

# Evaluating rail and multi-modal infrastructure options for agriculture—application of TraNSIT

Final Report

Updated 4<sup>th</sup> September 2018

Authors:

Andrew Higgins, Stephen McFallan, Adam McKeown, Caroline Bruce (CSIRO)

Michael Clancy (Australian Rail Track Corporation)

## Citation

Higgins AJ, McFallan S, McKeown A, Bruce C, Clancy M. (2018) Evaluating rail and multi-modal infrastructure options for agriculture— application of TraNSIT. CSIRO, Australia.

## Copyright

© Commonwealth Scientific and Industrial Research Organisation 2018. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

## Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

CSIRO is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact [csiroenquiries@csiro.au](mailto:csiroenquiries@csiro.au).

# Contents

1	Introduction .....	3
2	Model data.....	5
	2.1 Production volumes and locations .....	5
	2.2 Supply chain enterprises .....	5
	2.3 Road network .....	7
	2.4 Rail network.....	8
	2.5 Storage facilities .....	10
3	Baseline analysis .....	11
	3.1 Pinch point analysis of roads carrying grains .....	18
	3.2 Season Pinch Points.....	20
4	Scenarios.....	23
	4.1 Summary of transport costs .....	23
	4.2 Summary of freight movements .....	26
	4.3 Road upgrade scenarios .....	27
	4.4 Rail network and rolling stock upgrades .....	31
	4.5 Impact of Site Closures on Transport Costs .....	34
	Appendix A- Overview of TraNSIT.....	37

# Acknowledgements

This project has been jointly funded by:

Grower Co-operative Limited

Narrabri Shire Council

Moree Plains Shire Council

Cotton Research and Development Corporation

Australian Rail Track Corporation

# 1 Introduction

Northern New South Wales is a diverse production region comprising cattle, sheep, pigs, grains, cotton, dairy and horticulture. The region has a large number of processing and storage facilities, particularly for cotton, grains and livestock. Major rail and road agriculture transport corridors pass through the region, linking to the Port of Newcastle, Port of Brisbane and various domestic markets. Rail is heavily utilised for carriage of grains to port or flour mills and of cotton from warehouses to port. Upgrading intermodal hubs (i.e. hubs where product is transferred between rail and road or vice versa) and building storage/loading facilities at the right locations can reduce transport costs across the grain supply chain and maximise efficiencies of both road and rail. This project evaluated the transport cost savings (with road and rail combined) for improved up-country intermodal freight hubs and distribution facilities, under two different scenarios of agriculture utilisation. It also considers the transport cost savings of upgrading key freight routes to the freight hub sites.

CSIRO developed the Transport Network Strategic Investment Tool (TraNSIT) to provide a comprehensive assessment of transport logistics costs and benefits due to infrastructure investments and policy changes in agriculture supply chains in Australia. TraNSIT utilises a ground-up modelling approach that optimises transport routes between enterprises and their markets – a key consideration in Australia due to the long supply chains with large distances between production, processing and markets. The tool's outputs inform operational, investment and regulatory decisions and freight supply chain strategies from local to national scale. An overview of TraNSIT is provided in Appendix A.

TraNSIT was built in 2012/13 to model livestock supply chains in northern Australia, through an initiative of the Office of Northern Australia and with co-funding from the Northern Territory, Western Australian and Queensland Governments. In 2014, the tool was extended to all beef transport in Australia through a Meat and Livestock Australia initiative (Higgins et al., 2015). In 2014/2015, the tool was used to inform various road upgrades and regulatory changes for the beef industry, most notably the Northern Australia Beef Roads Programme. The Beef Roads Programme was the first of its type in Australia to use an optimisation tool like TraNSIT to evaluate the transport cost savings for a large number of submissions. TraNSIT evaluated 60 road upgrade submissions, with total construction cost estimated to exceed \$3 billion. A report outlining the application of TraNSIT to the Beef Roads Programme and the resultant transport cost savings for each road upgrade can be accessed via [www.csiro.au/transit](http://www.csiro.au/transit).

Through an initiative for “Building the infrastructure of the 21<sup>st</sup> Century” under the Agricultural Competitiveness White Paper (<http://agwhitepaper.agriculture.gov.au/>), TraNSIT was recently applied to 98% (by volume) of agricultural and horticultural supply chains across Australia. The final report (accessible from [www.csiro.au/transit](http://www.csiro.au/transit)) was announced by Assistant Minister Luke Hartsuyker in November 2017. Additional applications in recent years include assessment of sealing of roads in north Queensland and of tick clearing regulations for transport of cattle direct to abattoirs.

The range of scenarios TraNSIT can examine includes:

- Analysing the impact of road upgrades, e.g. sealing, widening, first/last mile, improving roads for higher productivity vehicles and bridges;

- Testing potential outcomes for changes in policy, e.g. driver fatigue, changed truck limitations for road classes;
- Comparing infrastructure investment and regulatory-change opportunities that maximise transport cost reductions for a given investment budget;
- Assessing potential for incorporation of rail transport in to commodity value chains.

For this project, TraNSIT was applied to estimating the transport travel cost savings for several initiatives relating to rail-enabled storage and handling facilities. The project assessed commodity movements across nine councils in northern NSW and southern Queensland, namely:

- Goondiwindi Regional Council,
- Gwydir Shire Council,
- Moree Plains Shire Council,
- Gunnedah Shire Council,
- Liverpool Plains Shire Council,
- Narrabri Shire Council,
- Walgett Shire Council
- Coonamble Shire Council
- Tamworth Regional Council

## 2 Model data

### 2.1 Production volumes and locations

The same agriculture production data set as used in the application of TraNSIT to the Agriculture White Paper initiative and outlined in Higgins et al (2017), was used in this project. However, volumes were updated using 2014 to 2016 NLIS data for cattle. Grains production locations and volumes were inferred from the 2010/2011 Australian national land use map (ALUM). Cotton production locations and volumes were mapped using farm boundary information produced by Cotton Australia for the 2011 to 2016 growing seasons. From this farm boundary data, de-identified farm locations and production volumes (number of bales per year) were derived. Pork production locations and supply chains were mapped using 2014/15 data provided by Australian Pork Limited. The data comprised number of pigs moved from each property to export/domestic abattoirs, to saleyards and to other properties. A national map of national poultry and meat infrastructure (sourced from NSW DPI) was used to identify the location of poultry meat farms, breeder farms, feed mills, hatcheries and processing plants. Spatial datasets of farm/paddock boundaries were mostly unavailable for horticulture, thus growing locations were inferred using the 2010/11 ALUM landuse map.

### 2.2 Supply chain enterprises

Post-harvest enterprises include abattoirs, feedlots, grain silos, saleyards, cotton gins and poultry processors. Figure 1 shows these for the nine LGAs in northern NSW and southern Queensland. Facilities shown are those that were utilised from 2014 to 2016, and processed >500 head or 1000 tonnes. Volumes of grain transported to silos was based on 2016 calendar year for GrainCorp and 2015/2016 financial year for other grain silos. For cotton transported to gins, volumes were based on the 2016 production year was used.

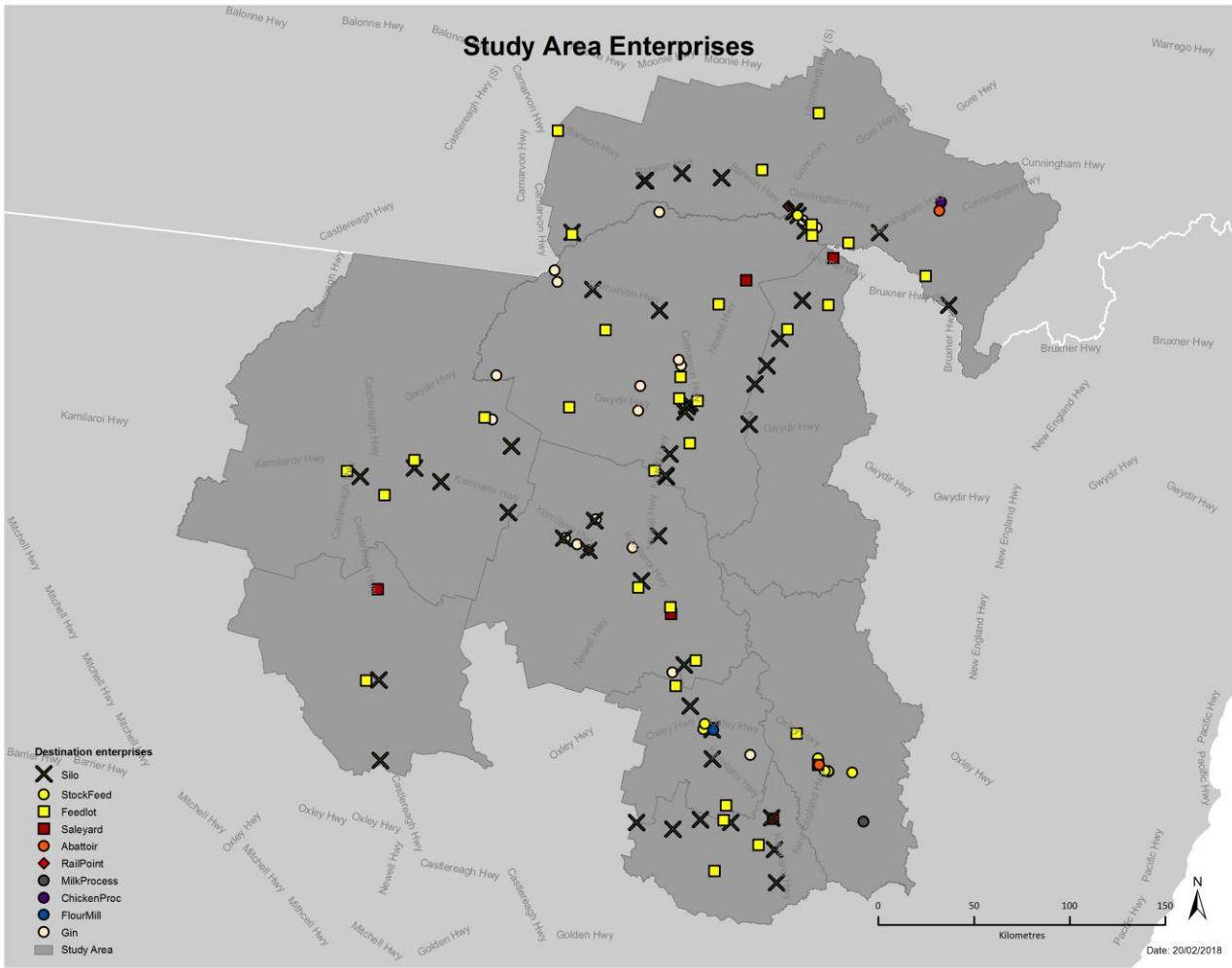


Figure 1 Location of post farm agricultural enterprises

## 2.3 Road network

Figure 2 shows the road network in northern NSW and southern Queensland that was used in TraNSIT for the project. Local roads were added for each of the 9 LGA's, and the map shows road rank and PBS rating.

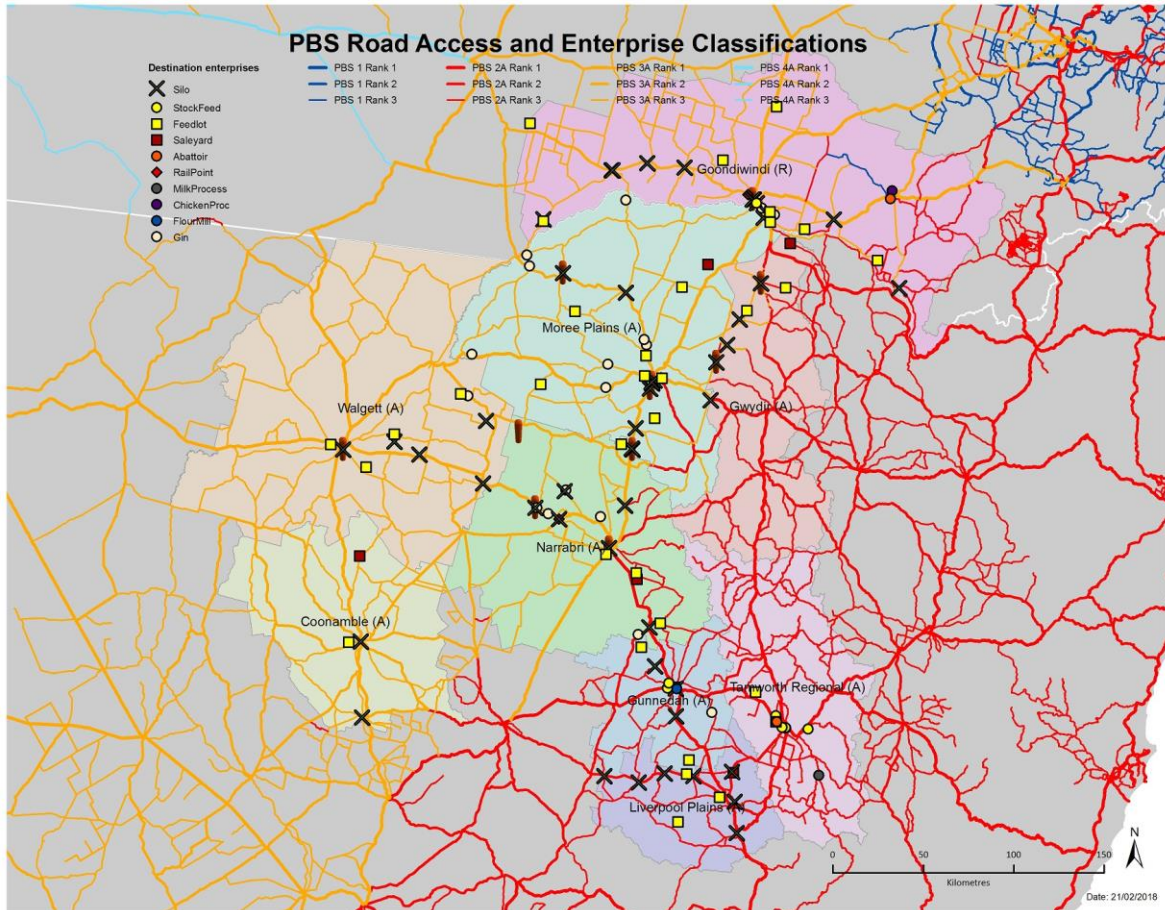


Figure 2 Road network in and around the 9 councils

## 2.4 Rail network

The rail system within the study area is currently operated by three different Network managers and is physically separated between New South Wales and Queensland due to different rail gauges preventing the transit of rolling stock between states. Additionally, the subject New South Wales Network is comprised of different branch and mainline infrastructure configurations. The various infrastructure configurations create a dynamic in which six different route standards exist which in turn mandate wagon gross mass, locomotive gross mass, train length and train speed. In general, due to a combination of the factors above, the further the loading location is from Newcastle the lower the overall payload per train.

In conjunction with rail infrastructure, the associated line side bulk handling facilities and terminals also play a critical part in the overall rail transport costs due to loading time impacts on train asset utilisation.

Figure 3 shows the rail network and average speeds travelled on each segment of the rail network, which includes proposed segments of the Inland Rail. The average speeds do not include stops or waiting at passing loops - these additional times are incorporated in the modelling process.

The axel load limits at the grain loading points and throughout the rail path to the port were used to determine the wagon capacities at each loading point. Actual wagon payloads are usually lower than axel load limit requirements, partly due to loading inefficiencies. The gap between wagon capacities and average loads were estimated using historical data provided by ARTC.

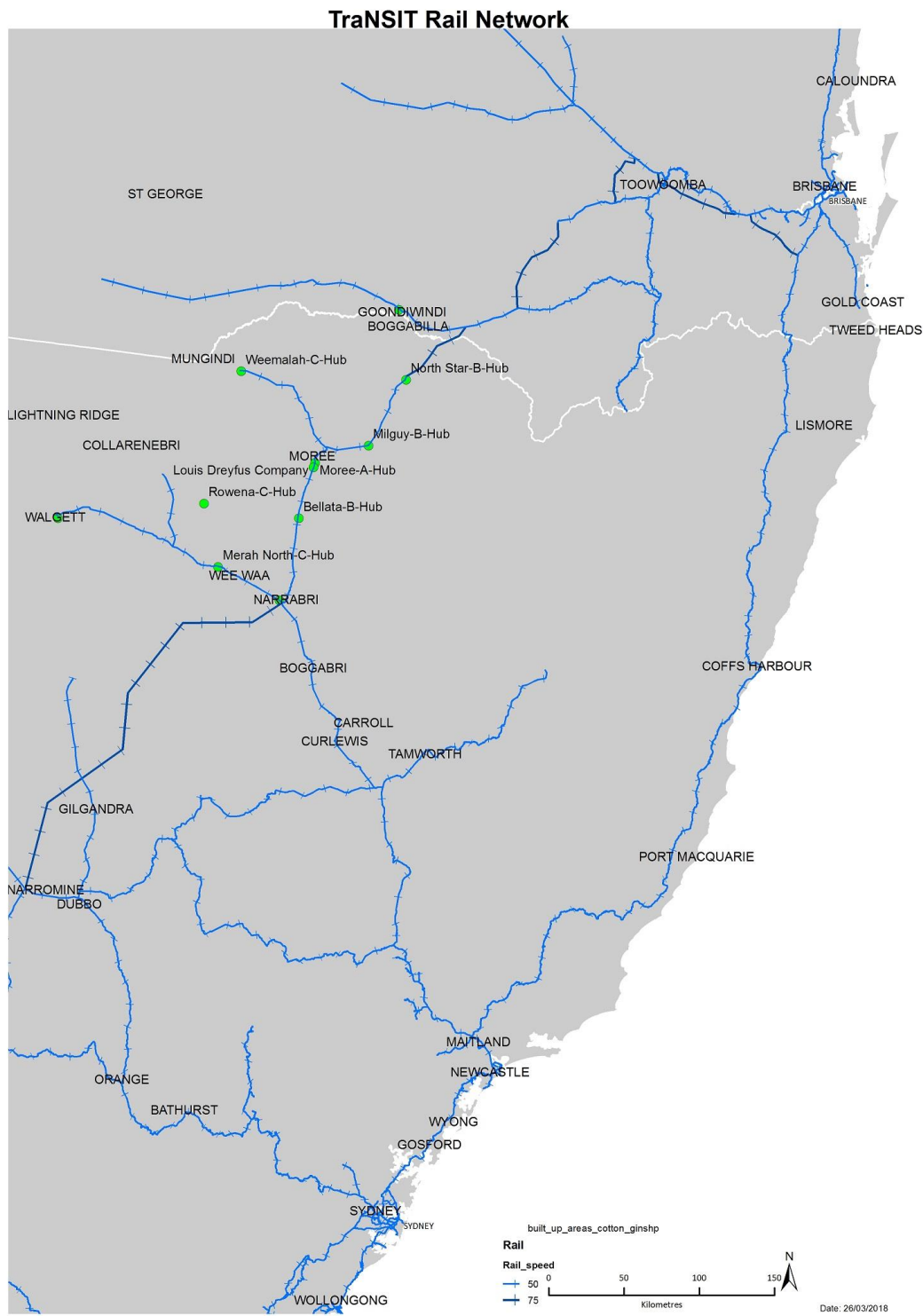


Figure 3 Rail network showing average line speeds and location of grain silos.

## 2.5 Storage facilities

Ten storage facilities (or hubs) with potential for expanded capacity are a focus for the scenarios in this report. They were classified in to three categories

- A-Hub – A large multi-commodity intermodal storage facility, accommodating grains plus other agriculture and non-agriculture commodities
- B-Hub – A large storage facility predominately used for grains
- C-Hub – A medium storage facility predominately used for grains

Current and proposed capacities, along with average wagon payload for each storage facility are shown in Table 1. For each storage scenario, the increased throughput was assumed to come from a reduction in farm storage, rather than a reduction or redistribution from other bulk storage facilities. When tested with TraNSIT, the total tonnes transported to the storage facilities did not exactly match those in Table 1 due to supply and demand availability differences of grain each month. However, these differences were usually within 3%, and did not impact the analysis. Each scenario was tested separately in TraNSIT and the outputs compared to the baseline. Expansion of each storage facility does not just impact supply chains passing through it, but will often have additional impacts on other supply chain in the region. For example, expansion of a storage facility can provide additional grain for nearby domestic markets (feedlots, flour mills, stock feed manufacturers supplying intensive livestock), thus reducing the need to source grain from grain storage facilities further away

**Table 1 Capacities of the current and proposed storage expansions, along with wagon payload.**

Storage facility	Current tonnes (2016)	Proposed tonnes	Average wagon payload (t)
Moree-A-Hub	340,000	400,000	56
Milguy-B-Hub	29,000	150,000	56
Weemalah-C-Hub	40,000	100,000	53
Goondiwindi-B-Hub	260,000	300,000	46
North Star-B-Hub	38,000	200,000	56
Bellata-B-Hub	194,000	300,000	56
Narrabri-A-Hub	78,000	400,000	60
Merah North-C-Hub	48,000	100,000	56
Walgett-A-Hub	280,000	400,000	56
Rowena-C-Hub	0	100,000	

### 3 Baseline analysis

A baseline analysis provides information on the number of vehicles travelling along each road/rail segment across the LGAs, and needs to be undertaken before scenarios can be tested. The main outputs from the baseline analysis for this project were:

- number of vehicles using each road or rail segment by commodity, month of year, origin and destinations routes;
- detailed cost of road/rail transport for every vehicle trip.

For the nine LGAs within this project, a summary of vehicle trips originating or terminating in the LGAs was produced (Table 2). This provides a profile of the commodities transported, and indicates that grains account for by far the greatest volume of agriculture traffic. If an agriculture movement consists of a trip from farm to storage facility and then from storage to port/market, it is labelled as two separate trips. Overall, there is not a large difference between the number of trips originating or terminating in the region. Also included in the maps are the storage facility scenarios. Most of the storage facilities are near road with high volumes of grain and agriculture traffic.

The baseline analysis also produces freight density maps showing the number of vehicles travelling along each road segment or rail wagons transported along the road network. Figure 4 shows the vehicle numbers using each road segment for all agriculture/forestry trips, while Figure 5 shows the number of vehicles for grain transport only.

A low grain production scenario was run to show a freight density comparison to 2016 production year used in this project. The 2014 calendar year was selected which has 57% of 2016 production, and the throughputs for each grain storage were adjusted accordingly. The low production year meant a significant reduction in the volume of grain transported to ports (Brisbane, Port Kembla, Newcastle) by rail, down from 5.03 million tonnes in 2016 to 2.13 million tonnes for the low yield scenario. Figure 5a shows the freight density along the road network for the low production year. It still shows the large volumes of grain transported between storage and feedlots in southern Queensland.

Figure 6, shows the number of rail wagons transported on each rail segment from within Goondiwindi LGA to Port of Brisbane, and rail wagons from NSW transported to Port of Newcastle.

For each of the storage facility scenario, Table 2 shows the cost of transporting grain to the existing storage facilities, and from the storage facilities to port (or market or stock feed processor). The total transport cost for each hub is dependent on the tonnes of grain transported to the hubs and transport distance (cost per tonne). Not all grain is transported from the storage facility by rail, since a large portion is transported to domestic markets (feedlots, stock feed manufacturers and flour mills) by road. For rail, Table 3 shows a separate cost per tonne for rail trips from silos and port silos to flour mills. All trips from the silos to port in Table 3 are by rail. Rail trips to flour mills are considerably shorter than trips to port.

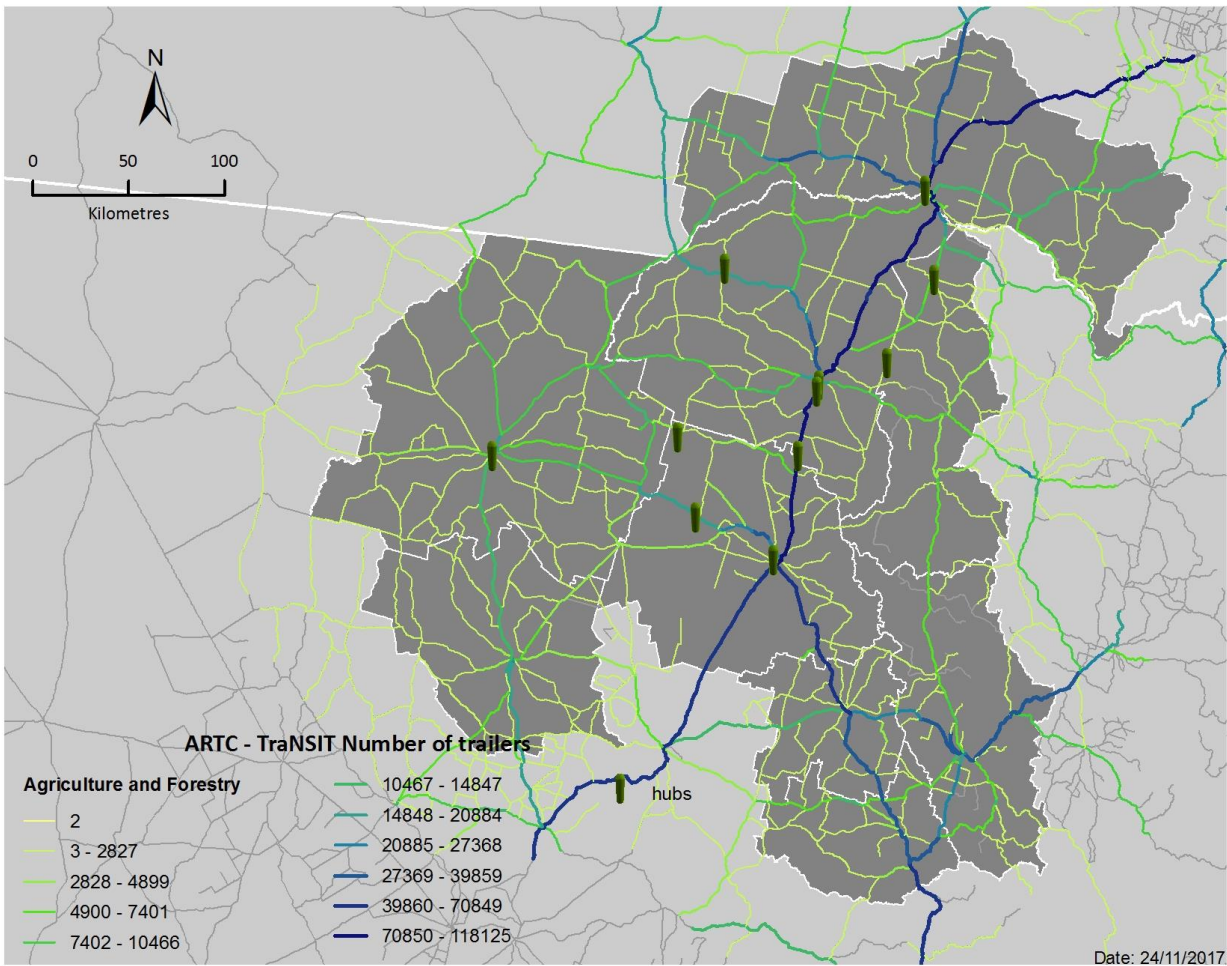
Road transport occurs between silos and feedlots, stock feed manufacturers and some flour mills. Some silo operators (e.g. Walgett) involve short trips to local feedlots thus the transport costs are low. In Table 3, rail costs cannot be directly compared to road costs due to the differences in destinations. To make a fair comparison, an additional scenario would need to be tested where the

existing rail trips are moved to road. Table 4 shows the average travel distances for the costs in Table 3. For road transport, the travel cost is mostly a function of travel distance, though road train access (PBS Level) and road condition (sealed versus unsealed) will also impact travel cost per kilometre.

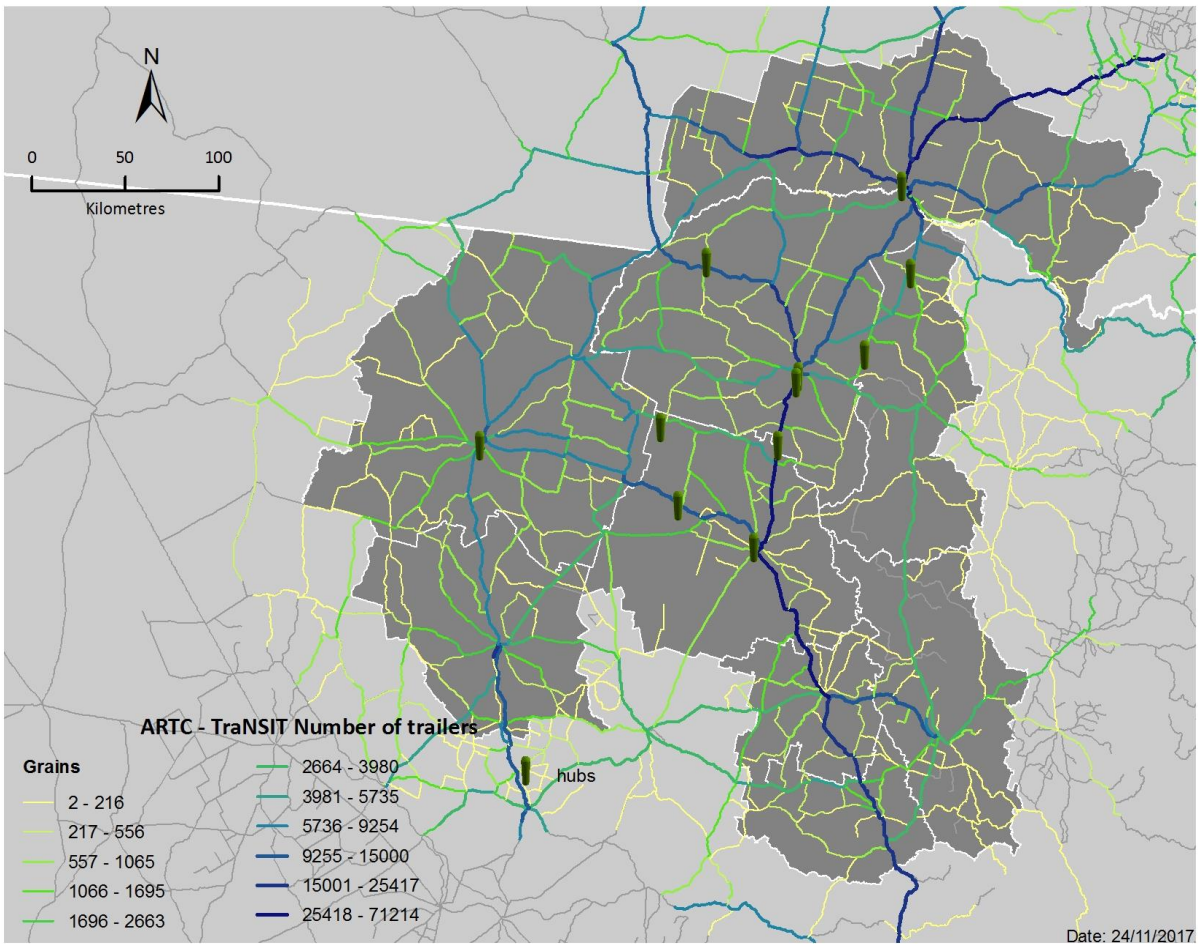
**Table 2 Summary of annual vehicle trips (semi-trailer equivalents) for each commodity having an origin or destination in the nine LGAs. Includes trips that: commence and finish the journey within the LGAs, commence the journey within the nine LGAs and finish the journey outside the LGAs, commence a journey outside the nine LGAs and finish the journey within the LGAs.**

Commodity	Number of vehicles (origin)	Number of vehicles (destination)
Beef	43,378	31,318
Grains <sup>+</sup>	224,525	199,120
Dairy	7,440	3,060
Sheep/Goats	11,832	13,224
Cotton	55,798	50,349
Pigs	739	41
Poultry	3,385	4,976
Horticulture	267	93
Retail and post processing*	11,915	2,831
Wood	1,430	

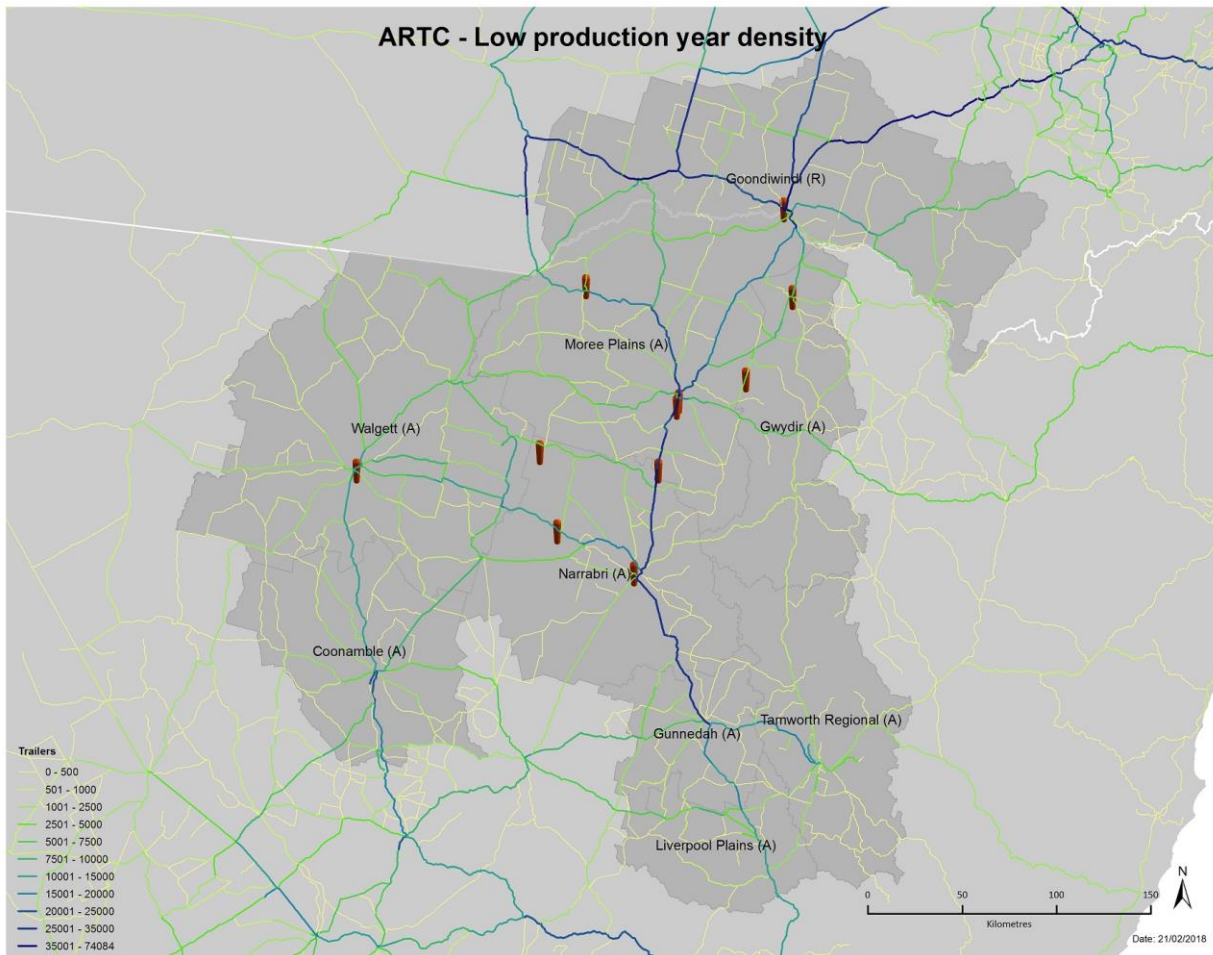
<sup>#</sup>Semi trailer equivalents, <sup>+</sup>Include grain transport for stockfeed, \*Post processing includes trips to distribution centres and supermarkets



**Figure 4** Baseline of transport density (number of semi-trailer equivalents on roads) for all agriculture and forestry in the 9 LGA's of this project, including the locations of the candidate freight hubs.



**Figure 5 Baseline of transport density (number of semi-trailer equivalents on roads) for grains in the nine LGA's of this project, including the locations of the candidate storage facilities.**



**Figure 6a Baseline of transport density (number of semi-trailer equivalents on roads) for grains in the nine LGA's of this project. It represents a low production year (2014), which is 57% of the grain production 2016.**

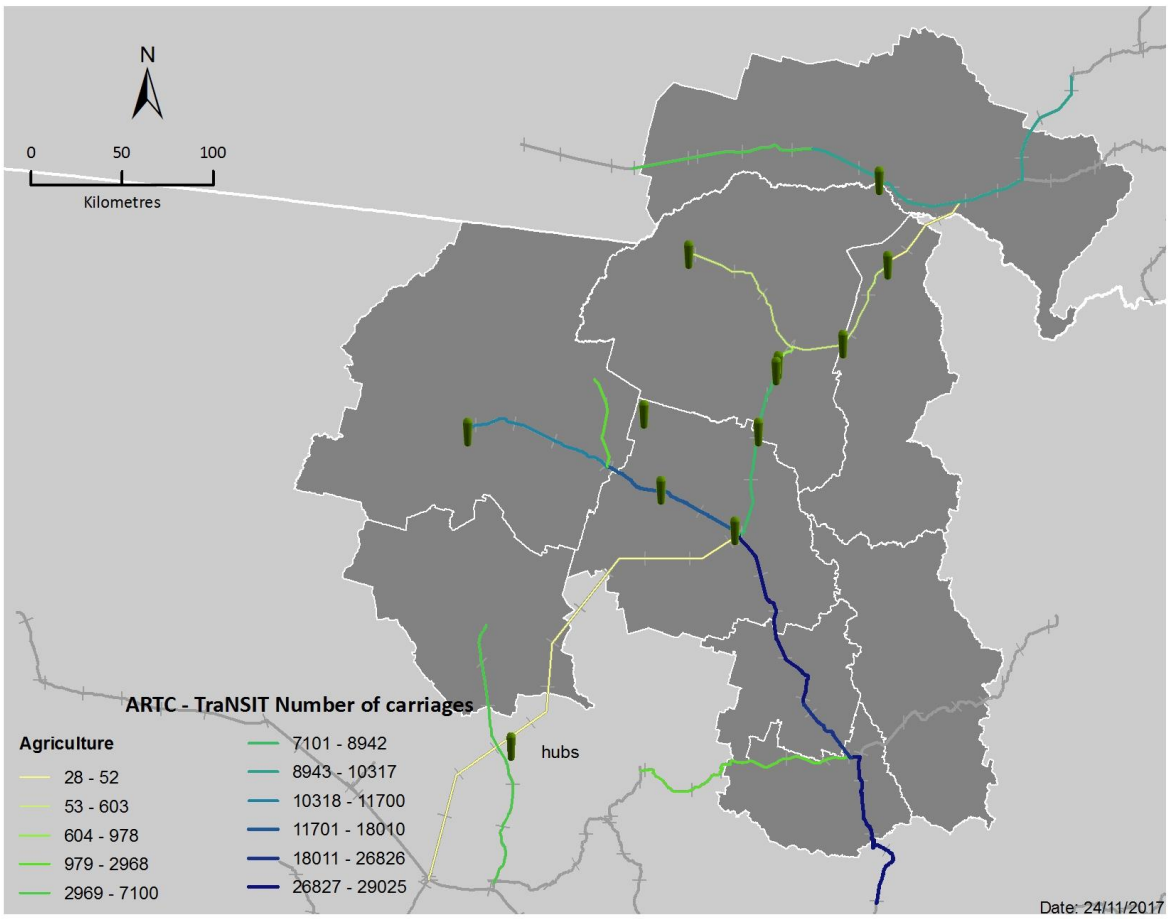


Figure 7 Freight density of rail for nine LGA's of this project, also showing the location of the storage facilities scenarios

**Table 3 Modelled transport costs for grains transported in and out of each storage facility (in the baseline analysis).**

Storage facility		Road		Rail	
		Total cost (\$)	Cost per tonne (\$)	Total cost (\$)	Cost per tonne (\$) To port To mill
Moree	Farm to Hub	\$7,887,000	\$21.49		
	Hub to port, mill or market	\$9,321,000	\$45.91	\$5,993,000	\$38.36 \$24.52
Milguy	Farm to Hub	\$528,000	\$16.92		
	Hub to port, mill or market	\$1,028,000	\$41.78	\$137,000	\$40.75 \$24.97
Weemelah	Farm to Hub	\$1,007,000	\$23.47		
	Hub to port, mill or market	\$755,000	\$50.67	\$1,106,000	\$43.22 \$28.15
Goondiwindi	Farm to Hub	\$6,604,000	\$18.76		
	Hub to port, mill or market	\$9,572,000	\$39.88	\$4,837,000	\$43.46
North Star	Farm to Hub	\$850,000	\$19.41		
	Hub to port, mill or market	\$1,463,000	\$38.50	\$201,000	\$42.91 \$27.83
Bellata	Farm to Hub	\$4,834,000	\$23.35		
	Hub to port, mill or market	\$7,196,000	\$49.29	\$2,874,000	\$34.56 \$20.29
Narrabri	Farm to Hub	\$1,305,000	\$20.51		
	Hub to port, mill or market	\$1,774,000	\$40.50	\$629,000	\$32.03 \$31.70
Merah North	Farm to Hub	\$1,439,000	\$27.89		
	Hub to port, mill or market	\$2,195,000	\$49.32	\$116,000	\$34.07 \$19.85
Walgett	Farm to Hub	\$6,157,000	\$22.31		
	Hub to port, mill or market	\$29,000	\$18.47	\$1,081,000	\$40.62 \$26.04

**Table 4 Average travel distance for grain transported into and out of each facility**

Storage facility		Road	Rail	
		Average travel distance (km)	Average travel distance (km)	
			To port	To mill
Moree	Farm to Hub	137		
	Hub to port, mill or market	362	504	188
Milguy	Farm to Hub	94		
	Hub to port, mill or market	285	548	232
Weemalah	Farm to Hub	150		
	Hub to port, mill or market	368	604	287
Goondiwindi	Farm to Hub	121		
	Hub to port, mill or market	303	415	
North Star	Farm to Hub	123		
	Hub to port, mill or market	283	600	284
Bellata	Farm to Hub	150		
	Hub to port, mill or market	393	466	150
Narrabri	Farm to Hub	131		
	Hub to port, mill or market	320	408	420
Merah North	Farm to Hub	187		
	Hub to port, mill or market	391	455	139
Walgatt	Farm to Hub	140		
	Hub to port, mill or market	121	576	260

### 3.1 Pinch point analysis of roads carrying grains

For this analysis, as the carrying capacity of the roads are not specified in the road network data. Roads that are sealed and are determined to be major carriage ways were excluded from the analysis. Two categories of pinch point roads were identified.

- A. Roads carrying above the 50<sup>th</sup> percentile load for the region (in this case 700 trailers per year or 600 in peak season) that are less than full width carriage way and not classified as a rank 1 road. (Figure 7)
- B. Roads that carry high volume loads (95<sup>th</sup> percentile for the region (18,000 annual or 12,400 in peak season), and not a rank 1 road. (Figure 8)

This analysis was completed for the annual load and for the high season flow, which is November/December for the region. The analysis represents a first pass selection of road segments where an upgrade would yield higher cost savings to grain transport to the storage facility scenarios.

### 3.1.1 Annual pinch points

Overall there are 2790 road segments in the road network for the nine LGA's, of these for the annual load there were 1710 that carried less than 700 trailers per year with 1009 of these carrying less than 50 per year.

There were 181 that carried > 700 trailers a year where the road was narrow and not identified as rank 1 road. (i.e. main freight road in the network). Tables of these roads are contained in Appendix B and C for the 50<sup>th</sup> percentile and 95<sup>th</sup> percentile respectively.

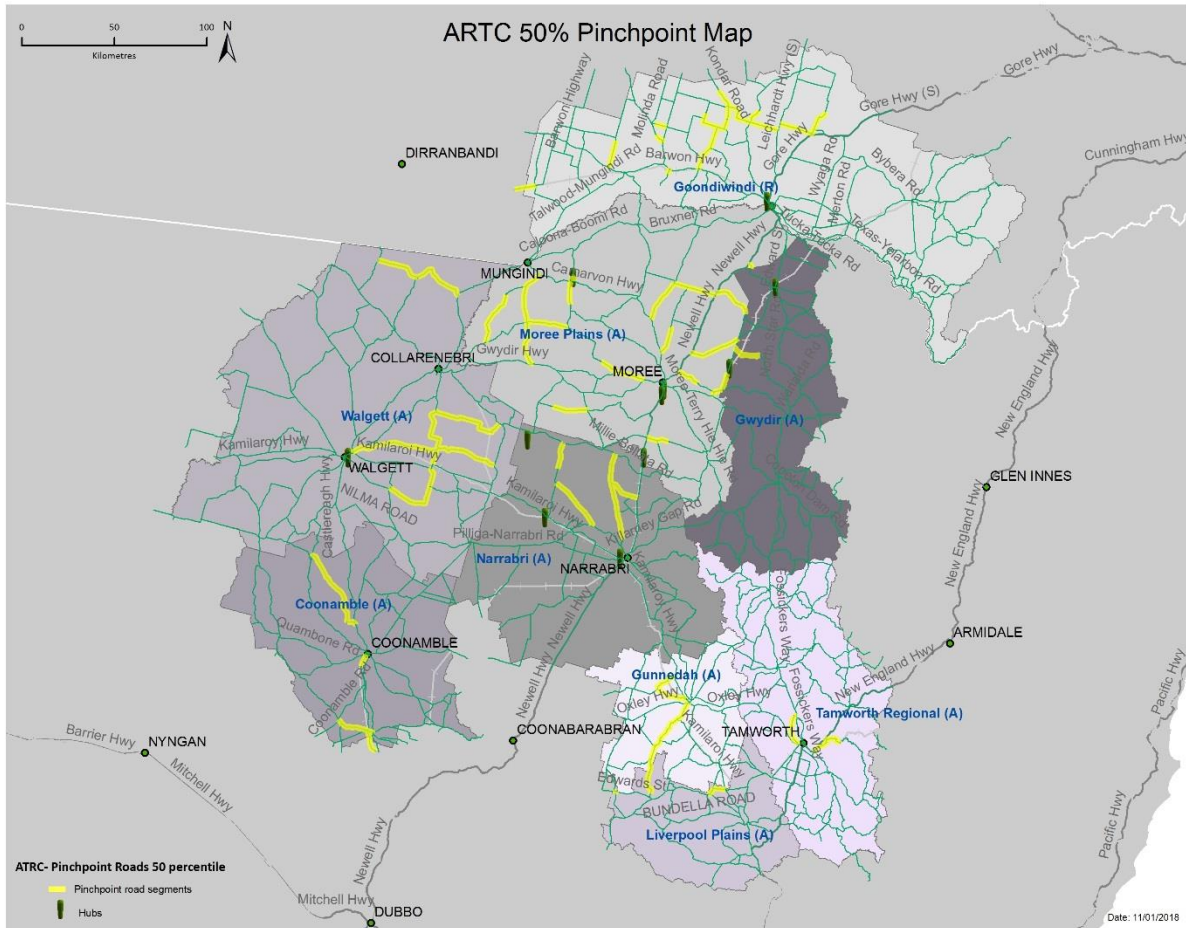


Figure 8 Map of pinch point roads for 50<sup>th</sup> percentile

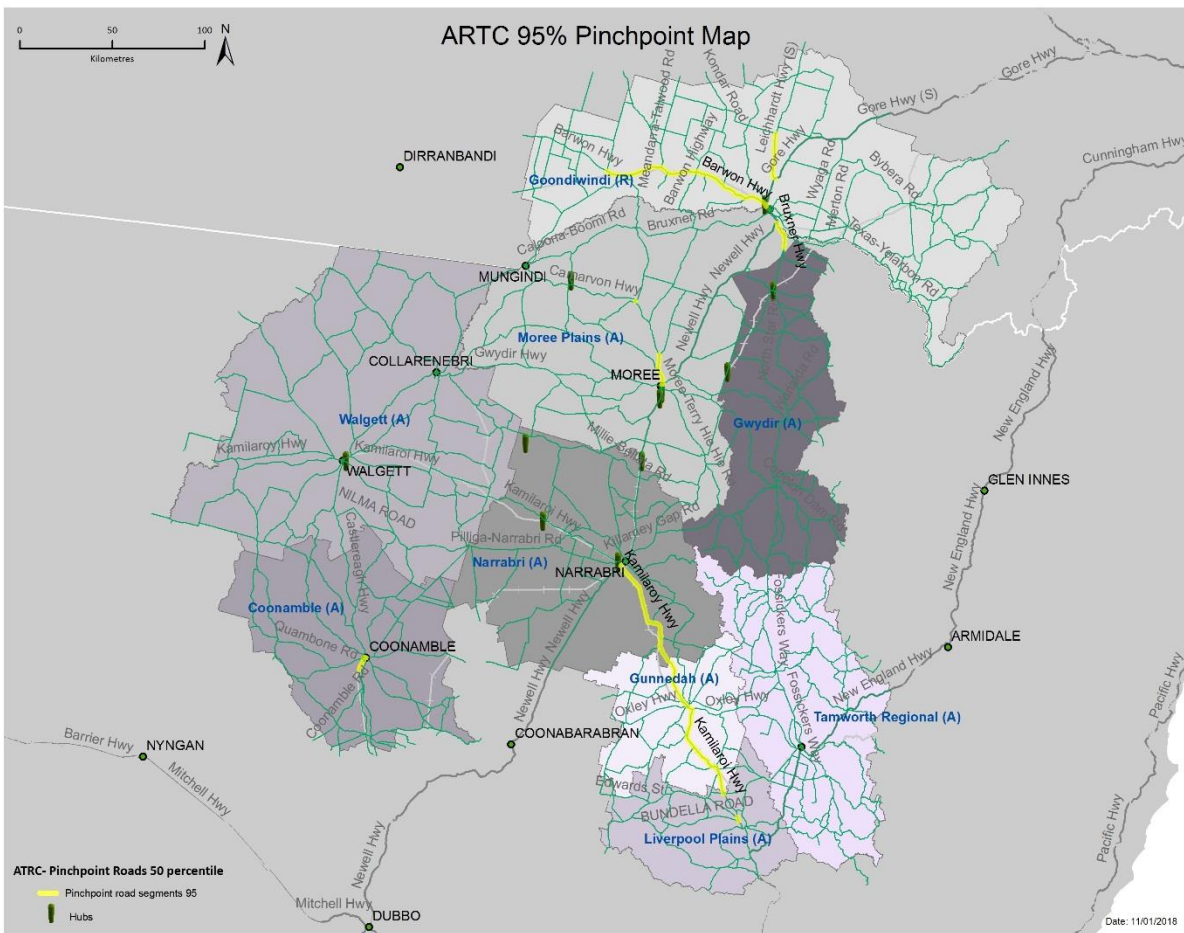


Figure 9 Map of pinch point roads for 95<sup>th</sup> percentile

### 3.2 Season Pinch Points

The November/December period results in 57% of annual grain movements, this is the peak season for grain transport in this region. Overall for the 2790 road segments in the road network for the nine LGA's, there were 1798 that carried less than 600 trailers per year with 994 of these carrying less than 50 per year.

There were 189 that carried > 600 trailers a year where the road was narrow and not identified as rank 1 road. (i.e. main freight road in the network). Maps for the 50<sup>th</sup> and 95<sup>th</sup> percentile are shown in Figures 9 and 10.

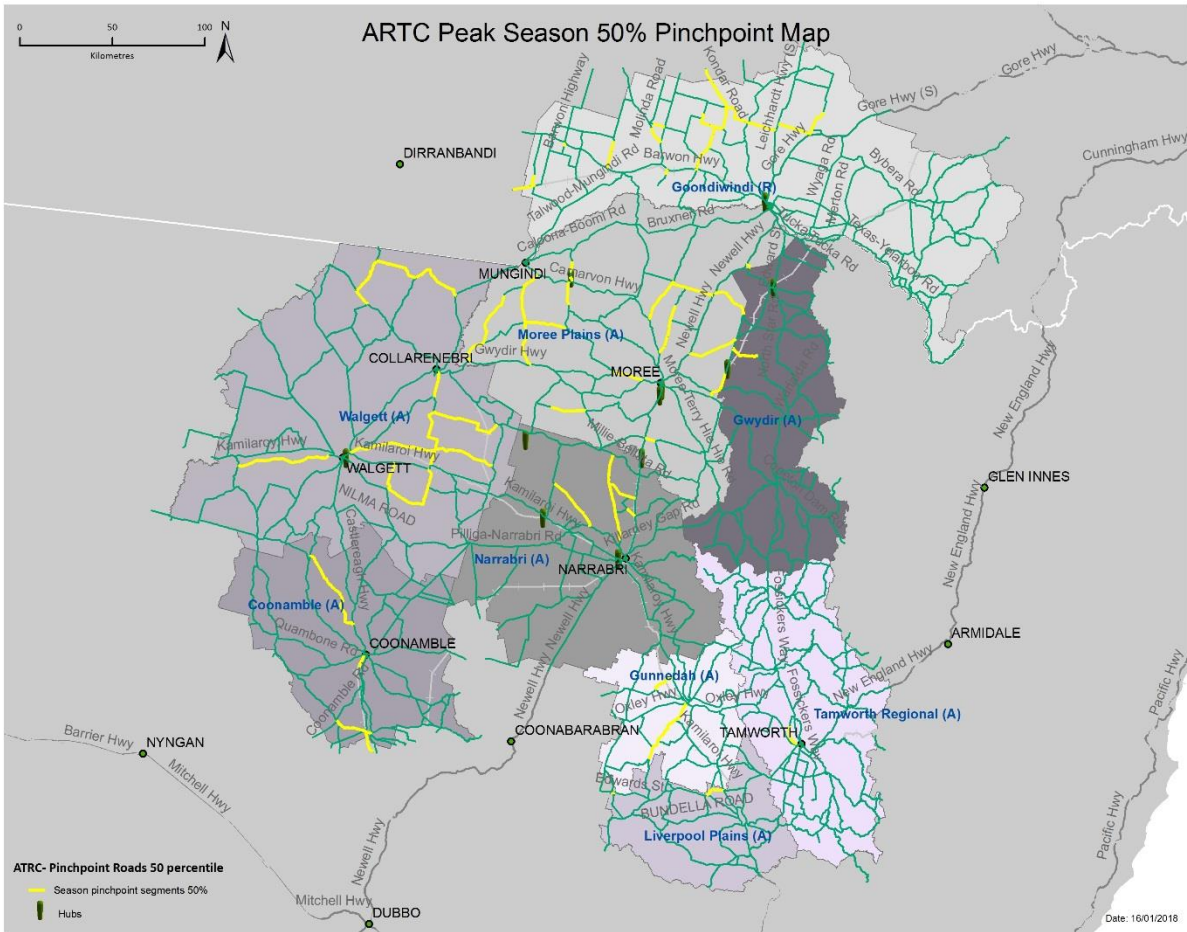


Figure 10 Map of pinch point roads for 50<sup>th</sup> percentile for peak season

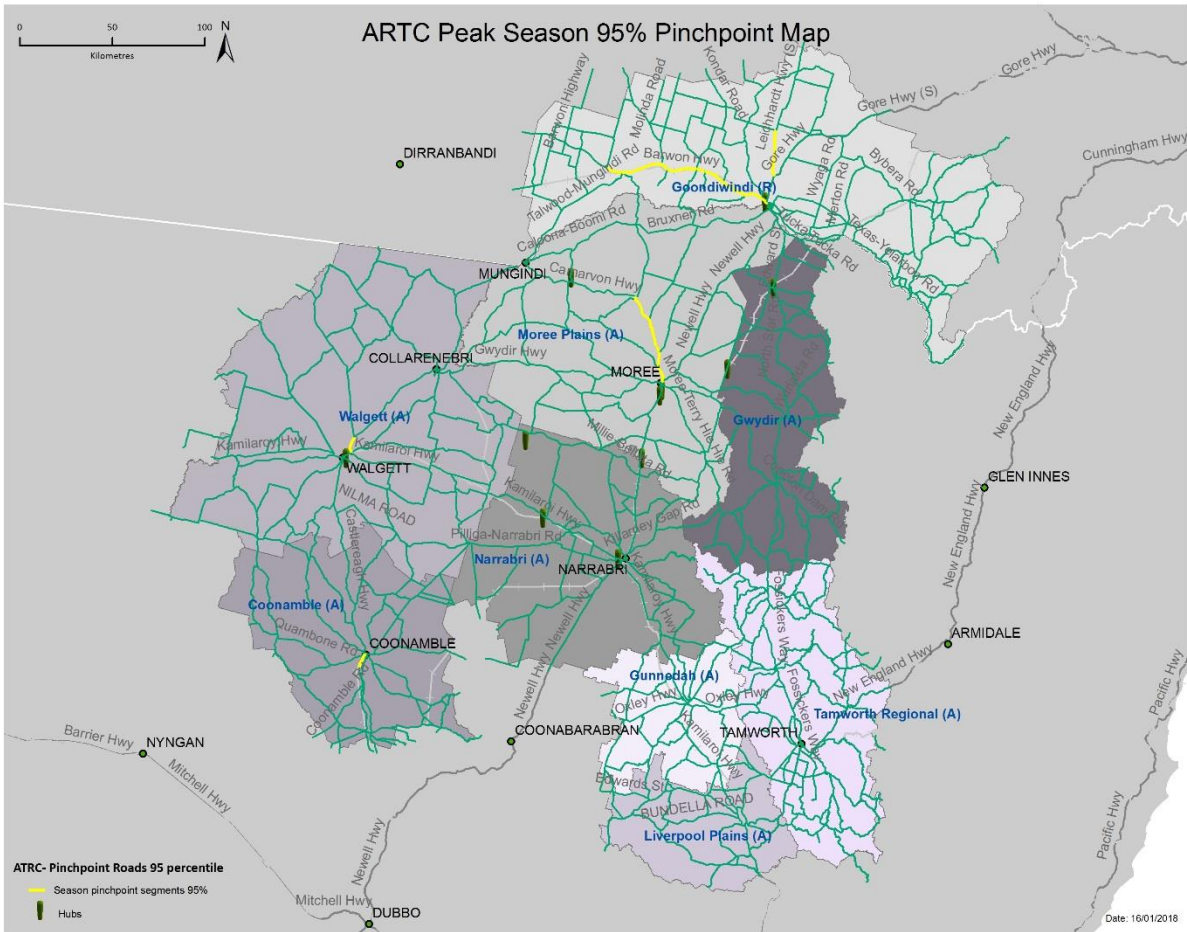


Figure 11 Map of pinch point roads for 95<sup>th</sup> percentile for peak season

## 4 Scenarios

### 4.1 Summary of transport costs

Table 5 shows the cost of transport for each storage facility upgrade as presented in Table 4. Each storage facility within Table 5 considered a separate scenario and run through TraNSIT separately. Thus the results for each storage facility in Table 5 are independent of one another. Table 6 shows the tonnes of grain transported from each storage facility (to mill, port, feedlot and stockfeed) according to the baseline and after the expansion. In Table 6, the effect on grain flows varies substantially for each storage facility expansion. For example, the additional grain with the expansion to Moree is evenly split whether or not transport is to the port or to domestic markets (e.g. feedlot). However, for North Star and Narrabri storage facilities, the additional grain is transported predominately to domestic markets rather than to the port. This is due to the close proximity of feedlots and to intensive livestock systems benefitting from additional grain with a shorter travel distance than alternative suppliers. For Walgett and Weemalah, the additional grain throughout is predominately transported to port. Since the grain demand for the domestic market is fixed, any additional grain in the broader region will be exported. In the storage expansions of Table 5 and 6 where additional grain predominately supplies domestic markets, other storage facilities will supply additional grain to ports. For example, whilst nearly all of the 121,000 tonne expansion supplies domestic markets, the same tonnage will be redistributed from domestic markets to ports elsewhere.

Comparing Table 5 scenarios to the baseline of Table 2, there is often a slight increase in transport cost (per tonne) of grain to the storage facility. This is due to the expansion allowing for grain to be sourced from further distances, and does not represent an increase in supply chain cost. There is a mixture of increased and decreased cost per tonne for road transport to mills or market (feedlot, stockfeed). In the case of increased cost per tonne, there is still a saving overall, since the expansion provides a closer source of grain for feedlots/stockfeed further away than in the baseline. For example, the large expansion to Milguy makes it a closer supplier to a broader range of feedlots and stockfeed manufacturers, more than offsetting the \$11 per tonne average increase in transport costs to these markets.

Rail costs per tonne are largely identical between the baseline and scenarios, which is expected since destinations ports are the same.

**Table 5 Modelled transport costs for grains transported in and out of each storage facility with the proposed expansion of Table 4.**

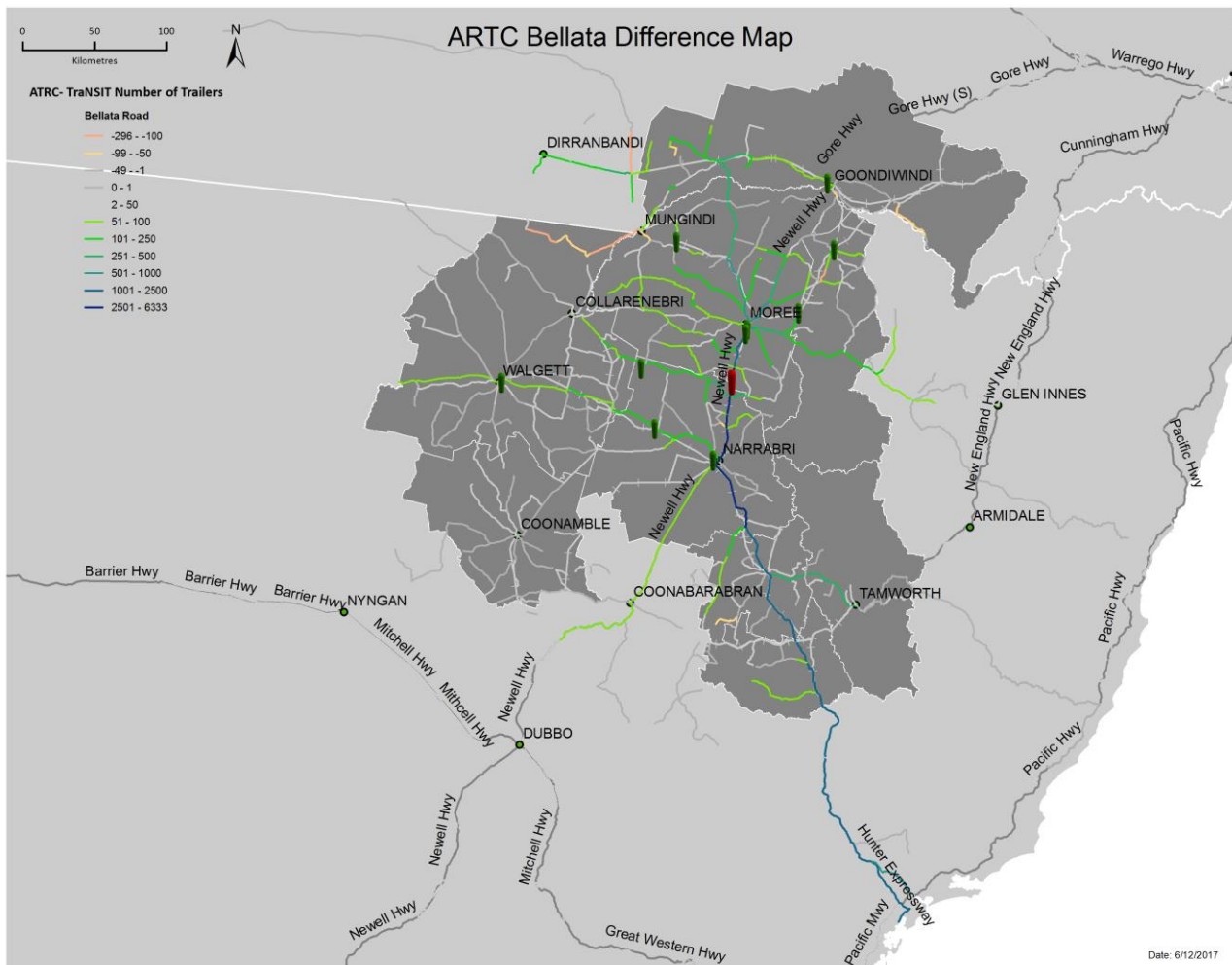
Storage facility		Road		Rail	
		Total cost (\$)	Cost per tonne (\$)	Total cost (\$)	Cost per tonne (\$) To port To mill
Moree	Farm to Hub	\$9,985,000	\$22.02		
	Hub to port, mill or market	\$9,984,000	\$44.97	\$6,885,000	\$38.36 \$23.46
Milguy	Farm to Hub	\$3,680,000	\$23.14		
	Hub to port, mill or market	\$7,721,000	\$52.88	\$99,000	\$24.97
Weemalah	Farm to Hub	\$2,483,000	\$23.64		
	Hub to port, mill or market	\$624,000	\$46.22	\$3,869,000	\$43.22 \$28.13
Goondiwindi	Farm to Hub	\$8,462,000	\$21.58		
	Hub to port, mill or market	\$10,983,000	\$44.28	\$5,334,000	\$43.47
North Star	Farm to Hub	\$4,902,000	\$22.80		
	Hub to port, mill or market	\$7,864,000	\$39.71	\$406,000	\$42.91 \$27.90
Bellata	Farm to Hub	\$7,058,000	\$22.05		
	Hub to port, mill or market	\$9,181,000	\$48.83	\$4,337,000	\$34.56 \$20.50
Narrabri	Farm to Hub	\$6,867,000	\$23.76		
	Hub to port, mill or market	\$12,111,000	\$48.63	\$1,236,000	\$32.03 \$34.68
Merah North	Farm to Hub	\$2,698,000	\$25.69		
	Hub to port, mill or market	\$5,594,000	\$54.84	\$71,000	\$34.07 \$19.85
Walgett	Farm to Hub	\$9,384,000	\$23.58		
	Hub to port, mill or market	\$104,000	\$23.22	\$15,704,000	\$40.62 \$26.04

**Table 6 Tonnes of grain transported from each grain storage**

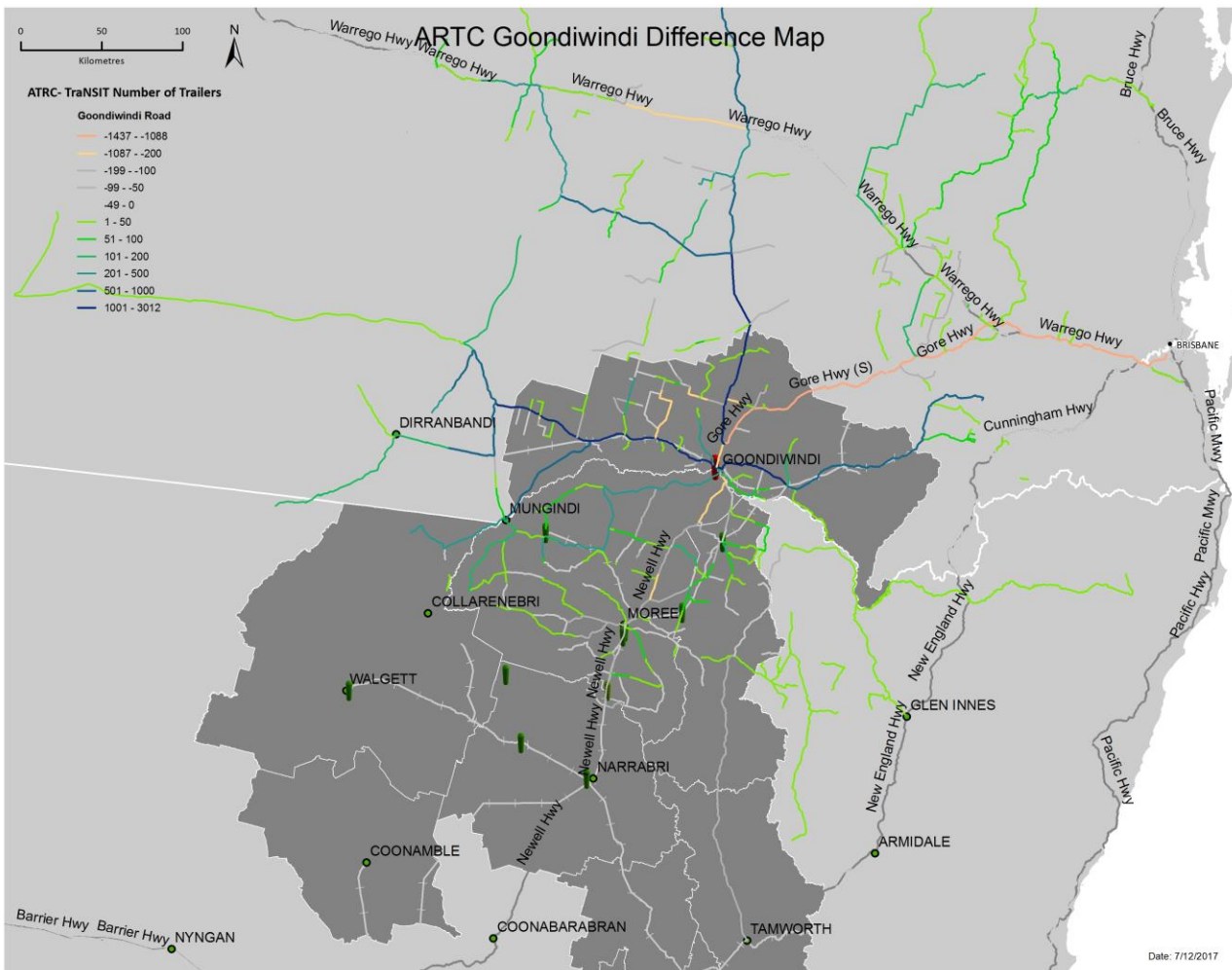
Storage facility		Road		Rail	
		Base tonnes	Scenario tonnes	Base tonnes	Scenario tonnes
Moree	Hub to port			151,881	175,126
	Hub to mill	21,190	21,630	6,854	6,854
	Hub to feedlot/stockfeed	180,312	202,299		
Milguy	Hub to port				
	Hub to mill	8,804	5,589	6,451	4,032
	Hub to feedlot/stockfeed	15,750	140,278		
Weemalah	Hub to port			21,469	87,951
	Hub to mill			6,451	2,822
	Hub to feedlot/stockfeed	14,298	13,539		
Goondiwindi	Hub to port			111,338	122,790
	Hub to mill	35,080	24,313		
	Hub to feedlot/stockfeed	170,032	207,124		
North Star	Hub to port			3,651	7,661
	Hub to mill	13,665	16,869	1,612	4,469
	Hub to feedlot/stockfeed	24,339	180,877		
Bellata	Hub to port			77,899	119,278
	Hub to mill	6,604	19,765	8,871	10,483
	Hub to feedlot/stockfeed	115,632	168,477		
Narrabri	Hub to port			1,134	4,134
	Hub to mill	6,004	7,136	18,746	31,861
	Hub to feedlot/stockfeed	37,804	242,078		
Merah	Hub to port			130	3,225
North	Hub to mill	6,832	3,584	5,645	205
	Hub to feedlot/stockfeed	37,534	98,611		
Walgett	Hub to port			260,743	383,746
	Hub to mill			8,467	4,435
	Hub to feedlot/stockfeed	1,488	4,512		

## 4.2 Summary of freight movements

Figures 11 and 12 show the change in road freight volumes resulting from the expansion of the Bellata and Goondiwindi storage facilities. In Figure 12, grain from the Goondiwindi expansion supplies feedlots in south east Queensland, whereas a large proportion of increased grain through Bellata supplies stock feed manufacturers towards the coast.



**Figure 12** Changes in freight volumes with the expansion of the Bellata storage facility



**Figure 13 Changes in freight volumes with the expansion of the Goondiwindi storage facility**

### 4.3 Road upgrade scenarios

Here, six different road corridors were upgraded to test the additional transport cost savings and complimentary benefits to transport of grain. The road segments were identified as freight upgrades in the Moree, Narrabri and Gwydir LGA’s. The selected four road upgrades for this report are only a small percentage of the possible road upgrade options that could lead to significant reductions in transport costs and complimentary benefits to rail loading points. For each road upgrade scenarios (Figure 14 and 15), only the benefits to grain transport are report, though there will be benefits to other agriculture and on-agriculture freight.

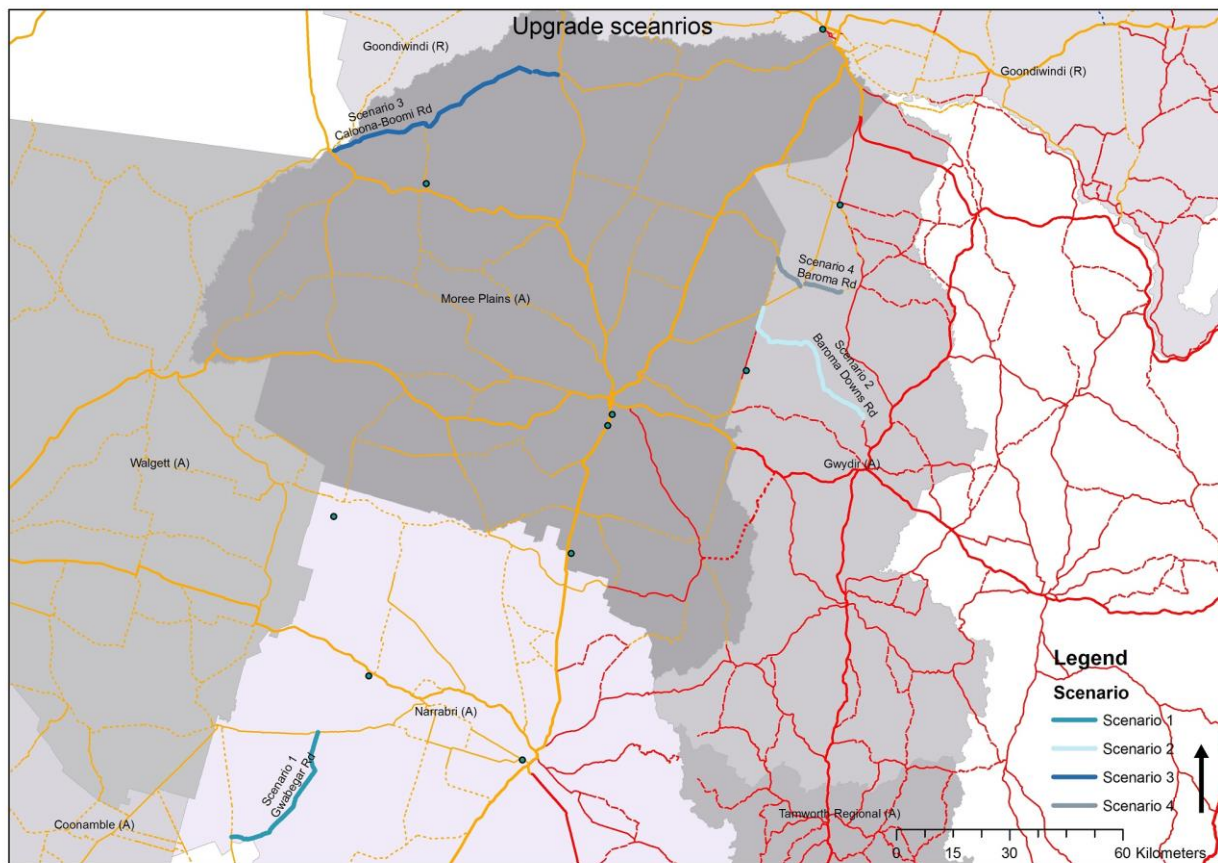


Figure 14 Locations of road segments upgraded under the four scenarios

### 4.3.1 Cypress Way (Gwabegar Road)– Narrabri LGA

This involved the sealing of 33.1km of road between Gwabegar and Pilliga, leading to increased average speed. Table 7 shows the road upgrade only produced transport cost savings for trips to grain storage facilities, with the largest saving per tonne across all of the road upgrade options. However, the low utilisation of the road segment led to the lowest total savings.

Table 7 Transport cost savings for Cypress Way upgrade

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	22	225	\$2.23	\$14,357
Feedlot/stockfeed	0	0	0	0
Flour mill	0	0	0	0
Total	22	225	\$2.23	\$14,357

### 4.3.2 Oregon Road (Baroma Downs)– Gwydir LGA

This involved the sealing of 37.5km segment of road to Gil Gil Creek Road, leading to an increased average speed and higher road rank. Despite the length of the road upgrade was slightly longer

than the Cypress Way scenario, the transport cost savings per tonne was considerably less. This is due to the road being B-Double access and fewer trips using the whole length of the road segment. However, due to the large number of vehicle trips utilising and benefitting from the road upgrade, the total savings were higher than the upgrade of Cypress way.

**Table 8 Transport cost savings for Oregon Road upgrade**

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	87	1717	\$0.84	\$39,830
Feedlot/stockfeed	21	423	\$0.43	\$4,944
Flour mill	9	742	\$1.59	\$31,124
<b>Total</b>	<b>117</b>	<b>2883</b>	<b>\$0.96</b>	<b>\$75,899</b>

### 4.3.3 Carrigan Road - Moree LGA

This involved the sealing of 52km of unsealed road between Boomi and Caloona, leading to increased average speed, higher road rank and fewer road closures. This was the large upgrade amongst the four scenarios, and led to large savings per tonne. The large number of vehicle trips (trailers benefitting) also meant it was the scenario with the largest transport cost savings.

**Table 9 Transport cost savings for Carrigan Road upgrade**

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	125	2776	\$1.28	\$100,853
Feedlot/stockfeed	20	402	\$2.49	\$28,372
Flour mill	0	0	0	0
<b>Total</b>	<b>145</b>	<b>3178</b>	<b>\$1.43</b>	<b>\$129,225</b>

### 4.3.4 Baroma Road – Gwydir LGA

This road upgraded involved the sealing of 14.75km segment of Baroma Road from Croppa Creek to Yallaroi, leading to an increased average speed and higher road rank. The Baroma road upgrade produced the largest total savings per km of road being sealed. This is due to the large vehicle utilisation and trailers benefitting.

**Table 10 Transport cost savings for Baroma Road upgrade**

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	131	2568	\$0.52	\$38,385
Feedlot/stockfeed	19	722	\$0.45	\$9,136
Flour mill	5	429	\$0.82	\$9,750
<b>Total</b>	<b>156</b>	<b>3719</b>	<b>\$0.54</b>	<b>\$57,272</b>

#### 4.3.5 Bald Hill Road – Narrabri LGA

This road upgraded involved the sealing and widening of 46 km of Bald Hills Road (Figure 15), leading to an increased average speed and higher road rank. The Bald Hill road upgrade produced \$58,361 total savings per year. This is due to the large vehicle utilisation and trailers benefitting.

**Table 11 Transport cost savings for Bald Hill Road upgrade**

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	80	8810	\$0.94	\$58,361
Feedlot/stockfeed	0	0	0	0
Flour mill	0	0	0	0
Total	80	8810	\$0.94	\$58,361

#### 4.3.6 Spring Plains Road – Narrabri LGA

This road upgraded involved 14 km of sealing and 53km of widening of the Spring Plains Road (Figure 15), leading to an increased average speed and higher road rank.

**Table 12 Transport cost savings for Spring Plains Road upgrade**

Destination	Routes	Trailers benefitting	Savings per tonne	Savings
Silo	101	2033	\$0.65	\$34272
Port	1	231	\$0.78	\$4895
Flour mill	0	0	0	0
Total	102	2264	\$0.62	\$39,618

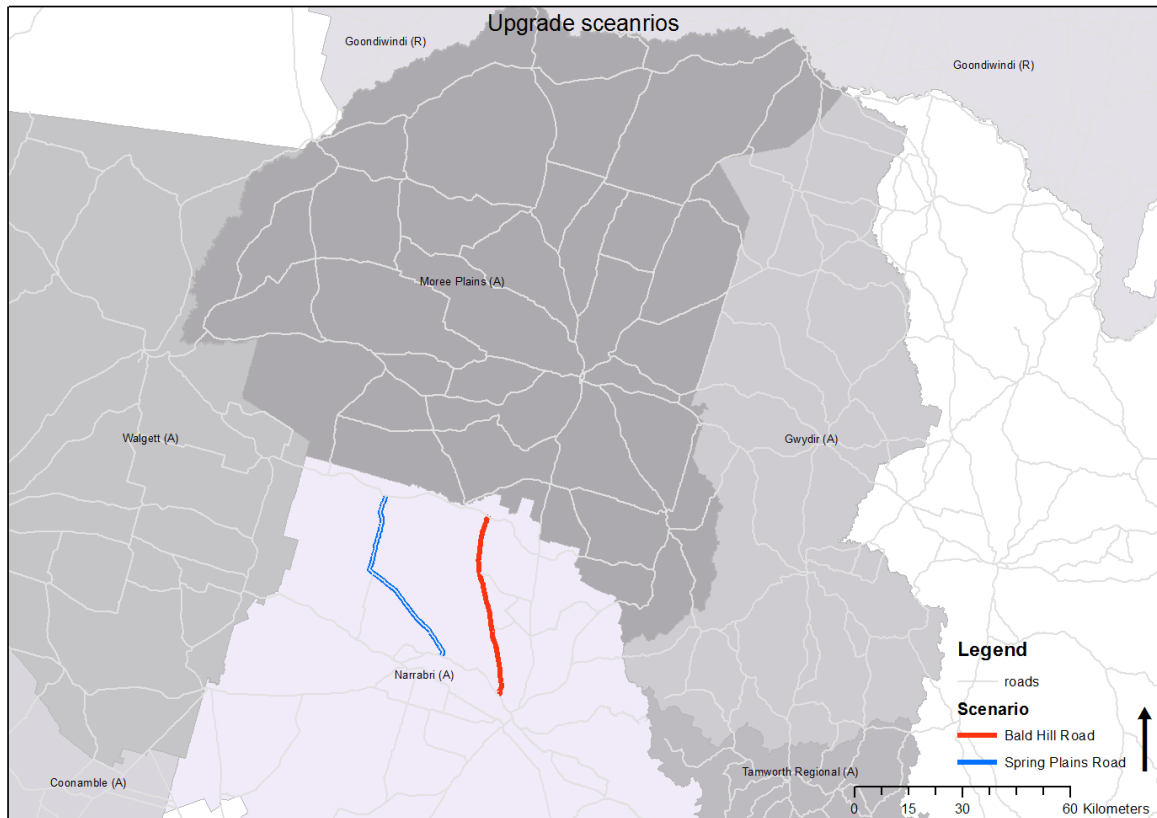


Figure 15 Location of the Bald Hill and Spring Plains road upgrade scenarios

#### 4.4 Rail network and rolling stock upgrades

For this scenario, several train configurations were tested, along with loading/unloading efficiency gains for the freight hub scenarios of Table 4. An overview of the train configurations is contained in Table 13. The wagon payload of Table 13 represents a theoretical payload given ideal loading equipment. We also tested likely wagon payload “scaled” for each TAL using historical data of wagon loads at storage facilities with the same TAL through to port. This historical payload is up to 15% less than the theoretical wagon payloads. The train configurations of Table 13 apply to all loading points along the ARTC network in NSW and Victoria, as well as the Walgett to Narrabri line. All other loading points were not considered in this analysis.

Coupled with the scenarios of Table 13, with likely and theoretical wagon payloads, there are improved load times at each storage facility. The baseline has an average load time of 11.5 hours, which is applied to all loading points. Two scenarios were tested for an improved load time: five hour load time for each of the scenario loading points of Table 4; and five hour load time for all ARTC load points.

Table 14 shows the transport cost for each grain train configuration of Table 13 and savings compared to the baseline. Wagon payload has a significant impact on transport cost savings. The “theoretical” and “scaled” wagon payloads represent the upper and lower bounds of the transport cost savings.

**Table 13 Summary of train configurations and theoretical payload**

Train Type	TAL	Loco Number	Wagon Number	Wagon Payload	Train Payload	Train Length
Base	current	2	42	Per TAL		
Bulk Grain (Type 1)	23	2	48	68	3264	860
Bulk Grain (Type 2)	23	3	74	68	5032	1324
Bulk Grain (Type 3)	25	3	60	76	4560	1086
Bulk Grain (Type 4)	25	3	74	76	5624	1324
IM Train (Type 1)- Cotton	25	3	38	52	1976	1282
IM Train (Type 2)-Grain	25	3	76	76	5776	1282

**Table 14 Summary of transport costs and savings across the ARTC network for the train configurations applied to the ARTC network (plus Walgett to Narrabri).**

Train type	Wagon payload (t)	Load time	Rail transport cost (\$)	Cost savings vs base (\$)	Cost savings per tonne (\$)
Base	Per TAL	11.5 hours	\$104,653,402		
Bulk Grain 1	68 scaled*	11.5 hrs	\$97,984,039	\$6,669,363	\$2.11
		5 hrs / 11hrs <sup>#</sup>	\$97,375,770	\$7,277,632	\$2.30
		5 hrs	\$94,491,608	\$10,161,795	\$3.21
	68	11.5 hrs	\$87,305,352	\$17,348,050	\$5.48
		5 hrs / 11hrs <sup>#</sup>	\$86,783,136	\$17,870,266	\$5.65
		5 hrs	\$84,279,550	\$20,373,852	\$6.44
Bulk Grain 2	68 scaled*	11.5 hrs	\$94,491,608	\$10,161,795	\$3.21
		5 hrs / 11hrs <sup>#</sup>	\$94,069,792	\$10,583,610	\$3.34
		5 hrs	\$91,950,549	\$12,702,853	\$4.01
	68	11.5 hrs	\$82,081,353	\$22,572,049	\$7.13
		5 hrs / 11hrs <sup>#</sup>	\$81,742,618	\$22,910,784	\$7.24
		5 hrs	\$80,118,670	\$24,534,732	\$7.75
Bulk Grain 3	76 scaled*	11.5 hrs	\$97,433,694	\$7,219,708	\$2.28
		5 hrs / 11hrs <sup>#</sup>	\$96,960,218	\$7,693,184	\$2.43
		5 hrs	\$94,690,300	\$9,963,102	\$3.15
	76	11.5 hrs	\$80,801,045	\$23,852,357	\$7.54
		5 hrs / 11hrs <sup>#</sup>	\$80,427,248	\$24,226,154	\$7.65
		5 hrs	\$78,635,208	\$26,018,194	\$8.22
Bulk Grain 4	76 scaled*	11.5 hrs	\$90,568,411	\$14,084,991	\$4.45
		5 hrs / 11hrs <sup>#</sup>	\$90,043,146	\$14,610,256	\$4.62
		5 hrs	\$87,628,262	\$17,025,140	\$5.38
	76	11.5 hrs	\$75,381,037	\$29,272,365	\$9.25
		5 hrs / 11hrs <sup>#</sup>	\$75,077,958	\$29,575,444	\$9.34
		5 hrs	\$73,624,952	\$31,028,450	\$9.80
IM Train 2	76 scaled*	11.5 hrs	\$89,794,099	\$14,859,303	\$4.69
		5 hrs / 11hrs <sup>#</sup>	\$89,420,302	\$15,233,100	\$4.81
		5 hrs	\$87,628,262	\$17,025,140	\$5.38
	76	11.5 hrs	\$74,769,794	\$29,883,608	\$9.44
		5 hrs / 11hrs <sup>#</sup>	\$74,474,691	\$30,178,711	\$9.53
		5 hrs	\$73,059,922	\$31,593,480	\$9.98

\*Wagon theoretical payload scaled back to likely loads - based on historical data of average loads for the loading points. Average loads up to 15% less than wagon capacities.

<sup>#</sup>5 hours for load points for storage facilities of Table 4 , 11.5 hours for the rest.

**Table 15 Transport cost savings for storage facilities**

Train type	Wagon payload (t)	Load time	Cost Savings per tonne(\$)					
			Bellata	Milguy	Moree	Narrabri	North star	Walgett
Bulk Grain 1	68 scaled*	11.5 hrs	\$1.64	\$1.28	\$2.88	\$1.58	\$2.92	\$1.98
		5 hrs	\$2.73	\$2.40	\$4.00	\$2.66	\$4.04	\$3.10
	68	11.5 hrs	\$4.62	\$4.25	\$6.98	\$4.45	\$7.08	\$6.41
		5 hrs	\$5.58	\$5.21	\$7.94	\$5.40	\$8.04	\$7.37
Bulk Grain 2	68 scaled*	11.5 hrs	\$2.73	\$2.40	\$4.00	\$2.66	\$4.04	\$3.10
		5 hrs	\$3.56	\$2.84	\$4.98	\$3.43	\$5.05	\$4.24
	68	11.5 hrs	\$6.31	\$5.58	\$8.78	\$6.08	\$8.90	\$8.34
		5 hrs	\$6.93	\$6.20	\$9.40	\$6.70	\$9.52	\$8.96
Bulk Grain 3	76 scaled*	11.5 hrs	\$1.33	\$1.79	\$3.45	\$1.29	\$3.49	\$2.56
		5 hrs	\$2.19	\$2.66	\$4.32	\$2.15	\$4.36	\$3.43
	76	11.5 hrs	\$6.72	\$5.94	\$9.21	\$6.48	\$9.33	\$8.79
		5 hrs	\$7.41	\$6.62	\$9.89	\$7.17	\$10.01	\$9.47
Bulk Grain 4	76 scaled*	11.5 hrs	\$3.56	\$3.46	\$5.84	\$3.43	\$5.92	\$5.17
		5 hrs	\$4.50	\$4.33	\$6.80	\$4.35	\$6.88	\$6.15
	76	11.5 hrs	\$8.49	\$7.26	\$11.10	\$8.17	\$11.25	\$10.84
		5 hrs	\$9.04	\$7.81	\$11.65	\$8.73	\$11.80	\$11.40
IM Train 2	76 scaled*	11.5 hrs	\$3.81	\$3.65	\$6.11	\$3.67	\$6.20	\$5.46
		5 hrs	\$4.50	\$4.33	\$6.80	\$4.35	\$6.88	\$6.15
	76	11.5 hrs	\$8.69	\$7.40	\$11.31	\$8.36	\$11.46	\$11.08
		5 hrs	\$9.23	\$7.94	\$11.85	\$8.90	\$12.00	\$11.62

For cotton, the baseline cost of rail transport is \$2.75 million per year or \$74.53/tonne, and reduces to \$1.84 million per year or \$49.68/tonne under the IM (Type 1) train configuration. These savings do not account for the additional capital and maintenance costs of the new three TEU capacity cotton wagons, where each TEU holds 13.5 tonnes of cotton..

## 4.5 Impact of Site Closures on Transport Costs

This scenario estimates the additional costs of transport between the farm and grain silos, in the event of consolidating storage facilities in some locations. In this example two sites are closed with grain transported to an upgraded facility , increasing the throughput at the single site to approximately 200kt. Also considered is the change in transport cost from the grain silo to the port, feedlots and flour mills.

In Table 16, the closure of Site leads to a \$1.40/t increase in transport costs (farm to silo) by redirecting the grain to Site C. However, those increased costs are offset by reduced road transport costs between Site C and the feedlots and flour mills. By closing Site B silo and redirecting grain to Site C, there is a \$2.75/t increase in transport costs from farm to silo. There is also a slight increase in grain transport costs from the silo to domestic markets (mostly feedlot). The additional road costs between the Site C silo and the domestic market would likely be reduced through adjustments in which silos supply each feedlot, stockfeed manufacturer and flour mill. For rail, there is about a \$1/t saving in transport to flour mills, and up to \$1.28/t saving to the port when transported from Site C.

Table 17 summarises the transport costs for supply chain (farm to silo by road and silo to port by rail) for the baseline (with Site A and Site B) and the Site C scenarios. There is an increased total cost of \$0.92, up from \$67.60 if Site A is closed and Site C used instead. For the closure of Site A, there is a total increased supply chain cost (farm to silo to port) of \$1.47 if Site C is used instead. These amounts represent upper end cost increases, since some grain may be transported to other sites which may be closer than of Site C due to respective drawing arcs. Improvements to the loading time at Site C (five hours down from 11.5 hours), coupled with the bulk grain configurations of Table 11, more than compensate for these additional costs, with savings up to \$3.41 under the Bulk Grain 4 scenario.

**Table 16 Modelled transport costs (\$/t) for grains transported for existing Site A and Site B silos compared to redirected to Site C.**

Storage facility		Road		Rail			
		Base	Site C	Base To port	To mill	Site C To port	To mill
Site A	Farm to Hub	\$26.37	\$27.77				
	Hub to port, mill or market	\$43.13	\$40.68	\$41.23	\$25.29	\$40.75	\$24.97
Site B	Farm to Hub	\$19.89	\$22.64				
	Hub to port, mill or market	\$30.35	\$32.47	\$42.03	\$26.02	\$40.75	\$24.97

**Table 17 Modelled transport costs (\$/t) and savings between farm and port**

Storage facility		Base	Site C	Site C with Bulk Grain 1 (11.5 hr load)	Site C with Bulk Grain 2 (11.5 hr load)	Site C with Bulk Grain 2 (5 hr load)	Site C with Bulk Grain 4 (5 hr load)
		Site A	Farm to Hub	\$26.37	\$27.77	\$27.77	\$27.77
	Hub to port	\$41.23	\$40.75	\$39.47	\$38.35	\$37.91	\$36.42
	Total	\$67.60	\$68.52	\$67.24	\$66.12	\$65.68	\$64.19
Site B	Farm to Hub	\$19.89	\$22.64	\$22.64	\$22.64	\$22.64	\$22.64
	Hub to port	\$42.03	\$40.75	\$39.47	\$38.35	\$37.91	\$36.42
		\$61.92	\$63.39	\$62.11	\$60.99	\$60.55	\$59.06

## References

Higgins AJ, McFallan S, McKeown A, Bruce C, Marinoni O, Chilcott C, Stone P, Laredo L, Beaty M. (2017). TraNSIT: Unlocking options for efficient logistics infrastructure in Australian agriculture. CSIRO, Australia.

Higgins AJ, McFallan S, Laredo L, Prestwidge D. (2015). Cost of transport infrastructure and regulatory constraints in Australian cattle supply chains. CSIRO report for Meat and Livestock Association. MLA Project NO G.POL.1405

## Appendix A- Overview of TraNSIT

TraNSIT is a modularised tool (Figure 16) where data for each agriculture sector is an input to the core engine, along with the infrastructure or regulatory scenarios to test. TraNSIT is programmed in Python ([www.python.org](http://www.python.org)) and uses the ESRI ArcGIS network analyst capability while accommodating multiple features about the road network and individual segments. Road network data are critical and roads ranked as primary, secondary and minor (including unsealed) roads are included. The road layer, represented in Figure 17, was constructed using shape files defining location, ranking, access restrictions and other road information (breakdown pads, biosecurity restrictions, rest stops) from several sources. Road layer characteristics were supplied by Geosciences Australia ([www.ga.gov.au](http://www.ga.gov.au)), each state government's roads department, various regional councils and the National Heavy Vehicle Regulator (NHVR) – [www.nhvr.gov.au](http://www.nhvr.gov.au). The NHVR provided information on access limitations for different types of heavy vehicles across the road network. The roads were classed as primary, secondary and minor (Figure 17), with these roads further broken into segments with attributes containing surface type, width, speed limit and any special limits (e.g. one-way bridges). These data were collected from the transport departments of each state/territory in mainland Australia. All of these attributes affect average speed and transport cost per kilometre. The road layer required enhancements (e.g. creating connections, correcting locations of some roads) to provide a fully routable road layer.

The road network has been updated (particularly for southern Australia) to accommodate minor roads linking farms to storage facilities and processors. Figure 17 and Figure 188 shows the latest version of the road layer used in TraNSIT. The layer also contains additional features including average speeds (by vehicle type), road conditions (sealed, narrow sealed, unsealed), and other features (decoupling locations, bridge limits, tick lines) that impact travel costs and vehicle routes.

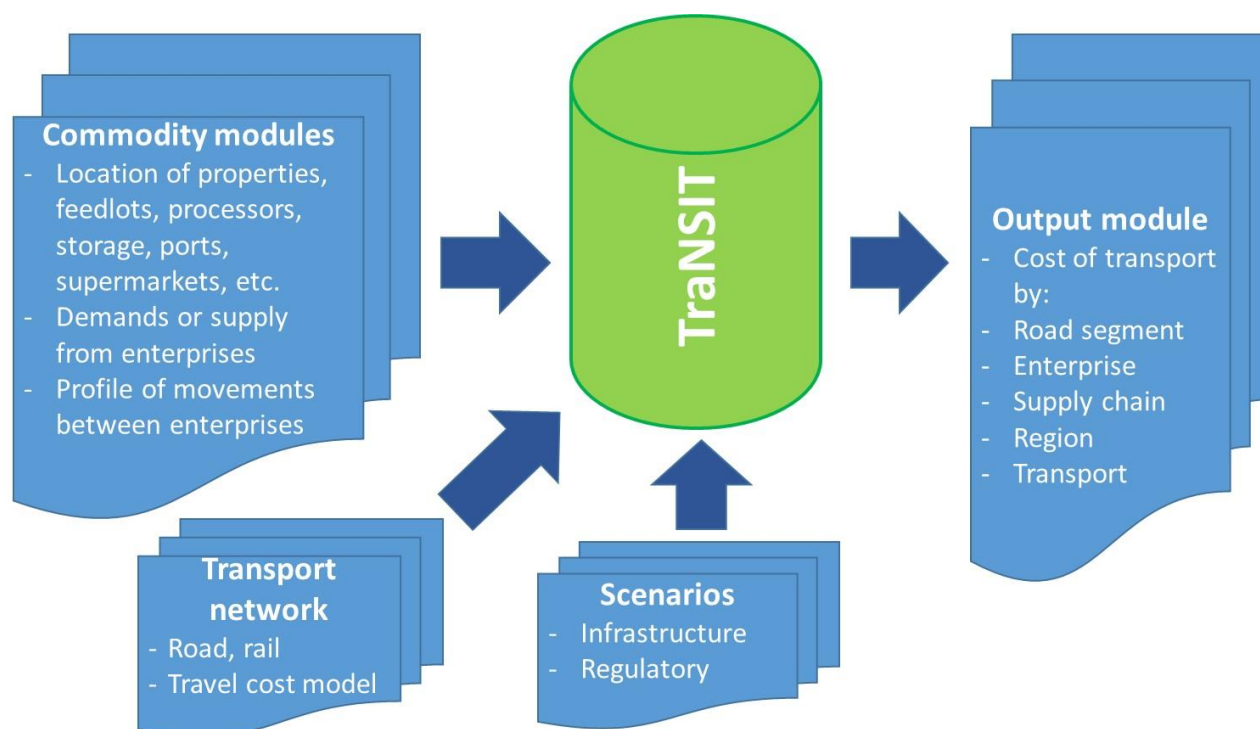


Figure 16 Components of TraNSIT

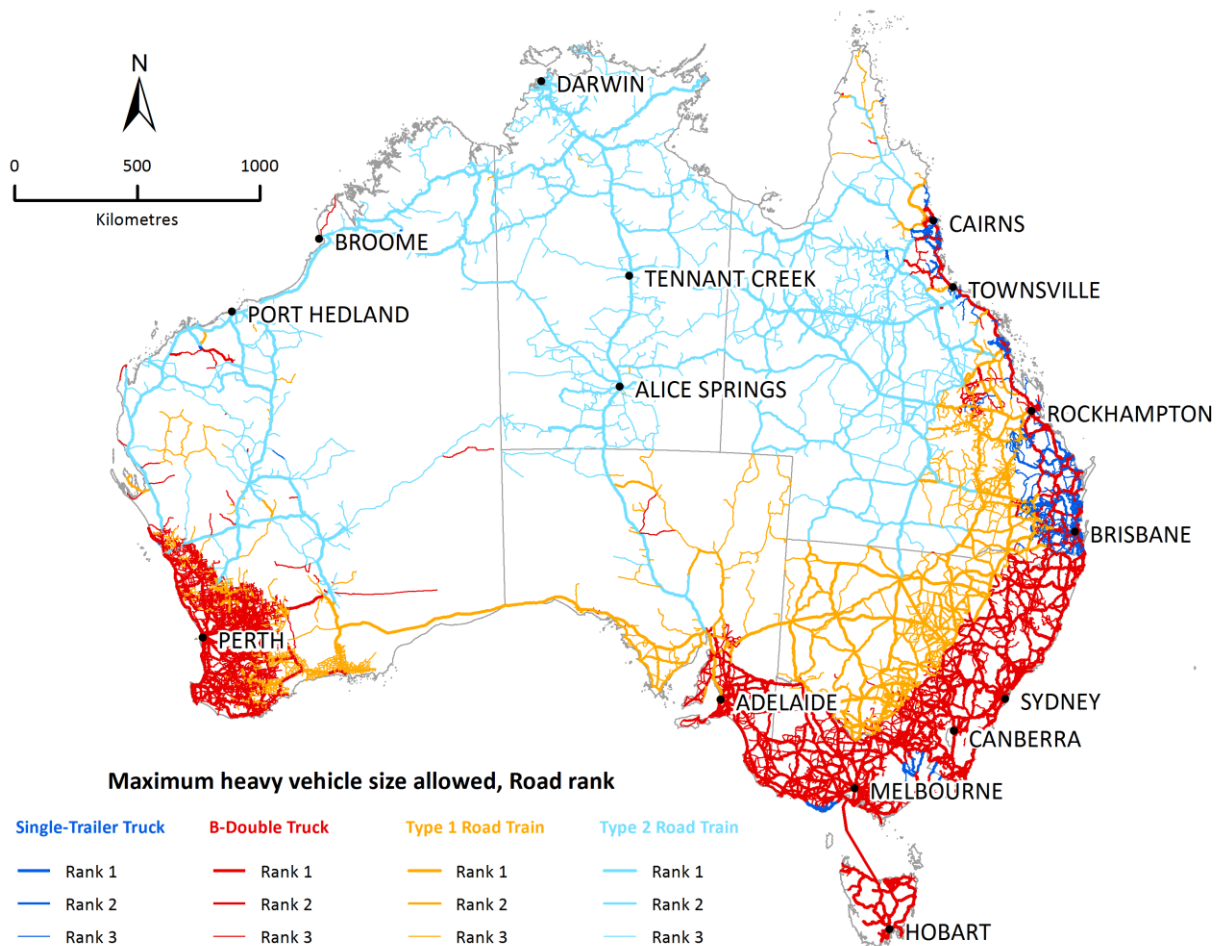
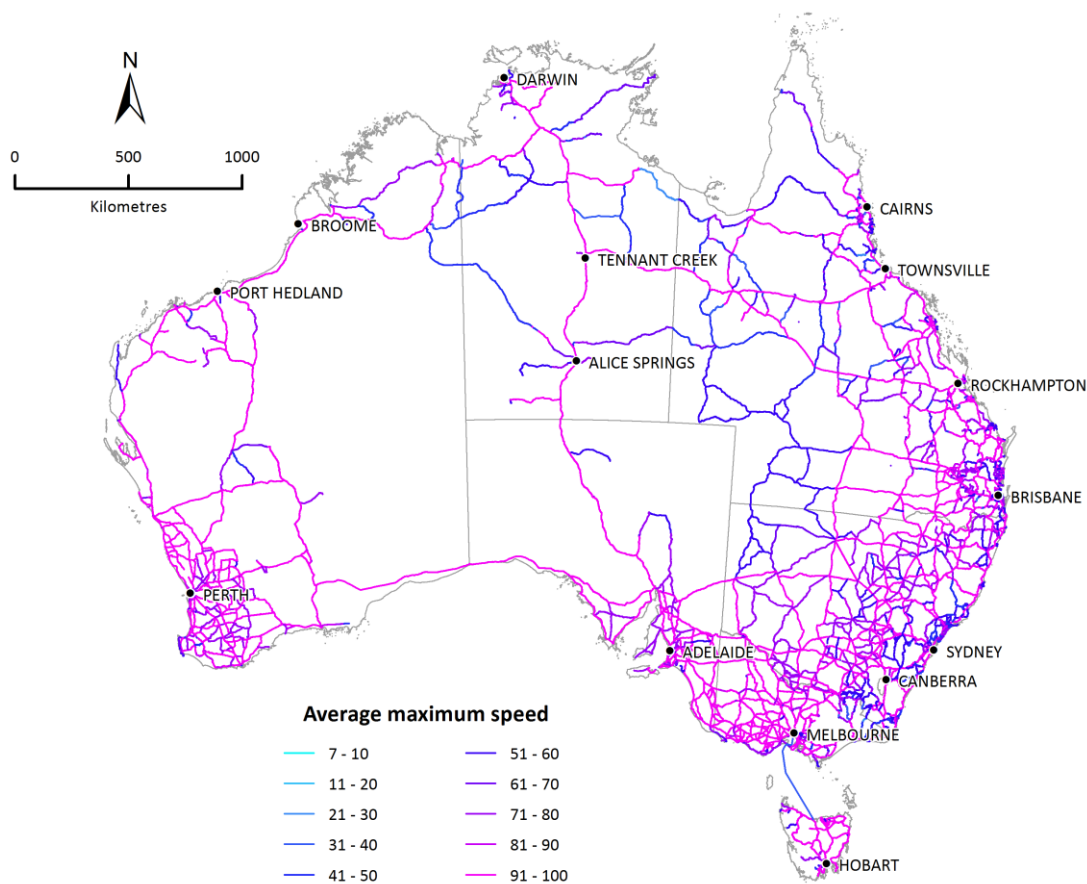


Figure 17 Current road layer used in TransIT showing road rankings and heavy vehicle access. A denser (Rank 3) road layer has been added at some locations, when required for some case studies



**Figure 18 Average maximum speed across the road network used in TraNSIT (minor Rank 3 roads not shown)**

TraNSIT uses a ground-up costing model for both road and rail. For road, it is based on the Freight Metrics ([www.freightmetrics.com.au](http://www.freightmetrics.com.au)) tool, and additional vehicle types (e.g. refrigerated, heavy rigid) have been incorporated within TraNSIT to accommodate vehicles used for different types of agriculture and post processing supply chains. A snapshot of the transport costs for different speeds and vehicles is contained in Table 18. The costing model has been enhanced for different types of unsealed roads, accommodating additional maintenance costs for vehicles. Greenhouse Gas emissions are also calculated using information on heavy vehicle fuel usage published by the Australian Trucking Association (ATA 2016) and emissions factors for different fuel combustion published in the National Greenhouse Accounts Factors (DEE 2016).

**Table 18. Overview of the vehicle transport costs**

PBS Scheme	Modelled cost (\$/km) per travel speed			Additional maintenance costs (\$/km)		
	100 km/h	60 km/h	20km/h	Good Unsealed	Poor Unsealed	Idle cost (\$/hr)
Level 1 (Semitrailer)	1.91	2.58	6.11	0.09	0.26	119
Level 2A (B-Double)	2.35	3.13	7.36	0.13	0.39	141
Level 3A (Type 1)	2.71	3.54	6.81	0.16	0.49	169
Level 4A (Type 2)	3.43	4.36	8.22	0.24	0.72	177

**Table 19. List of vehicle combinations that can be selected, depending on road access at origin**

TraNSIT Cost Model	Road Access Class – PBS Level			
	4A	3A	2A	1
Mod 1	4A	3A	1	1
Mod 2	4A	2A	2A	1
Mod 3	3A	3A	1	1
Mod 4	2A	2A	2A	1
Mod 5	1	1	1	1
Cap Tonnes <sup>^</sup>	84	56	42	28
Length (m)	53.5	36.5	26	19

<sup>^</sup> Depends on bulk density and axel load limits

TraNSIT simulates the number of vehicle trips per month moved between origin and destination enterprises. The goal of the TraNSIT module is to optimise the transport route and vehicle selection along the road/rail network for each of these trips from origin to destination, and then calculate the cumulative impacts at the enterprise or regional scale while evaluating against constraints on the number of vehicle trips on each route. To determine the optimal route, the analysis takes into account parameters such as costs, vehicle access, vehicle types and hierarchical value of the road segments. The least cost vehicle combination selected depends on heavy vehicle access restrictions throughout the journey from origin to destination. These restrictions define where road trains can decouple and influence the cost of operating larger versus smaller vehicle combinations for each part of the journey. For example, if the first 50km of the journey is PBS Level 4A vehicle access, and the last 800km is B-Double vehicle access, the least cost option would be to use a PBS Level 2A for the entire journey, due to the high cost of decoupling after 50km.

Table 18 shows the list of models for vehicle selection for a trip between an origin and destination. TraNSIT will select the least cost model depending on the vehicle access limitations between origin and destination and volume transported. Models 1 to 2 apply to trips where that allow a PBS Level 4A road train for at least part of the journey, but will accept smaller vehicles. Model 1 is typical for triple road trains that would normally decouple into PBS Level 3A double road trains or semitrailers for roads that are limited to smaller vehicles. Other vehicle types (e.g. BAB Quads, AB triples, A-Doubles) can readily be added. Model 3 are for trips where the maximum vehicle is a PBS Level 3A for any part of the journey. The vehicle selected may also affect the optimal route taken. For example, the use of a semitrailer vehicle from the origin could take the shortest travel time path and would not need to decouple. Commencing travel from the origin in a PBS Level 3A or 4A vehicle may take a longer travel time path to increase the proportion of the trip in the higher performance

vehicle before decoupling into smaller vehicles, to minimise costs. It is essential for all these parameters to link together logically, to allow proper solving of optimal routes.

Since a property is not always geographically attached to a road in the road network, a trip from an origin to destination (O-D) is modelled to travel from the closest road segment to the origin, and finish at the closest point on a road segment to the destination point. This process is repeated for all routes, always searching for the minimum cost route (including penalty costs), and selecting it as the optimal route.

Figure 19 represents a process diagram of TraNSIT. The first processing stage of TraNSIT is to construct a set of vehicle and train trips between enterprises across the supply chains. Once the set of movements have been produced, TraNSIT finds the optimal route (based on transport cost) and selection of vehicle types, for each Origin-Destination (O-D) pair input. Optimal road sections travelled for each O-D pair are saved. These road sections can be constrained by access restrictions such as vehicle size/load limit which will determine the route final set of route segments. The optimal route selected may not necessarily be the actual route taken by the driver in the existing network but rather the route that would be taken should the driver be seeking a least travel cost option. Once the optimal set of segments for all O-D pairs are saved, Python scripts calculate the cost of transport and number of vehicles for a given resource flow between each O-D pair. These are then aggregated over all O-D pairs to provide a total cost of transport for the scenario.

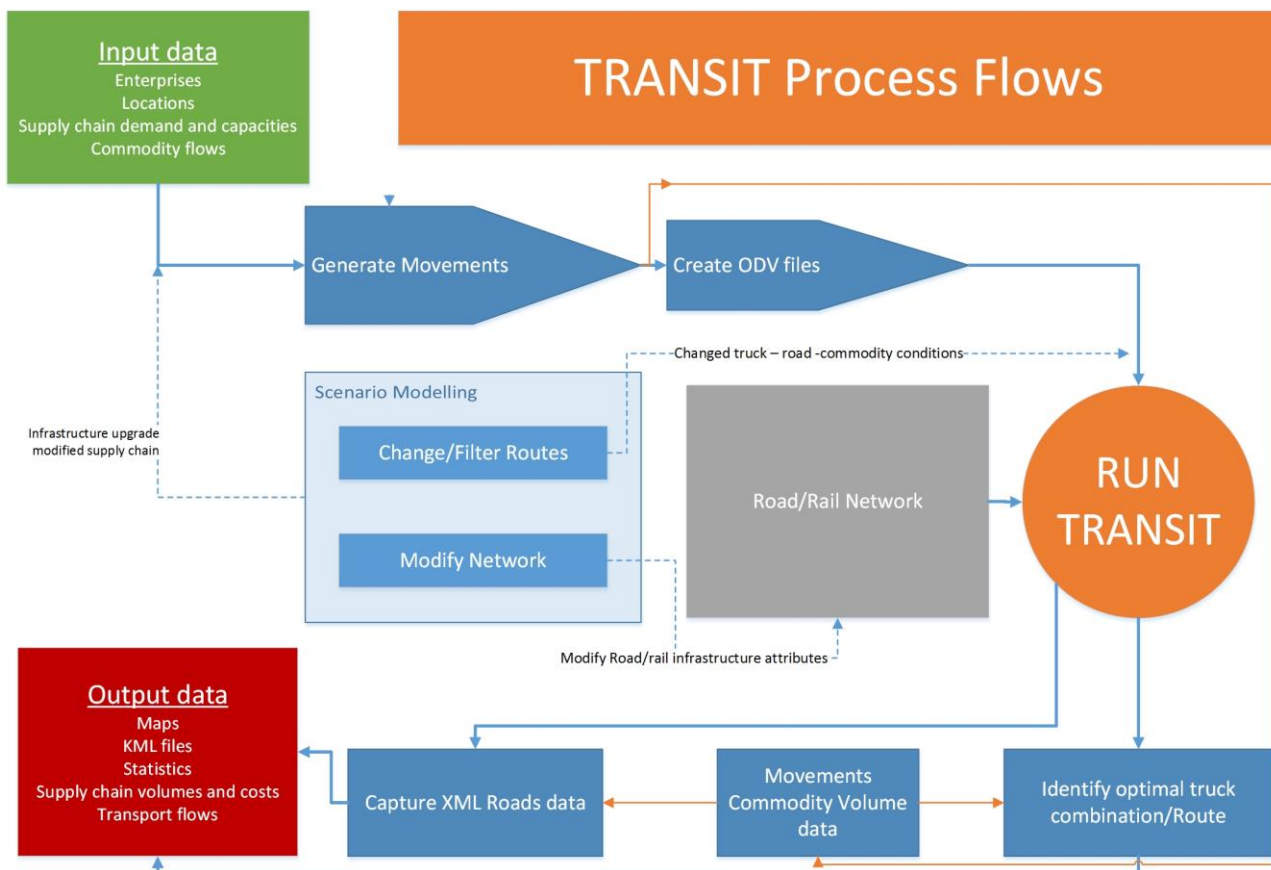


Figure 19 Process diagram of TraNSIT, comprising the stages from set up to running of each model component

## Appendix B Identified roads for pinch point analysis at 50<sup>th</sup> percentile

Below is a table of road segments by LGA where the segment carries grain freight greater than 700 trailers annually and the roads are not identified in the road network as Rank 1 roads and classified as narrow.

LGA	Road ID	Surface	Access PBS Level	Total length of roads (km)	Number of trailers per year total
Coonamble (A)	51030	UNSEALED	3A	5.1	993
	52587	UNSEALED	3A	44.0	1,020
	48349	SEALED	3A	14.9	1,097
	48365	SEALED	3A	0.3	1,112
	48453	SEALED	3A	2.6	1,112
	48183	SEALED	3A	0.1	1,260
	48190	SEALED	3A	0.4	1,260
	48182	SEALED	3A	3.1	6,458
	50146	SEALED	3A	6.9	18,706
	Gilgandra (A)	48181	UNSEALED	3A	12.2
Goondiwindi (R) - Waggamba	Barwon Highway	SEALED	3A	42.1	4,052
		UNSEALED	3A	18.3	1,402
	Bungunya Alton Road	UNSEALED	3A	6.6	887
	Goodar Road	SEALED	3A	0.0	966
	Gore Highway	SEALED	3A	16.1	2,984
	Kondar Road	SEALED	3A	12.1	1,048
		UNSEALED	3A	6.8	836
	Leichhardt Highway	SEALED	3A	52.0	4,084
	Meandarra Talwood Rd	UNSEALED	3A	5.5	794
	Minnel Road	UNSEALED	3A	13.4	1,496
	South Daymar Road	SEALED	3A	12.0	800
Gunnedah (A)	47447	UNSEALED	2A	21.0	767
	49471	SEALED	2A	0.9	828
	48978	SEALED	2A	0.8	864
	49011	SEALED	2A	0.7	864
	49181	SEALED	2A	16.2	881
	48440	SEALED	2A	15.6	990
	48503	SEALED	2A	2.2	993
	48573	SEALED	2A	1.6	993
	48793	SEALED	2A	4.8	993
	48881	SEALED	2A	3.0	993
	47959	SEALED	2A	4.2	999

	47818	SEALED	2A	7.4	1,036
	49483	SEALED	2A	12.5	1,387
Gwydir (A)	56522	SEALED	3A	6.7	961
	55965	UNSEALED	3A	16.0	1,499
	55649	SEALED	3A	9.3	1,824
	56097	SEALED	3A	24.7	4,881
Liverpool Plains (A)	46505	SEALED	2A	1.2	1,951
	46600	SEALED	2A	4.0	3,250
	46601	SEALED	2A	7.0	3,269
Moree Plains (A)	55588	SEALED	3A	3.0	708
	55789	SEALED	3A	5.7	710
	56259	SEALED	3A	3.3	719
	55990	SEALED	3A	4.6	720
	56128	SEALED	3A	5.4	720
	56865	UNSEALED	3A	7.5	721
	56166	SEALED	3A	1.7	726
	55720	SEALED	3A	4.2	740
	55608	SEALED	3A	1.3	757
	55657	SEALED	3A	8.3	802
	57092	UNSEALED	3A	3.2	845
	56532	UNSEALED	3A	1.3	852
	55228	SEALED	3A	19.1	879
	56317	UNSEALED	3A	23.1	890
	56864	UNSEALED	3A	6.0	894
	56809	UNSEALED	3A	9.6	898
	56880	UNSEALED	3A	3.2	898
	56658	UNSEALED	3A	30.1	943
	56428	SEALED	3A	3.9	1,040
	56468	UNSEALED	3A	1.6	1,040
	56561	UNSEALED	3A	5.1	1,061
	55662	SEALED	3A	16.8	1,119
	56729	UNSEALED	3A	7.0	1,132
	54800	SEALED	3A	6.5	1,135
	56663	SEALED	3A	6.6	1,192
	56710	SEALED	3A	1.4	1,201
	56742	SEALED	3A	6.4	1,297
	56730	SEALED	3A	3.9	1,331
	56808	UNSEALED	3A	9.9	1,335
	56687	SEALED	3A	1.9	1,351
	56697	SEALED	3A	0.1	1,438
	56827	SEALED	3A	4.0	1,479
	54819	SEALED	3A	5.4	1,545
	54821	SEALED	3A	0.2	1,545
	56165	UNSEALED	3A	1.5	1,763
	56315	UNSEALED	3A	6.1	1,798
	56695	SEALED	3A	15.7	1,830
	55775	UNSEALED	3A	1.6	1,840
	55927	SEALED	3A	6.6	1,840

	56131	UNSEALED	3A	9.1	1,854
	56877	SEALED	3A	3.8	1,928
	55399	SEALED	3A	0.5	1,989
	55428	SEALED	3A	4.5	1,989
	55382	SEALED	3A	2.0	2,009
	55398	SEALED	3A	0.4	2,009
	56979	SEALED	3A	6.0	2,158
	56906	SEALED	3A	0.9	2,599
	56950	SEALED	3A	2.1	2,708
	55914	SEALED	3A	2.8	4,565
Narrabri (A)	54751	UNSEALED	3A	14.2	713
	54131	UNSEALED	3A	16.5	719
	53588	UNSEALED	3A	14.9	722
	54132	UNSEALED	3A	13.4	791
	53938	UNSEALED	3A	3.9	930
	53308	SEALED	3A	1.1	1,104
	53566	SEALED	3A	6.7	1,104
	54136	SEALED	3A	23.2	1,298
	54586	UNSEALED	3A	16.1	1,404
Tamworth Regional (A) - Pt A	48568	SEALED	2A	1.6	721
	47669	SEALED	2A	0.9	1,050
	48015	SEALED	2A	19.5	1,062
	48313	SEALED	2A	11.5	9,322
Tamworth Regional (A) - Pt B	48567	UNSEALED	2A	5.4	884
Walgett (A)	54070	UNSEALED	3A	31.1	718
	55174	UNSEALED	3A	26.4	775
	54307	UNSEALED	3A	7.6	782
	54365	UNSEALED	3A	2.8	824
	54692	UNSEALED	3A	1.3	871
	54693	UNSEALED	3A	33.7	994
	55175	UNSEALED	3A	34.3	1,046
	57146	UNSEALED	3A	24.7	1,362
	54440	SEALED	3A	0.7	2,648
	54661	UNSEALED	3A	7.4	2,685
	57026	UNSEALED	3A	14.1	2,959
	56943	UNSEALED	3A	16.7	2,971
	54654	UNSEALED	3A	1.7	4,030
	54705	UNSEALED	3A	4.3	4,030
	54773	UNSEALED	3A	41.4	6,162
	55009	SEALED	3A	0.6	8,150
	55001	SEALED	3A	7.2	8,390
Total				1124.0	18,706

## Appendix C Identified roads for pinch point analysis at 95<sup>th</sup> percentile

Below is a table of road segments by LGA where the segment carries significant grain freight (> 18,000 trailers annually) and the roads are not identified in the road network as Rank 1 roads.

LGA	Road Id	Surface	Access PBS Level	Total length of roads (km)	Number of trailers per year total
Coonamble (A)		SEALED	3A	6.9	18,706
	Castlereagh Hwy (Coonamble)	SEALED	3A	1.1	18,236
	Quambone Rd (Coonamble)	SEALED	3A	0.6	18,445
	50146	SEALED	3A	6.9	18,706
Goondiwindi (R) - Goondiwindi	Barwon Hwy (Goondiwindi)	SEALED	3A	0.9	79,477
Goondiwindi (R) - Waggamba	Barwon Hwy	SEALED	3A	96.0	43,475
	Leichhardt Hwy (S)	SEALED	3A	25.3	21,404
Gunnedah (A)	Kamilaroi Hwy	SEALED	2A	54.8	20,649
	Kamilaroy Hwy	SEALED	2A	38.7	30,693
	Oxley Hwy (Gunnedah)	SEALED	2A	2.3	32,489
Liverpool Plains (A)	Kamilaroi Hwy	SEALED	2A	2.7	18,696
Moree Plains (A)	Bogabilla Rd (Moree)	SEALED	3A	0.8	18,999
	Bruxner Hwy	SEALED	3A	15.2	20,998
	Carnarvon Hwy	SEALED	3A	17.1	19,448
Narrabri (A)	Kamilaroy Hwy	SEALED	2A	51.9	32,528
	Kamilaroy Hwy	SEALED	3A	2.3	31,735
Total				316.4	79,477



#### CONTACT US

**t** 1300 363 400  
+61 3 9545 2176  
**e** [csiroenquiries@csiro.au](mailto:csiroenquiries@csiro.au)  
**w** [www.csiro.au](http://www.csiro.au)  
**w** [www.csiro.au/transit](http://www.csiro.au/transit)

#### AT CSIRO, WE DO THE EXTRAORDINARY EVERY DAY

We innovate for tomorrow and help improve today – for our customers, all Australians and the world.

Our innovations contribute billions of dollars to the Australian economy every year. As the largest patent holder in the nation, our vast wealth of intellectual property has led to more than 150 spin-off companies.

With more than 5,000 experts and a burning desire to get things done, we are Australia's catalyst for innovation.

CSIRO. WE IMAGINE. WE COLLABORATE.  
WE INNOVATE.

#### FOR FURTHER INFORMATION

##### **CSIRO Land and Water**

Andrew Higgins  
**t** +61 7 3833 5738  
**e** [Andrew.higgins@csiro.au](mailto:Andrew.higgins@csiro.au)

Stephen McFallan  
**t** +61 7 3833 5722  
**e** [Stephen.McFallan@csiro.au](mailto:Stephen.McFallan@csiro.au)

Oswald Marinoni  
**t** ++61 7 3833 5713  
**e** [Oswald.Marinoni@csiro.au](mailto:Oswald.Marinoni@csiro.au)

Libby Pinkard  
**t** ++61 3 6237 5656  
**e** [Libby.pinkard@csiro.au](mailto:Libby.pinkard@csiro.au)