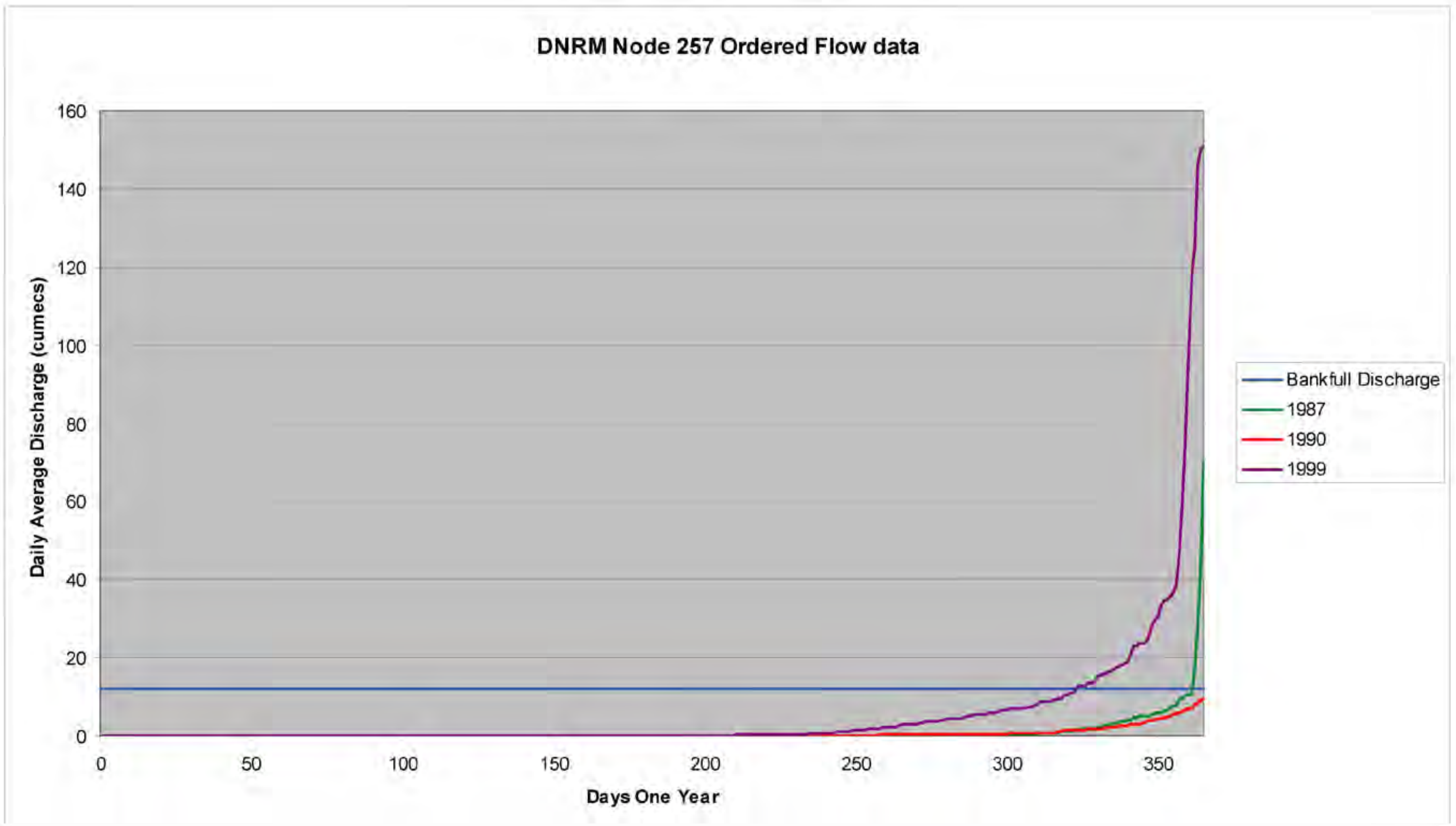
- Mapped nodes in both datasets to approximately homogenous zones.
- Calculated daily catchment area – discharge regression equations (everyday, for each zone, over 100,00 equations).
  - R^2 were poor, especially for high magnitude flows.

Hydrograph Interpolation.



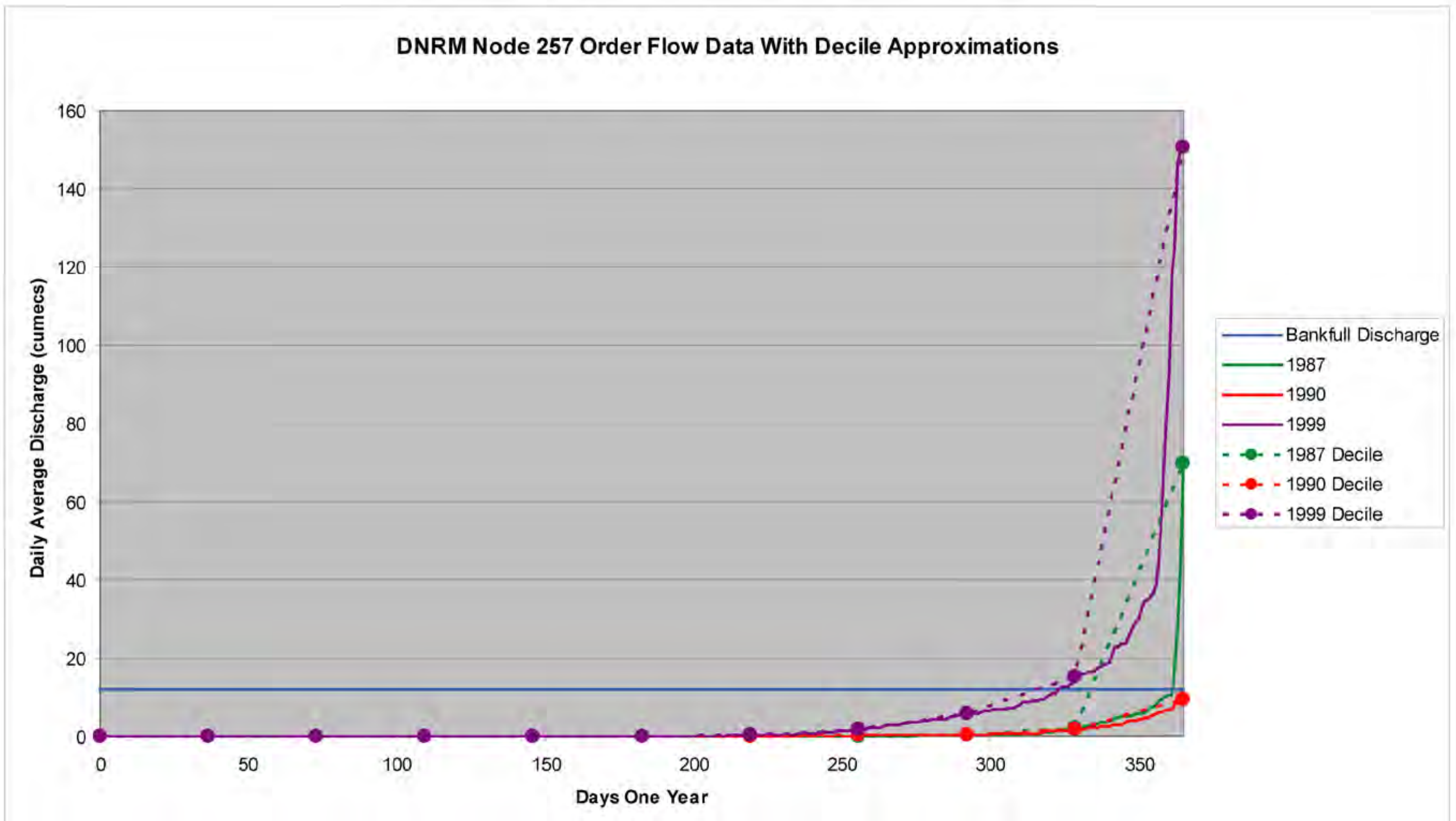
- Flows for 1 DNRM node for 3 different years..

Hydrograph Interpolation.



- Rearrange the data into an ordered set.

Hydrograph Interpolation.



- Rearrange the data into an ordered set.
- The deciles values roughly approximate a years flow distribution.
- Extracted the sum, max, min, and deciles values for each year for each node and calculated regression equations for each zone.

Hydrograph Interpolation.

Interpolation Zone	Yearly average daily average discharge			Yearly sum daily average discharge			Yearly minimum daily average discharge			Yearly 1st decile daily average discharge			Yearly 2nd decile daily average discharge		
	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2
Beattie Creek	0.9999	0.8944	0.9845	0.9999	0.8944	0.9845	0.9774	0.8768	0.9530	0.9828	0.8784	0.9591	0.9863	0.9104	0.9676
Brown Creek	0.9981	0.8095	0.9336	0.9981	0.8095	0.9336	0.9775	0.7127	0.8993	0.9748	0.7731	0.8717	0.9771	0.7676	0.8484
Deighton	0.9984	0.9554	0.9829	0.9984	0.9554	0.9829	0.9867	0.9524	0.9755	0.9842	0.8731	0.9677	0.9844	0.8966	0.9616
East Normanby	0.9983	0.9188	0.9777	0.9983	0.9188	0.9777	0.9818	0.3620	0.4825	0.8393	0.3620	0.5473	0.8414	0.4192	0.6088
Eastern Lower Floodplain	0.9987	0.8533	0.9797	0.9987	0.8533	0.9797	0.9952	0.9046	0.9773	0.9972	0.9371	0.9788	0.9949	0.9269	0.9731
Jack	0.9969	0.6600	0.9257	0.9969	0.6600	0.9257	0.9737	0.7901	0.9203	0.9853	0.8275	0.9367	0.9889	0.8505	0.9452
Kennedy	0.9975	0.8652	0.9680	0.9975	0.8652	0.9680	0.9982	0.9243	0.9765	0.9970	0.7688	0.9686	0.9979	0.8116	0.9695
Laura	0.9991	0.9202	0.9706	0.9991	0.9202	0.9706	0.9897	0.9324	0.9538	0.9984	0.9235	0.9592	0.9987	0.9268	0.9669
Morehead	0.9972	0.8689	0.9519	0.9972	0.8689	0.9519	0.7664	0.5942	0.6421	0.7790	0.6033	0.6354	0.7802	0.6062	0.6409
Mosman	0.9965	0.7916	0.9465	0.9965	0.7916	0.9465	0.9555	0.8852	0.9265	0.9518	0.8681	0.9148	0.9487	0.8750	0.9197
North East	0.9999	0.9396	0.9888	0.9999	0.9396	0.9888	0.7326	0.5406	0.6072	0.7261	0.5676	0.6424	0.7673	0.6105	0.6893
North West	0.9989	0.9462	0.9827	0.9989	0.9462	0.9827	0.8974	0.8257	0.8374	0.9269	0.8256	0.8440	0.9583	0.8257	0.8542
West Normanby	0.9988	0.8959	0.9768	0.9988	0.8959	0.9768	0.7190	0.7041	0.7075	0.7234	0.7038	0.7081	0.7478	0.7037	0.7130
Western Lower Floodplain	0.9986	0.8933	0.9668	0.9986	0.8933	0.9668	0.7491	0.6390	0.6534	0.7716	0.6386	0.6605	0.8416	0.6408	0.6770

Interpolation Zone	Yearly 3rd decile daily average discharge			Yearly 4th decile daily average discharge			Yearly 5th decile daily average discharge			Yearly 6th decile daily average discharge			Yearly 7th decile daily average discharge		
	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2
Beattie Creek	0.9864	0.9282	0.9719	0.9848	0.9065	0.9682	0.9886	0.9124	0.9584	0.9920	0.9075	0.9585	0.9924	0.9172	0.9608
Brown Creek	0.9240	0.7407	0.8300	0.9703	0.7325	0.8303	0.9844	0.7493	0.8351	0.9769	0.7477	0.8575	0.9827	0.7804	0.8974
Deighton	0.9852	0.9054	0.9593	0.9821	0.9011	0.9580	0.9873	0.9038	0.9570	0.9865	0.8494	0.9599	0.9931	0.7463	0.9523
East Normanby	0.8048	0.4555	0.6415	0.8705	0.4982	0.6892	0.9001	0.5424	0.7532	0.9629	0.6052	0.7907	0.9826	0.6901	0.8570
Eastern Lower Floodplain	0.9963	0.8453	0.9637	0.9969	0.8862	0.9716	0.9962	0.8165	0.9559	0.9949	0.7806	0.9541	0.9959	0.7392	0.9185
Jack	0.9948	0.8694	0.9525	0.9833	0.7967	0.9439	0.9887	0.7539	0.9226	0.9884	0.7669	0.8949	0.9981	0.7418	0.8914
Kennedy	0.9982	0.8476	0.9708	0.9978	0.8903	0.9757	0.9976	0.9046	0.9780	0.9974	0.9125	0.9819	0.9991	0.8492	0.9793
Laura	0.9989	0.9436	0.9749	0.9987	0.9485	0.9837	0.9980	0.9634	0.9900	0.9981	0.9707	0.9913	0.9971	0.9117	0.9868
Morehead	0.7913	0.6013	0.6493	0.8452	0.6010	0.6615	0.8949	0.6051	0.6915	0.9722	0.6127	0.7394	0.9932	0.6546	0.8257
Mosman	0.9487	0.8748	0.9228	0.9580	0.8450	0.9117	0.9567	0.7627	0.8862	0.9544	0.7116	0.8849	0.9567	0.7296	0.8991
North East	0.8136	0.6140	0.7139	0.8457	0.6307	0.7429	0.8510	0.5824	0.7472	0.9674	0.5319	0.7114	0.9863	0.5251	0.7172
North West	0.9659	0.8326	0.8672	0.9966	0.8294	0.8893	0.9893	0.8384	0.9123	0.9998	0.8619	0.9372	0.9988	0.8760	0.9588
West Normanby	0.7764	0.7041	0.7215	0.8071	0.7036	0.7341	0.8407	0.7071	0.7504	0.8817	0.7133	0.7741	0.8852	0.7146	0.8074
Western Lower Floodplain	0.8669	0.6491	0.7028	0.9619	0.6526	0.7498	0.9884	0.6767	0.8101	0.9956	0.7399	0.8703	0.9935	0.7864	0.9199

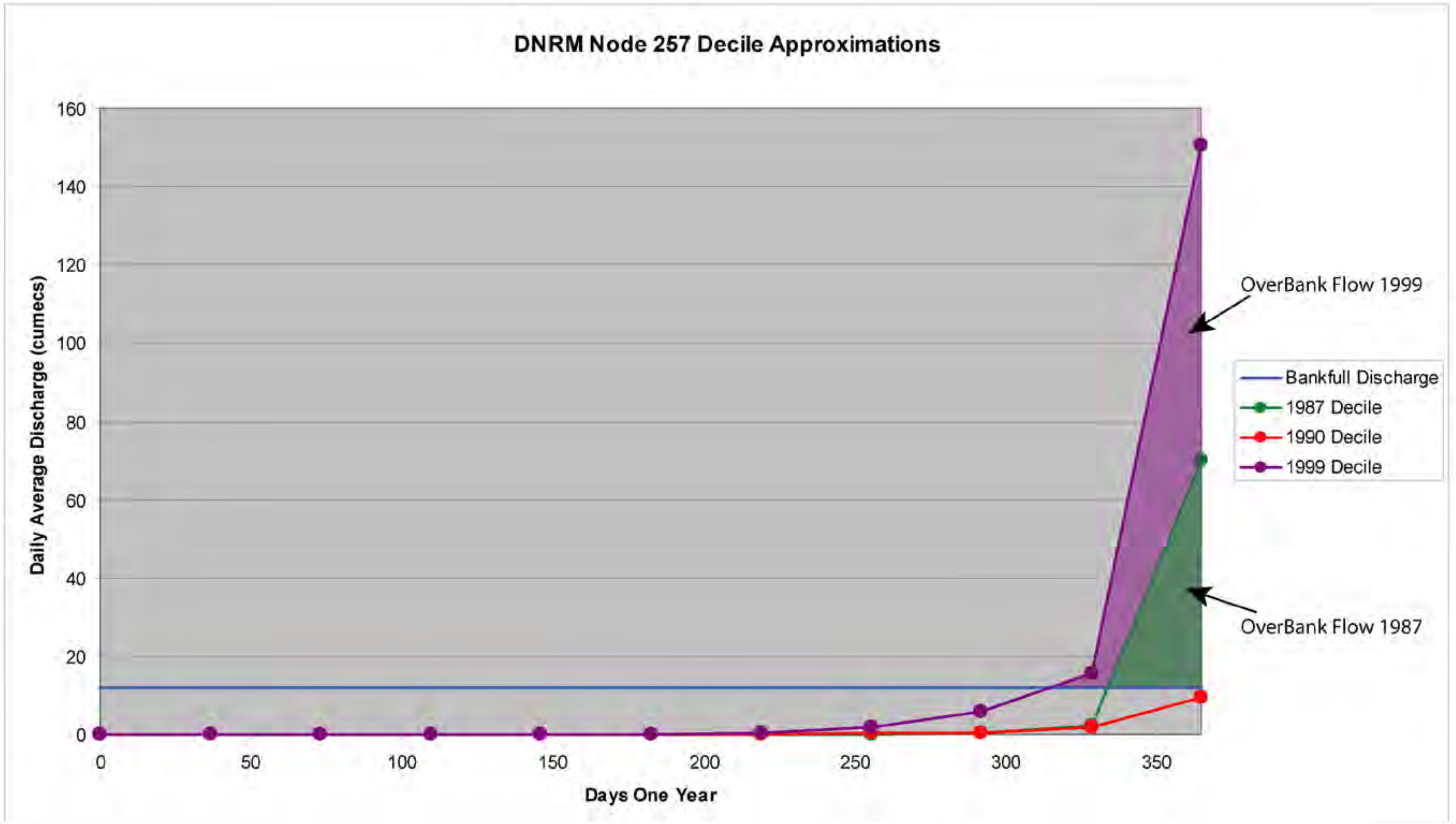
Interpolation Zone	Yearly 8th decile daily average discharge			Yearly 9th decile daily average discharge			Yearly maximum daily average discharge		
	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2	Max R^2	Min R^2	Ave R^2
Beattie Creek	0.9952	0.9309	0.9688	0.9990	0.9163	0.9790	0.9966	0.6225	0.9454
Brown Creek	0.9909	0.8503	0.9416	0.9932	0.8369	0.9385	0.9802	0.6416	0.8384
Deighton	0.9918	0.8898	0.9709	0.9963	0.9394	0.9768	0.9930	0.7442	0.9321
East Normanby	0.9937	0.6813	0.9181	0.9992	0.8491	0.9594	0.9842	0.5316	0.9027
Eastern Lower Floodplain	0.9985	0.6373	0.9354	0.9974	0.8222	0.9629	0.9946	0.7761	0.9529
Jack	0.9946	0.7165	0.9319	0.9980	0.8207	0.9346	0.9942	0.2848	0.8499
Kennedy	0.9980	0.9086	0.9694	0.9969	0.7973	0.9638	0.9733	0.4001	0.8038
Laura	0.9938	0.9536	0.9846	0.9952	0.9492	0.9795	0.9941	0.7454	0.9187
Morehead	0.9916	0.8462	0.9376	0.9972	0.9210	0.9733	0.9836	0.5364	0.8649
Mosman	0.9675	0.7562	0.9224	0.9951	0.8417	0.9398	0.9622	0.3880	0.7326
North East	0.9906	0.5389	0.8478	0.9972	0.6721	0.9423	0.9878	0.5090	0.8885
North West	0.9983	0.8688	0.9720	0.9979	0.9266	0.9792	0.9904	0.6293	0.8869
West Normanby	0.9932	0.7412	0.8648	0.9898	0.8349	0.9327	0.9812	0.8260	0.9134
Western Lower Floodplain	0.9955	0.8115	0.9441	0.9982	0.8797	0.9577	0.9945	0.8037	0.9255

R^2 values for 4368 catchment area – discharge equations for annual;

- average
- sum
- minimum
- maximum
- 1 to 9 deciles

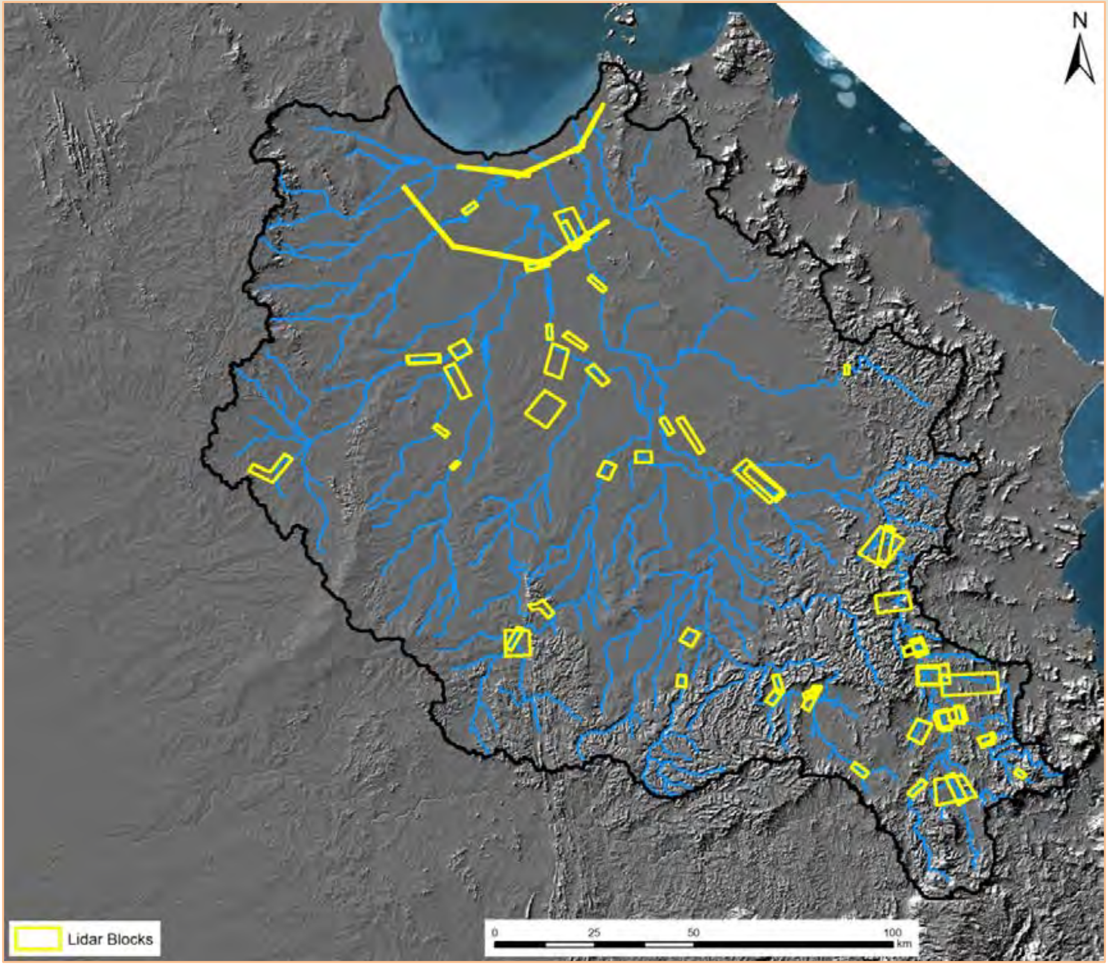
of daily discharge data for each year in each zone.

Hydrograph Interpolation.



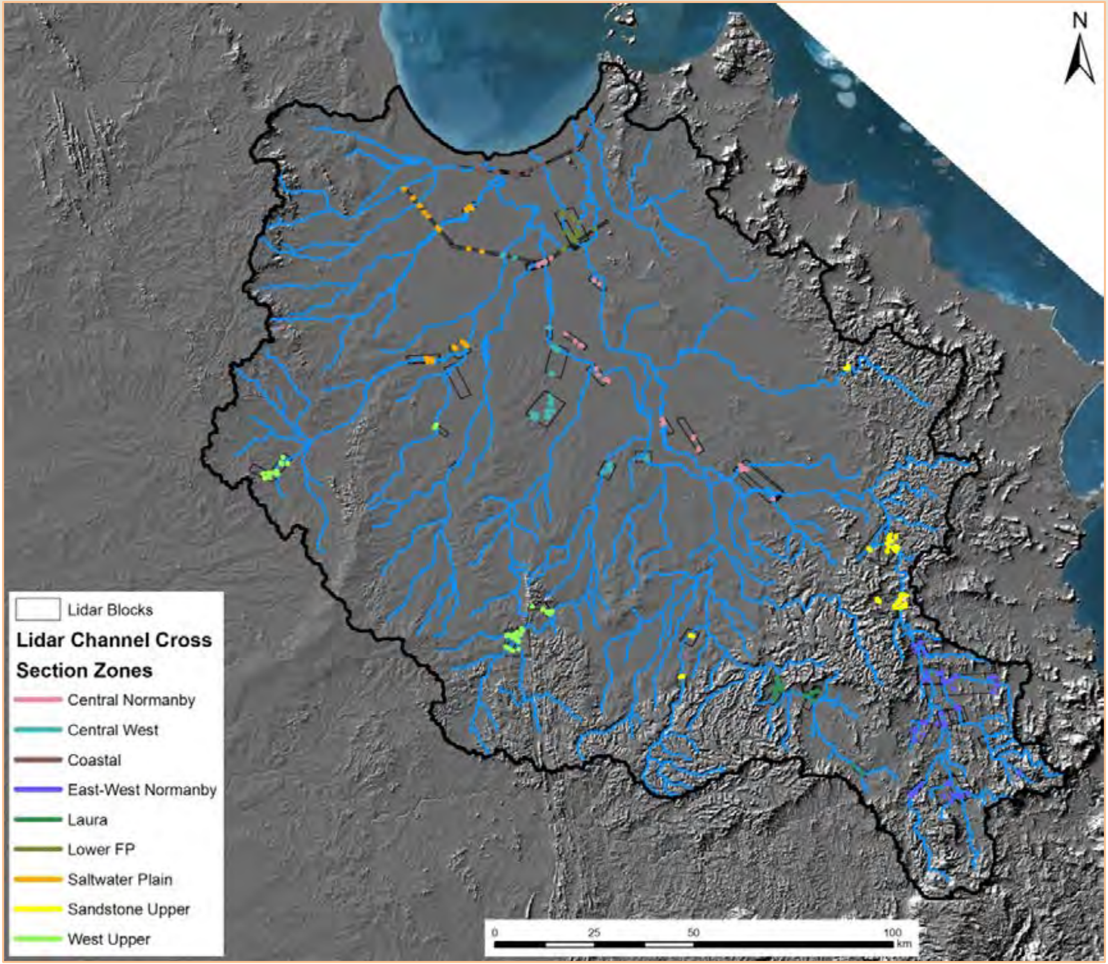
- Then an approximate modelled curve of yearly flow can be generated for each AHGF node.
- The yearly overbank discharge then becomes the area under the curve, but above the level of bankfull discharge.

Width - Depth Modelling.



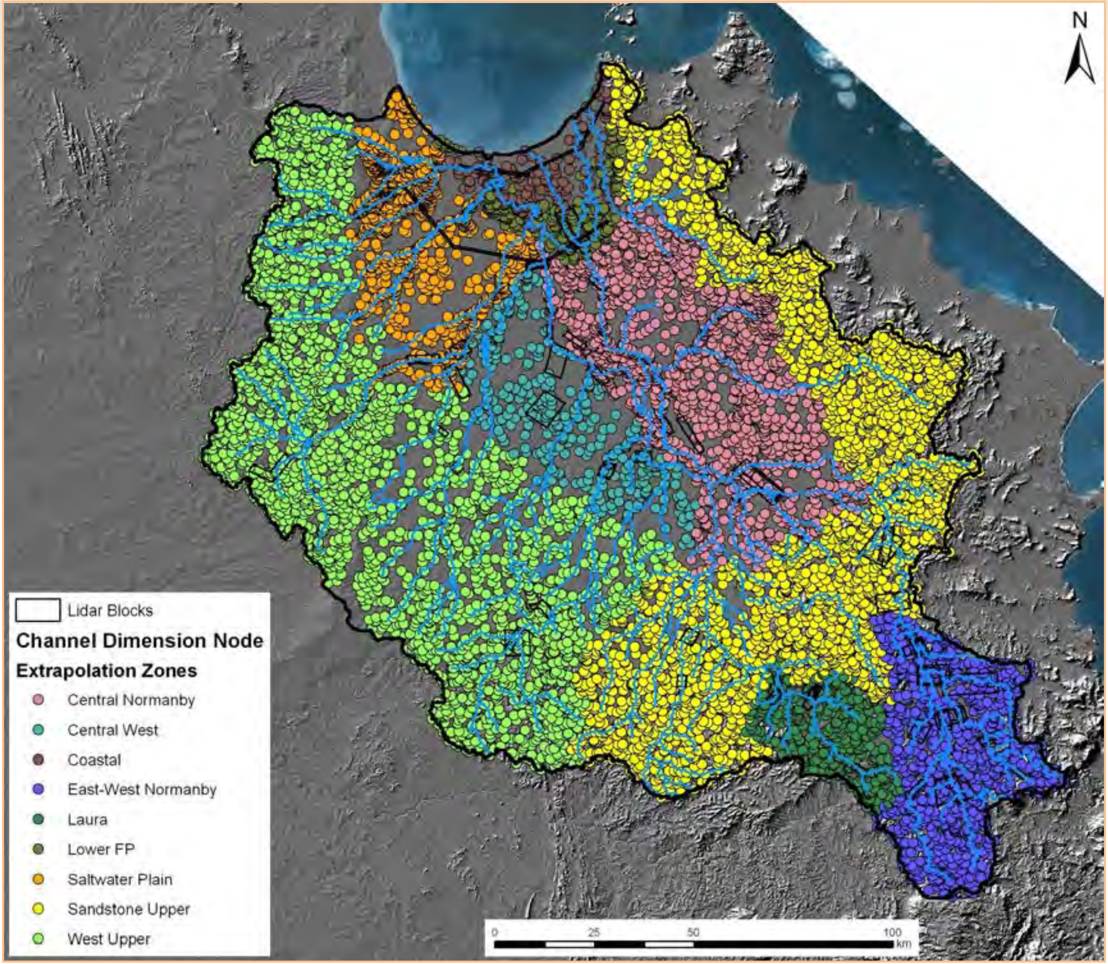
- Lidar DEM data for 3.4 % of the catchment provided the opportunity to model channel width and depth.

Width - Depth Modelling.



- Extracted cross section data from the lidar at representative positions (220 cross sections).

Width - Depth Modelling.



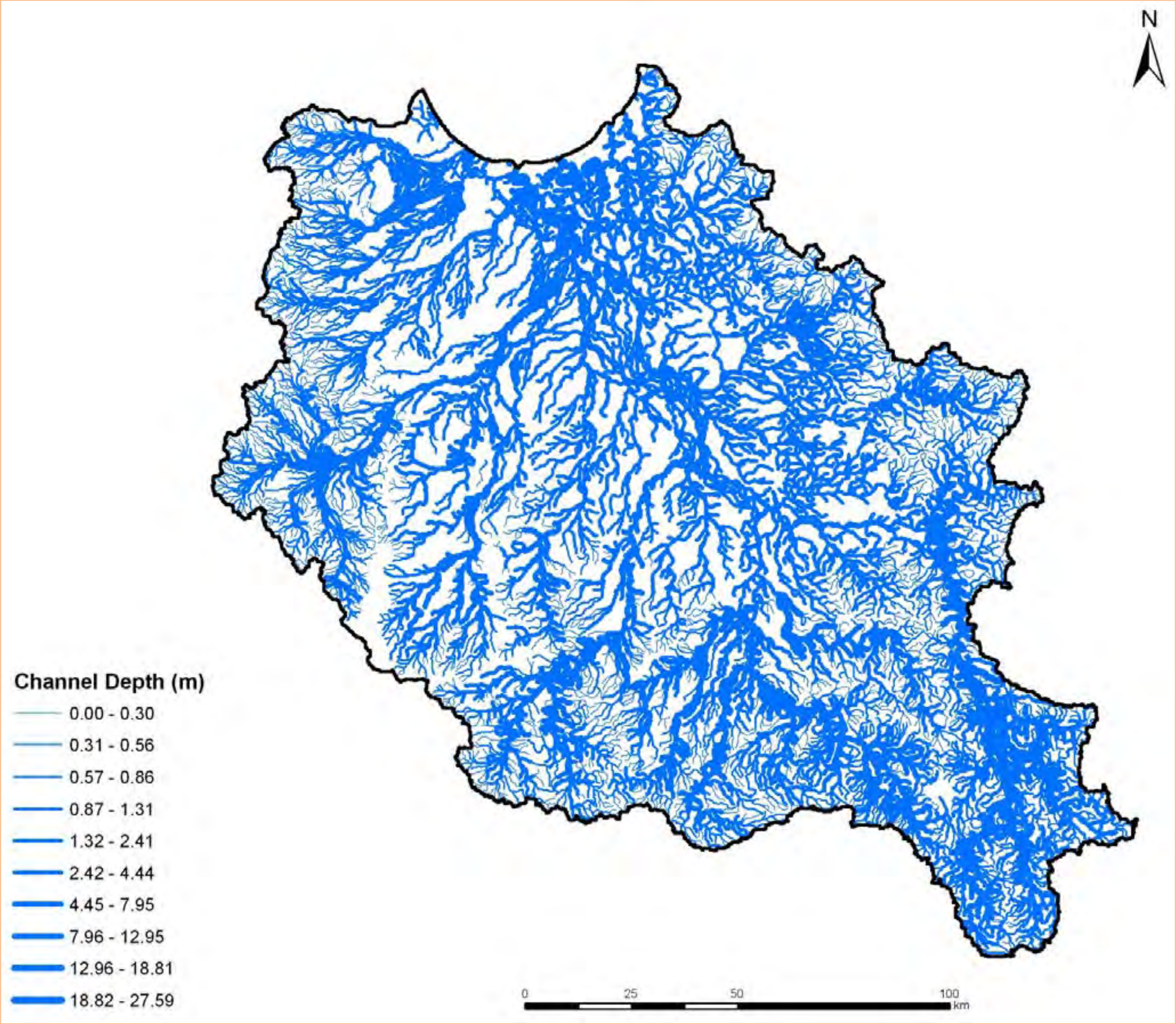
- The catchment was divided into zones which approximately represent downstream river patterns.
- Using catchment area as the dependent variable channel width and depth were modelled using polynomial equations.

Width - Depth Modelling.

Zone		R^2	Equation
Central Normanby	Depth	0.73	$y = 7.74E\text{-}21x^2 + 3.93E\text{-}10x + 1.31E{+}00$
	Width	0.69	$y = 2.53E\text{-}18x^2 + 2.07E\text{-}09x + 2.71E{+}01$
Central West	Depth	0.74	$y = -1.47E\text{-}18x^2 + 5.00E\text{-}09x + 1.14E{+}00$
	Width	0.65	$y = -2.11E\text{-}16x^2 + 5.39E\text{-}07x$
Coastal	Depth	0.24	$y = -7.47E\text{-}30x^3 + 9.32E\text{-}20x^2 - 2.009E\text{-}10x + 1.22E{+}00$
	Width	0.76	$y = 1.30E\text{-}27x^3 - 1.06E\text{-}17x^2 + 2.30E\text{-}08x + 4.16E{+}01$
East-West Normanby	Depth	0.60	$y = 2.65E\text{-}26x^3 - 8.35E\text{-}17x^2 + 7.76E\text{-}08x$
	Width	0.74	$y = 3.28E\text{-}25x^3 - 9.511E\text{-}16x^2 + 8.54E\text{-}07x$
Laura	Depth	0.64	$y = 1.37E\text{-}25x^3 - 1.97E\text{-}16x^2 + 8.70E\text{-}08x$
	Width	0.69	$y = 1.28E\text{-}24x^3 - 1.83E\text{-}15x^2 + 8.45E\text{-}07x$
Lower FP	Depth	0.72	$y = 1.73E\text{-}28x^3 - 1.95E\text{-}18x^2 + 5.25E\text{-}09x + 1.46E{+}00$
	Width	0.70	$y = -1.87E\text{-}28x^3 - 2.23E\text{-}18x^2 + 2.25E\text{-}08x + 4.03E{+}01$
Saltwater Plain	Depth	0.83	$y = -3.86E\text{-}28x^3 - 1.16E\text{-}20x^2 + 2.62E\text{-}09x + 8.59E\text{-}01$
	Width	0.79	$y = -2.54E\text{-}25x^3 + 7.37E\text{-}16x^2 - 2.90E\text{-}07x + 4.91E{+}01$
Sandstone Upper	Depth	0.62	$y = 6.31E\text{-}27x^3 - 2.59E\text{-}17x^2 + 3.58E\text{-}08x$
	Width	0.66	$y = 9.74E\text{-}26x^3 - 3.33E\text{-}16x^2 + 4.73E\text{-}07x$
West Upper	Depth	0.73	$y = -1.55E\text{-}17x^2 + 3.06E\text{-}08x$
	Width	0.75	$y = -2.95E\text{-}16x^2 + 4.99E\text{-}07x$

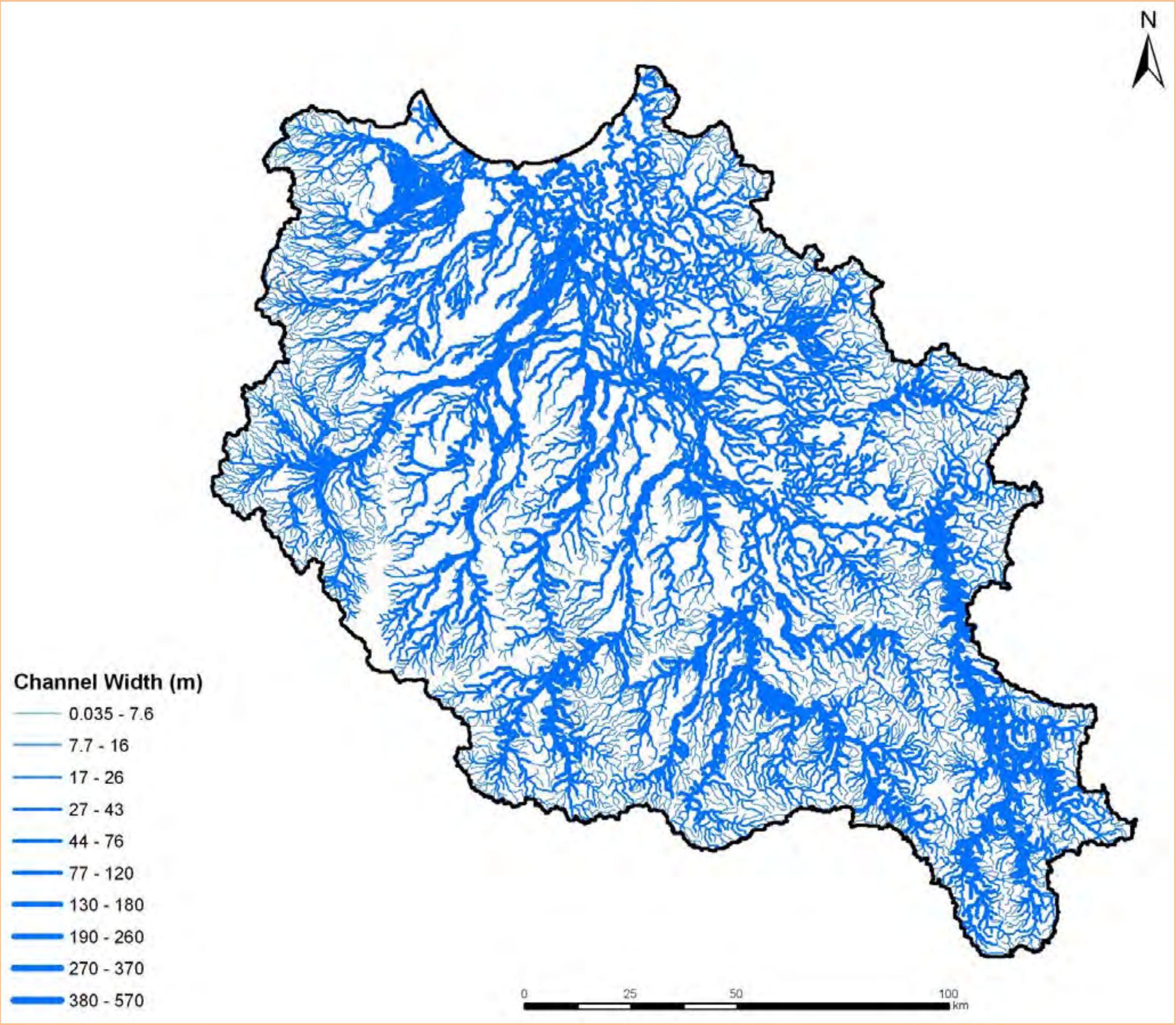
- To some degree the polynomials are capturing the downstream patterns of channel width and depth.

Width - Depth Modelling.



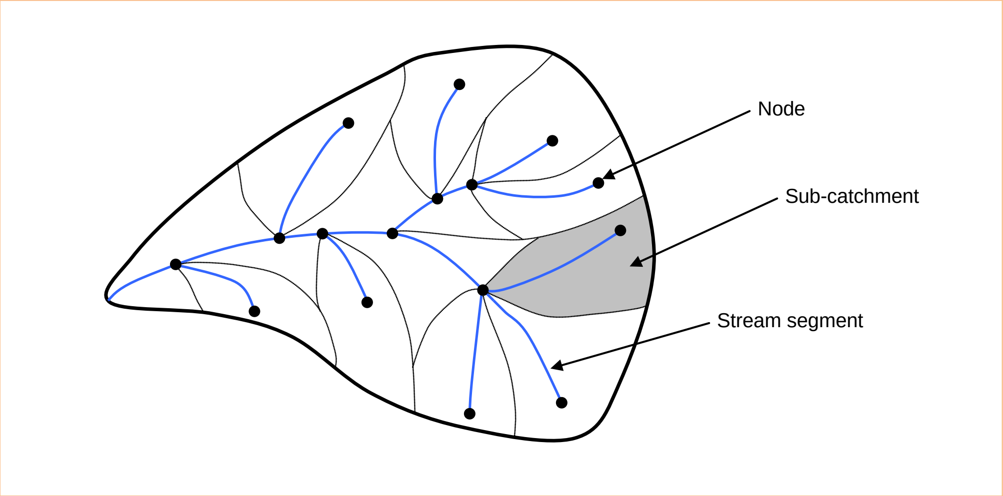
- Channel Depth

Width - Depth Modelling.



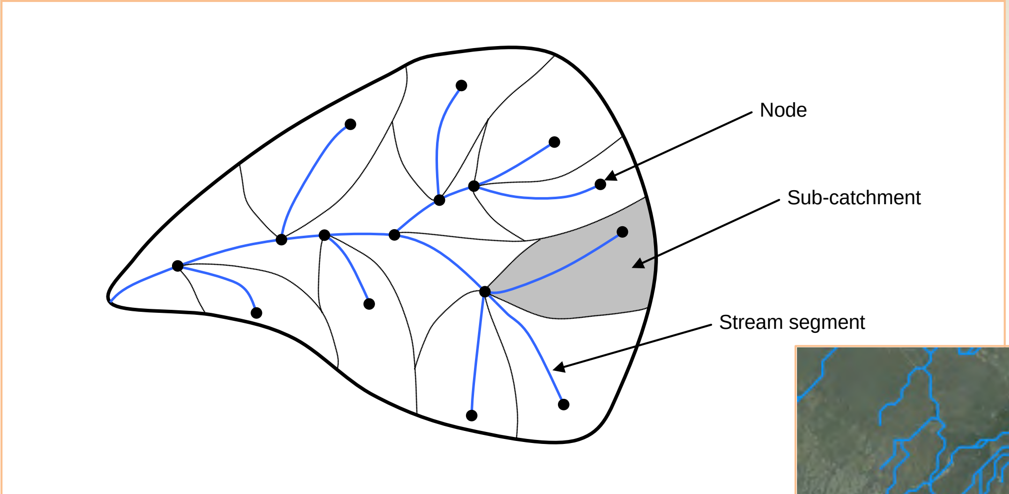
- Channel Width

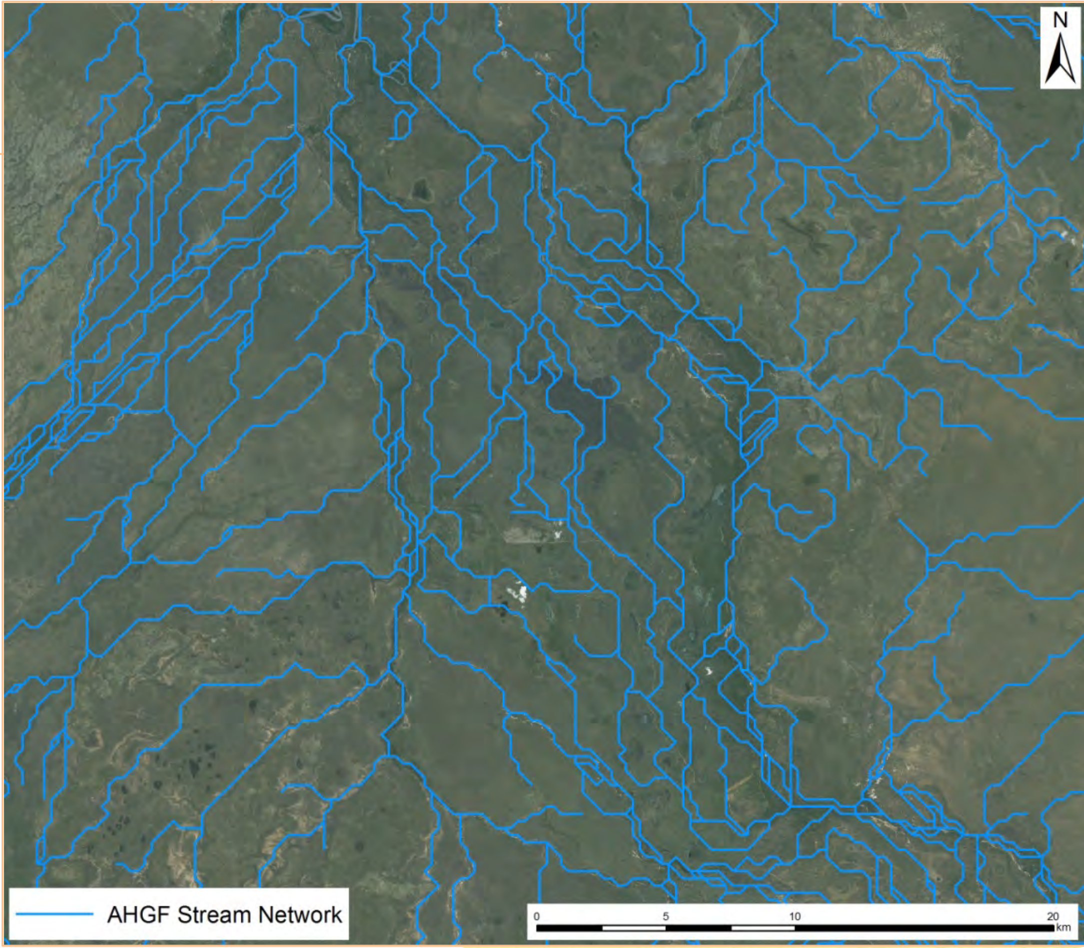
Distributaries and Multi - Channels.



- Simple representation of stream network.

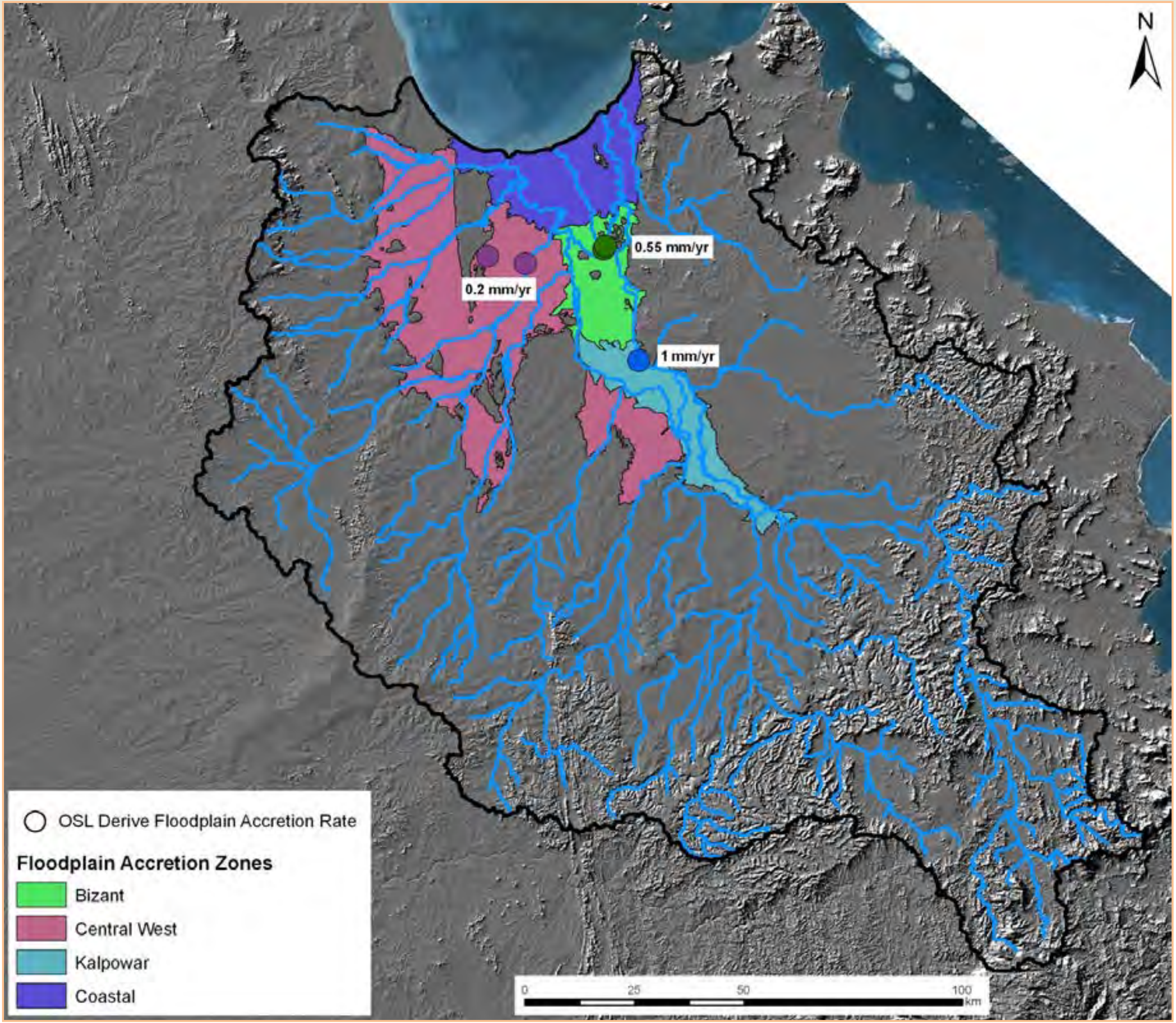
Distributaries and Multi - Channels.



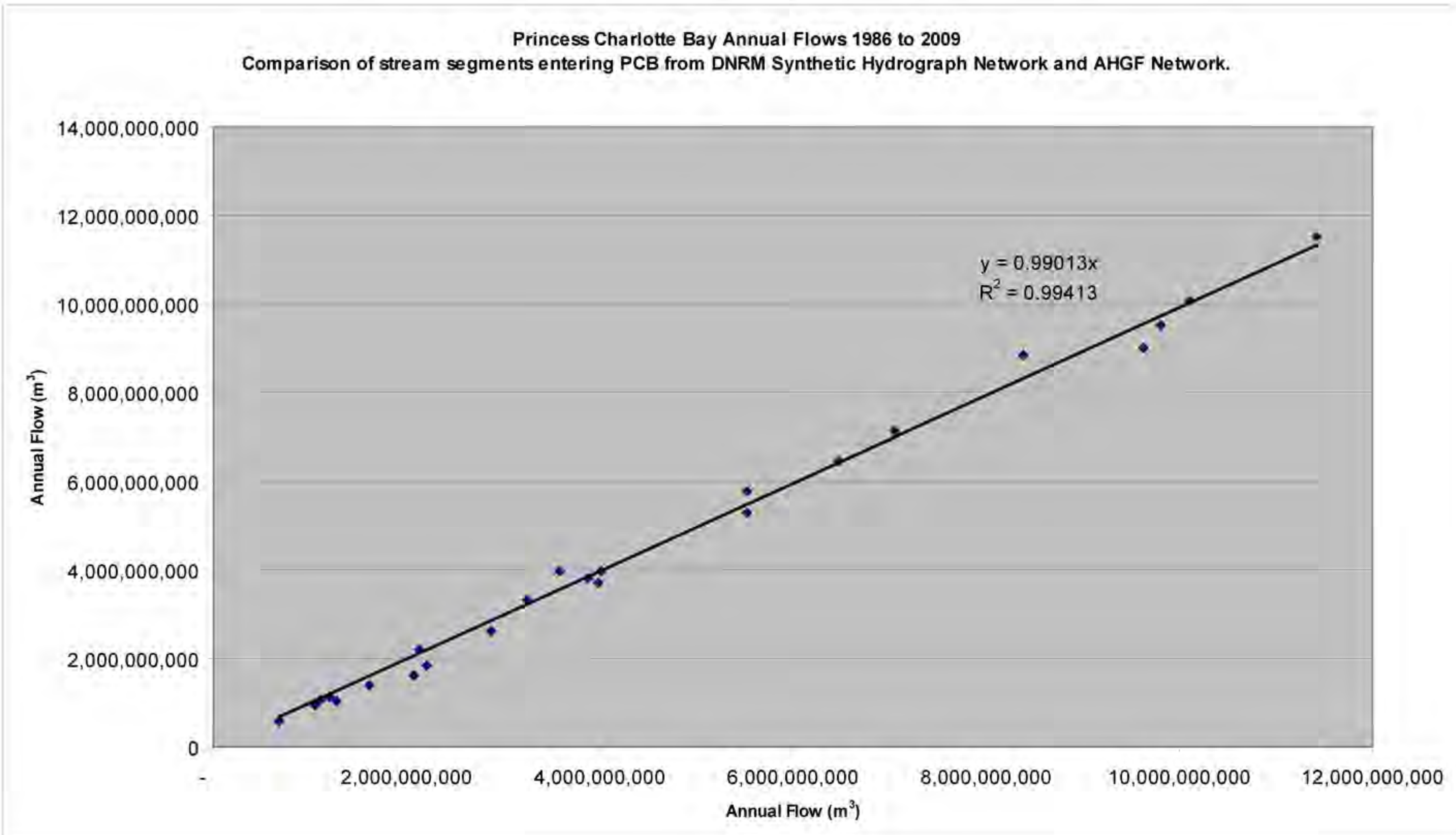


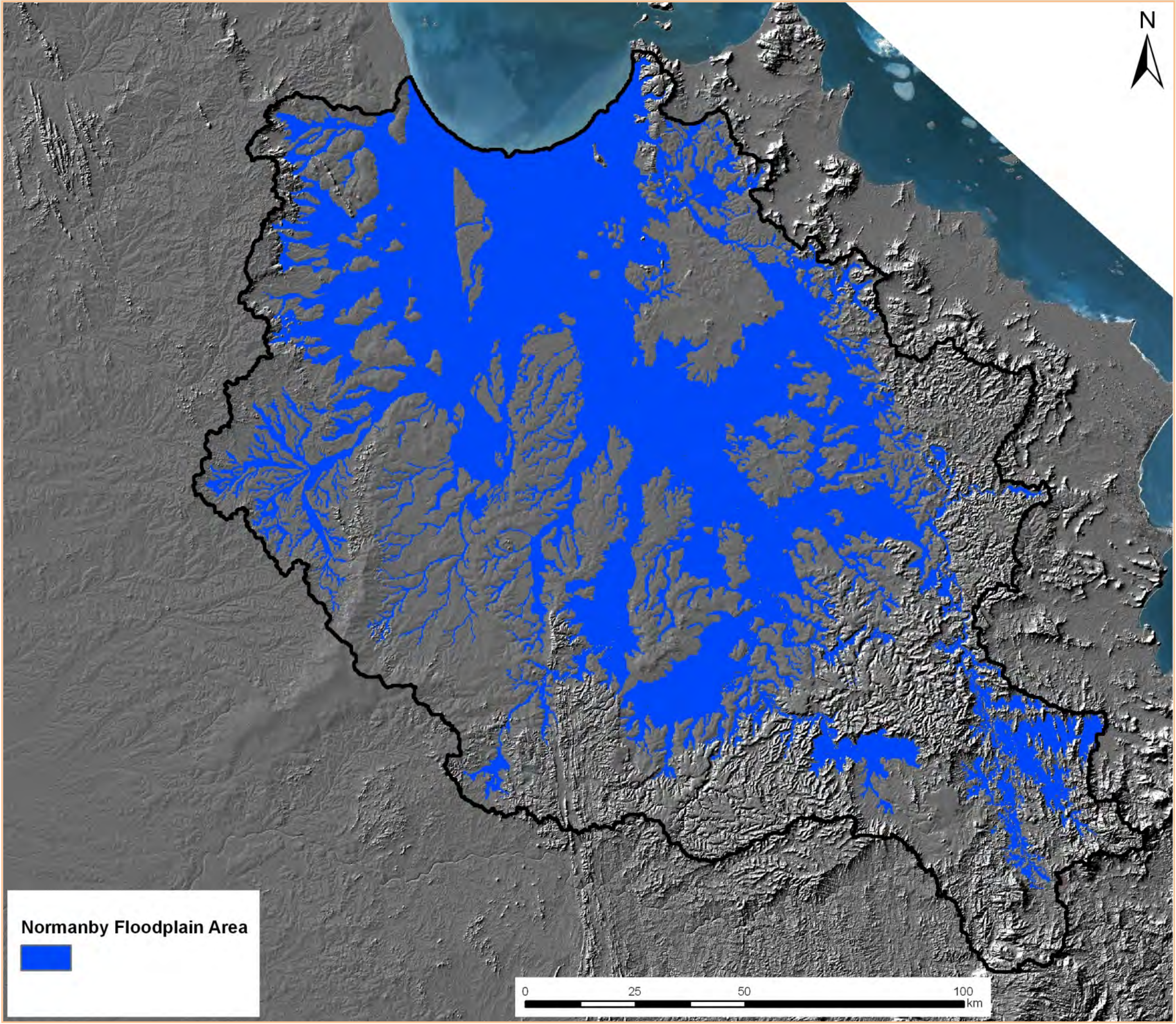
- Simple representation of stream network.
- Included in this model the partitioning of flow and suspended sediment at bifurcations and distributaries.
- This required the development of algorithms to partition and rejoin catchment area at relevant nodes.

Floodplain Accretion Rates.



- Experimented with forcing the floodplain accretion rates in the model to match OSL derive floodplain accretion rates for the sections of the lower floodplain shown above.


Princess Charlotte Bay Annual Flows 1986 to 2009
Comparison of stream segments entering PCB from DNRM Synthetic Hydrograph Network and AHGF Network.
14,000,000,000
12,000,000,000
10,000,000,000
8,000,000,000
6,000,000,000
4,000,000,000
2,000,000,000
0
Annual Flow (m3)
y = 0.99013x
R2 = 0.99413
-
2,000,000,000
4,000,000,000
6,000,000,000
8,000,000,000
10,000,000,000
12,000,000,000
Annual Flow (m3)


N
Normanby Floodplain Area
0
25
50
100
km