Arrow – Kupunn Springvale CSG Deviated Well Paths (RP122/004)

Response to Requirement Notice

December 2022

Part 1 – Introduction

The Queensland Government's *Regional Planning Interests Act 2014* (RPI Act) identifies and protects the state's important agricultural, living, environmental and cropping areas.

Under the act, a Regional Interests Development Approval, or RIDA, may be required when a resource or regulated activity is proposed for those areas.

In July 2022, Arrow made a RIDA application to develop coal seam gas wells around Kupunn Springvale, a Priority Agricultural Area on the Condamine floodplain. The application covers 14 subsurface coal seam gas wells (within existing Petroleum Leases 198, 238 and 252), part of Arrow's larger Surat Gas Project (SGP).

Sanctioned in 2020, the first phase of the SGP comprises more than 600 coal seam gas wells and will bring around 300 Terajoules/day (TJ/d) of new gas supply to market over 27 years. The SGP will create around 200 construction roles and help support the transition to cleaner forms of energy.

Arrow's RIDA application describes how the company plans to develop the Kupunn Springvale project, so the state receives the full benefits of both the agricultural and natural gas industries.

What's in this document

The Queensland Government's Department of State Development, Infrastructure, Local Government & Planning (DSDILGP) is responsible for assessing Arrow's RIDA application. In August 2022, DSDILGP issued a Requirement Notice seeking additional information from Arrow to help inform its assessment of the RIDA application.

The department's questions tend toward three main themes:

- Management of subsidence from coal seam gas activities
- Arrow's approach to Area Wide Planning and landholder consultation
- Landholder insurance and indemnities

The main body of this document provides technical detail to support Arrow's response to the Requirement Notice.

This introduction offers context to the technical discussion.

Subsidence

Regardless of the activity above ground, it's normal for the elevation of land to change to some degree from year to year. Coal seam gas extraction can add to that natural movement.

Coal seam gas is natural gas that's trapped in underground coal seams by water and ground pressure. When the water is extracted, the pressure is reduced, and the gas can flow to the surface through wells cased in steel and cement. When the pressure of water in coal seams is reduced, the surface can subside.

Farmers depend on an effective drainage of surface water for agriculture so it's important to understand whether, and by how much, coal seam gas production might change the elevation or slope of the land.

Arrow uses both radar (InSAR[1]) and laser technology (LiDAR[2]) to detect and monitor ground movement on its leases.

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[1] Interferometric Synthetic Aperture Radar

[2] Light Detection and Ranging

Arrow models subsidence from its activities and monitors for ground movement in line with the Underground Water Impact Report (UWIR) prepared by the Queensland Government's Office of Groundwater Impact Assessment (OGIA, 2021). Predictions of ground movement and outputs from monitoring are provided to landholders in Surface Elevation Baseline Reports, a format which has been reviewed by OGIA.

Predictive modelling done by OGIA indicates that subsidence is expected to result in relatively uniform changes in elevation and slope – and not in potholing or sink holes. The model indicates that the maximum all-time change in ground slope from coal-seam gas activity in most areas of the Condamine Alluvium region is less than 0.001% (10 mm/km) but can be up to 0.004% (40 mm/km) in some areas.

As almost all the existing slope in this area is greater than 0.03% (300mm/km), a change of up to 0.004% from coal-seam-gas production is not expected to significantly impact prime agricultural land use. Natural or "background" ground movement is in the order of ±25 mm/year (UWIR 2021, p12).

Under Arrow's federally required Water Monitoring and Management Plan (WMMP), if subsidence triggers are met, Arrow must develop and implement a plan that sets out activities to address any impact of subsidence. These measures may include, but are not limited to, re-laser levelling of paddocks or the re-establishment of gradient in irrigation ditches.

Arrow's approach to managing subsidence is based on identifying impacts as early as possible, so they may be mitigated or avoided entirely. Furthermore, the *Mineral and Energy Resources (Common Provisions) Act 2014* requires companies to make good and compensate landholders for the impacts of their operations.

More information about how Arrow manages subsidence is contained in Part 2 of the document.

Engagement
Landholders know their properties better than anyone. That's why Arrow incorporates their knowledge, and that of their neighbours, in its field development plans.

Under our Area Wide Planning process, we first understand how landholders use their properties and their long-term business plans. Then, landholders and Arrow staff jointly identify locations for infrastructure like well pads, gathering lines and access tracks.

It's consistent with the best practice approach recommended by the GasFields Commission Queensland, an independent statutory body created to foster relationships and respectful communication between Queensland's onshore gas, agriculture, business and government sectors[3].

Arrow's RIDA application and the Requirement Notice relate specifically to six properties around Kupunn Springvale. On average, Arrow Land Liaison Officers and these property owners had nine meetings or discussions about deviated wells and deviated well agreements over a span of one-to-two years. Additionally, neighbouring landholders without either surface or subsurface well paths have been engaged as part of Area Wide Planning either in respect of the wells the subject of this application or other CSG infrastructure proposed in the region.

More information about Arrow's approach to Area Wide Planning can be found in this document at **Item 3.** Also, a full account of Area Wide Planning associated with landholders for this application is in **Appendix 10** of the RIDA application.

[3] https://www.gfcq.org.au/

Insurance and indemnities
In May 2020 the GasFields Commission convened a Public Liability Insurance Working Group with the aim of better aligning the interests of landholders and gas companies and to confirm that public liability cover for landholders would continue to be available from a broad range of insurers.

The move followed confirmation by the Insurance Council of Australia that many insurance companies were excluding public liability insurance coverage for gas infrastructure (including legacy infrastructure) in farm pack insurance. Working group members included representatives from government and the gas, agriculture, and insurance industries.

In March 2021, the GasFields Commission issued a new Landholder Indemnity Clause to ensure ongoing farm public liability insurance coverage in Queensland. IAG provides insurance to landholders with coal seam gas infrastructure on their property where the clause is used in Conduct and Compensation Agreements.

This new indemnity clause, developed collaboratively with the working group members, provided greater clarity for landholders and gas companies where farming and gas infrastructure coexists.

In short, while insurance companies make operational and strategic business decisions about what assets they insure, if a landholder does not host CSG infrastructure, there is no CSG related reason for IAG to withhold insurance. Furthermore, Arrow will provide an Insurance Deed Poll to landholders which protects farm insurance cover taken out by landholders and indemnifies them for public liability associated with deviated wells. This deed is provided as part of the CCA or Deviated Well Agreement.

This document provides more information about Arrow's approach to mitigating financial risk to landholders in **Item 20.**

For more information
Arrow's RIDA application and supporting materials for the Kupunn Springvale project are available via the DSDILGP website Regional interests applications | Planning (statedevelopment.qld.gov.au)>

For more information about the Kupunn Springvale project, stakeholders can contact Arrow via email info@arrowenergy.com.au or 1800 038 856 (free call).

Part 2 – Response to Requirement Notices – RPI2204 Arrow – Kupunn Springvale CSG Deviated Well Path - Regional Interests Development Approval application

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
1	**Issue:** It is not clear if Figure 1-1 on page 6 of the Report to accompany an assessment application for a RIDA (Supporting report) is the same as referred to in Table 1-1 at s1.3, s1.7.2 and on page 64. **Actions:** Confirm that the figure on page 6 is Figure 1-1 and update the Supporting report accordingly.	The figure on page 6 of the application is Figure 1.1 and is the figure referenced in Table 1-1 at s1.3, s1.7.2 and on page 64. Figure 1.1 is provided in Appendix A of this response.	Appendix A of this Requirement Notice
2	**Issue:** s1.6.3 of the Supporting report: • refers to Table 3, however, no Table 3 is provided	a) The reference to Table 3 refers to Table 12-1 of the submitted RIDA report which is the criteria for Required Outcome 2 for PAA. Section 1.6.3 of the RIDA report has been updated to refer to Table 12.1, and not Table 3. See below. b) Arrow's co-existence commitments and implementation of activities are consistent with Table 3 (Table 12.1 of the submitted RIDA report), Prescribed Solution (a) for Required Outcome 2 for PAA by:	

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	• refers to coexistence and the creation of 12 commitments to coexistence in the Surat Basin in 2012, and refers to the establishment of community reference groups • states that a draft Construction and Operations simultaneous operations matrix (SIMOPS) has been developed. **Actions:** a) Update the Supporting report (including Table of contents) to include Table 3 as referenced in s1.6.3. b) To demonstrate compliance with Prescribed solution (1) (a) of Required Outcome (RO) 2: (i) Provide details to	• providing for mutual benefits to the landholder (through compensation and infrastructure upgrades) and Arrow (through ability to access CSG resources); • negotiating with landholders in regard to their land practices and schedules and developing simultaneous operations matrices to identify how Arrow can coexist with landholders through the project phases and not cause agricultural activities to need to pause and restart; • where practicable, construction activities will be undertaken during harvesting and planting or when the paddocks are in fallow; • ensuring the land is returned to full productive capacity as quickly as possible and undertaking all activities with regard to the landholder and their operations. Arrow's 12 Co-existence Commitments were released in 2012 and are our commitment to coexisting with landholders on Intensively Farmed Land. Arrow works in line with the commitments in terms of our engagement and field development planning. These commitments were augmented with the release in 2021 of our *Commitments to Surat Basin Landholders* which speaks in part to the way Arrow will work with landholders especially in relation to the drilling of deviated wells. Arrow's Surat Community Reference Group and IFL Committee meeting records can be located on the below link. https://www.arrowenergy.com.au/community/committees/surat-community-reference-group Arrow's draft SIMOPS can be located on the below link. https://www.arrowenergy.com.au/__data/assets/pdf_file/0009/27468/Arrow-Energy_draft-Construction-Coexistence-SIMOPS-Matrix.pdf Please note that a SIMOPs is designed to apply to the land on which we are undertaking	

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	demonstrate how these commitments are being implemented. (ii) Confirm and detail if these commitments have been updated since 2012 to remain contemporary (iii) Confirm that the community reference groups (including the IFL Committee) still meet and if so, how often. (iv) Provide a copy of the draft SIMOPS. (v) Advise whether the SIMOPS has been tested in the field and if so, provide the outcomes.	surface activities as the SIMOPS draft table is used as a guide for determining landholder access conditions (LACs). Additionally, it is provided to our contractors so they are able to manage their operations with consideration to the farming practices of the surface landholders. Arrow and our contractors have ongoing discussions with the landholders where we are constructing and operating to work through how we can undertake simultaneous operations where possible or for Arrow to manage our activities to minimise disruptions to landholders' businesses. In the last two years Arrow has constructed over 150 wells and several hundred kilometres of pipeline whilst minimising the impact on landholder's operations and productivity.	
3.	**Issue:** s1.6.4 on page 11 of the Supporting report refers to Area Wide Planning (AWP).	a) Area Wide Planning (AWP) is a process conducted over a period of time which includes numerous engagements with landholders across a geographic area. Planning with landholders occurs one-on-one and, where appropriate, in local area meetings with neighbouring landholders. A full account of Area Wide Planning associated with landholders for this application is in Appendix 10 of the RIDA application.	

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	<u>Actions:</u> To demonstrate compliance with prescribed solution (1) (a) of required outcome 2: a) Advise whether the owners of the lots subject to this application and neighbouring landholders have been involved in the AWP process. b) Provide information regarding the outcomes to support coexistence.	In this instance, a local area meeting was held on 26 August 2021, with all landholders within the Springvale development area invited to attend. The invitation was extended to 31 landholders on 13 August 2021. It is attached as Appendix I. For ease of reference, this has been provided in a map which accompanies the table of engagements in Appendix I. The information presented at the engagement was published online, and is available here: https://www.arrowenergy.com.au/__data/assets/pdf_file/0016/33334/AWP-Shed-Meeting-Presentation_Nandi-Springvale_Grassdale.pdf. On average, the landholders subject to this application had nine (9) separate meetings/discussions regarding deviated wells and Deviated Well Agreements with Arrow (Land Liaison Officer) over a period of one to two years. Appendix 10 of the application document provided a detail list of engagement with the landowners and/or their representatives. Privacy considerations of landholders prevent this document from being made public. For ease, we have attached a summary table at Appendix I. The recommendation is this table also remain confidential to respect the privacy considerations of landholders. This information provided in the table is current as at 12 July 2022. Arrow maintains records of all landholder contact. The negotiations and engagement with the landowners are confidential and are expressly without prejudice and for that reason a number of phone calls between the parties have not been included due to the commercial and confidential nature of the interactions. Engagements with landholders who are hosting the surface infrastructure have been ongoing since 2019 with all CCAs either signed or in the process of being finalised. These engagements take into account assessments of our impact on the relevant area. Neighbouring landholders without either surface or subsurface well paths have also been	

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		engaged as part of Area Wide Planning either in respect of the wells the subject of this application or other CSG infrastructure proposed in the region. b) In 2012, Arrow developed the 12 Co-existence Commitments that affirm how we work on Intensively Farmed Land (IFL). Those commitments ensure that we design our infrastructure in a way that minimises our footprint on IFL. The multi-well pad design (commitment 4) with deviated wells is central to minimising our operational footprint on IFL (commitment 2). We have also committed to placing CSG wells on by the edge of paddocks, where possible, (commitment 3) to further minimise our impact on farming practices. The placement of well pads is agreed with landholders to ensure pads are located in the area of least impact. The use of deviated wells means that we can place multiple wells on one pad, decreasing the need for multiple well pads and minimising our operational footprint on IFL. We recognise it is important for us to work with landholders and we do this through our Area Wide Planning (AWP) process which means we talk to landholders about our development plans and the placement of infrastructure on their properties at least two years out from our drilling activities (commitment 12). This process ensures that we understand the priorities of landholders and the way in which they use their properties. Through AWP, we work with a group of landholders to explain our development plans and the possible impacts of our activities. Working with landholders, we strive to find the delicate balance that minimises the impact of our infrastructure on our host properties, and also on neighbouring properties, within the stringent environmental, safety and geological constraints. In 2021 we expanded and improved this promise through our Commitments to Surat Basin Landholders where we articulate our long-term intentions to maintain positive and productive relationships with our landholders. This document sets out a commitment to engage early with landholders and set out the compensation obligation for future impacts such as subsidence.	

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		The GasFields Commission Queensland (GFCQ) and the Office of Groundwater Impact Assessment (OGIA) have been working together to make recommendations to the Queensland Government on possible regulatory reforms to provide improve certainty, clarity and transparency to landholders on CSG induced subsidence. These recommendations will be over and above what we are already obligated to do under the Federal Government's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Arrow Energy is committed to the early adoption of any Queensland Government policy position. For completeness, the 12 Co-existence Commitments are - : 1. No permanent alienation; 2. Minimised operational footprint – less than 2% of total IFL area; 3. Flexibility on CSG well locations, but all wells located by edge of farm paddocks; 4. Pad drilling (up to 8 wells from a single pad) used where coal depth and geology allows; 5. Spacing between wells maximised (average of between 800m – 1500m); 6. Pitless drilling only; 7. No major infrastructure facilities on IFL (dams, compression stations, gas gathering stations, water treatment); 8. Treated CSG water used to substitute existing users' allocations on IFL; 9. No brine/salt treatment or disposal on IFL; 10. Flexibility on power supply option; 11. Fair compensation; and 12. Continued proactive engagements with community and transparency on coexistence field activities.	

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4.	**Issue:** The Wayleave agreement (and crossing agreement) referred to in s1.7.4 of the Supporting report concerns Lot 1 RP83755. However, there is no rail line on that lot and there are no rail interests detailed on the lot's title deed. This agreement may concern the adjacent Lot 92 SP129747. **Actions:** Update the Supporting report as required. If the agreement concerns Lot 1 RP83755, provide summaries and conditions of these agreements, including details on anticipated surface impacts associated with the authorised works including scope, extent, location, and timing.	The Wayleave agreement referenced to Lot 1 RP83755 in Section 1.7.4 was in error. Section 1.7.4 of the application has been removed.	
5.	**Issue:** s2.1, s3 or s4 of the	Please see requested information at Appendix F of this report.	

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	Supporting report do not detail the depths of well paths entry and terminal points (i.e., the end point of the well path), the well path trajectories and surface area subject to dial before you dig requirements and latitude and longitude coordinates for these matters. **Actions:** Update the Supporting report to include these details in both a table format and accompanying 3D maps for each lot subject to the proposed activity.		
6.	**Issue:** Table 2-2 and Appendix 2 of the Supporting report details the properties subject of the application. However, the application does not provide the title deeds of the other lots that comprise these properties. **Actions:** Update the Supporting report by providing: a) Title deeds for all lots	Please see attached a revised Figure 2-1 (Appendix B) to show the 'property parcels' as a different colour and titles have been added.	

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	that make up properties subject to the application b) A map of the surrounding areas to those properties detailing the extent of the properties as well as the lot on plan and ownership details for all neighbouring and adjacent lots.		
7.	**Issue:** It is unclear whether Figure 2-1 on page 16 of the Supporting report is the same as referred to in s1.2 on page 4, Table 1-1 on page 5, s2.2 and s2.3 on page 14 and s3.2.1 on page 19. **Actions:** a) Confirm that the figure on page 16 is Figure 2-1 and update the Supporting report accordingly. b) Update the legend on	The figure on page 16 is Figure 2-1 and the legend has been updated to include the information from s2.3.1. The updated figure is provided at Appendix B.	

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	the figure on page 16 to include the referred to s2.3.1 on page 14.		
8.	**Issue:** s2.3.3 of the Supporting report details overlapping resource authorities. However, the narrative is not clear on the implications for any (future) proposed activity under that resource tenure if the proposed activity subject to this application is approved. **Actions:** Update the Supporting report to note the consequences of the area available for permitted impacts to priority agricultural land uses (PALUs) resulting from other proposed, and cumulative, impacts.	Only one of the land parcels subject of this application (Lot 1 on RP83755) is overlapped by a coal resource authority, being EPC1770, held by New Emerald Energy Limited (New Emerald) (EPC1770 overlaps Petroleum Lease 252). EPC activities are limited to exploration activities only. Any plans to progress this EPC is a decision for New Emerald Energy. During discussions in March 2022, New Emerald Energy advised that their short and medium term targets (1-10 years) are west of the Wilkie Creek Coal Mine (approximately 25km nor-north-west of this area). Based on this advice there are no cumulative impacts for further consideration at this time.	
9.	**Issue:** s3.2.1 of the Supporting report does not detail the water and gas extraction area for each well.	The planned wells are expected to cumulatively extract gas and water from the lots subject to this RIDA application.	

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	Actions: Update the Supporting report to provide indicative locations of gas and water extraction areas for each deviated well.		
10.	**Issue:** Insufficient information is provided in s3.2.1 (and s4.4.1 and Appendix 3) of the supporting report to determine if the dial before you dig requirement areas will constrain, prevent, or restrict the use of those areas for PALU or everyday farming practices or infrastructure essential to the operation of a PALU on the respective properties. **Actions:** a) Update the Supporting report to discuss any implications of the dial before you dig requirements. b) Provide updated figures to include these surface	a) Arrow voluntarily provides information to Dial Before You Dig to ensure that landholders have information regarding the well paths of deviated wells. As the deviated well paths are at a depth of approx. 189m below the surface, it is not considered that these will constrain, prevent or restrict the use of the subject lots for PALU or for everyday farming practices. The placement of a CSG well beneath a property will not preclude the drilling of a deep-water bore into the Hutton or Precipice aquifers across an entire property. At a high level, the Hutton and Precipice sandstone aquifers are widespread in this region so the location for a water bore is not geographically bound on a property. If a landholder chose to install a deeper bore, there may possibly be minor limitation in the location this could be installed. If it is preferred to be located nearby Arrow infrastructure, Arrow will work with the water bore driller to provide any additional information which can inform the downward well control, so that the bore can be drilled in such a way to avoid potential interception with CSG infrastructure, including any deviated wells. b) There are no updated figures relating to surface areas as this RIDA only deals with sub-surface infrastructure.	

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	areas.		
11.	**Issue:** s3.2.1 of the Supporting report states that operational activities will be undertaken remotely. **Actions:** Confirm whether operational activities include workovers and whether workover activities will require access to the sub-terranean land as a preliminary activity and the likely impacts to landholders.	Operational maintenance activities on the well head, well bore and well trajectories will be undertaken via access from the surface infrastructure. There will be no surface access required to the lots covered by this application. Therefore, these workover activities will not affect the PALU subject to the application. The landholders subject to this application will be advised by Arrow Land Liaison Officers prior to any workover activity for subterranean infrastructure under their properties.	
12.	**Issue:** s3.3 of the Supporting report does not discuss what the likely impacts are on landowners who undertake irrigation activities if water table and/or water pressure drops because of the proposed activity. **Actions:** Update the Supporting report	The water source for irrigation in this area is the Condamine Alluvium due to its water quality and yield. Modelling in the most recent Underground Water Impact Report (UWIR) (OGIA, 2021) indicates that the maximum impact to the Condamine Alluvium as a result of CSG production is expected to be "*less than 0.3 m for most of the area*" (page 94). This level of impact is "*less than the 2-m trigger threshold for unconsolidated aquifers*" (page 94, OGIA, 2021) nominated in Chapter 3 of the Water Act 2000. The 2021 UWIR does not identify any Make Good obligations for the Condamine Alluvium aquifer. Historical groundwater monitoring data also show the groundwater level in the Condamine Alluvium can fluctuate seasonally due to irrigation use by up to several metres.	

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	to include and discuss how adverse impacts to irrigators will be managed, mitigated, or avoided.	Furthermore, the 2021 UWIR predicts that there will be a net loss of water from the Condamine Alluvium to the Walloon Coal Measures of "*about 1,270 ML/year over the next 100 years*" (page 94) due to CSG development. The total reduction in volume of groundwater within the Condamine Alluvium that is due to Arrow's activity is estimated at about 58 GL over the next 100 years. For comparison, the total estimated use from Condamine Alluvium licenses and stock & domestic users is about 31,000 ML per year (or 3100 GL over 100 years) (see Table 3-1, OGIA, 2021). Although the 2021 UWIR predicts a minor impact to the Condamine Alluvium, Arrow proposes to mitigate this minor impact through its Condamine Alluvium Substitution Scheme. Further details of the scheme are provided in Section 8.	
13.	**Issue:** s4.1 of the Supporting report does not detail the Regional Outcomes and Policies concerning PAAs as detailed in the Darling Downs Regional Plan. **Actions:** Update the Supporting report to include and discuss the Regional Outcomes and Policies concerning PAAs as detailed in the Darling Downs Regional Plan with regards to agriculture having the primacy	**Section 4 – Overview** Priority Agriculture Areas (PAAs) are strategic areas, identified on a regional scale, that contain significant clusters of a region's high value intensive agricultural land uses. The PAA surrounding the land relevant to this application includes areas of high value agricultural land uses, in particular areas of dryland cropping and grazing. Within the PAA, Priority Agricultural Land Use (PALU) is given priority by ensuring that the location of resource activities can coexist with these uses. Protecting PALU while supporting co-existence opportunities for the resources sector on PAA are identified in the plan and comprise the region's strategic areas containing highly productive agricultural land uses. In these areas, PALU are the land use priority. PALUs within the PAA will be recognised as the primary land use and given priority over any other proposed land use. PAA co-existence criteria enable compatible resource activities to co-exist with high-value agricultural land uses within PAAs. This will in turn maximise opportunities for economic growth to ensure that the Darling Downs remains a resilient, diversified and prosperous region.	

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	land use.	To manage competing land use, regional outcomes and policies are contained within the Darling Downs Regional Plan. The plan provides policy responses to resolve the region's most important issues affecting its economy and the liveability of its towns. The plan specifically provides direction to resolve competing state interests relating to the agricultural and resources sectors, and to enable the growth potential of the region's towns **Section 4.1 - Regional Outcomes and Policies** The regional plan provides a regional context and regionally specific policies to guide certain land use planning and development outcomes within the Darling Downs region. The plan's regional policies address the emerging regional of land use competition between the agricultural and resources sectors, and the need to protect areas required for the growth of towns. The Darling Downs region includes some of Queensland's most productive and resource-rich terrain, comprising prime agricultural land and extensive and largely undeveloped deposits of thermal coal and coal seam gas (CSG). Within the region, the resources and agricultural industries compete for access to land due to the co-location of resources, infrastructure, and services required for each industry. This land use conflict has implications such as the loss of or encroachment on productive agricultural land, competition for access to water resources, and competition for freight and transport services. The regional plan has four regional policies to protect priority agricultural land uses while supporting co-existence opportunities for the resources sector. They are: • Regional policy 1 – Protect Priority Agricultural lands Uses within PAAs; • Regional policy 2 – Maximise opportunities for co-existence of resources and agricultural land uses within PAAs • Regional policy 3 – Safeguard the areas required for the growth of towns through establishment of Priority Living Areas (PLA); and	

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		• Regional policy 4 – Provide for resource activity to locate within PLAs where it meets the communities expectations as determined by the relevant local government. Under the State's assessment provisions, the following provisions apply to the States assessment process for resource activities where a proposal relates to land located within a PAA or a PLA. 1. Where a resource activity is proposed on land being used for a PALU in a mapped PAA then the PALU will be given priority through the application of coexistence criteria. 2. where a resource activity is proposed within a PLA then the state assessment is to include consideration of community expectations as determined by the relevant local government and articulated in the local planning scheme. Measures outlined in Section 3.2, 4.5 and 7.2 will minimise the potential for impacts and ensure that impacts are not material to ongoing PALU activities.	
14.	**Issue:** s4.2.2 and Table 4-1 and s4-2 of the Supporting report detail PALUs on lots subject to proposed activity. However, insufficient information is provided on how the non-cropping PALUs were considered. For example, there are areas on Lot 11 SP191489 and Lot 141 AG4261 that might have been used for grazing irrigated modified pastures, but no	Section 4.3 provides a summary of assessment to identify PALU on the subject land and the area of PALU on each parcel was presented in Table 4-2. PALUs in classes 3.4, 4.1, 4.2, 4.4, 4.5 and 5.1 (as defined by Australian Land Use and Management (ALUM) Classification Version 7, May 2010) were considered in the review of: 1. historical land use; 2. crop frequency mapping; 3. aerial imagery taken from 2012 to 2020; and 4. land use practices observed by Arrow Land Liaison Officers The relevant ALUM land use classes (including methodology) are:	

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	information is provided on how this was considered, or the methodology, assumptions and data used. **<u>Actions:</u>** Update the Supporting report to detail how PALUs in classes 3.4, 4.1, 4.2, 4.4, 4.5 and 5.1 were considered e.g. detailed methodology, assumptions and data used, and how it was determined that these PALUs did not occur on land subject to the proposed activities.	• 3.4 Perennial Horticulture – review of imagery did not provide an indication of the land having been previously used for intensive horticulture associated with fruit trees, oleaginous fruits, tree nuts, vine fruits, shrub nuts, fruits and berries, perennial flowers and bulbs, perennial vegetables and herbs, citrus or grapes; • 4.1 Irrigated Plantation Forestry – review did not provide an indication of the land having previously been used for plantation forestry; • 4.2 Grazed irrigated modified pastures- no indication was identified on the imagery that the land had been subject to irrigation (no obvious greening of the area compared to adjacent remnant vegetation, particularly in dry months); • 4.4 Irrigated Perennial Horticulture – as outlined above, no indication was found on the imagery of evidence of perennial horticulture (see 3.4 above) or of irrigation (see 4.2 above); • 4.5 Irrigated Seasonal Horticulture – review of imagery did not provide an indication of the land having been irrigated or used for intensive cultivation for seasonal horticulture associated with seasonal fruits, seasonal nuts, seasonal flowers and bulbs, seasonal vegetables, herbs and turf farming; • 5.1 Intensive Horticulture – review of imagery did not provide an indication of shade houses or glass houses associated with intensive forms of plant production. Based on this assessment of the above criteria, the above classifications were not identified on the parcels of land subject to this application.	
15.	**<u>Issue:</u>** s4.3 of the Supporting report includes Table 4.1 – Outcome of Identification of PALU on Lots (subject to the application) and associated properties.	Table 4-1 in Section 4.3 has been renamed i.e. Table 4-1 – Outcome of Identification of PALU on (subject to RIDA Application) associated properties.	

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	Actions: Rename Table 4-1 to 'Outcome of Identification of PALU on properties (subject to RIDA application)'.		
16.	**Issue:** Table 4-2 in s4.4.1 of the Supporting report indicates that the proposed area of disturbance of the PAA is 0 ha. This assumes that there will be no permanent impacts to areas of PALU through the impacts of CSG-induced subsidence. The information provided in the application indicates that the risk of impacts to land used for any PALU is being assessed through modelling and baseline monitoring to date. Consequently, appropriate monitoring and management should be established at the property scale for all properties in this application (e.g., via a	**a) Subsidence Impacts:** Extensive modelling has been undertaken by OGIA (modelling since 2019) and Arrow (monitoring since 2012). Modelling has predicted that there may be a relatively small change in slope (up to 40 mm/km or 0.004%). Given almost all the existing slope in this area is greater than 300mm/km, a relatively small change in slope (up to 40 mm/km) from coal-seam-gas production would not significantly impact prime agricultural land use. Impacts from subsidence can be remedied through a range of activities such as laser-relevelling of paddocks or the re-establishment of gradient in irrigation ditches (further discussion on whether the impact is temporary or permanent is provided in response to item 23). If the predicted level of CSG subsidence were to occur, any elevation changes to infrastructure (required for PALU) that may impact agricultural production on the subject properties could be rectified. Predictions of subsidence within the Condamine Alluvium footprint suggest that most of the cropping area is likely to experience less than 100 mm change in elevation by the end of 2060 (page 108, OGIA, 2021). The maximum all-time change in ground slope from CSG-induced subsidence in most areas is predicted to be less than 0.001% (10 mm/km) but can be up to 0.004% (40 mm/km) in some areas (page 108, OGIA, 2021). In comparison, natural or 'background' ground movement not affected by CSG development is in the order of ±25 mm/year (page 103, OGIA, 2021).	

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	property scale subsidence management plan (SMP)). *Note : The RPI Act Statutory Guideline 02/14 Carrying out resource activities in a Priority Agricultural Area at RPI Act - Statutory Guideline 02/14 (windows.net) discusses options for avoiding impacts on the PAA, for example 'To demonstrate compliance, the applicant may provide an explanation of how the everyday farm practices, or an activity or infrastructure that is essential to the operation of a PALU can continue. For example ... there is no change to the overland flow characteristics where it is relied upon for the PALU', and the 'To demonstrate compliance, the applicant may provide information about how the activity on the property does not have a significant impact on the PAA in which it is located. For example: ... evidence detailing how*	This prediction of change in slope is communicated to the landholder through Arrow's Surface Elevation Baseline Reports which show the location of a subject parcel overlaid on OGIA's output of predicted maximum change in ground slope (Figure 7-7 of the 2021 UWIR [OGIA, 2021]). The development of CSG-induced subsidence, as evident historically in existing CSG production areas and predicted through modelling, does not result in 'pothole' or 'sinkhole' caving mechanisms, but in the relatively uniform change in elevation and slope of the land. Detailed information regarding the existing slopes on the lots subject to this application is located on page 30 - Table 4.4 of the initial application. **b) Baseline Monitoring:** Monitoring of ground movement is carried out by Altamira using satellite borne Interferometric Synthetic Aperture Radar technology (InSAR), a radar technique used in geodesy and remote sensing (Altamira, 2016). Data was obtained from Radarsat-2 and ALOS-1 satellites for the periods July 2012 to November 2017 and December 2006 to March 2011, respectively, across Arrow leases. The Sentinel-1 satellite constellation is the current platform, with data obtained since August 2015. InSAR makes use of the amplitude and the absolute phase of the return signal data to enable accurate determination of change in surface elevation between survey passes. The change in phase difference between locations can be used to interpret changes in relative position, and indicate subsidence for different regions within areas potentially affected by CSG drawdown. The InSAR data provides a temporal baseline from which future data can be assessed to determine changes in vertical ground elevation, and also provides a snapshot of current vertical ground movement. OGIA (2021) selected InSAR as the most appropriate technique for ongoing monitoring of change in ground elevation for the purpose of establishing trends and subsequent identification of subsidence.	

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	overland flows will be restored to pre-activity capacity in the PAA'. **<u>Actions:</u>** a) Demonstrate how subsidence impacts will be avoided in accordance with the RPI Statutory Guidelines 02/14. b) Provide details of how a baseline has been determined and the monitoring techniques used to measure subsidence. (c)Provide the following detailed plans in a stand-alone format: (i) a property scale subsidence management plan (SMP) – including plans/actions to monitor/manage CSG-induced subsidence and resulting changes in overland flow (ii) should impacts resulting from CSG-induced subsidence occur, provide a restoration	Periodic surveys using Light Detection And Ranging (LiDAR), a remote-sensing technique using airborne laser scanning systems, have been undertaken to provide snapshots of elevation of the land and derived slopes at moment of capture. These surveys, which provide for accurate assessment of slopes at property and regional scale, have been acquired for Arrow in 2012, 2014, 2020 and 2021. OGIA note in Section 7.5.2 of the 2021 UWIR that "*In early 2021, in collaboration with interested landholders, OGIA selected representative properties to compare and test the suitability and viability of two different methods to establish ground elevation and slope – drone LiDAR and ground-based GPS survey. OGIA then further compared these products with regional airborne LiDAR data acquired and provided by Arrow. Results thus far conclude that the surface drainage pattern across a paddock, derived from an aerial LiDAR survey, is the most suitable and cost-effective method to establish background slope, as it also helps in identifying minor slopes and depressions. As drone and airborne LiDAR show a broadly similar drainage pattern, airborne LiDAR is therefore considered a cost-effective method for slope analysis and assessing changes over time at both a regional and property scale.*" The LiDAR data provides a temporal baseline from which future data can be assessed to determine changes in slope. Slopes within the Arrow tenements were calculated at 10m grid spacing from the 1m resolution DEM derived from LiDAR data. The results of the area and percentage of each slope class across the whole Arrow tenement are presented in Table 1, with the dominant slope class being greater than 0.5% (5m/km). When confined only to dryland and irrigated cropping lands, as presented in Table 2, the dominant slope class is 0.12 to 0.5% (1.2 to 5m/km). Slopes of 0.06% (0.6m/km) will not drain water adequately and yield loss from waterlogging can be a problem in heavy rainfall years, though during drought years with limited rainfall, the ponded areas may in fact lead to the highest yields due to soil water accumulation in these areas. The slope increments/classes were selected to focus on the very flat slopes in the landscape that are intensively farmed.	

<table>
<tr><td colspan="4">Requirement Notice 1</td></tr>
<tr><th>Item</th><th>The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice</th><th>Arrow's Response</th><th>Comment</th></tr>
<tr><td></td><td>plan where overland flow is impacted by CSG induced subsidsence.

Note: Refer also to Item 25.</td><td>
Table 1: Slope classes within Arrow tenements
<table>
<tr><th>Slope Class</th><th>Area (ha)</th><th>Area (%)</th></tr>
<tr><td>< 0.01%</td><td>465</td><td>0.07%</td></tr>
<tr><td>0.01 - 0.03%</td><td>3,650</td><td>0.52%</td></tr>
<tr><td>0.03 - 0.06%</td><td>11,766</td><td>1.68%</td></tr>
<tr><td>0.06 - 0.12%</td><td>39,420</td><td>5.62%</td></tr>
<tr><td>0.12 - 0.5%</td><td>190,452</td><td>27.15%</td></tr>
<tr><td>> 0.5%</td><td>455,790</td><td>64.97%</td></tr>
</table>
Table 2: Slope classes of cropping lands within Arrow tenements
<table>
<tr><th rowspan="2">Slope Class</th><th colspan="2">Dryland</th><th colspan="2">Irrigated</th><th colspan="2">Total Cropping Land</th></tr>
<tr><th>Area (ha)</th><th>Area (%)</th><th>Area (ha)</th><th>Area (%)</th><th>Area (ha)</th><th>Area (%)</th></tr>
<tr><td><0.01%</td><td>227</td><td>0.22%</td><td>130</td><td>0.26%</td><td>357</td><td>0.2%</td></tr>
<tr><td>0.01 - 0.03%</td><td>1,771</td><td>1.7%</td><td>1,037</td><td>2.0%</td><td>2,808</td><td>1.8%</td></tr>
<tr><td>0.03 - 0.06%</td><td>5,418</td><td>5.2%</td><td>3,425</td><td>6.7%</td><td>8,483</td><td>5.7%</td></tr>
<tr><td>0.06 - 0.12%</td><td>15,753</td><td>15%</td><td>10,843</td><td>21%</td><td>26,596</td><td>17.1%</td></tr>
<tr><td>0.12 - 0.5%</td><td>50,171</td><td>48%</td><td>26,711</td><td>52%</td><td>76,882</td><td>49.6%</td></tr>
<tr><td>>0.5%</td><td>31,097</td><td>30%</td><td>8,529</td><td>16%</td><td>39,526</td><td>25.5%</td></tr>
</table>
</td><td></td></tr>
</table>

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		As well as CSG induced subsidence, other anthropogenic and natural ground movement processes also affect surface elevations and slopes. Reactive clays such as the vertisols of the Condamine River floodplain swell and shrink in response to moisture changes, an effect which is greatest close to the surface where the clay is less confined by overburden and where the moisture can be more quickly changed by rainfall or irrigation and by evapo-transpiration. OGIA (2021) analysed available InSAR data and found that "*ground movement unrelated to CSG depressurisation and away from existing CSG development, both within and outside the Condamine Alluvium, suggests that the ground can frequently move up and down by around 25 mm/year and the ground movement can also vary significantly at a local scale (by up to 25 mm within 100 m). This is likely to be due to variations in soil type and associated changes in moisture content"*. DataFarming (2021) also looked at the natural variations in the surface due to the swell shrink nature of the vertisol clays present on the Darlings Downs. Anecdotal evidence from soil experts suggest that vertical movement is up to 200mm between wet and dry, and assessment of strip cropping by DataFarming found likely vertical movement due to differences in soil water content of up to 200mm. Non-CSG induced ground movement resulting in change in slope has been assessed, using transects derived from the 2012, 2014 and 2020 LiDAR surveys. Eight properties were selected in the Condamine Floodplain away from CSG production, clear of infrastructure, riparian vegetation and earthworks, with locations shown in Figure 1. Of the 86 profiles assessed across these properties using the same method as presented in Response to Item 23 (Investigation Level assessment) for comparison to investigation levels, 230 transect pairs (subsets of the profiles comparing slopes from one LiDAR survey to the next) were available for review, with the histogram of changes in slope provided in Figure 2. Of these, 135 transect pairs (59%) experienced change in slope of 100mm/km or less, with 199 (86%) transect pairs experiencing change in slope of 300mm/km or less. Of the transect pairs with slopes greater than 900mm/km, 20 (9%) experienced change in slope of greater than 15% of the previous slope. Other processes which cause ground movement include depressurisation resulting from	

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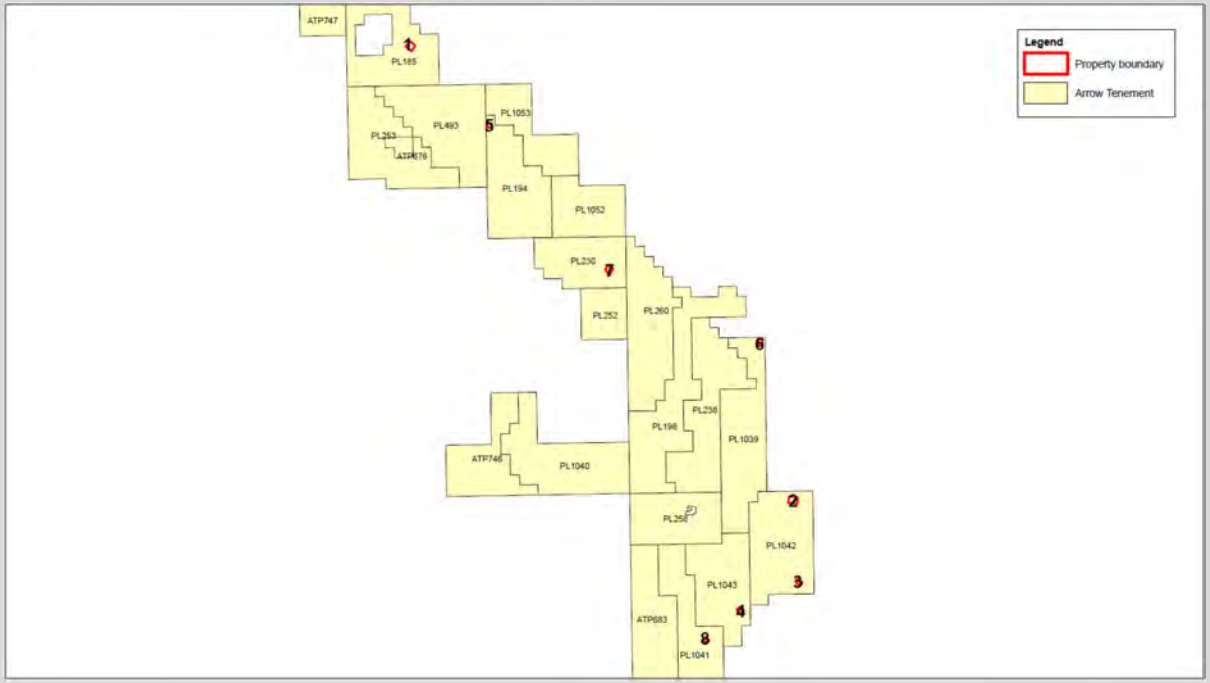
		groundwater use in aquifers overlying the target coal formation, erosion/deposition processes, and land management practices such as irrigation, tillage and land contouring. Arrow will provide baseline ground surface data reports to landholders with, or proposed to have, gas infrastructure on or under the land. Details of the baseline reports is provided in Section 4.4.4.  **Figure 1: Location of properties for review of non-CSG induced changes in slope**	

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		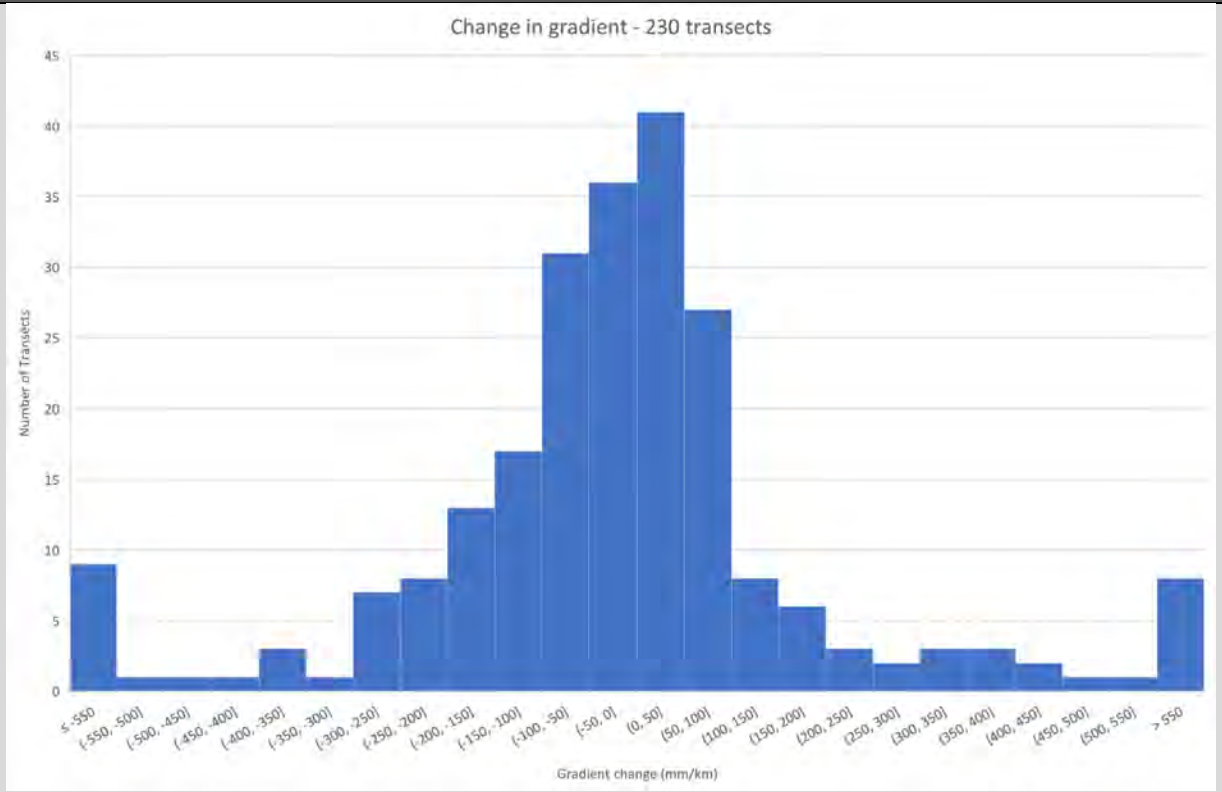 **Figure 2: Histogram of non-CSG induced changes in slope on cropping land** <u>Monitoring techniques used to measure subsidence</u> Details of the monitoring techniques used to measure subsidence is provided in Section 7.2 of the Supporting Document. These techniques are in line with that recommended by OGIA in the 2021 UWIR.	

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		c) Property scale management: Arrow has provided landholders with baseline elevation packs which can be used to compare against the ongoing monitoring by Arrow and OGIA (future UWIRs). Currently, the GasFields Commission Queensland is leading a research project, in partnership with OGIA, to develop a framework for assessing at a farm scale, the risk to farming operations on intensively farmed land arising from predicted CSG-induced subsidence. The research is focused on gaining an understanding of the impacts of subsidence on a farm scale in terms of the change in slope and what may be required to remediate the impacts. The Commission is also reviewing the adequacy of the current regulatory framework. Arrow will work within any new regulatory framework which will be over and above that already required by our EPBC and UWIR obligations.	
17.	**Issue:** There is an inconsistent use of depths to detail minimum depths of well trajectories. For example, one metre is referenced in s4.4.1 of the Supporting report whereas 189 metres in s4.4.2 and 190 metres in s4.4.3.	The report has been updated to reflect 189 metres.	

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	Actions: Update the Supporting report to detail consistent minimum depths of the well trajectories.		
18.	**Issue:** s4.4.4 of the Supporting report discusses: • Office of Groundwater Impact Assessment's (OGIA) predicted change in slope for land subject to the proposed activity. However, the figures provided in Appendix 8 are too small to thoroughly investigate • Figure 7-5 in OGIA 2021 Underground Water Impact Report (UWIR), but does not provide this figure • that Coffey's subsidence modelling (2021) 'indicates that any subsidence that occurs will be relatively widespread and even'.	a) These figures in the original application have been updated as A3 in Appendix D of this response document b) Figure 7.7 has been incorrectly referred to as Figure 7.5. c) Where CSG infrastructure is required on the surface or within the subsurface of a landholders' property, a voluntary agreement has been negotiated, or that land will form part of a potential future RIDA application where required. Land that is not within the infrastructure footprint, where a RIDA may not be required, will be regulated by the MERCP Act and our obligations under the EPBC Act, through the WMMP. Under MERCP Act, if a landholder experiences an impact a general compensation obligation applies. The WMMP provides a further layer of regulatory rigour, and specifies triggers which, if eventuate, will require management plans and may lead to rectification.	

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	The application, however, excludes those lots that are not subject to the proposed activity but that are likely to be impacted by coal seam gas (CSG) induced subsidence and where voluntary agreements have not been entered into. **<u>Actions</u>** Update the Supporting report to: a) show each of the four maps provided per lot subject to the proposed activity at the A3 scale b) include Figure 7-5 discuss why land that is likely to experience CSG induced subsidence because of the proposed activity, and where there is no voluntary agreement, has not been addressed		

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19.	**Issue:** s4.4.5 of the Supporting report does not detail the production and productive capacity of the lots the subject to the proposed activity. **Actions:** Update the Supporting report to detail the production and productive capacity of the lots subject to the proposed activity.	The lots subject to this application are classified Class 1 capability class.	
20.	**Issue:** s4.5 of the Supporting report does not discuss any measures to minimise impacts to PALU associated with the risk to landowners to secure new or refinance existing debt, insurance and other financial products resulting from the undertaking of the proposed activity on their properties. **Actions:**	**Section 4.5.1 - Mitigation measures to reduce financial risk (refinancing and insurances) to the landholder related to Deviated Wells** **1. Finance** Our experience to date is that compensation payments (generally negotiated to be an annual annuity) provides a reliable additional income source which can assist in meeting serviceability requirements in finance applications and capital outlays for farming infrastructure improvements. **2. Insurance and Indemnities** Our insurance and indemnity clauses were subject to extensive consultation across industry and stakeholders to ensure that our activities should not result in increased insurance premiums or denial of insurance to landowners.	

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	Update the Supporting report, specifically in addressing prescribed solution (1)(e) for RO2 and Prescribed Solution (3)(d) for RO1 in Tables 12-1 and 12-2 respectively, to include discussion on the risks for affected landholders to secure and or refinance debt, insurance and other financial services and products and include commitments to provide a management strategy and actions that seeks to avoid, minimise, and mitigate such instances at pre-activity rates, premiums, and excesses, as well as relative terms and conditions.	In March 2021, the GasFields Commission (the Commission) released a new 'Landholder Indemnity Clause'. Use of the clause in Conduct and Compensation Agreements would ensure ongoing farm public liability insurance coverage in Queensland. Working group members (including IAG, parent company to WFI) developed the clause. IAG agreed to insure landholders who host CSG infrastructure when the agreed Landholder Indemnity Clause is used in Conduct and Compensation Agreements. During the transition period between Dec 2020 and March 2021, IAG also agreed to continue insurance cover for landholders who hosted CSG infrastructure. Furthermore, Arrow will provide an Insurance Deed Pool to landholders which protects farm insurance cover taken out by landholders and indemnifies them for public liability associated with deviated wells. This deed is provided as part of the CCA or Deviated Well Agreement.	
21.	**Issue:** s7.2 of the Supporting report: • discusses that a CSG Water Monitoring and Management Plan (WMMP) includes a three-tiered subsidence management	**a) Trigger threshold exceedance response** Trigger thresholds are developed based on a site-specific assessment of changes to drainage and impacts to farming. Where an investigation level is breached, additional investigation of the affected area will be carried out. The results of the investigation will be tested against asset-specific thresholds. For irrigated and dryland cropping lands, the following assessment will be undertaken where an investigation level is exceeded. The process described below will be undertaken for only	

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	framework. However, insufficient information is provided in this section to determine how this approach, including trigger thresholds and management/mitigation actions, may apply to lots subject to the proposed activity. • refers to the amendments to the Stage 1 WMMP and states that 'additional monitoring method, including bi-annual collection of LiDAR...'to Required Outcome 2 Part (1)(b), Table 12-1 at Section 12.1 of the report states that *'Information about the selection of the layout is provided in Section 7*' (page 88). **<u>Actions:</u>** a) Update the Supporting	those parts of the property where the investigation level is exceeded. The trigger threshold is considered exceeded if it is considered reasonably likely that Arrow CSG-induced subsidence has caused or significantly contributed to: • some form of demonstrated loss (in any relevant metric e.g. crop yield) on the property; and • a material alteration to the drainage and slope of the surface of the property which coincides with the demonstrated loss on the property. Arrow will also consider if any material alteration to the drainage and slope of the property have contributed to the demonstrated loss. This will include evaluation of whether Arrow CSG-induced subsidence has likely caused or materially contributed to the demonstrated loss and alteration to the drainage and slope of the surface of the property. This evaluation will include analysis of depressions, comparison of contours at 100mm intervals, and drainage mapping to compare to pre-CSG drainage and slope. The trigger threshold will not be considered exceeded if it is reasonably apparent that the demonstrated loss was: • Caused by a pre-existing characteristic of drainage or slope of the property; or • The alteration to drainage or slope of the property was caused by a non-CSG factor, activity or event. Where adverse impacts are identified to have occurred based on the results of the site-specific investigation, a trigger threshold is considered to have been exceeded and an action plan will be employed. <u>Trigger threshold exceedance response actions</u> If a trigger threshold is exceeded a Trigger Threshold Exceedance Action Plan (TTEAP) will be developed and implemented to address the impacts. Actions in the TTEAP will be dependent on the: • Evaluation of the cause of the exceedance;	

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	report to discuss the response, should CSG induced subsidence exceed the trigger thresholds. b) Confirm that the proposed amendments to the WMMP will not have a material impact of the decision-making process associated with the application. c) Clarify whether bi-annual means twice yearly or every other year.	• Magnitude, location and expected duration of the impacts; • Site specific conditions e.g. crop type, cropping frequency, soil type, slope, etc.; • Remediation or compensation options including the landholder's preferences; and • Any other relevant factors. The TTEAP will: • Identify potential mitigation measures and response actions. • Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude. • Evaluate time frames within which impacts would be expected to occur and within which mitigation or response actions would need to be successful. • Schedule mitigation and response action implementation, with consideration for the anticipated timing of the indicated impact. • Contain procedures to evaluate the effectiveness of the mitigation measures or response actions. . **b) Proposed changes to the WMMP** The proposed changes to the WMMP are aimed at expanding the current framework to take into account irrigated and dryland cropping areas. The updates also reflect the further work that OGIA have undertaken in the 2021 UWIR. These proposed changes will not impact this application. **c) LiDAR frequency** Bi-annual means twice per year.	
22.	**Issue:** s8 of the Supporting report discusses that the most recent	Arrow will provide treated water to Condamine Alluvium groundwater licence holders through our Condamine Alluvium Substitution Scheme Network. The scheme will offset potential impacts from drawdown on the Condamine Alluvium aquifers as a result of Arrow's coal	

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	modelling presented in OGIA's 2021 UWIR indicates that the '*maximum impact to the Condamine Alluvium as a result of CSG production is expected to be less than 0.3 metres for most of the area...*' This includes discussion on how the Substitution Scheme has been designed to supply water to the area as a mitigation measure to potential impacts to the Condamine Alluvium. **<u>Actions</u>** Update the Supporting report to discuss how offsetting impacts to the Condamine Alluvium by purchasing allocations will not adversely impact the undertaking of current PALU within the affected area. *Note: If water allocation purchases are progressed, a separate application for a RIDA to manage the expected regional impacts to the PAA maybe required.*	seam gas extraction and maximise the beneficial use of treated coal seam water. Arrow is not currently, nor does it have plans to progress a purchase of allocation scheme. Section 8 of the supporting report has been updated.	

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23.	**Issue:** Table 5.1 in s5 of the Supporting report indicates that the proposed area of disturbance of strategic cropping area (SCA) is 0 ha. This assumes that there will be no permanent impacts to areas of strategic cropping land (SCL) through the impacts of CSG-induced subsidence. The information provided in the application indicates that the risk of temporary and permanent impact to SCL is being assessed through modelling and baseline monitoring to date. Consequently, appropriate monitoring and management should be established at the property scale for all properties in this application (e.g. via a property scale subsidence management plan (SMP)). The RPI Act Statutory Guideline 03/14 Carrying out	**a) Predicted impact** Permanent and Temporary Impact The impact of subsidence on SCL is not considered permanent given the land can be returned to its pre-activity condition in the context of RPI Act Statutory Guideline 03/14. OGIA note in Section 7.4.4 of the 2021 UWIR that of the environmental values that could be potentially affected by subsidence, irrigation of cropping land is the key consideration because subsidence may, depending upon the magnitude and rate of change over time, potentially affect the ground slope of irrigated cropping land and hence the irrigation practices. This together with water runoff of dryland cropping areas are the main aspects of this potential impact. Although the predicted change in slope resulting from CSG-induced subsidence is not considered to be of a magnitude that would materially impact irrigation or dryland practices on SCL (Section 4.4.4), any impact of subsidence on SCL can be remediated (through practices such as laser levelling the land to re-establish the required slope for irrigation / runoff) demonstrating that the impact of subsidence on SCL is not permanent. Ability to Remediate to Pre-Activity Condition The predominant impact of CSG-induced subsidence is a change in the slope of the SCL which could impact irrigation practices and dryland runoff. In light of this, the relevant aspect of SCL that may require restoration is the slope of the land across a property to ensure adequate runoff of water within dryland and irrigated areas. Remediation would likely involve land forming (land levelling) which can be achieved through a range of techniques using agricultural machines to achieve either (Data Farming, 2021): • A single (or multiple) flat plane(s) at a consistent grade (slope) primarily for flood/surface irrigation. Surface irrigation using formed furrows works most effectively where there is consistent grade to ensure even wetting of the soil profile. In the past this approach has primarily been implemented by using what's termed as a 'laser	

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	resource activities in the Strategic Cropping Area at RPI Act - Statutory Guideline 03/14 (windows.net) discusses options for avoiding permanent impacts on the mapped SCA and includes that: *'For land to be restored to pre-activity condition, it will require an adequate restoration to the former or original condition of the land, including the productive capacity of the land.* *It does not simply mean 'revegetated', 'rehabilitated' or 'reclaimed' which are all commonly used terms under other state government permit and approval processes.* *Restoring the land means that the land is not only returned to its pre-activity use but that it is also returned to its pre-activity productive capacity or potential productive capacity ...* *In the context of SCL, the productive capacity refers to*	bucket'. • Removal of water pondage areas in dryland and irrigated paddocks by levelling the ground to ensure all areas of the field are within a set slope range, and water freely drains from the field. This is a newer technique using GNSS (GPS) technology. The same earth moving bucket is used, however control is now conducted by satellite positioning. • The use of a large blade towed by a tractor to smooth out the landscape by essentially removing the high points and grading them into the low areas. This has been used to smooth out gilgai. <u>Pre-Activity Condition Assessment</u> Arrow has on hand baseline surface elevation data such as LiDAR and InSAR which has been used to determine the pre-activity condition (i.e. terrain, landform and slope [as noted in RPI Act Statutory Guideline 09/14] of dryland and irrigated cropping areas) of the SCL. Assessment of other SCL attributes such as soils is not considered necessary given the predicted impact is associated with a physical change in landform. Arrow has acquired InSAR monitoring data back to 2006. Current InSAR monitoring is conducted using the European Space Agency Sentinel satellite constellation, with an acquisition frequency of every six days. Arrow has also acquired airplane borne LiDAR in 2012, 2014, 2020 and 2021. This InSAR and LiDAR monitoring provides a baseline from which future data can be assessed to determine changes in vertical ground elevation and slopes, and also provides a snapshot of current non-CSG ground movement. To establish pre-activity condition and to assist with identifying any gradient changes over time on each of the subject parcels, Arrow has prepared Surface Elevation Baseline Reports for all subject parcels associated with this RIDA application (provided in Appendix E). The Baseline Report provides historical surface elevation data obtained from LiDAR and InSAR monitoring and is made up of five sections, namely: 1. Digital Elevation Models (DEMs)	

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	the intrinsic capability of the land and soil to store and supply the water and nutrients required to sustain crops in the future'.a The RPI Act Statutory Guideline 09/14 How to determine if an activity has a permanent impact on Strategic Cropping Land at RPI Act - Statutory Guideline 09/14 (windows.net) provides guidance on how applicants can demonstrate that a proposed activity does not have a permanent impact on SCL. A restoration plan and a subsidence management plan could also be used to help demonstrate this requirement, e.g. for monitoring and managing temporary impacts, and then restoration at the end of the activity, if required. Independent third-party review by a suitably qualified and experienced person/panel of the property scale subsidence monitoring and management	2. Contour Lines 3. Drainage Lines 4. InSAR 5. OGIA predicted maximum change in ground slope A summary of each section is provided below noting that the method used to generate these has been reviewed by OGIA. 1. DEM • The DEMs are derived from LiDAR point clouds and have been collected from aerial surveys in 2012, 2014 and 2020. • The DEMs, within the absolute accuracy of the surveys, provide the change in elevation across the landscape for these periods of time. • The DEMs, within the relative accuracy of each survey, provide the change in slope across the landscape for these periods of time. • This is relevant because at a farm level, if an area of the farm changes due to observable ground movement (e.g. a depression) or land form change (e.g. a new dam) the DEM will depict the relative change in the landscape. 2. Contour Lines • 10cm contour lines have been generated from each DEM for the periods of 2012, 2014 and 2020. • This is a visual representation of the slope across the DEM. • This again is based on the relative accuracy of the DEM. • This is relevant because any changes on the landscape will change the contour lines. • As this is a very fine resolution of contour lines, farming activities will have an effect on the contour lines to some extent. 3. Drainage Lines • The overland flow of the bare earth was modelled into drainage lines, to indicate how	

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	plan is recommended as a further means of ensuring or confirming that there will be no permanent impacts on mapped SCA. **<u>Actions:</u>** a) Demonstrate how permanent impacts will be avoided in accordance with the RPI Statutory Guidelines 03/14 and 09/14. b) Statutory Guidelines 03/14 and 09/14. c) Provide the following detailed plans in a stand-alone format: (i) a property scale subsidence management plan (SMP) – including plans/actions to monitor/manage CSG-induced subsidence and resulting changes in soil erosion	water would accumulate and flow over the surface of the property based on each DEM. • Any major change to the slope or surface of the land will change the direction and accumulation of water. • Agricultural practices, such as furrowing and contouring will have an effect on these drainage lines. • Changes in these lines' direction or intensity may affect flow across the surface. 4. InSAR • Interferometric synthetic aperture radar (InSAR) is a remote-sensing technique whereby radar signal data is collected from satellites to determine the change in ground elevation. • The InSAR map represents the location of InSAR scatter points, which contain time series data on the cumulative ground movement since 2015. A selection of scatter points has been plotted in a graph to demonstrate the available time series data. 5. OGIA predicted maximum change in ground slope • This figure provides a regional context for the lot on plan regarding OGIA's predicted maximum change in ground slope from CSG-induced subsidence. This figure is presented in the 2021 UWIR (Figure 7-7). • OGIA used their predicted groundwater impacts from their groundwater model as an input into their subsidence model to predict CSG-influenced subsidence in the Walloon Coal Measures. The output from this model was used to calculate a predicted change in slope within cropping land across the Condamine Alluvium. <u>Productive Capacity</u> See response to Item 19 <u>Management and Mitigation of Temporary Impacts, and Restoration Plan</u> OGIA (2021) predict subsidence will be relatively uniform across a network of CSG wells and that InSAR is therefore the most effective tool for monitoring regional-scale ground	

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	(ii) should temporary impacts resulting from CSG-induced subsidence occur, provide a restoration plan. Note: It is recommended that the SMP is subject to third-party independent review by a suitably qualified and experienced person/panel prior to lodgement. This would need to include an independent review of property specific CSG-induced subsidence triggers. *Supporting information to the SMP that would be useful for identifying the pre-activity condition would include a suitably scaled soil survey – see Queensland Soil and Land Resource Survey Information Guideline (Department of Resources 2020) and RPI Act Statutory Guideline 08/14 How to demonstrate that land in the strategic cropping area does not meet the criteria for strategic cropping land Document title (windows.net) for further*	movement over time, which is then used to assess subsidence. The content of a Restoration Plan (as noted in RPI Act Statutory Guideline 09/14) will be developed upon an exceedance of a Trigger Threshold as contained in the approved WMMP. It should be noted that the timing for the development of a Trigger Threshold Exceedance Action Plan (TTEAP) (following discussions with the landholder throughout the investigation phase) will allow for a true site specific management approach to ensure it is current and all encompassing to the SCL. Temporary impacts will be managed and mitigated through Arrow's WMMP three tiered subsidence management framework comprising: 1. Screening Level: involves comparison of InSAR data at a to identify areas of downward ground movement. 2. Investigation level: involves comparison of changes in the slope of the ground or differential movement, with criteria specific to each asset class (e.g. linear infrastructure, cultivated lands). The following investigations will be undertaken where the screening level is exceeded, or where there is insufficient InSAR data for a screening level determination. An evaluation of approximate slope and changes in slope will be undertaken in a manner that is readily repeatable using the InSAR and LiDAR data. An example of a process which may be followed to evaluate approximate slope is described below. Any alternative equivalent process may also be used. Transects of the surface along and across the relevant asset will be prepared. When assessing changes in slope for dryland or irrigated cropping areas, transects may be prepared parallel to, and perpendicular to, the longest boundary of the cropped areas. At least four transects will be considered in each direction, being approximately equally spaced starting with the boundaries of the cropping areas in each direction. For all asset types the gradient of each transect will be estimated by approximating the slope from	

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	guidance	one end of the transect to the other unless the lowest point on the transect clearly occurs away from either end of the transect. Multiple slopes may be fitted to the transect profile to best approximate the general slope of the transect. Transects will exclude elevation data from all riparian zones, mining operations, roads, tracks, and earthen structures as these features are likely to be subject to significant non-CSG related processes such as erosion, deposition, earthworks, etc which are many times greater than the expected magnitude of CSG-induced subsidence. It is noted that variations in soil moisture content across paddocks and/or storm events that results in uneven soil wetting can also cause material changes to surface elevations. However, no attempt has been made to exclude particular areas from further assessment because of these effects. The gradients of any slopes identified along the transect will be compared between the: • Most recent measurement / survey event, and • Pre-CSG influenced measurement / survey event(s). The change in gradients or differential movement will then be compared against the investigation levels defined in the WMMP. Where an investigation level is exceeded, more detailed investigation will be undertaken in accordance with the process to assess the site-specific asset that may be impacted and identify whether an impact has occurred because of the Action. 3. Trigger Threshold: is developed based on a site-specific assessment of changes to drainage and impacts to farming. Where an investigation level is breached additional investigation of the affected area will be carried out. The results of the investigation will be tested against asset-specific thresholds.	

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		For irrigated and dryland cropping lands, the following assessment will be undertaken where an investigation level is exceeded. The process described below will be undertaken for only those parts of the property where the investigation level is exceeded. The trigger threshold is considered exceeded if it is considered reasonably likely that Arrow CSG-induced subsidence has caused or significantly contributed to: • some form of demonstrated loss (in any relevant metric e.g. crop yield) on the property; and • a material alteration to the drainage and slope of the surface of the property which coincides with the demonstrated loss on the property. Arrow will also consider if any material alteration to the drainage and slope of the property have contributed to the demonstrated loss. This will include evaluation of whether Arrow CSG-induced subsidence has likely caused or materially contributed to the demonstrated loss and alteration to the drainage and slope of the surface of the property. This evaluation will include analysis of depressions, comparison of contours at 100mm intervals, and drainage mapping to compare to pre-CSG drainage and slope. The trigger threshold will not be considered exceeded if it is reasonably apparent that the demonstrated loss was: • Caused by a pre-existing characteristic of drainage or slope of the property; or • The alteration to drainage or slope of the property was caused by a non-CSG factor, activity or event. Where adverse impacts are identified to have occurred based on the results of the site-specific investigation, a trigger threshold is considered to have been exceeded and an action plan will be employed. <u>Trigger threshold exceedance response actions</u> If a trigger threshold is exceeded a Trigger Threshold Exceedance Action Plan (TTEAP) will be developed and implemented to address the impacts. Actions in the TTEAP will be	

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		dependent on the: • Evaluation of the cause of the exceedance; • Magnitude, location and expected duration of the impacts; • Site specific conditions e.g. crop type, cropping frequency, soil type, slope, etc.; • Remediation or compensation options including the landholder's preferences; and • Any other relevant factors. The TTEAP will: • Identify potential mitigation measures and response actions. • Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude. • Evaluate time frames within which impacts would be expected to occur and within which mitigation or response actions would need to be successful. • Schedule mitigation and response action implementation, with consideration for the anticipated timing of the indicated impact. • Contain procedures to evaluate the effectiveness of the mitigation measures or response actions.	
24.	**Issue:** The CSG-induced subsidence management discussions in the Supporting report (s7.4) are not tailored to the specific properties within this application, nor reflected in a stand-alone subsidence management plan. While some of this detail required may be found in separate documentation (e.g., the WMMP), these should be	OGIA (2021) predict subsidence will be relatively uniform across a network of CSG wells and that InSAR is therefore the most effective tool for monitoring regional-scale ground movement over time, which is then used to assess subsidence. InSAR is therefore integrated into Arrow's subsidence monitoring plan. **a) Vertical accuracy and post processing of the Sentinel InSAR data** In general, the precision of an individual monitoring point value lies within the range ±1 mm to ±5 mm, with a corresponding displacement rate range between ±0.5 mm/year to ±2.0 mm/year. Where datasets are made of a few images, accuracies tend towards the upper limits and occasionally exceed them. However, the larger the dataset, the lower is the	

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	specifically adapted for subsidence monitoring and management purposes at the property scale – for the properties associated with this application. There is a concern that the Tier one screening referred to on page 99 using a 1km x 1km grid is insufficiently scaled to identify changes in slope and ponding (of more than 8mm per year) at the property scale. Specific exceedance triggers requiring action (at the property scale) for the properties within this application have not been included. Analysis of ground movement was completed using a Sentinel InSAR dataset. Due to the limitations (e.g., vertical accuracy) of InSAR, the conclusions regarding the differences in elevation that have been observed since 2015 are difficult to substantiate. For example, it is unclear how InSAR can be used to accurately report on ground movement in 'mm' to form a baseline for a property scale monitoring program.	standard deviation values. The estimated precision of SqueeSAR® (proprietary multi-interferogram technique patented by TRE ALTAMIRA) displacement rate measurements as a function of time (supposing a regular satellite acquisition over the area of interest and a distance of the measurement point (MP) from the reference point of less than 4 km) is reported in Figure 1. It can be seen that high resolution satellites, with an effective repeat cycle of 8/11 days, can achieve sub-millimetre standard deviation values well before older medium resolution sensors. Sentinel images acquired from April 2015 are used as a baseline for future data acquisitions. This provides a robust stack of more than 298 images in Track 45 and more than 130 images in Track 147 as a historical baseline. Such quantity of images will enable the extraction of an optimal and stable measurement of the motion phenomena. Every new update will be linked to the previous period to obtain a continuity in the time series. Sentinel is expected to acquire 60 new images for the Track 45 (1 new image every 6 days) and 30 for the Track 147 (1 new image every 12 days) per year over the Area of Interest. The descending geometry is used for the analysis. By statistically exploiting the imagery, SqueeSAR® finds MP on the ground that display stable amplitude and coherent phase throughout every image of the dataset. For each one of these MP, SqueeSAR® is able to measure and report the history of displacement. The MP's belong to two different families: • Permanent Scatterers (PS): point-wise radar targets characterised by high stable radar signal return (e.g. buildings, rocky outcrops, linear structures, etc.) • Distributed Scatterers (DS): patches of ground exhibiting a lower but homogenous radar signal return (e.g. uncultivated land, debris, deserted areas, etc.). Further information on the data acquisition and processing methodology is provided in	

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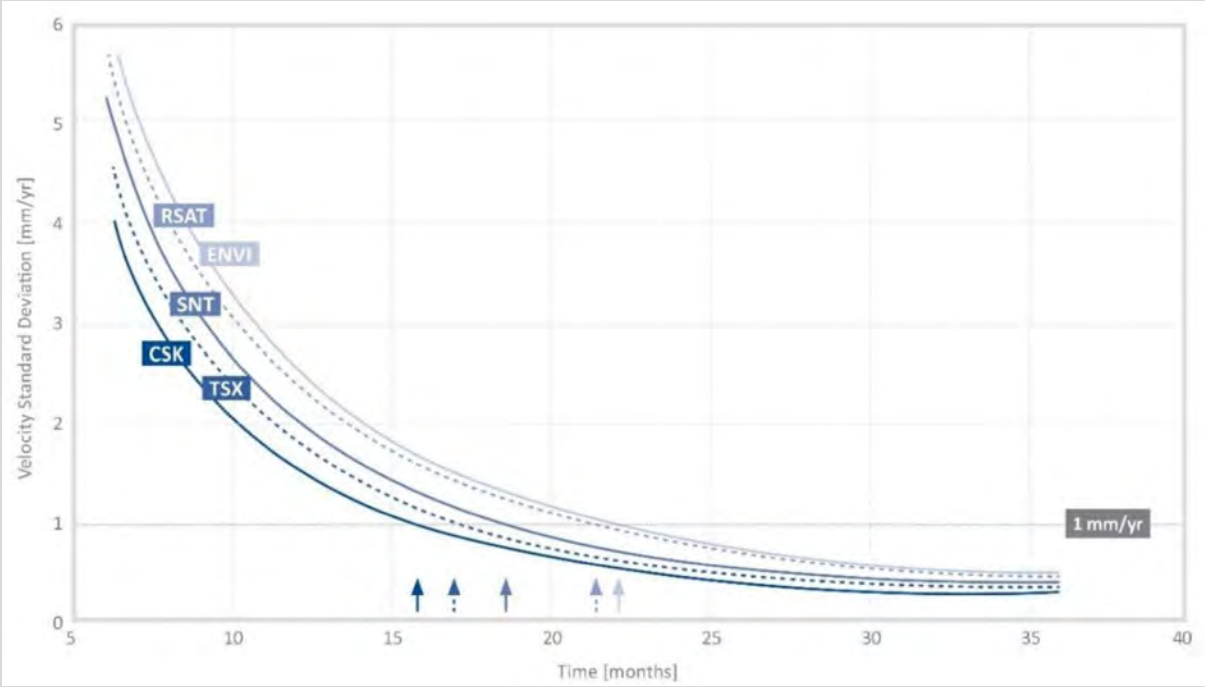
	It is conceded that the movement of shrink/swell soils is cyclical and will be different during periods of drought or high rainfall, which makes it extremely difficult to establish a baseline elevation. Cultivation adds another complexity, as does the specifics of the cropping system. Even airborne LiDAR with a vertical accuracy of ± 50 mm may not be sufficiently accurate to detect critical changes in slope or depressions resulting from ponding that may temporarily and/or permanently impact the SCA and farming operations at the property scale – particularly in landscapes of very low relief. Property scale monitoring of CSG-induced subsidence may require more accurate technology (e.g. RTK Drone LiDAR) to establish a baseline and monitor against this baseline for the properties associated with this application. There is no analysis of the DEM provided in Appendix 6. For example, there are no Figures demonstrating change	Appendix C.  **Figure 1: Comparison of time required for each satellite to obtain sub-millimetre standard deviation results. As the number of images acquired increases, the velocity standard deviation decreases. Depending on the satellite, this accuracy is obtained according to the orbit repeat time of the satellite.** **b) Sentinel InSAR metadata** The metadata for the InSAR is provided in Table 7-1 of Section 7.2 in the Supporting Document.	

<table>
<tr><th colspan="4">Requirement Notice 1</th></tr>
<tr><th>Item</th><th>The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice</th><th>Arrow's Response</th><th>Comment</th></tr>
<tr><td></td><td>in slope over 2012, 2014 and 2020 at the property scale. There has been no discussion of climatic variables which may explain changes in elevation due to changes in soil moisture.

<u>Actions:</u>

All issues described below should be addressed in a Subsidence Management Plan at the property scale, for the specific properties associated with this application and include details relating to proposed monitoring, appropriate exceedance action triggers if CSG-induced subsidence is detected at the property scale, reporting, and appropriate actions for management if CSG-induced subsidence is detected at the property scale:

a) provide the vertical accuracy of the Sentinel InSAR data and discuss any post capture</td><td>c) LiDAR metadata
LiDAR data are processed in line with the Australian Standard. An xml file is not generated as part of the process, instead details of the datasets are summarised in a PDF file. Further to the summarised metadata provided in Section 7.2 of the RIDA Supporting Document, the full metadata for the 2012, 2014 and 2020 LiDAR datasets are provided in the following tables.

<u>2012 LiDAR</u>

<table>
<tr><td>Dataset Description Abstract</td><td>Arrow Energy LiDAR derived products</td></tr>
<tr><td>Dataset Language</td><td>English</td></tr>
<tr><td>Dataset Character Set</td><td>ASCII and binary</td></tr>
<tr><td>Dataset Topic Category</td><td>ModelKeyPoints,. Vegetation, DEM and Contours</td></tr>
<tr><td>Geographic Location Description</td><td>Queensland, Australia</td></tr>
<tr><td>Geographic Bounding Box</td><td>MGA55
WEST LONGITUDE=147° 48' 12.4318" E
NORTH LATITUDE= 21° 03' 09.8450" S
EAST LONGITUDE=148° 47' 21.7982" E
SOUTH LATITUDE= 22° 56' 22.2815" S
MGA56
WEST LONGITUDE=149° 51' 10.6505" E
NORTH LATITUDE= 25° 38' 10.6859" S
EAST LONGITUDE=151° 28' 32.3475" E
SOUTH LATITUDE= 28° 12' 21.3936" S</td></tr>
<tr><td>Acquisition Start Date</td><td>16th June 2012</td></tr>
<tr><td>Acquisition End Date</td><td>29th July 2012</td></tr>
<tr><td>Sensor Type Name</td><td>Leica ALS50-2</td></tr>
<tr><td>Sensor/Lens serial ID</td><td>SN087</td></tr>
<tr><td>Flying Height (AGL)</td><td>2500m</td></tr>
</table></td><td></td></tr>
</table>

<table>
<tr><td colspan="4">Requirement Notice 1</td></tr>
<tr><th>Item</th><th>The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice</th><th>Arrow's Response</th><th>Comment</th></tr>
<tr><td></td><td>processing required to achieve that vertical accuracy

b) confirm the metadata for the Sentinel InSAR and whether it was collected to Australian Standards

c) provide detailed metadata of the LiDAR DEMs. Note: the metadata for all the LiDAR generated Digital Elevation Models must be collected to the relevant Australian Standard (link).

d) confirm the difference in accuracy and precision between the LiDAR and InSAR

e) clarify whether all LiDAR monitoring has been aligned to permanent survey markers of a known and recorded location (e.g., the network of geodetic permanent survey markers, and based on a common geodetic datum – e.g.,</td><td>
<table>
<tr><td>INS / IMU Used</td><td>IPAS10</td></tr>
<tr><td>Number of Runs</td><td>MGA55 159
MGA56 198</td></tr>
<tr><td>Swath Width</td><td>1892m</td></tr>
<tr><td>Flight Direction</td><td>Non-Cardinal</td></tr>
<tr><td>Side Overlap (%)</td><td>20</td></tr>
<tr><td>Output Data Format</td><td>1m DEM, Model key points and Vegetation in ASCII XYZ</td></tr>
<tr><td>Horizontal Datum</td><td>GDA94</td></tr>
<tr><td>Vertical Datum</td><td>AHD as defined by AUSGeoid09 v1</td></tr>
<tr><td>Map Projection</td><td>MGA Zone 55 South and MGA Zone 56 South</td></tr>
<tr><td>Number of control points</td><td>No Control Was used on this project</td></tr>
<tr><td>Spatial Accuracy (Hz) meters</td><td>0.29m @ 67 % CI</td></tr>
<tr><td>Spatial Accuracy (Vt) meters</td><td>0.12m @ 67 % CI</td></tr>
<tr><td>Surface Type</td><td>Various</td></tr>
<tr><td>Average Point Separation</td><td>Target spacing 1 pt/m^2</td></tr>
<tr><td>Laser Return Types</td><td>All Returns</td></tr>
<tr><td>Data Thinning</td><td>None</td></tr>
<tr><td>Laser Footprint Size (meters)</td><td>0.60</td></tr>
<tr><td>Data Tile size (km 2)</td><td>3km^2</td></tr>
</table>

<u>2014 LiDAR</u>

Source Data
<table>
<tr><th>Item</th><th>Source</th><th>Description</th><th>Ref No</th><th>Date</th></tr>
<tr><td>Primary survey control</td><td>AAM</td><td>New & Existing Ground control</td><td></td><td>various</td></tr>
<tr><td>Laser System</td><td>AAM</td><td>Riegl Q1560</td><td>24066A</td><td>November, December</td></tr>
</table>
</td><td></td></tr>
</table>

<table>
<tr><td colspan="4">Requirement Notice 1</td></tr>
<tr><th>Item</th><th>The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice</th><th>Arrow's Response</th><th>Comment</th></tr>
<tr><td></td><td>GDA2020). All current and future surveys should reference these permanent survey markers to ensure accurate comparisons can be made between surveys.

f) conduct spatial analysis to compare change of elevation and slope between different years of LiDAR capture (Example DEM of difference). Surveys should be captured at the same time of the year to minimise seasonal differences due to soil moisture variability. Any changes in soil moisture (e.g., drought or un- seasonally high rainfall) should be accounted for in the analysis

g) confirm with a suitably qualified and experienced agronomist, the exceedance triggers where critical changes in slope or the development of</td><td>
<table>
<tr><td></td><td></td><td></td><td></td><td>2014, January, February 2015</td></tr>
<tr><td>Pulse Rate Frequency</td><td>AAM</td><td>400 kHz</td><td>24066A</td><td>November, December 2014, January, February 2015</td></tr>
<tr><td>GPS Base Data</td><td>CORS</td><td>SmartNet Aus CORS Network (WNDN,TARO, DALB,4JON & MILL)</td><td>24066A (Wandoan,Taroom,Dalby & Millmerran) Chinchilla</td><td>November, December 2014, January, February 2015</td></tr>
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Metadata Elements
<table>
<tr><th>Characteristic Description</th><th>Characteristic Description</th></tr>
<tr><td>Device Name</td><td>Riegl Q1560</td></tr>
<tr><td>Half Scan Angle</td><td>29 degrees</td></tr>
<tr><td>Laser Pulse Rate</td><td>800kHz</td></tr>
<tr><td>Laser Scan Frequency</td><td>32Hz</td></tr>
<tr><td>Overlap Percentage</td><td>60%</td></tr>
<tr><td>Laser Pulse Mode</td><td>Single Pulse</td></tr>
<tr><td>Swath Width</td><td>700m</td></tr>
<tr><td>Average Point Spacing</td><td>16pts/m^2</td></tr>
<tr><td>File Format</td><td>ASCII XYZ</td></tr>
<tr><td>Horizontal Datum</td><td>GDA94</td></tr>
<tr><td>Vertical Datum</td><td>AHD using Ausgeoid09</td></tr>
<tr><td>Map Projection</td><td>MGA Zone 55,56</td></tr>
<tr><td>Vertical Accuracy Specification</td><td>±0.07m at 68% confidence interval</td></tr>
</table>
</td><td></td></tr>
</table>

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<tr><td colspan="4">Requirement Notice 1</td></tr>
<tr><th>Item</th><th>The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice</th><th>Arrow's Response</th><th>Comment</th></tr>
<tr><td></td><td>depressions result in ponding that may 1. temporarily and 2. permanently impact the SCA and farming operations at the property scale – this may be different for each property.

h) once the critical changes in slope or depressions that may result in ponding (exceedance triggers) have been identified, investigate using suitably accurate monitoring measurement techniques (e.g., RTK Drone LiDAR) to accurately identify the baseline DEM, monitor against the triggers, and focus any management to ensure there is no permanent impact.

Note: Department of Agriculture and Fisheries may need to be consulted to confirm the critical changes in slope and depressions resulting in ponding at the</td><td>
<table>
<tr><td>Horizontal Accuracy Specification</td><td>±0.15m at 68% confidence interval</td></tr>
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Reference Systems
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<tr><th></th><th>Horizontal Vertical</th><th>Horizontal Vertical</th></tr>
<tr><td>Datum</td><td>GDA94</td><td>AHD</td></tr>
<tr><td>Projection</td><td>MGA Zone 55 & 56</td><td>N/A</td></tr>
<tr><td>Geoid Model</td><td>N/A</td><td>Ausgeoid09</td></tr>
</table>

<u>2020 LiDAR</u>

Source Data
<table>
<tr><th>Item</th><th>Source</th><th>Description</th><th>Ref No</th><th>Date</th></tr>
<tr><td>Laser System
Camera</td><td>AAM
AAM</td><td>Galaxy Prime 424
A3 Edge - 33</td><td>PRJ37870
PRJ37870</td><td>15/10 to 6/11/2020
1/11 to 3/11/2020</td></tr>
<tr><td>Laser System
Camera</td><td>AAM
AAM</td><td>Galaxy Prime 424
A3 Edge - 33</td><td>PRJ37870
PRJ37870</td><td>15/10 to 6/11/2020
1/11 to 3/11/2020</td></tr>
<tr><td>Airborne GPS Solution</td><td>AAM</td><td>RTX</td><td>PRJ37870</td><td></td></tr>
<tr><td>Ground control</td><td>AAM</td><td>RTK GPS</td><td>PRJ38780</td><td>29/10 to 5/11/2020</td></tr>
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Metadata Elements
<table>
<tr><th>Characteristic</th><th>Description</th></tr>
<tr><td>Device Name:</td><td>Galaxy Prime 424</td></tr>
<tr><td>Half Scan Angle:</td><td>25 degrees</td></tr>
<tr><td>Laser Pulse Rate:</td><td>450 kHz</td></tr>
<tr><td>Laser Scan Frequency:</td><td>40 Hz</td></tr>
<tr><td>Laser Pulse Mode:</td><td>Automatic</td></tr>
<tr><td>Imagery:</td><td>NA</td></tr>
<tr><td>Laser Footprint Size:</td><td>0.4m</td></tr>
<tr><td>File Format:</td><td>ESRI ASCII, Shape, LAS V1.2</td></tr>
</table>
</td><td></td></tr>
</table>

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<tr><td></td><td>property scale (i.e., exceedance triggers). These will need to be unique to the cropping systems in the application area. These should also be verified by an independent third-party.

Changes in slope of approximately 25 mm per kilometre as derived from Sentinel InSAR are unlikely to reflect subsidence at the property scale. Any triggers should be based on the properties applicable to this application – even minor changes to slope in self-mulching, black Vertosol soils can significantly increase the erosion risk.</td><td>
<table>
<tr><td>Contour Interval:</td><td>1.0m</td></tr>
<tr><td>DTM GSD:</td><td>1.0m</td></tr>
<tr><td>Horizontal Datum:</td><td>GDA2020</td></tr>
<tr><td>Vertical Datum:</td><td>AHD using Ausgeoid2020</td></tr>
<tr><td>Map Projection:</td><td>MGA Zone 56</td></tr>
<tr><td>Vertical Accuracy:</td><td>±0.05m Standard Error (68% confidence level or 1 sigma)</td></tr>
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Reference Systems
<table>
<tr><th></th><th>Horizontal</th><th>Vertical</th></tr>
<tr><td>Datum</td><td>GDA2020</td><td>AHD</td></tr>
<tr><td>Projection</td><td>MGA Zone 50</td><td>N/A</td></tr>
<tr><td>Geoid Model</td><td>N/A</td><td>Ausgeoid2020</td></tr>
</table>

d) Accuracy difference between InSAR and LiDAR

InSAR and LiDAR data are used for different monitoring applications. InSAR is appropriate for monitoring relative change in surface elevation while LiDAR is appropriate for monitoring changes in ground slope. Due to this difference in applications of the two data types, it is not considered necessary to compare their accuracy and precision.

Nonetheless, the accuracy and precision of the InSAR and LiDAR is provided in the response to Items 24a and 24c above respectively.

e) LiDAR permanent survey markers

Ground control survey of each LiDAR acquisition is undertaken using existing permanent survey markers. The same markers are used wherever possible between LiDAR acquisitions however sometimes they are disturbed / moved since the last monitoring event and may therefore may not be appropriate to be used. The approach to this process is:
• Locate markers previously used within the primary control network.</td><td></td></tr>
</table>

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
		• Verify these markers have not moved by resurveying the primary control network via 6 hour static GPS observation and processed using a Final Orbit Auspos solution. • After removing disturbed markers from the network, establish a target patch of markers relevant to the data acquisition area. Data from the target patch are used to validate the LiDAR data capture. **f) Analysis of changes in elevation and slope** <u>Changes in slope</u> Given the proposed activity has not yet commenced, the LiDAR data collected in 2012, 2014, 2020 form a baseline dataset and changes in slope across these baseline data is not required to be assessed prior to the activity commencing. However, these data (and any future LiDAR data collected) would be used to assess changes in slope during the Investigation Level assessment phase of Arrow's three tiered subsidence management plan. As per the response to Item 23a, the following investigations will be undertaken where the screening level is exceeded, or where there is insufficient InSAR data for a screening level determination. An evaluation of approximate slope and changes in slope will be undertaken in a manner that is readily repeatable using the InSAR and LiDAR data. An example of a process which may be followed to evaluate approximate slope is described below. Any alternative equivalent process may also be used. Transects of the surface along and across the relevant asset will be prepared. When assessing changes in slope for dryland or irrigated cropping areas, transects may be prepared parallel to, and perpendicular to, the longest boundary of the cropped areas. At least four transects will be considered in each direction, being approximately equally spaced starting with the boundaries of the cropping areas in each direction. For all asset types the gradient of each transect will be estimated by approximating the slope from one end of the transect to the other unless the lowest point on the transect clearly occurs away from either end of the transect. Multiple slopes may be fitted to the transect profile to best approximate	

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
		the general slope of the transect. Transects will exclude elevation data from all riparian zones, mining operations, roads, tracks, and earthen structures as these features are likely to be subject to significant non-CSG related processes such as erosion, deposition, earthworks, etc which are many times greater than the expected magnitude of CSG-induced subsidence. It is noted that variations in soil moisture content across paddocks and/or storm events that results in uneven soil wetting can also cause material changes to surface elevations. However, no attempt has been made to exclude particular areas from further assessment because of these effects. The gradients of any slopes identified along the transect will be compared between the: • Most recent measurement / survey event, and • Pre-CSG influenced measurement / survey event(s). The change in gradients or differential movement will then be compared against the investigation levels defined in the WMMP. See also response to Item 16b which provides an overview of assessment of regional change in slope across the DEMs. <u>Changes in elevation</u> InSAR data are provided to Arrow upon the completion of each 6 monthly batch processing. These data provide a relative (and cumulative) change in elevation which are assessed by Arrow upon receiving the data against the WMMP Screening Level criteria. <u>LiDAR timing</u> Arrow has committed to biannual LiDAR capture. Arrow seek to conduct these LiDAR capture events at the same time each year however factors outside of Arrow's control sometimes inhibit this timing (i.e. cloud cover, safe flying conditions).	

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
		g) Exceedance Triggers The WMMP subsidence management framework was peer reviewed by both the suitably qualified water resources expert (Glenn Harrington) approved by the Minister for the Environment on 7 July 2015, and Emeritus Professor John Carter of Fugro Ag Pty Ltd. Further to response to Item 21b, the proposed changes to the WMMP subsidence management framework were also developed in consultation with Arrow's community reference groups. It should be noted that OGIA (2021) predict subsidence will be relatively uniform across a network of CSG wells as opposed to localised depressions. Nonetheless, as outlined in response to Item 23a Arrow don't consider the impact of subsidence on SCL to be permanent given the land can be returned to its pre-activity condition in the context of RPI Act Statutory Guideline 03/14. Arrow's subsidence management framework is consistent with OGIA's subsidence impact predictions. **h) Monitoring** In light of the preceding responses for item 24, and as per Section 7.2 of the Supporting Document, the program for monitoring ground movement provided in the Stage 1 WMMP includes satellite imaging using InSAR, groundwater level monitoring, geodetic ground movement monitoring monuments and an extensometer array. Arrow has proposed amendments to the Commonwealth for the Stage 1 WMMP. These amendments are to provide additional monitoring methods, including bi-annual collection of LiDAR where there is insufficient reliable InSAR data, and bi-annual surveying of benchmark locations to cross-check the LiDAR and InSAR data. This monitoring framework is considered appropriate to monitor for subsidence impacts as predicted by OGIA.	

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
25.	**Issue:** Impacts on SCL due to salinity associated with any irrigation from treated CSG water has not been addressed or acknowledged. If irrigation is to occur using treated CSG water from wells on these properties, a salinity risk assessment may be required. This may require further discussion with Department of Resources Land Resource Officers. **Actions:** Consider consulting with Department of Resources Land Resource Officers in relation to developing a salinity risk assessment where treated CSG water may be used for irrigation (if applicable).	None of the properties associated with this application will use CSG water for irrigation.	
26.	**Issue:** The figures provided in	Figures have been updated and are included in Appendix F of this document.	

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
	Appendix 3 of the Supporting report do not clearly identify the Australian Land Use Mapping (ALUM) classes of PALUs detailed in the Darling Downs Regional Plan. **Actions:** Update the figures including legends to clear identify the ALUM Classes of PALUs detailed in the Darling Downs Regional Plan.		
27.	**Issue:** The figures provided in Appendix 4 of the Supporting report do not clearly identify the ALUM classes of PALUs detailed in the Darling Downs Regional Plan. **Actions:** Update the figures including legends to clear identify the ALUM Classes of PALUs detailed in the Darling Downs Regional Plan.	The figures have been updated and are included in Appendix G of this document.	

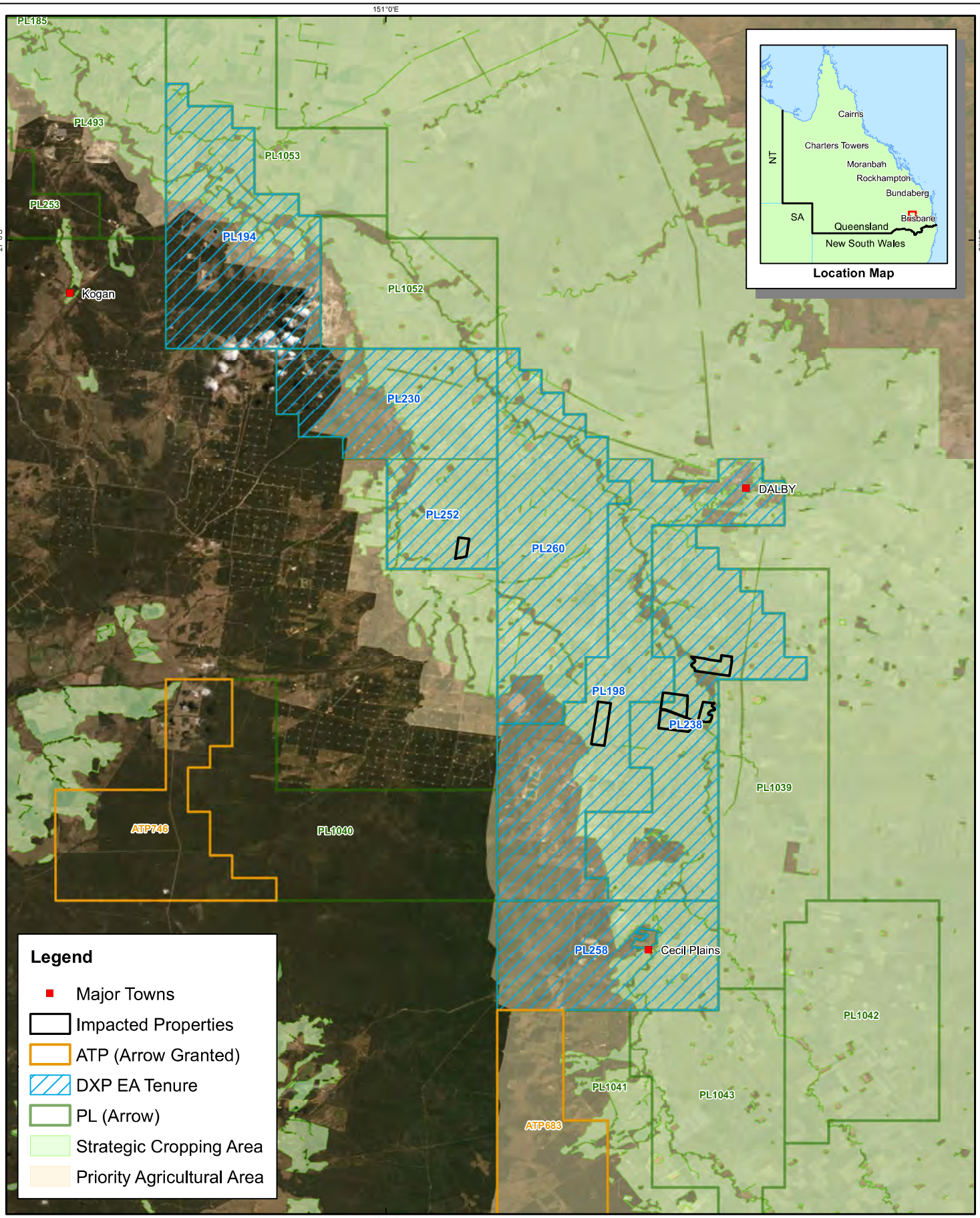
Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
	Arrow Response: These are State Govt generated figures and so legend cannot be amended. This has previously been addressed by inclusion of Section 4.2.3 of the report & a note added to the Appendix 4 cover.	This information is included in Appendix G of this document.	
28.	**Issue:** Appendix K, containing details on asset specific thresholds and investigation methods of subsidence, is referenced in Appendix 9 but is not provided as an attachment to the Supporting report. **Actions:** Provide Appendix K.		
	Arrow Response: This issue is requesting that Appendix K of the WWMP be included along with the Subsidence Assessment and	This information has been included in Appendix H of this document.	

Requirement Notice 1			
Item	**The Department of State Development, Infrastructure, Local Government and Planning Requirement Notice**	**Arrow's Response**	**Comment**
	Monitoring extract that is included as Appendix 9 of the application. It appears that Appendix K of the WWMP is the technical memorandum.		

Part 3 – Appendices

Appendix A -Revised Figure 1.1.

ARROW ENERGY - SURAT BASIN



Appendix A - Figure 1-1 DXP EA Tenures

Source: Arrow Energy Pty Ltd
Geoscience Australia
Dept. Natural Resources and Mines

Date: 1/11/2022
Issued To: A Tapsall
Author: awolhuter

0 5 10
Kilometres

Scale: 1:300,000 @ A3
Coordinate System: GCS GDA 1994

N

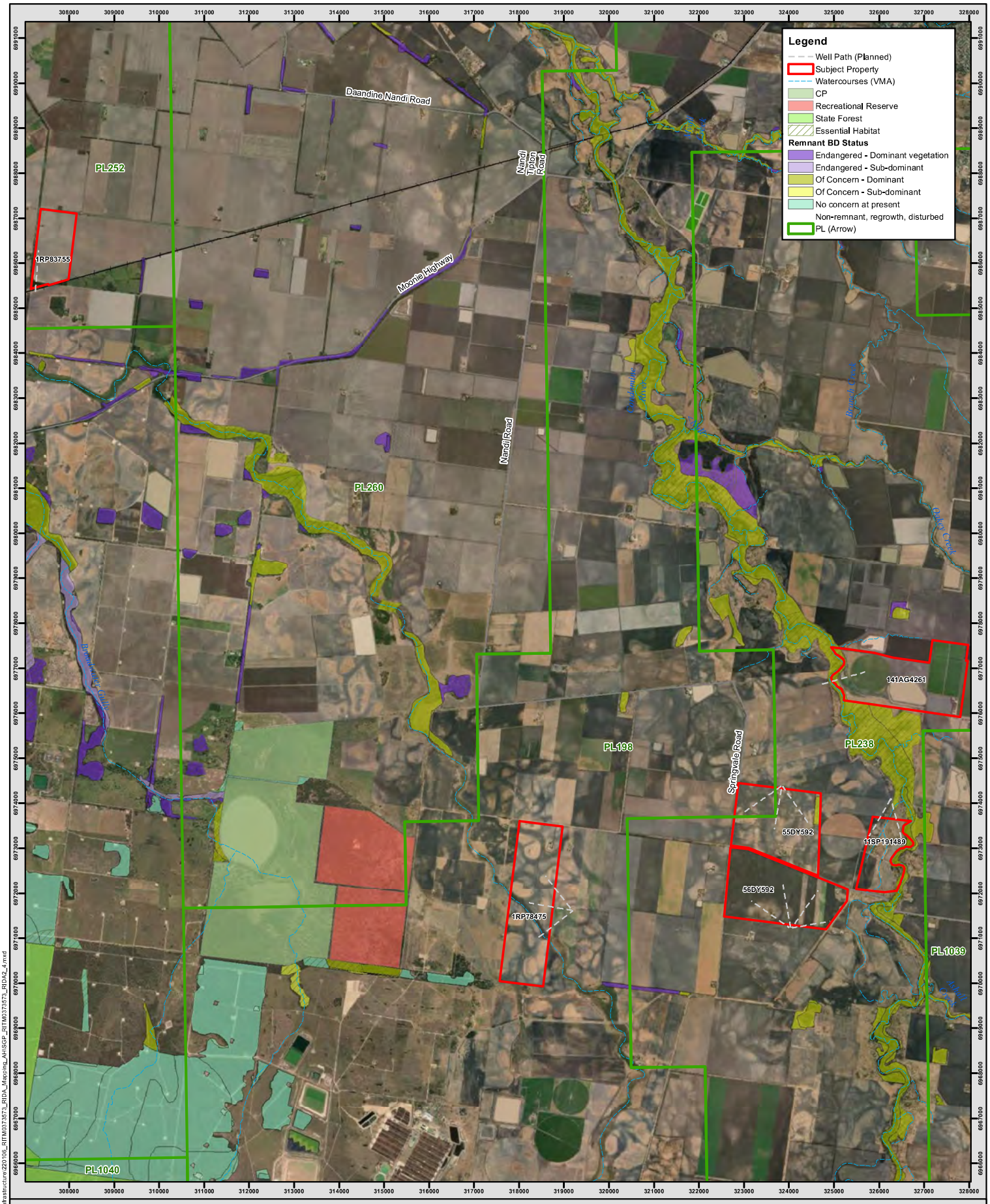
arrow energy
go further

Document R:\GIS\Geomatics_Team\WORK_REQUESTS\General\220624_RITM0422088_DXP_EA_Tenures_AH\21101_RITM0422088_DXP_EA_Tenures_AT.mxd

NOT FOR CONSTRUCTION

Date: 1/11/2022

Appendix B – Revised Figure 2.1



Appendix B - Figure 2-1 RIDA - Properties associated with Application

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 12/07/2022
Issued To: A Hall
Author: coellermann

Kilometres
0 0.5 1 2 3 4

Scale 1:77,500 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\Infrastructure\220106_RITM0373673_RIDA_Mapping_AH\SGP_RITM0373673_RIDA2_4.mxd

Appendix C – Subsidence Technical Memorandum

Level 19, Tower B, 799 Pacific Highway
Chatswood
NSW 2067 Australia

coffey.com

Memorandum

Recipient	Arrow Energy Pty Ltd
Memo date	25/09/2018
Author	Coffey Environments Australia Pty Ltd
Project number	ENAUABTF20484AA
Memo Subject	SGP Stage 1 CSG WMMP: Subsidence Technical Memorandum

1. Introduction

This memorandum presents a subsidence monitoring technical memorandum as part of development of recommendations for a monitoring network and sampling regime for the Arrow Energy Pty Ltd (Arrow) Surat Gas Project.

The work was carried out as part of a programme of work by Coffey Services Australia Pty Ltd (Coffey) to establish the Stage 1 Coal Seam Gas (CSG) Water Monitoring and Management Plan (WMMP) for the Arrow Surat Gas Project (SGP). This programme includes development of a monitoring network and sampling regime compliant with approval conditions, the Environmental Impact Statement (EIS) and a Supplementary Report to the EIS (SREIS).

This memorandum responds to Condition 13g which calls for:

> *A program to monitor subsidence impacts from the action, including trigger thresholds and reporting of monitoring results in annual reporting required by condition 28.*
>
> *If trigger thresholds are exceeded, the approval holder must develop and implement an action plan to address impacts within 90 calendar days of a trigger threshold being exceeded.*

Coffey interpret that compliance with Condition 13g will require:

1) A subsidence monitoring program.

2) Trigger thresholds.

3) Reporting of monitoring results in annual compliance reporting.

4) Action plan for trigger exceedances.

Arrow contributes with other CSG proponents to a subsidence monitoring program involving use of satellite imaging using Interferometric Synthetic Aperture Radar (InSAR) which provides baseline data and a regular interpretation of ground movement over the area of CSG extraction or planned extraction.

Development of a subsidence monitoring program that utilises information available, together with dedicated subsidence measuring devices, establishes trigger thresholds and defines an action plan for trigger exceedances will require:

- Calculated assessments of indicated subsidence for different regions within areas potentially affected by CSG drawdown.
- A risk assessment process to establish locations for strategic geodetic monitoring and/or extensometers.
- Trigger levels, derived from the calculated assessments of potential subsidence, and taking into account the outcomes of the risk assessment process.
- A program for annual monitoring or longer term monitoring if considered necessary.
- Reporting of the results of the ongoing monitoring, including interpretation, and an action plan for trigger exceedances that would be included in the annual reporting.

The objective of the subsidence monitoring program will be to identify whether assets or the environment are adversely affected by ground subsidence resulting from SGP CSG extraction activities.

This memorandum provides:

- Assessment of long term subsidence associated with proposed Arrow Surat Gas Project operations based on:
  - Review of measurement of subsidence and groundwater levels carried out in proximity to existing Arrow domestic gas CSG projects (these current domestic gas projects do not form part of the SGP); and
  - Estimates of subsidence based on predicted groundwater drawdown from the EIS and SREIS.
- An assessment of risks posed by subsidence to assets within or in close proximity to Arrow SGP operations.
- Recommendations for additional ground movement monitoring such as strategically located geodetic monitoring and extensometers.
- Recommended trigger levels for the SGP.
- Recommendations for continuing monitoring for the SGP.

2. Background

This memorandum addresses the Arrow Surat Gas Project (SGP). The SGP will be developed in a series of Drainage Areas shown in Figure 1. The drainage areas define the extent of individual well fields which will be developed.

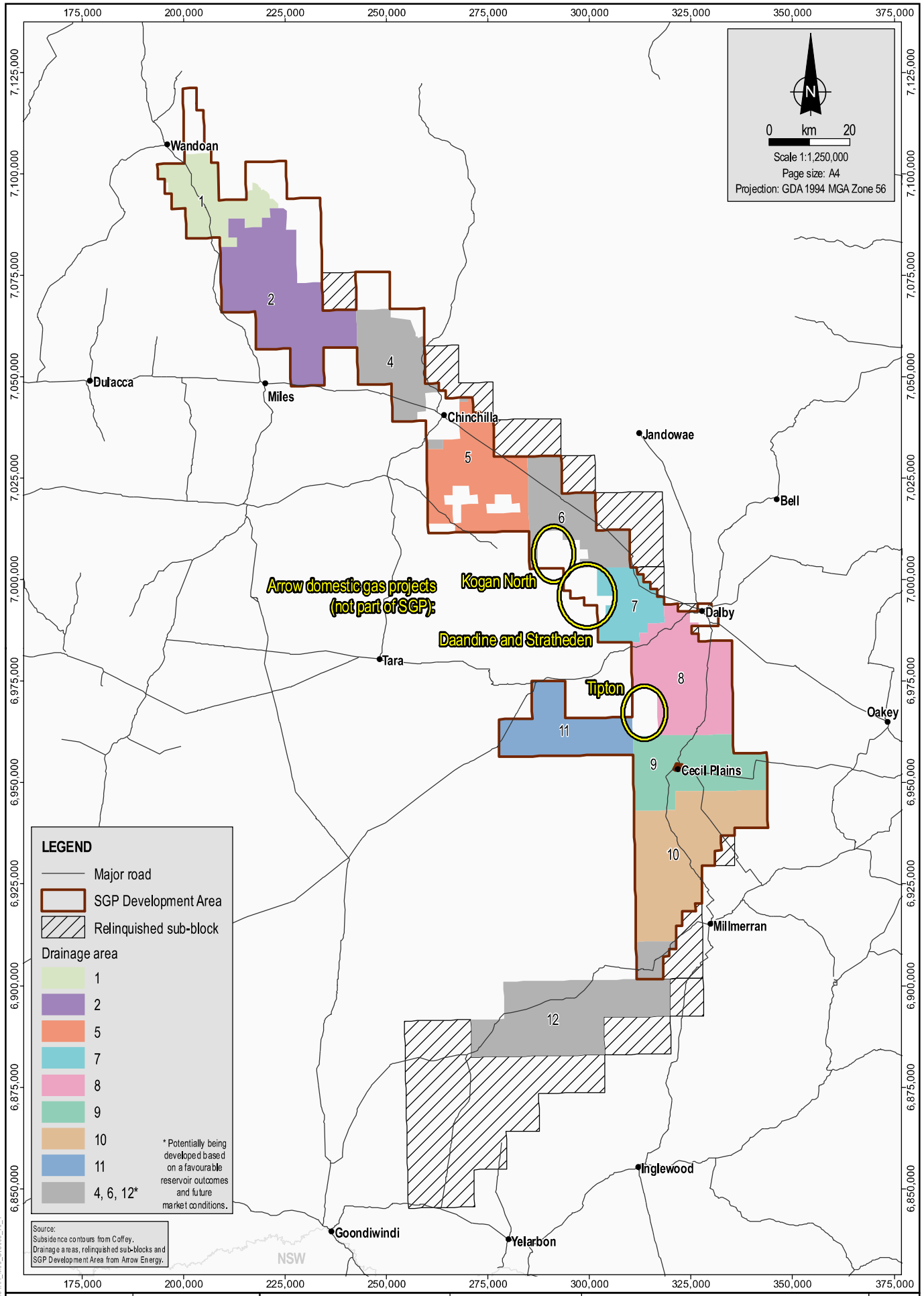
The SGP project development area totals 61,000 km^2 with projected CSG water production of 510 GL over 40 years involving approximately 6,500 wells.

Arrow also has four domestic gas production fields in the Surat Basin which do not form part of the SGP. The domestic gas production by Arrow has occurred since 2006 at:

- Tipton West - approximately 20 km south of Dalby in production since September 2006;
- Kogan North - approximately 40 km west of Dalby (owned in joint venture with Stanwell Corporation Ltd) in production since January 2006;
- Daandine - approximately 40 km west of Dalby in production since September 2006; and
- Stratheden - approximately 20 km west of Dalby.

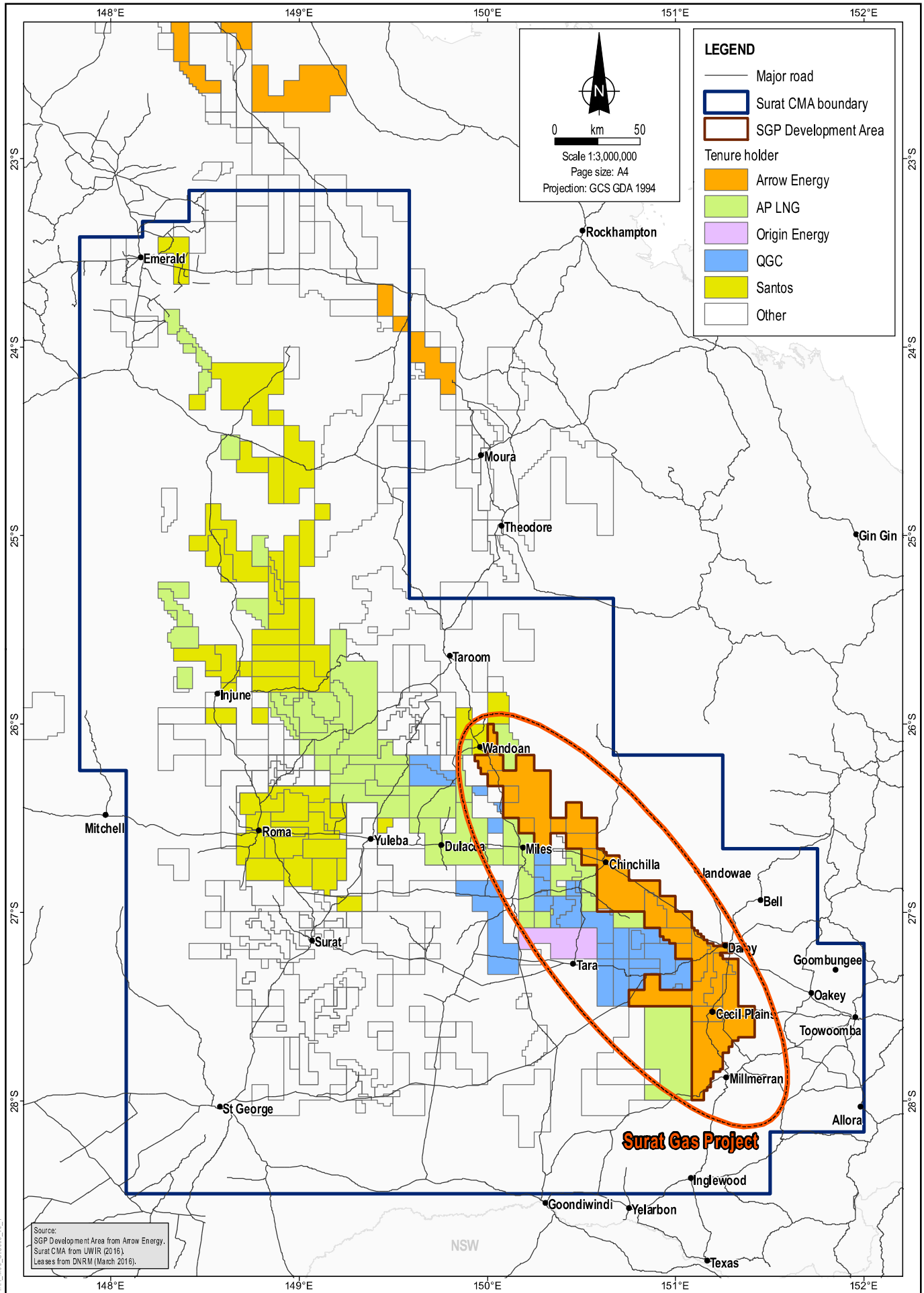
Production drilling of Arrow's Surat Basin domestic gas fields started in 2005. Initial development began at Kogan North, followed by Tipton West, Daandine and Stratheden. The target coal seams in the Surat Basin are the Walloon Coal Measures. While these domestic operations do not form part of the Arrow Surat Gas Project they provide valuable experience in relation to groundwater drawdown and subsidence occurring during their operation. The locations of the Arrow domestic production fields are also shown in Figure 1.

Other proponents also have CSG developments in the Surat Basin. These are to the west of the Arrow SGP as shown in Figure 2.



MXD Reference: 20484AA_M05_GIS005_v0_1

coffey A TETRA TECH COMPANY	Date: 04.05.2017 Project: ENAUABTF20484AA File Name: 20484AA_M05_F001_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Arrow Drainage Areas Surat Gas Project (Domestic CSG Projects also shown)	Figure No: 1



MXD Reference: 20484AA_M05_GIS006_v0_1

coffey A TETRA TECH COMPANY	Date: 04.05.2017 Project: ENAUABTF20484AA File Name: 20484AA_M05_F002_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Arrow CSG leases in relation to leases held by others	Figure No: 2

2.1. Cause of subsidence

Coal seam gas occurs within coal formations through adsorption to the surface of the coal under hydrostatic pressure. Depressurisation of the coal seams below a threshold (by groundwater extraction) reduces hydrostatic pressure and liberates the gas from the formation. As the pressure falls, the gas migrates to the extraction wells. This process requires substantial lowering of groundwater pressure.

At any point below the ground surface, the weight of overlying strata is supported partly by water pressure and partly by the fabric of the rock mass. Any reduction in water pressure therefore results in an increased proportion of the load being carried by the rock mass, leading to compression of the rock. The combined compression over the thickness of rock strata affected by reduced water pressure results in subsidence at the ground surface.

This process commonly occurs during dewatering for construction, though, in the construction case, the materials involved are typically soils which are much more susceptible to settlement than the consolidated coal measure rocks that are subject to groundwater depressurisation for CSG production. Engineering methods for assessment of settlement from this effect are well developed and require knowledge of the mechanical properties of the ground and the changes in groundwater pressure across the full ground profile.

In addition to the above mechanism, liberation of adsorbed gas from coal surfaces can result in a reduction in coal volume and provide a further component of subsidence. Sorption-induced compaction has been measured in laboratory studies at around one per cent (for carbon dioxide and methane combined) of the coal thickness (Robertson 2005). The extent of this effect will relate to initial adsorbed gas content and the quantity of gas released.

The properties governing the contraction of coal due to gas removal from seams in the Walloon Coal Measures are not available. Robertson (2005) reported a strain of 0.001 for a gas pressure change of 500 kPa (equivalent to pressure under 50 m of water) in a bituminous coal seam. While it is unclear if this value would relate to Surat Basin coals, it does give an indication of potential for shrinkage due to reduction in gas content.

2.2. Geological setting

A description of the geological setting is provided in the SGP Environmental Impact Statement (EIS). Elements of this in the context of their properties as relevant to groundwater behaviour are discussed below.

The Surat Basin forms a north south oriented trough with the Arrow SGP operations concentrated along the eastern margin west of the Condamine River.

Figure 3 sets out the typical stratigraphic profile within the Surat Basin in areas of Arrow SGP operations. The Walloon Coal Measures is the host formation. It includes the Juandah and Taroom Coal Measures, the target strata normally screened in Arrow's Surat SGP wells. Lower permeability Tangalooma Sandstone separates the Juandah and Taroom.

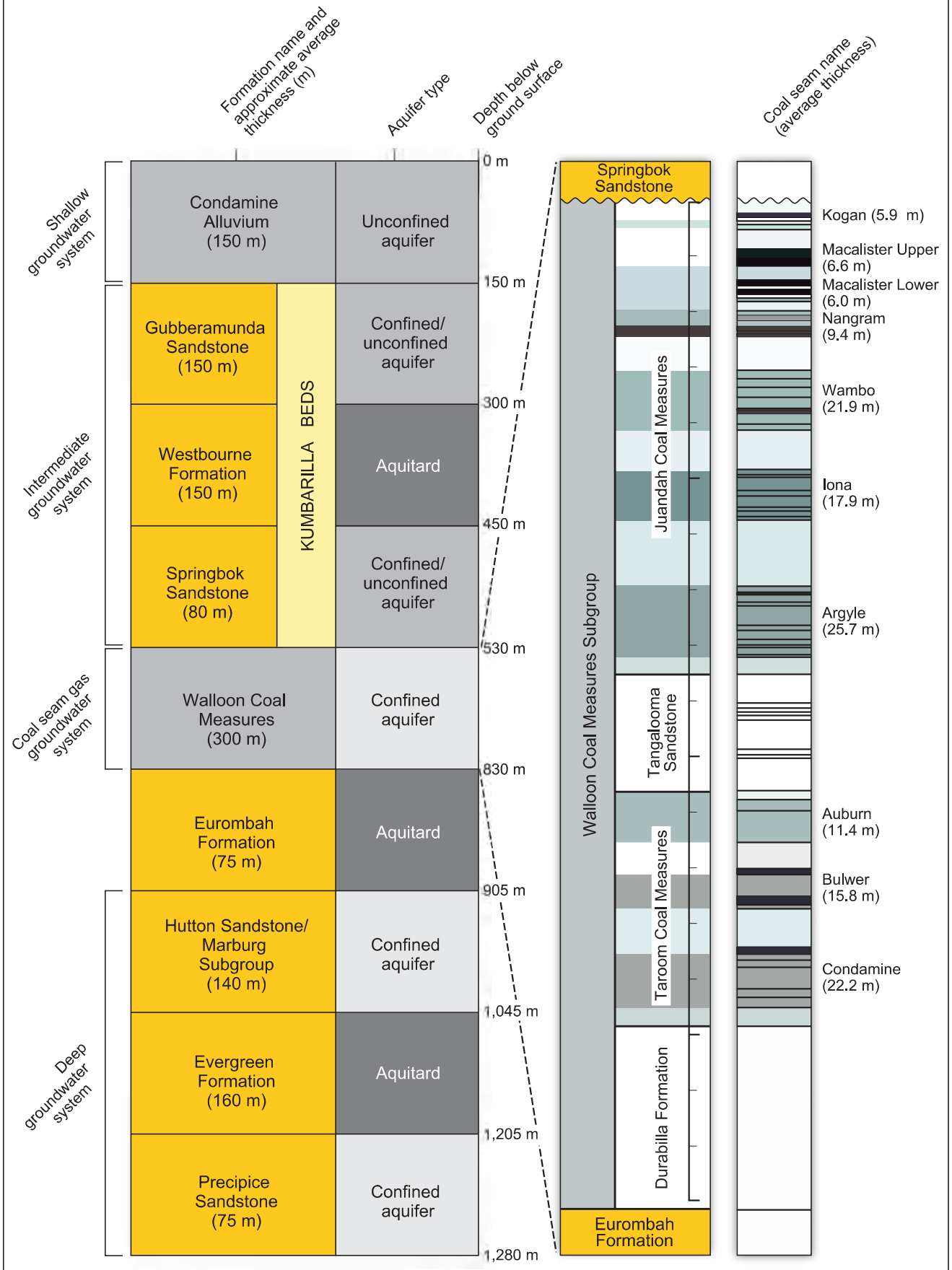
Overlying the Walloon Coal Measures are the Kumbarilla Beds comprising the Gubberamunda Sandstone, the Westbourne Formation and the Springbok Sandstone. The Kumbarilla Beds are generally of low permeability and act to separate groundwater pressure changes in the Walloon Coal Measures from the overlying alluvial sediments of the Condamine Alluvium.

Underlying the Walloon Coal Measures is the Hutton Sandstone. This lower permeability aquifer formation reduces the influence of drawdown below the Walloon Coal Measures.

The upper units of the Kumbarilla Beds which overlie the coal measure rocks are truncated by erosion at the eastern margin of the basin where Arrow SGP operations are concentrated. As a result the Gubberamunda Sandstone is not present in some Arrow SGP leases. This is also true of the Westbourne Formation and Springbok Sandstone, such that in the east of some tenements the coal measures subcrop underneath the Condamine Alluvium. Low permeability clays at the base of the

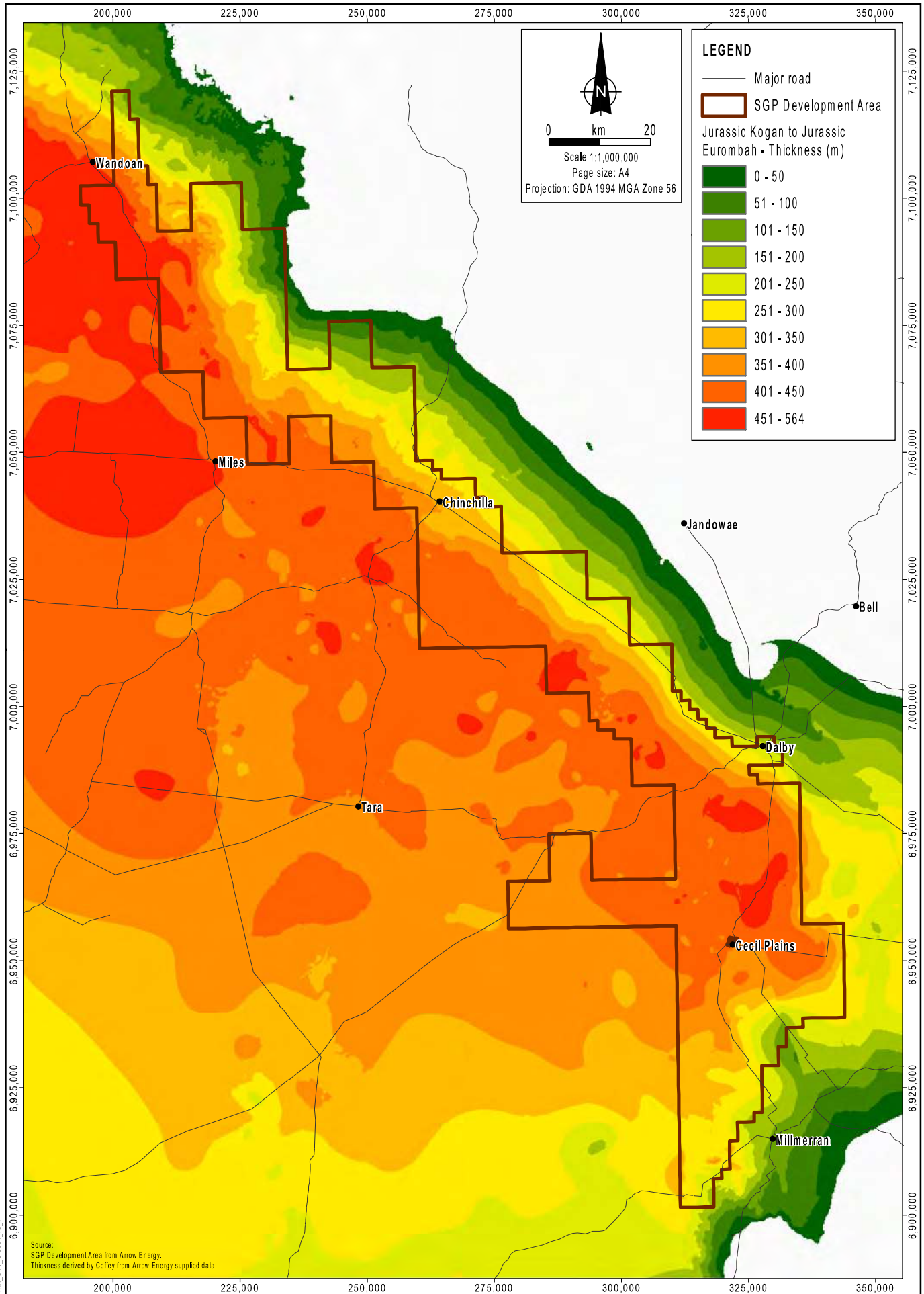
alluvium, as well as low permeability weathered and unweathered sediments interbedded in the coal measures also act to separate groundwater pressures between the alluvium and the coal measures.

The thickness of the Walloon Coal Measures changes over the Surat Basin. In particular, along the eastern margin the Walloon Coal Measures are truncated at the erosional contact with the Springbok Sandstone. Figure 4 presents contours of thickness of the Walloon Coal Measures obtained by adding the thicknesses of the component units provided by Arrow from their geological model of the area. Within the Arrow leases (the SGP Development Area) the thickness ranges from greater than 450 m to less than 50 m.



coffey A TETRA TECH COMPANY	Date: 05.05.2017 Project: 754-ENAUABTF20484AA File Name: 20484AA_M05_F003_GRA	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Typcial Surat geological profile in Arrow SGP tenements	Figure No: 3

AI Reference: 20484AA_M05_GRA001.ai_1



coffey A TETRA TECH COMPANY	Date: 31.03.2017 Project: ENAUABTF20484AA File Name: 20484AA_GT1_F004_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Jurassic Kogan to Jurassic Eurombah	Figure No: 4

MXD Reference: 20484AA_GT1_GIS004_v0_1

3. Subsidence Assessment

3.1. Subsidence monitoring

Monitoring of subsidence was carried out by Altamira (Altamira, 2016) using employed data obtained from Radarsat-2 satellite images covering 10,736 km^2 of Arrow SGP leases. Over the period July 2012 to December 2015 a total of 34 or 35 images were obtained for Arrow SGP leases (the number of images changed slightly depending on the ground location in relation to satellite paths). The images were generated using a radar with a working frequency of 5.3 GHz (C-band) and a wavelength of 5.6 cm.

The change in phase difference between locations was used to interpret changes in relative position. Interpretation involves identification of phase difference between points within the areas scanned for each data set and applying various corrections to account for the elevation of the points, the velocity of the satellite and atmospheric effects.

The phase difference between locations is recorded from the satellite which is not directly overhead on each traverse and the effect of ground slope also influences the phase shift from differing vantage points. These factors have an influence on the interpreted movement. For the purposes of this assessment movements interpreted from the InSAR monitoring have been treated as being vertical.

Some areas are unsuited to the use of this method of movement interpretation. For example ploughed fields produce variable response, and generally produce a low density of reliable interpretations. Altamira assessed the quality of each interpreted point and did not report those points of low reliability. The method produced results on an 8 m by 5 m grid, and further averaging appears to have been carried out to yield results at approximately 30 m spacing. The error of the resulting values is not identified explicitly by Arrow. An indication of the magnitude of error for individual points can be assessed from the time variation of results for individual locations. These show variability typically within 5 mm from point to point around a trend.

The interpreted results were presented in the form of coloured dots representing the rate of ground movement per year. Movement of less than 8 mm per year (rise or fall) was treated as stable and is marked with a green dot. Other colours were used to indicate upward or downward movement in the range 8 to 16 mm per year and greater than 16 mm per year. Areas where reliable data could not be obtained were not assessed and were left blank.

Figure 5 presents the interpreted average rate of ground movement from July 2012 to December 2015.

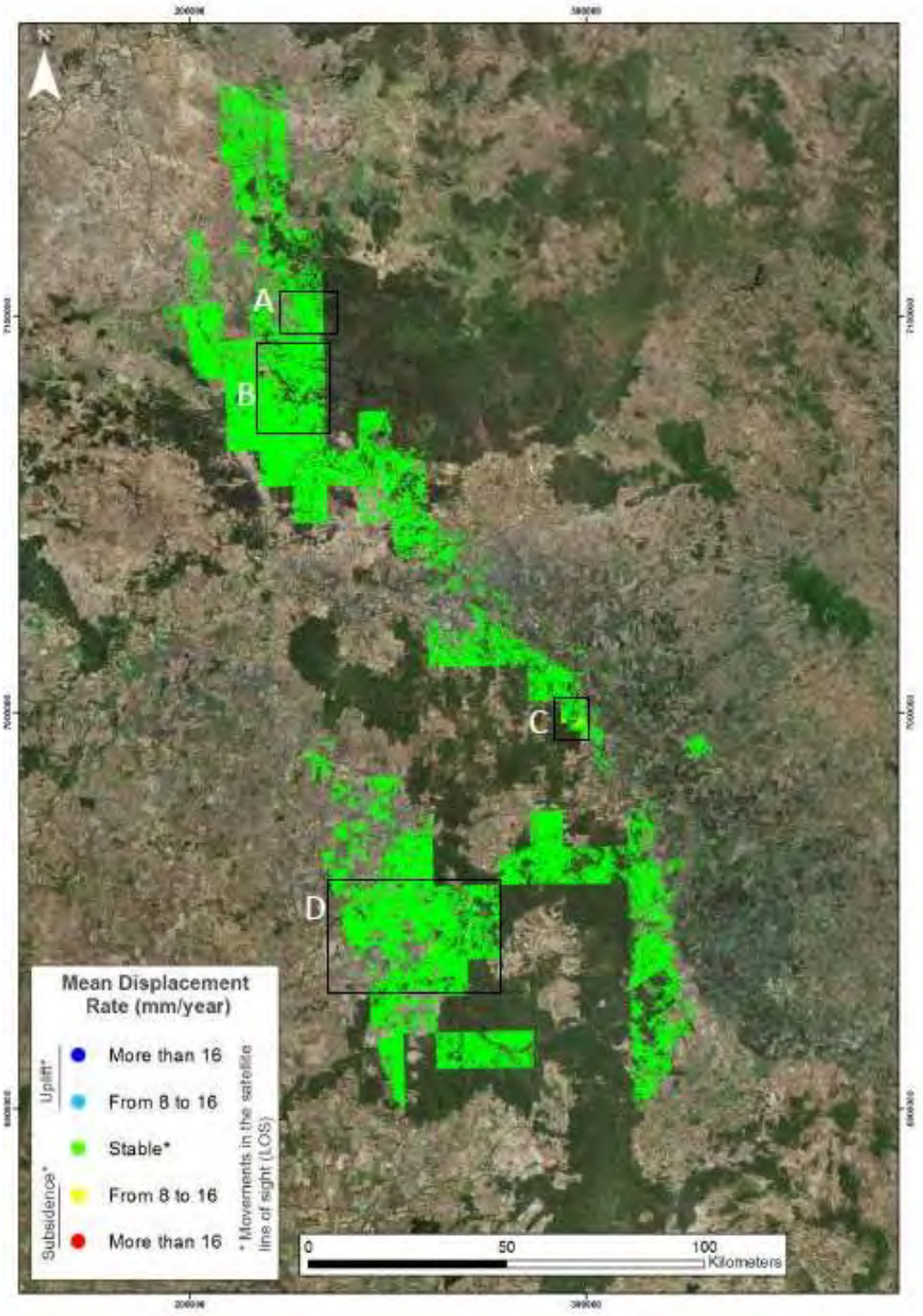


Figure 5 - Interpreted ground movement rate - Arrow SPG leases (Altamira 2016)

It is clear from Figure 5 that no widespread subsidence occurred over the period of monitoring. Altamira highlighted areas where ground movement (at rates greater than 8 mm per year) was detected. These are marked in Figure 5 as Areas A to D.

3.2. Domestic gas project

Of these areas the only area corresponding to active CSG extraction by Arrow is Area C which contains the Daandine CSG field. Figure 6 presents a more detailed view of this area.

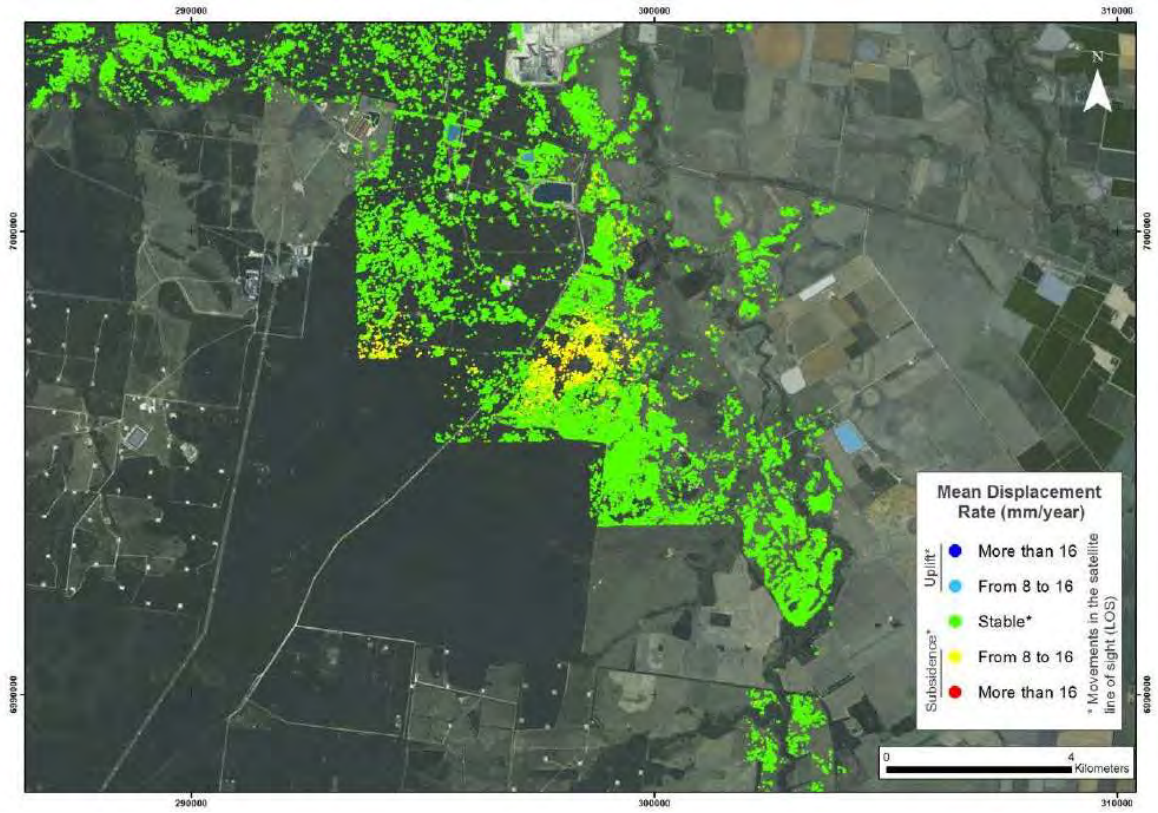


Figure 6 - Subsidence InSAR results - Area C - covering Daandine CSG field (Altamira 2016)

The area containing yellow shading (with some red points) at the centre of Figure 7 corresponds approximately to the Daandine CSG field, and is further enhanced (zoomed in) in Figure 7.

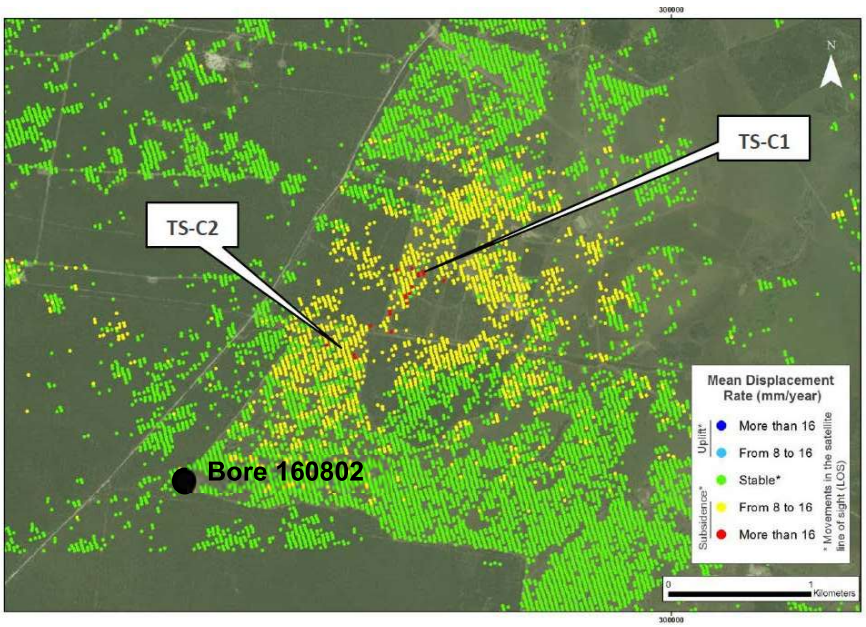


Figure 7 - Detail of ground movement interpretation - Daandine CSG field (Altamira 2016)
At highlighted time-series monitoring points TS-C1 and TS-C2 in Figure 7 Altamira provided an assessment of the variation of movement over the period of monitoring, as presented in Figure 8.

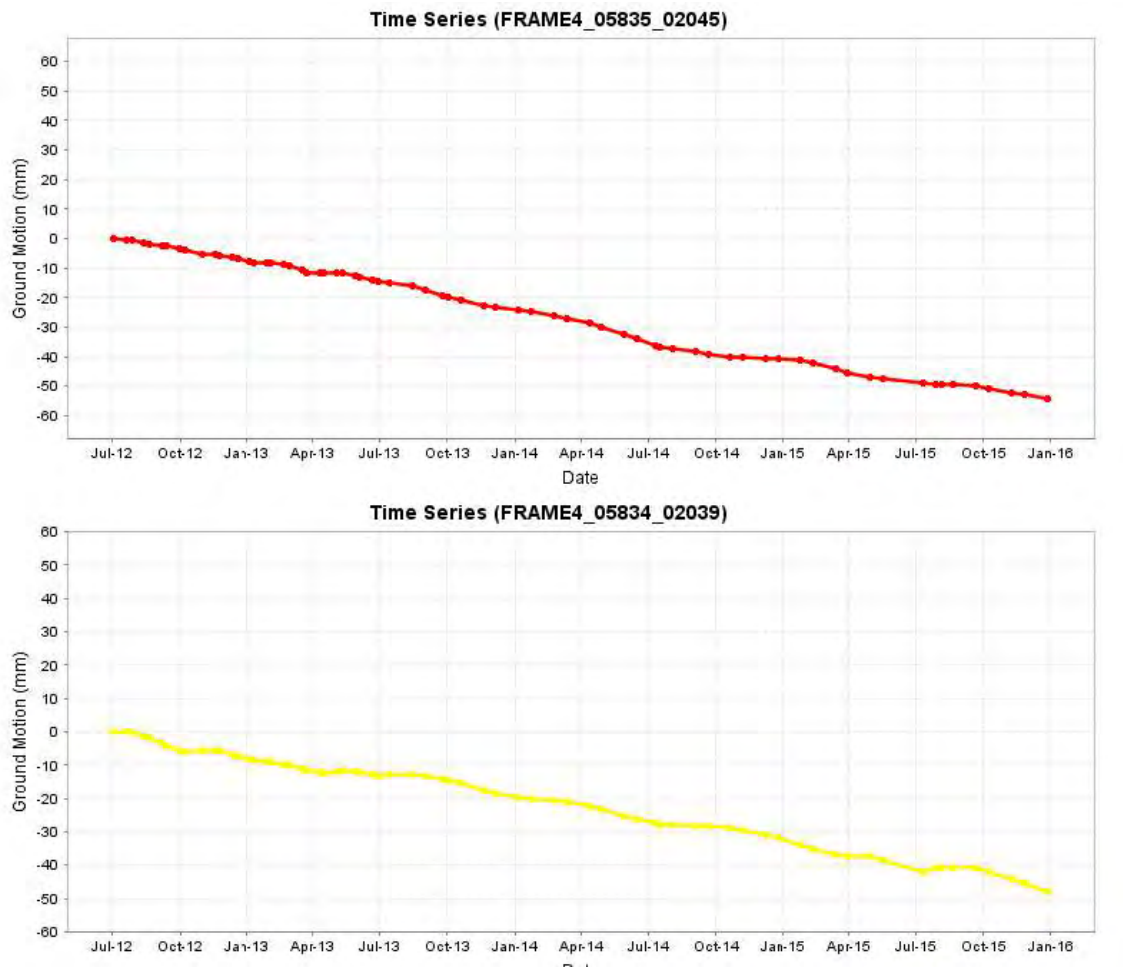


Figure 8 - Ground movement interpretation versus time TS-C1 (upper) TS-C2 (lower) (Altamira 2016)

Interpretation of the rate of downward groundwater movement based on these results is 17 mm/year for TS-C1 (50 mm over three years) and 14 mm/year for TS-C2 (41 mm/year over three years). From the form of the interpreted ground movement it is clear that the rate of movement is reasonably even over the affected area. Undulations in the response with time are apparent in the interpreted ground movement. Earlier work by ARUP (2014) compared early results from InSAR monitoring with rainfall records and concluded that widespread movements less than 5 mm occur and appear to be associated with seasonal rainfall and temperature.

Coffey considers the semi-regular undulations in the time-series response (Figure 8) are due to effects of rainfall and temperature, but the overall decline is expected to be a result of drawdown associated with the Daandine CSG depressurisation.

By way of contrast with Daandine, the interpreted movement at the Tipton CSG field to the south is less than 8 mm per year, as is the interpreted movement for the Stratheden and Kogan CSG fields.

Daandine area ground movement

Arrow provided access to the detailed records from the Altamira InSAR analysis. These records were used to review InSAR results in the vicinity of monitoring bores. Ground movement in the vicinity of monitoring bore 160802 was obtained and revealed movement of 30 mm from April 2012 to December 2016.

Ground movement was extracted from the InSAR records covering an east-west section across the southern limit of the Daandine CSG well field, and crossing a series of CSG wells (Figure 9). InSAR results show settlement up to approximately 60 mm over the monitoring period (April 2012 to December 2016). This was carried out to assess the level of variability of ground movement between wells.

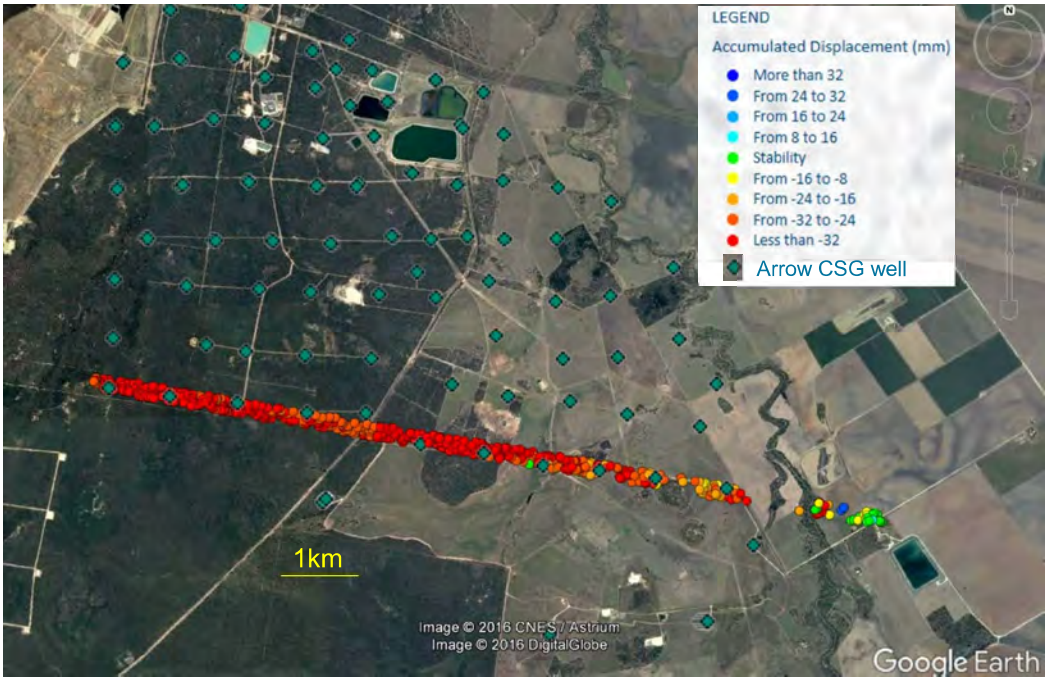


Figure 9 - East-west traverse through Daandine CSG Field – Displacement (April 2012 to December 2016)

Interpreted ground movement monitoring for this traverse is plotted in Figure 10, which also indicates the position of the individual CSG wells along the traverse. It is interesting to note that the scatter of result is greater in the cleared ground than in the wooded areas (darker green in Figure 9).

In comparing the ground movement results with the positions of the CSG wells there is no indication of greater settlement at the well locations with less settlement between wells. Within the scatter of the results, the ground movement is indicated to be quite even.

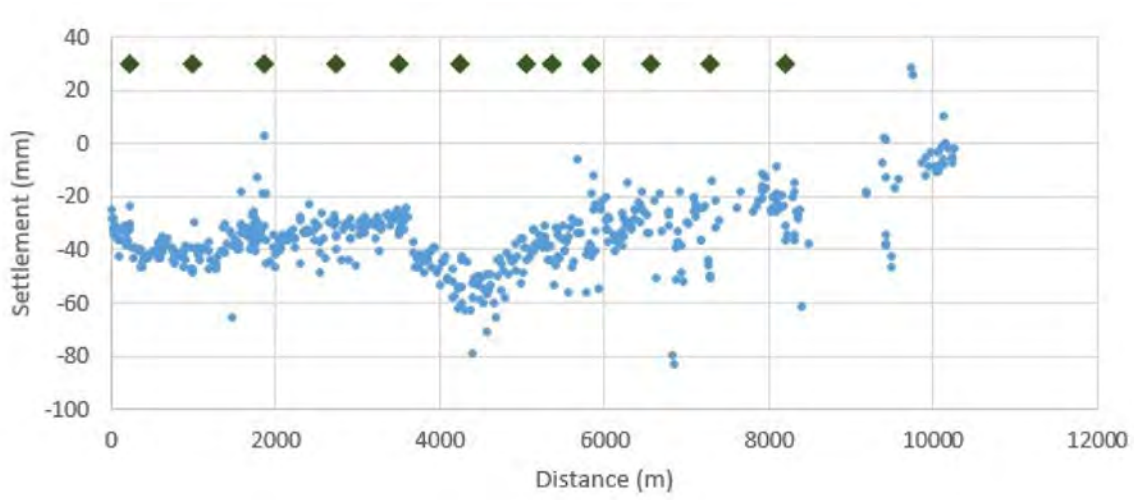


Figure 10 - Ground movement - East-west traverse at southern limit of Daandine CSG Well Field (Well locations marked as green diamonds)

It is also useful to note the steepest gradient of movement (at distance 4000 m in Figure 10) is approximately 30 mm per kilometre.

3.2.1. Groundwater level monitoring

A large number of groundwater monitoring bores are in operation in the Surat Basin in support of CSG operations. These results are accessible via the Queensland Government data globes on Google Earth. Monitoring bore 160802 is located at the southern limit of the Daandine CSG field (see Figure 7). Figure 11 presents measured drawdown from November 2014 to March 2016 for monitoring bores screened within the Juandah Coal Measures. The results show steady decline in groundwater level over this period. InSAR results averaged from the area surround Monitoring Bore 160802 showed a gradual downward movement of 30 mm over the period April 2012 to December 2016. Monitoring Bore 160802 is accompanied by two adjacent bores 160553 and 160394 each within 20 m horizontal distance of 160802. The cluster of bores covers a very useful set of monitoring results covering the target coal measures and the overlying and underlying formations.

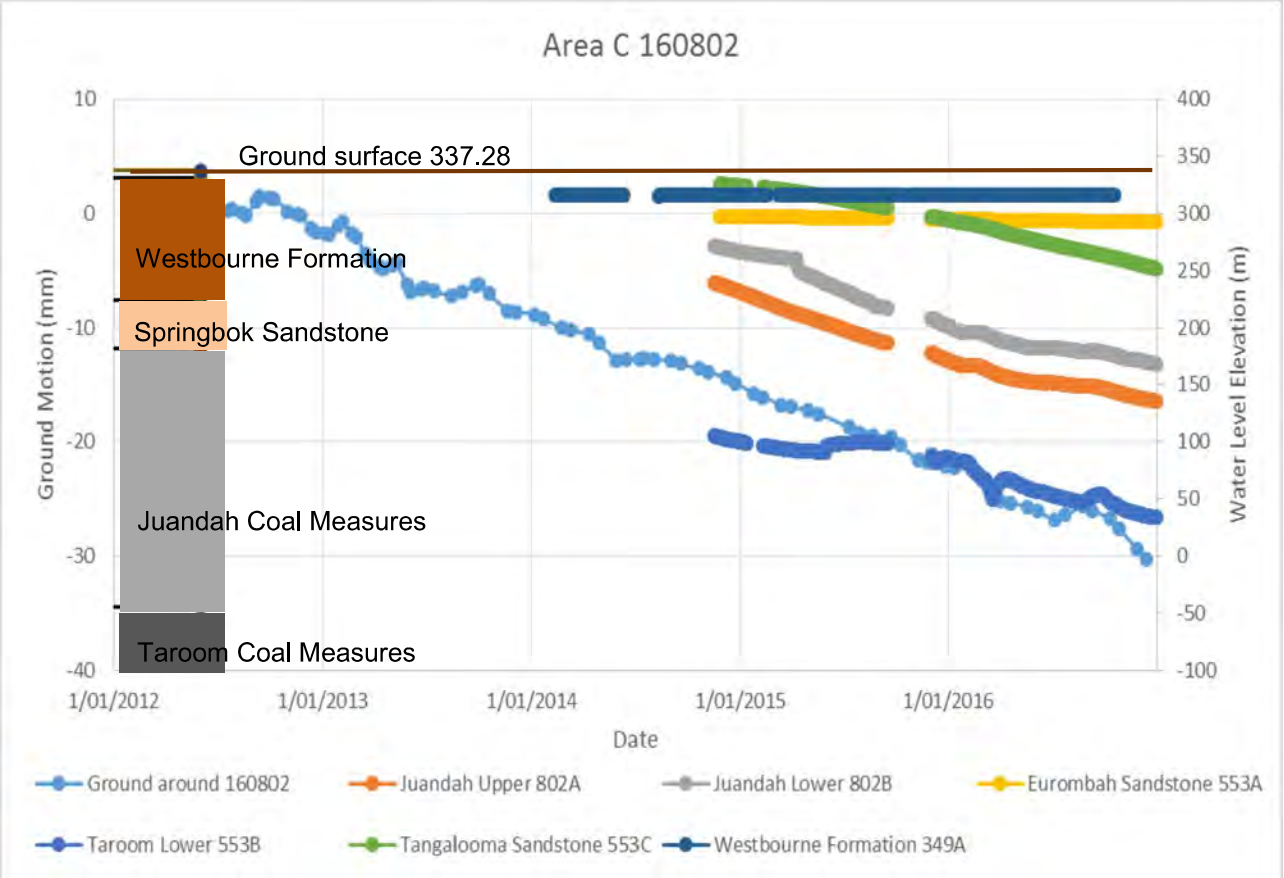


Figure 11 - Groundwater levels - Daandine CSG Field - Area C (Bore cluster 160802, 160349, 160553)

Groundwater levels obtained for 160802 for the Juandah Formation appear to have an offset in the data obtained from the Queensland Government Globe as Arrow advised that artesian pressures are not encountered in the Daandine CSG field. For this assessment it is assumed that the relative changes in groundwater pressure are correct, irrespective of any offset in the absolute level. Corrected values were obtained from Arrow and these were plotted in Figure 11. The length of record was greater than that available from the Queensland Globe records. The extended period was not available in time to be analysed for this memorandum. The cluster of bores is located approximately 50 m from the nearest CSG well. Arrow have advised:

> *The Target Flowing Pressure is around 35 Psi at the bottom of lowest Seam or Water Level around 5 to 10 meter below the lowest seam (Condamine coal seam).*

This is interpreted to mean that for the Juandah the groundwater level would be at 24 m (24 m water head is 35 psi) above the base of the Argyle and for the Taroom the groundwater level 24 m above the base of the Condamine. These values would reflect conditions at the CSG well. Away from the well groundwater level would rise and average groundwater level between wells could be substantially higher.

Groundwater monitoring in an adjacent Bore 160553 (part of the cluster of monitoring bores at 160802) shows little drawdown within the Taroom Coal measures during 2016 and an overall decline of 55 m from November 2014 to March 2016 but relatively stable levels in the Eurombah Formation (variation within 5 m of the starting level) over the same period. A further adjacent monitoring bore (Bore 160349) shows stable groundwater level in the Westbourne Formation (above the Walloon Coal Measures). This is interpreted to indicate that groundwater drawdown in this area has occurred over the full thickness of the Walloon Coal Measures (comprising the Juandah Coal Measures and the Taroom Coal Measures) but very limited drawdown has occurred in the units above and below the Walloon Coal Measures.

Groundwater levels in the Tipton CSG field as recorded in Bore 160799 (see Figure 12 below) show smaller changes compared with those recorded at Bore 160802.

Figure 12 - Measured groundwater level change - Tipton (Bore 160799)

This monitoring illustrates that from November 2014 to March 2016 some 45 m of drawdown had occurred in the Juandah Coal Measures in this area but very little drawdown took place in the lower Taroom Coal Measures. Bore 160799 (see Figure 13) is at the western margin of the Tipton CSG field. CSG Bores are also present to the west of Bore 160799 on a lease owned by QGC Pty Ltd. Settlement records from the InSAR data for this period indicate a settlement of only 4 mm on average for the area surrounding Bore 160799 (see Figure 12).

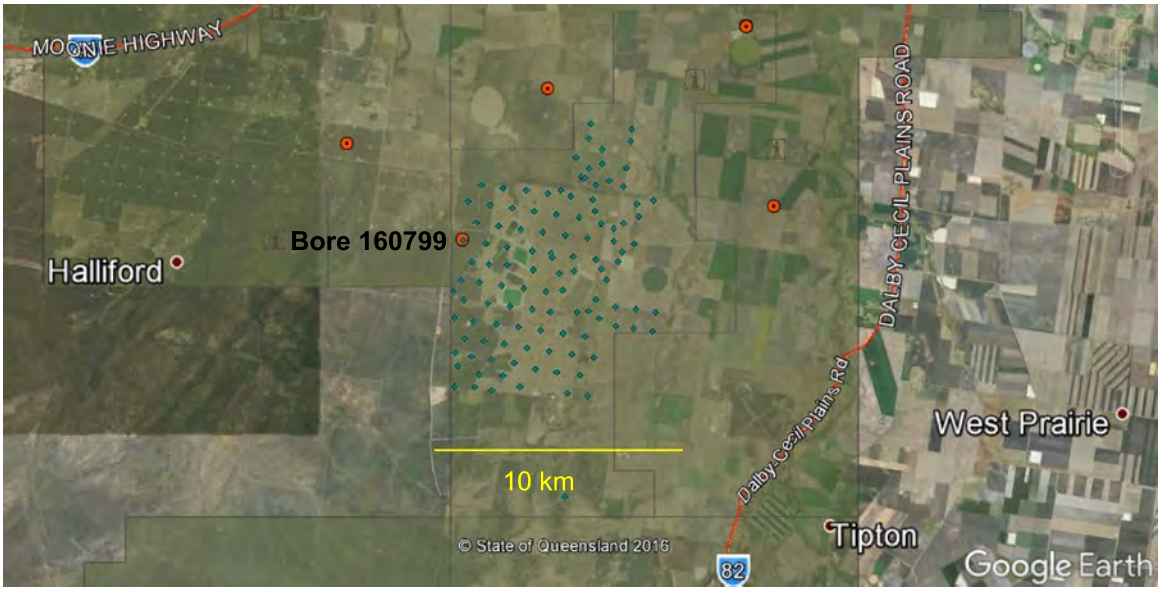


Figure 13 - Tipton CSG field (green dots) showing Bore 160799 location (Google Earth and Queensland Data Globe)

Bore 160678 located some 8 km to the east of the Daandine CSG field (see Figure 14) shows comparatively little change in groundwater level within the Juandah Coal Measures (see Figure 15 below). The groundwater level is presented together with the measured vertical movement at location TS-C1. Note that the scale of the water level axis is changed significantly from the previous water level plots to show the detail of the comparatively small change in groundwater level.

The monitoring shows a gradual reduction in groundwater level within the Juandah Coal Measures of approximately 2 m over a one year period. The InSAR data set does not cover the location of Bore 160678 but does provide results for a nearby area (see Figure 14). The average movement for these locations shows movement within a range of 5 mm from April 2012 to December 2016 and does not correlate with Arrow SGP operation.

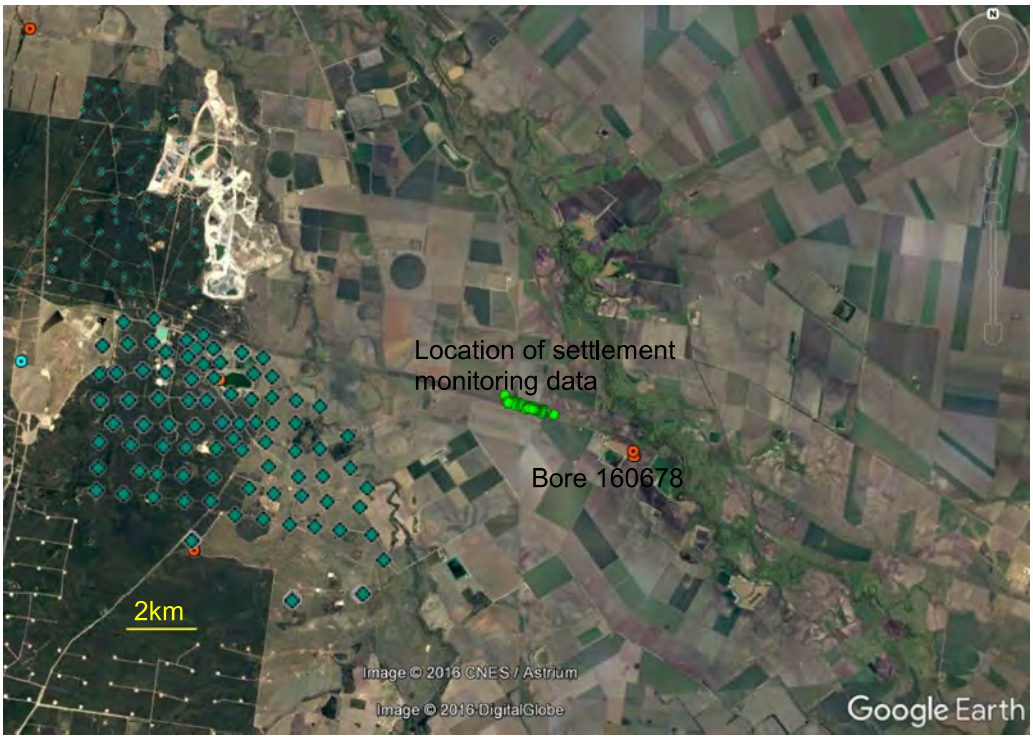


Figure 14 - Location Bore 160678 and settlement monitoring data location

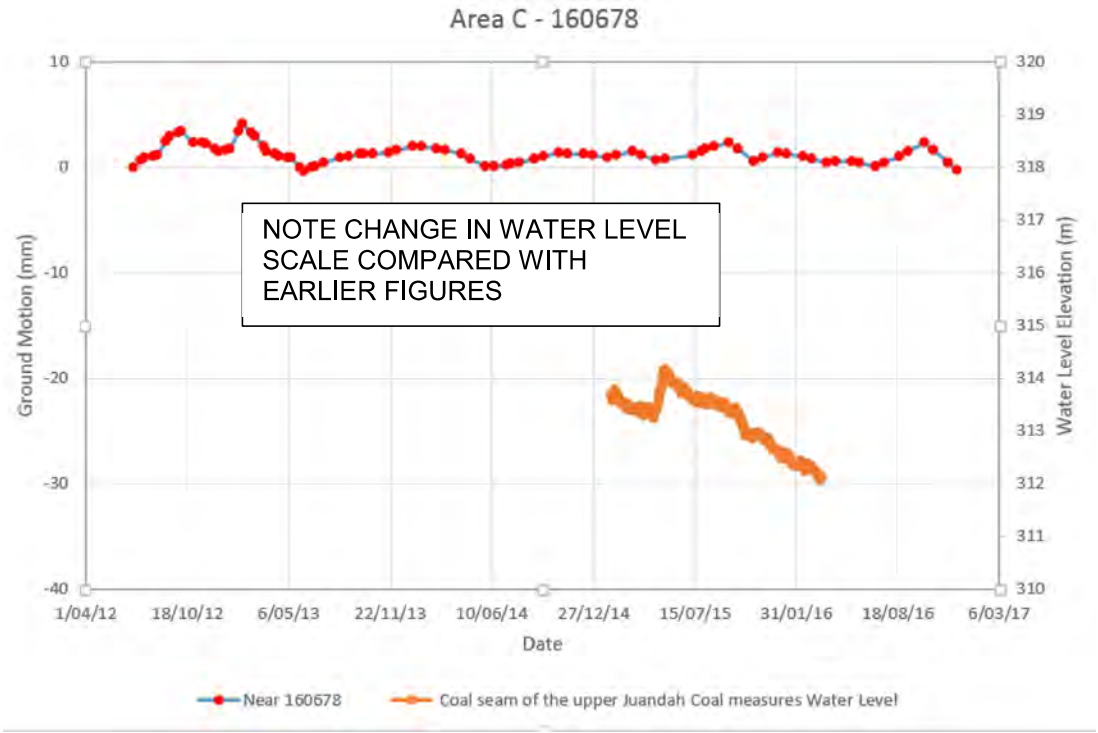


Figure 15 - Measured groundwater response Bore 160678 (8 km west of Daandine CAG field)

3.2.2. Settlement response to drawdown

The results of monitoring groundwater level variation and settlement provide a basis for assessing settlement as a function of groundwater level in the coal measure rocks of the Walloon Coal Measures. The Walloon Coal Measures are approximately 325 m thick in the current areas of operation of the Arrow domestic gas production fields (Tipton, Daandine, Kogan and Stratheden) as illustrated from drilling record for Bore 160802 (and adjacent bores) shown in Table 1 below. For the purposes of this assessment the Eurombah Formation (a sandstone unit) which is the lowest unit in the Walloon Coal Measures was not considered as it showed little drawdown response to CSG operations.

Table 1: Stratigraphy – Aggregated from Bore 160802 and adjacent 160553 (Daandine)

Formation	Top Depth (m)	Base Depth (m)	Top RL[1] (mAHD)	Base RL (mAHD)	Thickness (m)
Undifferentiated	0	5.99	337.18	331.19	5.99
Westbourne Formation	5.99	112.88	331.19	224.3	106.89
Springbok Sandstone	112.88	155	224.3	182.18	42.12
Juandah Sandstone	155	380.43	182.18	-43.25	225.43
Tangalooma Sandstone	380.43	381.63	-43.25	-44.45	1.2
Taroom Coal Measures	381.63	481.18	-44.45	-144	99.55
Eurombah Formation	481.18	not encountered	-144	-	-

1: Surface level 337.18 mAHD

Groundwater level monitoring in the Daandine CSG field indicated substantial drawdown in the Walloon Coal Measures (in both the Juandah and Taroom). Over the period November 2014 to March 2016 drawdown averaging 78 m occurred in the Juandah and 49 m occurred in the Taroom. Averaged over the Walloon Coal Measures, recognising the greater thickness of the Juandah, this corresponds to a decline in groundwater level of 69 m over the period November 2014 to March 2016. The InSAR results prepared by Altamira show a settlement of 11.4 mm over this period (see Figure 11).

Recognising that little drawdown occurred in the units above the Juandah Coal Measures or below the Taroom Coal Measures (taking a thickness of 325 m) an assessment of the average Young's Modulus of these units was made assuming a Poisson's ratio of 0.25. This gave a value of 16 GPa for Young's modulus using the relationship discussed in Section 5. This is higher than would be expected for the coal measure rocks. In other work, values of 10 GPa have been adopted for sandstone and 2 GPa for coal (Santos 2014). Allowing for 25 m of coal within a thickness of 300 m of Walloon Coal Measures, this would give an effective modulus of 7.6 GPa (note: harmonic averaging used rather than an arithmetic averaging).

$$E' = \frac{B\ \alpha\ \delta u}{\delta}\ \frac{(1+\upsilon')(1-2\ \upsilon')}{(1-\upsilon')} = \frac{325\ m\ x\ 690\ kPa}{11.4\ mm}\ \frac{(1+0.25)(1-2\ x\ 0.25)}{(1-0.25)} = 16\ GPa$$

Where:

δ is the subsidence at the ground surface (11.4 mm over the period)

δu is the average pressure change in the unit (690 kPa over the period)

B is the thickness of the unit (325 m)

υ' is the Poisson's ratio of the unit (0.25 assumed)

α is the Biot's coefficient of the unit (0.85 assumed)

E' is the drained Young's modulus of the unit

The interpreted settlement is 30 mm over four years from mid-2012 to December 2016 (see Figure 11). The change in groundwater level over this period is not clear in the monitoring because the groundwater level monitoring records do not go back far enough. For this reason, it is not considered productive to use this period for back analysis. The records do show a steep decline in drawdown within the Taroom from 82.4 mAHD on 2 February 2016 to 49.1 mAHD on 19 March 2016 (a drawdown of 33.3 m). Over this period a ground movement of 3 mm was obtained from the InSAR records.

If this movement is attributed to the Taroom alone a modulus of the Taroom coal measure rock is assessed as 7.8 GPa using the approach described above. This is an uncertain assessment given the short period and small settlement involved. Settlement could also be affected by climatic factors resulting in movement of a similar magnitude.

An assessment of modulus was also made based on the records at monitoring bore 160799 in the Tipton CSG Well Field (see Figure 13 for location). A measured groundwater level change from mid-November 2014 to late March 2016 of 49 m in the Juandah (upper Juandah and lower Juandah experienced very similar response) was associated with a settlement of 4.2 mm over the same period based on InSAR results in the area surrounding this bore. Records from construction of Bore 160799 indicate a thickness of the Juandah Coal Measures of 165 m. Based on these results a modulus of 13.6 GPa for the Juandah is assessed using the approach described above. Again there is a significant level of uncertainty given the low magnitude of the settlement and the possibility of shallow influences from climatic or other effects.

The above assessments are based upon results at a single location and contain interpretation of settlement which is subject to uncertainty. It is therefore recommended similar assessments are carried out, as further data providing correlation between settlement and groundwater drawdown becomes available.

4. Surat Gas Project

4.1. Observed response

In order to assess the variability of the InSAR movement results, two sites well away from present CSG extraction were selected at the locations illustrated in Figure 16. Each selected area is rectangular and approximately 2 km^2 in area. One area was of cleared farmland (Site A) while the other contained tree cover (Site B). These sites are within Drainage Area DA5.

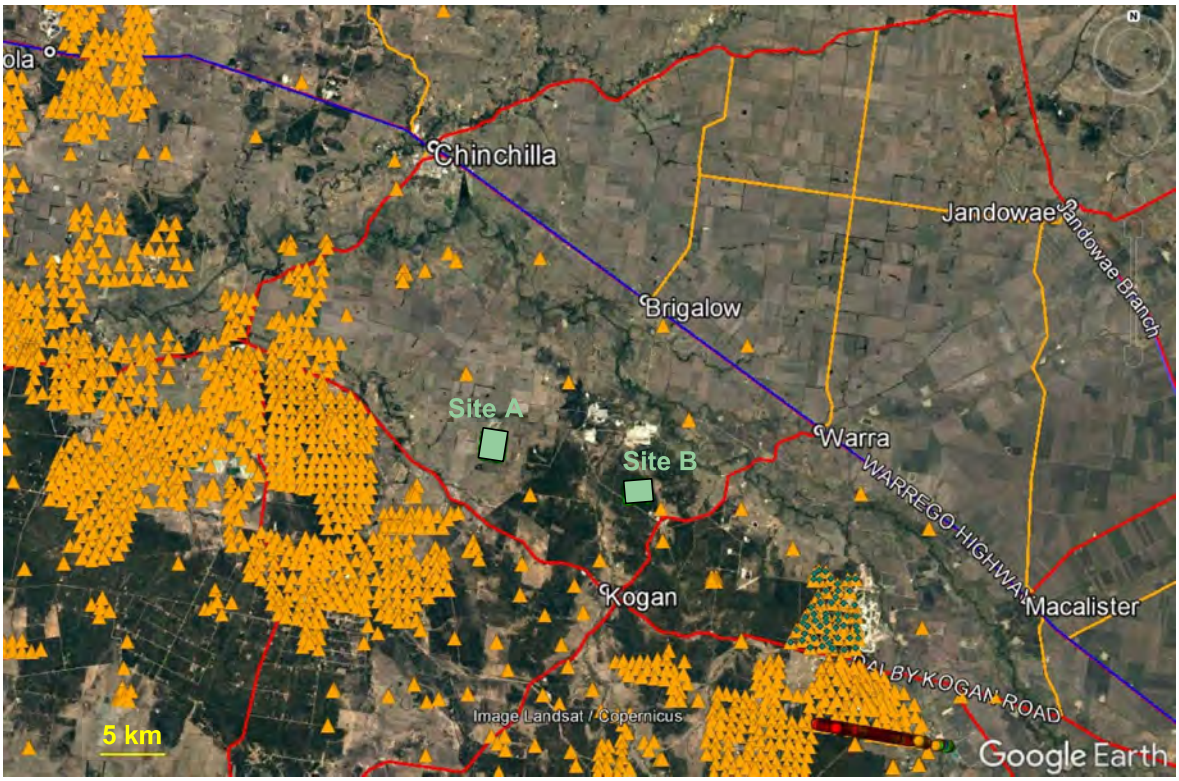


Figure 16 - Sites selected for background InSAR response (yellow triangles show locations of installed CSG wells based on the Queensland Government Globe)

The variation in InSAR interpreted movement over the period April 2012 to December 2016 is shown for the two sites in Figures 17 and 18. The cleared site (Site A) displays a substantially higher level of variability with a spread of results over a 90 mm span at the end of the period, while the tree covered site (Site B) showed less variability, with results predominantly within a 40 mm span at the end of the period.

The average of the results (as shown by the blue markers and line near the centre of the band of results) provides a consistent response in both cases. For the farmland the results indicated on average no vertical movement over the monitoring period while a gradual rise in ground level of 10 mm over the period for the area with tree cover. The reason for this rise is not clear.

Small scale changes in the average movement at each site of the order of 5 mm occur in a pattern consistent between the two sites, and are considered likely to relate to climatic effects influencing upper soil moisture and resulting shrink swell response.

It would be useful to select reference sites to check for background movements associated with climatic conditions for comparison with movement monitoring in the vicinity of SGP drainage areas.

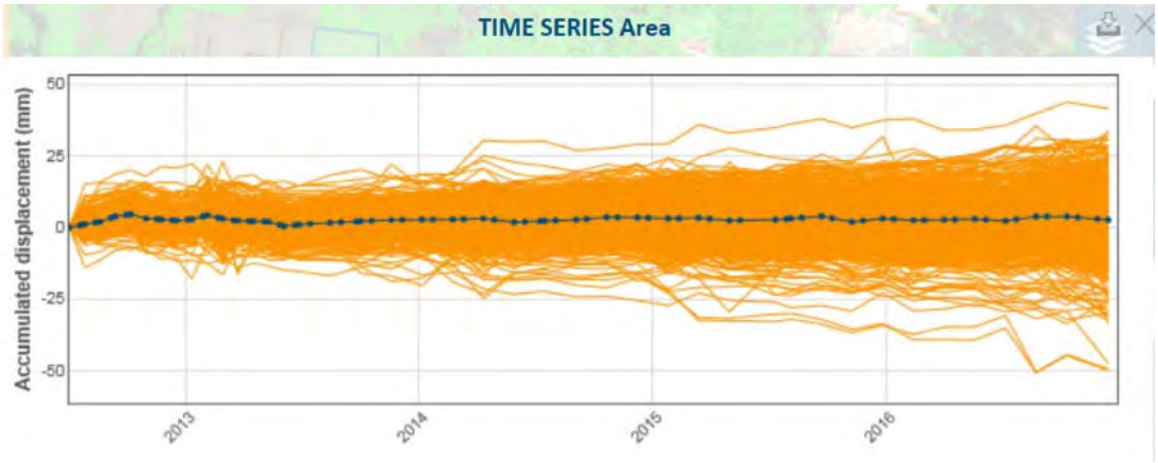


Figure 17 - InSAR movement results - Cleared farmland (Site A)

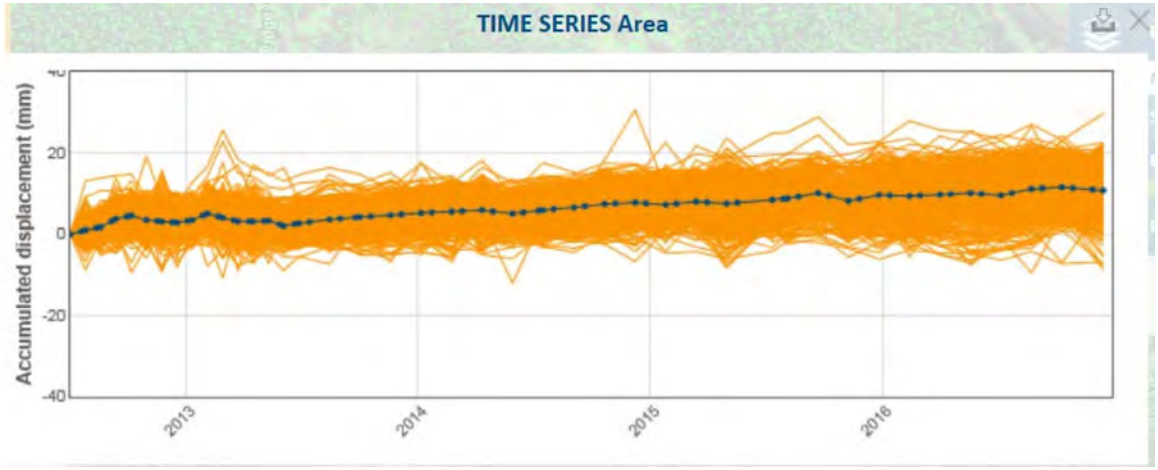


Figure 18 - InSAR movement results - Area with tree cover (Site B)

4.2. Predicted drawdown

Predictions of drawdown resulting from the Arrow SGP operations are presented in a technical memorandum prepared by Coffey (*SGP Stage 1 CSG WMMP: Groundwater modelling technical* memorandum, 1 December 2017) for Arrow. The predictions are based upon modelling carried out by GHD (2013) using the OGIA 2012 Groundwater Model (QWC, 2012). Predictions of drawdown were developed for the effects of operations by Arrow alone as well as predictions of Arrow in combination with the other CSG producers.

The effects of CSG operation take time to develop and so predictions were developed for three times (2030, 2050 and 2094) to account for the progressive geographical spread of CSG operations and the timing of drawdowns associated with development of individual leases.

Figure 19 presents the predicted drawdown at 2030 within the Springbok Sandstone (the unit overlying the Walloon Coal Measures), the Walloon Coal Measures and the underlying Hutton Sandstone (the unit underlying the Walloon Coal Measures) due to Arrow SGP operations alone.

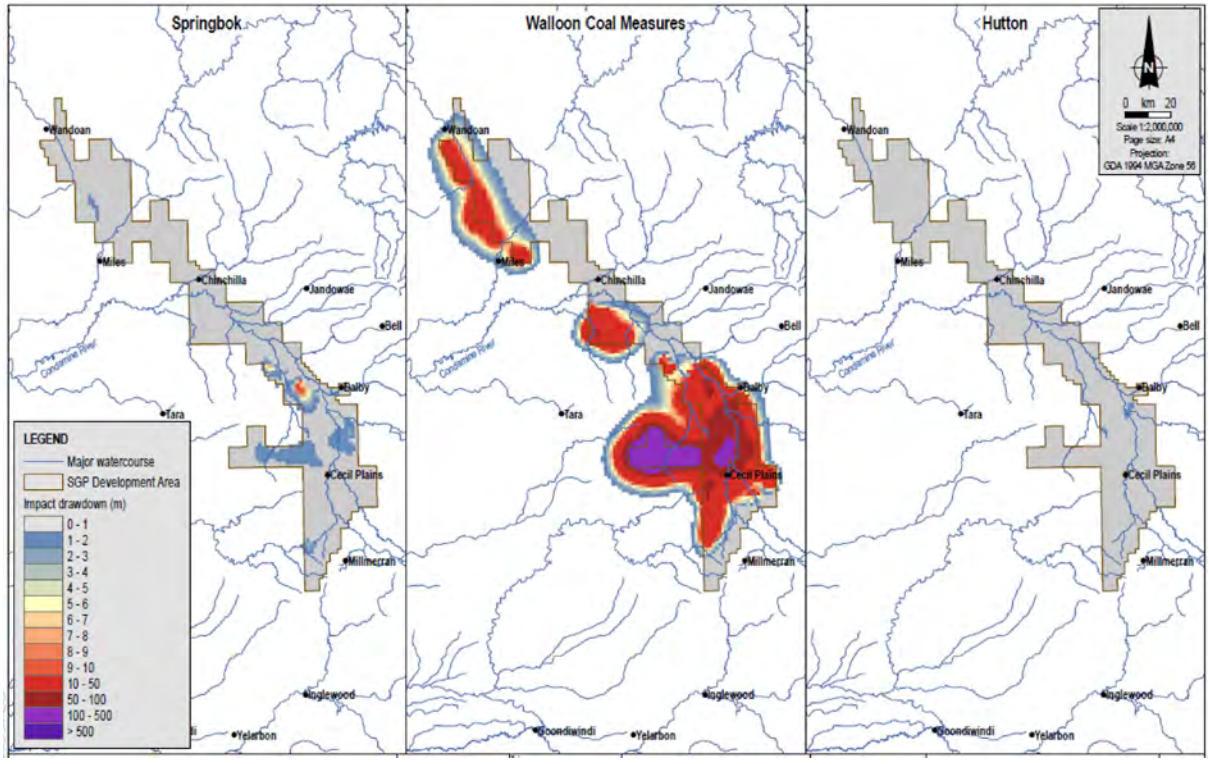


Figure 19 - Predicted drawdown by 2030 due to Arrow SGP operations

By 2030 in the Arrow SGP leases, the predicted drawdown in the Springbok Sandstone is less than 3 m and the predicted drawdown in the Hutton Sandstone is less 2 m with much larger drawdown of in excess of 100 m predicted within the Walloon Coal Measures.

Figures 20 and 21 present the prediction of drawdown for the same formations by 2050 for Arrow SGP operations alone for the years 2050 and 2095. In both cases the predicted drawdown within the Springbok Sandstone and Hutton Sandstone was much less than that predicted in the Walloon Coal Measures.

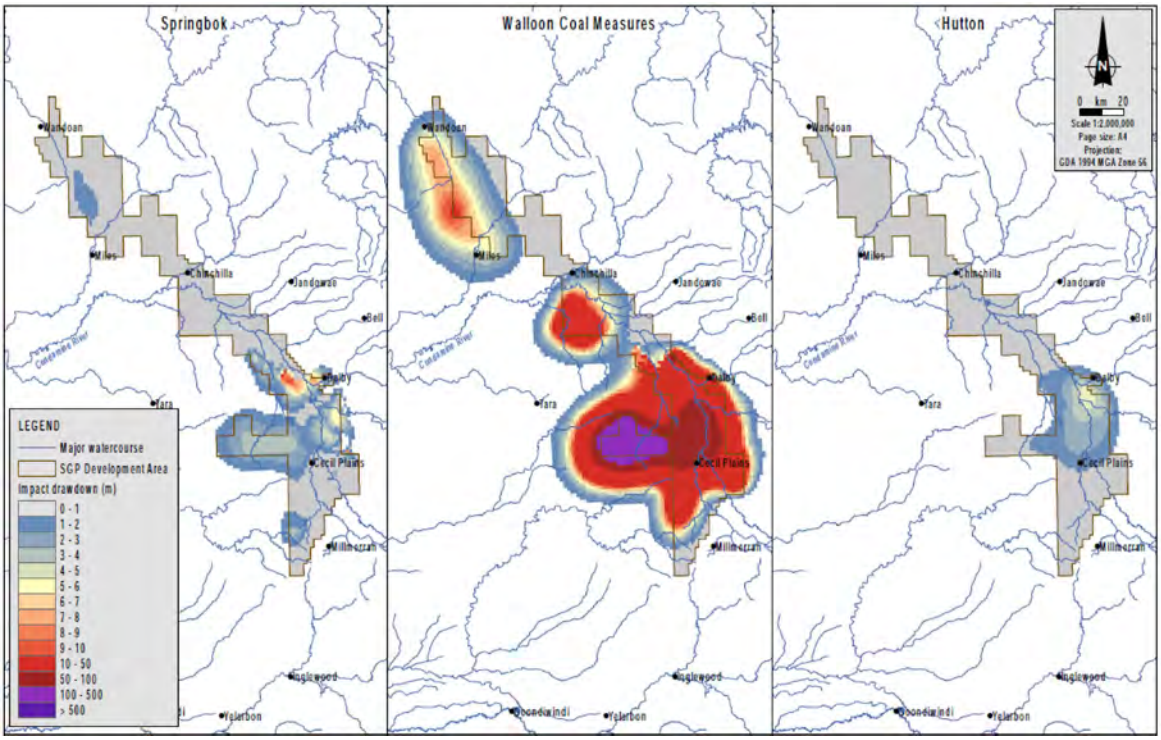


Figure 20 - Predicted drawdown by 2050 due to Arrow SGP operations

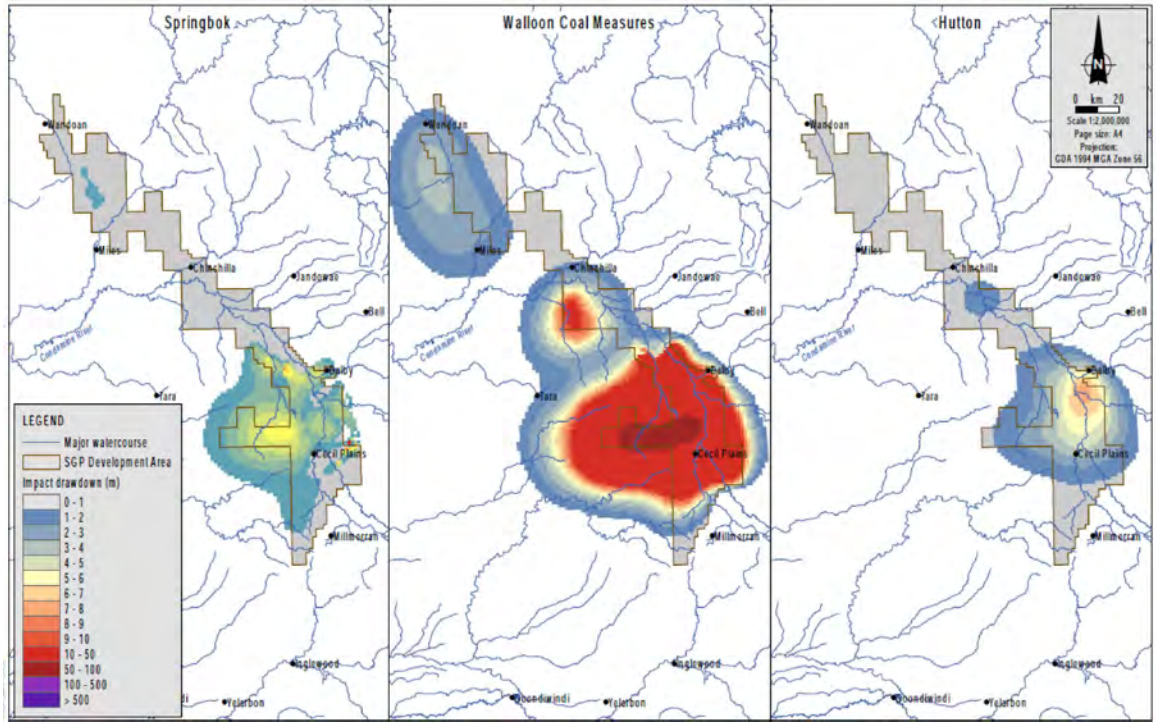


Figure 21 - Predicted drawdown by 2094 due to Arrow SGP operations

Based on the results of these predictions it is clear that the drawdowns predicted for 2030 are typically being larger than those predicted for 2050. The predictions for 2090 show reduction in the peak drawdown and spreading of the area of influence within the Walloon Coal Measures.

Figure 22 presents the predicted drawdown for Arrow plus the other CSG proponents for the year 2050. Over much of the area (and in particular in the Arrow SGP drainage areas and the nearby areas) the combined drawdown for 2050 is typically greater than that predicted for 2030 or 2094. Again the drawdown predicted in the Springbok Sandstone and Hutton Sandstone is substantially lower than that predicted for the Walloon Coal Measures.

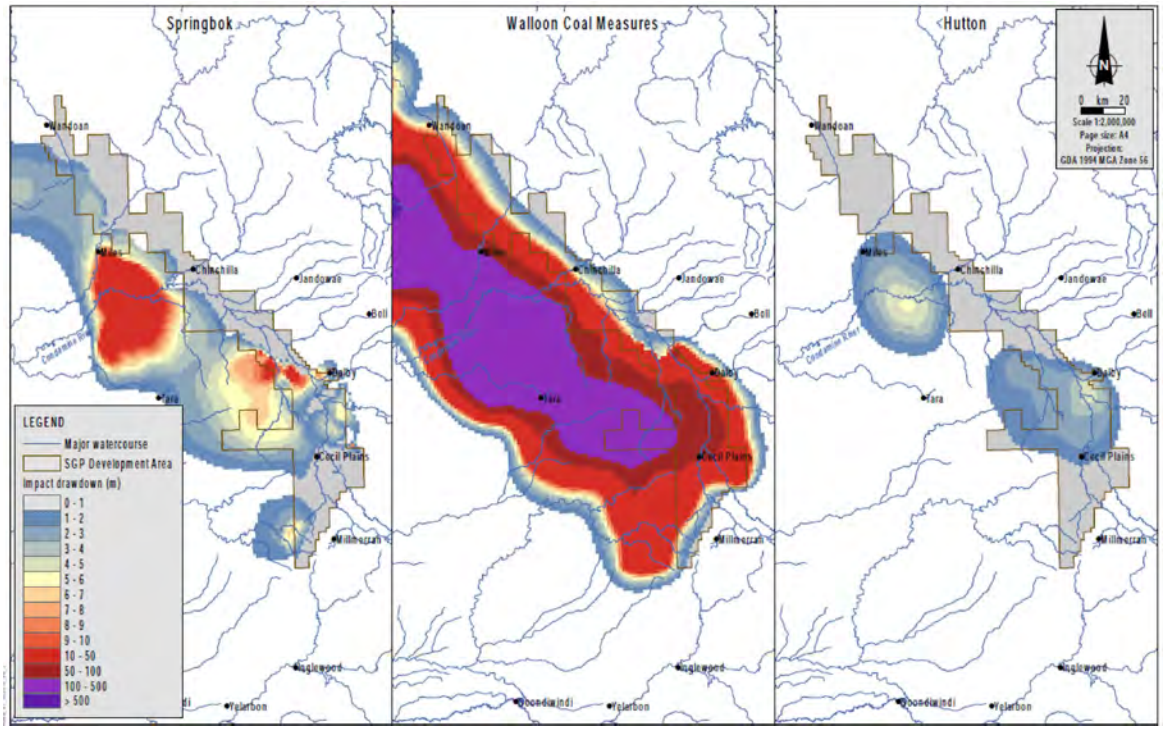


Figure 22 - Predicted drawdown by 2050 due to combined CSG operations (Arrow and other CSG proponents)

It is also clear that the magnitude of drawdowns predicted for the Arrow SGP are a small component of the overall predicted drawdown impacts.

In addition to the assessment of drawdown contained in the SREIS report Arrow have indicated that for production CSG well fields that:

> *The Target Flowing Pressure is around 35 Psi at the bottom of lowest Seam or Water Level around 5 to 10 meter below the lowest seam (Condamine coal seam).*

This is interpreted to mean that for the Juandah the groundwater level would be at 24 m (24 m water head is equivalent to 35 psi) above the base of the Argyle and for the Taroom the groundwater level 24 m above the base of the Condamine. These values would reflect conditions at the well. Away from the well, groundwater level would rise and average groundwater level between wells could be substantially higher. The extent to which average groundwater levels would depart from conditions in the vicinity of production wells will be a function of the local geology, the density of CSG operating wells, the timing and the operating conditions. For the purposes of this assessment the drawdown predictions based on groundwater modelling report by Coffey (2016) were used for subsidence assessments set out in Section 5.

5. Assessment of Subsidence

Subsidence can be assessed by considering the mechanical properties of each component within the geological profile together with predictions of water pressure changes, to predict compression of each stratigraphic component. The total subsidence experienced at the surface can then be determined by integrating the individual component compressions.

Subsidence associated with this mechanical process is expressed using the following relationship (based upon integration of one dimensional settlement of an elastic material under pore-pressure change – stress stain relationships are described in Sanderson (2012)):

$$\delta = \int_{z=\infty}^{z=0} \delta u \, \alpha \, \frac{(1+\upsilon')(1-2\,\upsilon')}{(1-\upsilon')E'} \, dz$$

Where:

- δ is the subsidence at the ground surface
- z is the depth below the ground surface
- δu is the pore pressure change at depth z below the ground surface
- υ' is the Poisson's ratio of the ground at depth z
- α is the Biot's coefficient of the ground at depth z
- E' is the drained Young's modulus of the ground at depth z

Ideally, calculations would be based on the measured properties of each formation or rock type. However for the project area, measurements of the mechanical properties of each of the geological units affected are limited to unconfined compression tests of core samples from borehole Stratheden-61 (within lease PL252). The results in Table 2 are set out in the Arrow Well Completion Report for this borehole.

Table 2: UCS test results- Stratheden-61 core

Sample ID	Depth (m)	Lithology	Formation	Uniaxial Compressive Strength (MPa)	Secant Young's Modulus (GPa)	Corrected Poisson's Ratio
GT016	92.39	Sandstone	Kogan (Upper Juandah)	9.3	8.3	0.42
GT018	102.09	Siltstone	Kogan (Upper Juandah)	9.7	4.18	0.09
GT024	117.1	Coal	Macalister (Juandah)	7.0	2.45	0.22
GT025	123.49	Coal	Macalister (Juandah)	9.5	3.13	0.3
GT027	126.84	Sandstone	Macalister (Juandah)	9.4	1.34	0.25

Measurements in the area for other geological units have not been identified.

A review of the test results indicated that the secant Young's modulus values interpreted were based in some cases after the sample was in significant distress and may therefore not be representative of behaviour of intact material at depth under lateral confinement. In particular, sandstone is expected to be significantly stiffer than coal. In an earlier assessment of subsidence at Moranbah (located in the Bowen Basin) Coffey adopted the following values:

- Modulus of sandstone 10 GPa
- Modulus of coal seams 3 GPa

Biot's coefficient is a value relating the effective stress change in rock (the stress carried by the solid matrix) to the pore pressure change. For a sandstone this could be expected to be in the range 0.75 to 0.9 (Sanderson 2012). For the purposes of this study a value of 0.85 was adopted.

An assessment of potential subsidence carried out by ARUP (2014) employed a series of approaches for assessment of ground movement:

1. Use of shear modulus and Poisson's ratio to assess volume compressibility.
2. Use of specific storage adopted for groundwater modelling work to assess settlement.
3. Use of porosity and void ratio derived from geophysical testing.

These methods, that each involve different approaches to assess the relevant mechanical properties of the ground, are all subject to significant uncertainty. Therefore judicious interpretation is required. ARUP (2014) predicted settlement of up to 85 mm after 25 years though higher values were recognised as being possible.

For this work, Coffey makes use of results of subsidence measurements combined with measured drawdown in the Daandine CSG field. Use of direct measurements is considered to provide a more robust basis for assessment. This approach was unavailable to ARUP as no subsidence measurements due to CSG extraction were available at the time of their assessment. The use of field scale measurement readily takes account of the averaging across the thickness of the affected geological units to obtain average behaviour, without needing to make separate assessments for changes in lithology within each geological formation.

Hence, the approach adopted by Coffey for this assessment was as follows:

1. Records of subsidence within the Daandine CSG field were reviewed.
2. Records of drawdown measured within the Daandine CSG field were reviewed.
3. Correlation between the measured drawdown and interpreted subsidence used to develop an effective Young's modulus for the Walloon Coal Measures.
4. Predictions of maximum drawdown were used to assess maximum subsidence within Arrow SGP.

For the purposes of this memorandum two assessments of long term subsidence associated with CSG extraction were made for the Arrow SGP. These assessments used different modulus values and drawdown estimates, as follows:

- **Low assessment:** This assessment was made using the higher of the effective modulus values (13.6 GPa) assessed in Section 3.3 together with a range of drawdown values covering drawdown predictions. No contribution from reduction of coal thickness due to loss of coal seam gases is included.
- **High assessment:** A second assessment was made for a range of drawdown values and using the lower of the effective modulus values 7.8 GPa) assessed in Section 3.3. An additional allowance of settlement is included associated with reduction in thickness of the accumulated coal bands due to loss of coal seam gasses. This is based on an assumed strain of 0.001 across 25 m of coal seams for each 50 m head change (after Robertson (2005) as quoted in Section 2.1).

It should be noted that these assessments do not necessarily represent the encompassing range of settlement, as the linkage between settlement and drawdown is based upon very limited information. Other data might provide a different range. The assessments of modulus are based on limited field records and the assessment of volume loss due to coal seam gas loss for the coal components of the profile is based on a single published result which may not reflect the conditions in the Surat. As a result, the settlement predictions carry uncertainty.

Example calculations for the low assessment and high assessment cases are presented below. In each case a thickness of 325 m for the Walloon Coal Measures, including an aggregate thickness of 25 m of coal seams, was adopted.

Low Assessment

Allowing a typical thickness of 325 m for the Walloon Coal Measures for the low assessment, settlement of 0.17 mm is associated with each 1 m of average drawdown (10 kPa) across the Walloon Coal Measures (adopting the method in Section 3.3):

$$\delta = \frac{B\ \alpha\ \delta u}{E'}\ \frac{(1+\upsilon')(1-2\ \upsilon')}{(1-\upsilon')} = \frac{325\ m\ x\ 0.85\ x\ 10\ kPa}{13.6\ GPa}\ \frac{(1+0.25)(1-2\ x\ 0.25)}{(1-0.25)} = 0.17\ \text{mm}$$

The OGIA predicted drawdown indicates that the bulk of the drawdown response within the Arrow SGP leases is predicted to occur within the Walloon Coal Measures with little response in overlying and underlying units as indicated in the groundwater modelling results presented in Figure 19 to 21.

High Assessment

For the high assessment a settlement of 0.30 mm is associated with each 1 m of average drawdown in the Walloon Coal Measures:

$$\delta = \frac{B\ \alpha\ \delta u}{E'}\ \frac{(1+\upsilon')(1-2\ \upsilon')}{(1-\upsilon')} = \frac{325\ m\ x\ 0.85\ x\ 10\ kPa}{7.8\ GPa}\ \frac{(1+0.25)(1-2\ x\ 0.25)}{(1-0.25)} = 0.30\ \text{mm}$$

A further 25 mm is allowed for coal thickness reduction due to loss of coal seam gasses for each 50 m of drawdown.

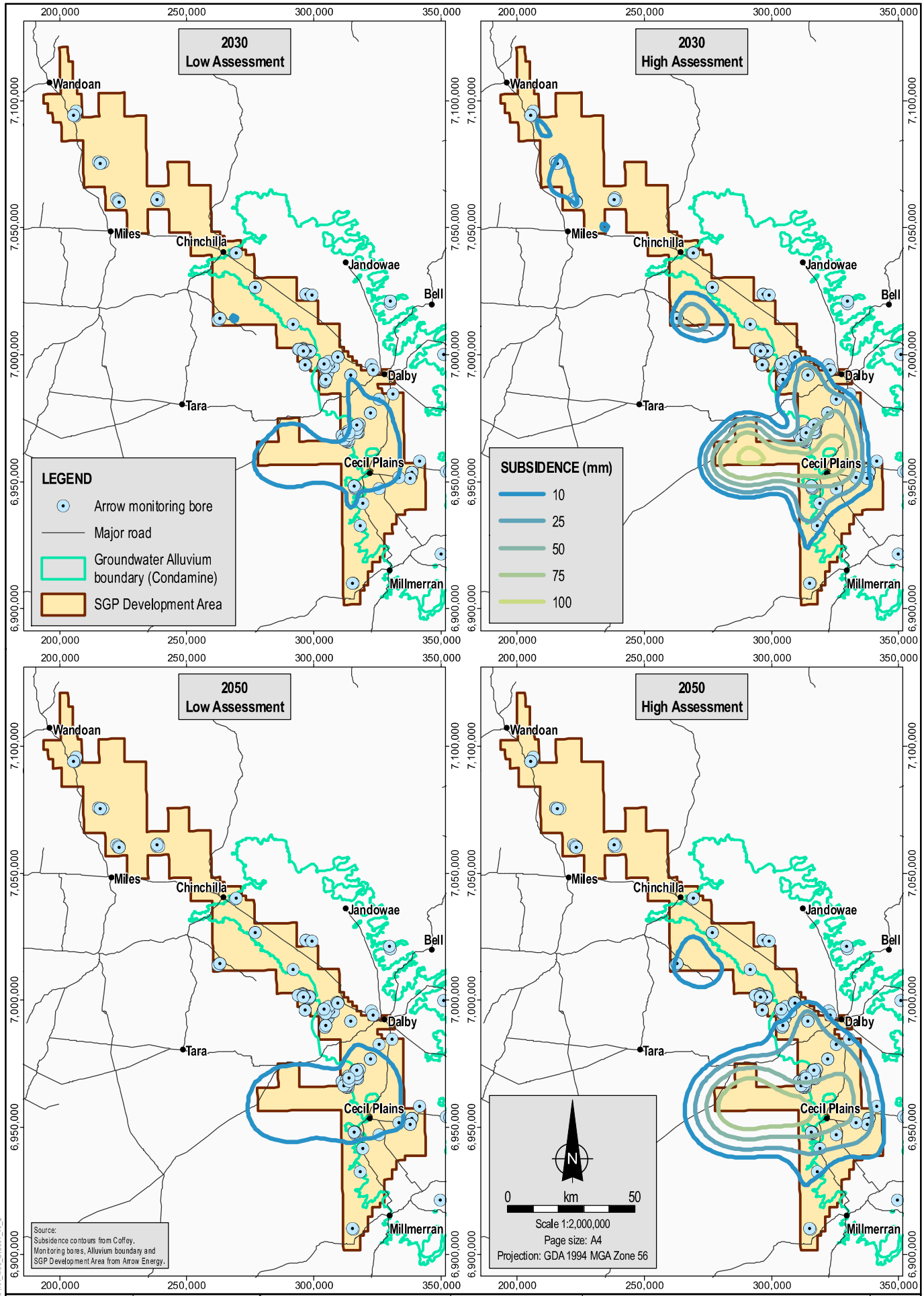
Thickness contours of the Walloon Coal Measures (shown Figure 4) were combined with the predicted drawdown showing in the figures in Section 4.2 using the methods described in this section to assess subsidence.

Figure 23 presents assessed subsidence contours associated with predicted drawdown from Arrow SGP operations alone for 2030 and 2050 for both the high and low settlement assumptions set out above. Predicted subsidence is limited to the Arrow SGP leases and their immediate surrounds. For the low assessment, predicted subsidence is minimal and based on experience to date would seem to understate potential subsidence. For the high assessment subsidence is predicted to be within 100 mm. Subsidence within the Condamine Alluvium is predicted to be up to 75 mm within the southern part of the SGP due to the Arrow SGP alone in 2030 and 2050.

Figure 24 present assessed cumulative subsidence contours associated with predicted drawdown from Arrow and other operations for 2030 and 2050 for the high and low settlement assumptions. Under this scenario, predicted subsidence in the vicinity of the Arrow leases is significantly greater than that predicted for the Arrow activities alone.

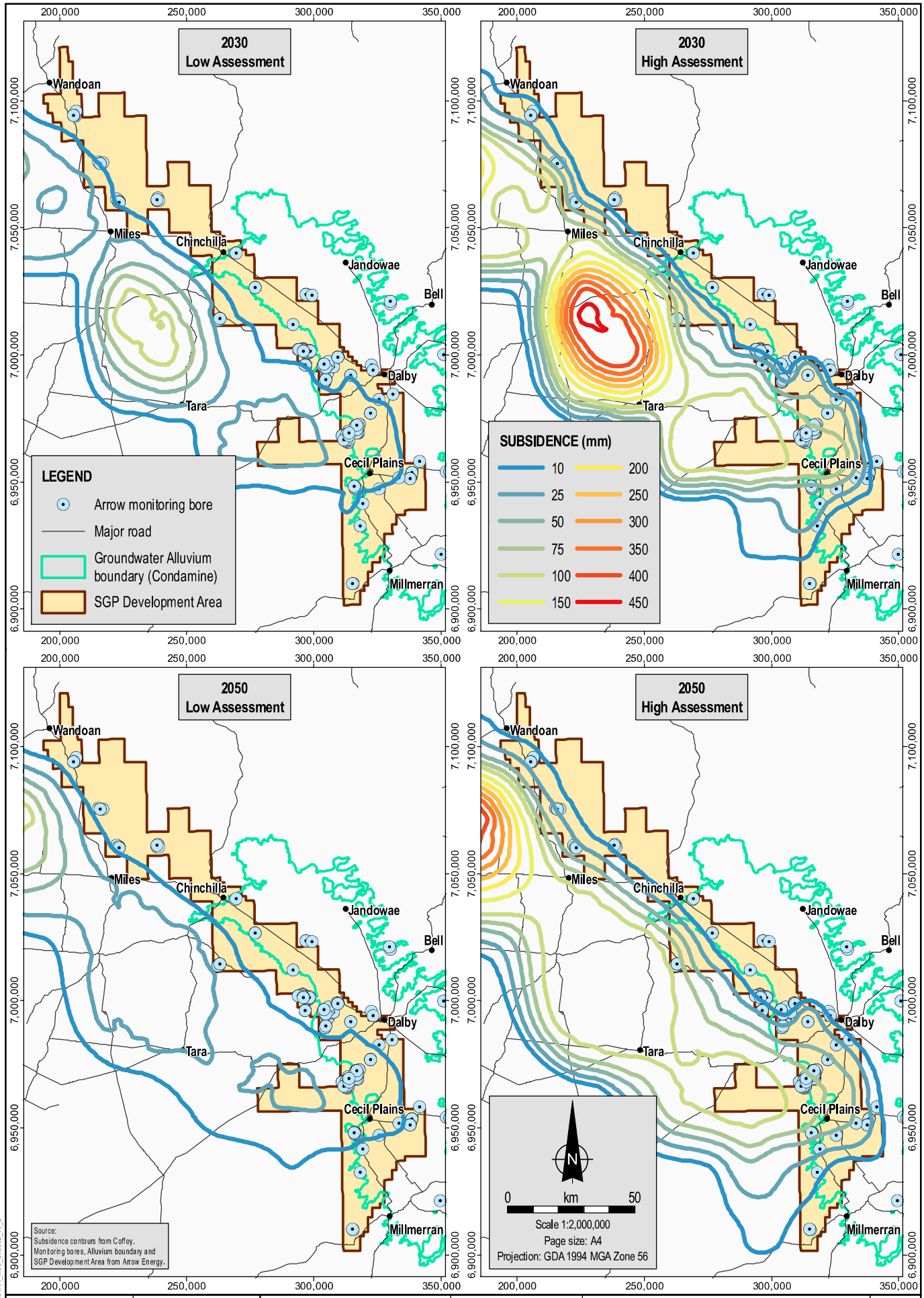
For these cumulative case assessment figures, the peak subsidence in 2050 is lower than in 2030 in some locations. These are shown in Figures 25 and 26 for the Arrow SGP Only Case and the Cumulative Case overlaid upon the Arrow SGP drainage areas. The assessment process adopted does not account for recovery of groundwater levels and the predicted reduction in subsidence shown in the contour plot is not anticipated as the subsidence process is considered to be largely irreversible. Subsidence should be taken as the maximum value over time obtained from the assessment process employed.

The largest subsidence of 100 mm associated with the Arrow SGP due to the SGP alone is predicted to occur within Drainage Area DA11. Larger subsidence values are predicted to the west of the SGP associated with drawdown due to CSG production by other proponents. Within the SGP subsidence including the effects of other proponents of up to 120 mm is predicted within Drainage Area DA11.



coffey A TETRA TECH COMPANY	Date: 04.05.2017 Project: 754-ENAUABTF20484AA File Name: 20484AA_M05_F023_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Subsidence assessments Arrow SGP only case (contours of predicted subsidence in mm)	Figure No: 23

MXD Reference: 20484AA_M05_GIS001_v0_2



coffey A TETRA TECH COMPANY	Date: 04.05.2017 Project: 754-ENAUABTF20484AA File Name: 20484AA_M05_F024_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Subsidence assessments cumulative case (contours of predicted subsidence in mm)	Figure No: 24

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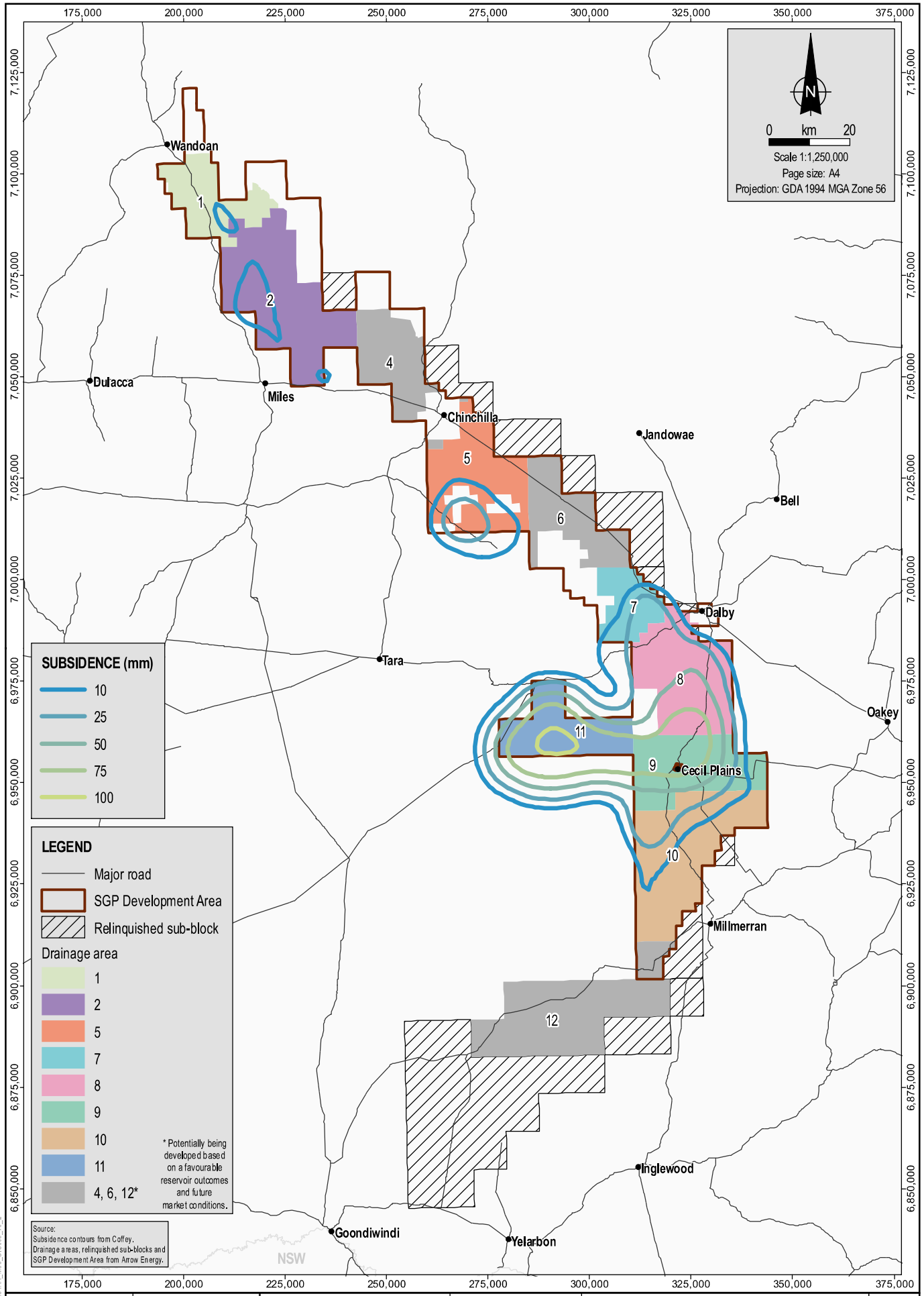

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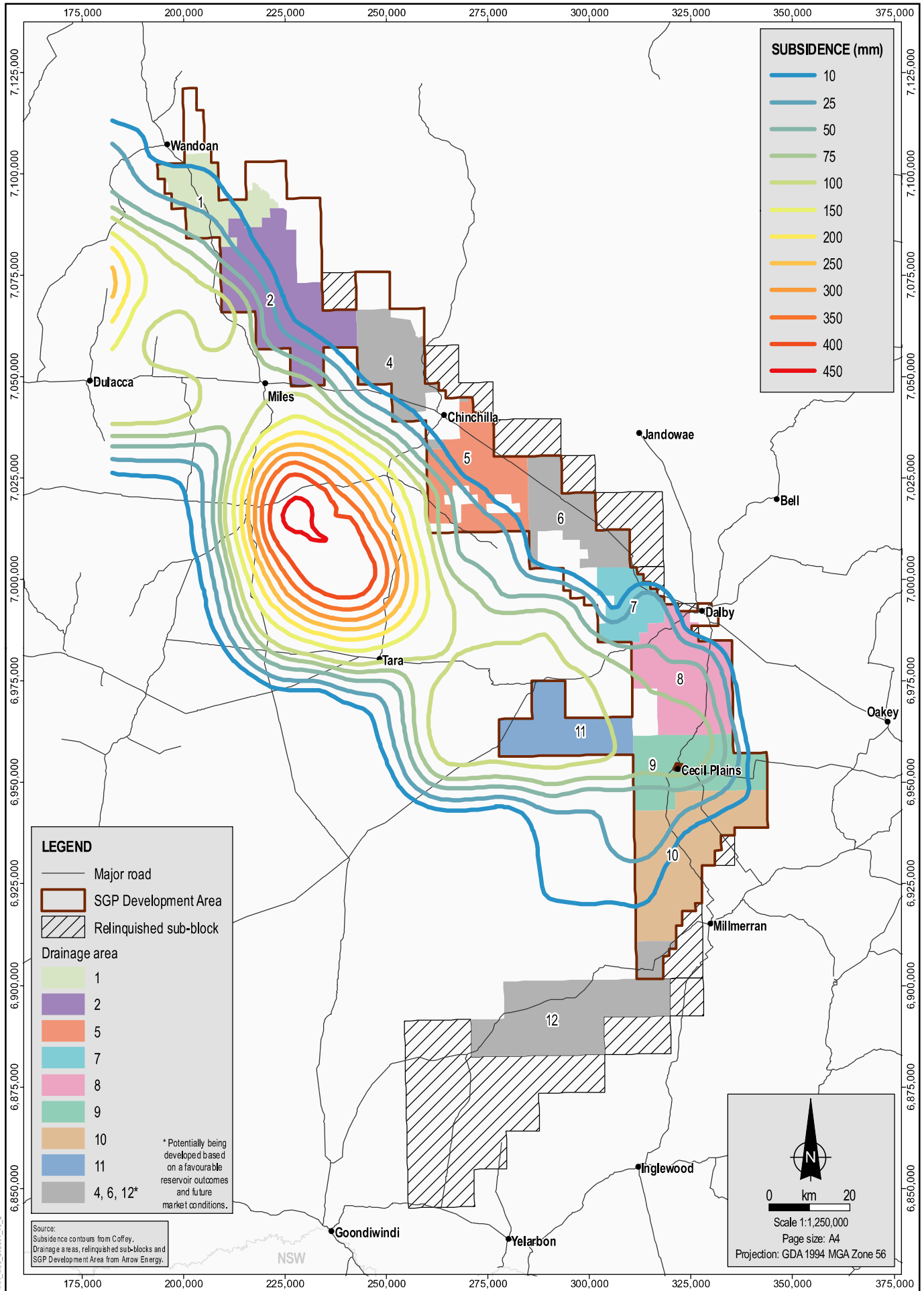

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Date: 04.05.2017
Project: ENAUABTF20484AA
File Name: 20484AA_M05_F026_GIS

Arrow Energy

Surat Gas Project WMMP

arrow energy
go further

Predicted Subsidence 2030
(contours in mm)
High Assessment - Cumulative Case

Figure No:
26

6. Risk Assessment

An assessment of risk associated with ground subsidence associated with the Arrow SGP was carried out.

Risk associated with subsidence are developed though consideration of the likelihood of impacts of a nominated magnitude and the consequence of such an event. Subsidence can have an impact on the following assets:

- Linear infrastructure – roads, pipelines, rail lines, power lines, irrigation canals.
- Buildings and structures.
- Rivers and streams.
- Farm irrigation systems.
- Swamps and low lying areas.

Review of the existing use of the areas within the Arrow SGP and in the vicinity reveals the following assets:

- Roads, rail lines, power lines, pipelines.
- Farmland including irrigation on land laser levelled land.
- Forested areas.
- Small dams.
- Condamine River and tributaries.
- Farmhouses and other small buildings.
- Mines and mine infrastructure.

The potential impacts upon these assets are discussed in the following sections. In considering potential impacts consideration needs to be given to absolute magnitude and the differential settlement.

Potential impacts on general farmland, small dams, and river flow for movements of less than 100 mm over distance of 1 km are not considered likely to result in adverse impacts and these have not been considered further. Mines and mine infrastructure are typically subject to ground movement associated with the mining operation and are considered unlikely to be adversely affected by the magnitudes of subsidence anticipated. Hence, they are not considered further. Farmhouses, farm sheds and other small buildings can be assessed under the criteria for other buildings and structures.

Laser levelling is carried out for farms to facilitate efficient use of irrigation water. Subsidence occurring after farm levelling has taken place could potentially affect irrigation performance by changing the slope of the ground. The orientation of the change in slope in comparison with the alignment of furrows and drainage channels is relevant to the assessment of potential impacts on laser levelled farm plots. A change in gradient of 30 mm per 100 m (refer Section 6.6) is used as an investigation level at which further investigation will be carried out for affected areas.

6.1. Risk assessment approach

The risk management strategy for Arrow SGP should comprise the following:

- Formulate a risk assessment and mitigation measures register.
- Adopt appropriate design to reduce residual risk to acceptable levels.
- Implement appropriate field monitoring during various stages of construction.
- Conduct additional geotechnical investigations at the appropriate time.

The proposed risk assessment is further discussed below.

Risks associated with subsidence caused by CSG extraction are assessed using the approach set out in the Australian and New Zealand Standards Association Handbook SA/SNZ HB 89:2013. Within this framework, an 'event' is considered as CSG induced subsidence movement affecting an existing asset. The likelihood of subsidence of a particular magnitude has been assessed by reference to the subsidence measured to date, and the predictions for future subsidence. The consequence of an event of particular magnitude is assessed based on the nature of an asset and its sensitivity to movement.

The risk associated with particular events is assessed based on the likelihood of movement above a particular magnitude and the sensitivity of the asset affected. A consequence/likelihood matrix approach has been adopted for assessment of risks. The definition and risk evaluation matrix are recommended to be reviewed following consideration by Arrow for consistency with their corporate risk stance.

For the purpose of this assessment the definitions of likelihood (Table 3) and consequence (table 4) are adopted

Table 3: Likelihood category definition

Likelihood Category	Description
Rare	The event may not occur or if it does it will occur over less than 0.1% of the lease area
Unlikely	The event may occur over a small proportion 1% of the lease area
Possible	Instances of the event would occur in a number of places though not more than 10% of the area
Probable	Will occur over most of the area
Certain	The event will occur over a widespread area

Table 4: Consequence category definition

Consequence	Description
Insignificant	Little influence on
Minor	Noticeable influence without serious consequences Damage caused tolerated with possible compensation payment (less than $10,000)
Medium	Rectification works or substantial additional monitoring required (costs less than $1,000,0000) Local press critical of outcome
Major	Substation rectification works in excess of $5m required Environmental damage requiring intervention or remedial works National press critical of outcome
Catastrophic	Serious environmental consequences Damage with major disruption to public facilities Loss of life or serious injury to people

The risk evaluation matrix in Table 5 is employed.

Table 5: Risk Matrix

Likelihood Category Rating	Consequence Category Rating				
	Insignificant	Minor	Medium	Major	Catastrophic
Rare	Very Low	Very Low	Low	Medium	High
Unlikely	Very Low	Low	Medium	High	High
Possible	Low	Medium	High	High	Very High
Probable	Medium	High	High	Very High	Very High
Certain	High	High	Very High	Very High	Very High

6.2. Linear infrastructure

The sensitivity of various structures to subsidence including roads, rail lines and pipelines are discussed in Commonwealth of Australia (2014). Table 6 summarises material from that document.

Table 6: Thresholds of adverse impact from ground movement – Linear infrastructure

Asset	Guideline	Potential impacts from SGP induced subsidence
Pipelines	Tensile strain less than 2% Slope change less than 1/140 Sewer pipeline 0.4% grade change	Negligible
Roads and highways	0.3 % over a chord length of 10 m	Negligible
Rail lines	Operation of railway services over areas affected by mine subsidence has proven manageable	Negligible
Drainage channels	Slope change relative operating gradients should be checked	Slope changes unlikely to significant

6.3. Buildings and structures

Guidelines for assessment of settlement impacts upon buildings exist for assessment of potential impacts from activities such as construction dewatering. Damage is a function of differential settlement rather than the absolute value and damage is also a function of horizontal strain. Figure 27 below by Burland (2012) provides an indication of the significance of differential movement on buildings. Results are presented in the form of damage categories for differing levels relative to deformation.

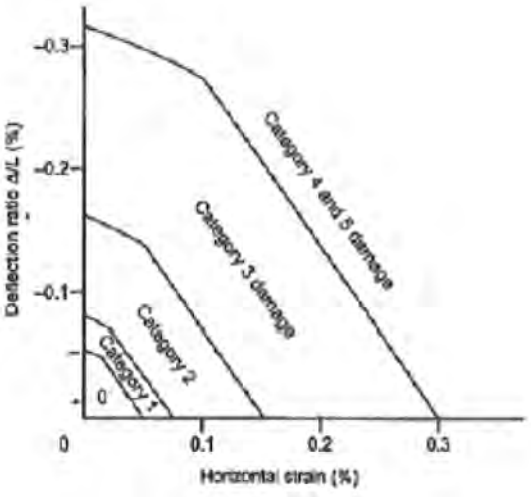

Figure 27 - Damage categories for buildings as a result of ground movement (Burland, 2012)

In Category 0 damage is described as negligible, limited to minor hairline cracks. Category 1 corresponds to minor architectural damage and Categories 4 and 5 correspond to major damage and risk of instability.

The deflection ratio is a measure of the change in vertical movement between two points and is illustrated in Figure 28.

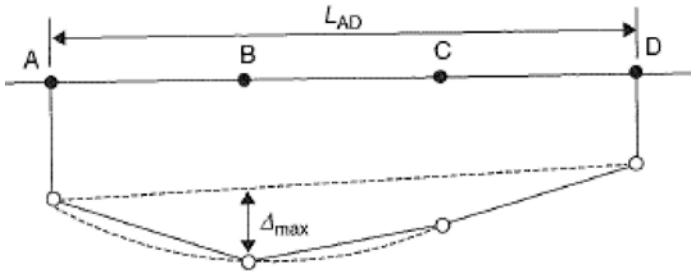

Figure 28 - Definition of deflection ratio (Burland, 2012)

As subsidence associated with SGP arises from compression of geological units at depth the changes at the surface will be gradual and no measureable horizontal strain is anticipated at the ground surface.

Rather than use of deflection ratio, use of differential settlement is adopted for assessment of the significance of differential movement for structures. For a uniform curvature the maximum differential settlement (the gradient of settlement) would be four times the deflection gradient. Taking a deflection ratio of 0.025% (half the limit for Class 0 damage (defined by Burland as negligible with hairline crack less than about 0.1 mm) this corresponds to a deflection gradient (change in deflection per unit length) of 0.1% or 1/1000. This is considered a conservative threshold for damage to buildings and other structures.

6.4. Dams

A water storage dam approximately 800 m by 450 m in area is present to the north of the Daandine CSG field. It is constructed using a raised perimeter embankment. Other water storages are present within or near Arrow SGP (including raw water dams, treated water dams and brine dams).

Tensile strains associated with CSG related subsidence could potentially result in cracking of embankment materials. For a compacted clay core, tensile strain of less than 0.5% is considered unlikely to have a material influence on its performance in a water retaining structure. Tensile strains approaching this magnitude are assessed as being highly unlikely to arise from subsidence induced by SGP CSG extraction.

No major dams are present within or in proximity to the Arrow SGP in the Surat Basin. If major dams where failure would cause significant risk to human life or the environment are to be constructed in the area (either project related or for other purposes) it is recommended that a separate assessment be made of subsidence potential and susceptibility as part of design studies.

6.5. Rivers and watercourses

Dafny and Silburn (2013) note that:

> *The Condamine plain occupies the area between Ellangowan (E151.67o, S27.92o) and Chinchilla (E150.72o, S27.74o), southern inland Queensland. It stretches over an area of about 7,000 km2, and is ~190 km long. Its upstream and downstream edges are narrow, but most of floodplain is 15-40 km wide. The topography drops steadily from the south-west to the north-east, from +400 m near Ellangowan to +350 m near Dalby and to +310 m near Chinchilla, with an overall topographic gradient of 0.5 m/km.*

Using the existing topographic gradient as a guide it is assessed that subsidence leading to changes in gradient of less than 5% of the existing gradient (0.025 m/km) would be unlikely to have significant impact on the performance of the Condamine River or tributary watercourses.

6.6 Farmland

Farming involving irrigation is carried out in the area potentially affected by Arrow SGP operations. Laser levelling is widely used to improve the efficiency of irrigation. The Cotton Research and Development Corporation (2012) recommend slopes in the range 1 in 500 to 1 in 1650 for furrow irrigation, advising that slopes steeper than 1 in 500 are subject to erosion and slopes flatter than 1in 1650 are subject to waterlogging. Similar experience is reported in research on the effects of slope on furrow irrigation of grain-legumes (soybean, navy bean, pigeon pea, adzuki bean, cowpea and mung bean) at Narrabri, New South Wales (Hodgson *et al* 1989). Field slopes of 1:500, 1:1000, 1:1500 and 1:2000 were evaluated.

As slopes established using laser levelling will generally be greater than 1 in 1650 (a gradient of 0.06 %) an investigation level of a 0.03 % (1 in 3300 or 30 mm in 100 m) change in slope is adopted as half the gradient of the flattest slopes likely to be employed below which changes in slopes are considered unlikely to be significant.

7. Subsidence Trigger Thresholds

Trigger thresholds have been developed for CSG induced subsidence as required by approval condition 13(g). They are derived from the calculated risk assessments of potential subsidence, and taking into account the outcomes of the risk assessment process.

An initial screening level has been set to identify areas for targeted assessment of settlement and assessment of whether the trigger thresholds have been exceeded. The general assessment process that will be implemented is presented in Figure 29.

It is clear from the discussion of potential impacts of subsidence on existing assets that absolute ground movement is generally less important than the differential movement over the extent of a relevant asset. Sensitivity to horizontal strain has been noted as relevant for a range of assets including dams, buildings, pipelines and roads. The form of subsidence that has been recorded to date indicates that development of horizontal strain will be extremely small. As a result investigation levels are nominated which do not include consideration of horizontal strain and risk associated with horizontal strain on assets is considered negligible.

Review of potential impacts on various assets indicates that differential settlement or change in slope is more relevant than total subsidence. A three-step assessment process is set out. Initial assessment would involve screening of areas where significant subsidence is occurring based upon the annual rate of subsidence reported from InSAR monitoring results. In areas where this significant movement is recorded further investigation will be carried out to identify movement with potential to impact on particular assets. The assets identified where potential impacts are identified will be subject to further investigation using conventional survey checking movement against the trigger thresholds in Section 6.

7.1. Screening level

Initial screening will involve identification of areas where significant subsidence is occurring based upon the annual rate of subsidence reported from InSAR monitoring results. This initial screening will involve identification of areas of 1 km by 1 km where more than 50% of the InSAR monitoring points indicate an annual subsidence rate of more than 8 mm/yr (a movement rate discernible using InSAR methods). In areas where this level of movement is recorded, further assessment will be carried out to assess whether the trigger thresholds as nominated in Table 7 are exceeded.

7.2. Investigation levels

In areas where the screening level is exceeded, further assessment of relevant data relating to subsidence will be undertaken. This will include an assessment of the CSG-related subsidence component of the reported InSAR measurements with consideration for the cumulative industry impact and reported subsidence since the commencement of the Arrow SGP operations.

Investigation levels have been defined as set out in Table 7. Where the CSG-related subsidence exceeds the investigation levels set out in Table 7, further assessment will be carried out to assess the site-specific infrastructure that may be impacted and identify whether an impact has occurred as a result of the Arrow SGP operations.

7.3. Trigger threshold

Where the investigation levels nominated in Table 7 are breached additional investigation of the affected area will be carried out using conventional survey methods for a period of six months. The results of the survey will be tested against asset-specific thresholds set out in Section 6 of this memo. For example in the case of structures, assessment of damage categories as a result of ground movement would be based upon the guidance presented in Burland, 2012.

Where adverse impacts are identified to have occurred based on the results of the site-specific investigation, a trigger threshold is considered to have been exceeded and mitigation measures will be employed following the approach set out in Section 7.6.

Table 7: Subsidence monitoring screening level, investigation levels and trigger threshold

Item	Description	Criteria	Relevant assets	Basis for selection / comment
Screening level	Settlement rate	8 mm/year (for >50% of sampling points in 1 km by 1 km block)	All natural features, man-made features and built infrastructure	Areas where this criteria is exceeded will be subject to investigation of subsidence.
Investigation levels	Gradient change	0.03 % (300 mm per 1,000 m)	Irrigation system (laser levelled)	Based upon half the slope of minimum grades recommended by the Cotton Research and Development Corporation for furrow irrigation. Areas where this criteria is exceeded will be subject to investigation of subsidence (refer Section 6), including review of laser levelling practices.
	Differential settlement (built infrastructure)	0.001 m/m	Buildings, structures	• Selected for buildings as the most sensitive item in this group (refer Section 6). • Not relevant to linear infrastructure (roads, rail, transmission lines and pipelines) as predicted differential settlement is well within the tolerance of these facilities. • Not relevant to bushland or farmland.
	Change in slope (natural features)	25 mm/1,000 m	Flood flow in watercourses	• Taken as 5% of topographic gradient of the Condamine Plain. • Applies only to the main channel of the Condamine River. • Review of effects on flow and conventional survey would be carried out to assess the significance of the change.
Trigger threshold	Outcome of site specific monitoring using conventional survey and review of risk to asset.	Individual threshold based on the local conditions	Irrigation system, structure or watercourse	Site specific assessment based upon conventional survey of identified asset. In the case of potential impacts on structures within populated areas the assessment will be based upon selected structures considered to be most vulnerable.

7.4. Industry trigger levels

A review has been undertaken of subsidence trigger levels and thresholds prepared by other CSG proponents in the Surat Basin. This has been presented here for reference.

Other proponents have nominated alternative trigger levels. For the Santos GLNG Project a subsidence trigger has been nominated as:

- *The subsidence trigger associated with CSG production (natural and anthropogenic non-CSG effects removed) is defined as an annual average ground motion of 16 mm/yr for over 50% of data points of a 1.5* km *x 1.5 km region*.

No explicit trigger level for subsidence was noted in QCG (2016). QGC listed the following activities in monitoring and management of subsidence in their 2016 water monitoring and management plan 2016 annual report:

- Ongoing Monitoring and Collection – The first year of analysed and processed data from the Stage 3 data acquisition (January 2015 to December 2015) was delivered on schedule in April 2016.
- Satellite Data Interpretation - The analysis of the average annual ground motion indicates that more than 98% of the study area is stable for the period from July 2012 to December 2015. Where there was movement above 8 mm per year it was primarily subsidence, 76% of which occurs in the CDA. Over the last 12 months of data acquisition, the rate of subsidence appears to have slowed over most areas.
- Ground Motion Trigger Assessment - An aggregation of the data from July 2012 to December 2015 into UWIR grid squares does not result in the triggering of the response plan for any area.
- Monitoring Data Management - Processed ground motion data, including the electronic vector files showing the location of the points, information on data quality and deformation values have been uploaded to the Web-based database, hosted by TRE Altamira and accessible to QGC, for the period from July 2012 to December 2015. The database is currently operating as planned, and has been successful in enabling the quick and accurate review and assessment of results.
- Ground Truthing - Condition 65a of the Department of the Environment approval specifies that the ground motion monitoring program must consist of a geodetic survey, so ground truthing is required.
- Five surveys have been completed for 29 identified permanent survey markers during the data acquisition period from July 2012 to December 2015. The results show an overall trend that is consistent with the results from the satellite-derived data.
- Predictive Assessments - In order to potentially predict ground deformation over time, QGC has used cumulative groundwater model outputs in conjunction with geo-mechanical theory to characterise potential deformation. The results of this geo-mechanical modelling indicate that the project is not expected to have any impact on the flow (direction or volume) of identified waterways of interest, and no wetlands within the QCLNG tenure are currently predicted to be impacted by ground motion.
- This predictive deformation assessment is being rerun using the outputs of the revised OGIA cumulative groundwater model which was delivered in September 2016.

7.5. Assessment of subsidence against screening, investigation and trigger levels

Assessment of subsidence measurement against the screening, investigation and trigger levels set out above should be carried out in a way that can allow comparison against the proposed thresholds. An initial screening should be carried out on the basis of movement exceeding 8 mm/yr to avoid assessment of areas of low movement. It is recommended that assessments of areas where movement rate exceeds 8 mm/yr over an area of 1 km by 1 km be investigated using aggregate subsidence since the commencement of CSG extraction in each drainage area. As the guidelines are expressed in terms of differential settlement and change of slope, the following approach is proposed:

1) Based on InSAR results identify areas of 1 km x 1 km for which 50% of the values exceed a settlement rate of 8 mm/yr.

2) For areas which meet the criteria in 1) above:

   a. Obtain interpreted cumulative subsidence since the commencement of CSG extraction for areas of active production.

   b. Where subsidence exceeding 100 mm[1] over areas greater than 1 km^2 (a reasonable measure of area surrounding a single CSG well) are encountered apply the following method:

      i. Prepare traverses averaging subsidence assessed using InSAR results over a 100 m wide band crossing the area affected.

      ii. Interpret the maximum differential settlement and change in slope along the traverse for comparison with the investigation values.

      iii. Where investigation levels are exceeded check if these relate to the activities or land use nominated in Table 7.

      iv. If investigation levels are exceeded in the relevant areas, carry out further site specific assessment using conventional survey methods over a period of six months to assess the significance of the impact. Impact on structures within populated areas are to be based upon evaluation of structures considered to be the most sensitive to subsidence.

      v. Where adverse impacts are demonstrated based upon the threshold values nominated in Section 6 mitigation measures are to be employed.

7.6. Trigger threshold exceedance response actions

Approval condition 13(g) requires the development and implementation of an action plan to address identified subsidence impacts within 90 calendar days of a trigger threshold being exceeded.

Trigger threshold exceedance response actions are dependent on the evaluation of the cause of the exceedance, and if the potential for detrimental impacts is confirmed, a Trigger Threshold Exceedance Action Plan will be developed and implemented within 90 days to minimise impact.

The action plan will:

- Identify potential mitigation measures and response actions.
- Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude.
- Evaluate time frames within which impacts would be expected to occur and within which mitigation actions would need to be successful.
- Schedule mitigation implementation, with consideration for the anticipated timing of the indicated impact.
- Contain procedures to evaluate the effectiveness of the mitigation measures.

Where an action plan is not developed and implemented within 90 calendar days of the identified trigger threshold exceedance this represents a non-compliance and the Minister will be notified.

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[1] Accumulated vertical movement of less than 100 mm is considered unlikely to result in breach of the nominated thresholds.

This process is illustrated in Figure 29.

Assessment of subsidence for SGP alone

Within the SGP predicted subsidence due to SGP alone is not predicted to exceed 100 mm except within Drainage Area DA11. The steepest subsidence gradient is assessed to occur under high assessment prediction near the western margin of DA11. The predicted gradient is approximately 50 mm over 7 km. This is well below the adopted investigation levels for protection of buildings, road, railways, pipelines of 1 in 1000 and for protection of field irrigation systems and the flow in the Condamine River of 25 mm/km.

Assessment of subsidence for Cumulative Case

An assessment of the predicted subsidence due to SGP and CSG extraction by other proponents is assessed as having a maximum value of 120 mm within DA11. The steepest predicted gradient is at the western margin of Drainage Area DA5 of 50 mm over 6 km. This is well below the adopted investigation thresholds for protection of buildings, road, railways, pipelines of 1 in 1000 and for protection of field irrigation systems of 0.3 m/km and the flow in the Condamine River of 25 mm/km.

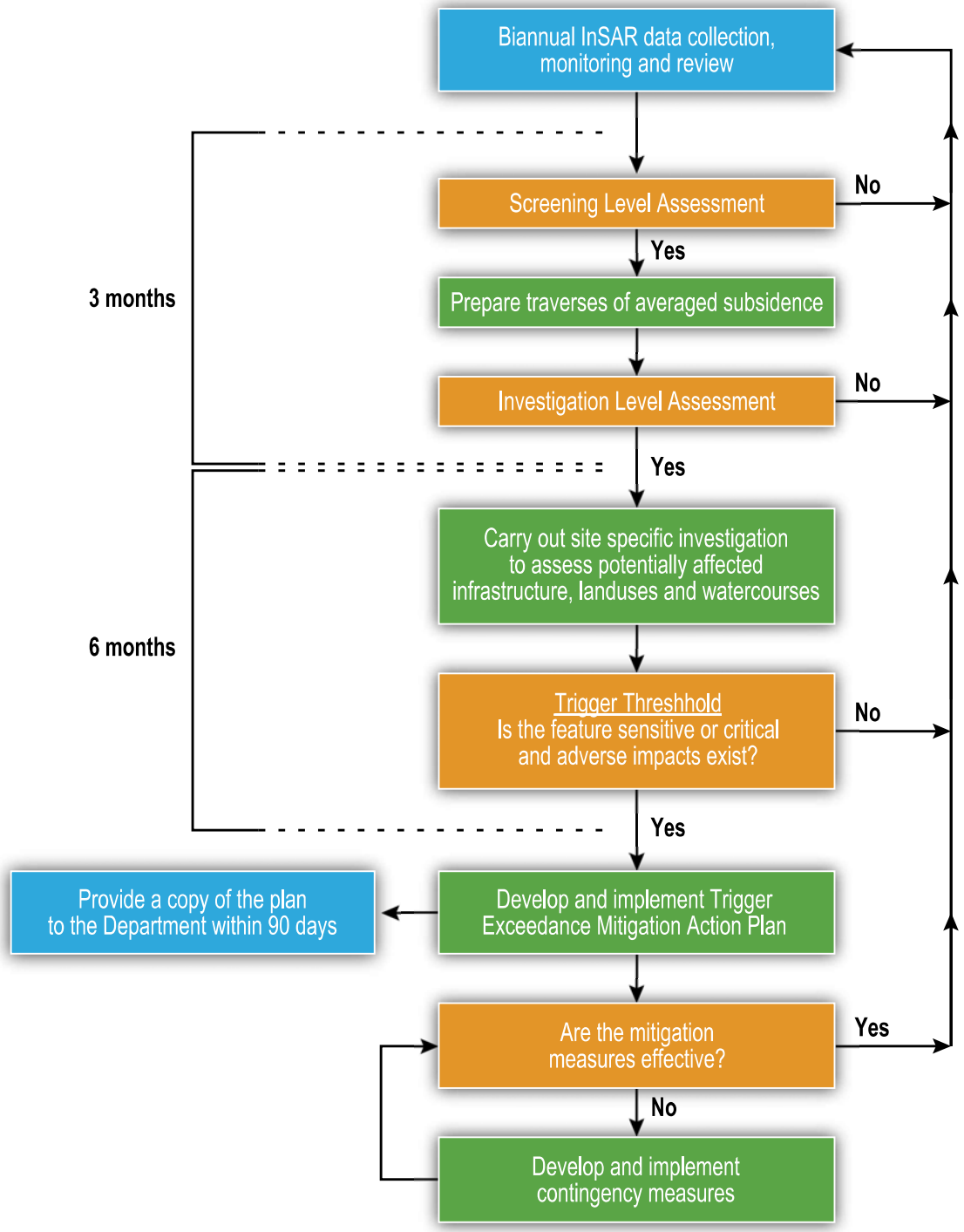
For the impacts assessed in Section 6 the nominated investigation levels wold not be breached.

7.7. Uncertainties

While the predicted subsidence would not breach the adopted investigation levels it must be recognised that the assessment is based on limited data and contains significant uncertainty. The assessment is sensitive to the adopted values of:

- Modulus of the coal measure rocks.
- Volume loss of coal associated with removal of coal seam gas.
- Predicted groundwater drawdown.

It is recommended that the subsidence assessment be reviewed as groundwater monitoring becomes available for the initial development of the SGP and as further assessments of groundwater drawdown are developed.



coffey A TETRA TECH COMPANY	Date: 19.09.2018 Project: 754-ENAUABTF20484AA File Name: 20484AA_M05_F029_GRA	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Subsidence monitoring assessment flow chart	Figure No: 29

8. Monitoring Program Development

The current monitoring program provides groundwater level monitoring and monitoring of subsidence using InSAR technology. The interpretation of subsidence responses and prediction of future subsidence, requires good quality groundwater level monitoring over the depth of the affected ground, and collocated ground movement measurements. The review described in the Altamira report encountered the following difficulties:

- Groundwater level monitoring did not capture initial response within a key formation
- Water production records relevant to particular areas were not readily accessible
- Gas yield results relevant to particular areas were not accessible.

While the InSAR technology provides high resolution and wide coverage, it is recommended that alternative geodetic measurement of ground movement are taken at selected locations to provide a ground-truthing check on the InSAR results. It is recommended that locations for geotechnical ground movement monitoring are collocated with groundwater monitoring bores which provide coverage of the full ground profile potentially influenced by Arrow SGP operations. It is recommended that these instrumented sites are located at the centre of selected Arrow SGP well fields and are installed to provide baseline information prior to the initiation of production pumping in the area.

Measures which can be of value in assessment of subsidence impacts include:

- Tiltmeters can measure small changes ground slope.
- Survey using traditional or GPS methods.
- Extensometers.
- Condition assessments of structures at risk.

Of these methods use of extensometers and survey to ground truth the results of InSAR monitoring are considered most useful. Extensometers allow identification of the horizons in the ground profile contributing to surface settlement. It is considered that tiltmeters would be subject to shallow influences unrepresentative of movements originating from Arrow SGP activities.

Figure 30 sets out locations recommended for establishment of subsidence monitoring stations. These stations would comprise:

- Groundwater monitoring at multiple locations including within, above and below the Walloon Coal Measures.
- Geodetic ground movement (vertical) monitoring monument (installed to avoid shrink swell movement of the upper soils).

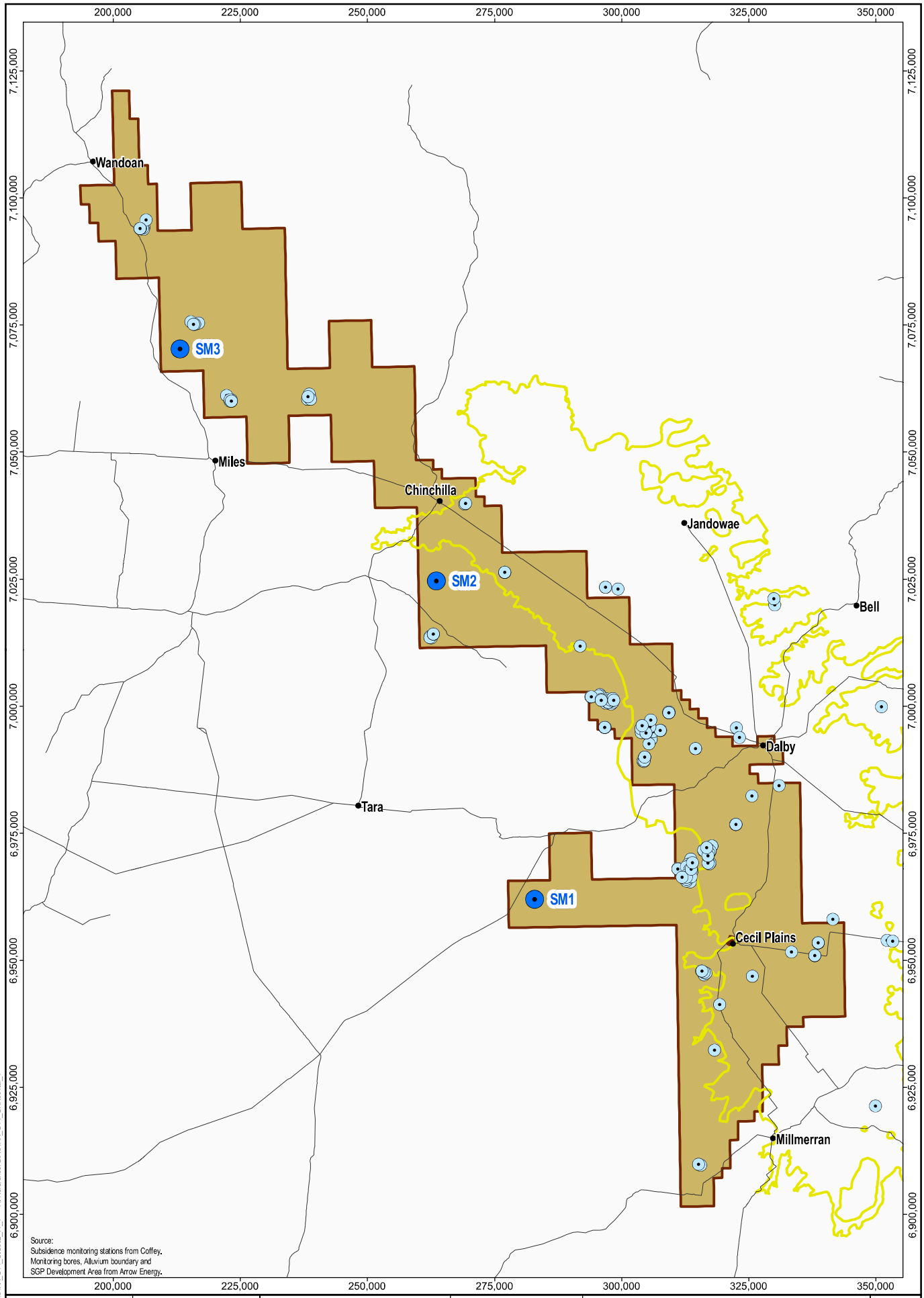
In addition, at one station (SM1 in Drainage Area 11) an extensometer array is recommended to separately record compression within the Juandah Coal Measures and the Taroom Coal Measures.

8.1. Ongoing monitoring

Measurement of settlement and extensometers is proposed on an initially monthly frequency. Ongoing reviews of the baseline established will determine when changeover to monitoring commences on a quarterly basis (with associated continuous groundwater level measurement using data loggers).

A program for ongoing monitoring will be implemented to confirm that subsidence is within the predicted behaviour of the strata over time. Where deviation from predictions is observed, revised predictions will be prepared and assessment of the significance of the predictions made.

InSAR data updates will be received on a 6-monthly basis. Review of the updated InSAR data will be undertaken within 3 months of the data being received.



coffey A TETRA TECH COMPANY	Date: 24.03.2017 Project: ENAUABTF20484AA File Name: 20484AA_GT1_F002_GIS	Arrow Energy Surat Gas Project WMMP	arrow energy go further	Recommended subsidence monitoring stations	Figure No: 30

MXD Reference: 20484AA_GT1_GIS002_v1_1 AI Reference: 20484AA_GT1_GRA001.ai_1

9. Reporting recommendations

Monitoring of subsidence and groundwater level variation based on existing data indicates that settlement is gradual and accompanies groundwater level drawdown. The changes develop gradually over months and years, and as a result it is recommended that a review of subsidence is carried out on an annual basis. It is recommended that surveillance reports are prepared annually providing diagnostic plots of drawdown and ground movement for each of the subsidence monitoring stations. Annual review and reporting is recommended covering:

- Changes from the baseline condition.
- Incremental changes in groundwater level and ground movement over the previous twelve months.
- Review of ground movement monitoring against adopted trigger level.
- Review of trigger levels.
- Consideration of complaints in relation to ground movement.
- Recommendations for actions in response to breaches of trigger levels.
- Recommendations in relation to the future frequency of monitoring, repair or investigation of instruments producing inconsistent results, revision of trigger levels.

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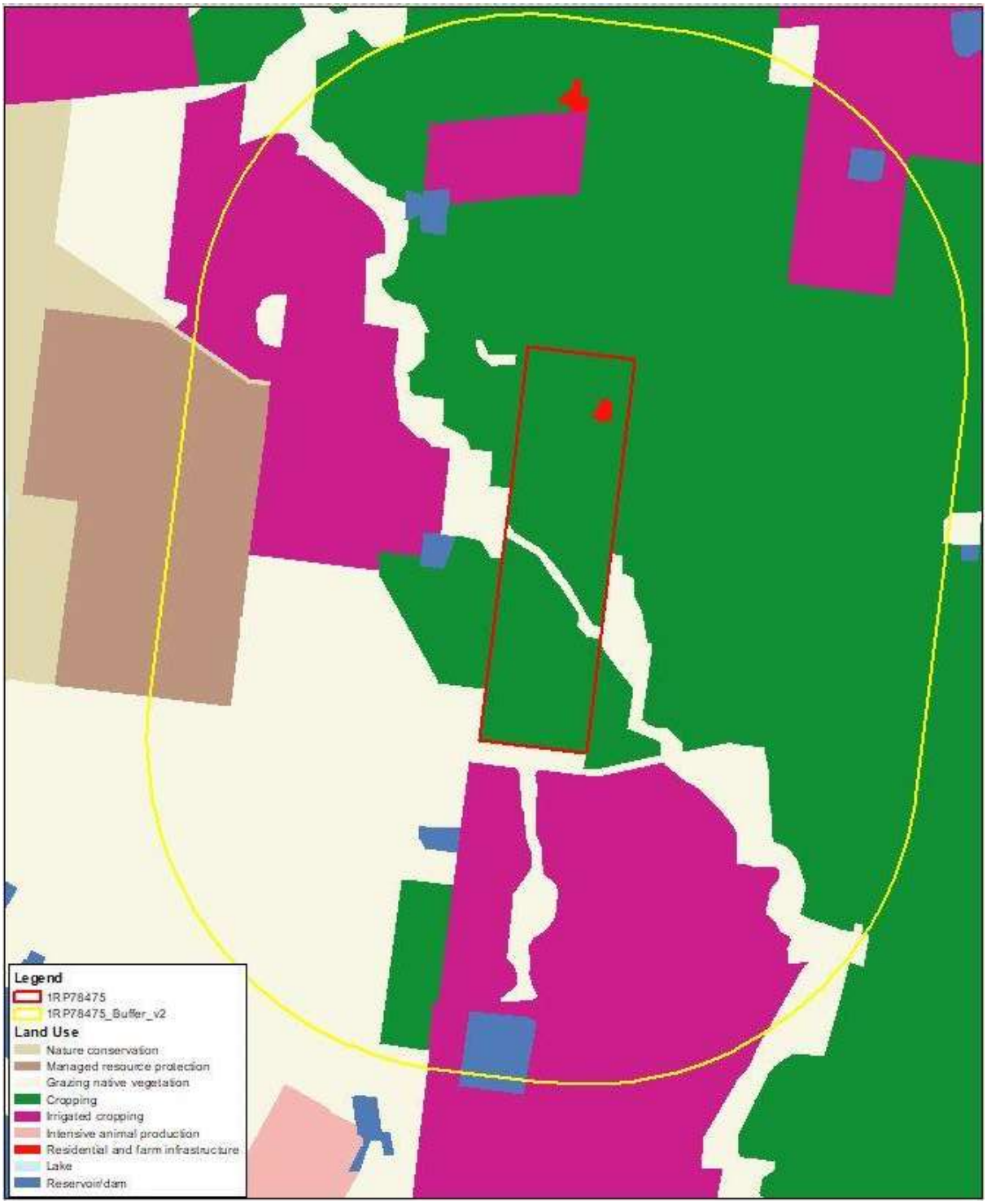
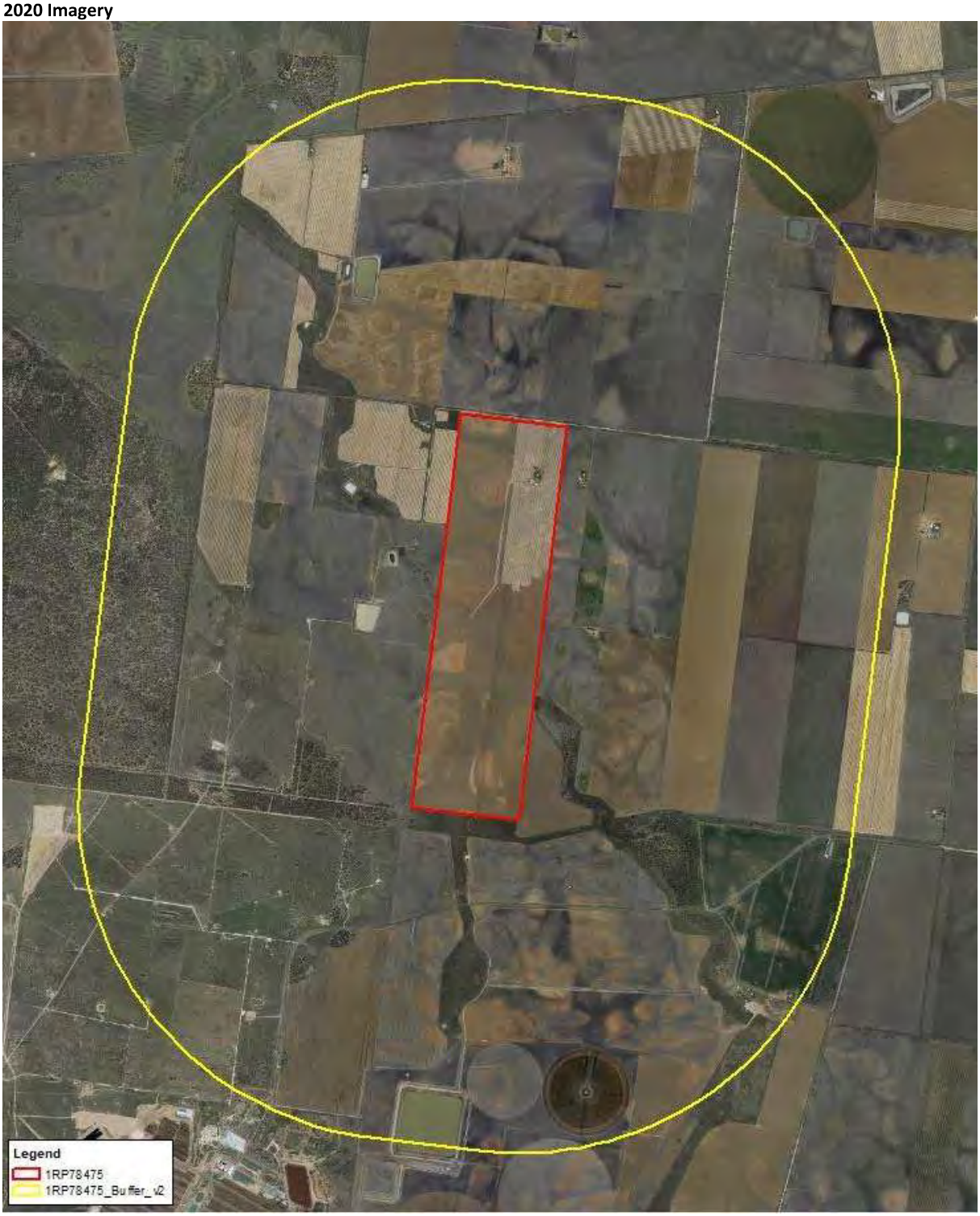
Appendix D – Revised Appendix 2 (Response to Item # 18 a)

Appendix D – Revised Appendix 2 (Response to Item # 18 a)

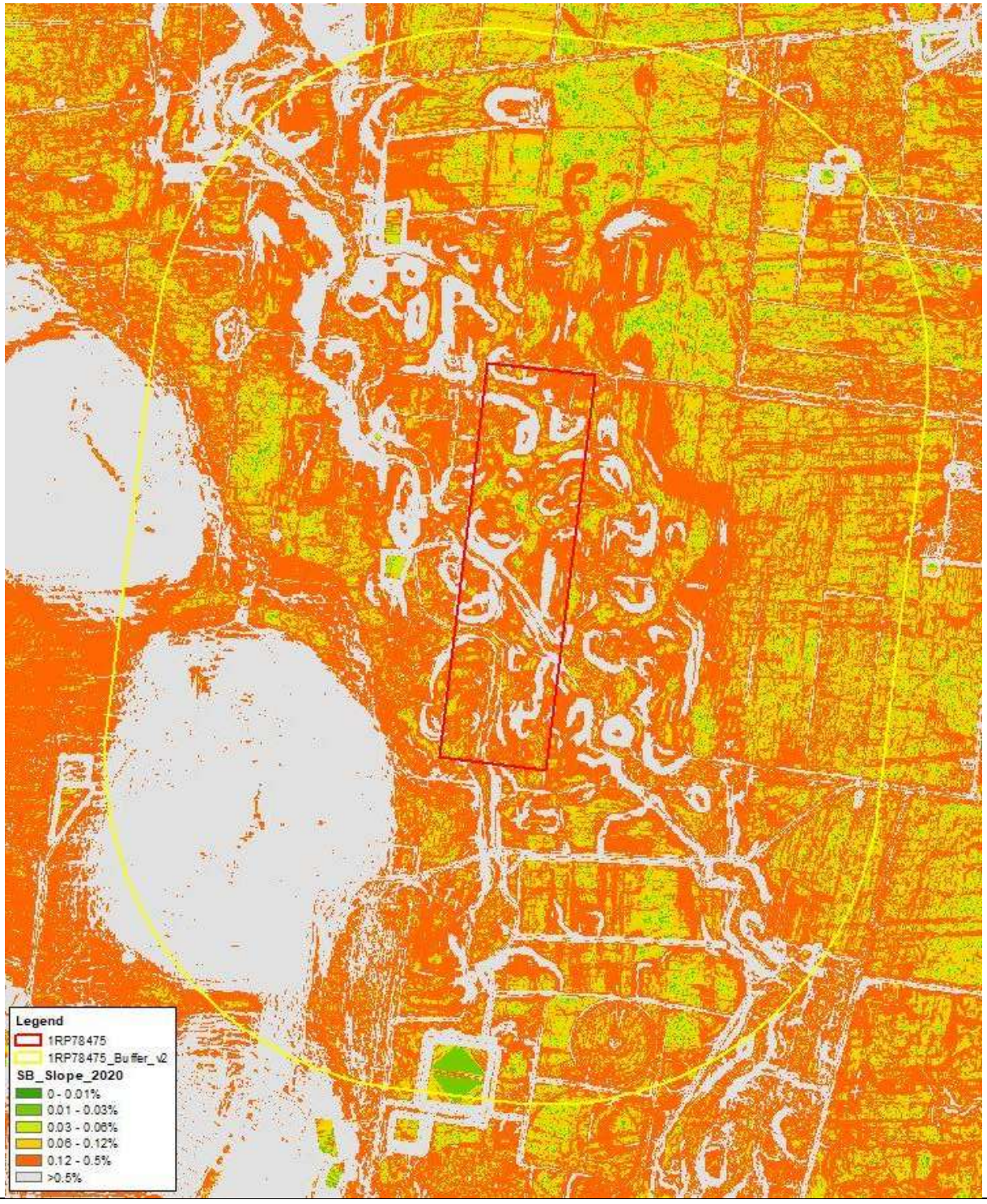
Lot on Plan	Item
1RP78475	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as cropping with grazing native vegetation and residential/farm infrastructure. Surrounding land use (within 3km buffer) includes cropping, irrigated cropping, dams, grazing native vegetation, residential/farm infrastructure and managed resource protection. 

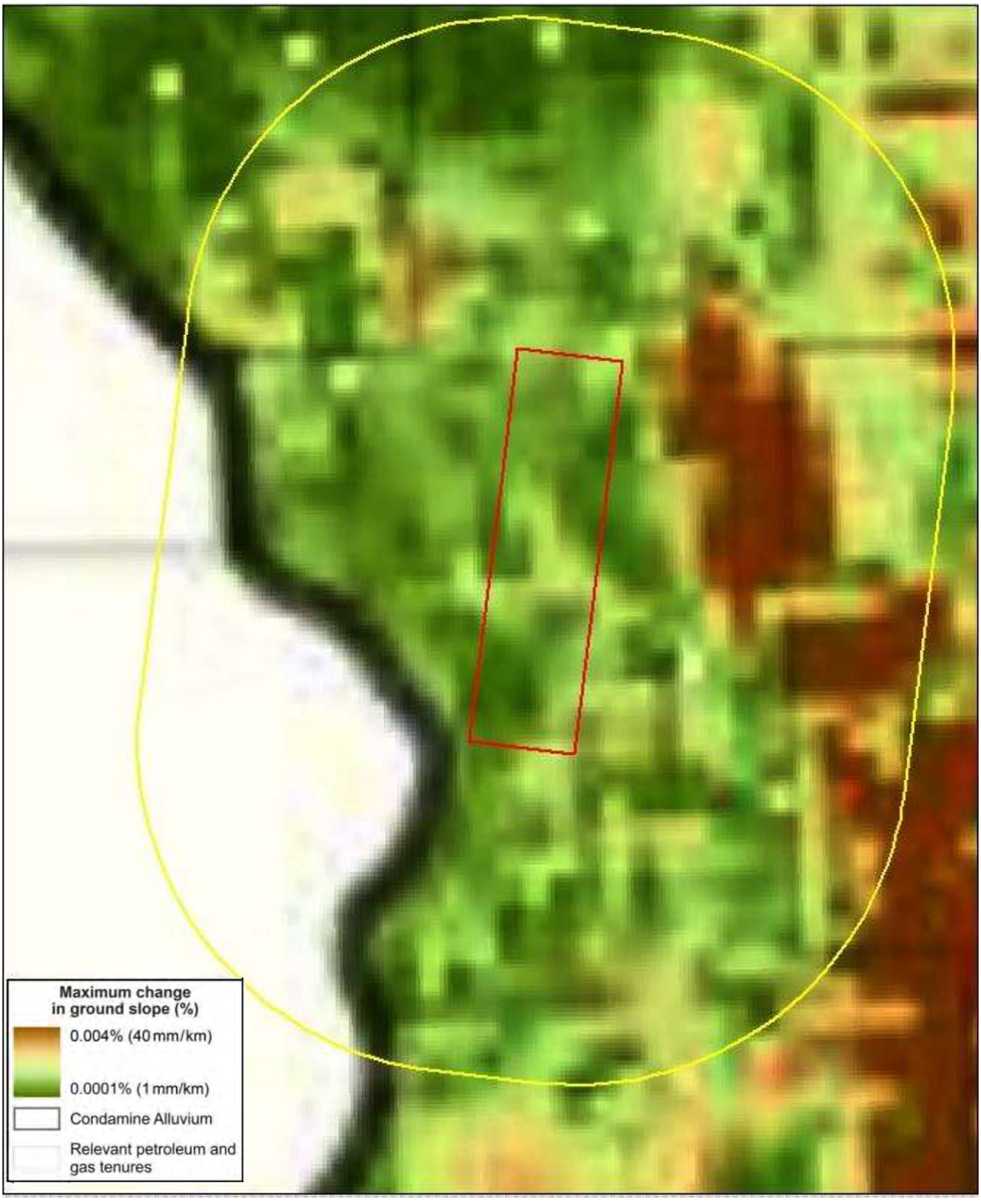
1RP78475	**2020 Imagery** 

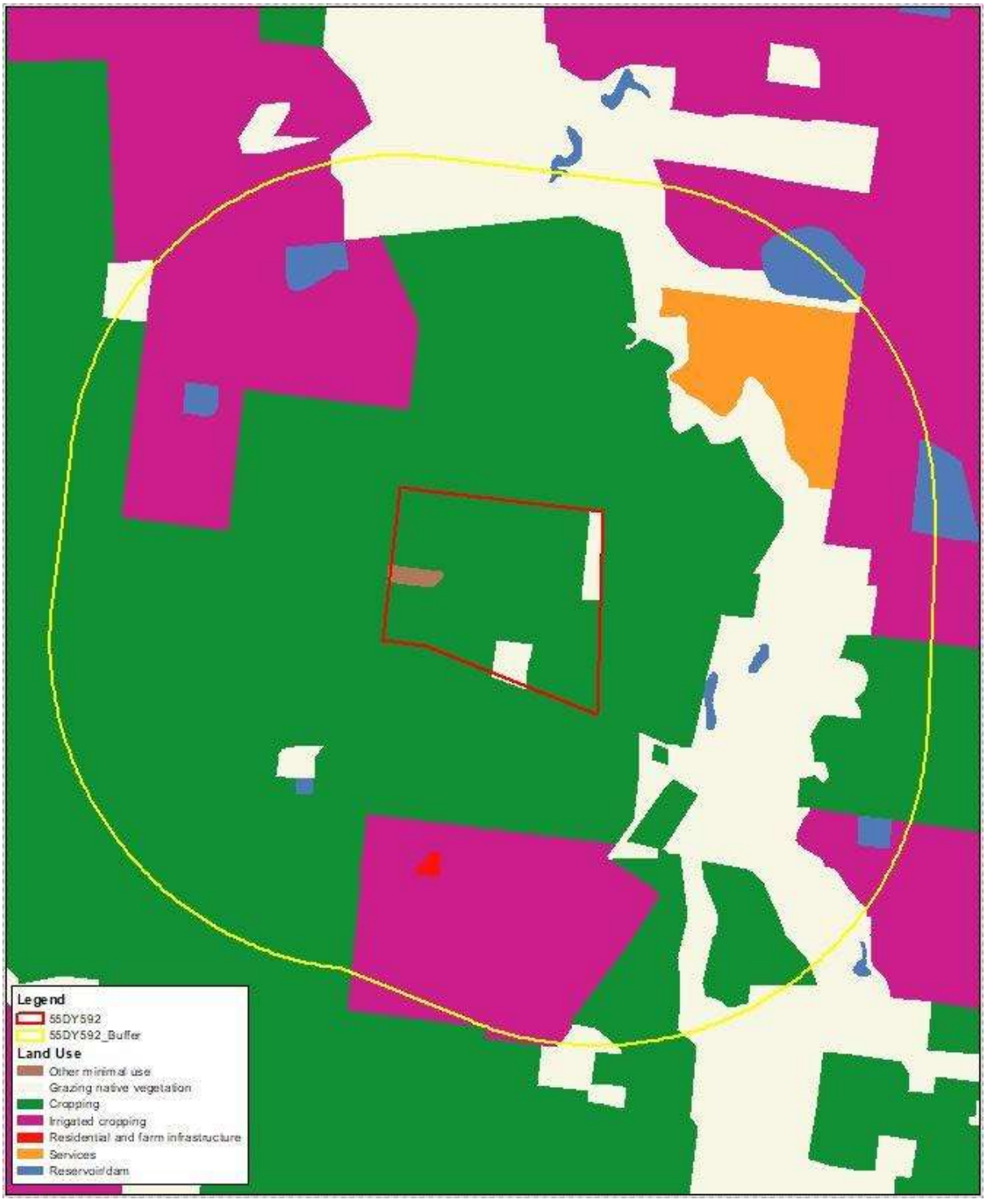
1RP78475

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	0.5	0.1%	17.45	0.3%
0.01 – 0.03	3.94	1.1%	140.6	2.5%
0.03 – 0.06	11.25	3.3%	372.06	6.7%
0.06 – 0.12	34.32	9.9%	924.25	16.6%
0.12 – 0.5	203.5	58.8%	2542.95	45.8%
> 0.5	92.32	26.7%	1555.65	28.0%



1RP78475	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021** Lot on plan approximate predicted maximum change in ground slope 0.0001% to 0.00205% (based on scale in original figure [Figure 7-7, 2021 UWIR]). Surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.004% (based on scale in original figure [Figure 7-7, 2021 UWIR]) 

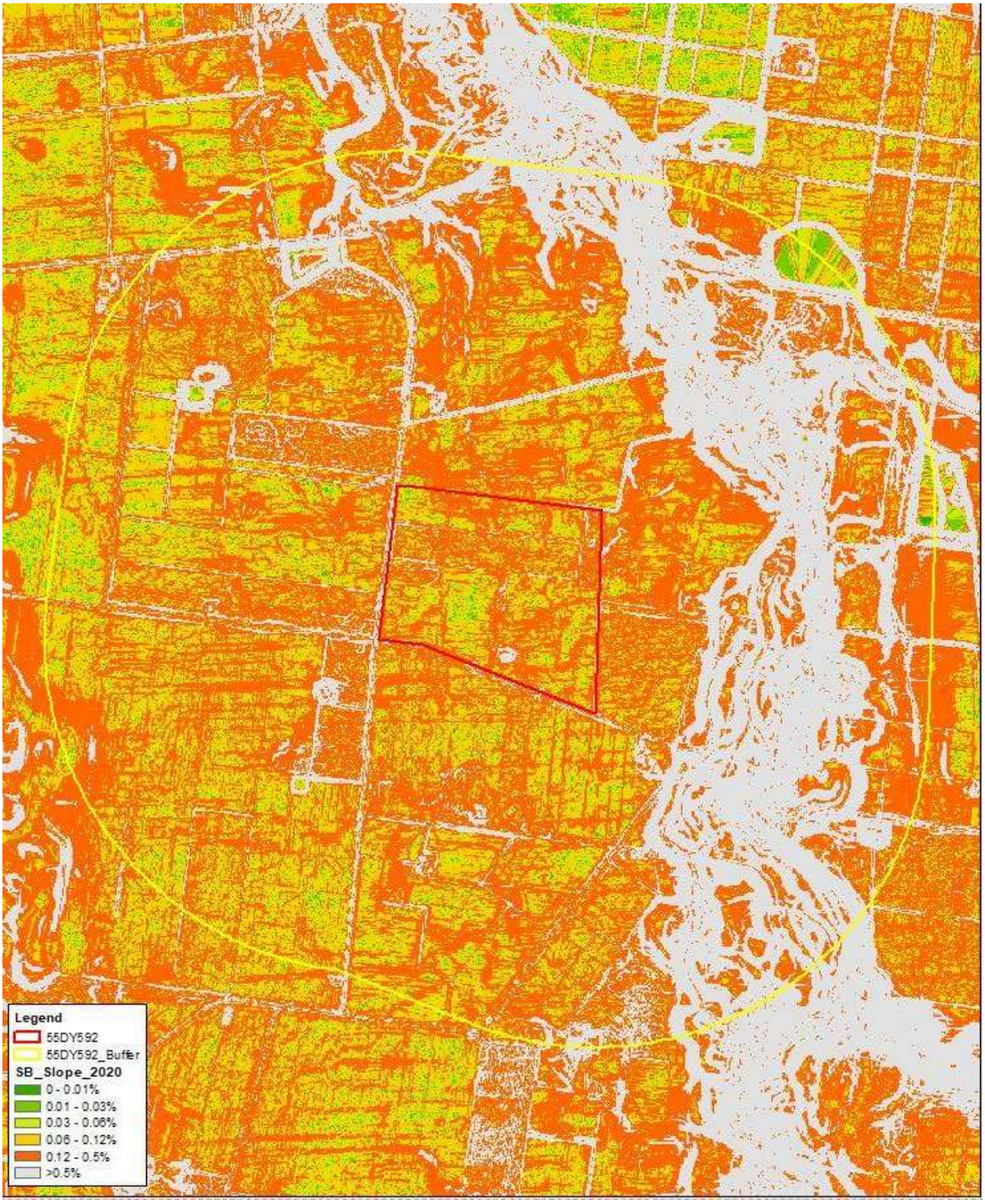
55DY592	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as cropping with grazing native vegetation and other minimal use. Surrounding land use (within 3km buffer) includes cropping, irrigated cropping, dams, grazing native vegetation, other minimal use, residential/farm infrastructure and services. 

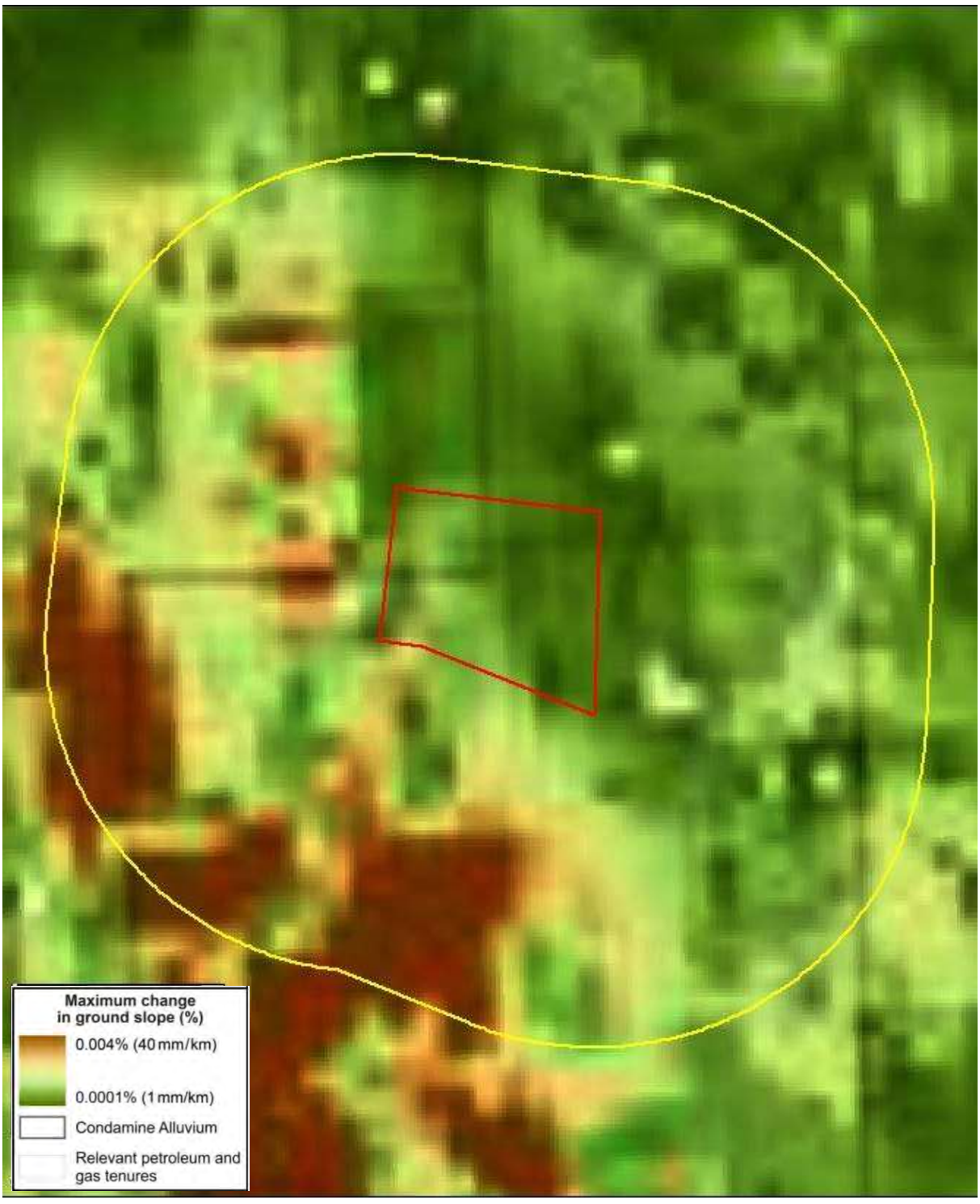
55DY592	**2020 Imagery** 

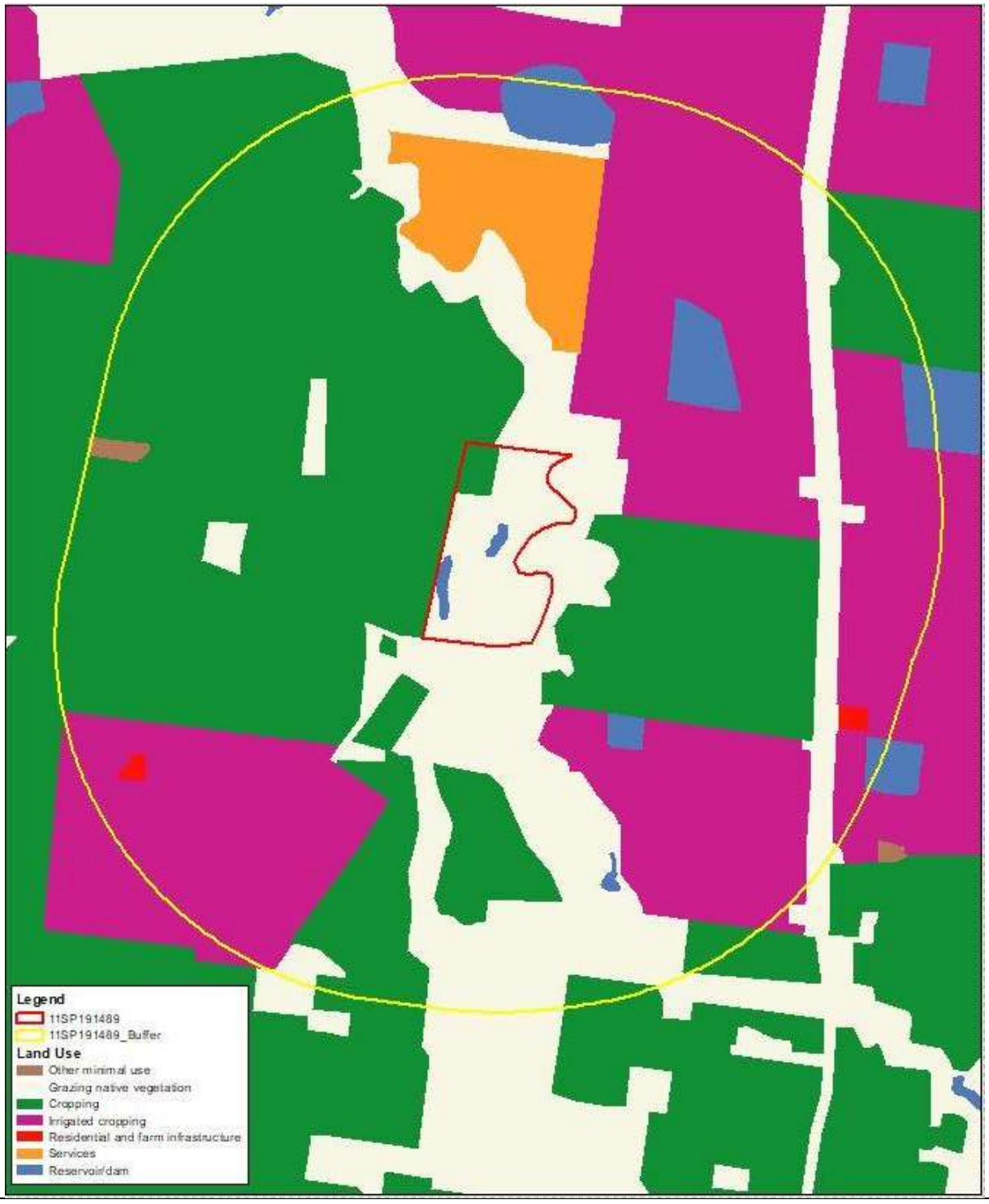
55DY592

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	1.46	0.5%	16.44	0.3%
0.01 – 0.03	11.73	3.9%	120.07	2.4%
0.03 – 0.06	33.91	11.3%	344.73	7.0%
0.06 – 0.12	82.97	27.6%	911.47	18.5%
0.12 – 0.5	157.85	52.6%	2222.52	45.1%
> 0.5	12.31	4.1%	1310.59	26.6%



55DY592	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021)** Lot on plan approximate predicted maximum change in ground slope 0.0001% to 0.00205% (based on scale in original figure [Figure 7-7, 2021 UWIR]). Surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.004% (based on scale in original figure [Figure 7-7, 2021 UWIR]). 

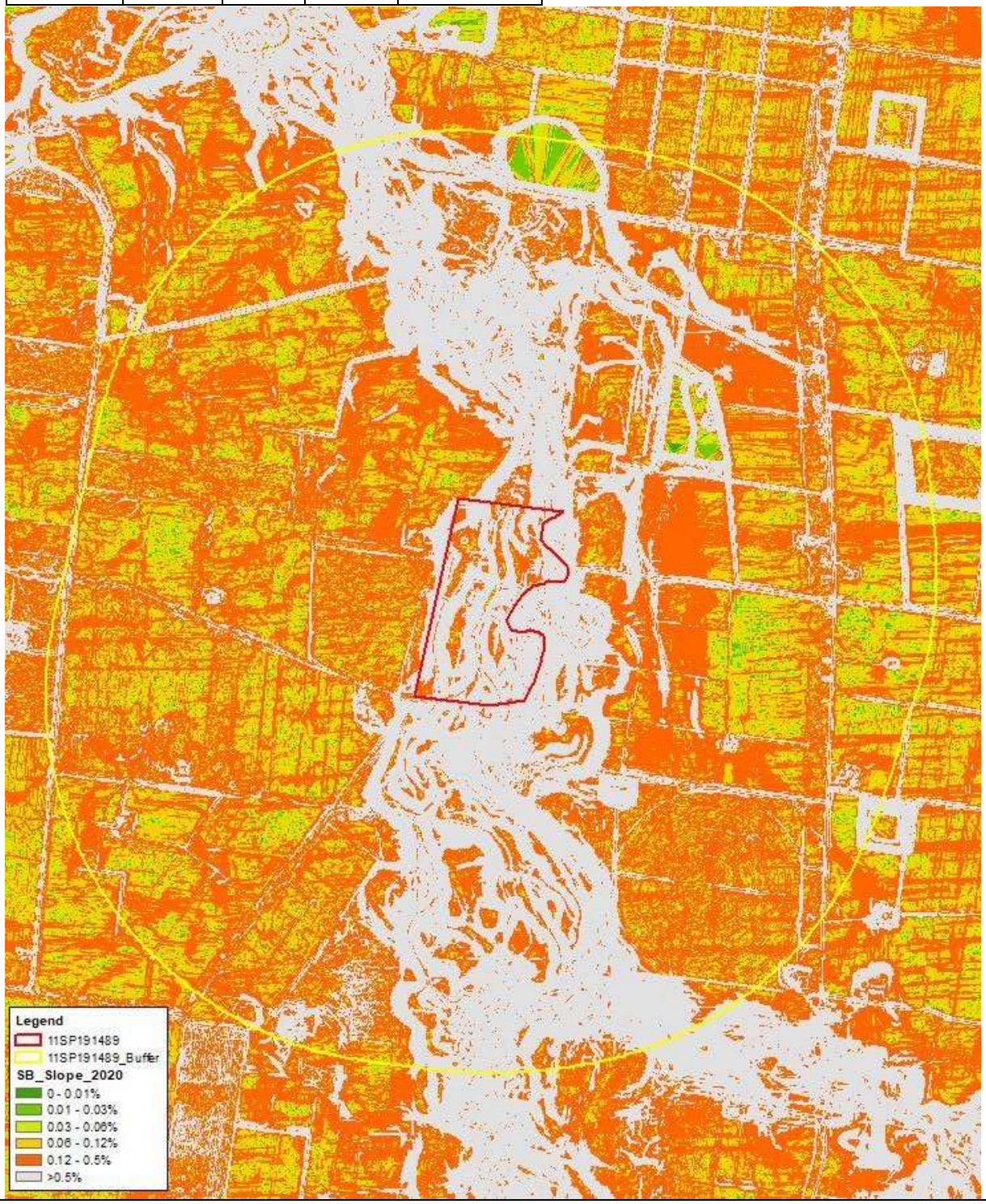
11SP191489	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as cropping with grazing native vegetation and dams. Surrounding land use (within 3km buffer) includes cropping, irrigated cropping, dams, grazing native vegetation, other minimal use, residential/farm infrastructure and services. 

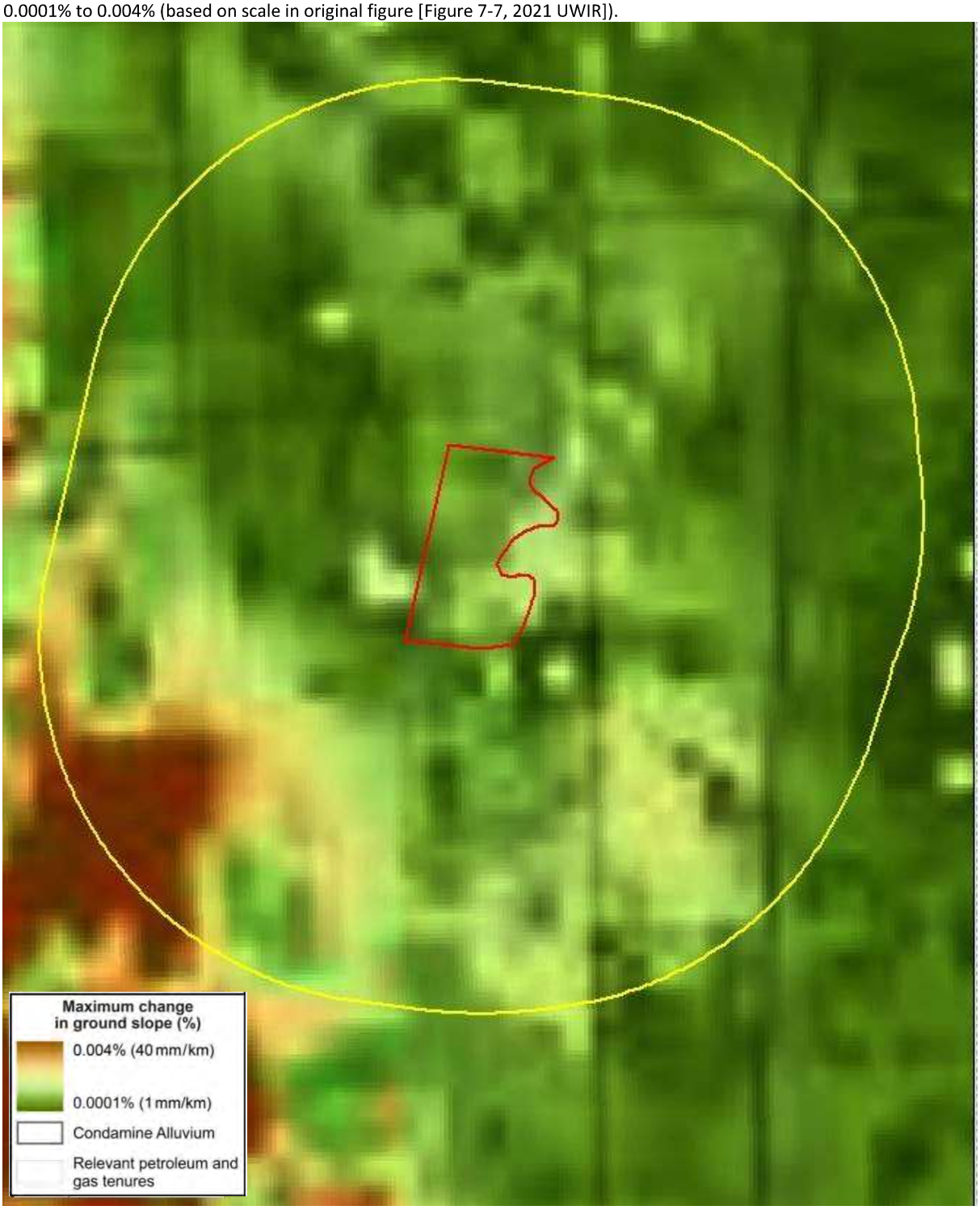
11SP191489	**2020 Imagery** 

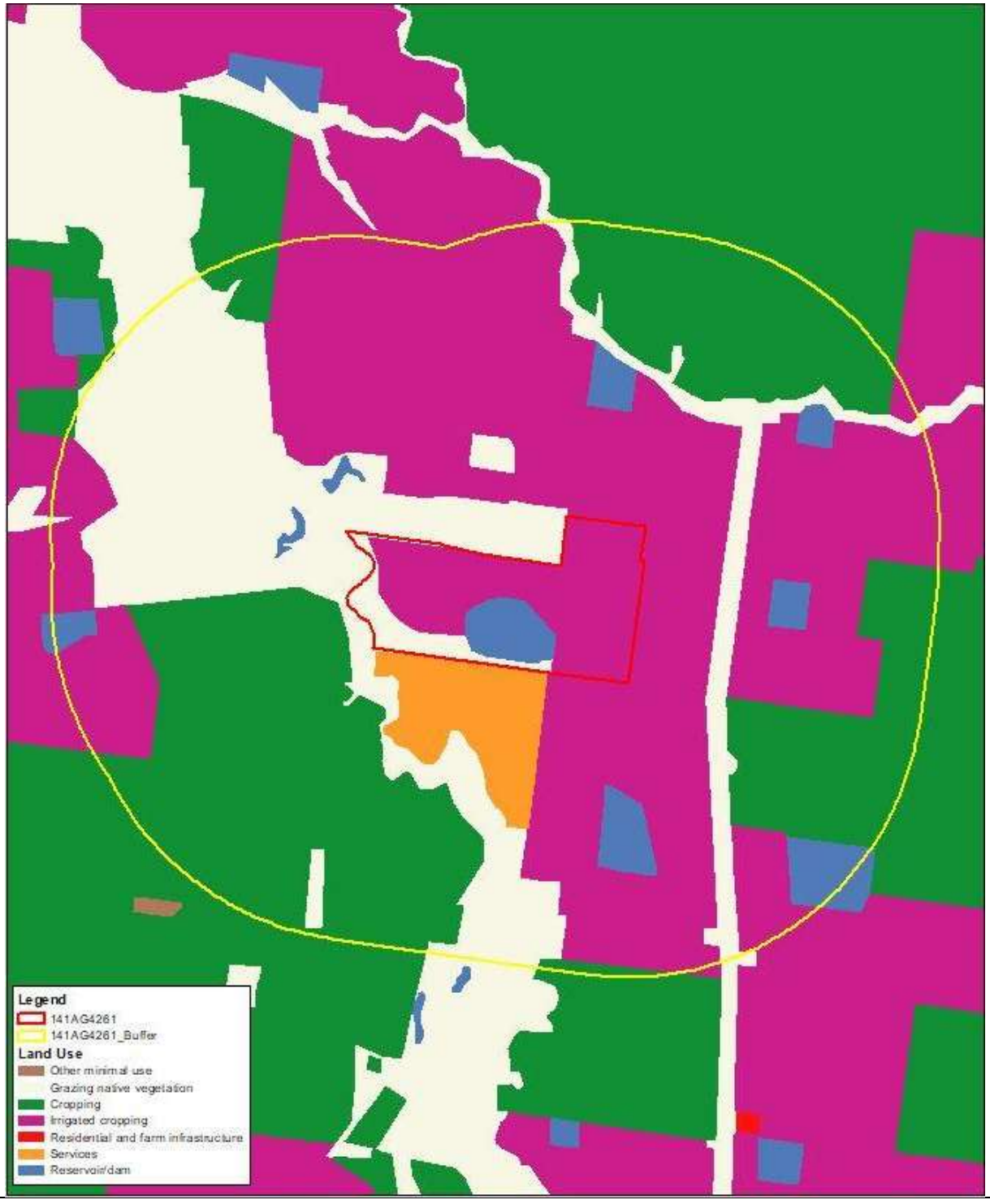
11SP191489

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	0.04	0.0%	13.03	0.3%
0.01 – 0.03	0.22	0.2%	97.8	2.3%
0.03 – 0.06	0.74	0.6%	269.69	6.3%
0.06 – 0.12	2.34	1.7%	704.11	16.4%
0.12 – 0.5	29.46	22.0%	1939.88	45.1%
> 0.5	100.99	75.5%	1278.96	29.7%



11SP191489	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021)** Lot on plan approximate predicted maximum change in ground slope 0.0001% to 0.00205% (based on scale in original figure [Figure 7-7, 2021 UWIR]). Surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.004% (based on scale in original figure [Figure 7-7, 2021 UWIR]). 

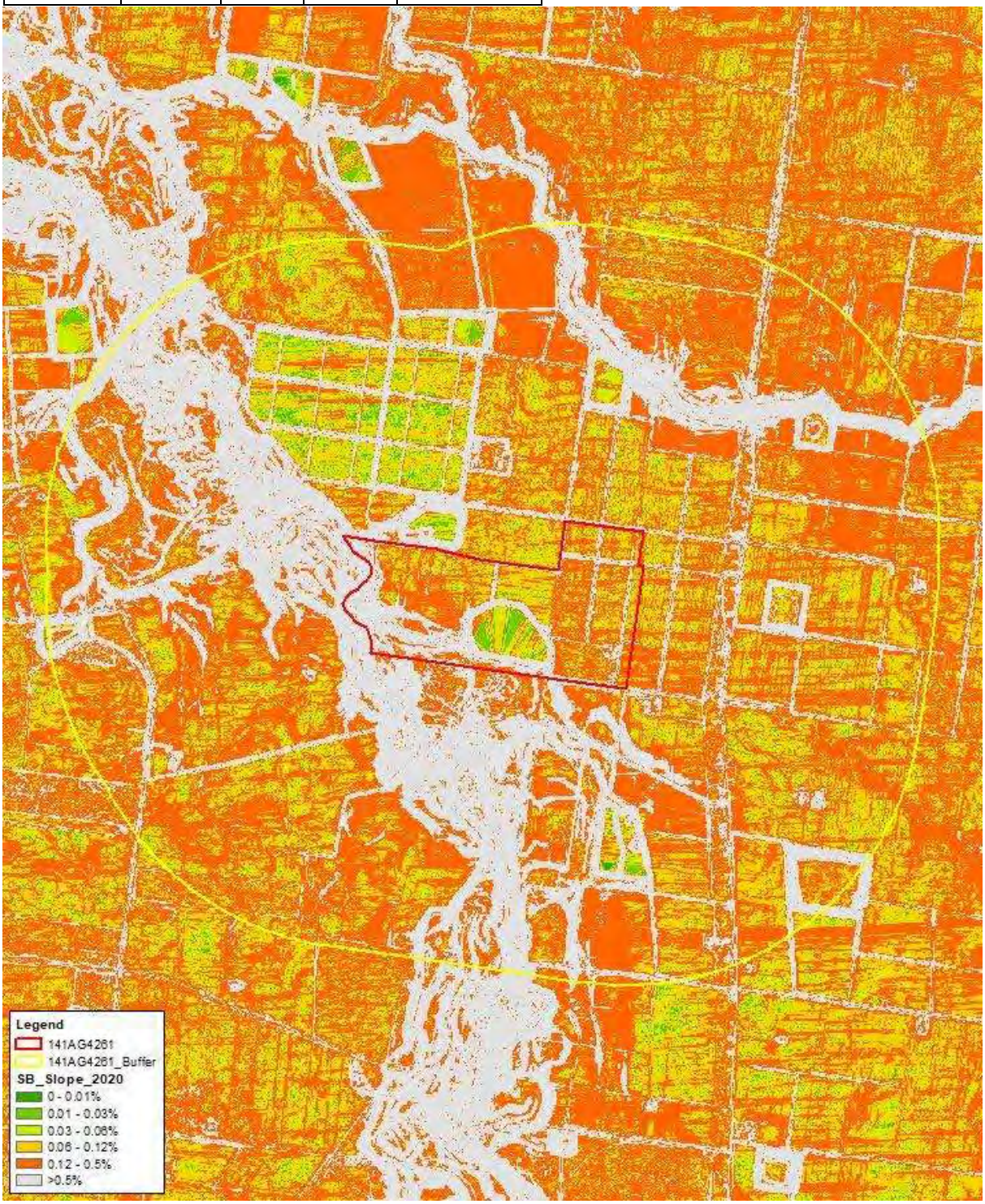
141AG4261	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as irrigated cropping, grazing native vegetation and dams. Surrounding land use (within 3km buffer) includes cropping, irrigated cropping, dams, grazing native vegetation, other minimal use and services. 

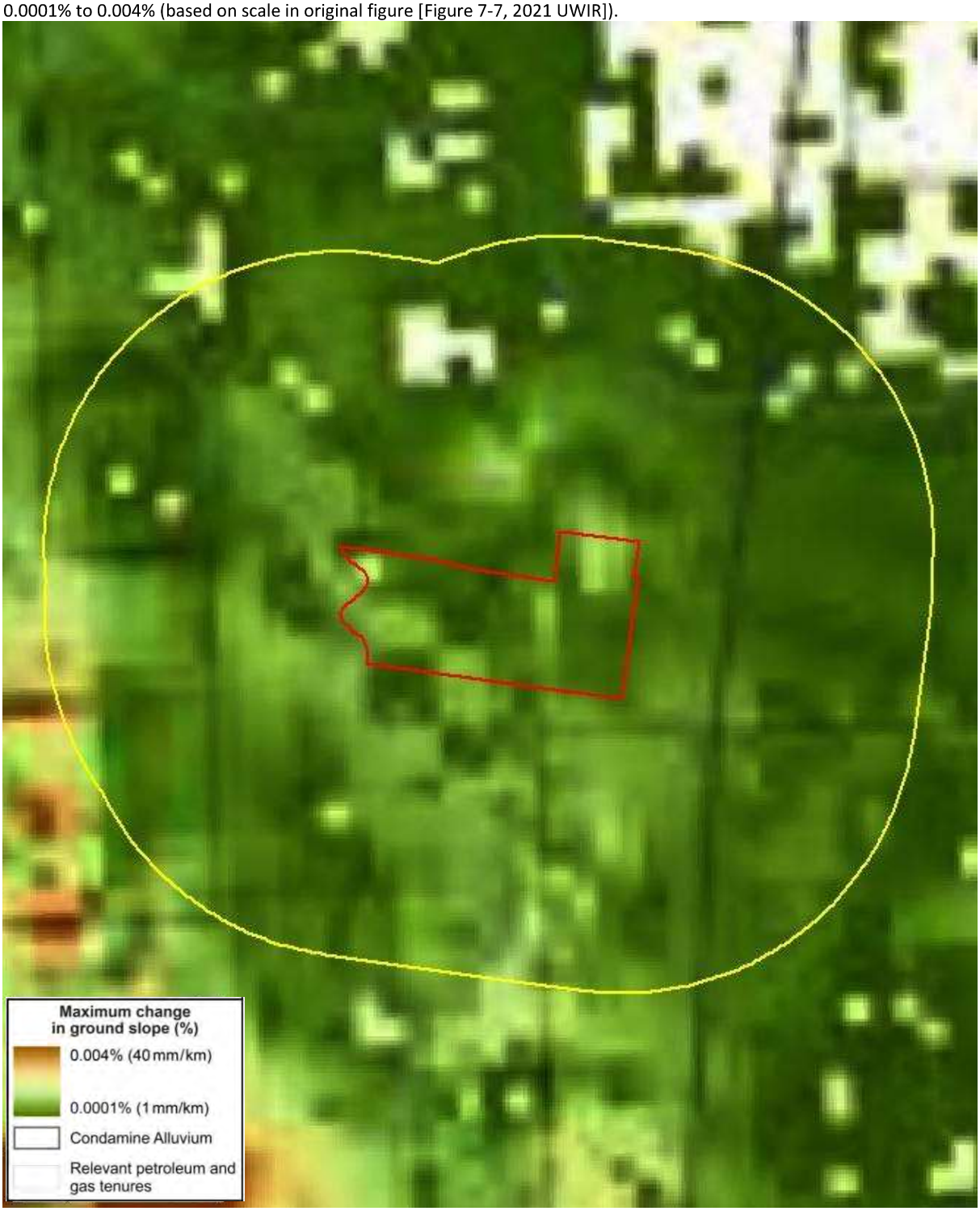
141AG4261	**2020 Imagery** 

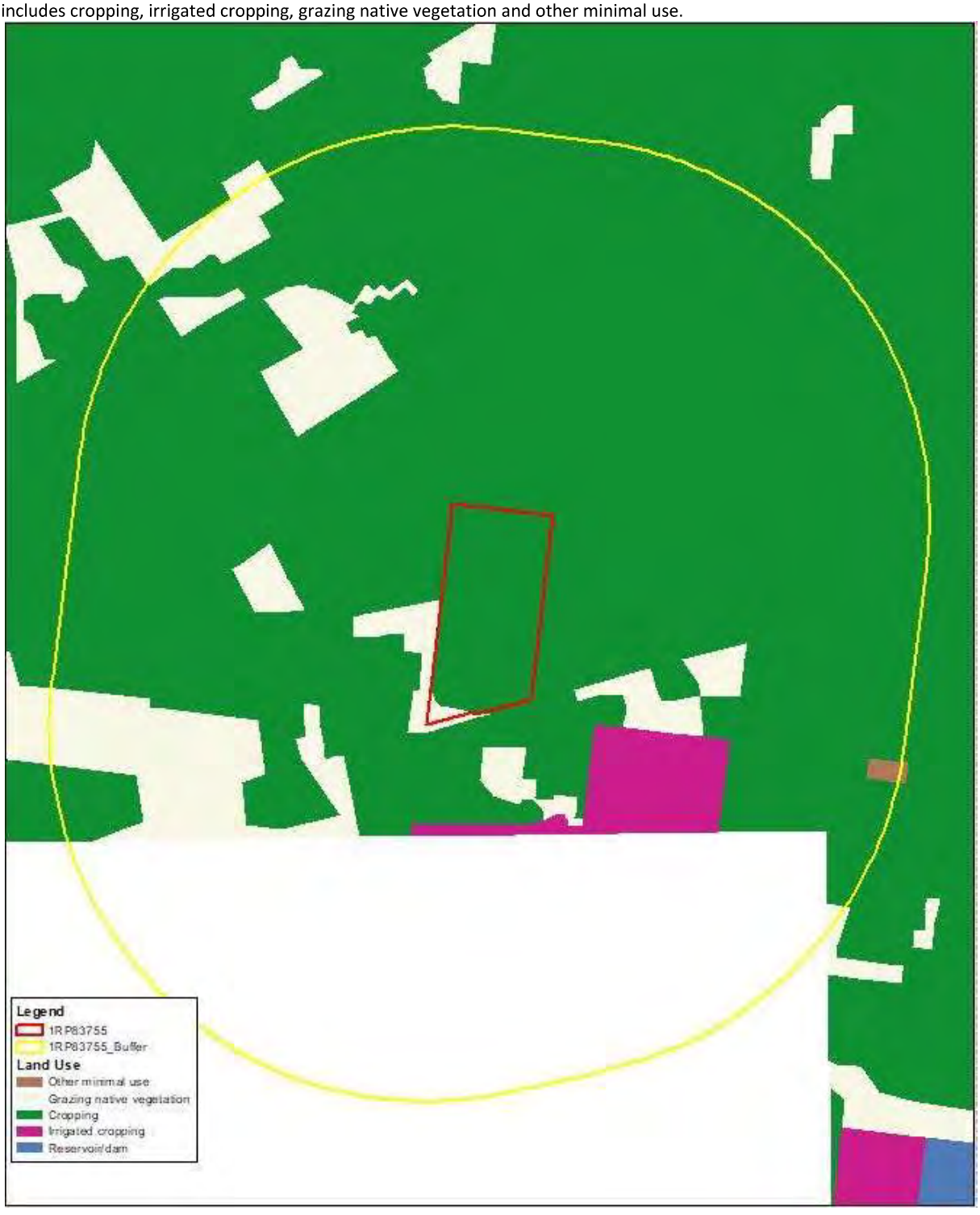
141AG4261

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	1.77	0.5%	18.48	0.3%
0.01 – 0.03	16.2	4.6%	134.35	2.5%
0.03 – 0.06	29	8.2%	356.3	6.6%
0.06 – 0.12	64.79	18.4%	898.73	16.7%
0.12 – 0.5	136.36	38.8%	2433.73	45.2%
> 0.5	103.72	29.5%	1548.71	28.7%



141AG4261	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021)** Lot on plan approximate predicted maximum change in ground slope 0.0001% to 0.00205% (based on scale in original figure [Figure 7-7, 2021 UWIR]). Surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.004% (based on scale in original figure [Figure 7-7, 2021 UWIR]). 

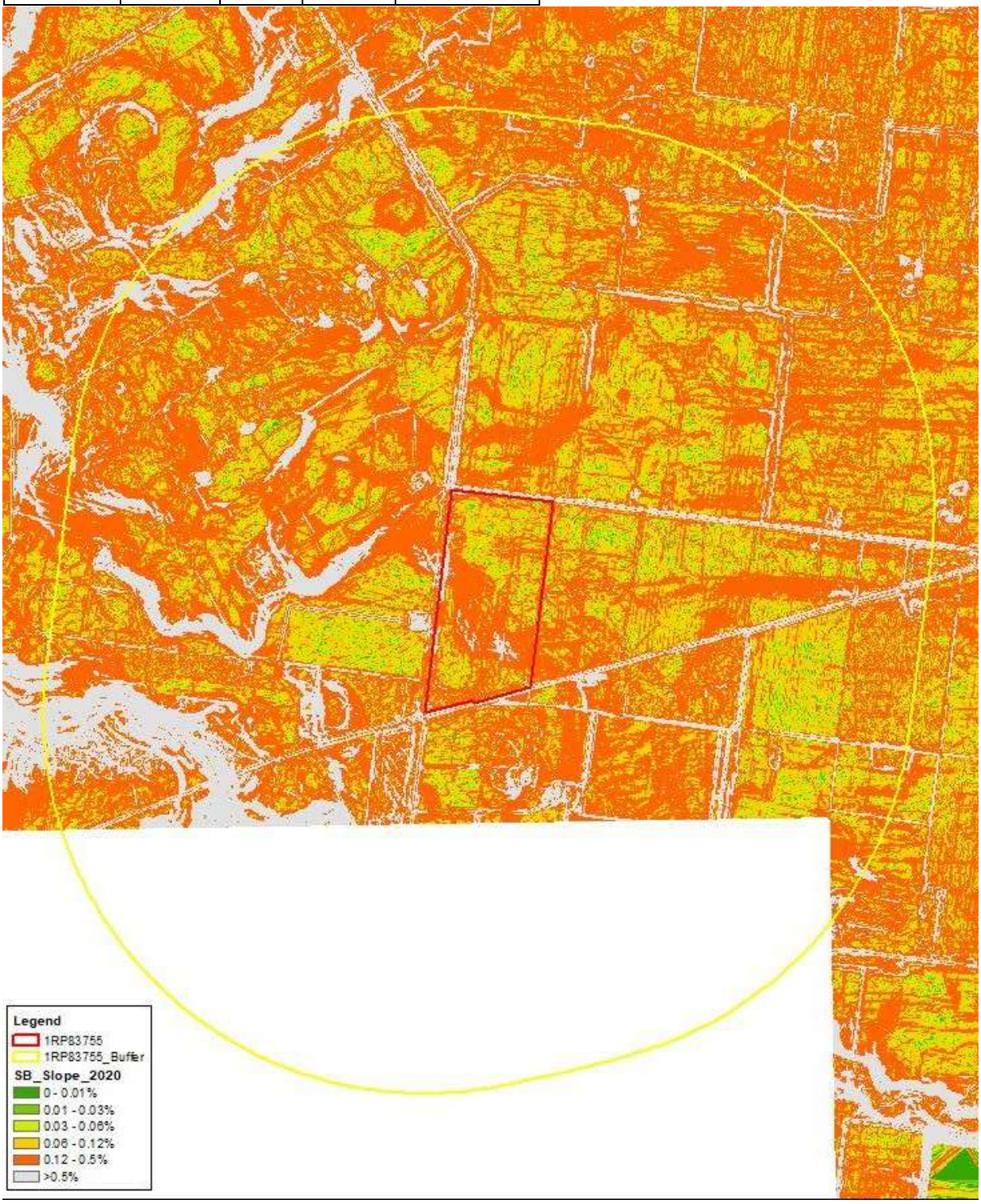
1RP83755	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as cropping and grazing native vegetation. Surrounding land use (within 3km buffer) (within tenure) includes cropping, irrigated cropping, grazing native vegetation and other minimal use. 

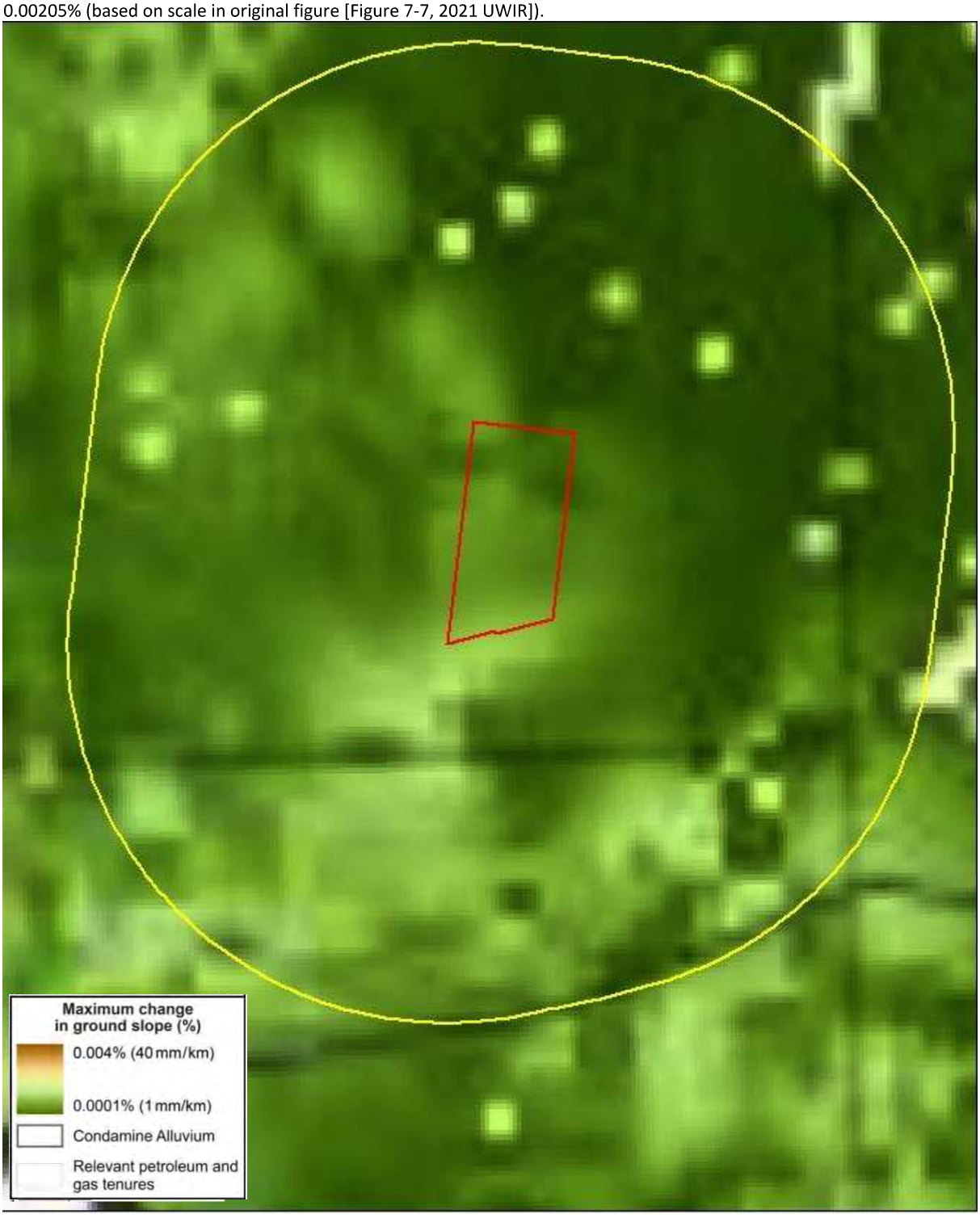
1RP83755	**2020 Imagery** 

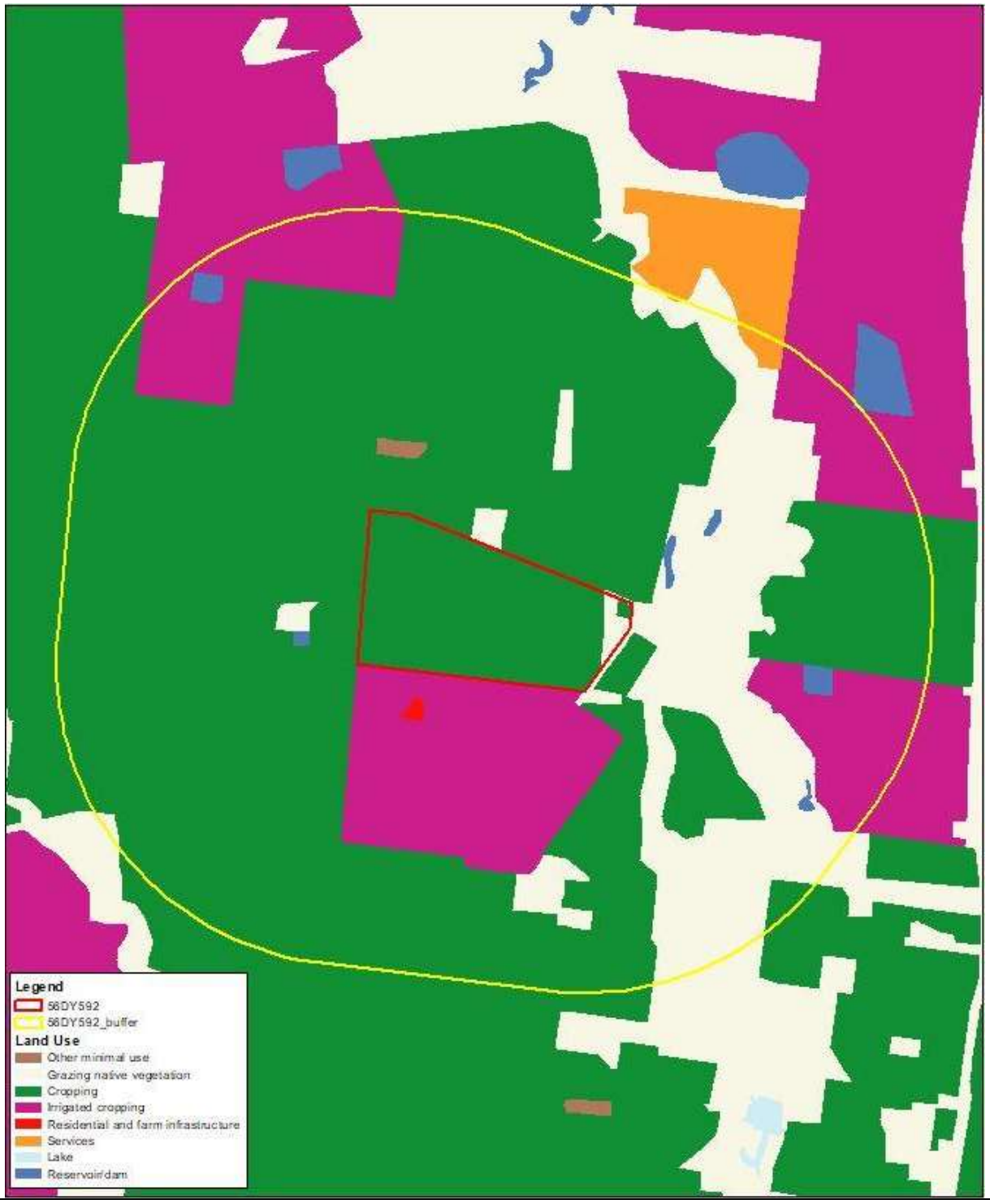
1RP83755

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	0.41	0.3%	11.9	0.4%
0.01 – 0.03	3.76	2.9%	90.1	2.7%
0.03 – 0.06	11.51	8.8%	272.44	8.2%
0.06 – 0.12	33.23	25.4%	743.35	22.5%
0.12 – 0.5	74.4	56.8%	1769.06	53.5%
> 0.5	7.69	5.9%	419.27	12.7%



1RP83755	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021)** Lot on plan and surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.00205% (based on scale in original figure [Figure 7-7, 2021 UWIR]). 

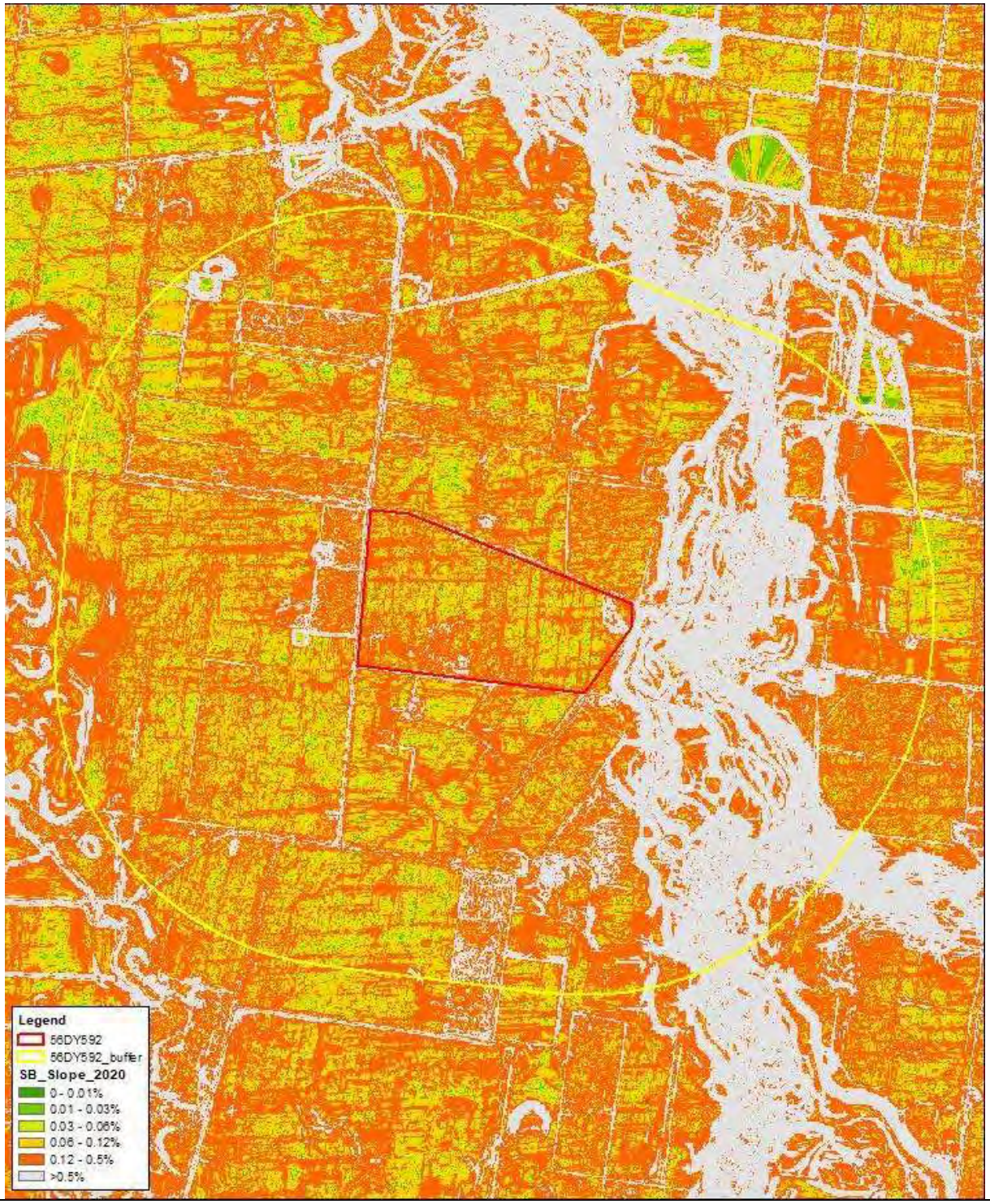
56DY592	**Qld Land Use Mapping (Queensland Government, 2021)** Lot on plan mapped as cropping and grazing native vegetation. Surrounding land use (within 3km buffer) (within tenure) includes cropping, irrigated cropping, grazing native vegetation, farm infrastructure, dams, services and other minimal use. 

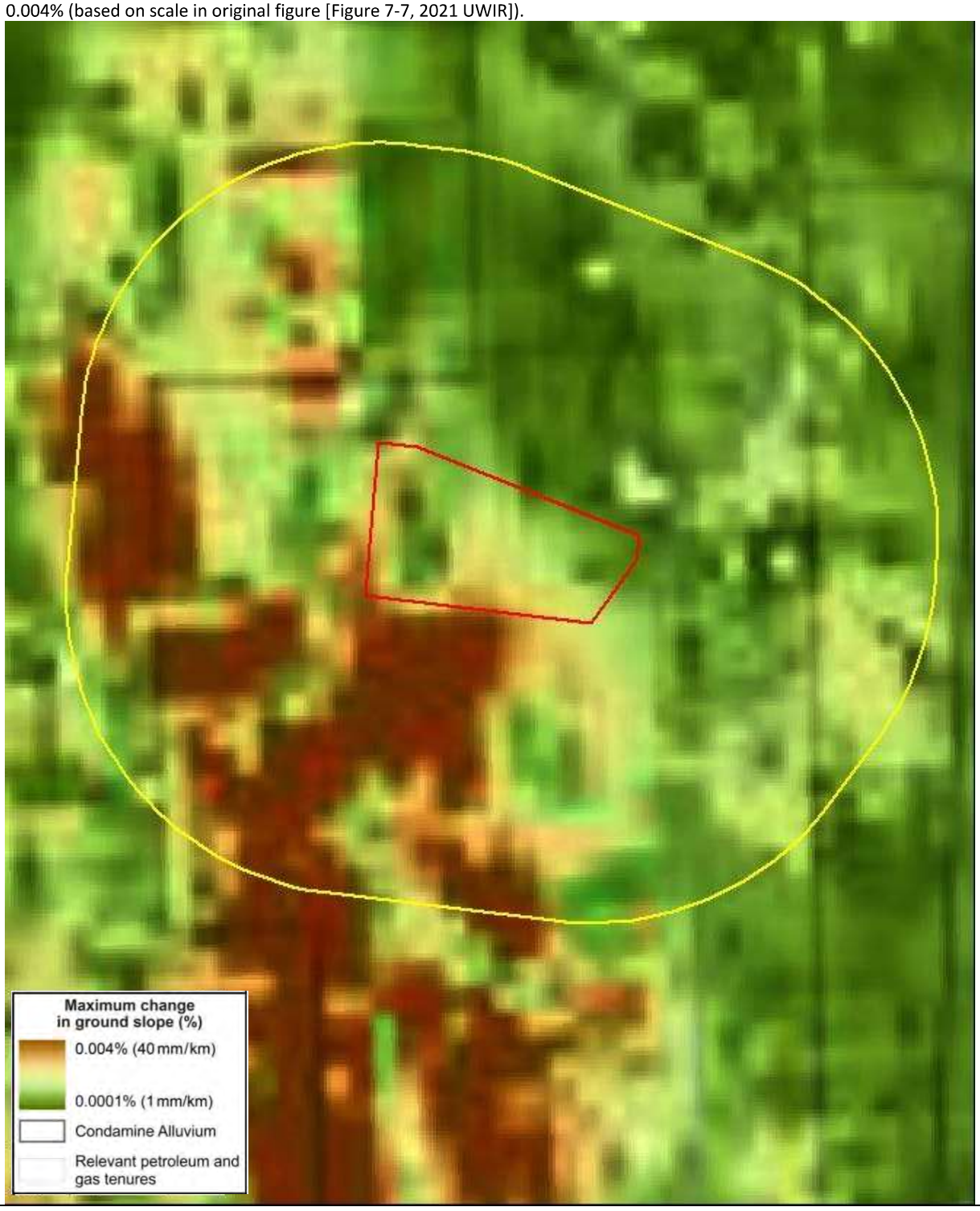
56DY592	**2020 Imagery** 

56DY592

2020 DEM 10m x 10m slope (%)

Slope Class	Hectares	%	Hectares	%
	Within Lot on Plan		Outside Lot on Plan but within 3km buffer	
< 0.01	1.49	0.5%	17.38	0.3%
0.01 – 0.03	11.36	3.4%	131.54	2.6%
0.03 – 0.06	34.54	10.4%	386.8	7.6%
0.06 – 0.12	90.74	27.5%	1020.51	19.9%
0.12 – 0.5	177.48	53.7%	2379.85	46.5%
> 0.5	14.95	4.5%	1180.77	23.1%



56DY592	**2021 UWIR maximum change in ground slope (%) (OGIA, 2021)** Lot on plan and surrounding area (within 3km buffer) approximate predicted maximum change in ground slope 0.0001% to 0.004% (based on scale in original figure [Figure 7-7, 2021 UWIR]). 

Appendix E - Surface Elevation Baseline Reports

Report

Safe Work. Strong Business.

Appendix E - Baseline Report

Surface Elevation Data – 1RP78475

Version	1
Released	17/12/2021

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Contents

List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lot on plan 1RP78475:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
- 2012 DEM drainage lines (Figure 7),
- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
- InSAR persistent and distributed scatter points and time series plot (Figure 10), and
- OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) (Figure 11).

Electronic copies of the above datasets can be made available upon request.

The elevation related maps represented are based on light detection and ranging (LiDAR) elevation data acquired over 3 periods during Arrow Energy's operations (Table 1). The ground displacement map provides points based on interferometric synthetic aperture radar (InSAR), with time series graphs of selected persistent scatter points provided as an example of the data collected.

The LiDAR data is provided to Arrow as classified point clouds (with ground and non-ground points) and a Digital Elevation Model (DEM) generated from the ground classified points by the LiDAR providers. The LiDAR providers undertook surveying of a ground control network across the acquisition area to provide information on accuracy of the DEM. The DEM's derived from these LiDAR point clouds represent the most accurate regional scale datasets using industry leading experts available at the time of capture.

The InSAR data is provided to Arrow as persistent and distributed scatter points by the InSAR provider, processed using their proprietary SqueeSAR technology. The InSAR data provided commenced in 2015 with the Sentinel satellite system, and provides continual information on regional ground movement using industry leading experts.

Table 1: LiDAR Metadata

	2012 LIDAR	2014 LIDAR	2020 LIDAR
Company	FUGRO	AAM	AAM
Acquisition Start	16-Jun-12	Nov-14	15-Oct-20
Acquisition End	29-Jul-12	12-Feb-15	6-Nov-20
Spatial Accuracy (Hz)	0.29m @ 67% CI	0.15m @ 68% CI	0.20m @ 68% CI
Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

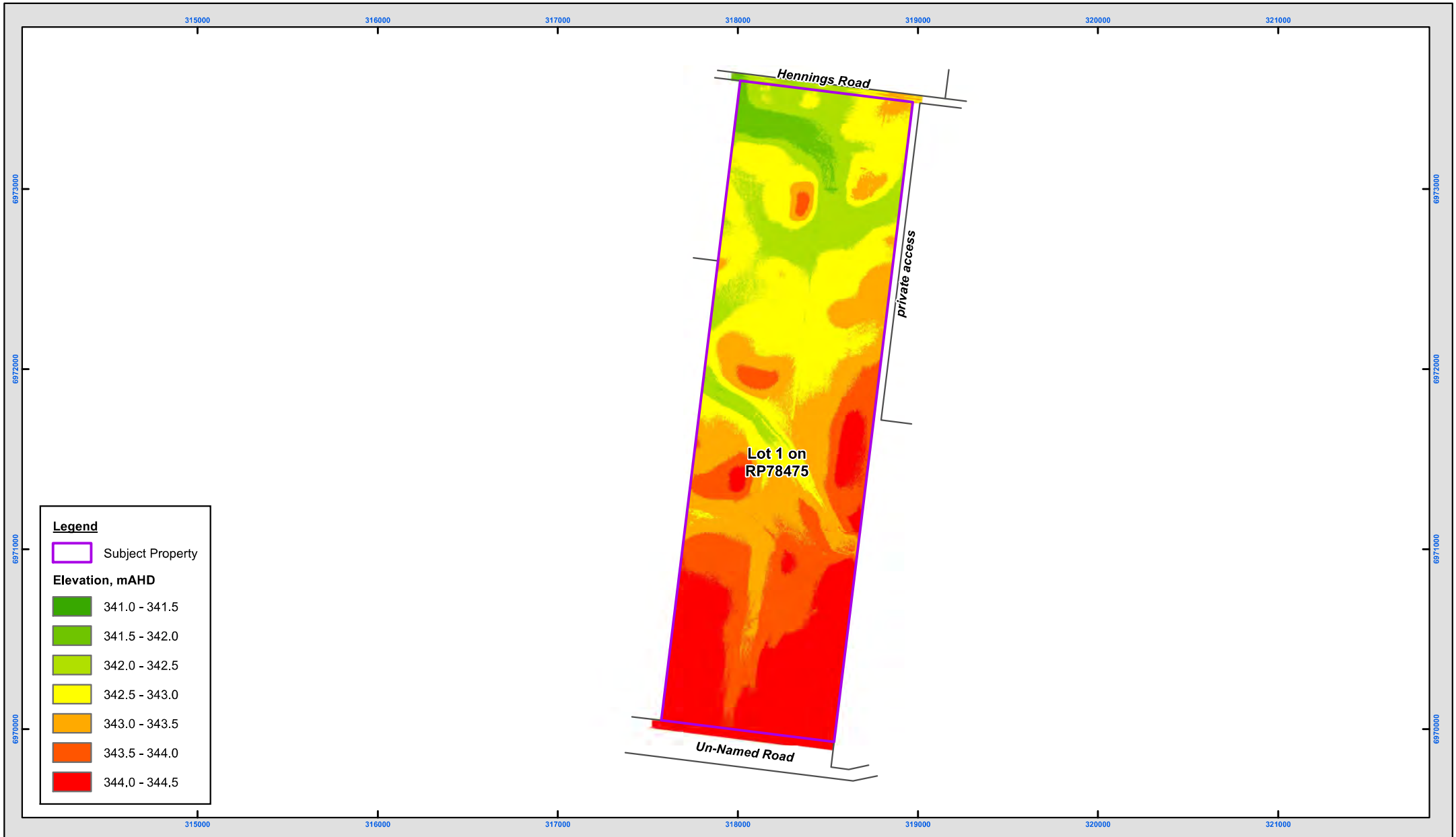


Figure 1 : 2012 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 28/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

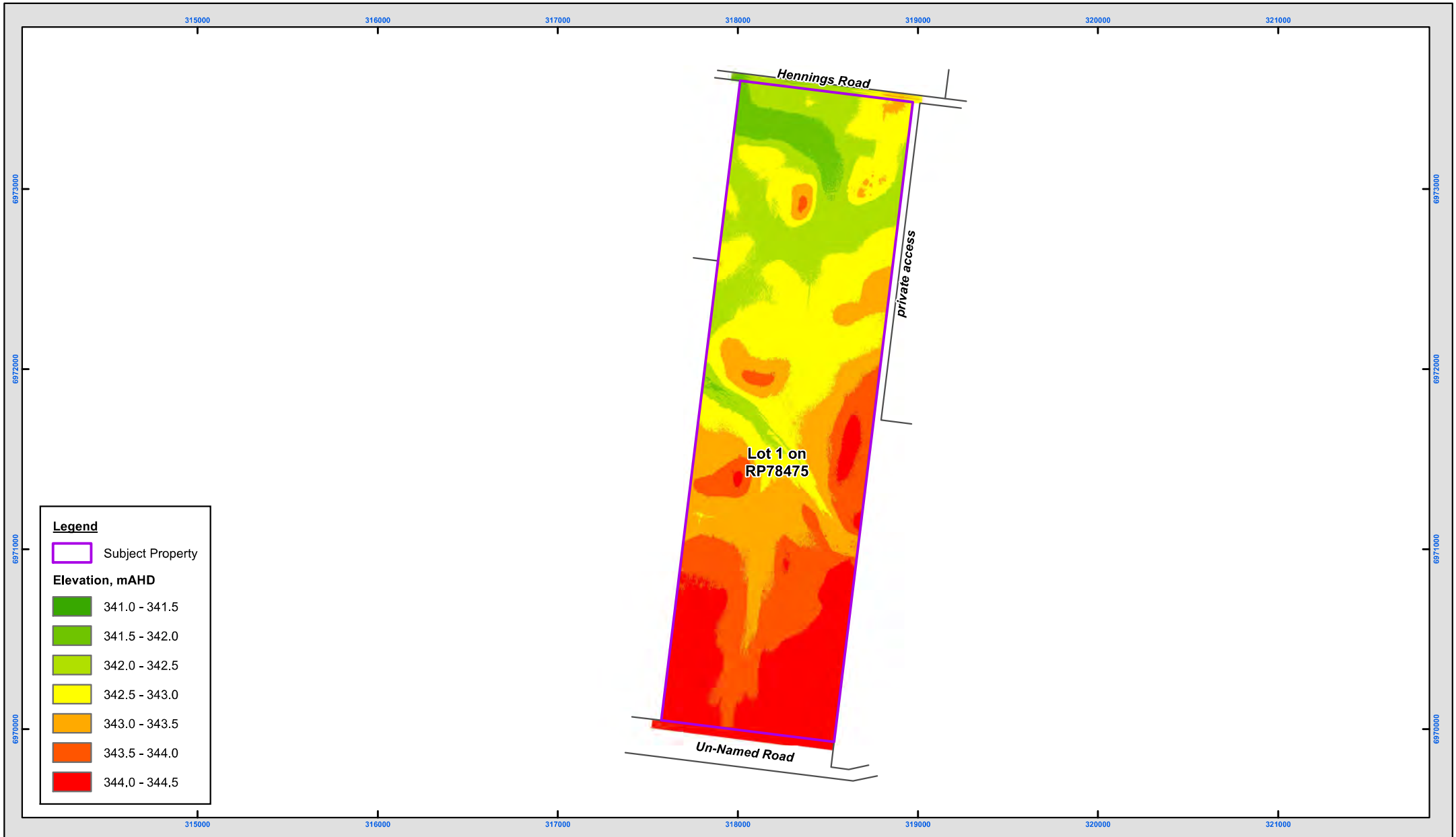


Figure 2 : 2014 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 28/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

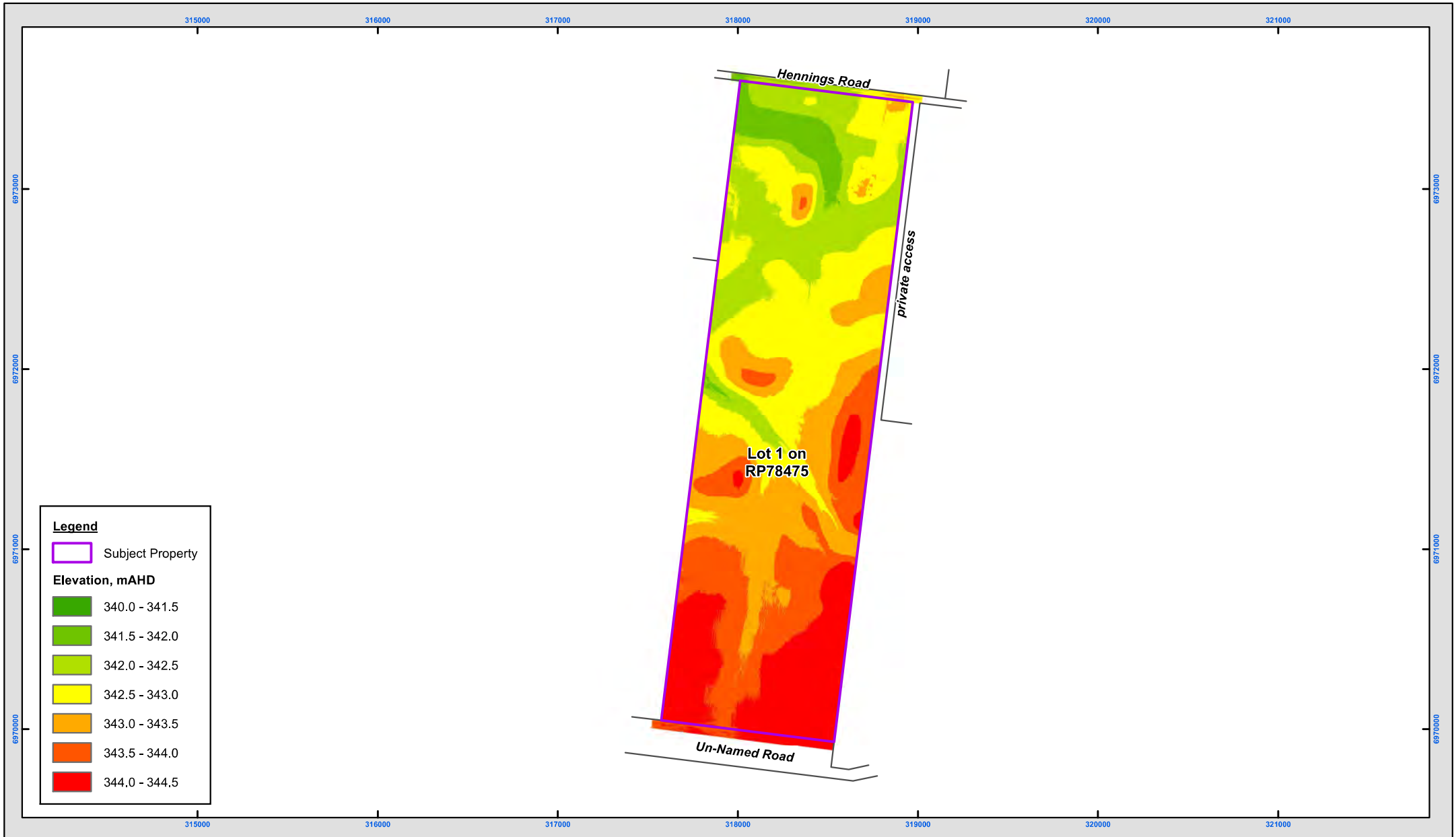


Figure 3 : 2020 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 28/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

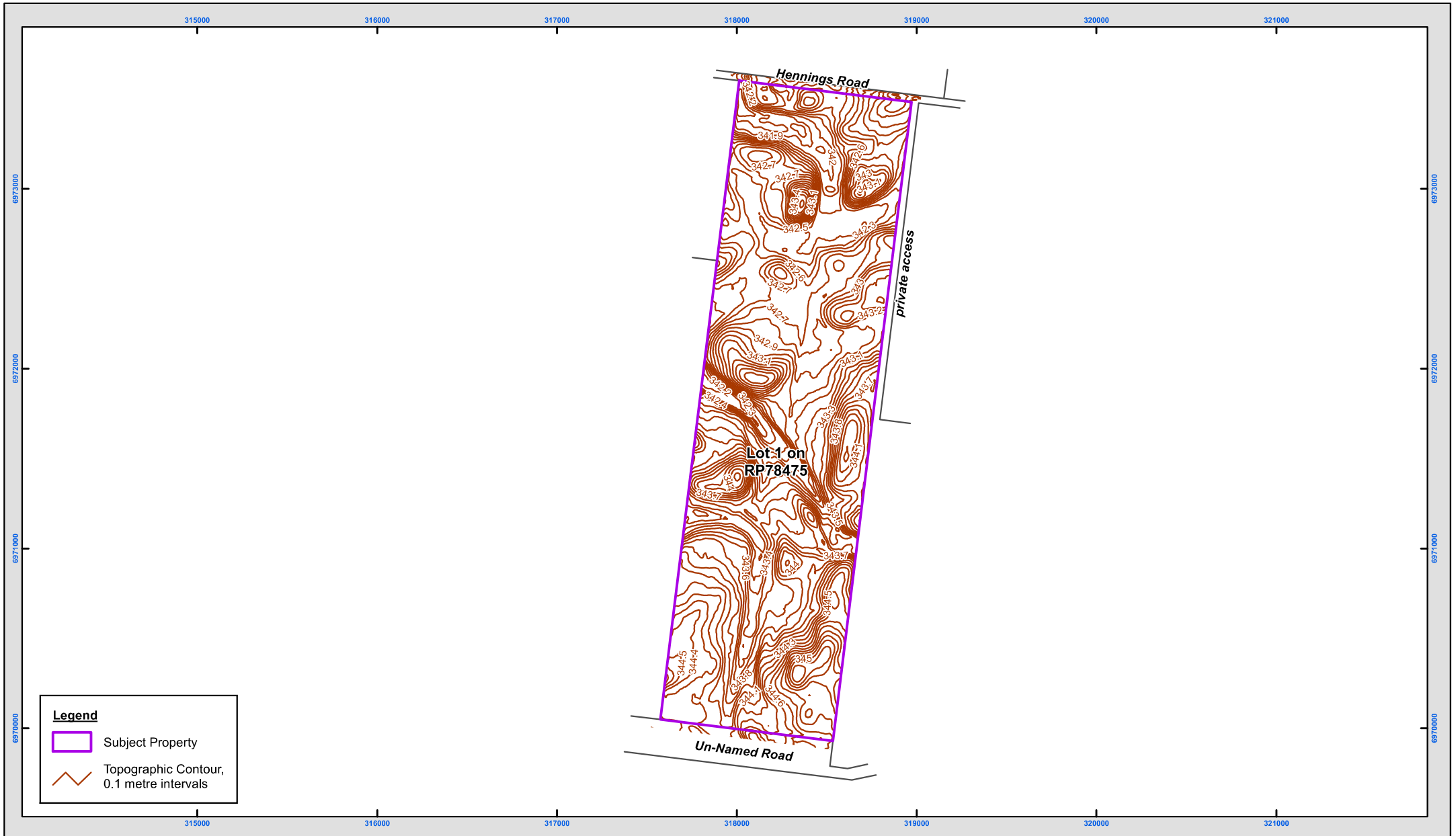


Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

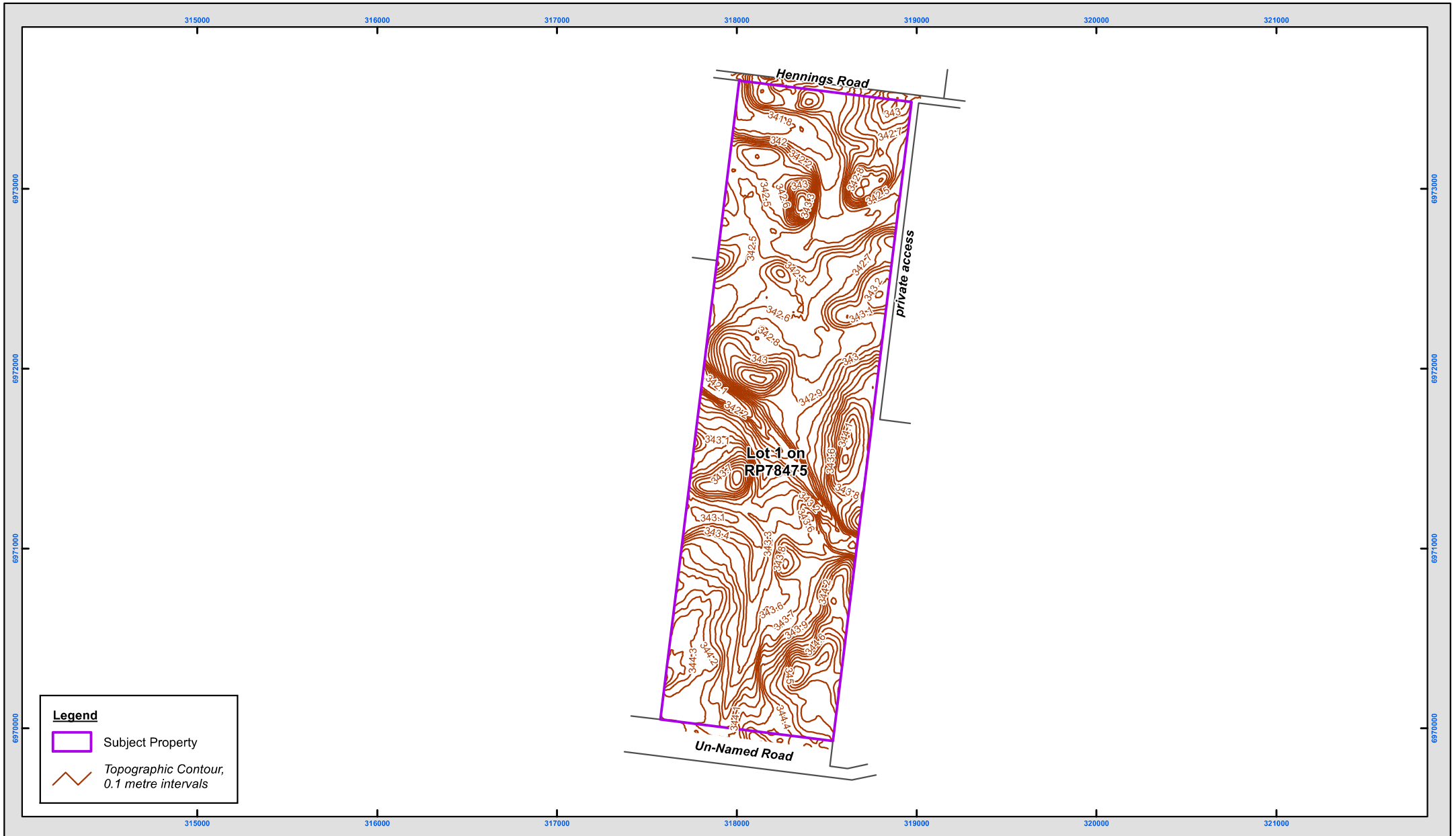


Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

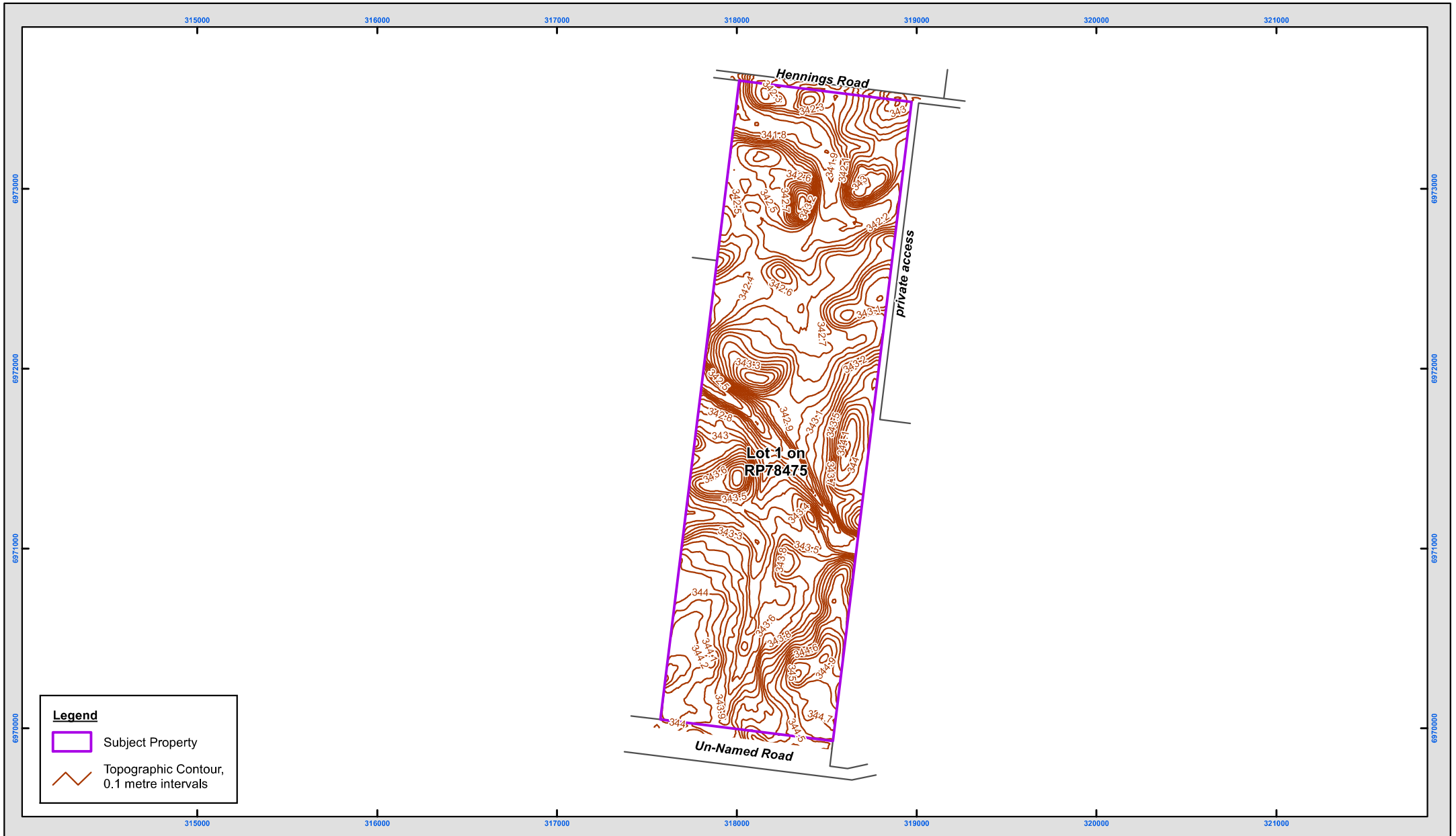


Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

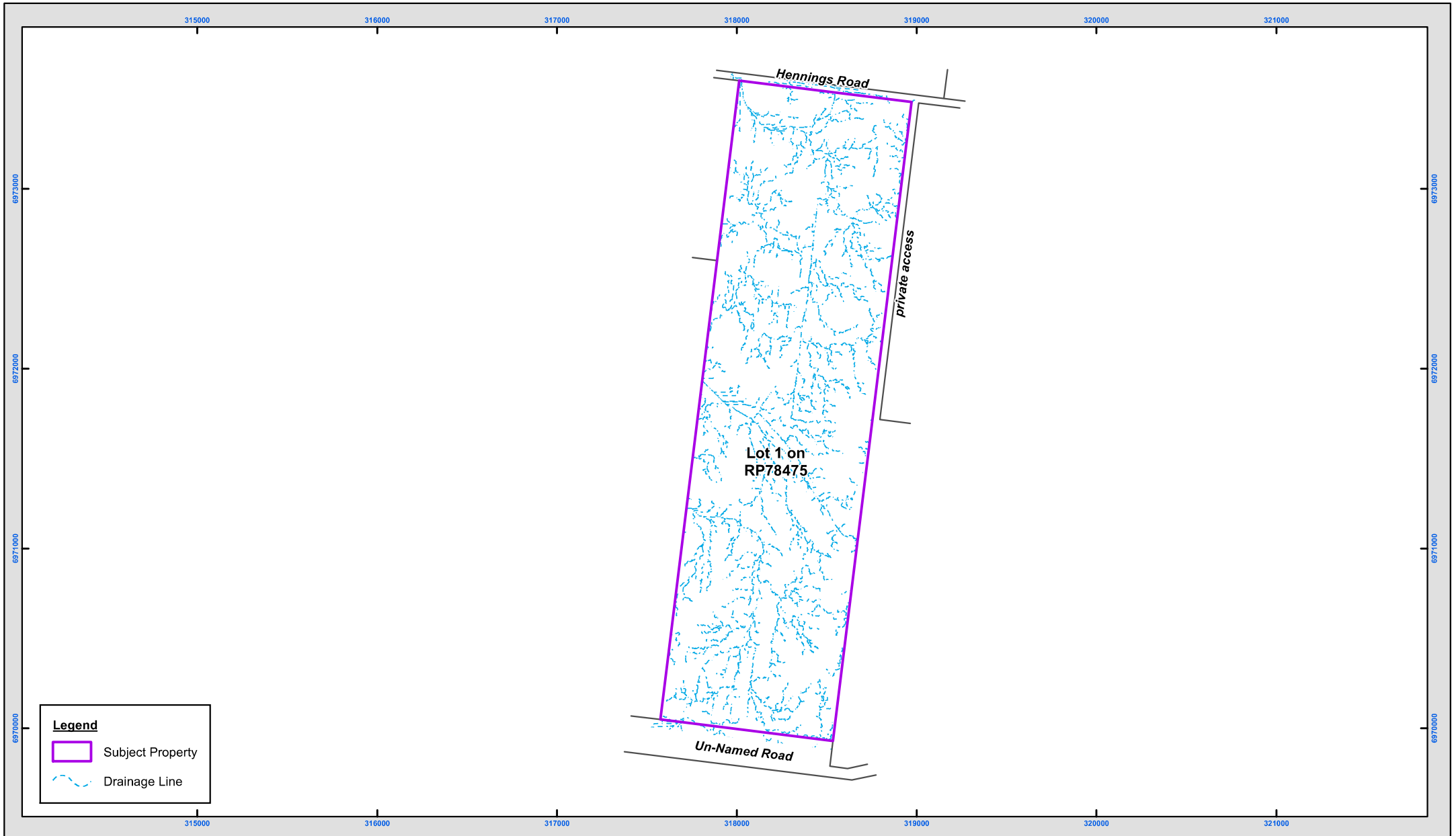


Figure 7 : 2012 DEM, Drainage Lines, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

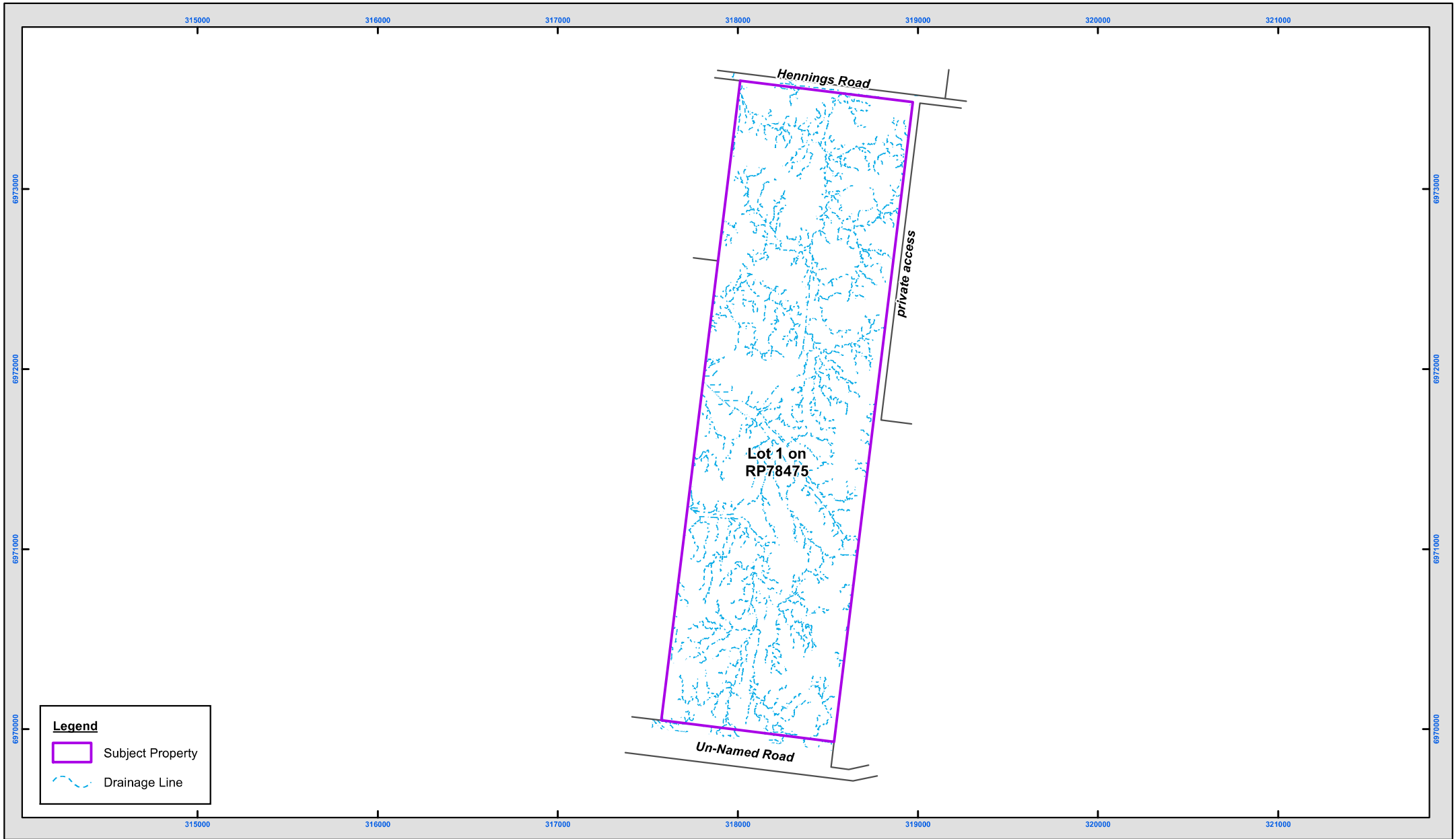


Figure 8 : 2014 DEM, Drainage Lines, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

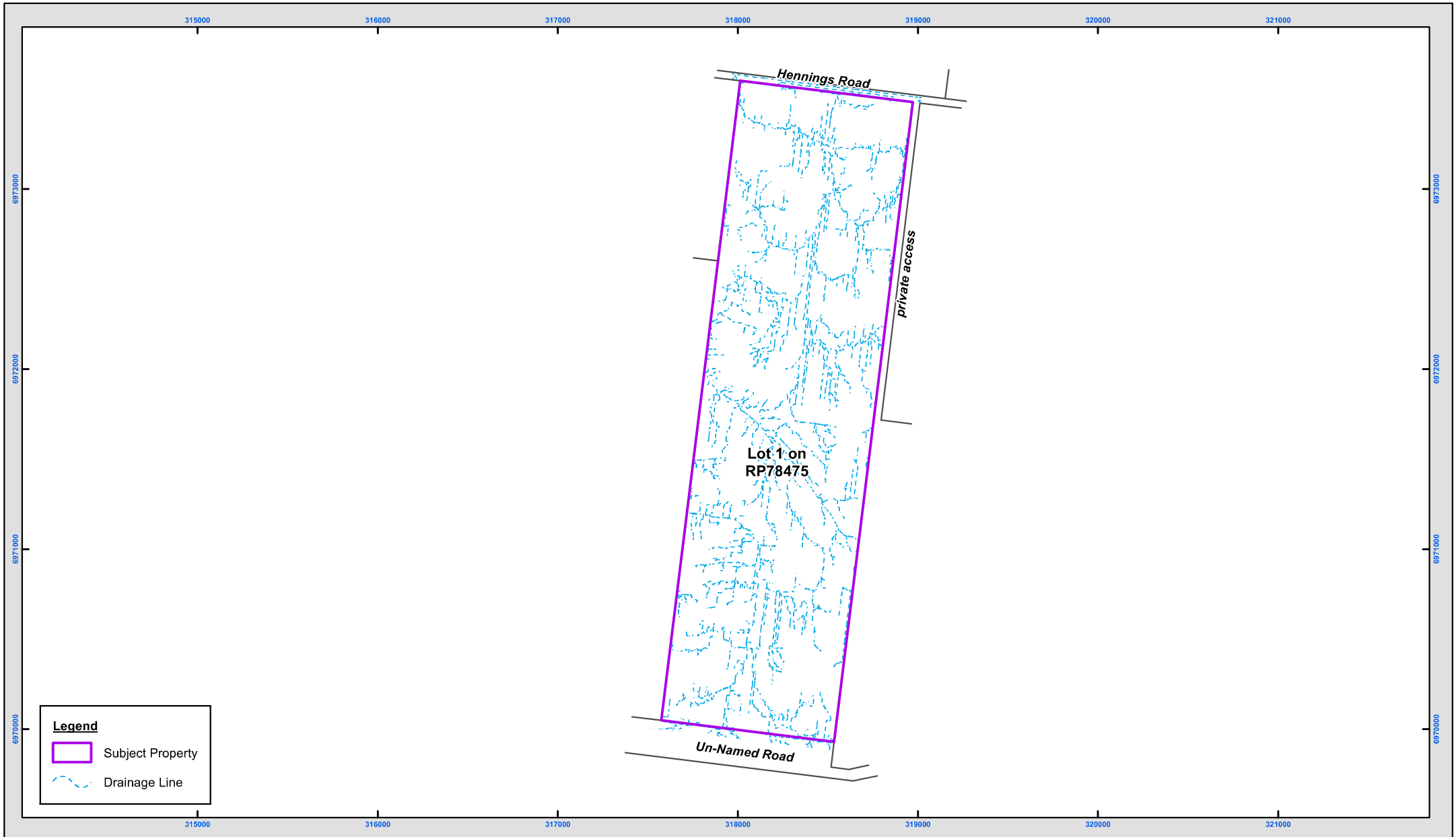


Figure 9 : 2020 DEM, Drainage Lines, Lot on Plan : 1RP78475

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 24/11/2021

Author: Arrow Energy

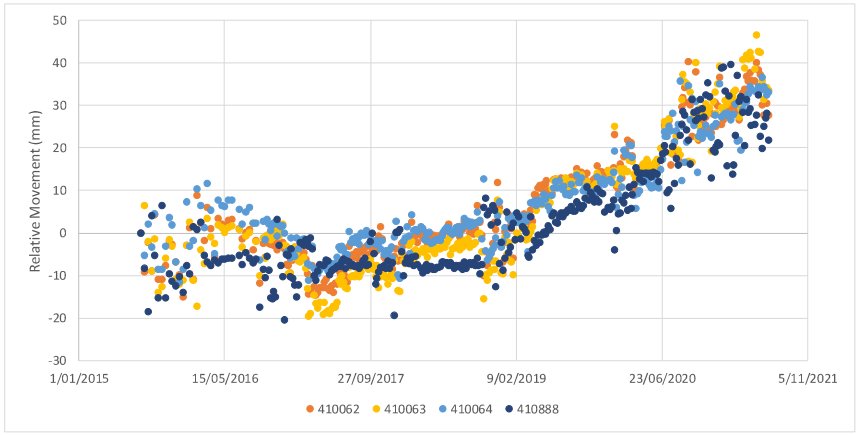
0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION



Legend

- Subject Property
- InSAR distrubuted scatter points
- InSAR persistent scatter points

314000 315000 316000 317000 318000 319000 320000 321000

6973000 6972000 6971000 6970000

Figure 10 : InSAR persistent and distributed scatter points on Lot on Plan : 1RP78475 and time series plot.

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 10/02/2022

Author: Arrow Energy

0.55 0.275 0 0.55 Kilometres

Scale: 1:20,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

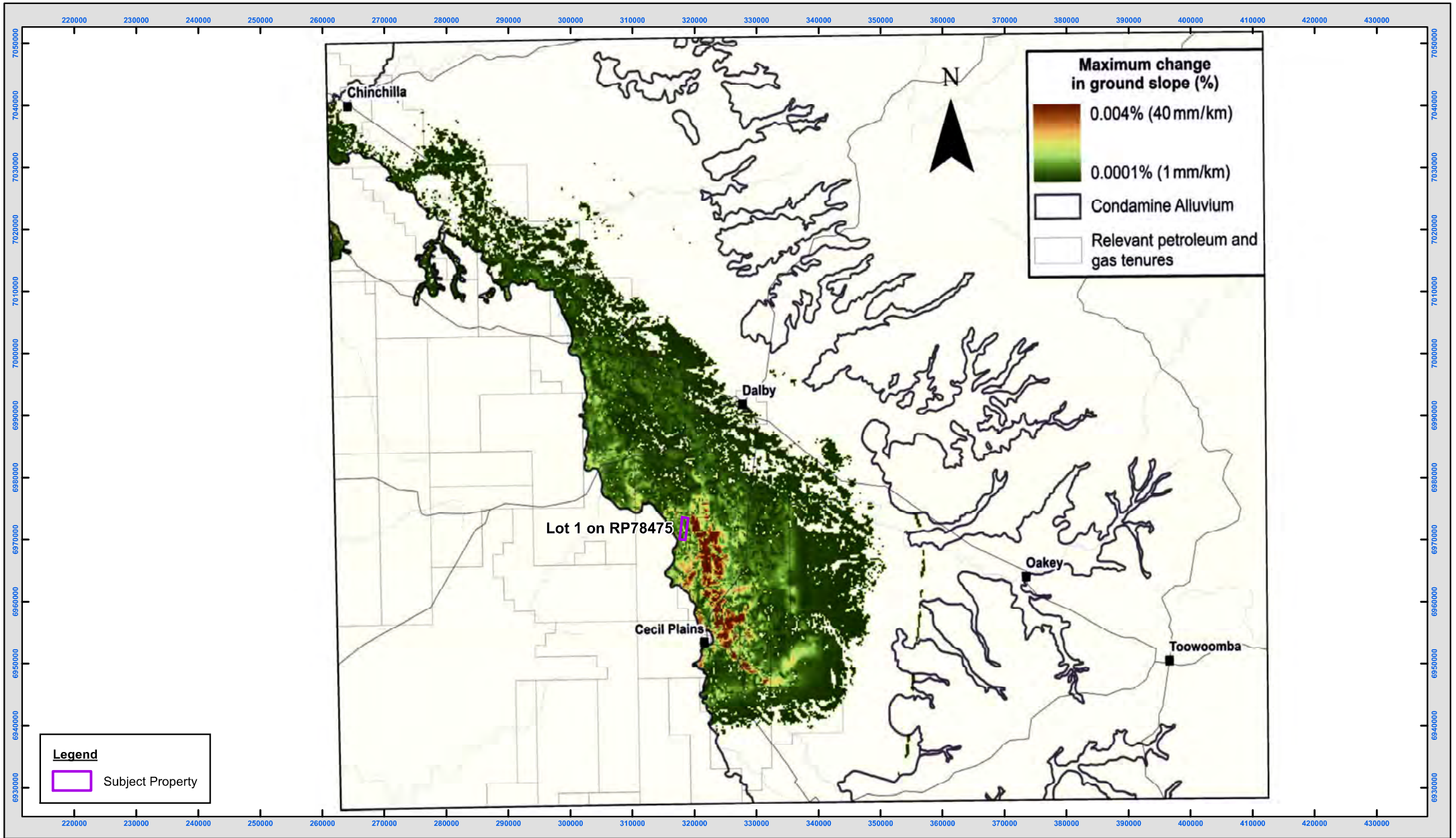


Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lot on Plan : 1RP78475.

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/12/2021

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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Report

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Baseline Report

Surface Elevation Data – 1RP83755

Version	1
Released	04/01/2022

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List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lot on plan 1RP83755:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
- 2012 DEM drainage lines (Figure 7),
- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
- InSAR persistent and distributed scatter points and time series plot (Figure 10), and
- OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) (Figure 11).

Electronic copies of the above datasets can be made available upon request.

The elevation related maps represented are based on light detection and ranging (LiDAR) elevation data acquired over 3 periods during Arrow Energy's operations (Table 1). The ground displacement map provides points based on interferometric synthetic aperture radar (InSAR), with time series graphs of selected persistent scatter points provided as an example of the data collected.

The LiDAR data is provided to Arrow as classified point clouds (with ground and non-ground points) and a Digital Elevation Model (DEM) generated from the ground classified points by the LiDAR providers. The LiDAR providers undertook surveying of a ground control network across the acquisition area to provide information on accuracy of the DEM. The DEM's derived from these LiDAR point clouds represent the most accurate regional scale datasets using industry leading experts available at the time of capture.

The InSAR data is provided to Arrow as persistent and distributed scatter points by the InSAR provider, processed using their proprietary SqueeSAR technology. The InSAR data provided commenced in 2015 with the Sentinel satellite system, and provides continual information on regional ground movement using industry leading experts.

Table 1: LiDAR Metadata

	2012 LIDAR	2014 LIDAR	2020 LIDAR
Company	FUGRO	AAM	AAM
Acquisition Start	16-Jun-12	Nov-14	15-Oct-20
Acquisition End	29-Jul-12	12-Feb-15	6-Nov-20
Spatial Accuracy (Hz)	0.29m @ 67% CI	0.15m @ 68% CI	0.20m @ 68% CI
Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

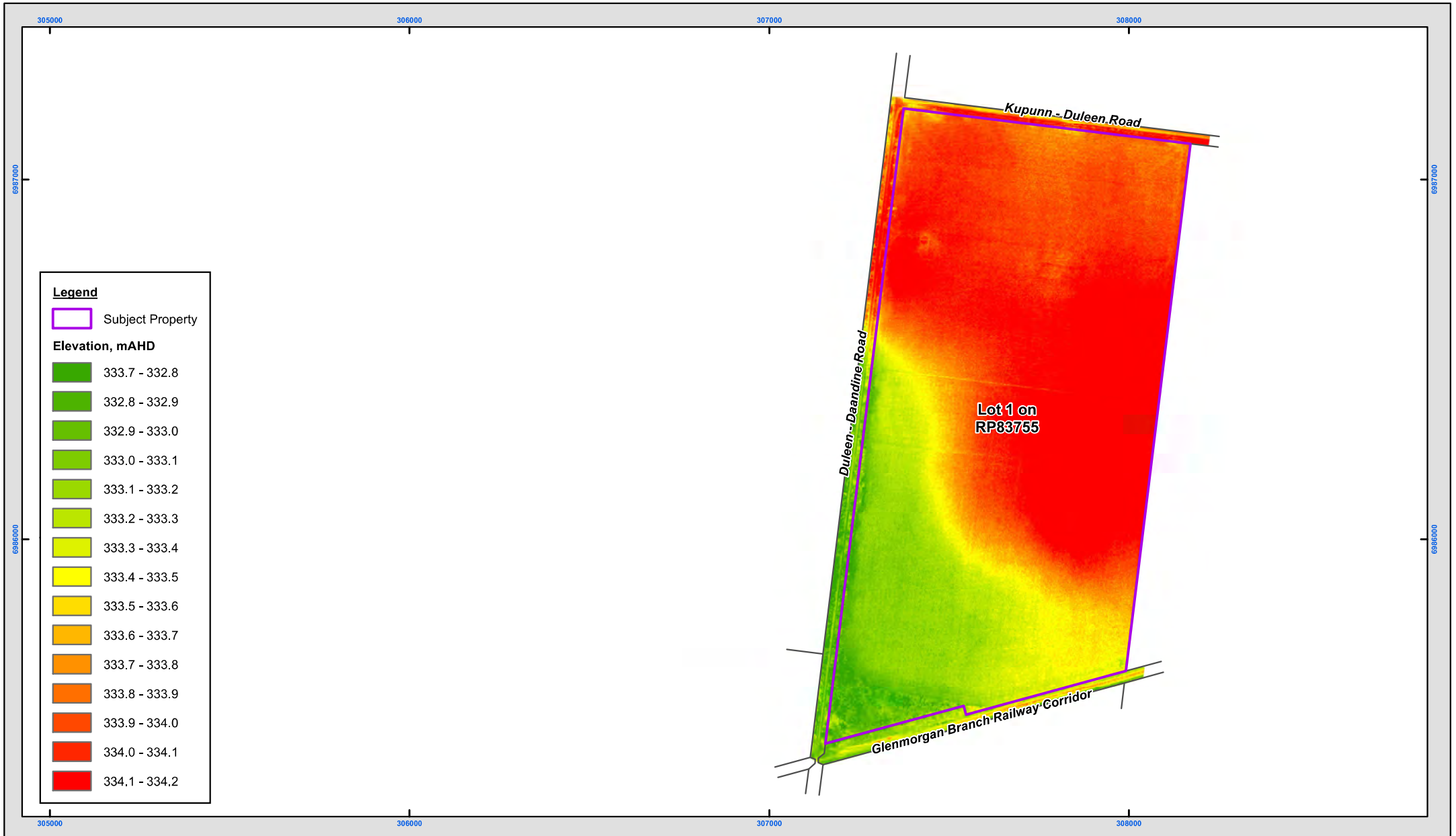

Figure 1 : 2012 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

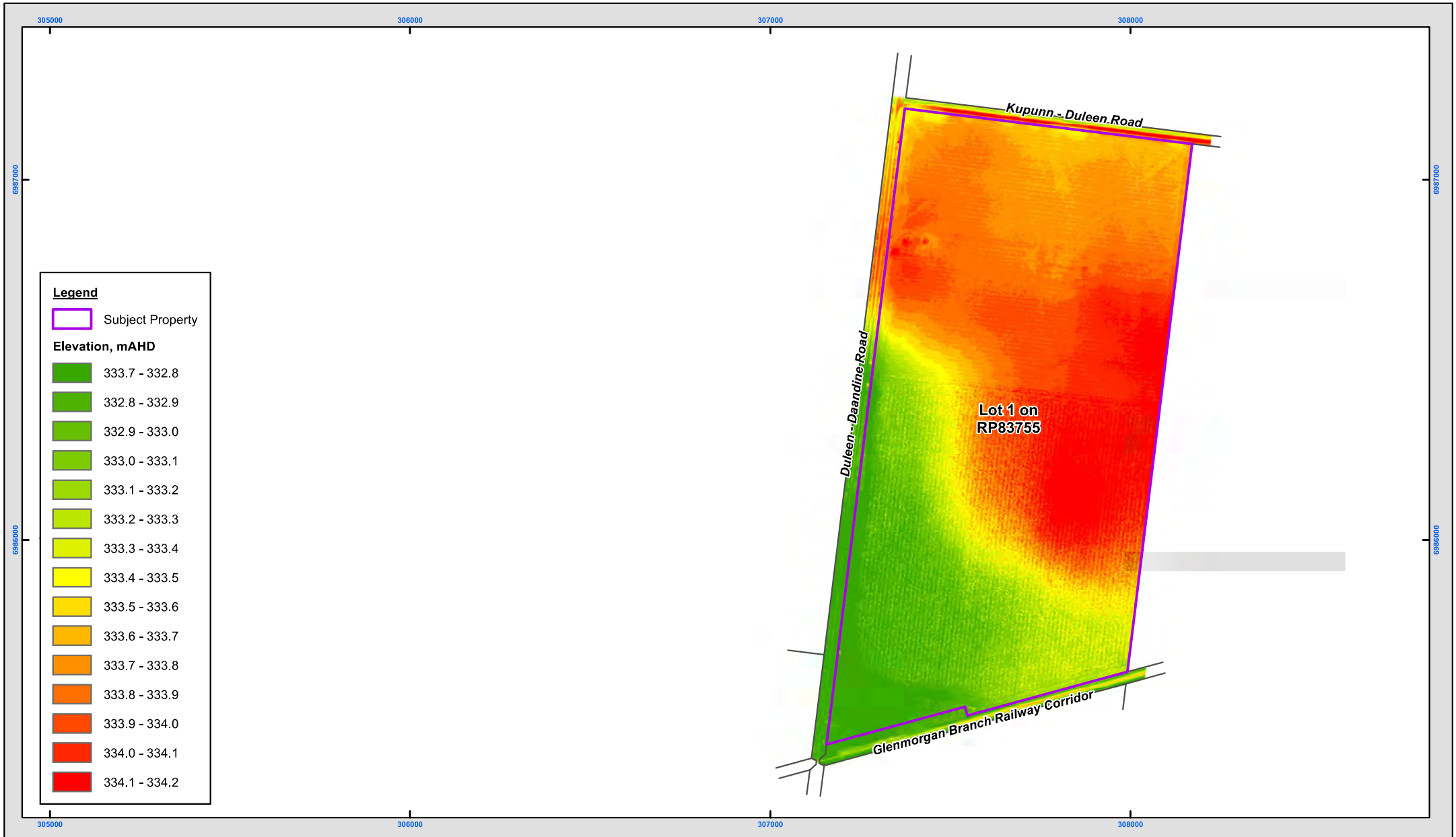

Figure 2 : 2014 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

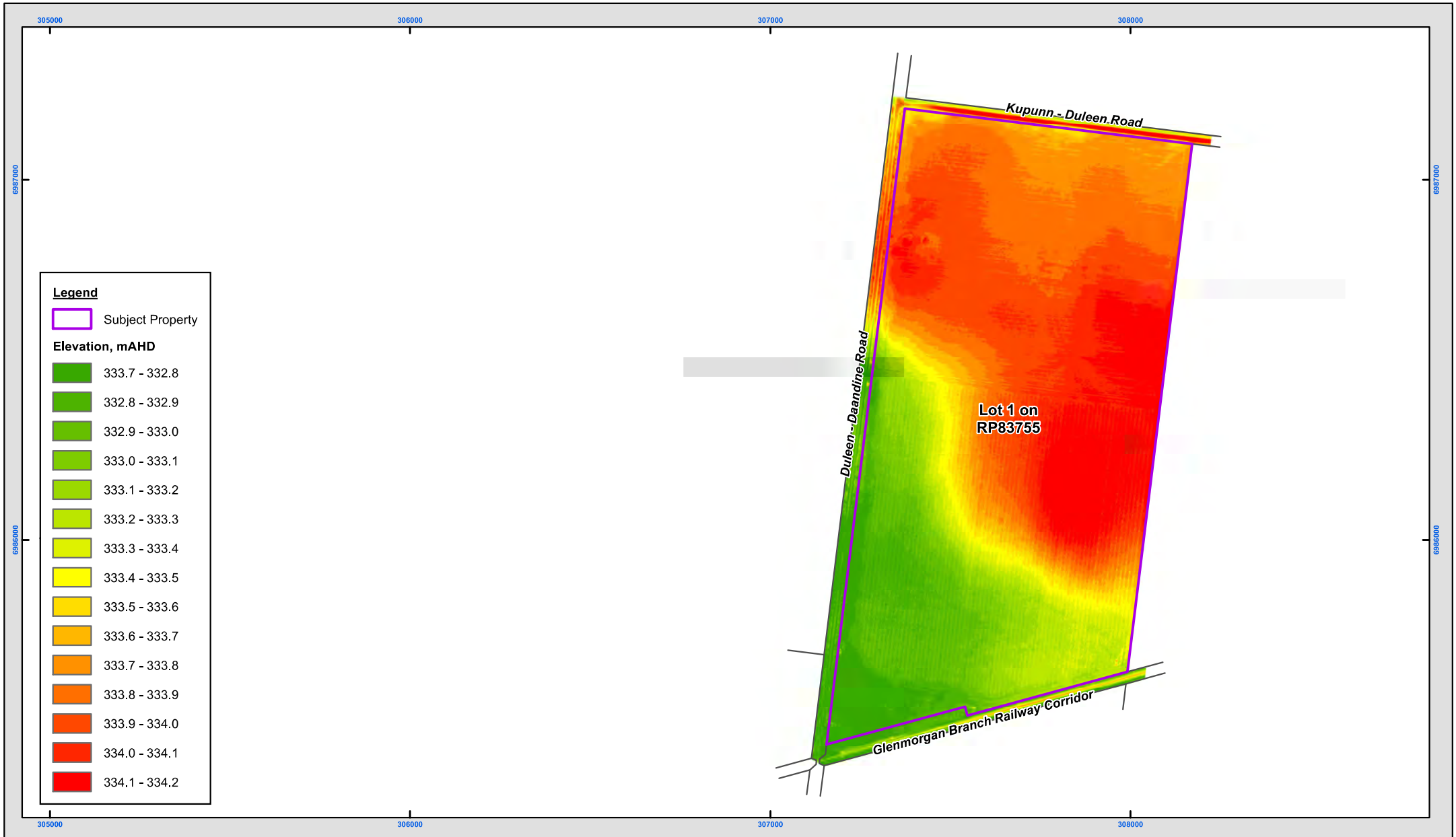

Figure 3 : 2020 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 31/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

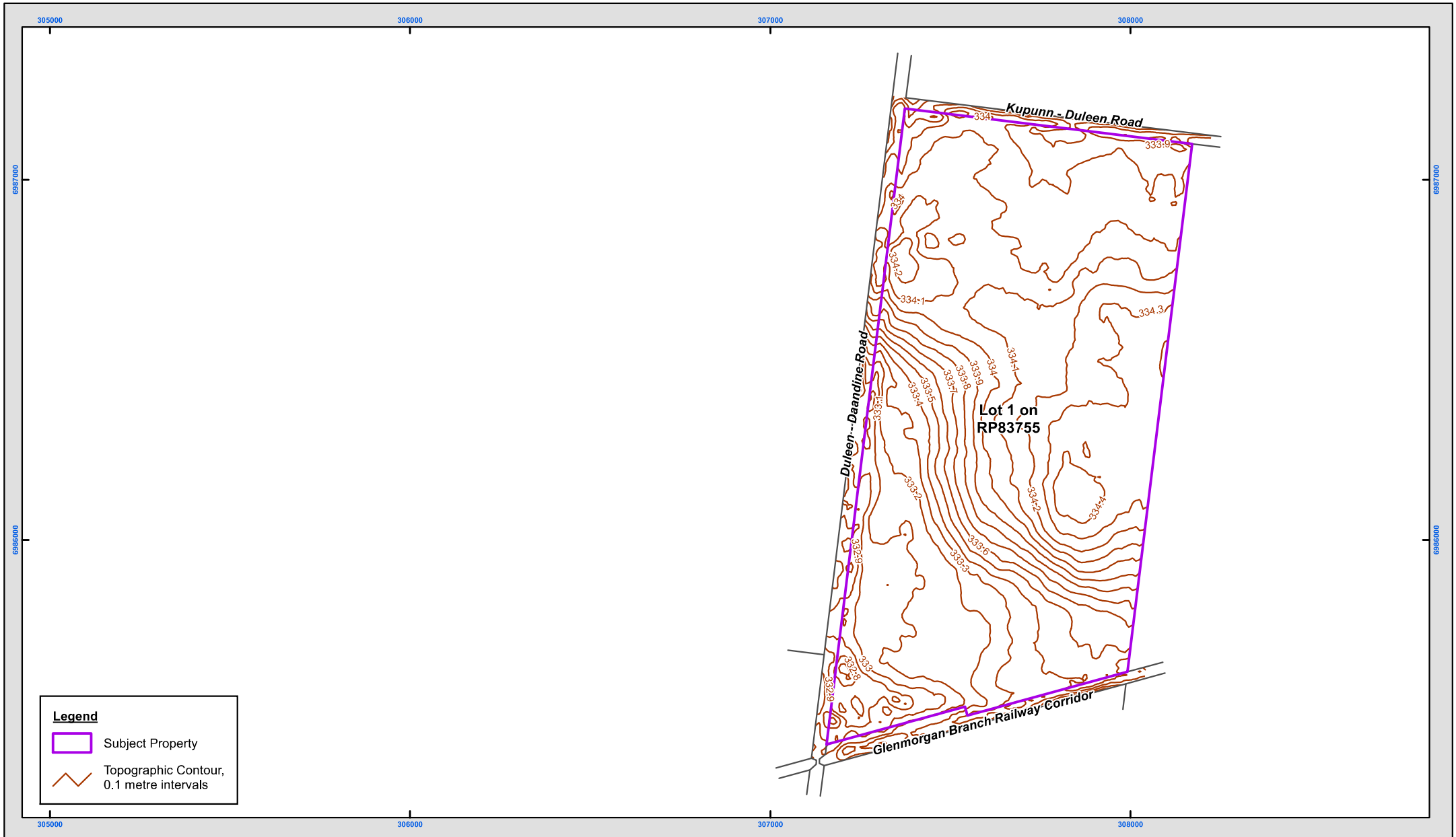

Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

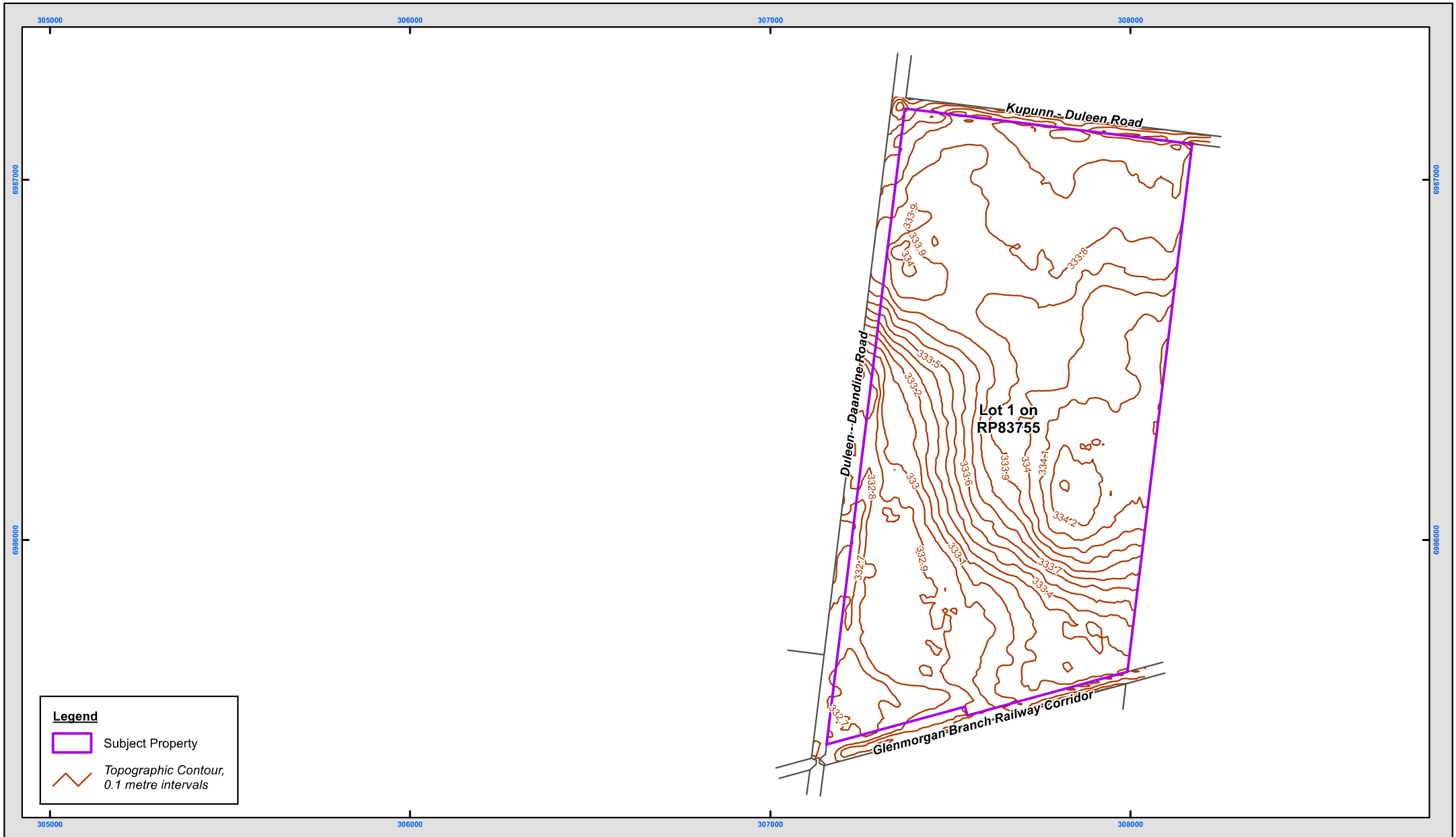

Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

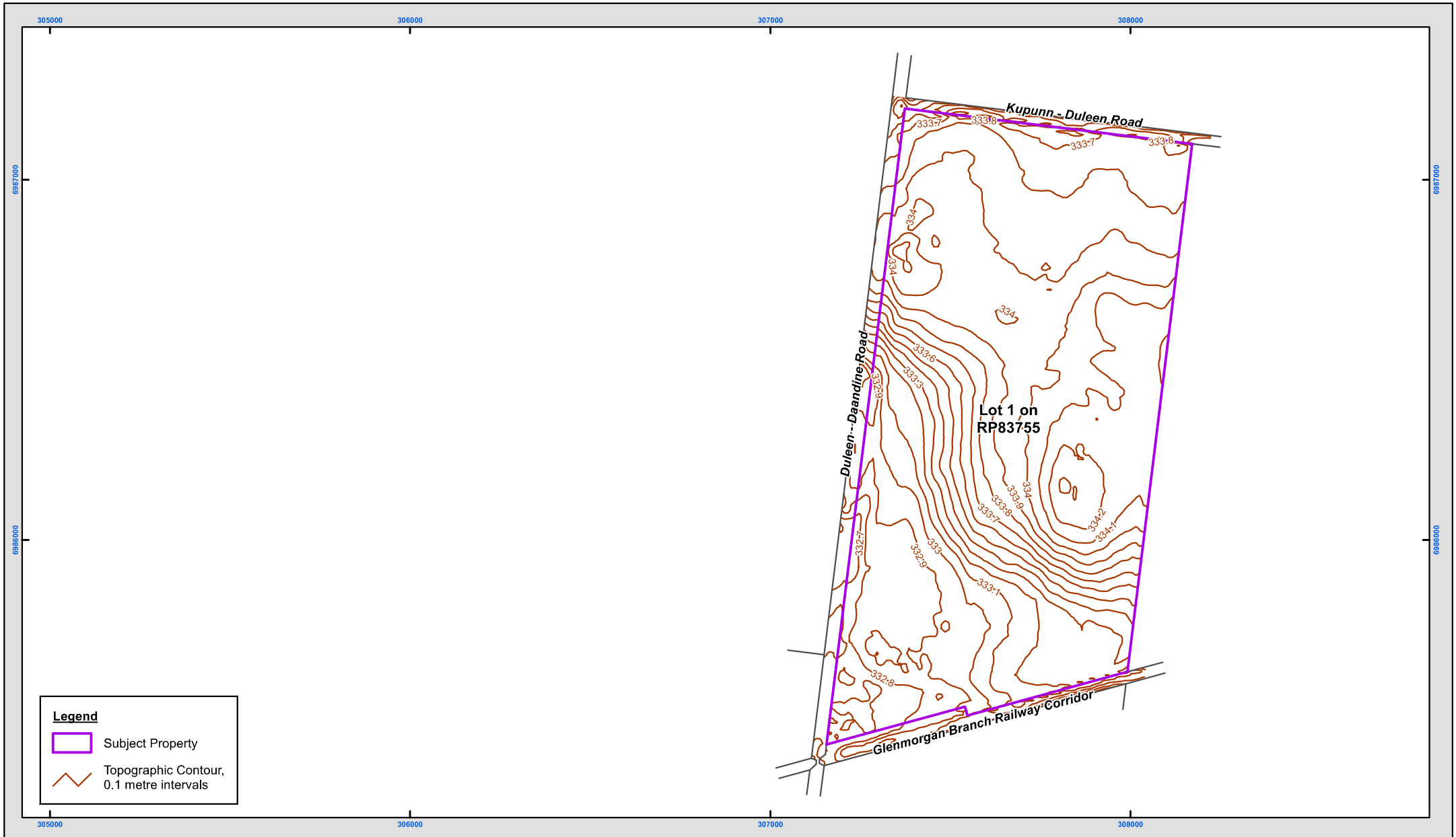

Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

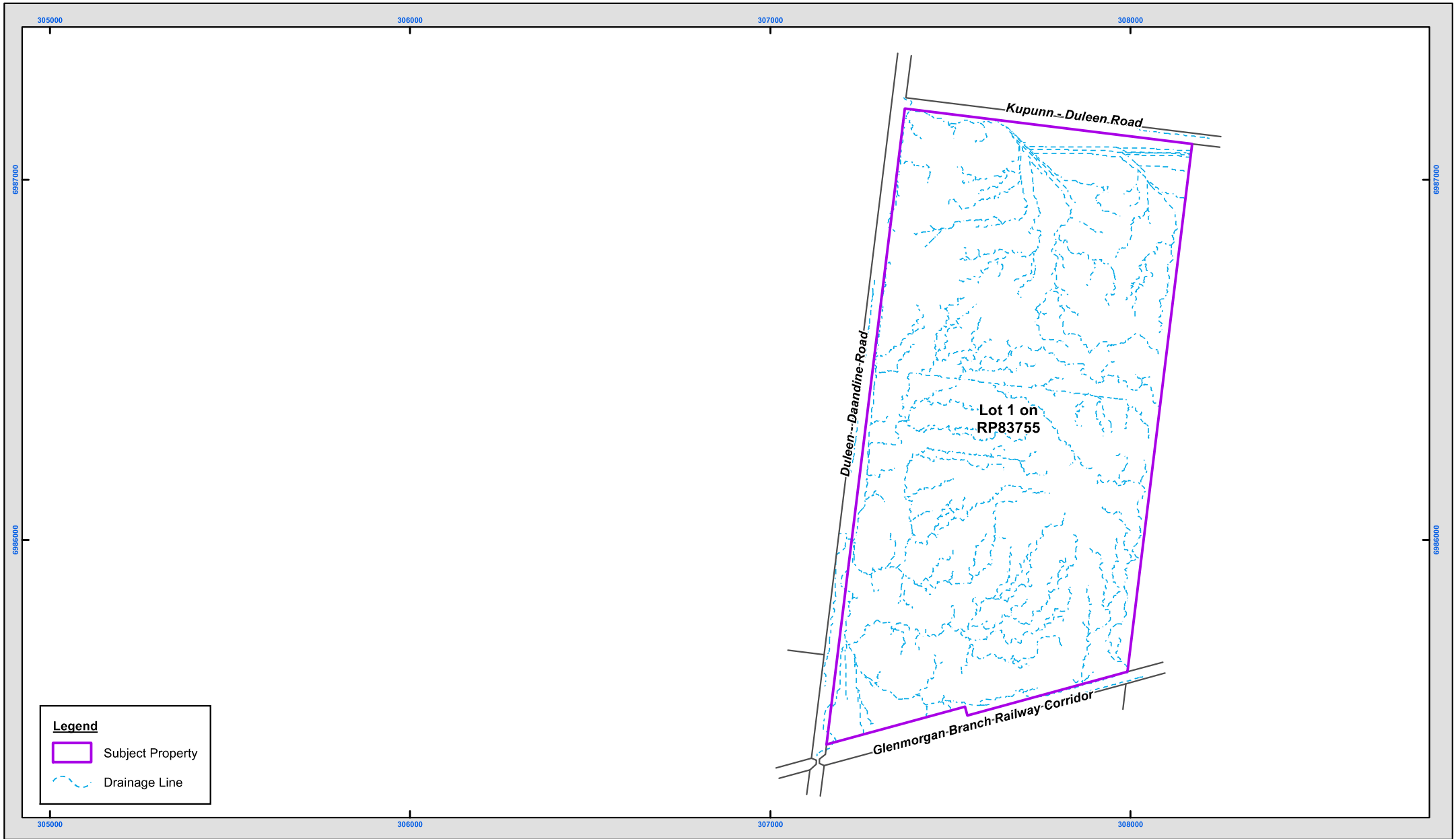

Figure 7 : 2012 DEM, Drainage Lines, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

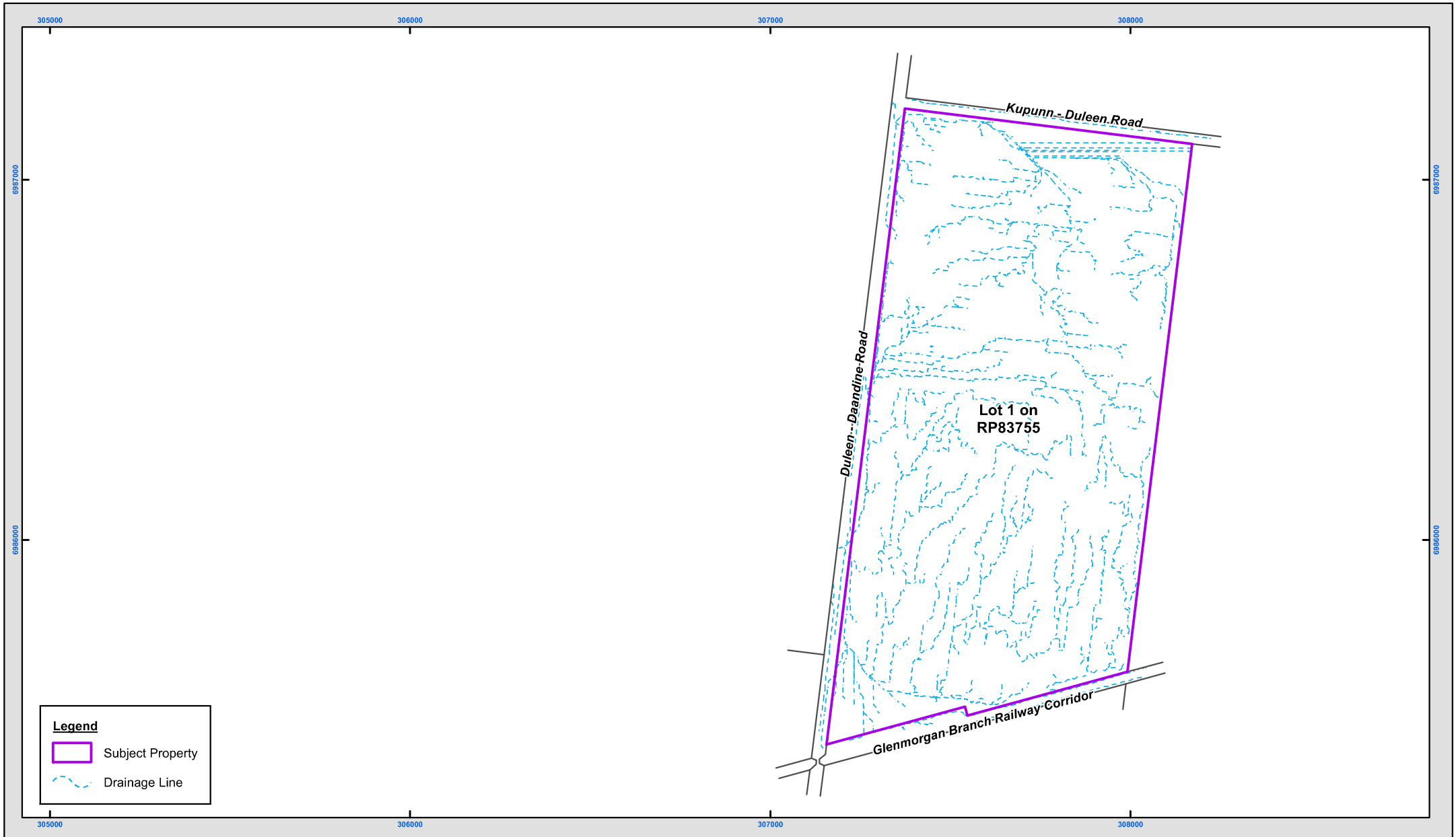

Figure 8 : 2014 DEM, Drainage Lines, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

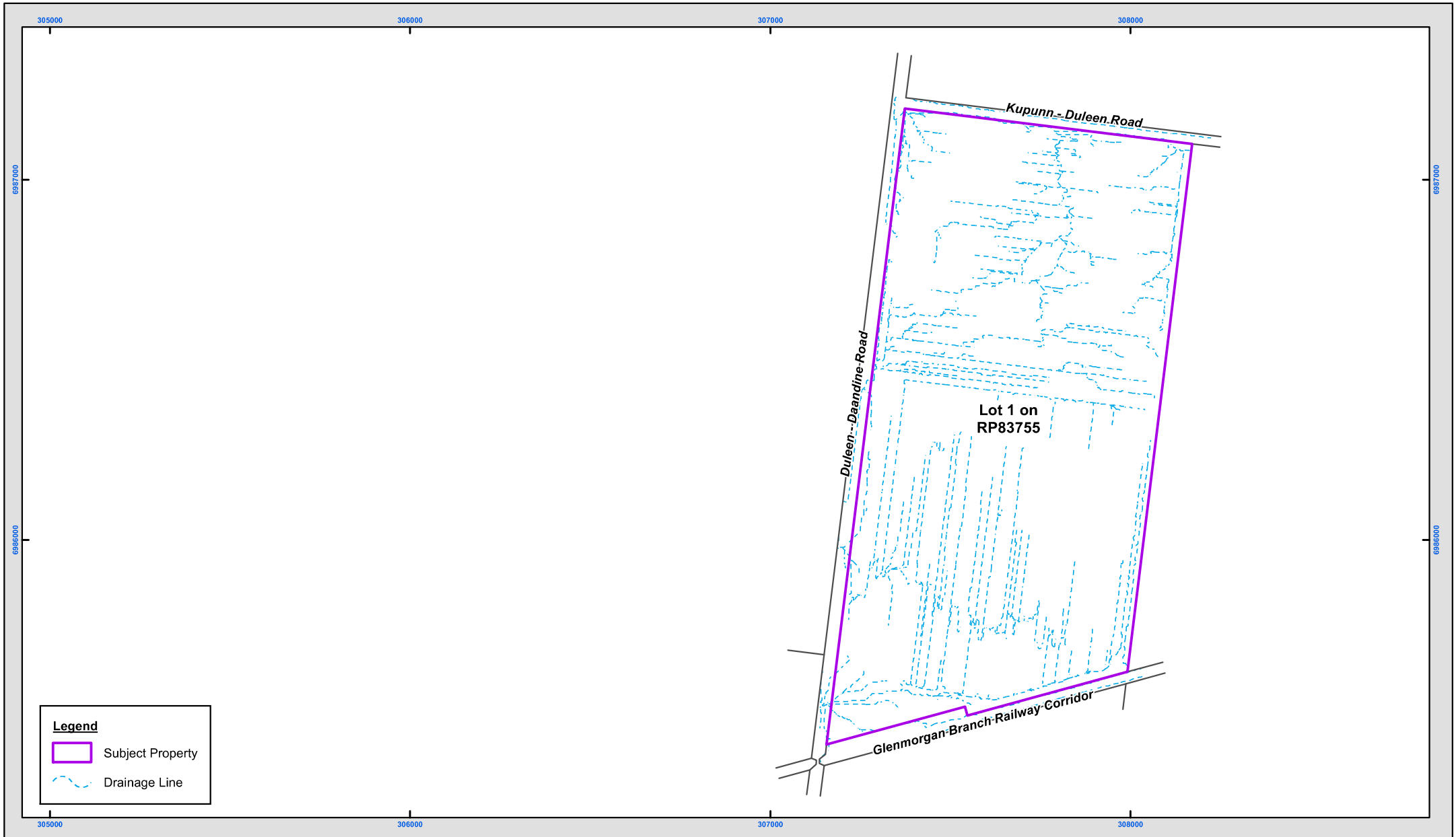

Figure 9 : 2020 DEM, Drainage Lines, Lots on Plans : 1RP83755

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:10,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

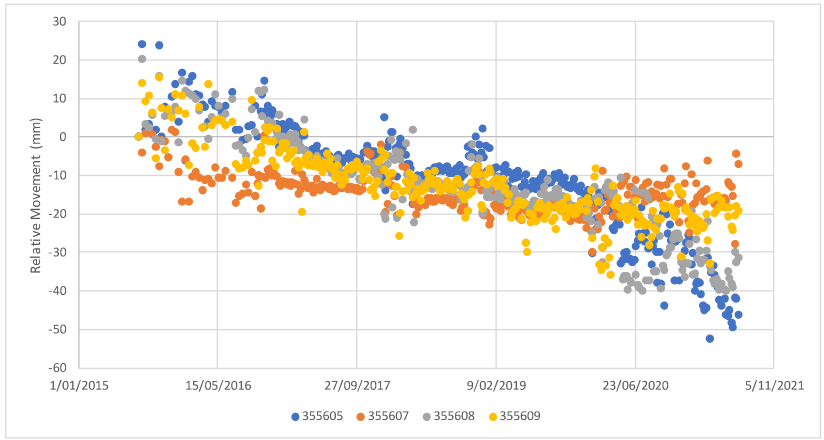

Figure 10 : InSAR persistent and distributed scatter points on Lot on Plan : 1RP83755, and time series plot

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,416 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

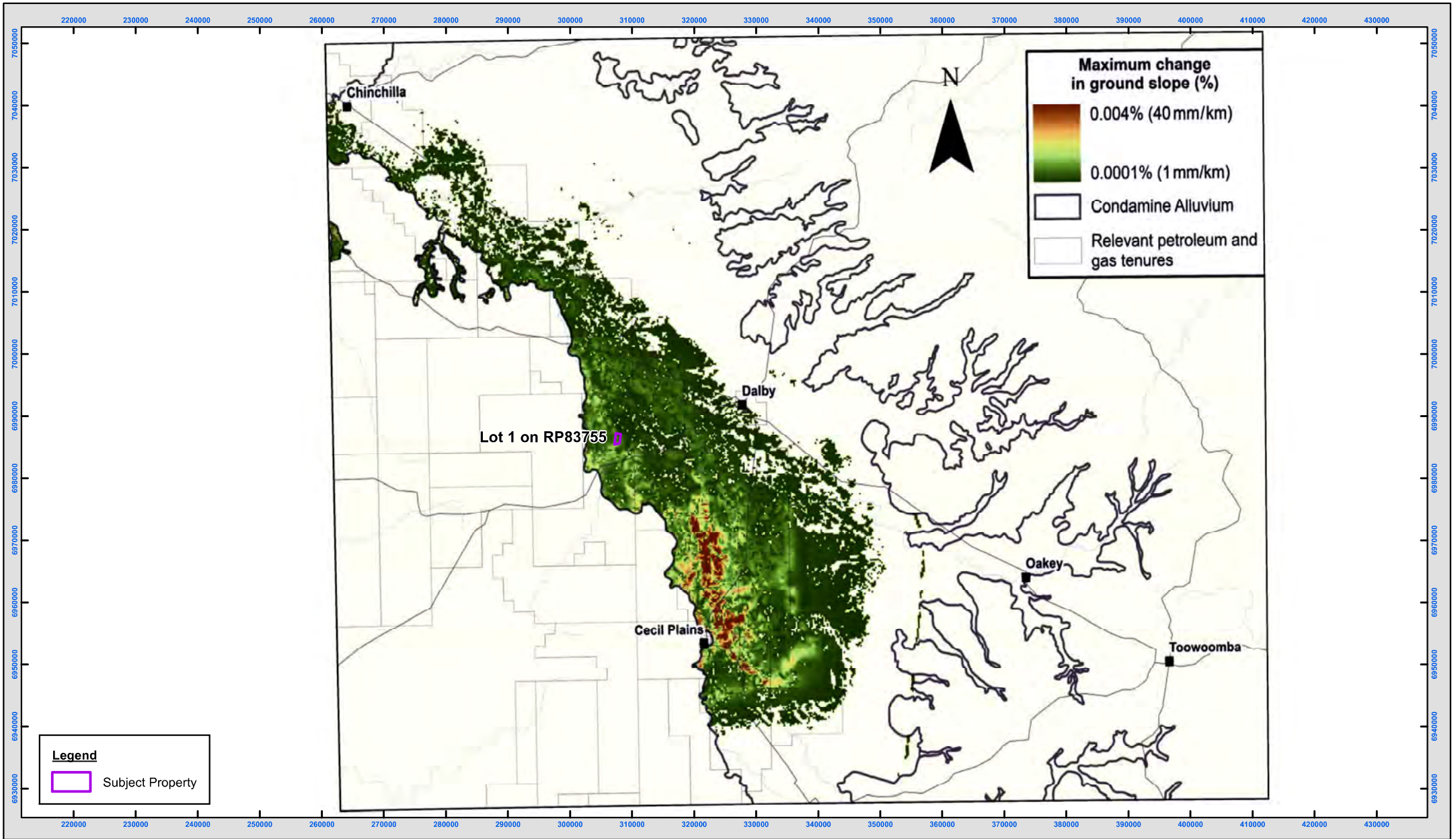

Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lot on Plan : 1RP83755.

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 1/01/2022

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

Report

Safe Work. Strong Business.

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Baseline Report

Surface Elevation Data – 10SP191489 and 11SP191489

Version	1
Released	04/01/2022

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Contents

List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lots on plans 10SP191489 and 11SP191489:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
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- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
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Electronic copies of the above datasets can be made available upon request.

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Table 1: LiDAR Metadata

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Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

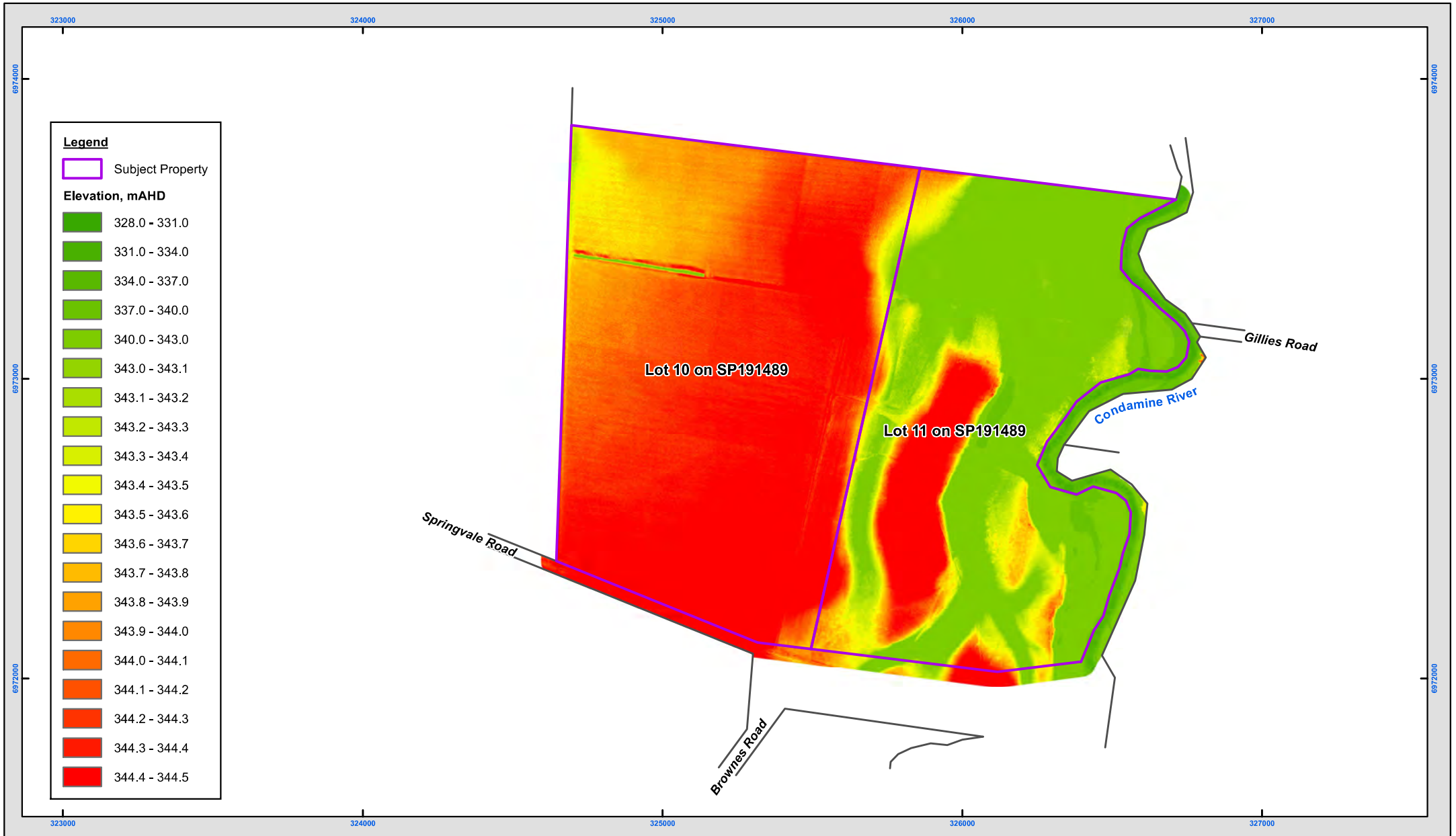

Figure 1 : 2012 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

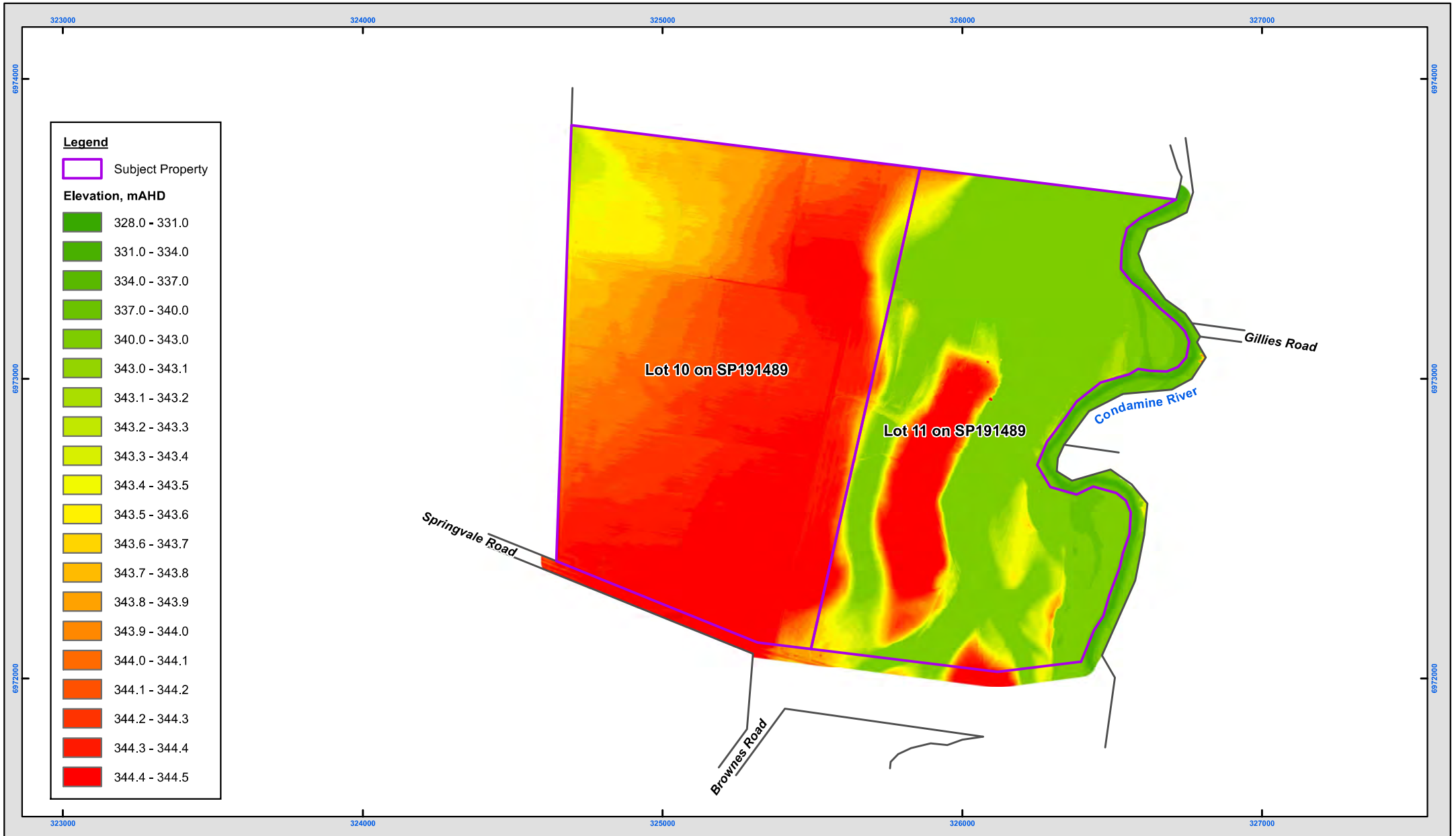

Figure 2 : 2014 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

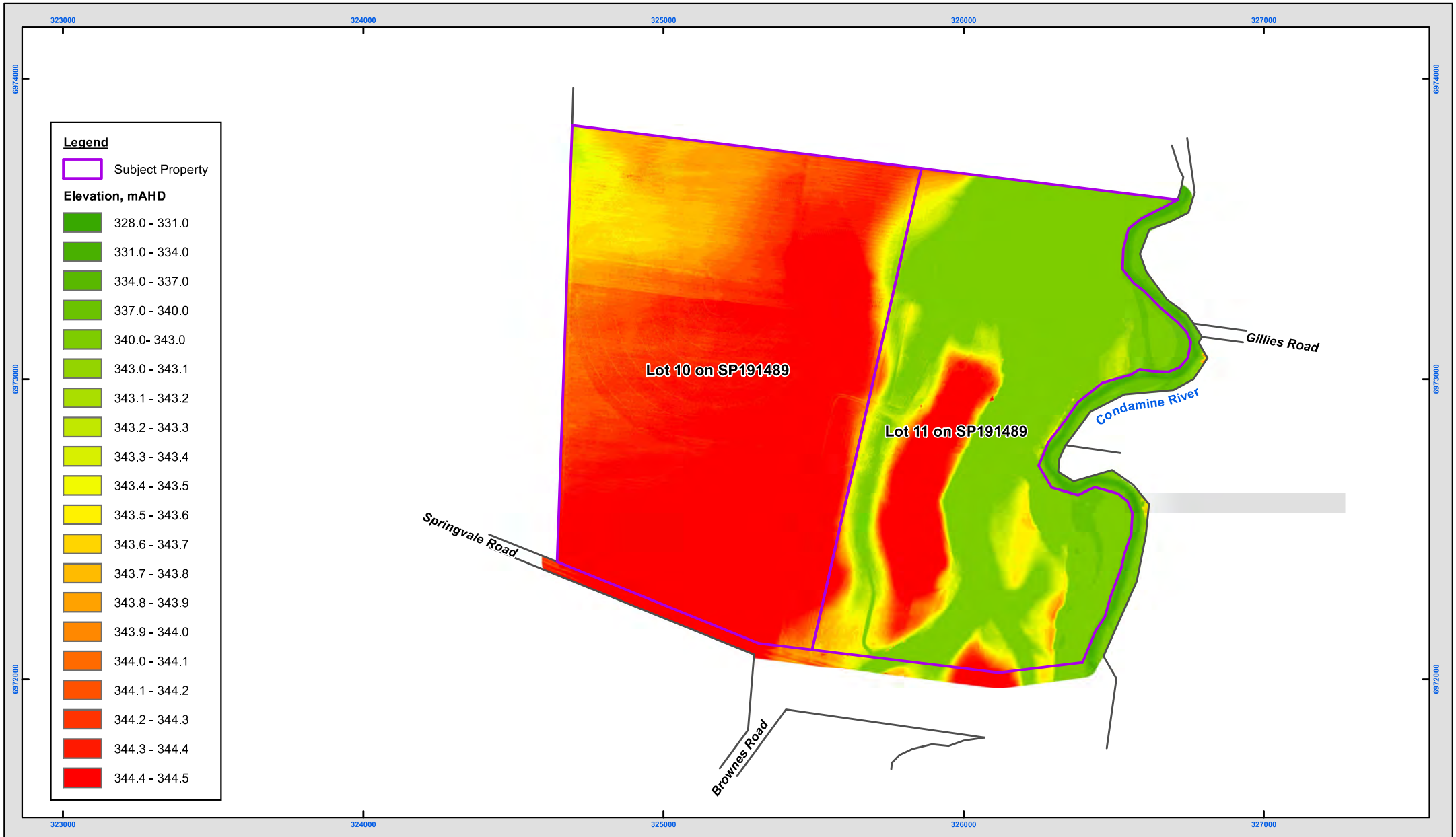

Figure 3 : 2020 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 9/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

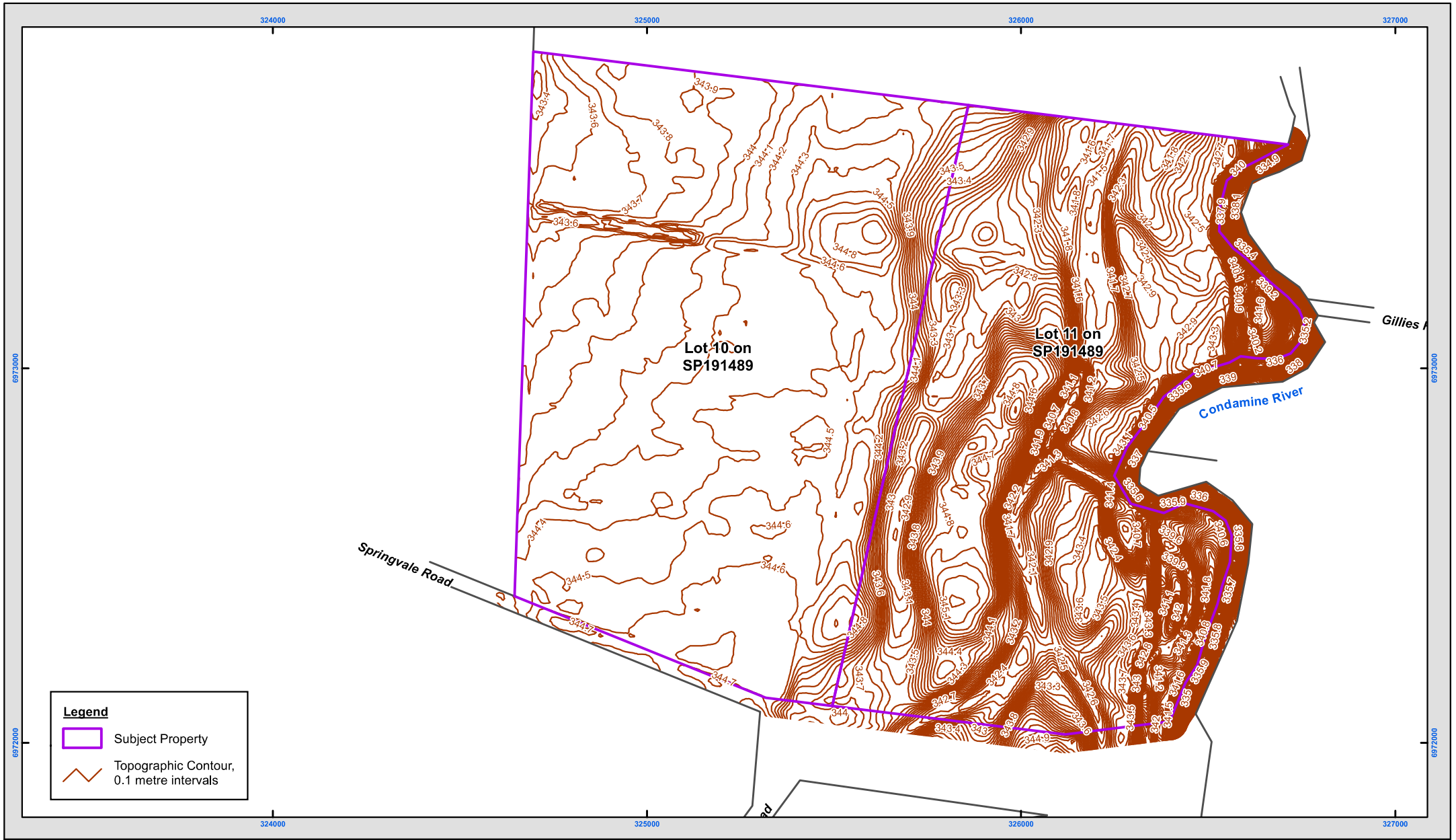

Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

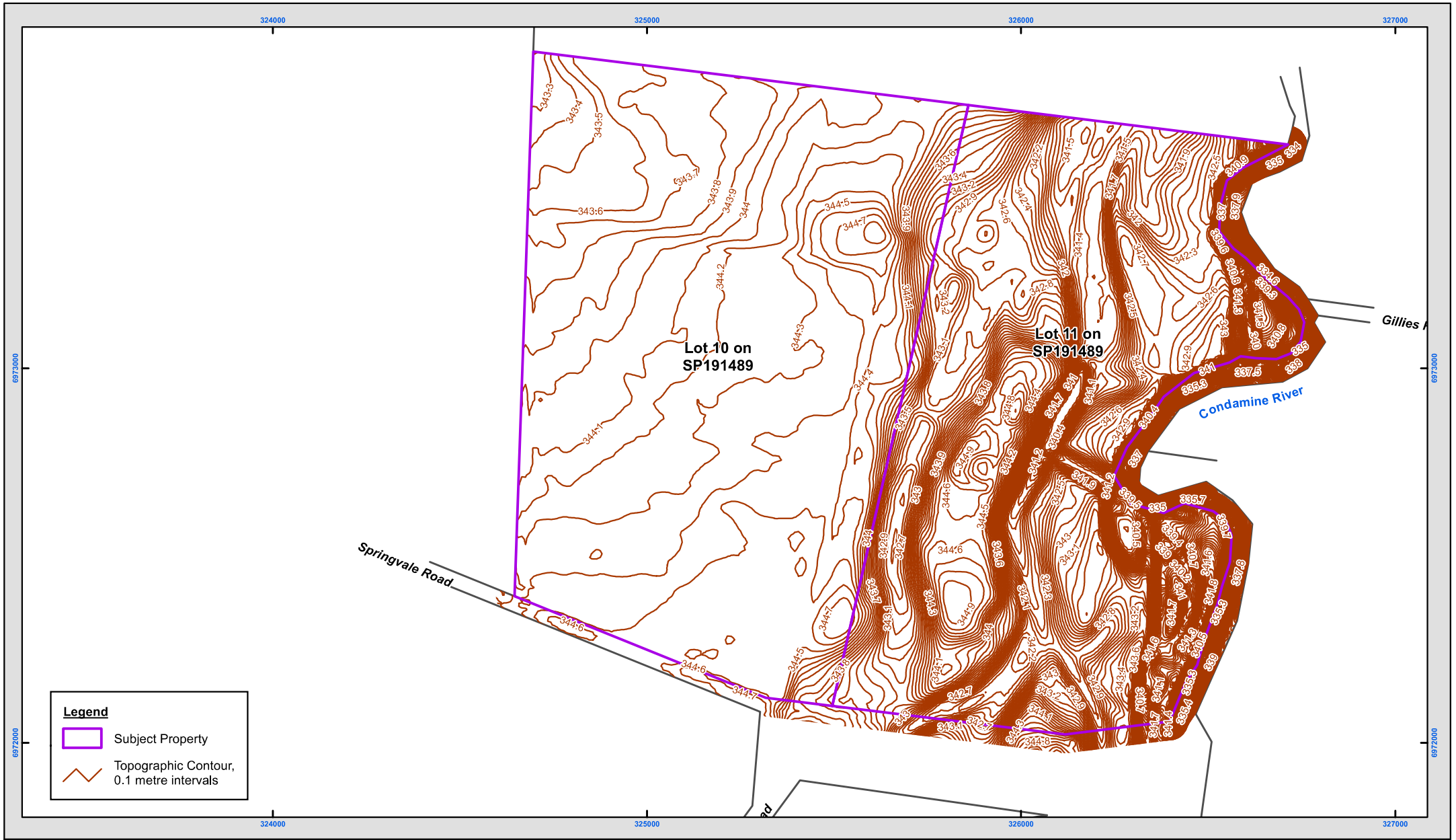

Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

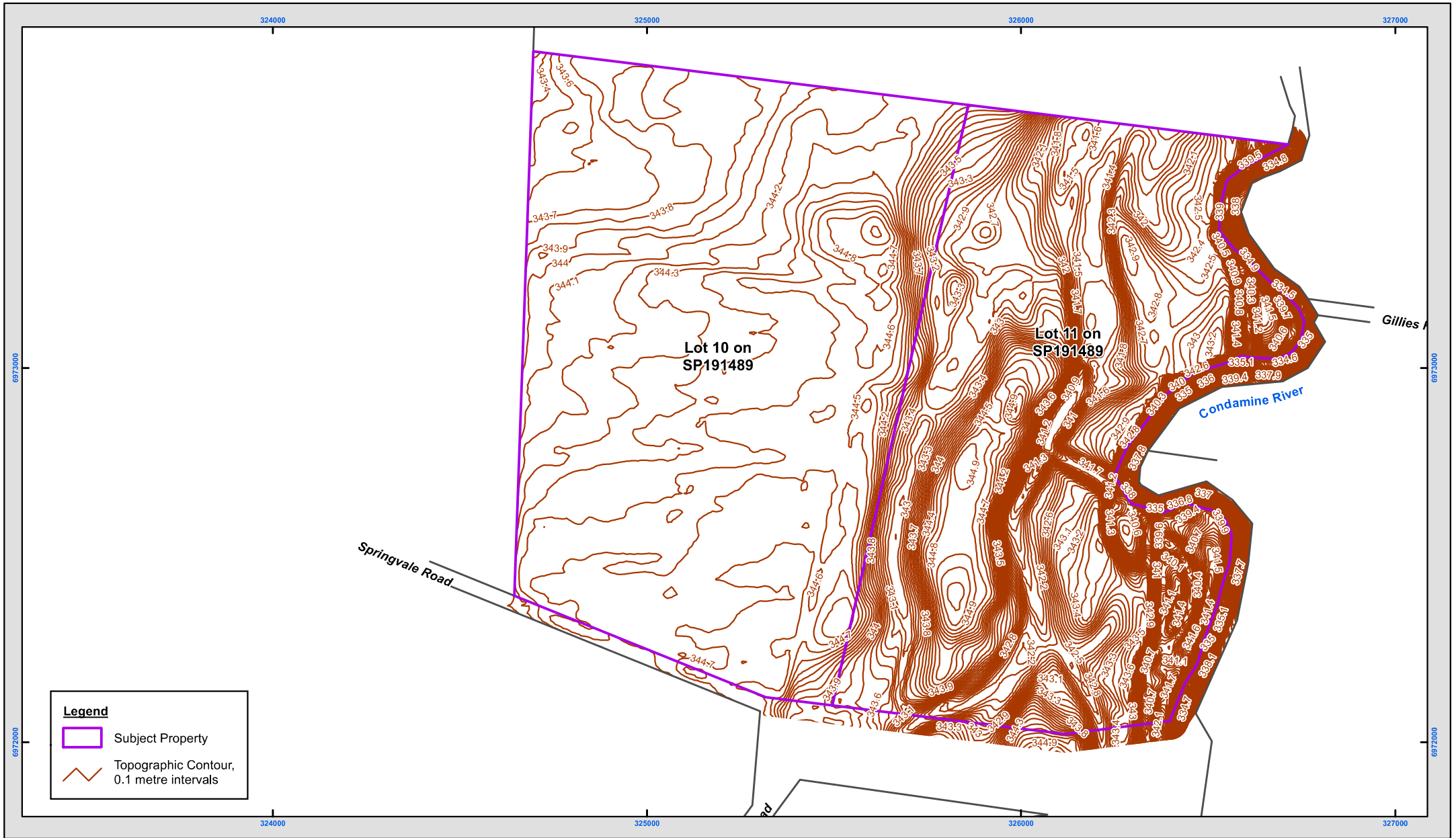

Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

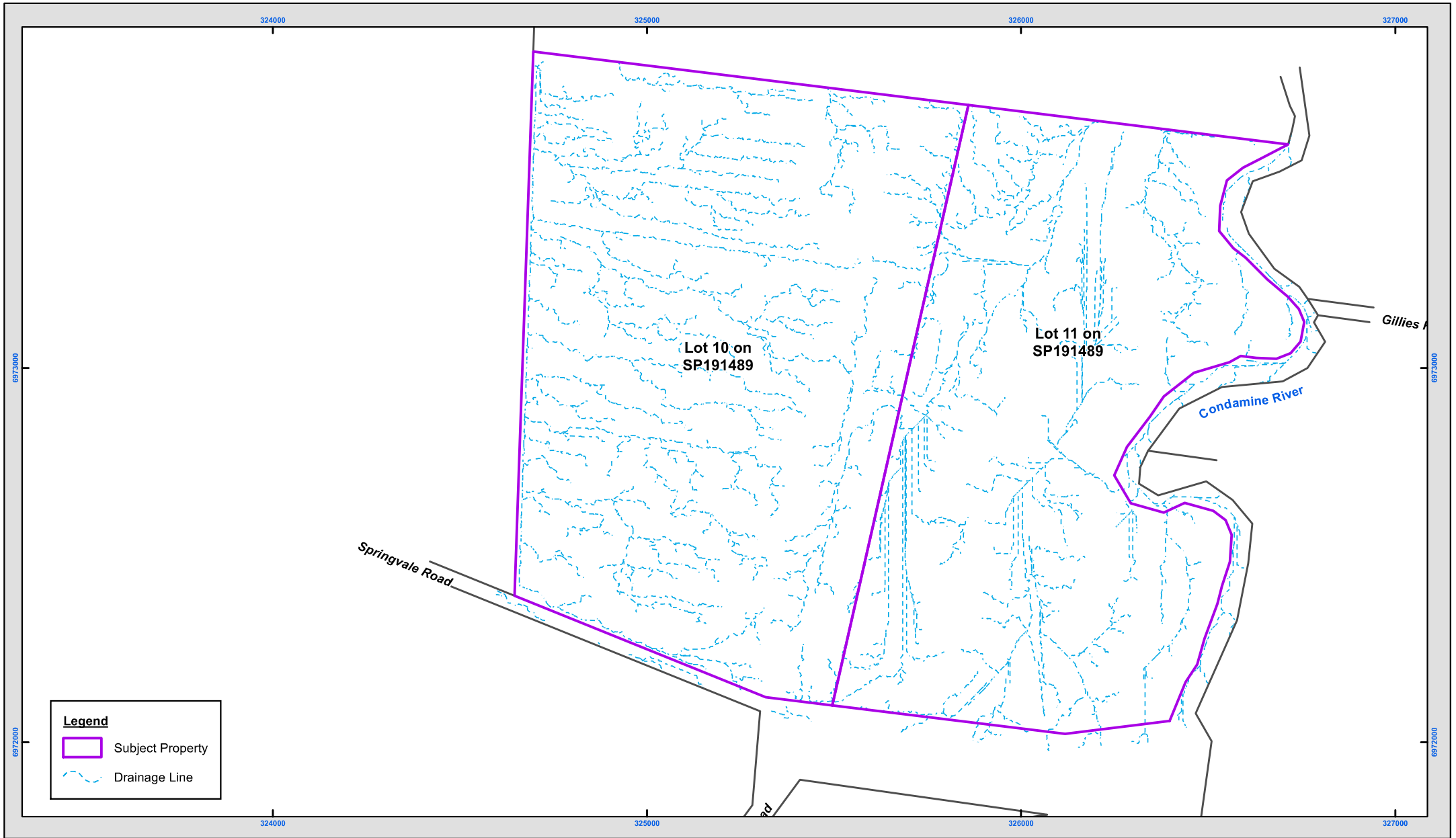

Figure 7 : 2012 DEM, Drainages Lines, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

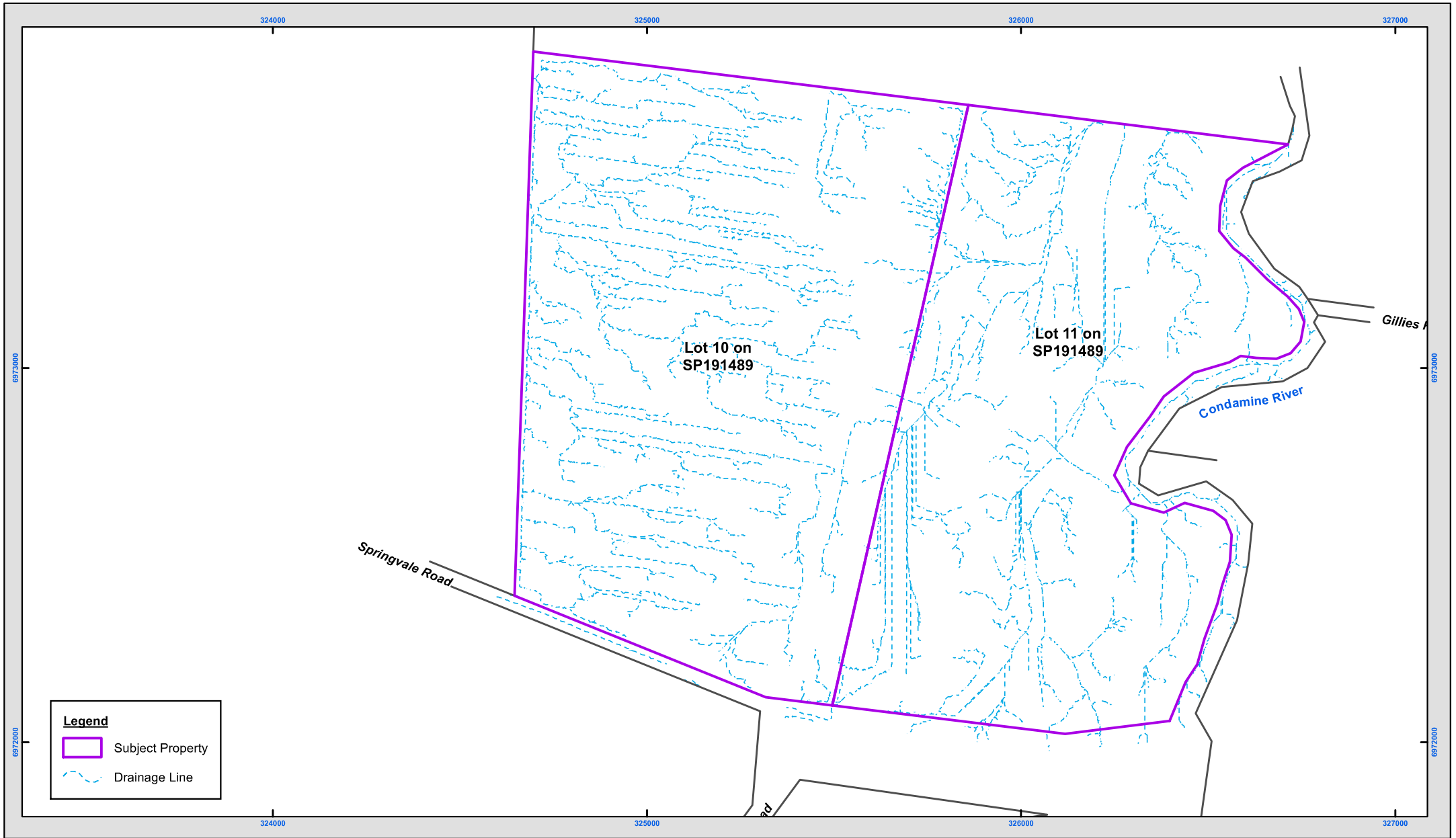

Figure 8 : 2014 DEM, Drainages Lines, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

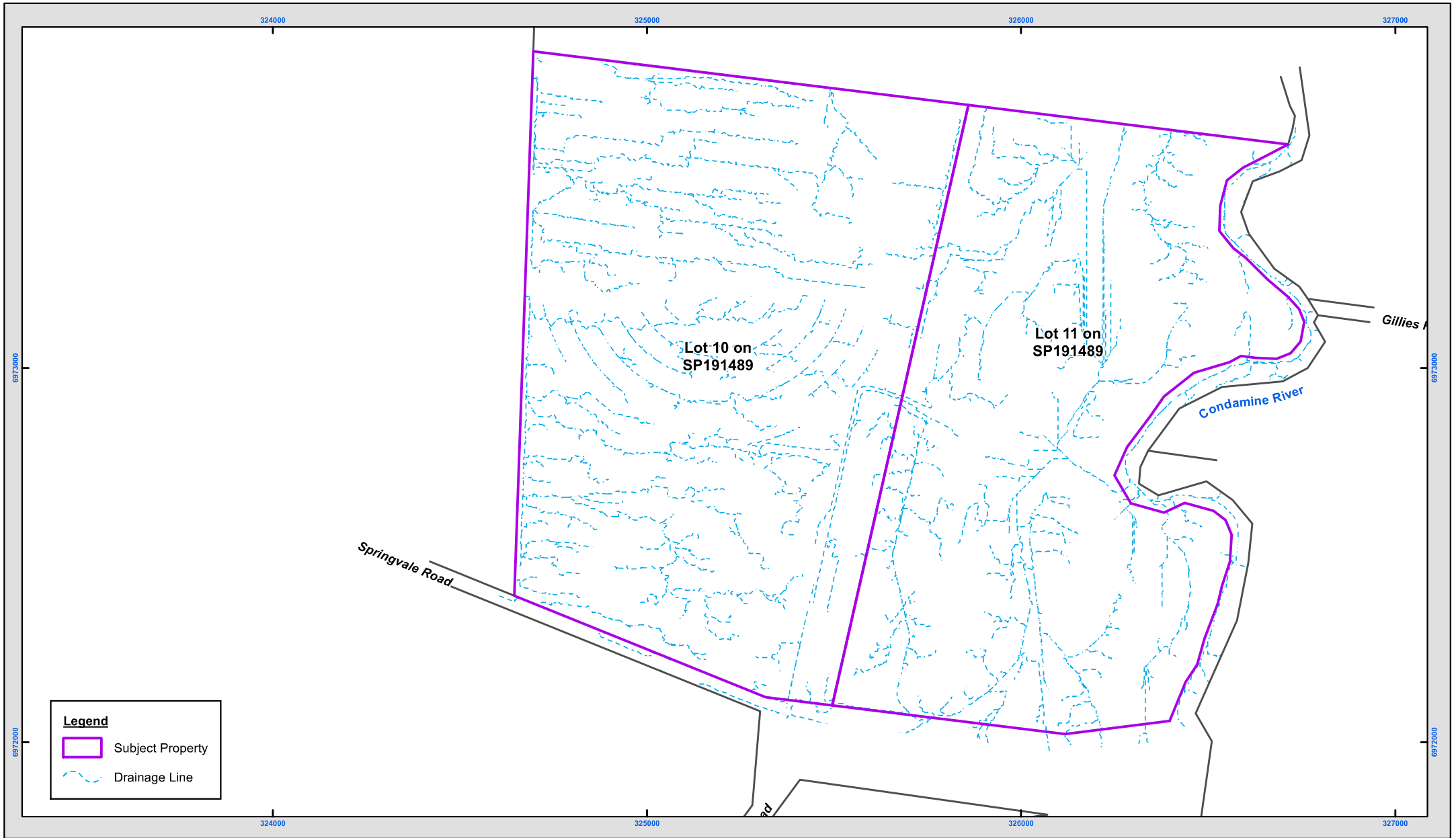

Figure 9 : 2020 DEM, Drainages Lines, Lots on Plans : 10SP191489 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 15/11/2021

Author: Arrow Energy

0.25 0.125 0 0.25 Kilometres

Scale: 1:9,615 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

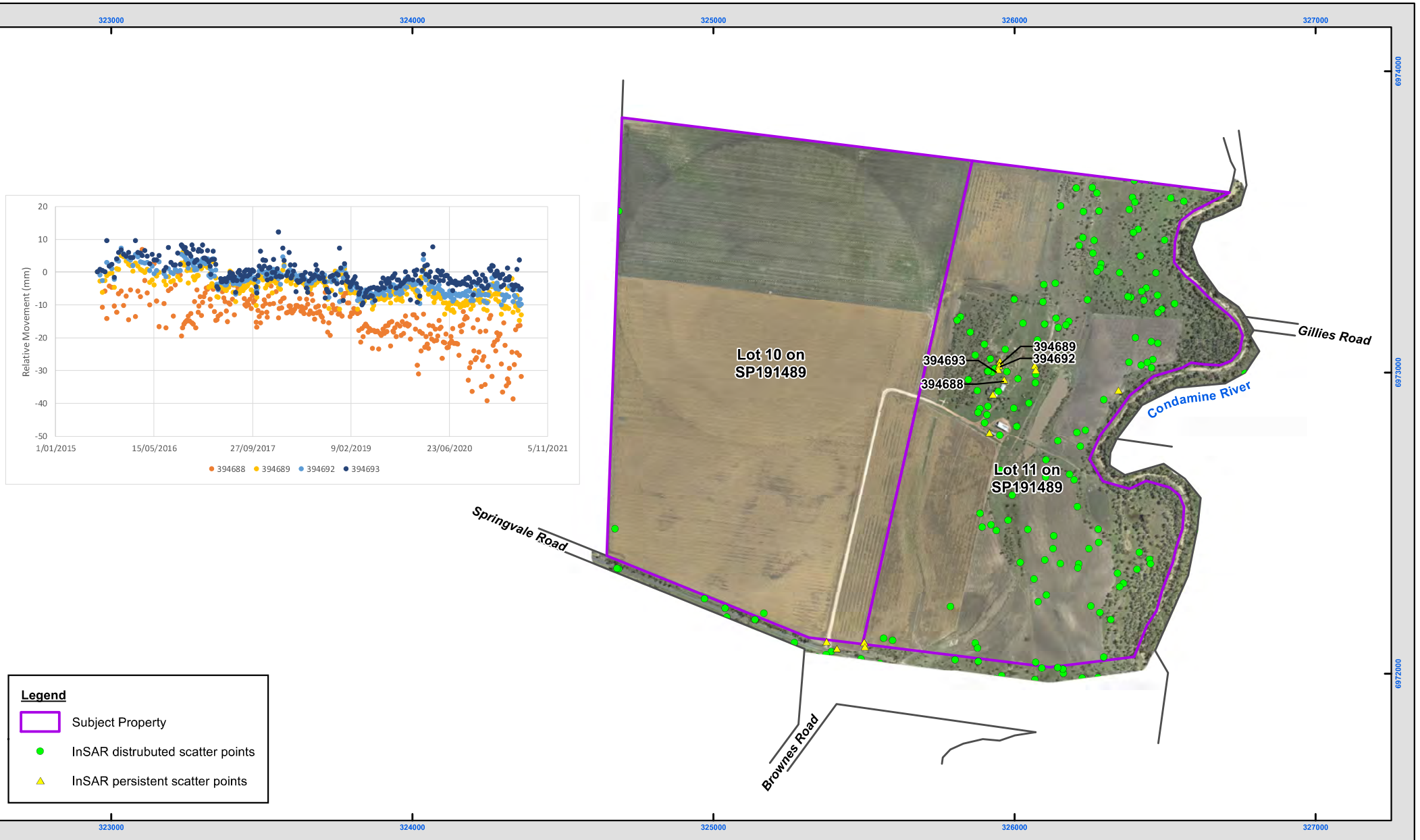

Figure 10 : InSAR persistent and distributed scatter points on Lots on Plans : 10SP191489 & 11SP191489 and time series plot.

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 2/02/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

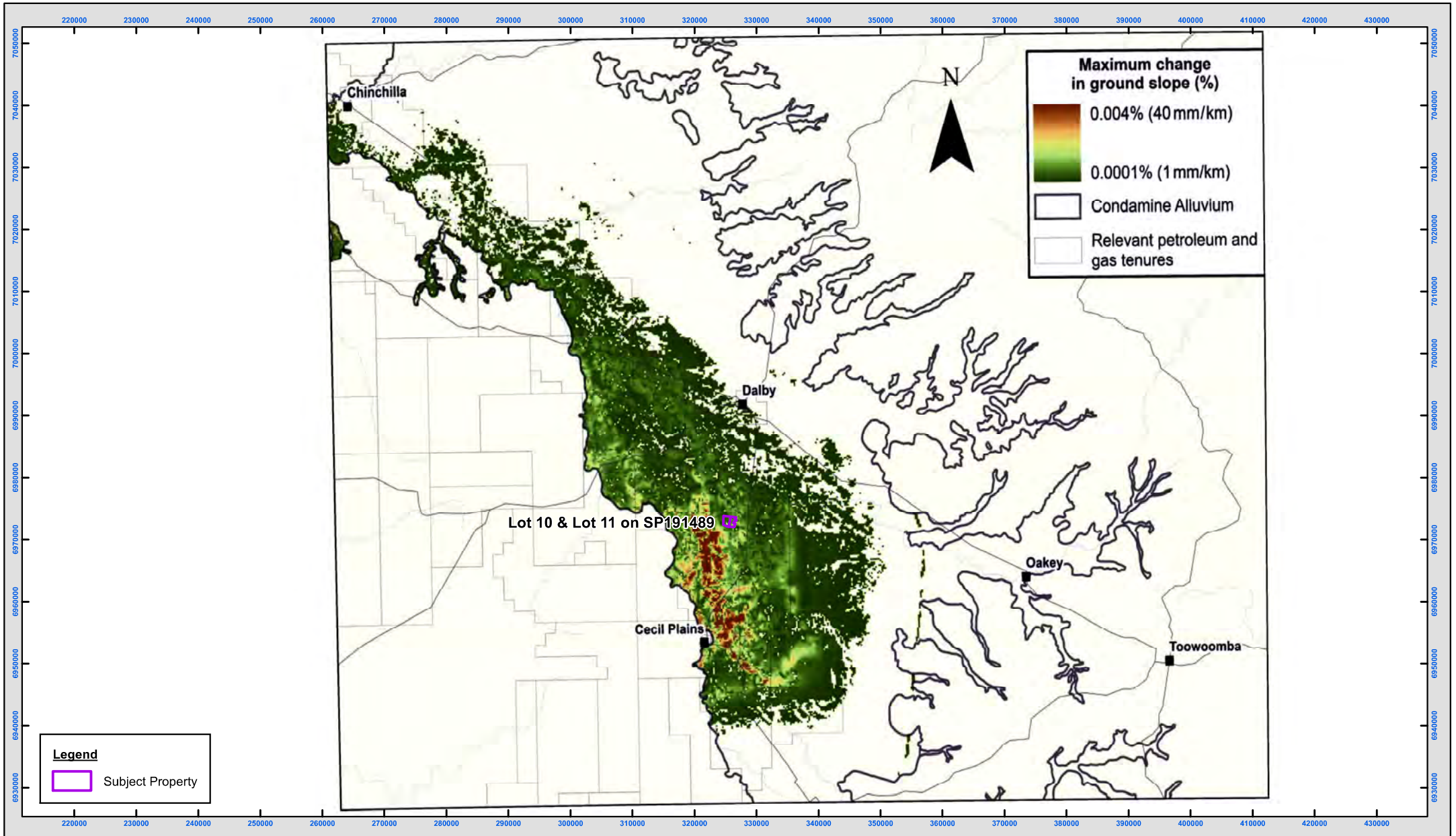

Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lots on Plans : 10 & 11SP191489

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 11/12/2021

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

Report

Safe Work. Strong Business.

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Baseline Report

Surface Elevation Data – 55DY592

Version	1
Released	17/11/2021

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List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lot on plan 55DY592:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
- 2012 DEM drainage lines (Figure 7),
- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
- InSAR persistent and distributed scatter points and time series plot (Figure 10), and
- OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) (Figure 11).

Electronic copies of the above datasets can be made available upon request.

The elevation related maps represented are based on light detection and ranging (LiDAR) elevation data acquired over 3 periods during Arrow Energy's operations (Table 1). The ground displacement map provides points based on interferometric synthetic aperture radar (InSAR), with time series graphs of selected persistent scatter points provided as an example of the data collected.

The LiDAR data is provided to Arrow as classified point clouds (with ground and non-ground points) and a Digital Elevation Model (DEM) generated from the ground classified points by the LiDAR providers. The LiDAR providers undertook surveying of a ground control network across the acquisition area to provide information on accuracy of the DEM. The DEM's derived from these LiDAR point clouds represent the most accurate regional scale datasets using industry leading experts available at the time of capture.

The InSAR data is provided to Arrow as persistent and distributed scatter points by the InSAR provider, processed using their proprietary SqueeSAR technology. The InSAR data provided commenced in 2015 with the Sentinel satellite system, and provides continual information on regional ground movement using industry leading experts.

Table 1: LiDAR Metadata

	2012 LIDAR	2014 LIDAR	2020 LIDAR
Company	FUGRO	AAM	AAM
Acquisition Start	16-Jun-12	Nov-14	15-Oct-20
Acquisition End	29-Jul-12	12-Feb-15	6-Nov-20
Spatial Accuracy (Hz)	0.29m @ 67% CI	0.15m @ 68% CI	0.20m @ 68% CI
Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

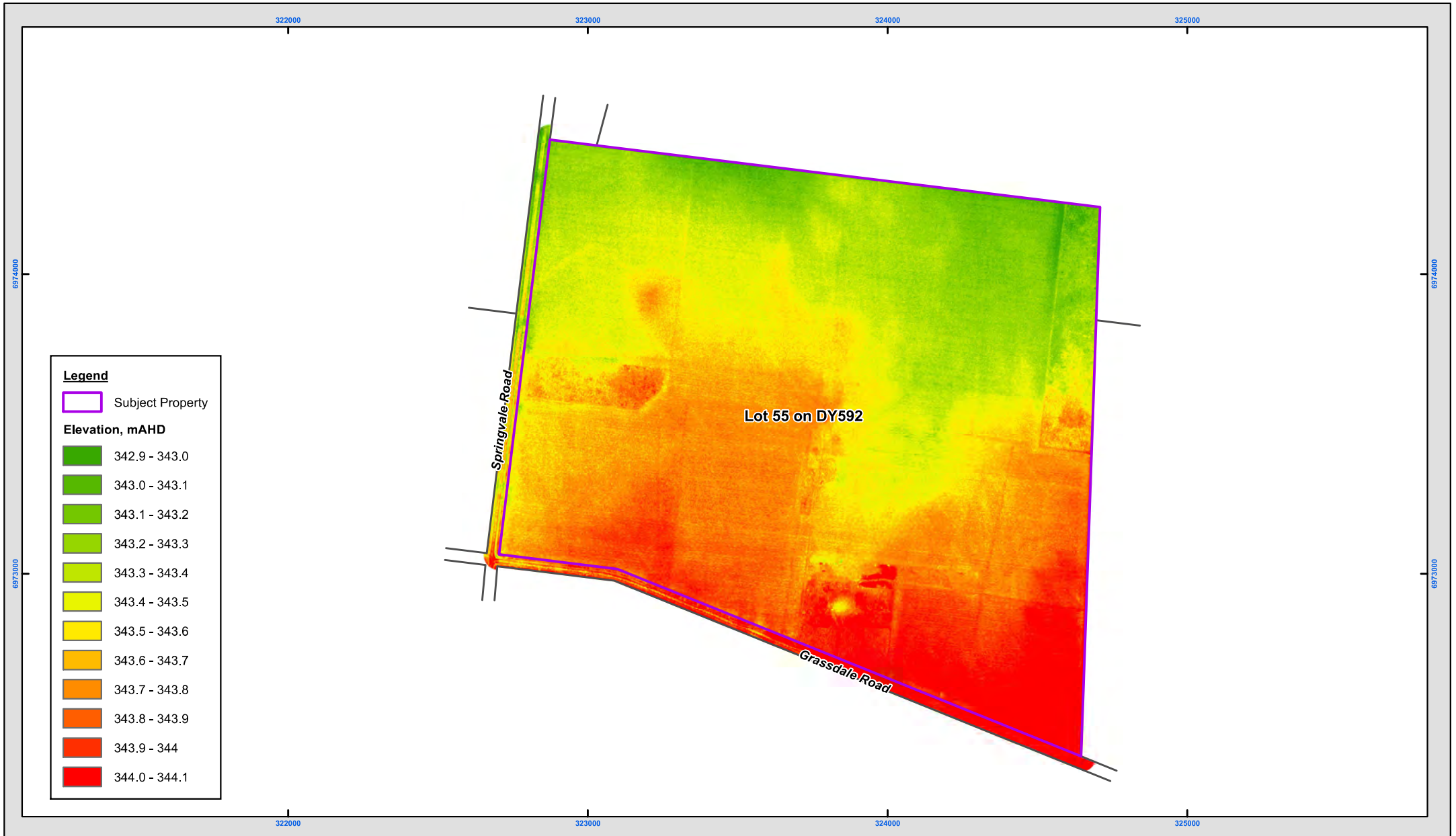

Figure 1 : 2012 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

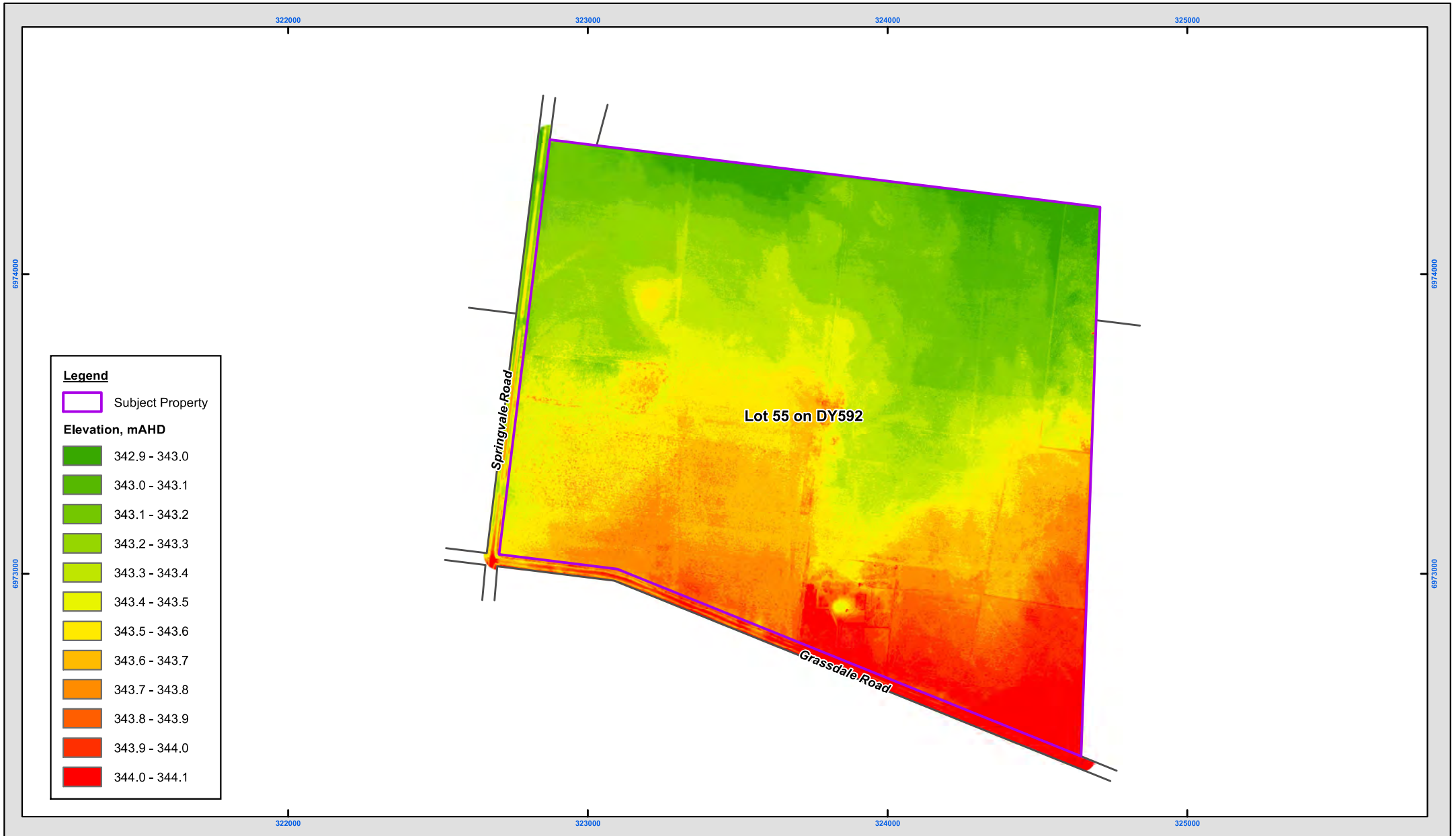

Figure 2 : 2014 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

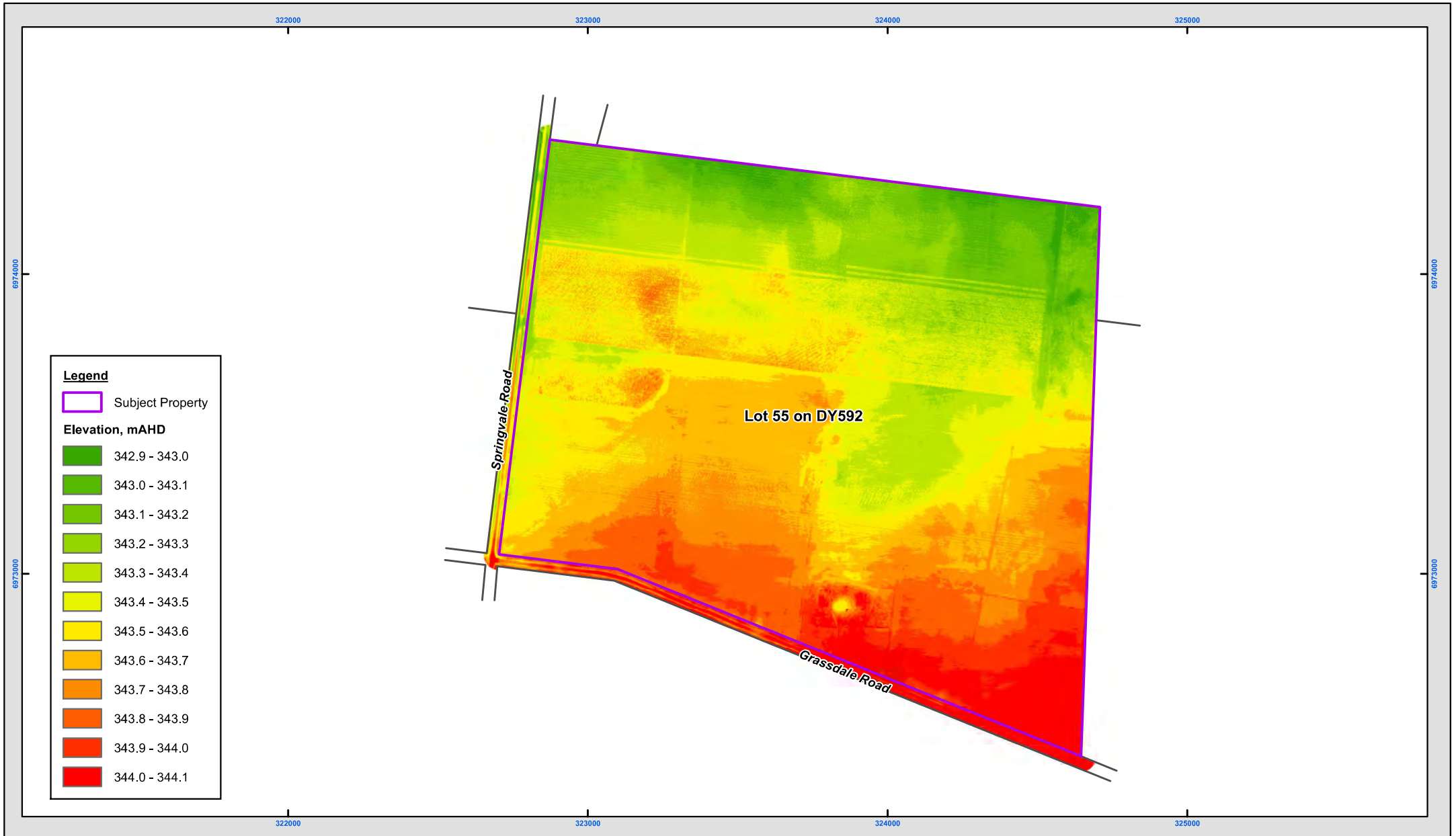

Figure 3 : 2020 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

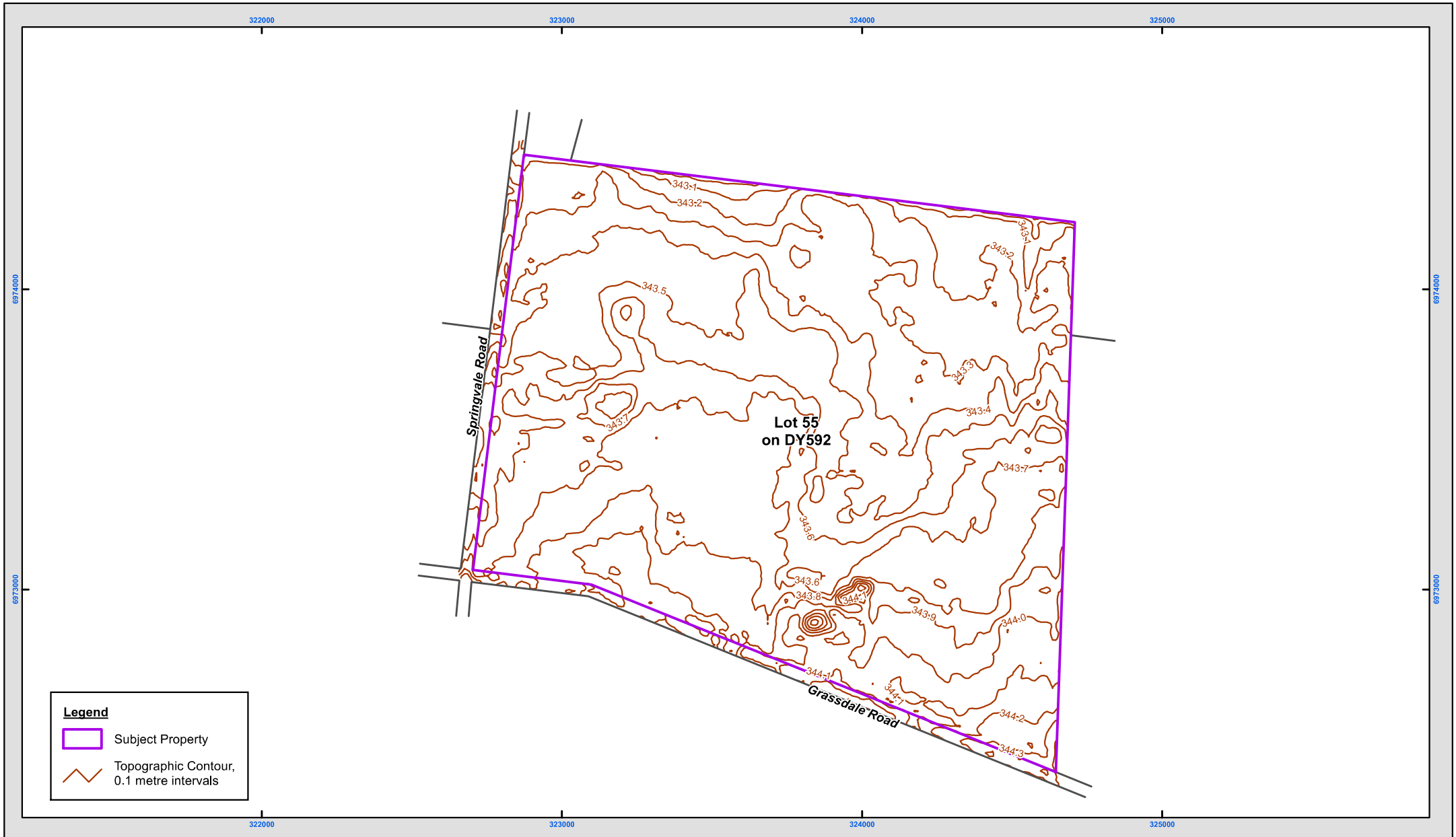

Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 10/02/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

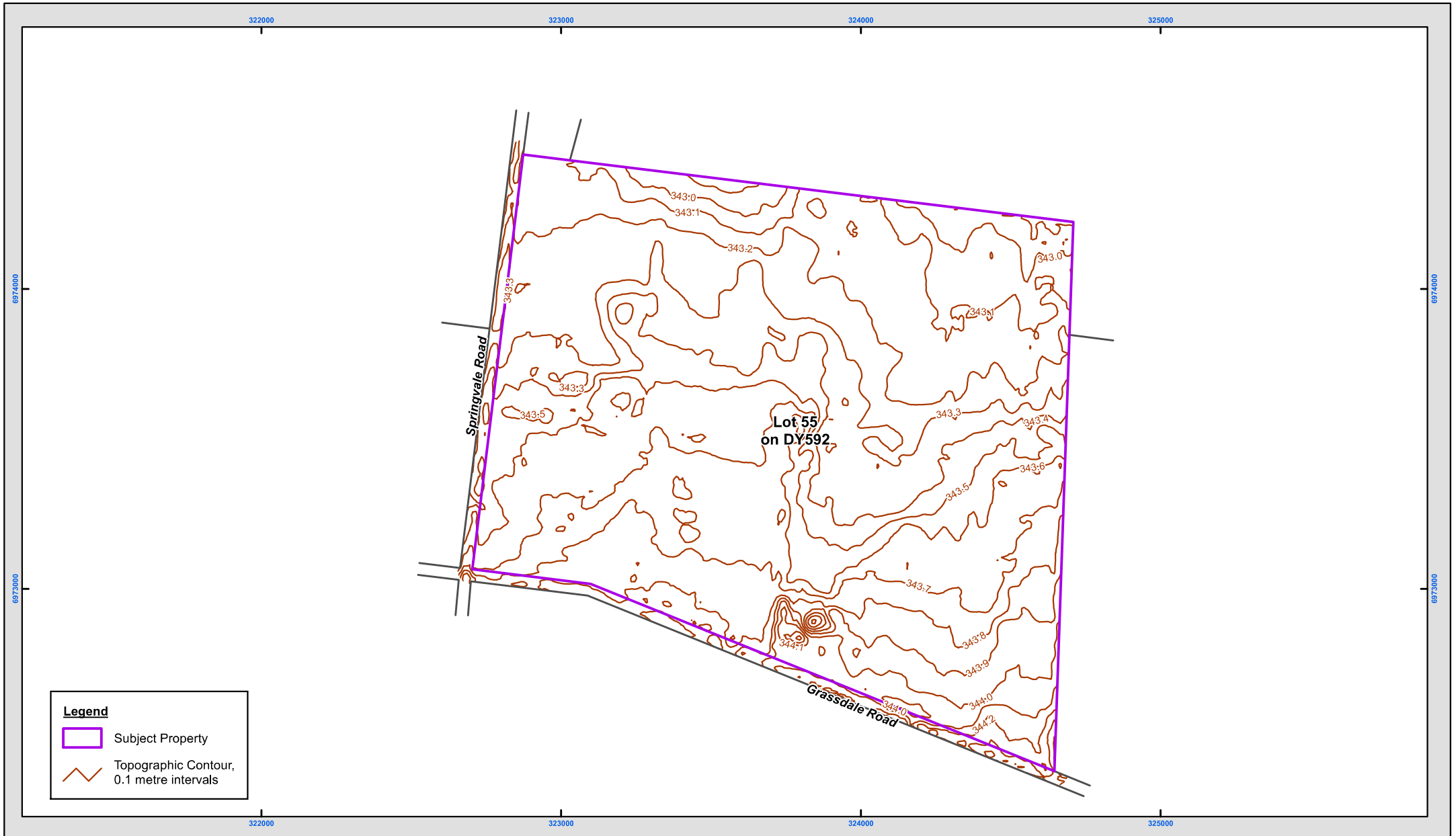

Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 10/02/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

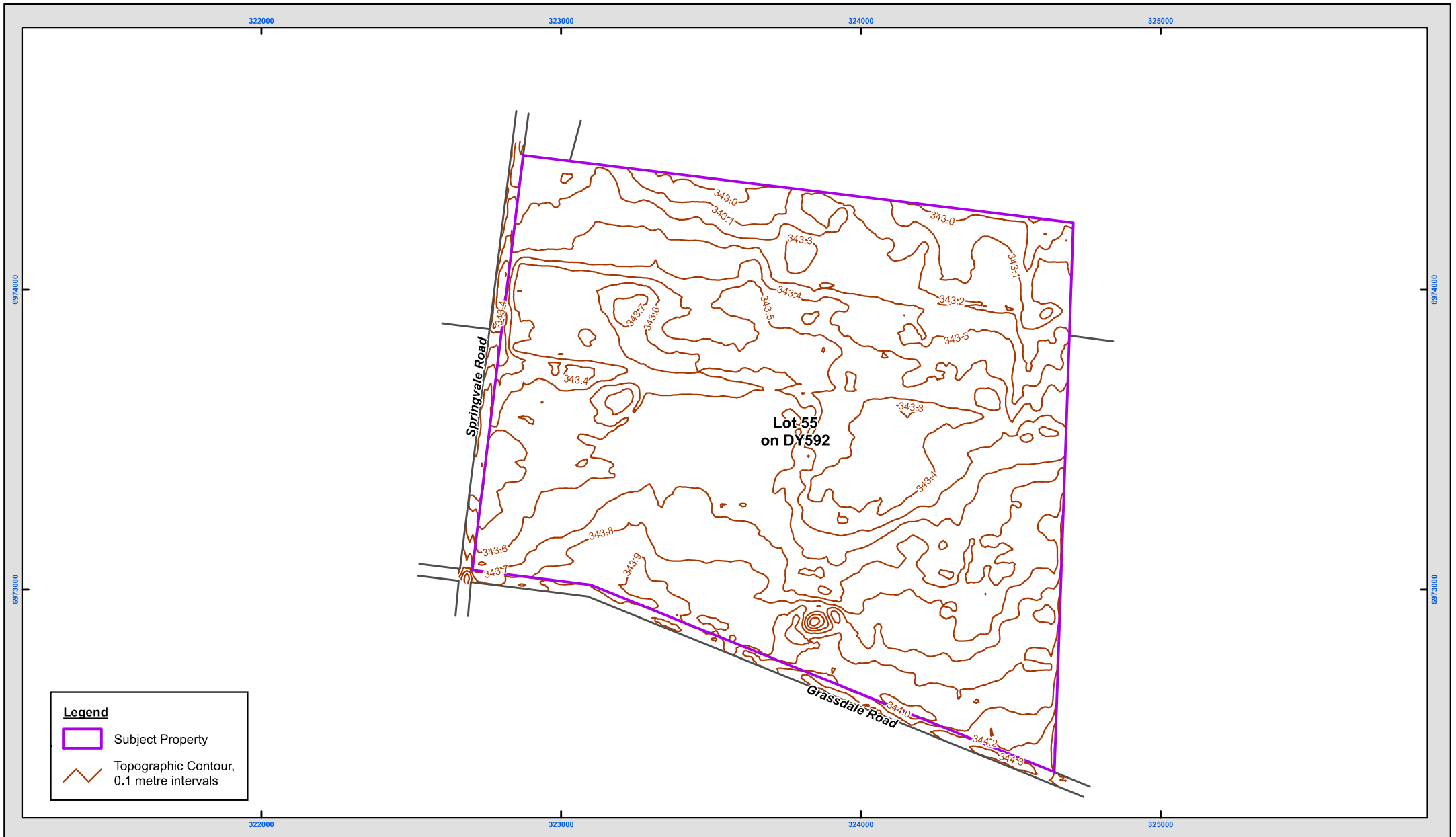

Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

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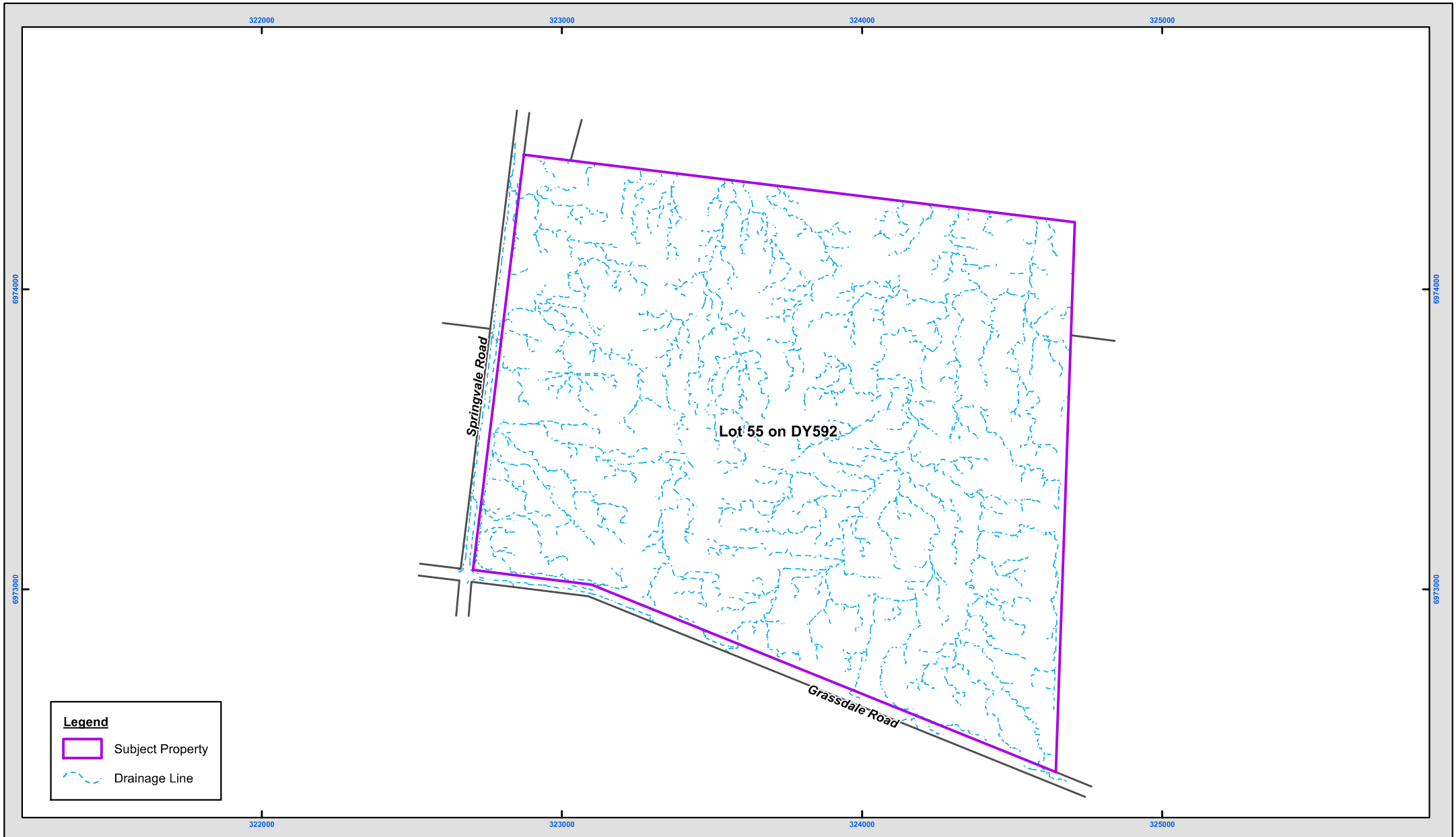

Figure 7 : 2012 DEM, Drainage Lines, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

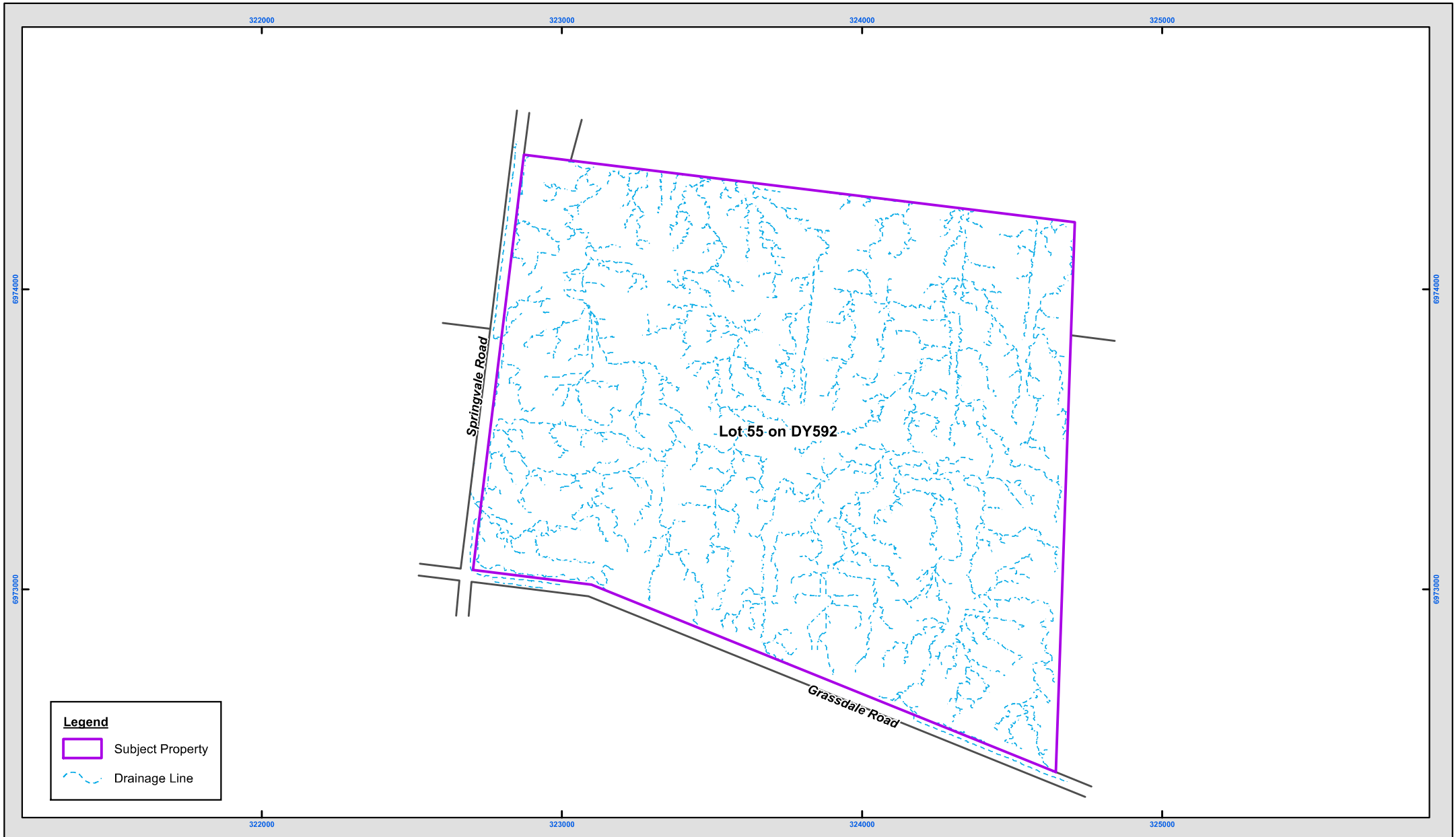

Figure 8 : 2014 DEM, Drainage Lines, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

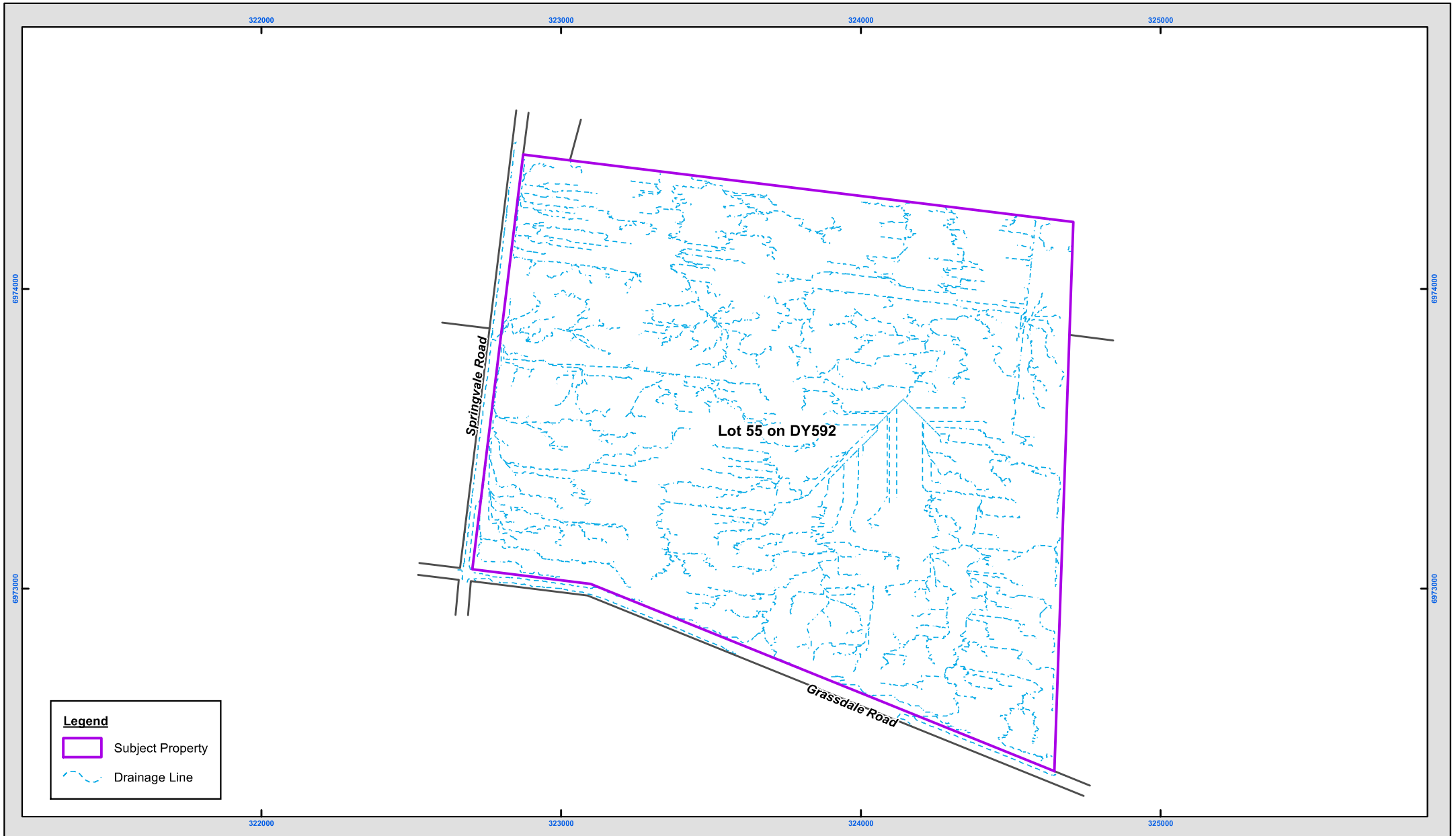

Figure 9 : 2020 DEM, Drainage Lines, Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

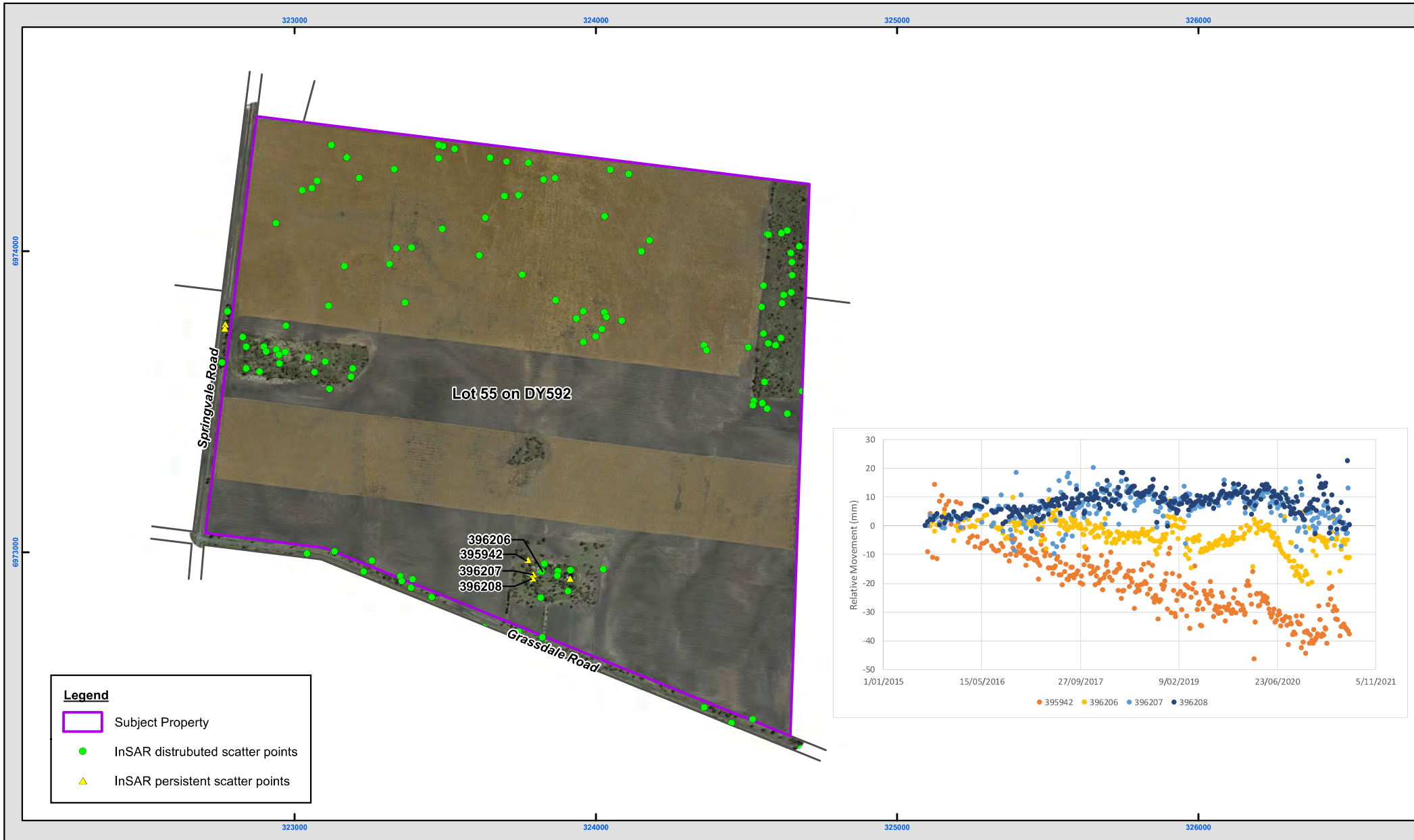

Figure 10 : InSAR persistent and distributed scatter points on Lot on Plan : 55DY592, and time series plot

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 9/02/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

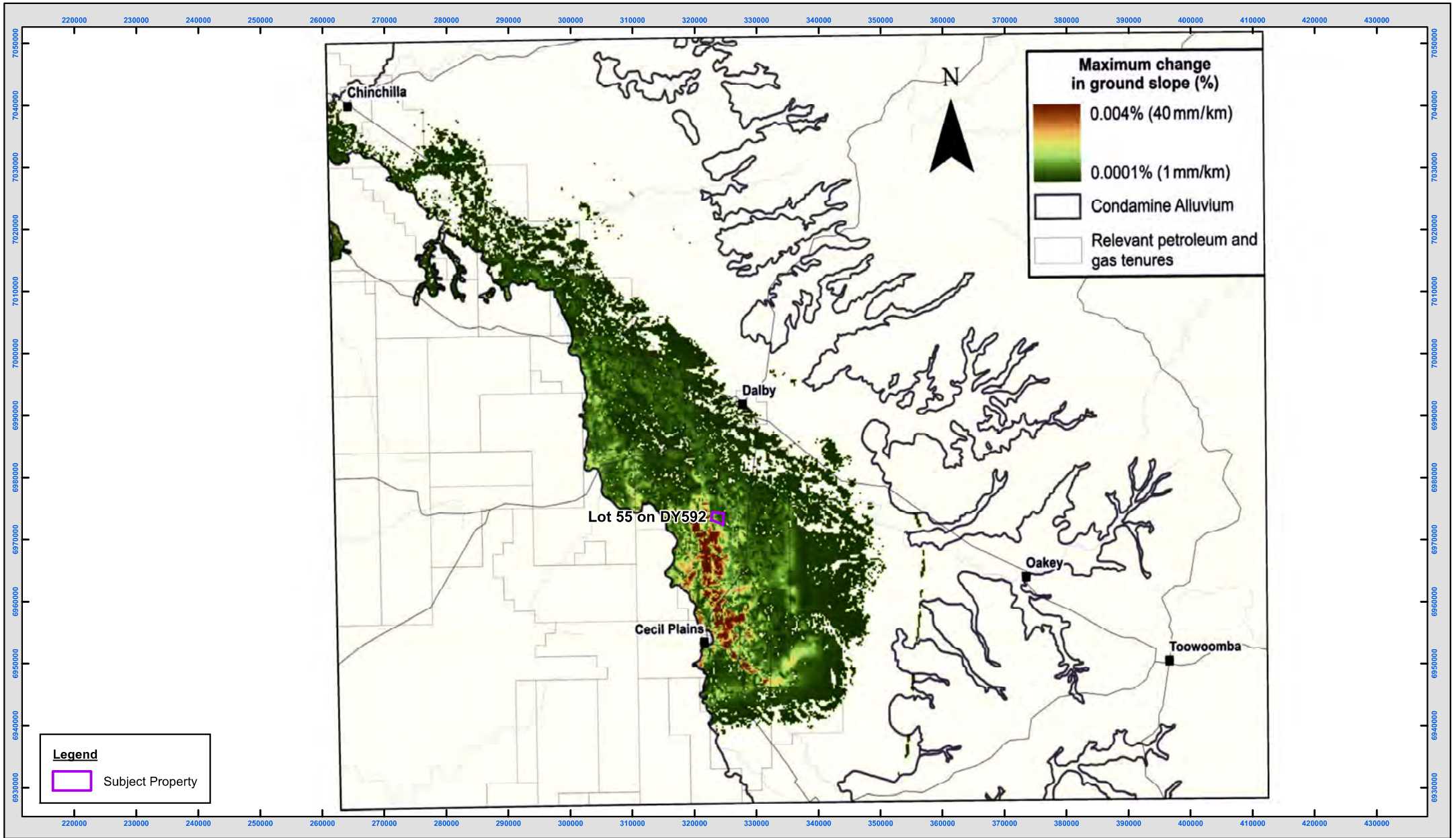

Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lot on Plan : 55DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 11/12/2021

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

Report

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target zero

Baseline Report

Surface Elevation Data – 56DY592

Version	3
Released	04/01/2022

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Contents

List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lot on plan 56DY592:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
- 2012 DEM drainage lines (Figure 7),
- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
- InSAR persistent and distributed scatter points and time series plot (Figure 10), and
- OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) (Figure 11).

Electronic copies of the above datasets can be made available upon request.

The elevation related maps represented are based on light detection and ranging (LiDAR) elevation data acquired over 3 periods during Arrow Energy's operations (Table 1). The ground displacement map provides points based on interferometric synthetic aperture radar (InSAR), with time series graphs of selected persistent scatter points provided as an example of the data collected.

The LiDAR data is provided to Arrow as classified point clouds (with ground and non-ground points) and a Digital Elevation Model (DEM) generated from the ground classified points by the LiDAR providers. The LiDAR providers undertook surveying of a ground control network across the acquisition area to provide information on accuracy of the DEM. The DEM's derived from these LiDAR point clouds represent the most accurate regional scale datasets using industry leading experts available at the time of capture.

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Table 1: LiDAR Metadata

	2012 LIDAR	2014 LIDAR	2020 LIDAR
Company	FUGRO	AAM	AAM
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Acquisition End	29-Jul-12	12-Feb-15	6-Nov-20
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Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

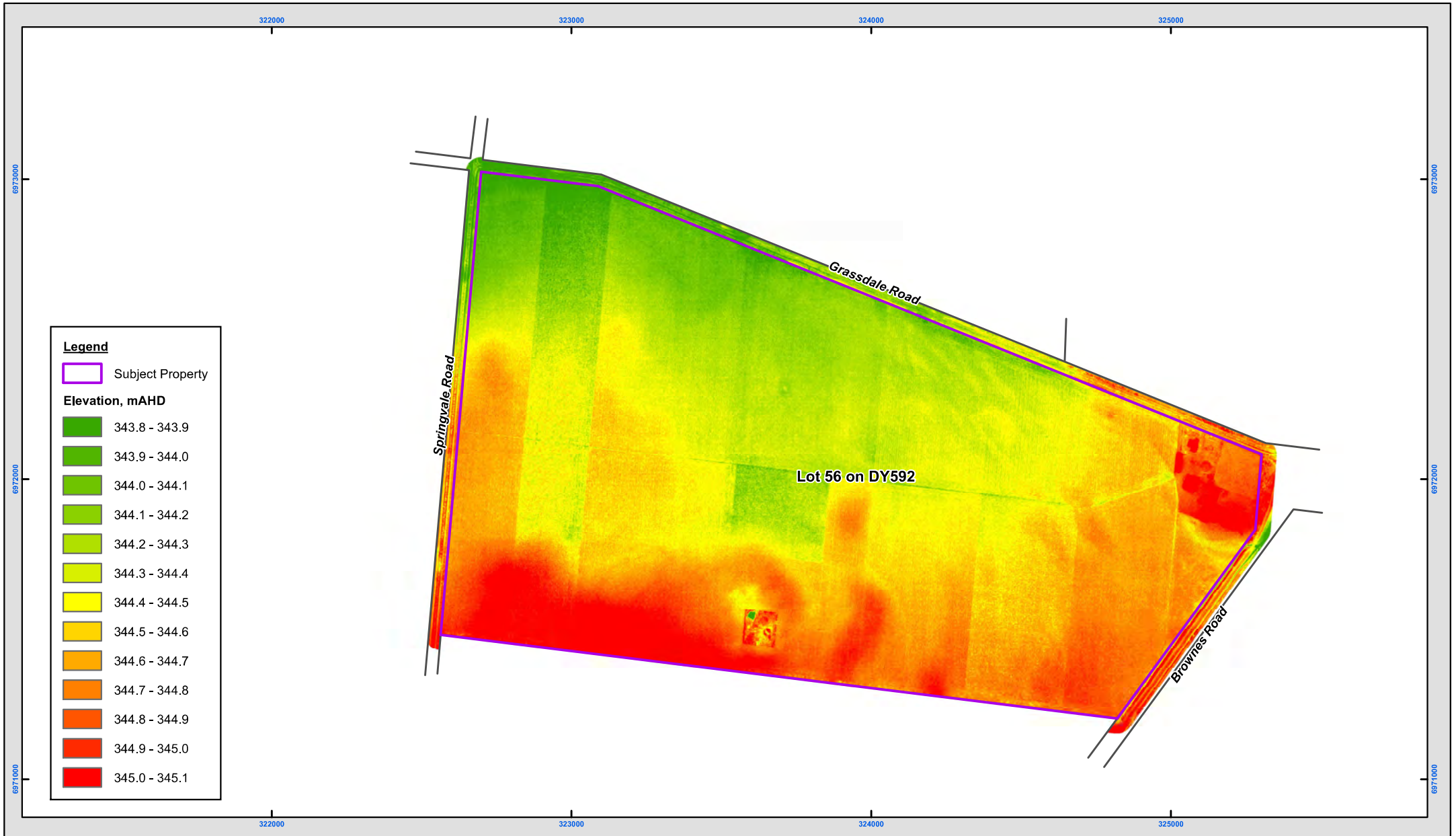

Figure 1 : 2012 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

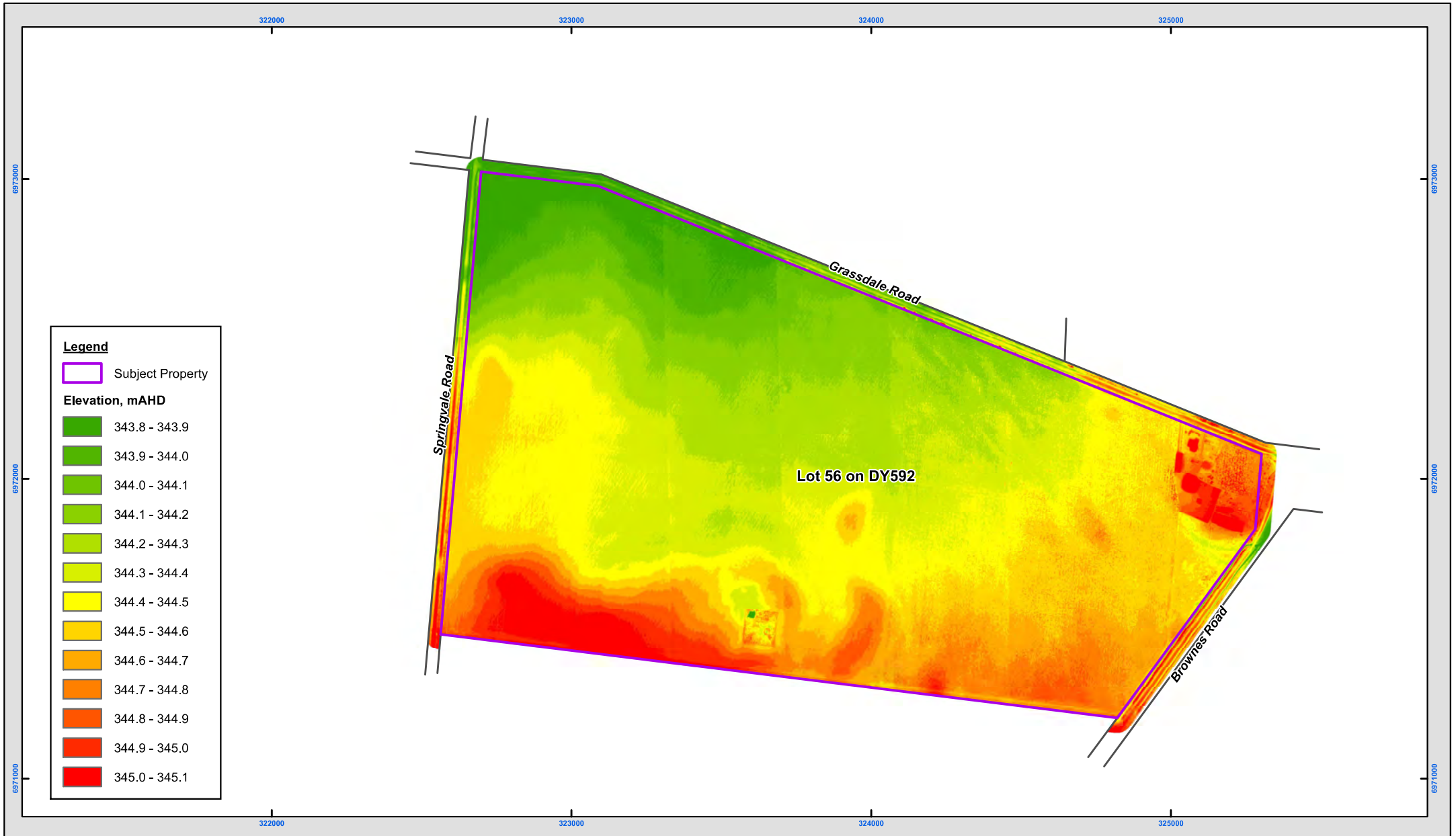

Figure 2 : 2014 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

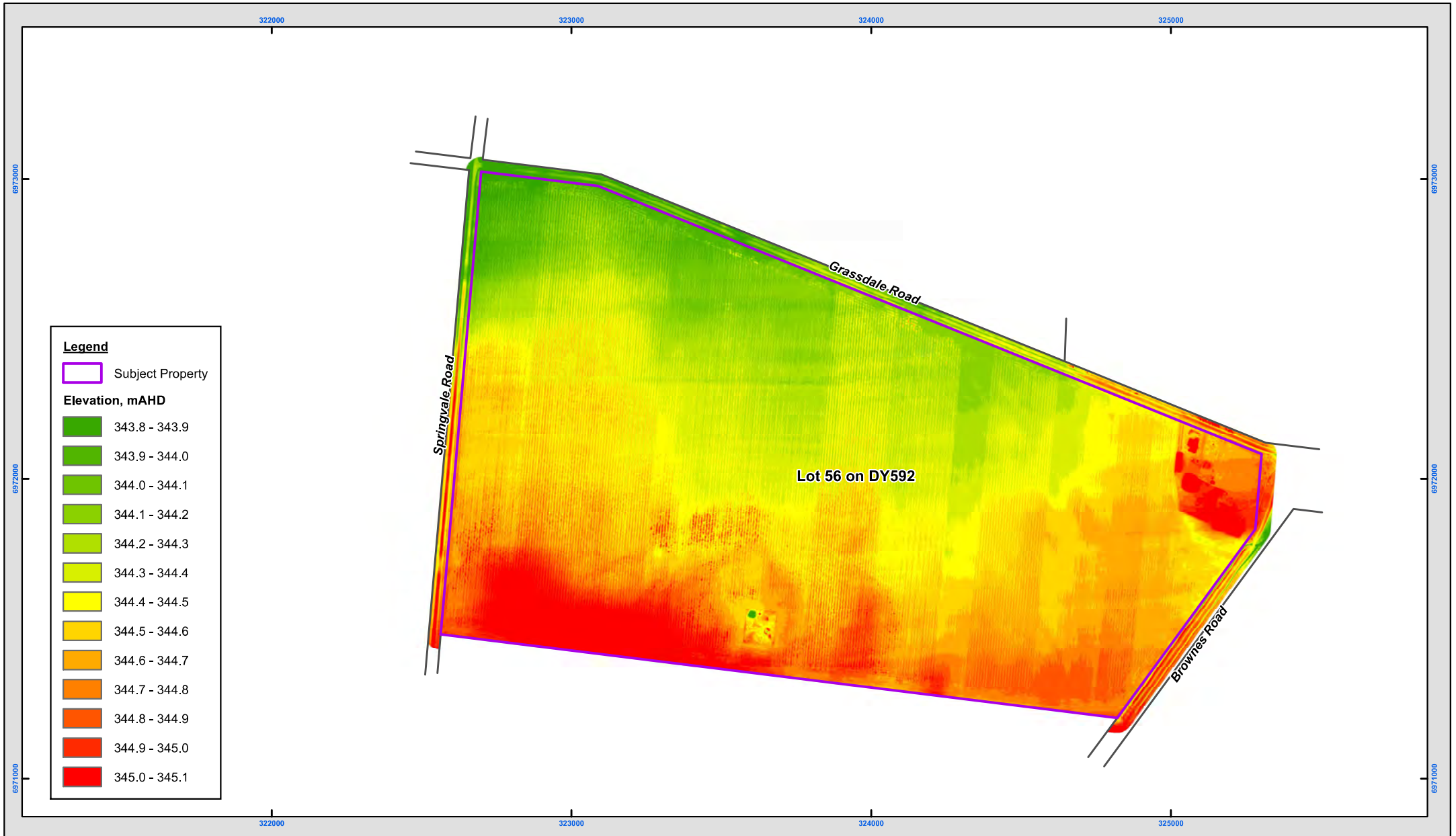

Figure 3 : 2020 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

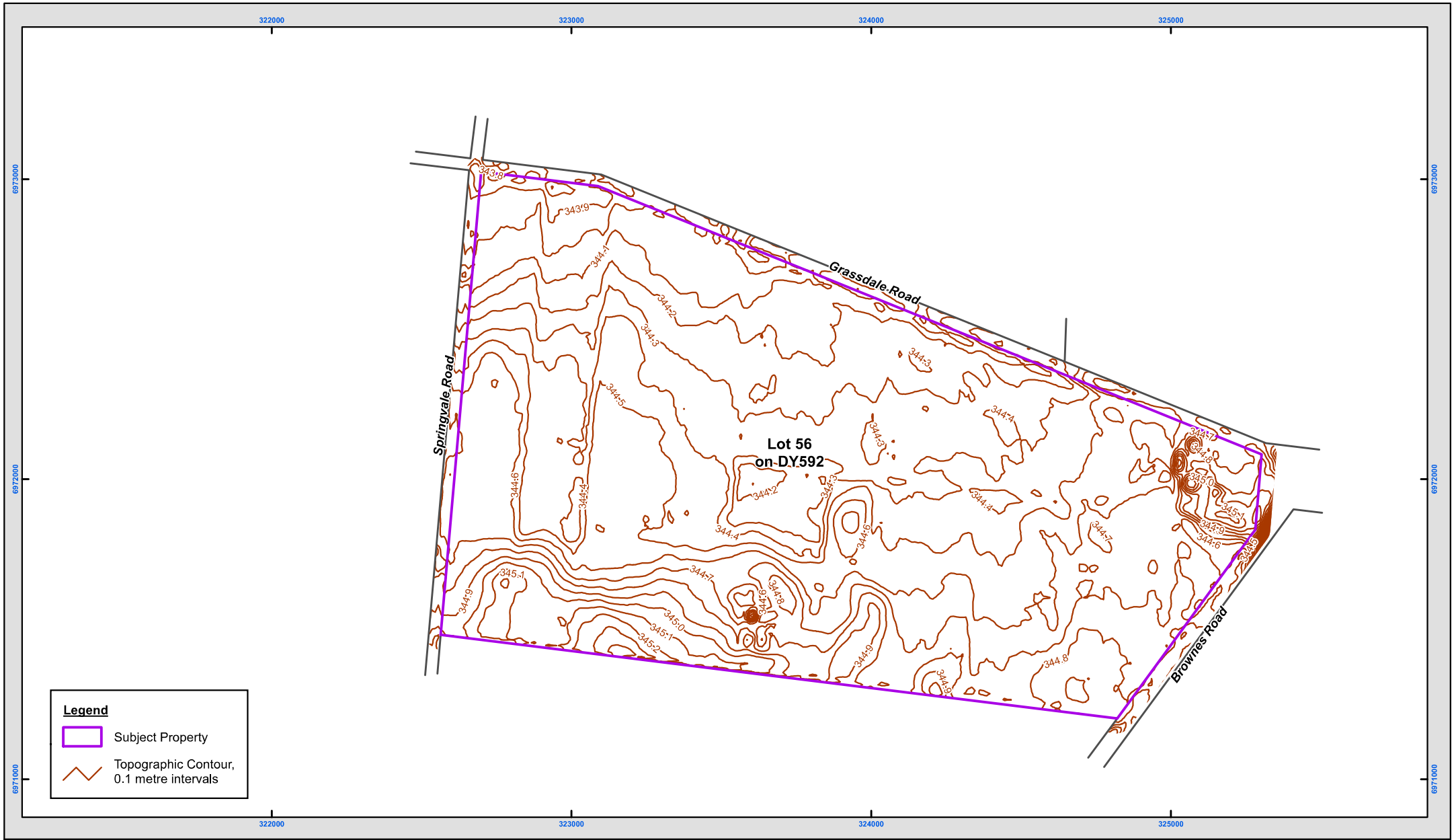

Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

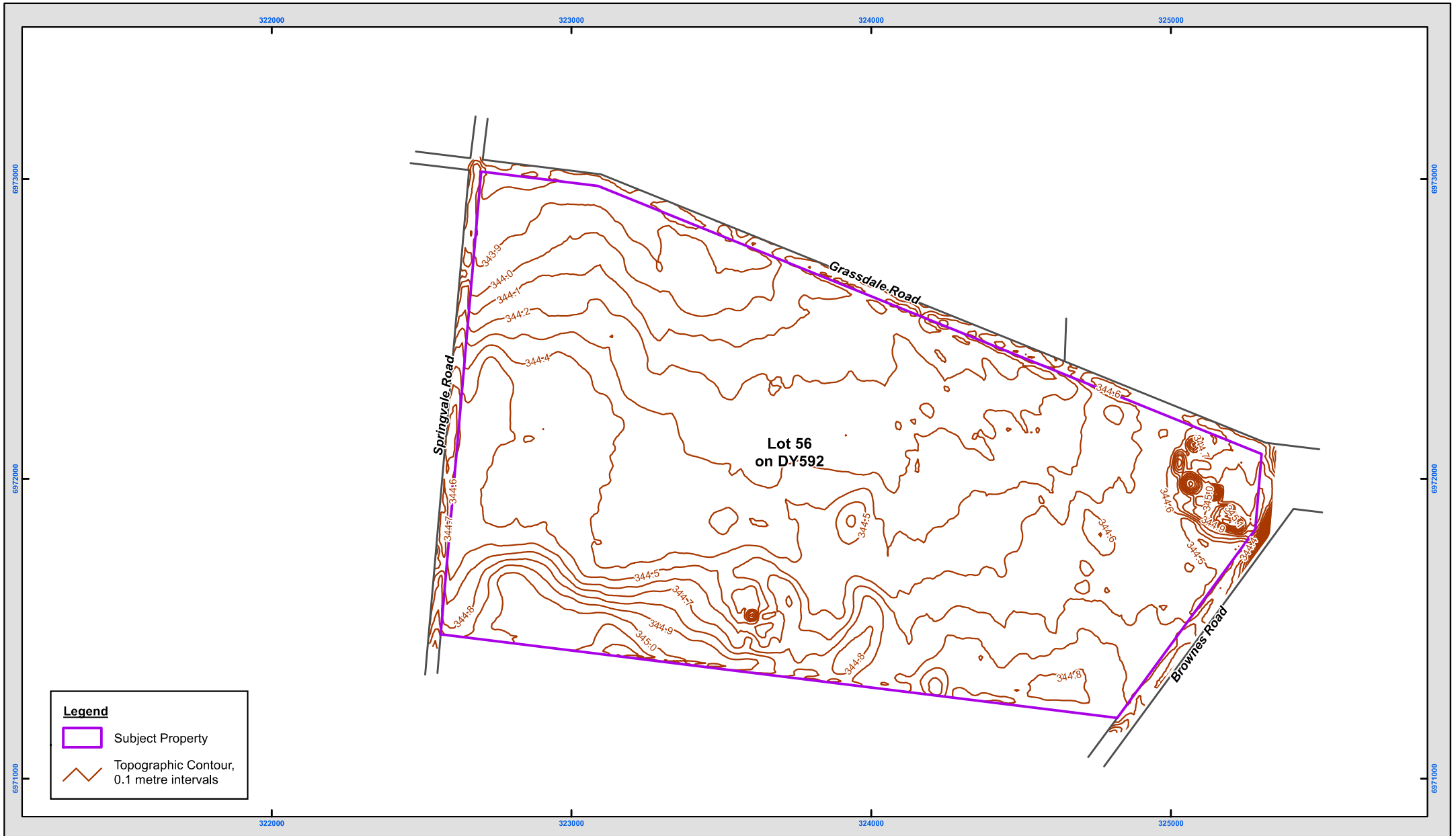

Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

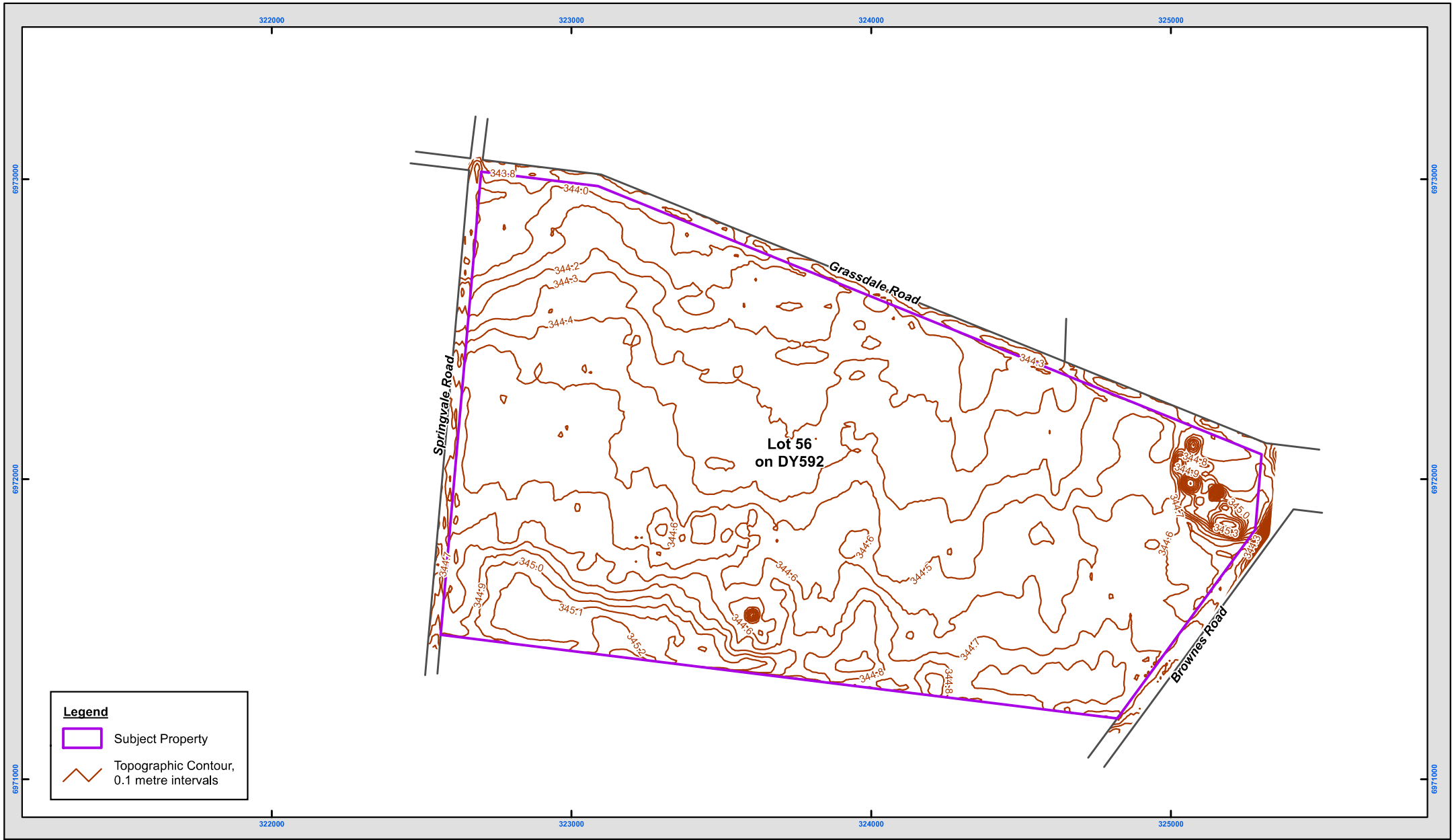

Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

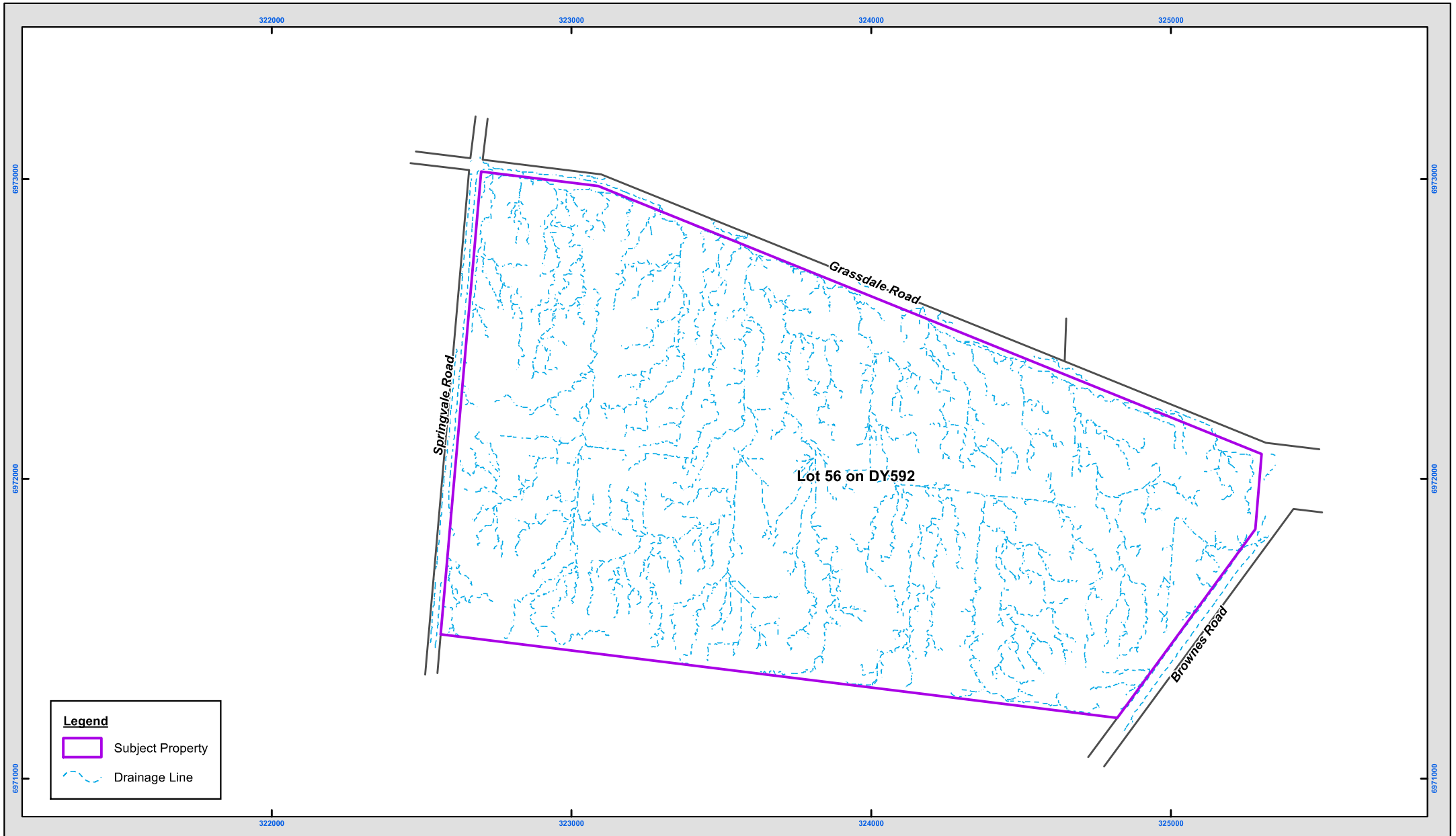

Figure 7 : 2012, Drainage Lines, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

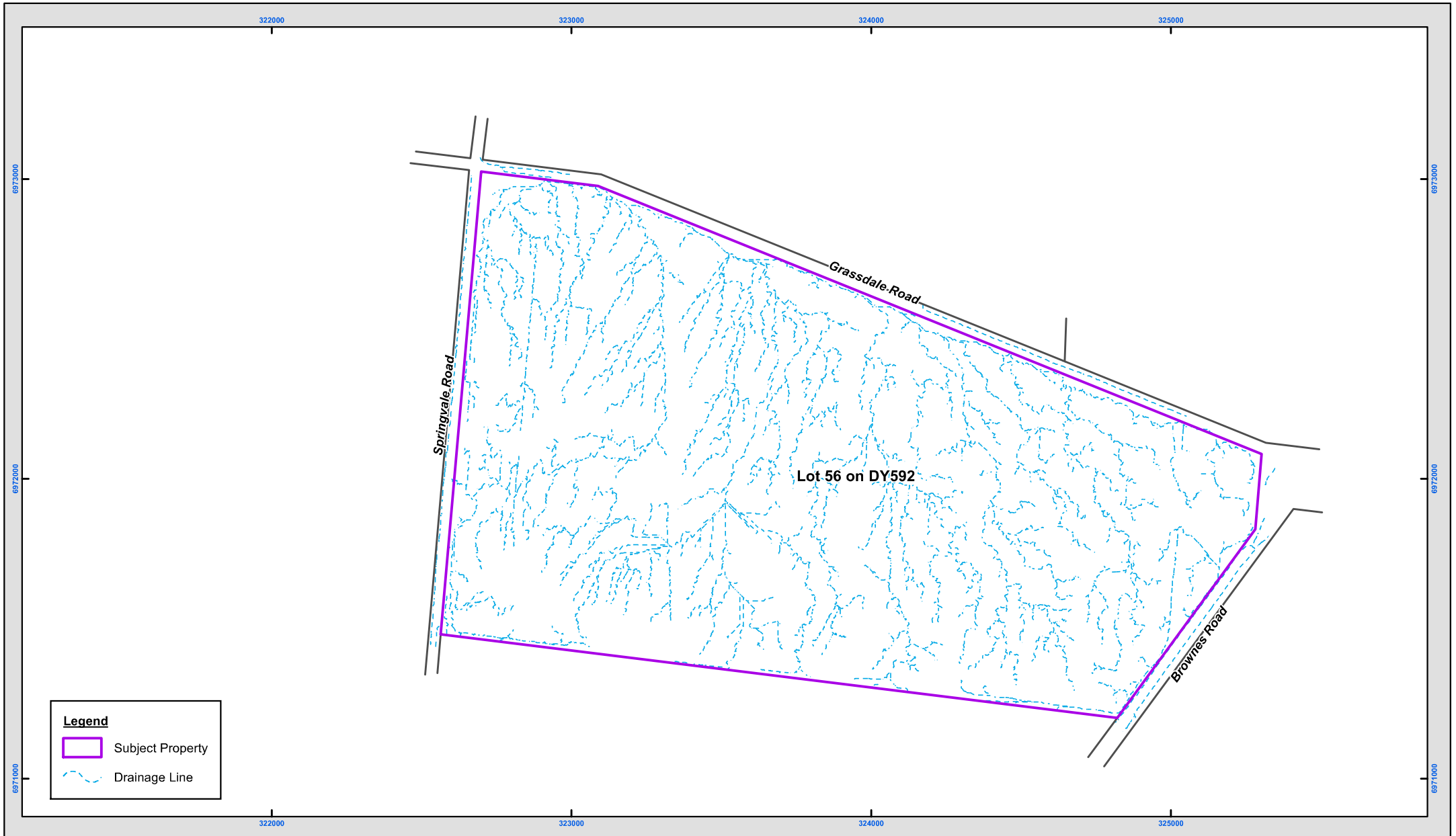

Figure 8 : 2014, Drainage Lines, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

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Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

NOT FOR CONSTRUCTION

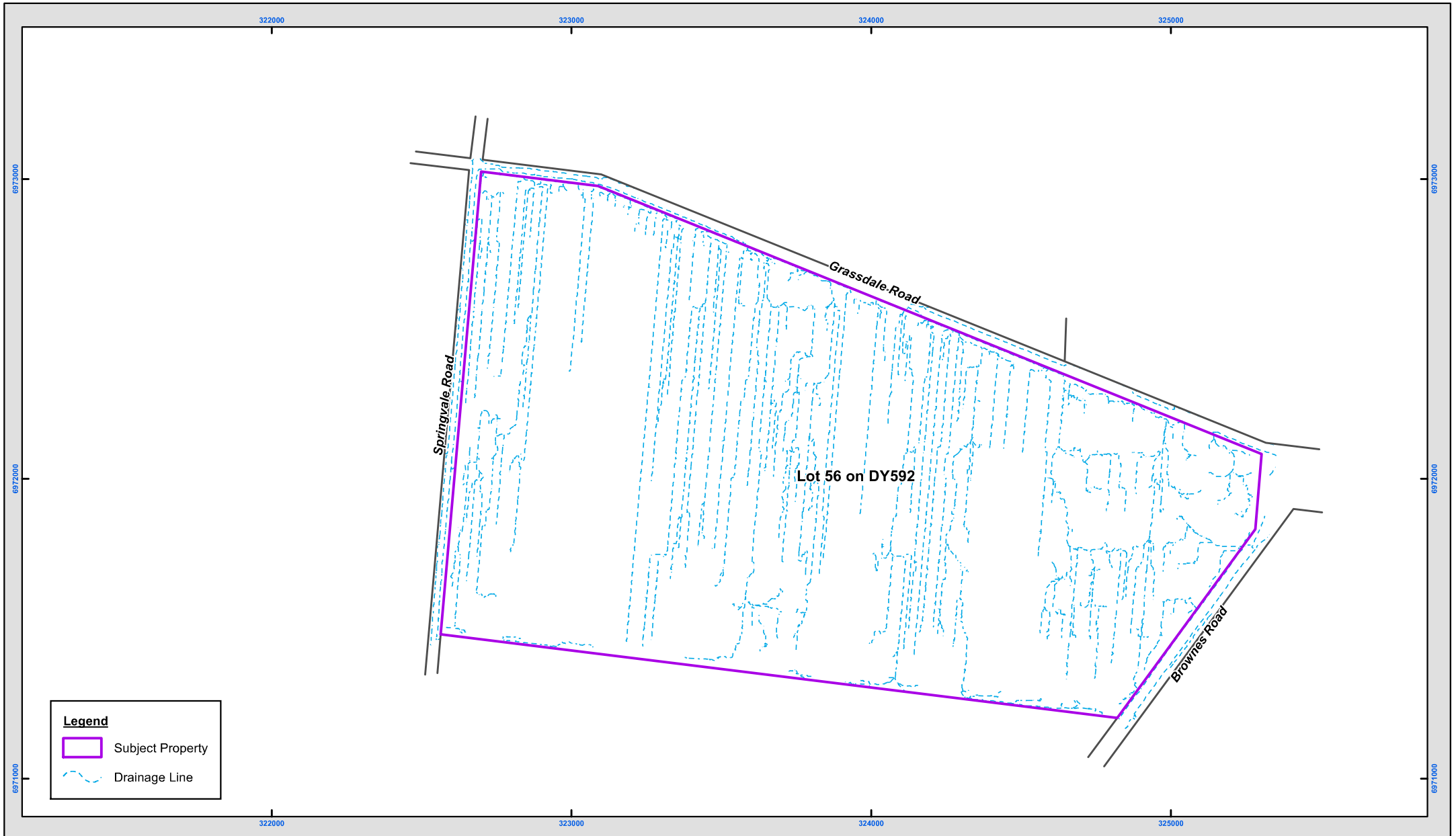

Figure 9 : 2020, Drainage Lines, Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 14/11/2021

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

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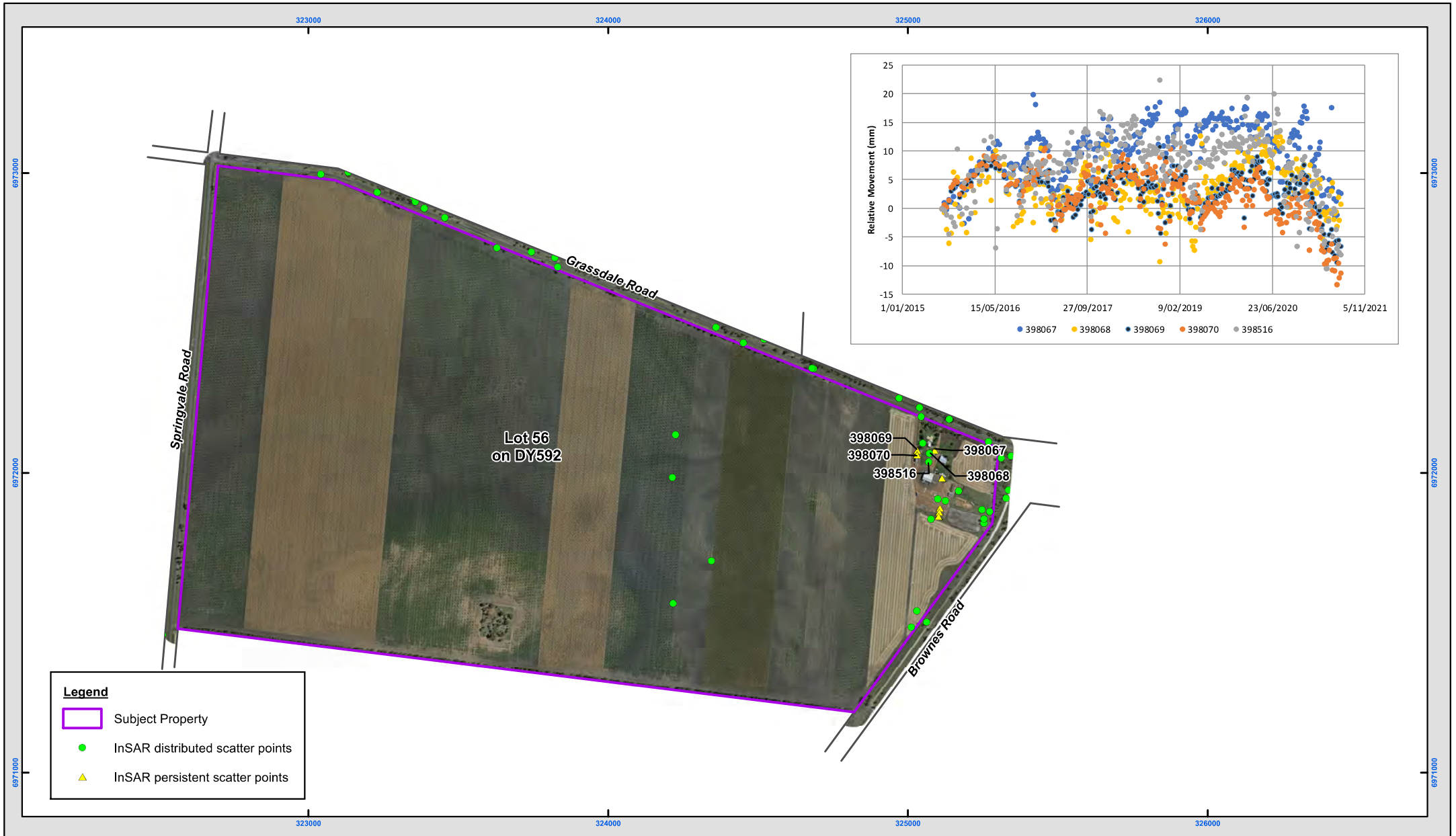

Figure 10 : InSAR persistent and distributed scatter points on Lot on Plan : 56DY592, and time series plot

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/03/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

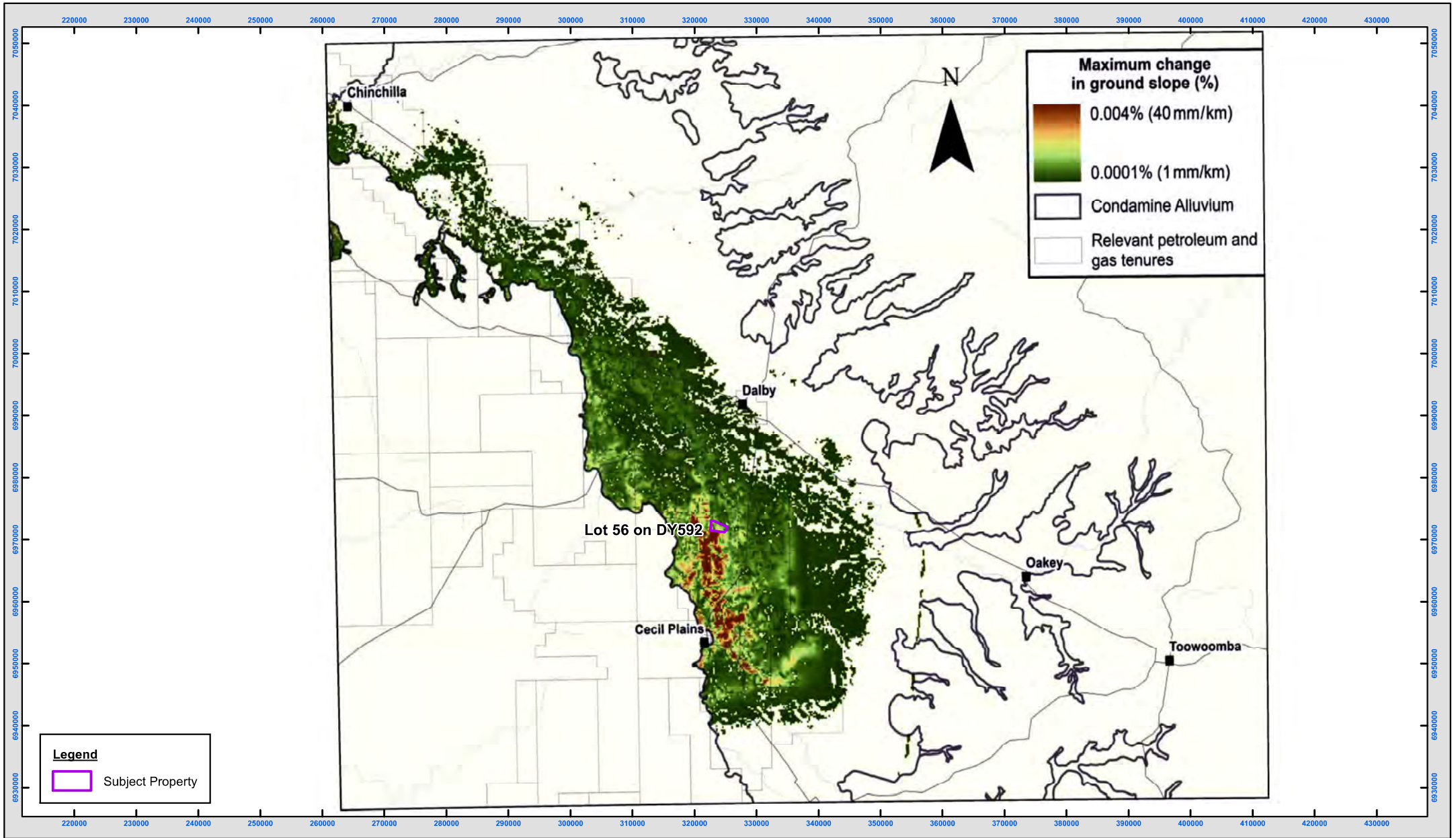

Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lot on Plan : 56DY592

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 11/12/2021

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

Report

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Baseline Report

Surface Elevation Data – 141AG4261

Version	1
Released	13/12/2021

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Contents

List of Figures

1. Purpose

This Report provides the following surface elevation datasets overlaid on lot on plan 141AG4261:

- 2012 Digitial Elevation Model (DEM) (Figure 1),
- 2014 DEM (Figure 2),
- 2020 DEM (Figure 3),
- 2012 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 4),
- 2014 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 5),
- 2020 DEM 0.1 m elevation contours (10m x 10m cells) (Figure 6),
- 2012 DEM drainage lines (Figure 7),
- 2014 DEM drainage lines (Figure 8),
- 2020 DEM drainage lines (Figure 9),
- InSAR persistent and distributed scatter points and time series plot (Figure 10), and
- OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) (Figure 11).

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The InSAR data is provided to Arrow as persistent and distributed scatter points by the InSAR provider, processed using their proprietary SqueeSAR technology. The InSAR data provided commenced in 2015 with the Sentinel satellite system, and provides continual information on regional ground movement using industry leading experts.

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	2012 LIDAR	2014 LIDAR	2020 LIDAR
Company	FUGRO	AAM	AAM
Acquisition Start	16-Jun-12	Nov-14	15-Oct-20
Acquisition End	29-Jul-12	12-Feb-15	6-Nov-20
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Spatial Accuracy (Vt)	0.12m @ 67% CI	0.07m @ 68% CI	0.05m @ 68% CI
Device Name	Leica ALS50-2	Riegl Q1560	Galaxy Prime 424
Half Scan Angle	not reported	29 degrees	25 degrees
Laser Pulse Rate	up to 150 kHz[1]	400 kHz	450 kHz
Laser Scan Frequency	up to 90 Hz[1]	32 Hz	40 Hz
Horizontal Datum	GDA94	GDA94	GDA2020
Map Projection	MGA Zone 56	MGA Zone 56	MGA Zone 56
Vertical Datum	AHD	AHD	AHD
Geoid Model	AusGeoid09	AusGeoid09	Ausgeoid2020

Table 2: InSAR Metadata

	InSAR
Satellite	Sentinel Constellation
Satellite Track	45
Satellite Track Geometry	Descending
Satellite Image Resolution	20m in range and 5m in azimuth
Acquisition Start	4 August 2015
Acquisition End	Ongoing
Acquisitions	320 at date of dataset presented (27 June 2021)
Processing	TreAltamira SqueeSAR
Horizontal Datum	GDA94
Map Projection	MGA Zone 56

[1] These values are based on the range of Leica ALS50-2

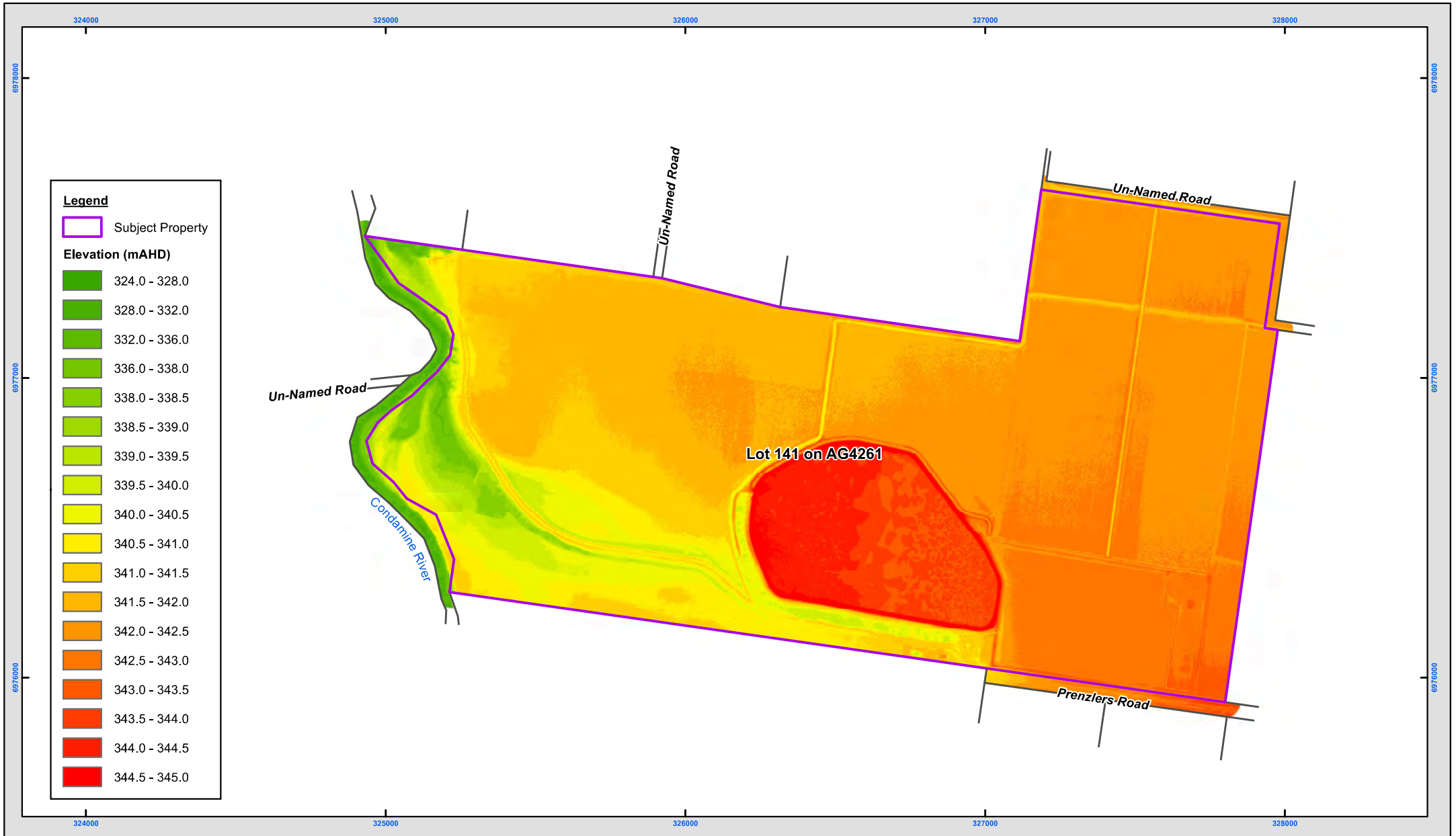


Figure 1 : 2012 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

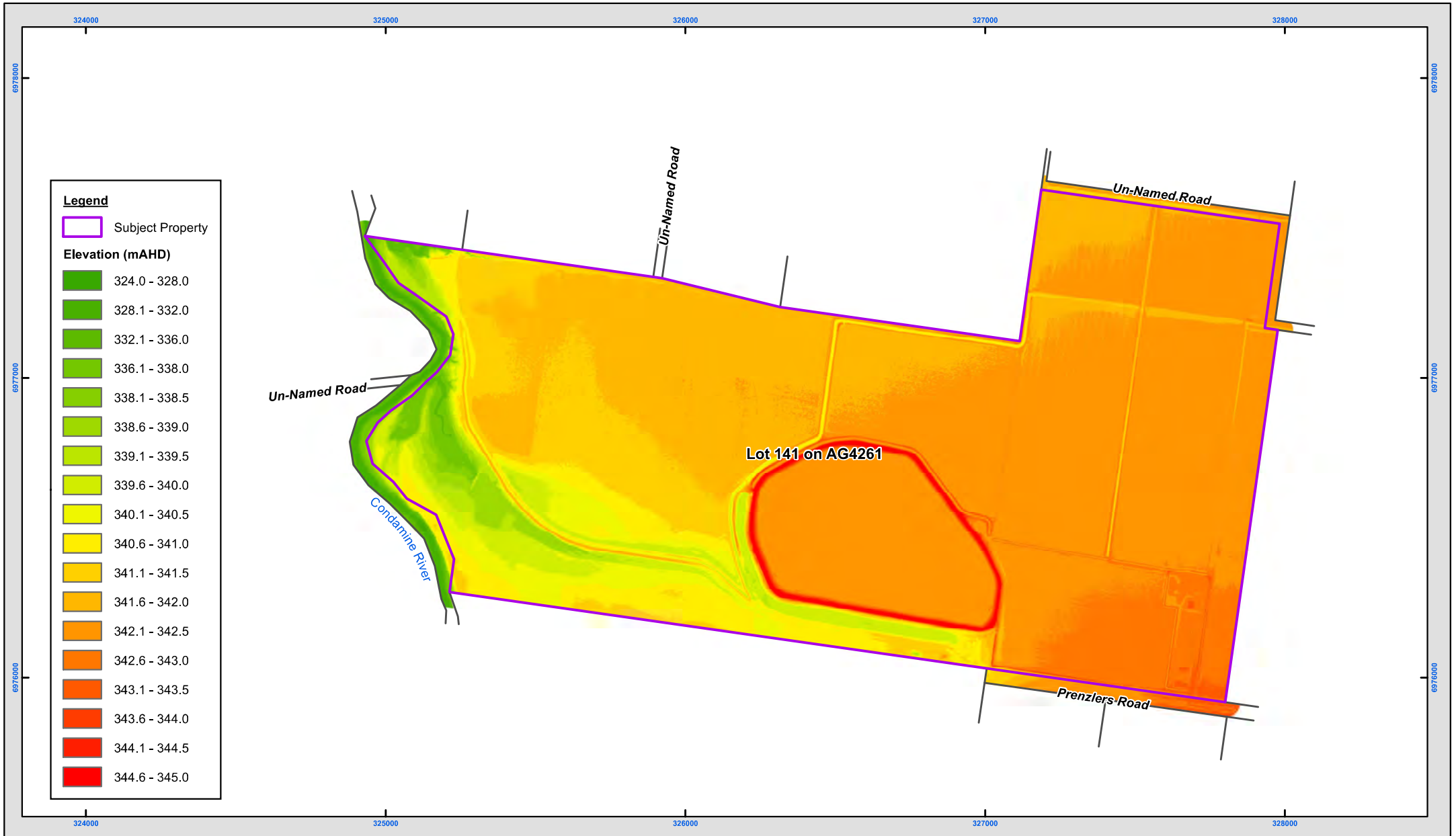


Figure 2 : 2014 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

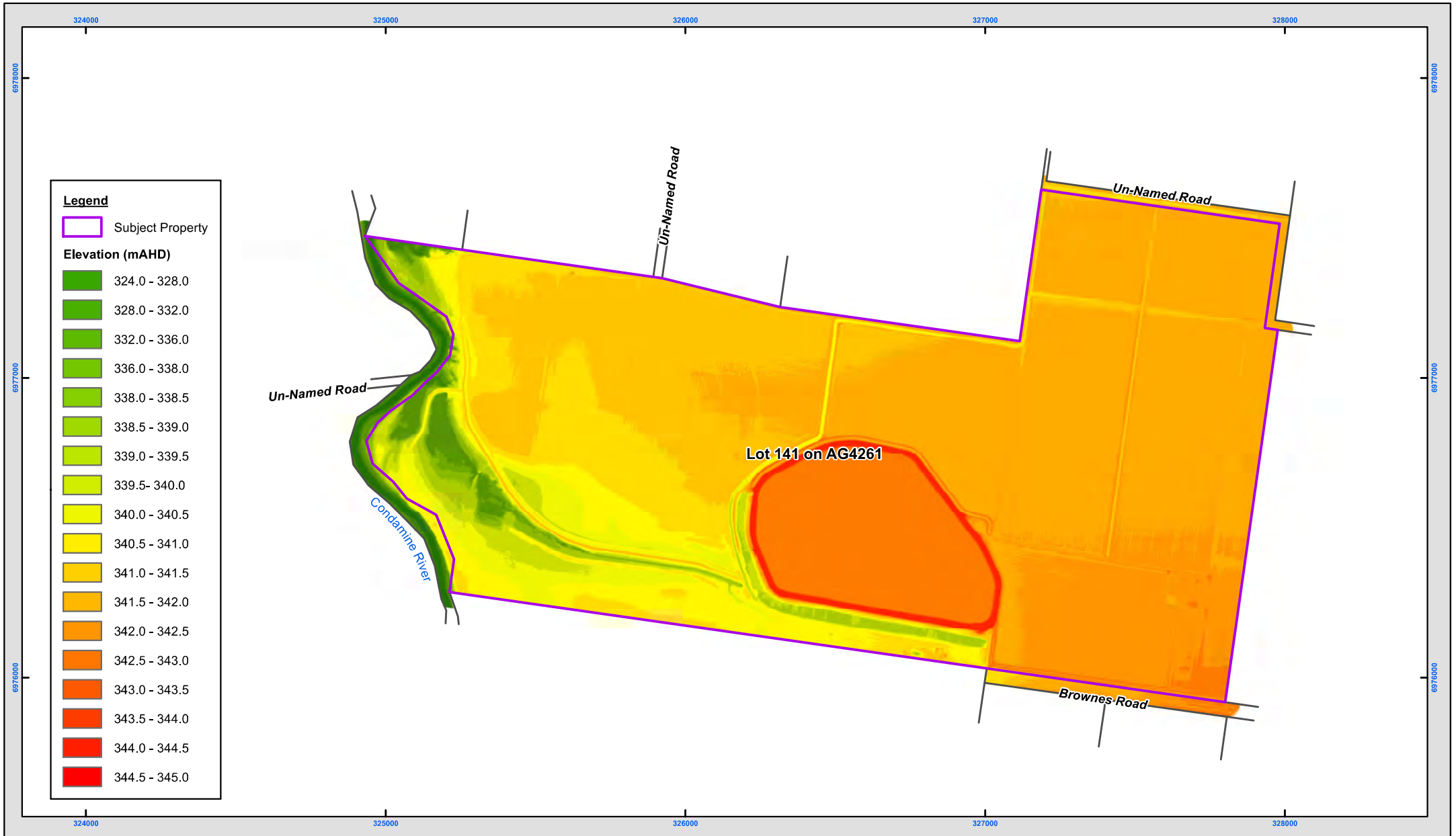


Figure 3 : 2020 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

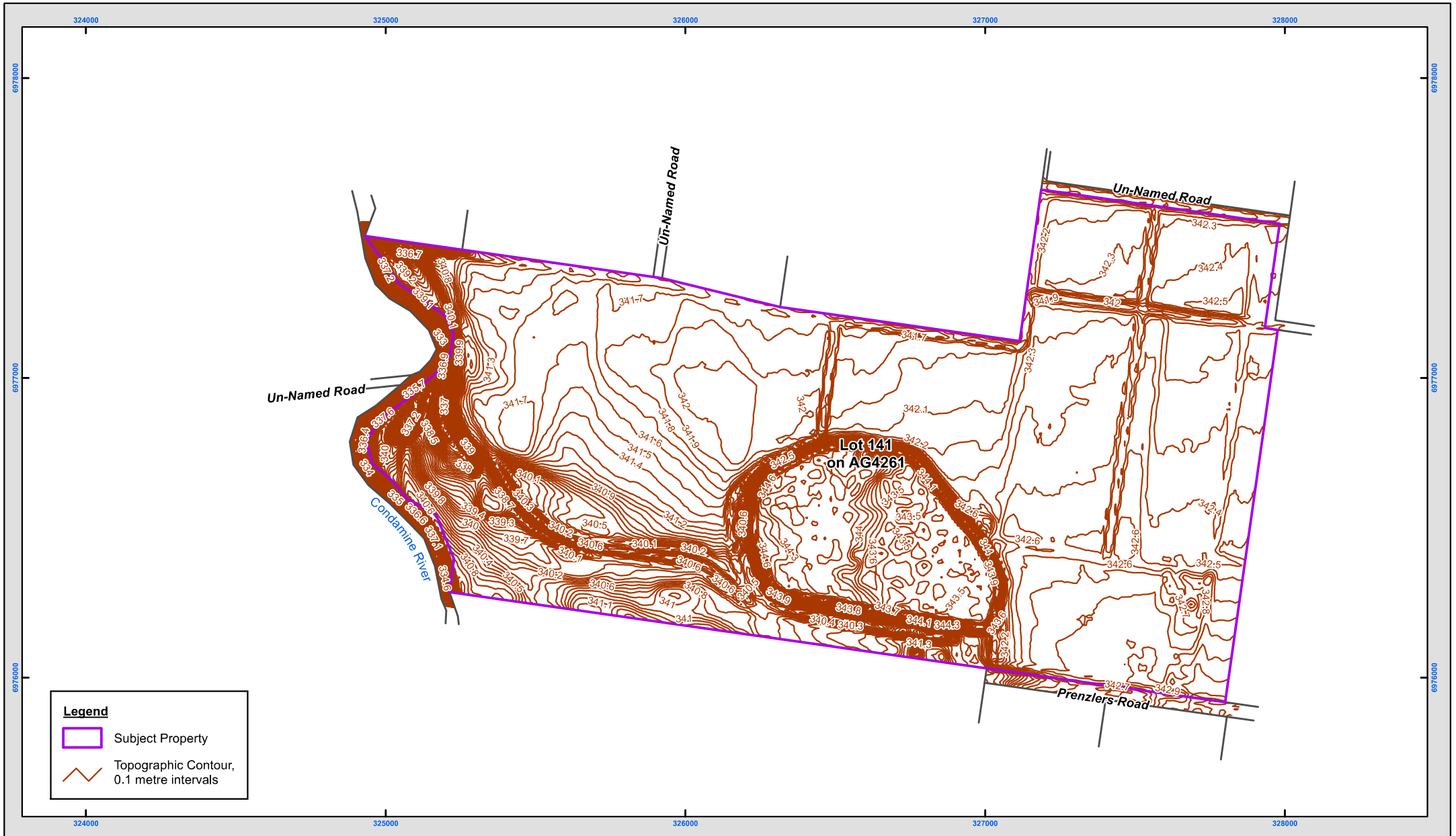


Figure 4 : 0.1m contours (10m x 10m cells) of the 2012 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

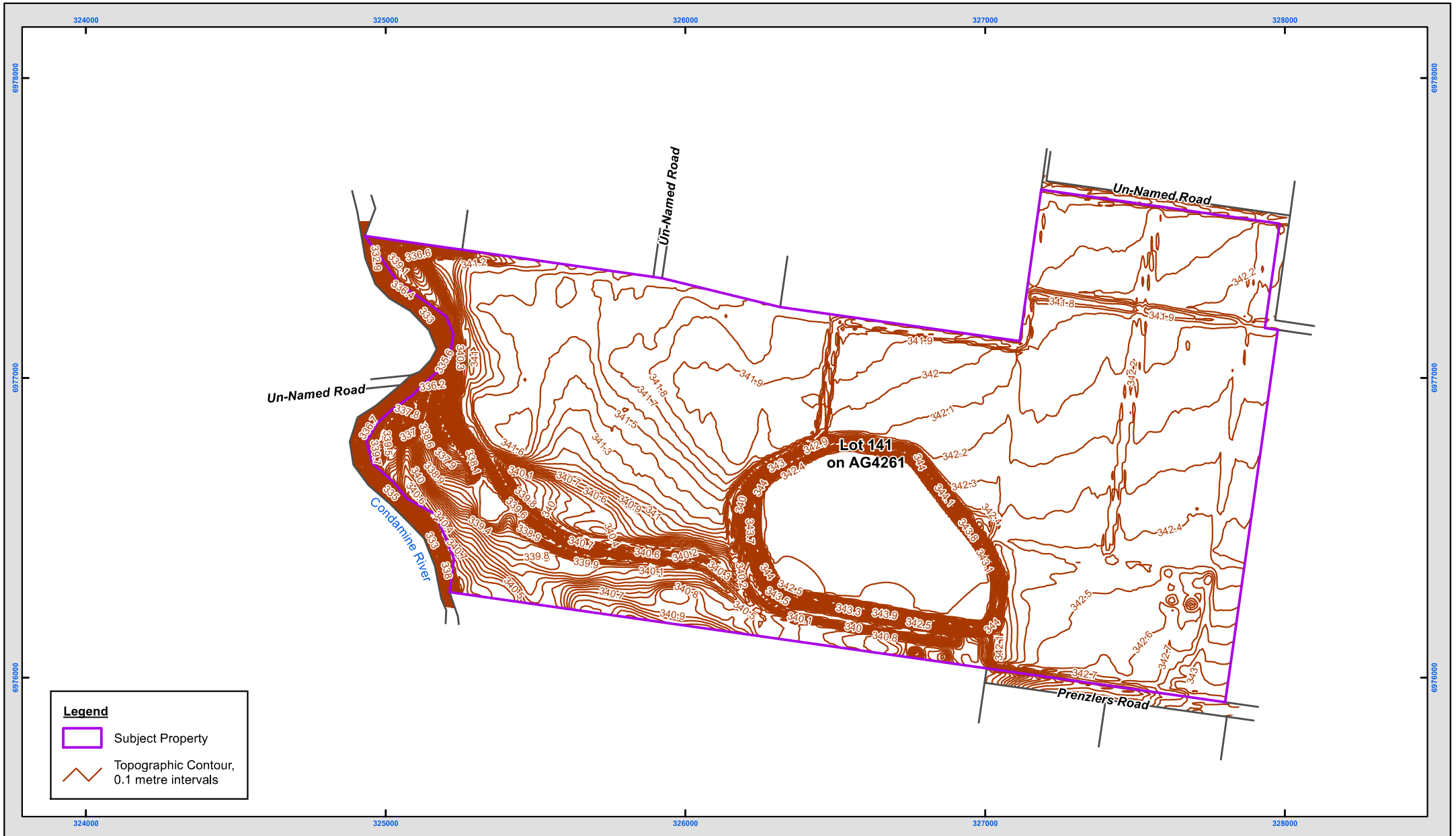


Figure 5 : 0.1m contours (10m x 10m cells) of the 2014 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

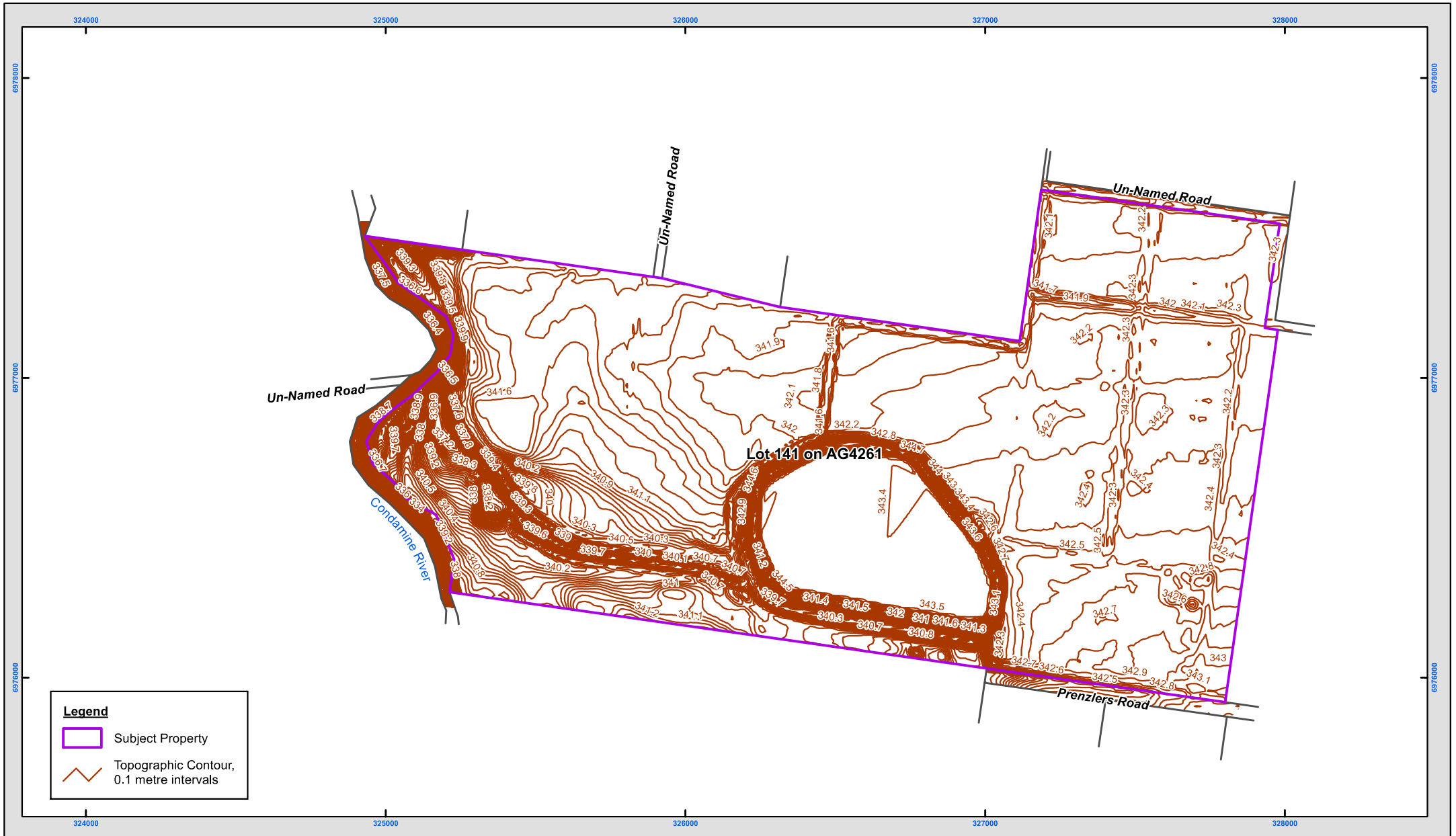


Figure 6 : 0.1m contours (10m x 10m cells) of the 2020 DEM, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 31/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

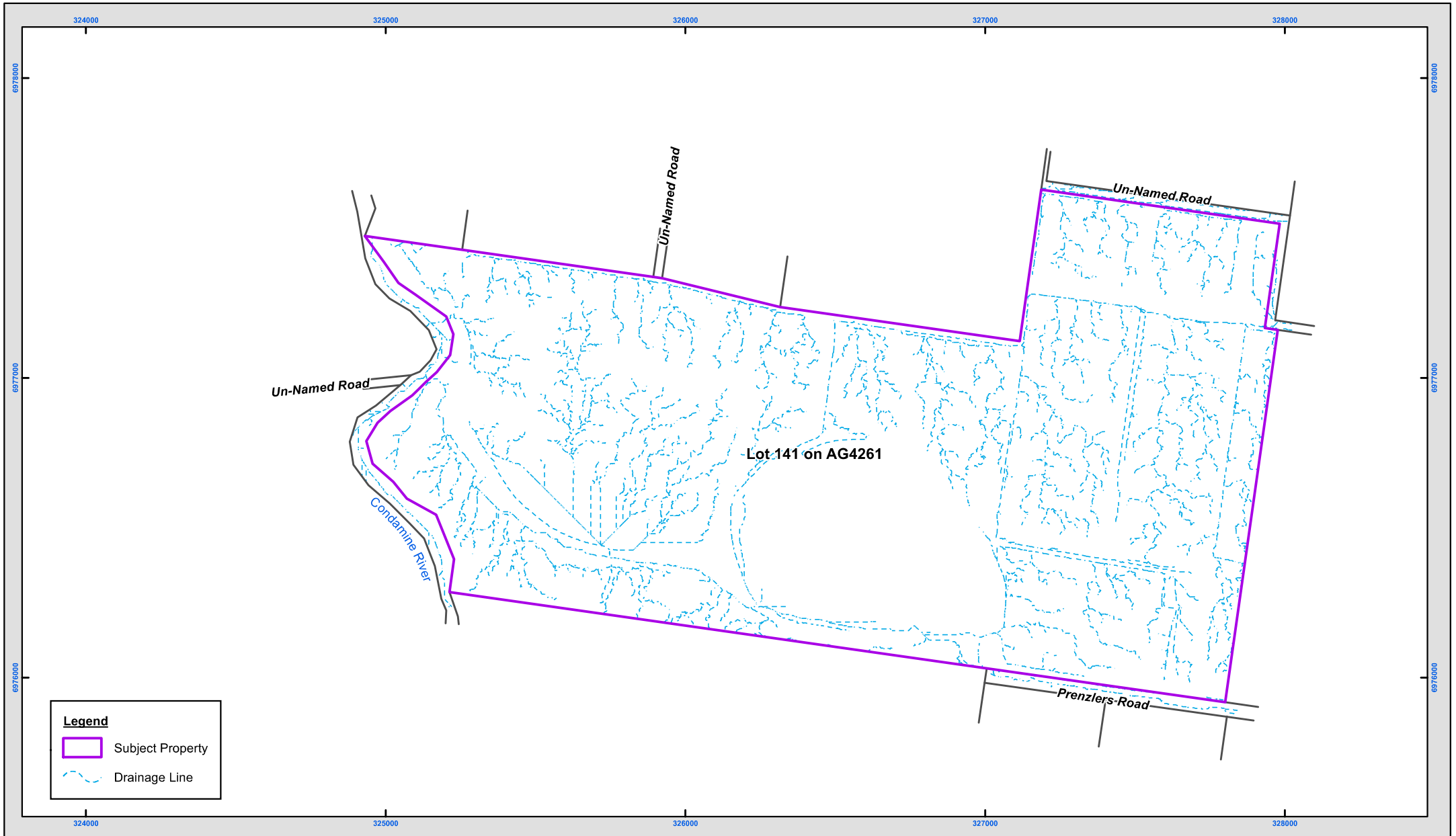


Figure 7 : 2012 DEM, Drainage Lines, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

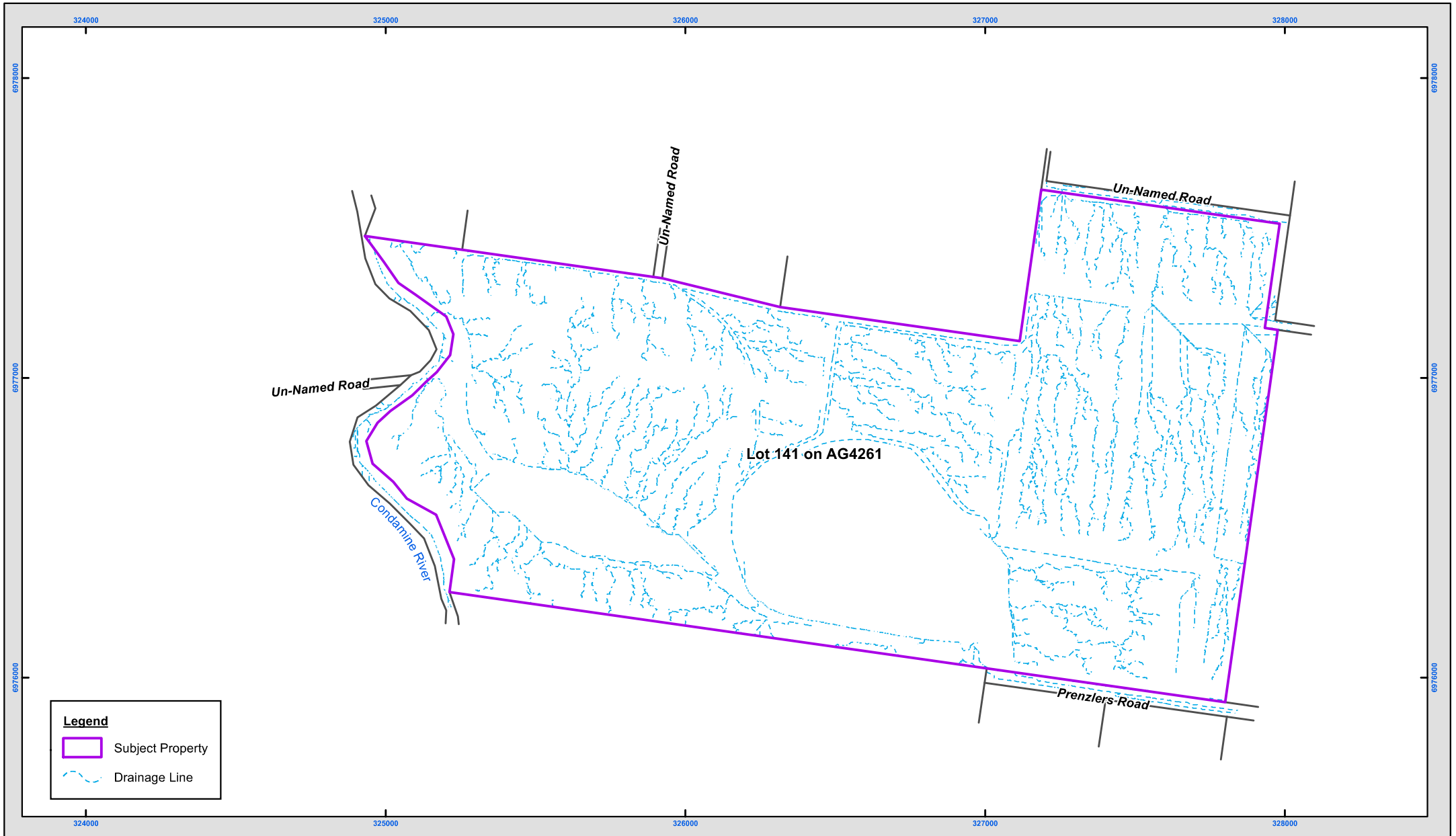


Figure 8 : 2014 DEM, Drainage Lines, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

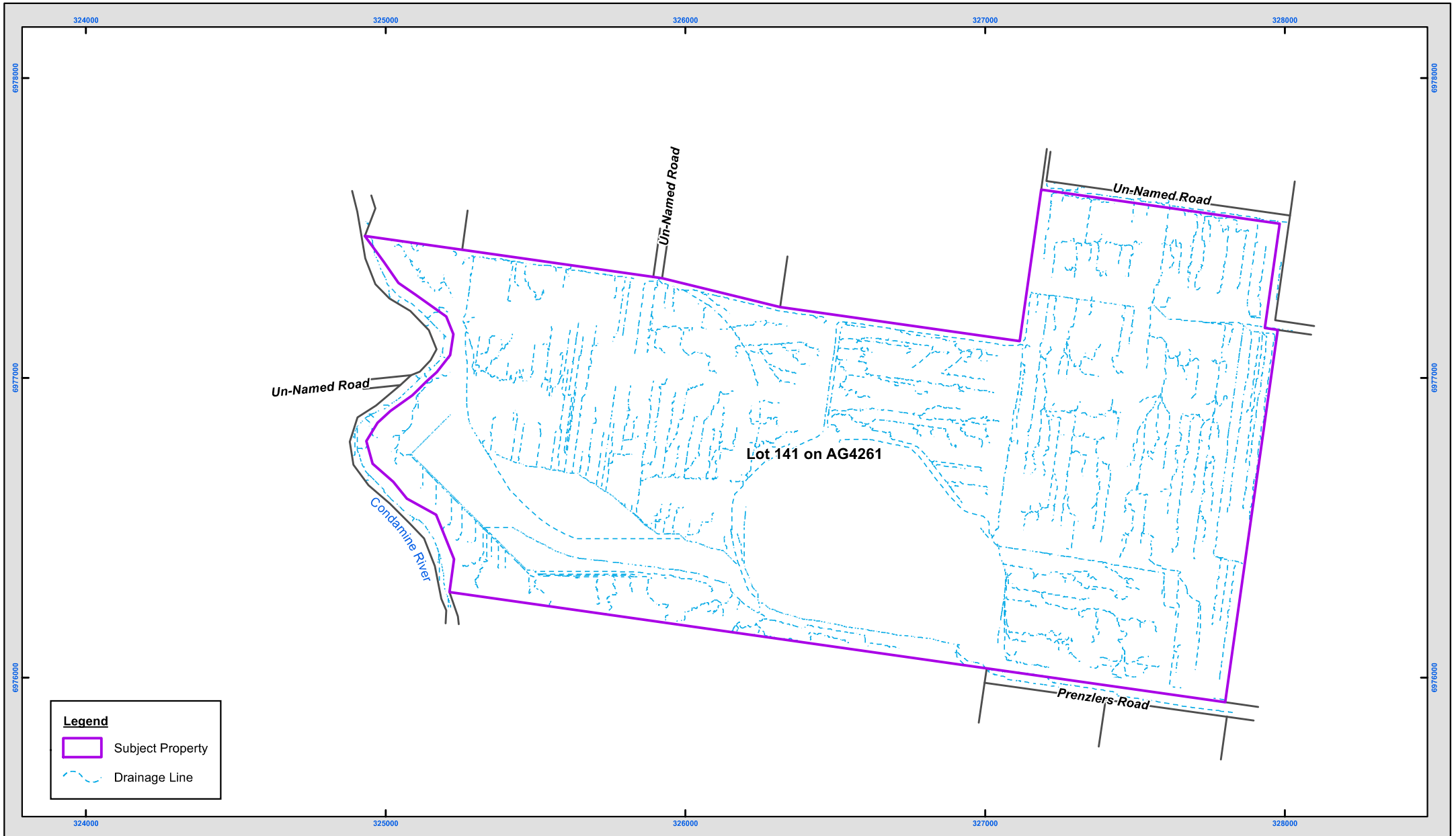


Figure 9 : 2020 DEM, Drainage Lines, Lot on Plan : 141AG4261

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 3/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

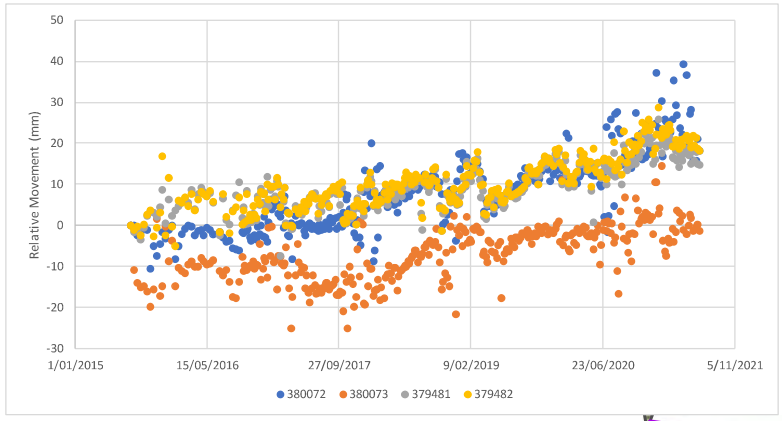


Figure 10 : InSAR persistent and distributed scatter points on Lot on Plan : 141AG4261, and time series plot

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 31/01/2022

Author: Arrow Energy

0.35 0.175 0 0.35 Kilometres

Scale: 1:12,000 @ A3

Coordinate System: GDA2020 MGA Zone 56

NOT FOR CONSTRUCTION

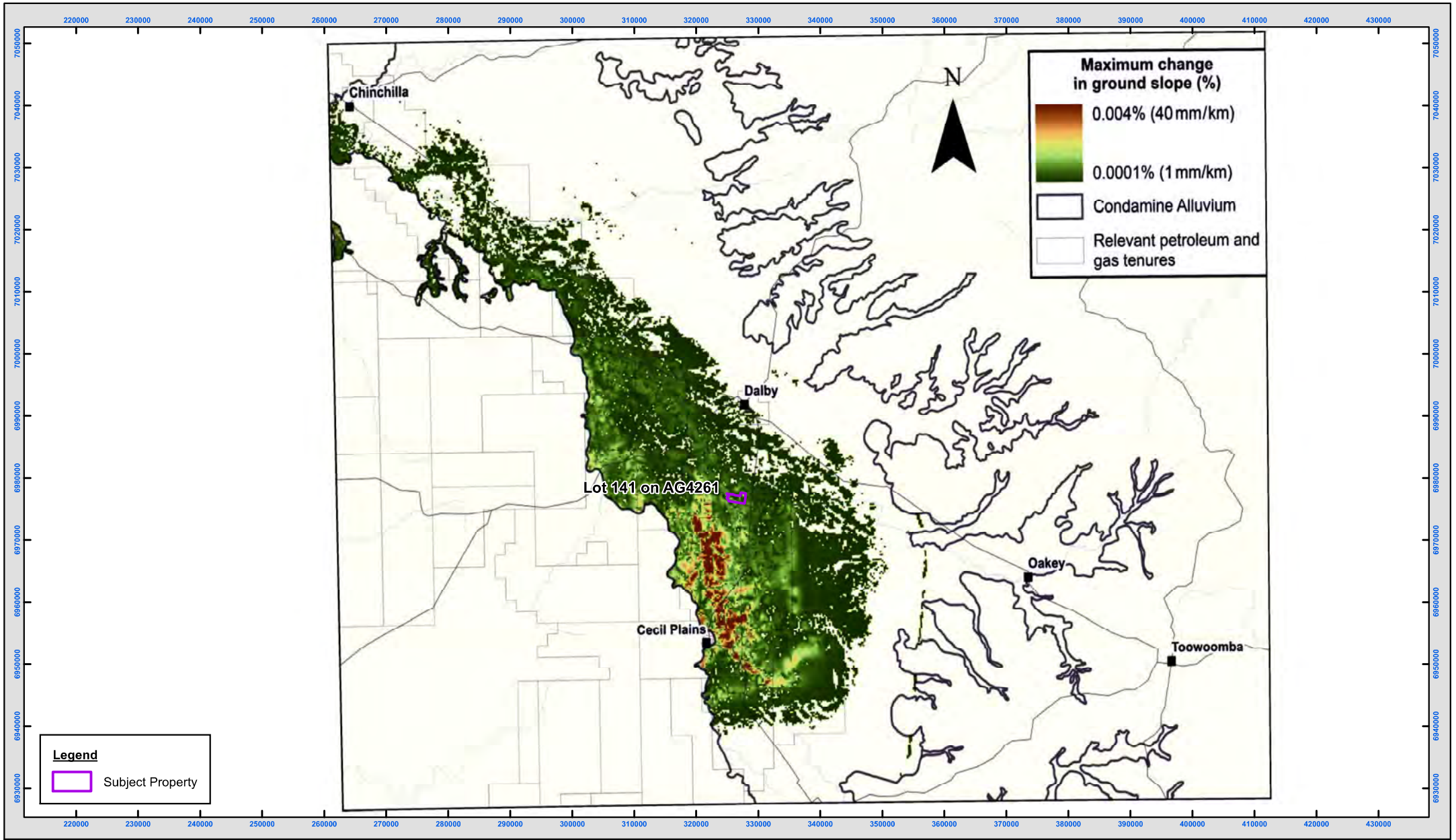


Figure 11 : OGIA predicted maximum change in ground slope from CSG-induced subsidence (source: draft 2021 UWIR for the Surat CMA, OGIA 2021) and Lot on Plan : 141AG4261.

Source: Arrow Energy Pty Ltd
Geosciences Australia
Dept. Natural Resources and Mines

Date: 8/12/2021

Author: Arrow Energy

10 5 0 10 Kilometres

Scale: 1:580,000 @ A3

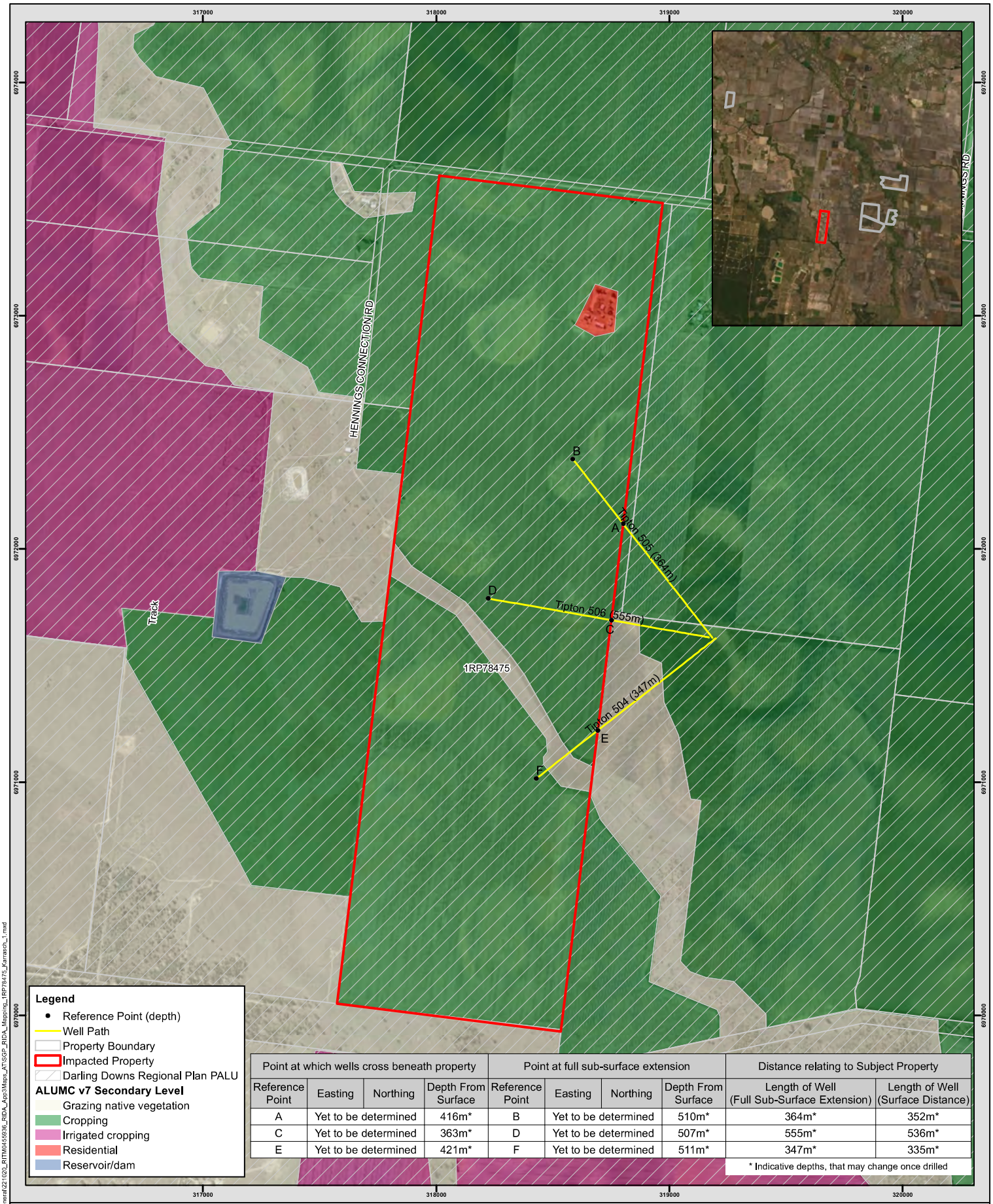
Coordinate System: GDA2020 MGA Zone 56

The dimensions, areas, number of lots, size & location of corridor information are approximate only and may vary.

NOT FOR CONSTRUCTION

Appendix F – Updated Appendix 3 - Australian Land Use Mapping (ALUM) classes of PALUs detailed in the Darling Downs Regional Plan.

ARROW ENERGY - SURAT BASIN GAS PROJECT



Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		416m*	B	Yet to be determined		510m*	364m*	352m*
C	Yet to be determined		363m*	D	Yet to be determined		507m*	555m*	536m*
E	Yet to be determined		421m*	F	Yet to be determined		511m*	347m*	335m*

* Indicative depths, that may change once drilled

RIDA Application

Lotplan: 1RP78475

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 25/10/2022
Issued To: A Hall
Author: awolhuter

0 100 200 400 600 800 1,000 Metres

Scale 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_App3Maps_ATS&SP_RIDA_Mapping_1RP78475_Karraech_1.mxd

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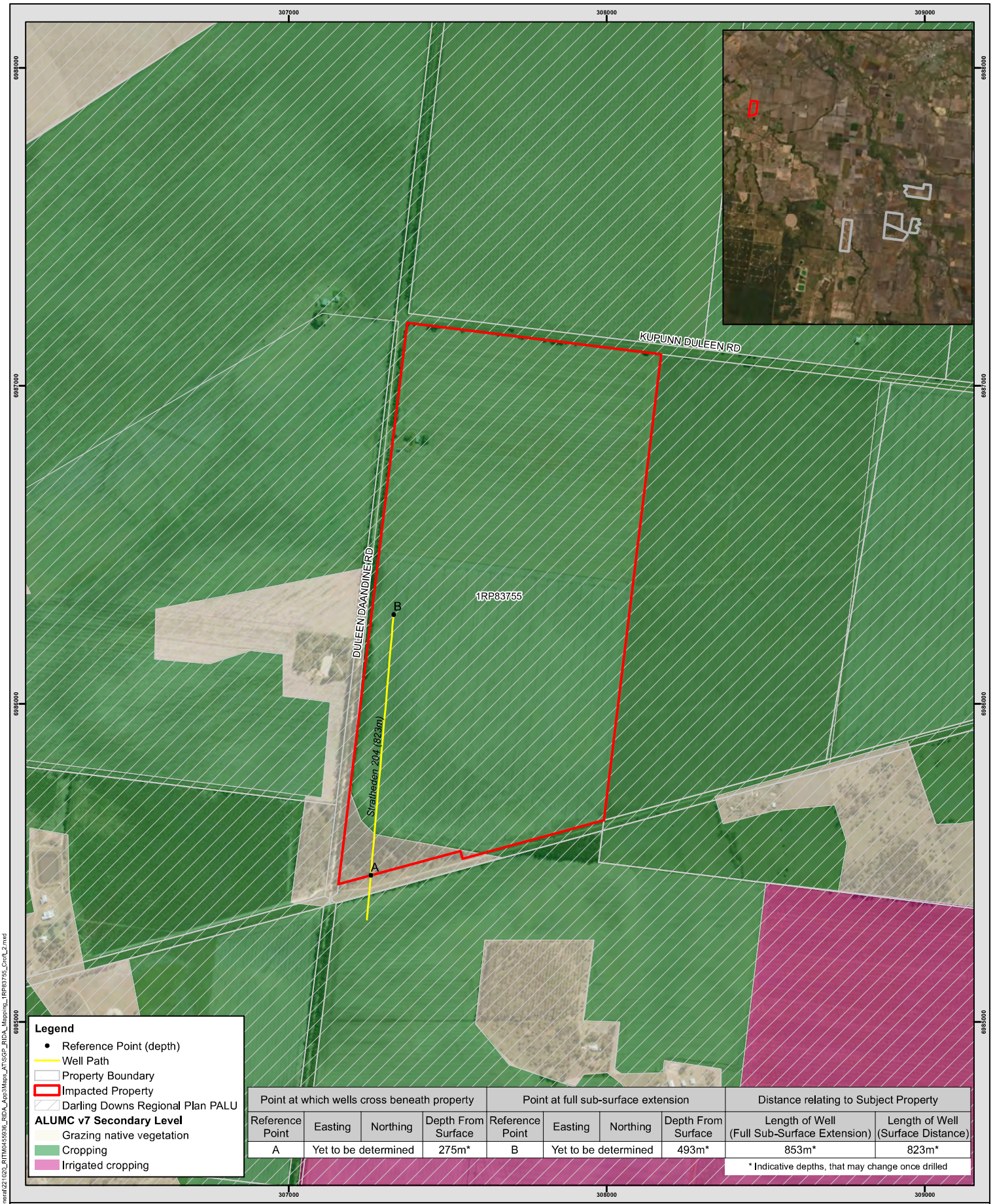


Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		275m*	B	Yet to be determined		493m*	853m*	823m*

* Indicative depths, that may change once drilled

RIDA Application

Lotplan: 1RP83755

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 25/10/2022
Issued To: A Hall
Author: awolhuter

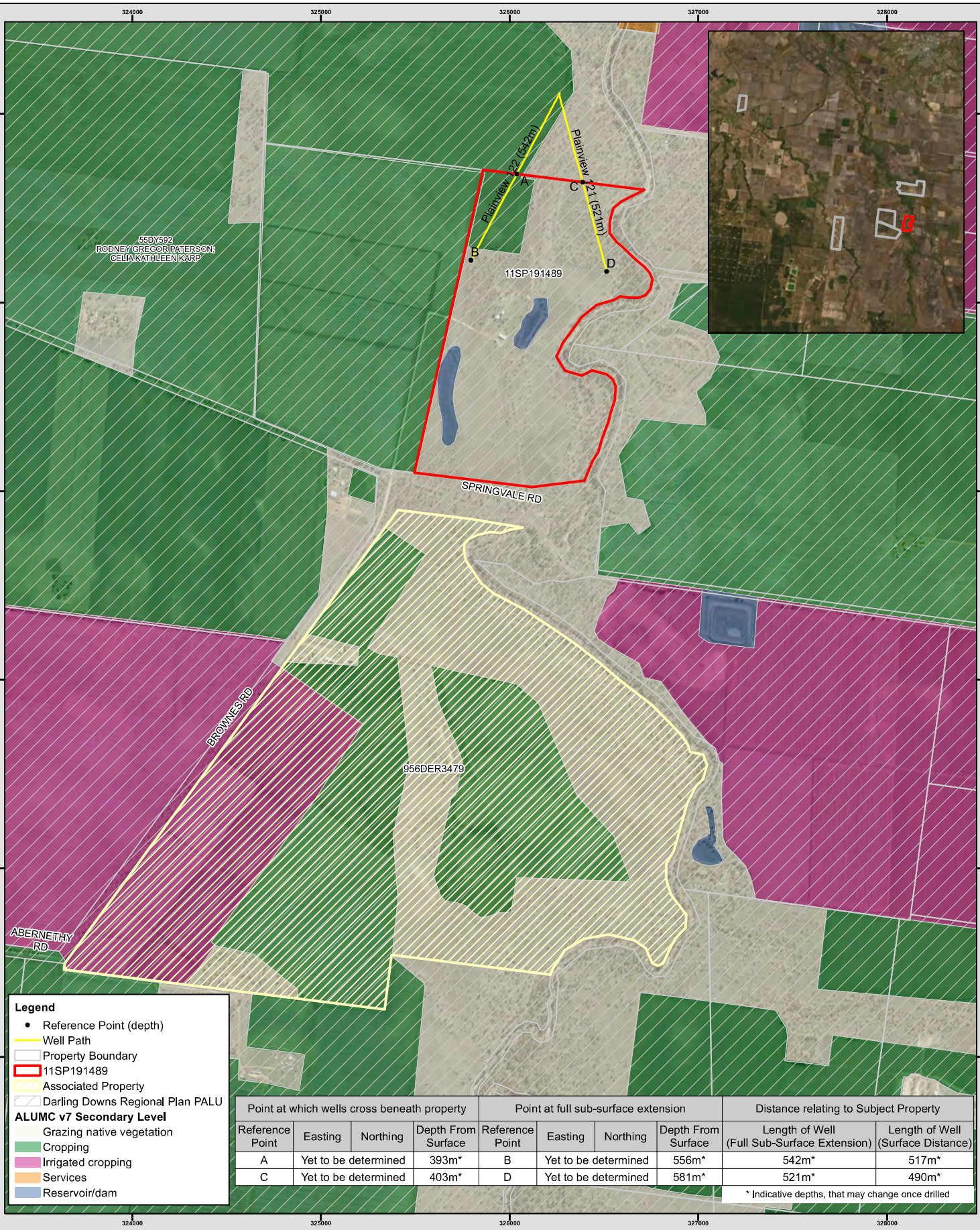
0 100 200 400 600 800 1,000 Metres

Scale 1:11,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_Aps3Maps_ATSGP_RIDA_Mapping_1RP83755_CnrFt_2.mxd



Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		393m*	B	Yet to be determined		556m*	542m*	517m*
C	Yet to be determined		403m*	D	Yet to be determined		581m*	521m*	490m*

* Indicative depths, that may change once drilled

RIDA Application

Lotplan: 11SP191489

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 25/10/2022
Issued To: A Hall
Author: awolhuter

0 130 260 520 780 1,040 1,300 Metres

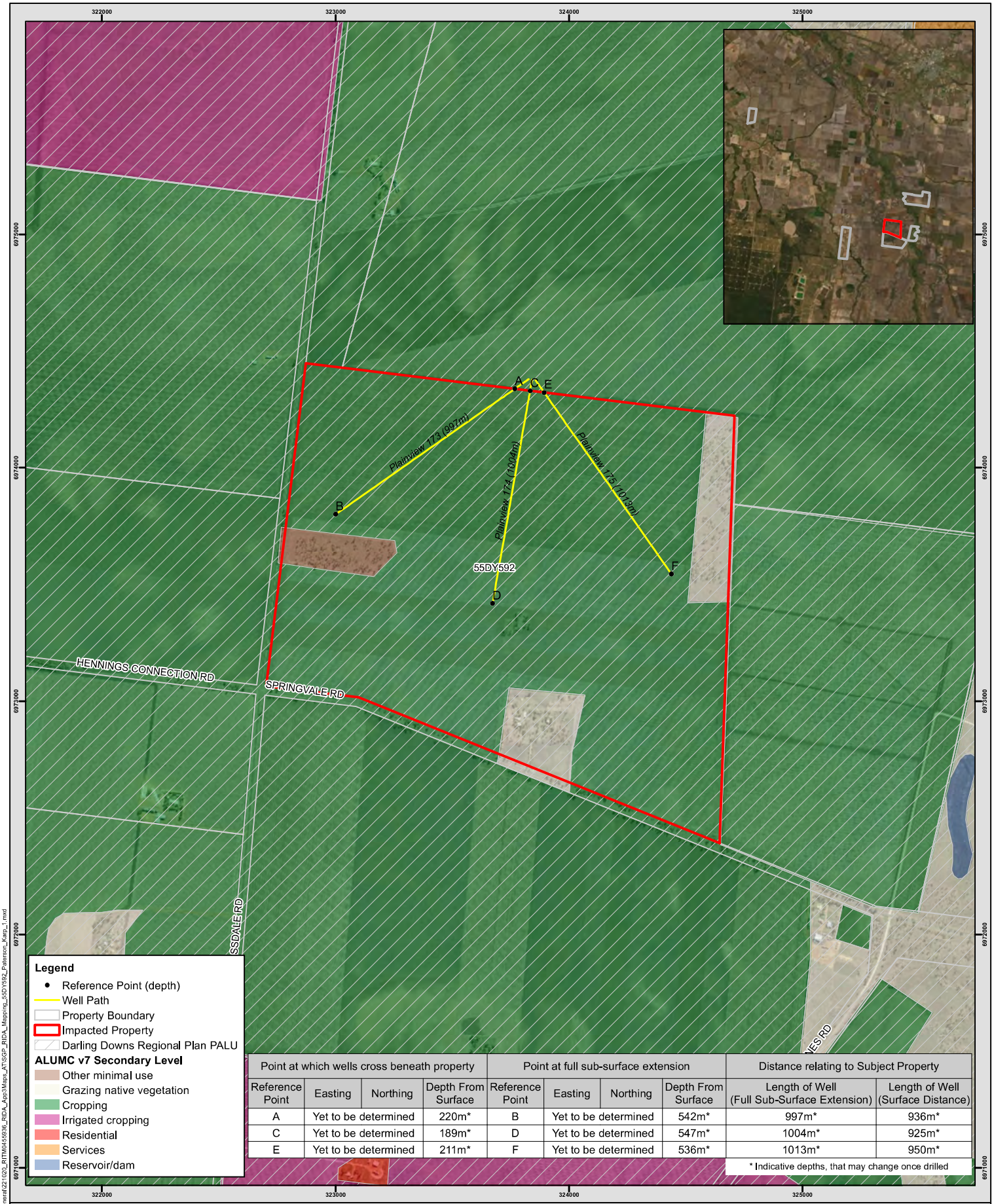
Scale 1:19,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_Asp3Maps_AT\SGP_RIDA_Mapping_11SP191489_Browne_1.mxd



Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		220m*	B	Yet to be determined		542m*	997m*	936m*
C	Yet to be determined		189m*	D	Yet to be determined		547m*	1004m*	925m*
E	Yet to be determined		211m*	F	Yet to be determined		536m*	1013m*	950m*

* Indicative depths, that may change once drilled

RIDA Application

Lotplan: 55DY592

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 24/10/2022
Issued To: A Hall
Author: awolhuter

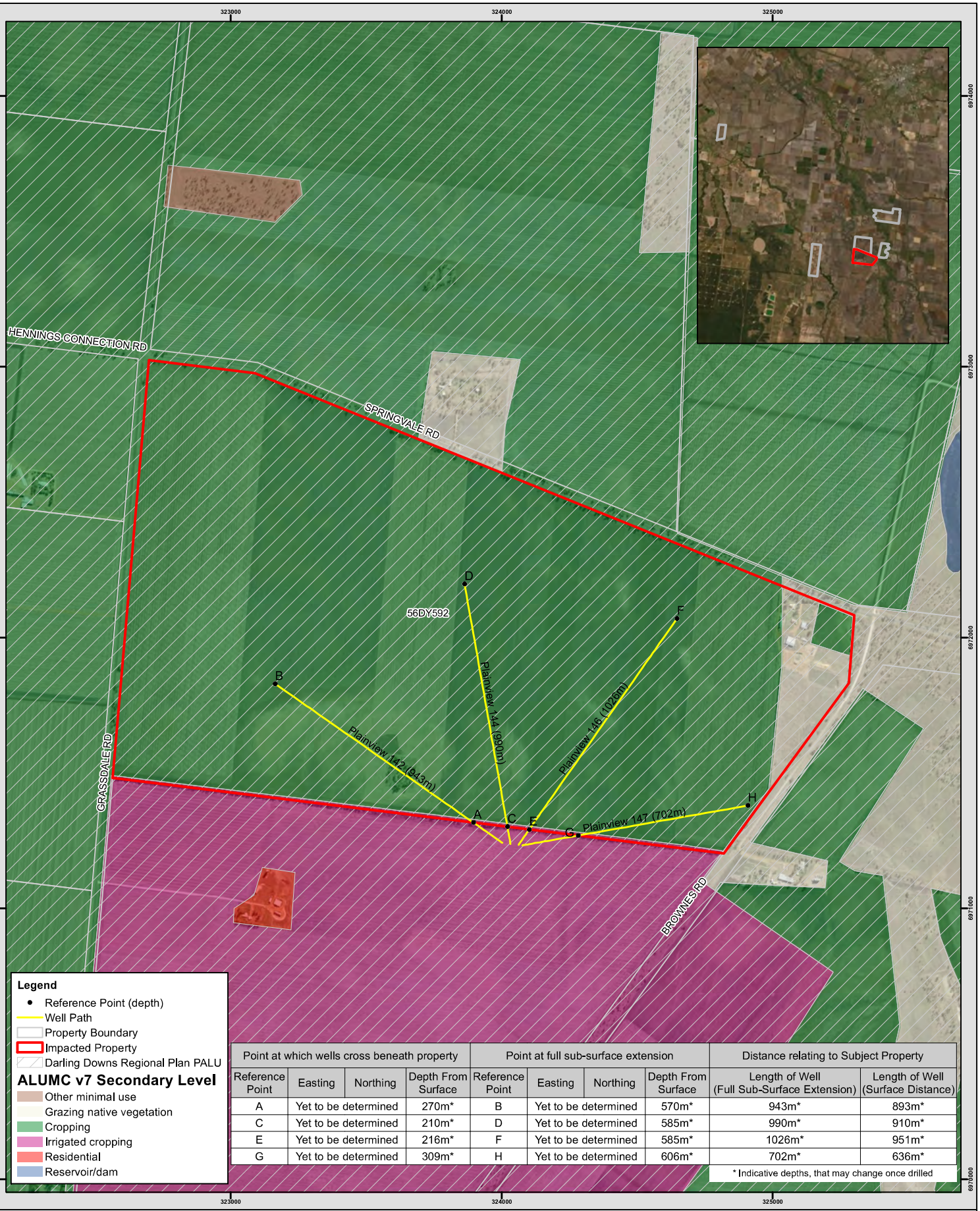
0 100 200 400 600 800 1,000 Metres

Scale 1:15,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.



Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		270m*	B	Yet to be determined		570m*	943m*	893m*
C	Yet to be determined		210m*	D	Yet to be determined		585m*	990m*	910m*
E	Yet to be determined		216m*	F	Yet to be determined		585m*	1026m*	951m*
G	Yet to be determined		309m*	H	Yet to be determined		606m*	702m*	636m*

*Indicative depths, that may change once drilled

RIDA Application

Lotplan: 56DY592

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 25/10/2022
Issued To: A Hall
Author: awolhuter

0 100 200 400 600 800 1,000 Metres

Scale 1:13,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

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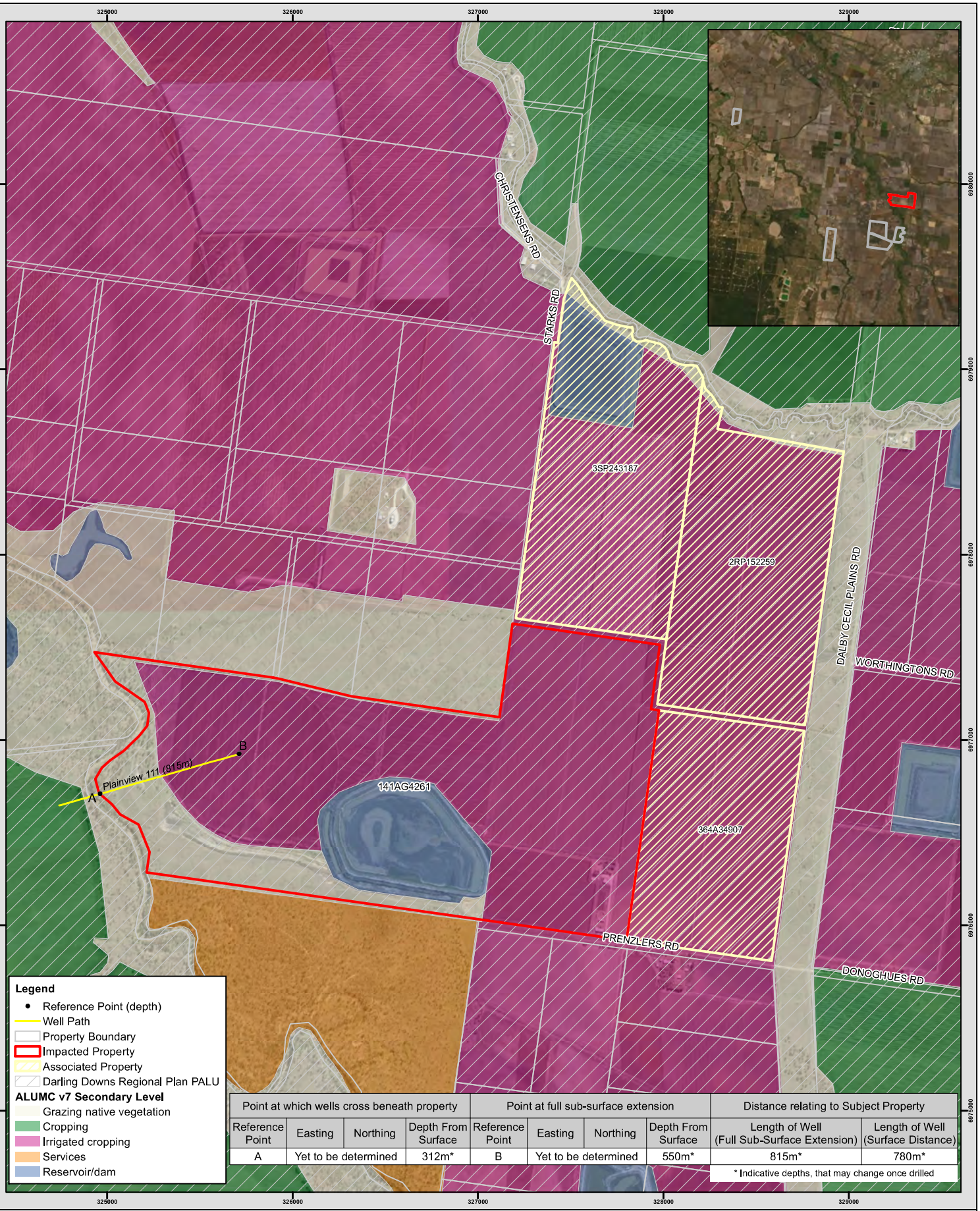


Point at which wells cross beneath property				Point at full sub-surface extension				Distance relating to Subject Property	
Reference Point	Easting	Northing	Depth From Surface	Reference Point	Easting	Northing	Depth From Surface	Length of Well (Full Sub-Surface Extension)	Length of Well (Surface Distance)
A	Yet to be determined		312m*	B	Yet to be determined		550m*	815m*	780m*

* Indicative depths, that may change once drilled

RIDA Application

Lotplan: 141AG4261

Source: Arrow Energy Pty Ltd, Geoscience Australia, DNRME
Date: 24/10/2022
Issued To: A Hall
Author: awolhuter

Metres
0 100 200 400 600 800 1,000

Scale 1:19,000 @ A3
Coordinate System: GDA 1994 MGA Zone 56

N

Note: The dimensions, areas, number of lots, size and location of corridor information are approximate only and may vary.

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_Aug23Maps_ATSGP_RIDA_Mapping_141AG4261_Breza_1.mxd

Appendix G – Updated Appendix 4 - Australian Land Use Mapping (ALUM) classes of PALUs detailed in the Darling Downs Regional Plan.

Appendix G - Updated Appendix 4 - Australian Land Use Mapping (ALUM) classes of PALUs detailed in the Darling Downs Regional Plan.

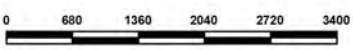
Land Use

Queensland Land Use Mapping Program

Legend

ALUM v8 Secondary level

- Selected Lot and Plan
- Other minimal use
- Grazing native vegetation
- Cropping
- Irrigated cropping
- Residential and farm infrastructure
- Services
- Lake
- Reservoir/dam
- Freeways / motorways; Highways
- Secondary roads; Streets



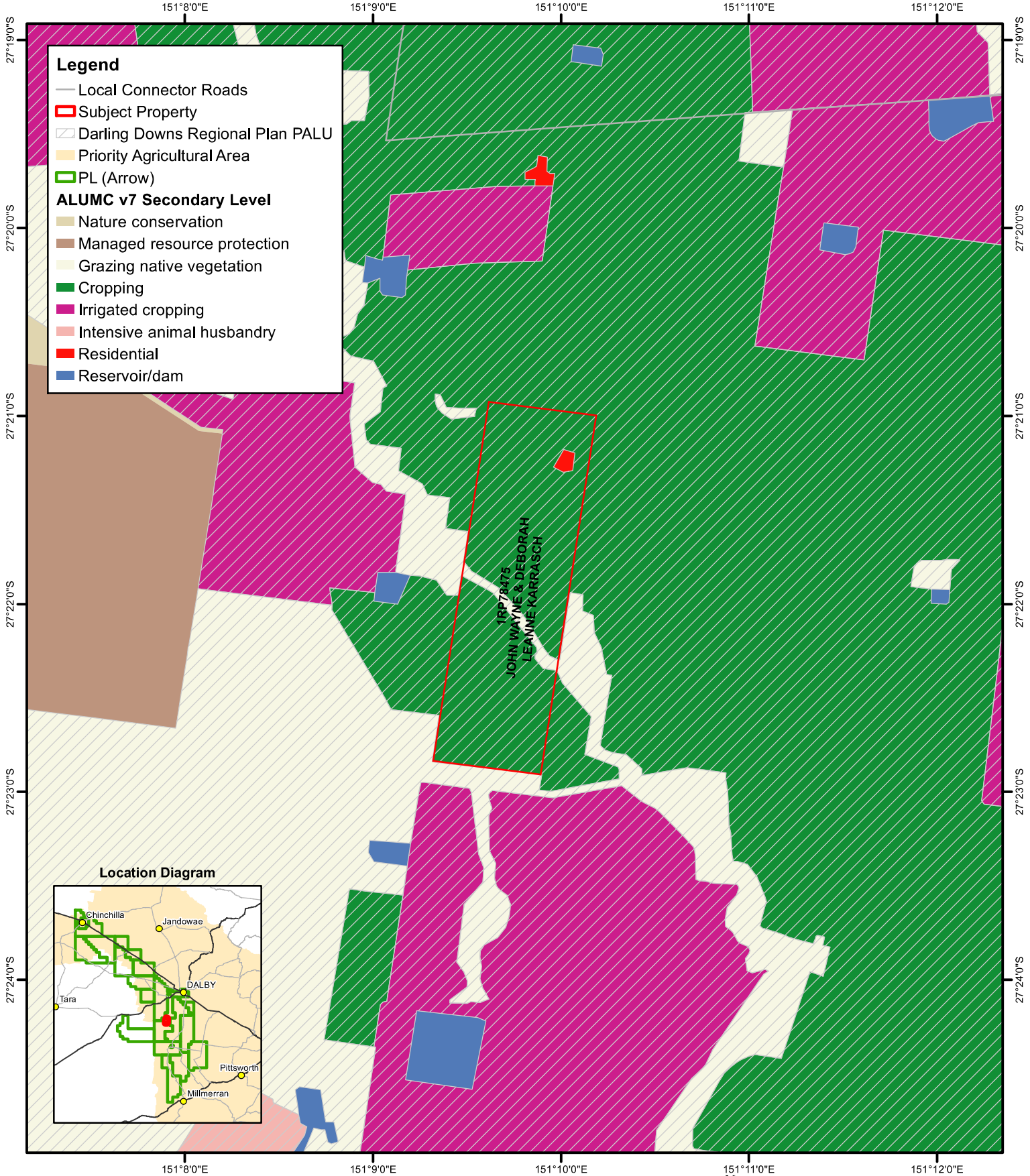
This product is projected into GDA 1994 Queensland Albers

The land use dataset is a product of the Queensland Land use Mapping Program (QLUMP), at a nominal scale of 1:50,000. The layer is a polygon dataset with each feature having attributes describing land use . It presents the most current land use information available in Queensland.

Land use is classified according to the Australian Land Use and Management Classification (ALUMC) Version 8, October 2016. Primary and secondary levels relate to land use (i.e. the principal use of the land in terms of the objectives of the land manager), the tertiary level further discriminate land use, eg. commodity/intensity. Where required and possible, attribution is performed to tertiary level. QLUMP maps the land use classes of sugar and cotton consistently to tertiary level. The minimum attribution level for land use mapping in Queensland is secondary land use, as presented in this map.

Refer to the contact position for additional information regarding source data. Further information relating to land use mapping can be found at http://www.qld.gov.au/environment/land/vegetation/mapping/qlump/ and http://www.agriculture.gov.au/abares/aclump/land-use/

While every care is taken to ensure the accuracy of this information, the Department of Environment and Science makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaims all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which might be incurred as a result of the information being inaccurate or incomplete in any way and for any reason.



This dataset is a digital land use map of the Condamine NRM region, Queensland. As nearly as possible it shows land use in 2012. The dataset is a product of the Queensland Land Use Mapping Program (QLUMP) and was produced by the Queensland Government. The dataset comprises an ESRI vector geodatabase at a nominal scale of 1:50,000. The layer is a polygon dataset with each class having attributes describing land use. Land use is classified according to the Australian Land Use and Management Classification (ALUMC) Version 7, May 2010.
In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws.

Meters 0 200 400 800 1200 1600 2000

N

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it.

Note: The information shown on this map is a copyright of Arrow Energy Limited and, where applicable, its affiliates and co-venturers.

Rev	Date	Revision Description	Orig	Chk	Eng	QA	App
1	21.10.22	DDRP PALU areas added	AW	XX	XX	AT	AT
0	21.04.22	First issue	AW	XX	XX	AH	AH

arrow energy
go further

Scale @ A4: 1:50,000
Coordinate System: GCS GDA 1994

Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
Geosciences Australia
Qld Gov.

Land Use

Queensland Land Use Mapping Program

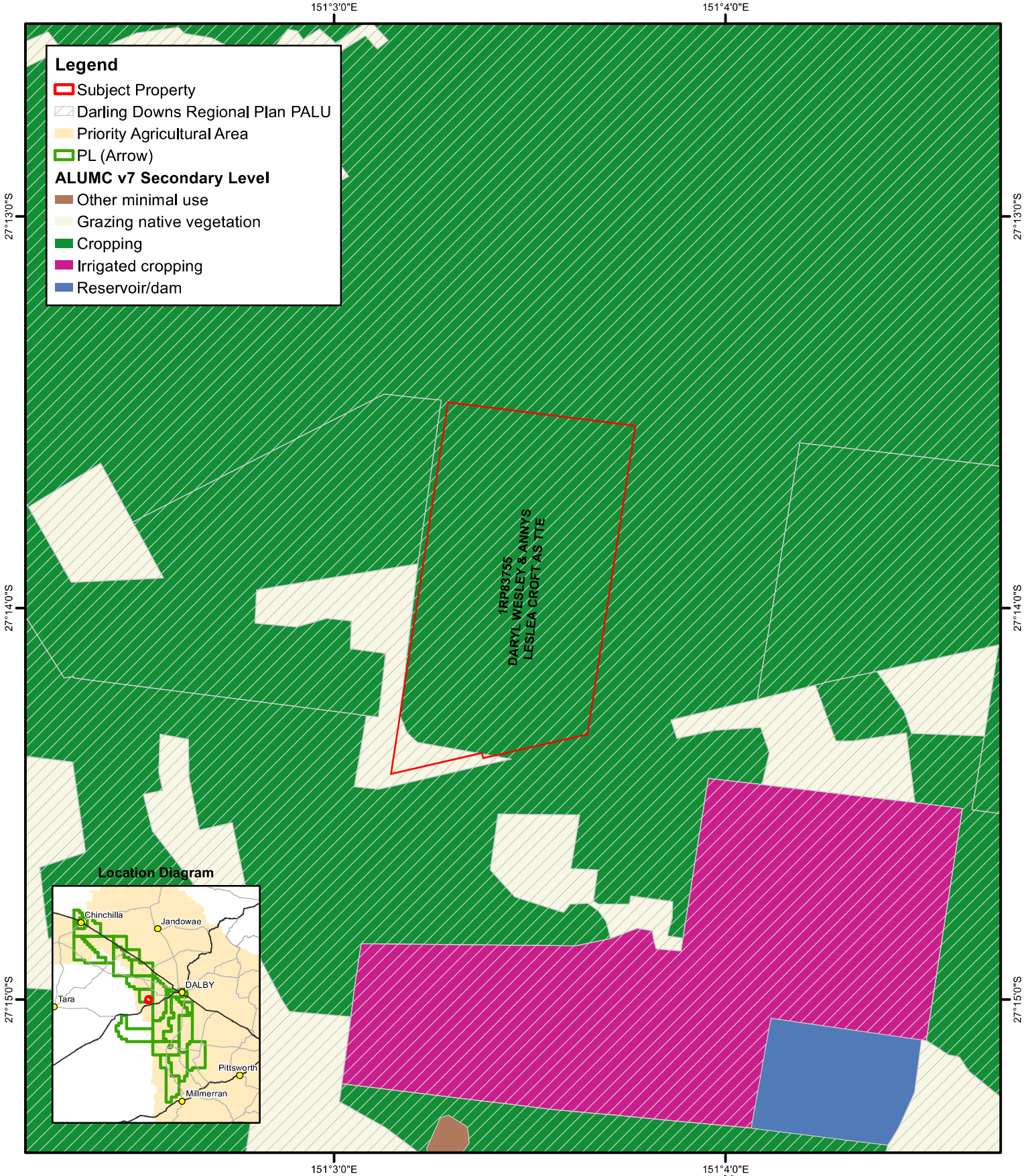
1RP78475

Uncontrolled (1)

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_App3Maps_AT\LandUseMaps_1RP78475_1.mxd

NOT FOR CONSTRUCTION

Print Date: 21/10/2022



This dataset is a digital land use map of the Condamine NRM region, Queensland. As nearly as possible it shows land use in 2012. The dataset is a product of the Queensland Land Use Mapping Program (QLUMP) and was produced by the Queensland Government. The dataset comprises an ESRI vector geodatabase at a nominal scale of 1:50,000. The layer is a polygon dataset with each class having attributes describing land use. Land use is classified according to the Australian Land Use and Management Classification (ALUMC) Version 7, May 2010.
In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for direct marketing or be used in breach of the privacy laws.

Meters 0 95 190 380 570 760 950

N

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no warranty is given that the information contained on this map is free from error or omission. Any reliance placed on such information shall be at the sole risk of the user. Please verify the accuracy of all information prior to using it.

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Rev	Date	Revision Description	Orig	Chk	Eng	QA	App
1	21.10.22	DDRP PALU areas added	AW	XX	XX	AT	AT
0	21.04.22	First issue	AW	XX	XX	AH	AH

arrow energy go further

Scale @ A4: 1:24,000
Coordinate System: GCS GDA 1994

Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
Geosciences Australia
Qld Gov.

Land Use

Queensland Land Use Mapping Program

1RP83755

Uncontrolled (1)

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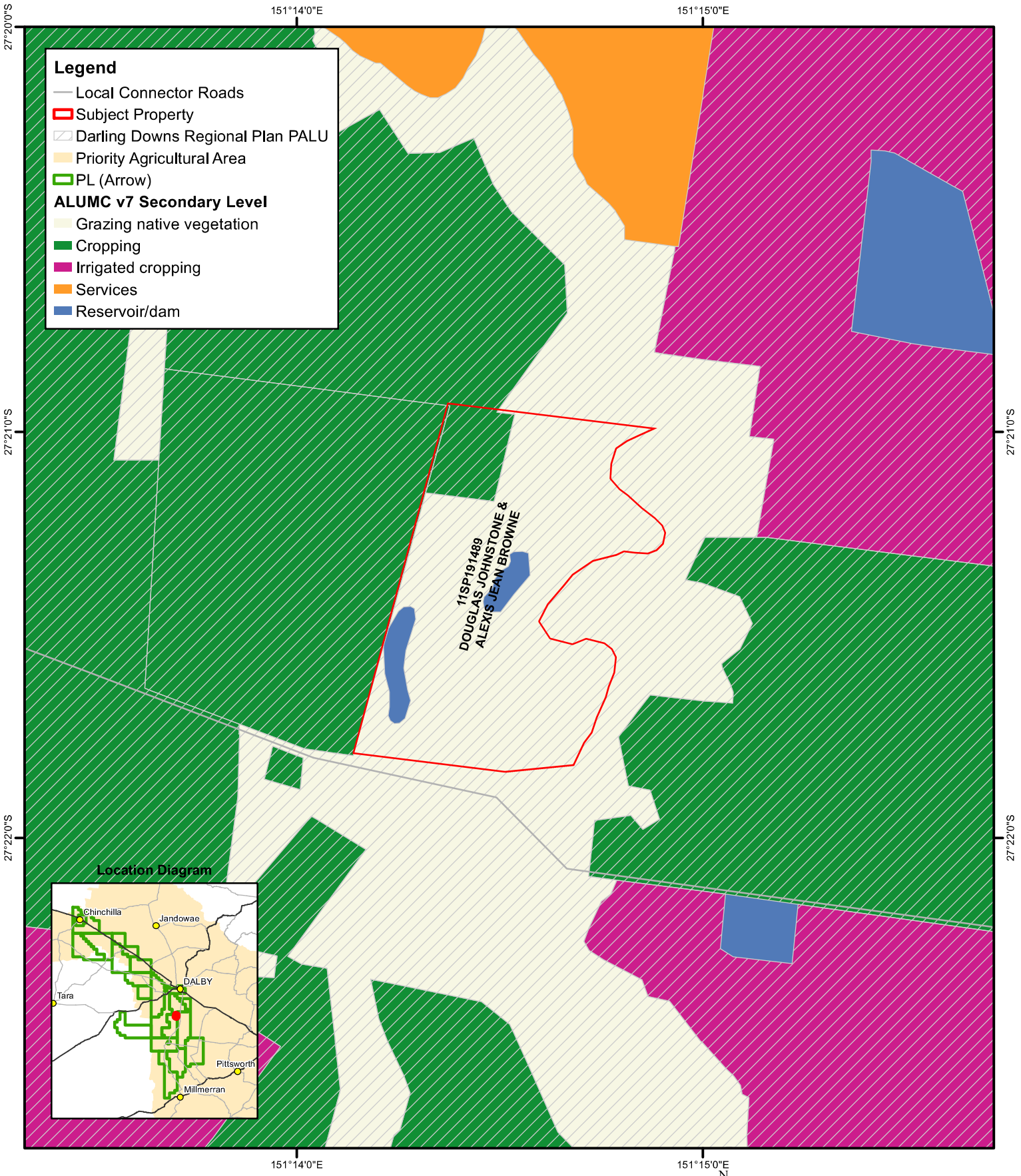
NOT FOR CONSTRUCTION

Print Date: 21/10/2022



This dataset is a digital land use map of the Condamine NRM region, Queensland. As nearly as possible it shows land use in 2012. The dataset is a product of the Queensland Land Use Mapping Program (QLUMP) and was produced by the Queensland Government. The dataset comprises an ESRI vector geodatabase at a nominal scale of 1:50,000. The layer is a polygon dataset with each class having attributes describing land use. Land use is classified according to the Australian Land Use and Management Classification (ALUMC) Version 7, May 2010.
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Rev	Date	Revision Description	Orig	Chk	Eng	QA	App
1	21.10.22	DDRP PALU areas added	AW	XX	XX	AT	AT
0	21.04.22	First issue	AW	XX	XX	AH	AH

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Scale @ A4: 1:23,000
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Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
Geosciences Australia
Qld Gov.

Land Use

Queensland Land Use Mapping Program

11SP191489

Uncontrolled (1)

Document: R:\GIS\Geomatics_Team\WORK_REQUESTS\General\221020_RITM0455936_RIDA_App3Maps_AT\LandUseMaps_11SP191489_1.mxd

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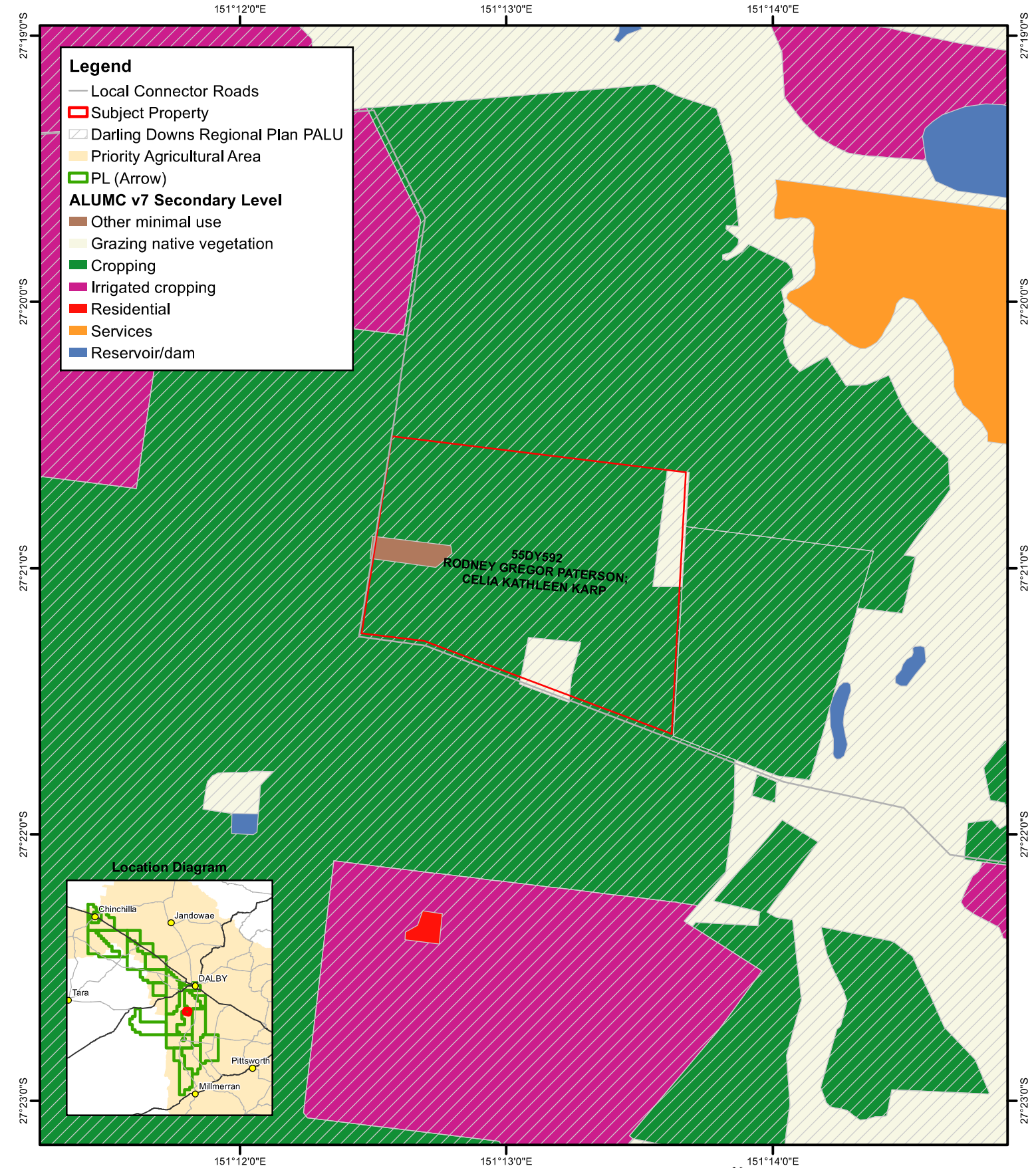

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0	21.04.22	First issue	AW	XX	XX	AH	AH

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Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
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Land Use

Queensland Land Use Mapping Program

55DY592

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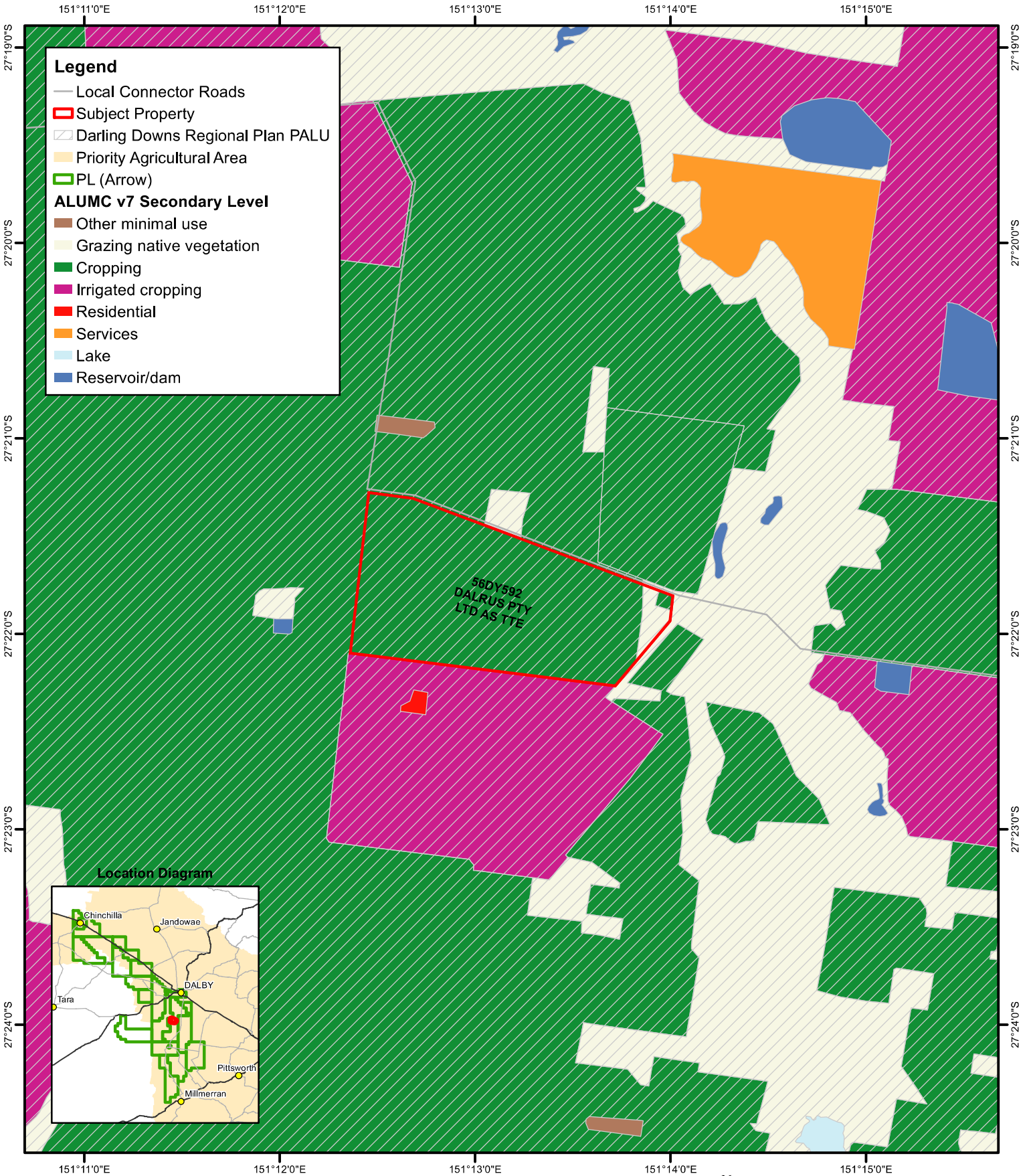
Print Date: 21/10/2022



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Meters 0 200 400 800 1200 1600 2000

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Rev	Date	Revision Description	Orig	Chk	Eng	QA	App
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Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
Geosciences Australia
Qld Gov.

Land Use

Queensland Land Use Mapping Program

56DY592

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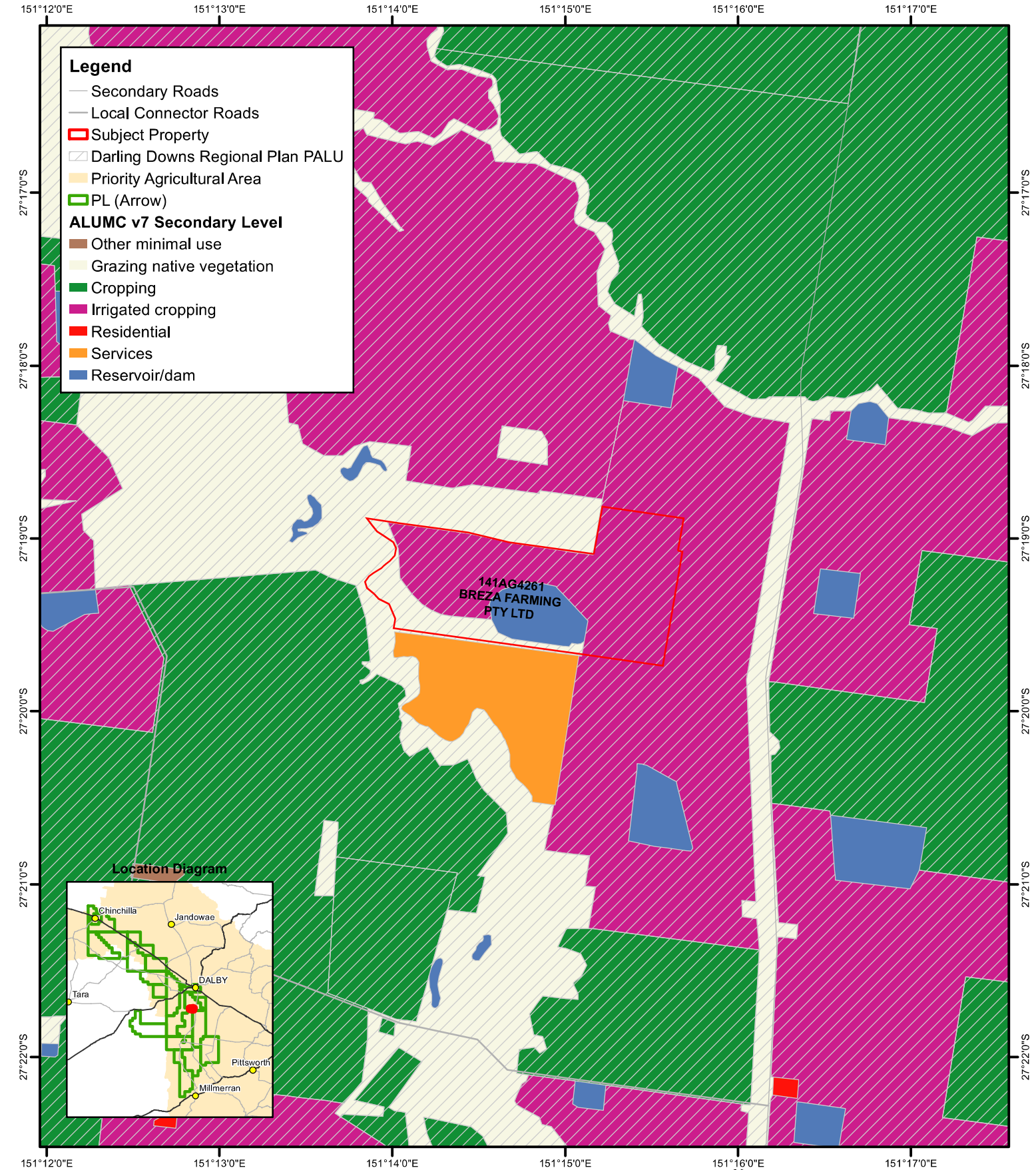

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Rev	Date	Revision Description	Orig	Chk	Eng	QA	App
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0	21.04.22	First issue	AW	XX	XX	AH	AH

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Status: IFI
Issued To: A Tapsall
Author: awolhuter

Source: Arrow Energy Limited
Geosciences Australia
Qld Gov.

Land Use

Queensland Land Use Mapping Program

141AG4261

Uncontrolled (1)

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Appendix H – Arrow Energy Stage 1 WMMP

7. SUBSIDENCE ASSESSMENT AND MONITORING

A technical memorandum relating to subsidence was prepared to support development of the Stage 1 CSG WMMP and to address the requirements of condition 13(g) and is provided in Appendix K.

7.1 Baseline monitoring

Monitoring of subsidence was carried out by Altamira using satellite borne Interferometric Synthetic Aperture Radar technology (InSAR), a radar technique used in geodesy and remote sensing (Altamira, 2016). Data was obtained from Radarsat-2 satellite images covering 10,736 km^2 of Arrow SGP leases. InSAR makes use of the amplitude and the absolute phase of the return signal data to enable accurate determination of surface elevation. The change in phase difference between locations can be used to interpret changes in relative position, and indicate subsidence for different regions within areas potentially affected by CSG drawdown.

The InSAR data provides a baseline from which future data can be assessed to determine changes in vertical ground elevation, and also provides a snapshot of current vertical ground movement.

7.2 Assessment of subsidence

Predictions of drawdown resulting from the Action underpin the predictions of potential subsidence.

7.2.1 Predicted subsidence

The method for predicting subsidence is presented in detail in Appendix K.

When assessing subsidence impacts, consideration was given to both the absolute subsidence magnitude, as well as differential settlement.

Predicted subsidence effects on general farmland, small dams, and river hydrology, for movements of less than 100 mm over a distance of 1 km, are not considered likely to result in adverse impacts. Farmhouses, farm sheds and other small buildings can be assessed under the criteria for other buildings and structures.

Mines and mine infrastructure are typically subject to local ground movement associated with the mining operation and are also considered unlikely to be adversely affected by the anticipated magnitudes of CSG induced subsidence.

Assessed subsidence contours associated with predicted drawdown from Arrow operations only and cumulative cases for 2030 and 2050 for both the high and low settlement assumptions are presented in Figures 7.1 and 7.2 respectively.

Figures 7.3 and 7.4 present the predicted subsidence at 2030, for the high assessment, overlaid upon the Arrow SGP drainage areas for each scenario (Arrow only and cumulative cases respectively).

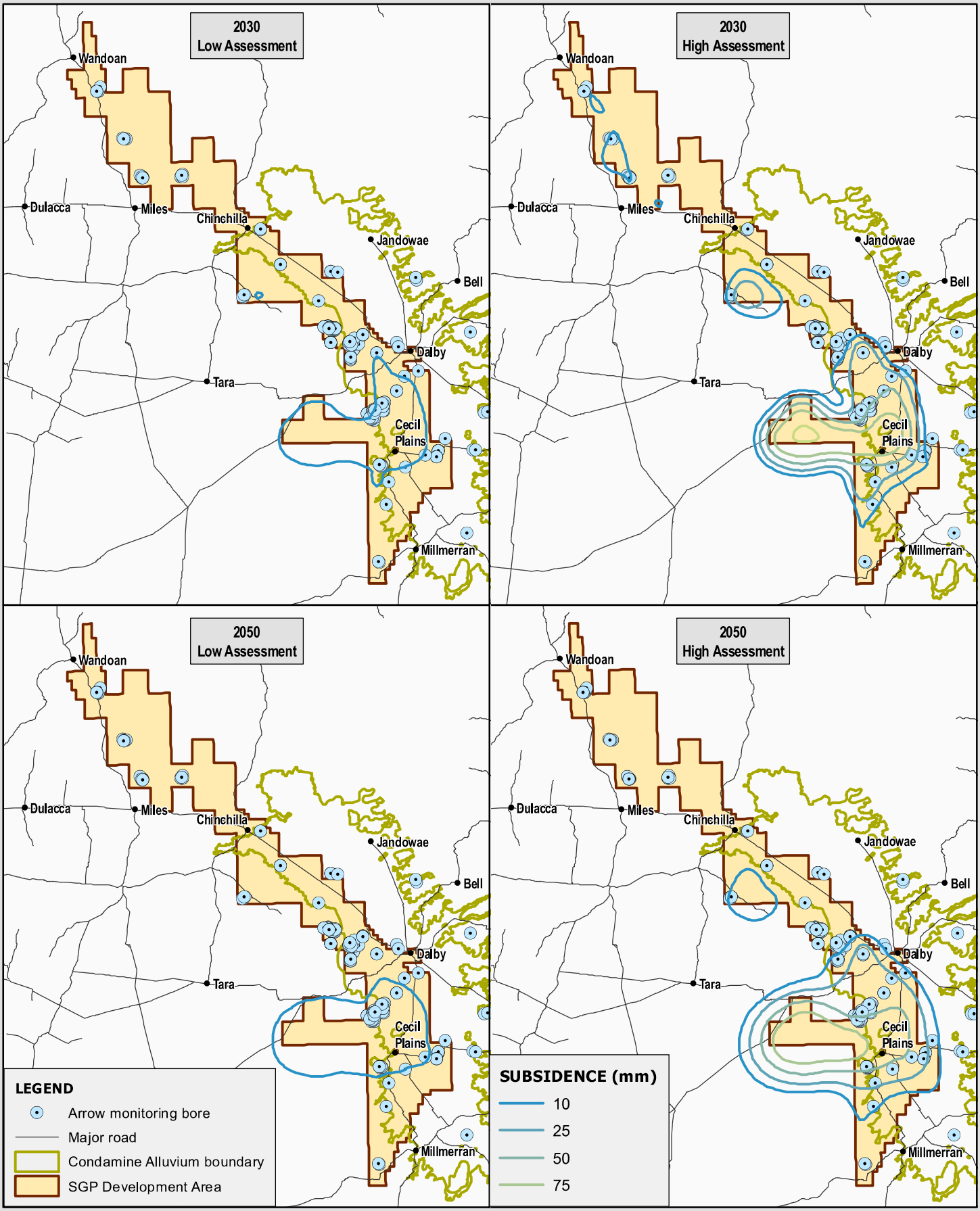

Figure 7.1 Subsidence assessment - Arrow only case

Source:
Arrow Energy Pty Ltd
Coffey

Date: 14/07/2017
Issued To: Arrow Energy
Author: grant.young

0 10 20 40 60 80 100 120
Kilometres
Scale: 1:2,000,000 @ A4
Coordinate System: GDA 1994 MGA Zone 56

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arrow energy go further

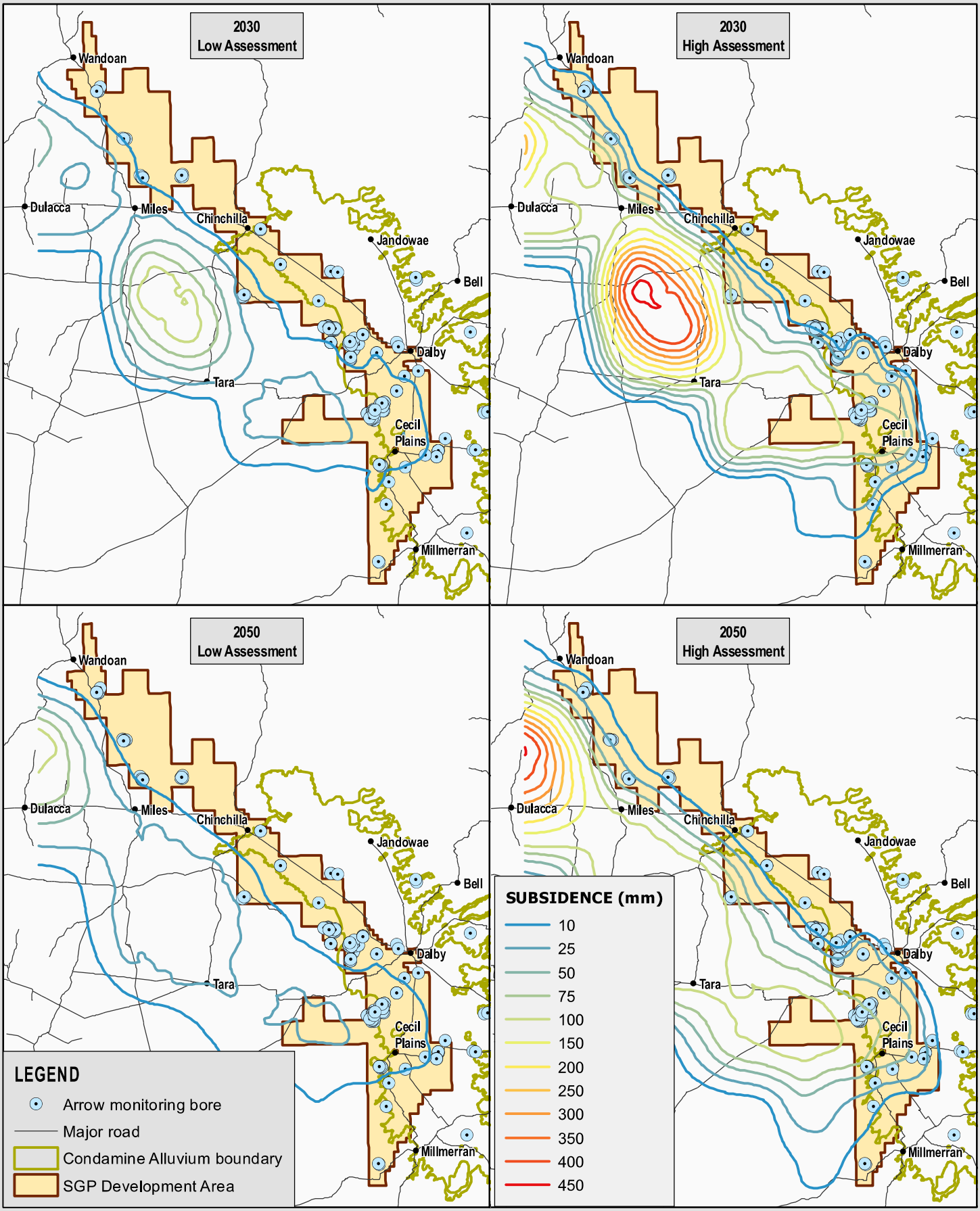

Figure 7.2 **Subsidence assessment - cumulative case**

Source:
Arrow Energy Pty Ltd
Coffey

Date: 14/07/2017
Issued To: Arrow Energy
Author: grant.young

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Kilometres
Scale: 1:2,000,000 @ A4
Coordinate System: GDA 1994 MGA Zone 56

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arrow energy go further

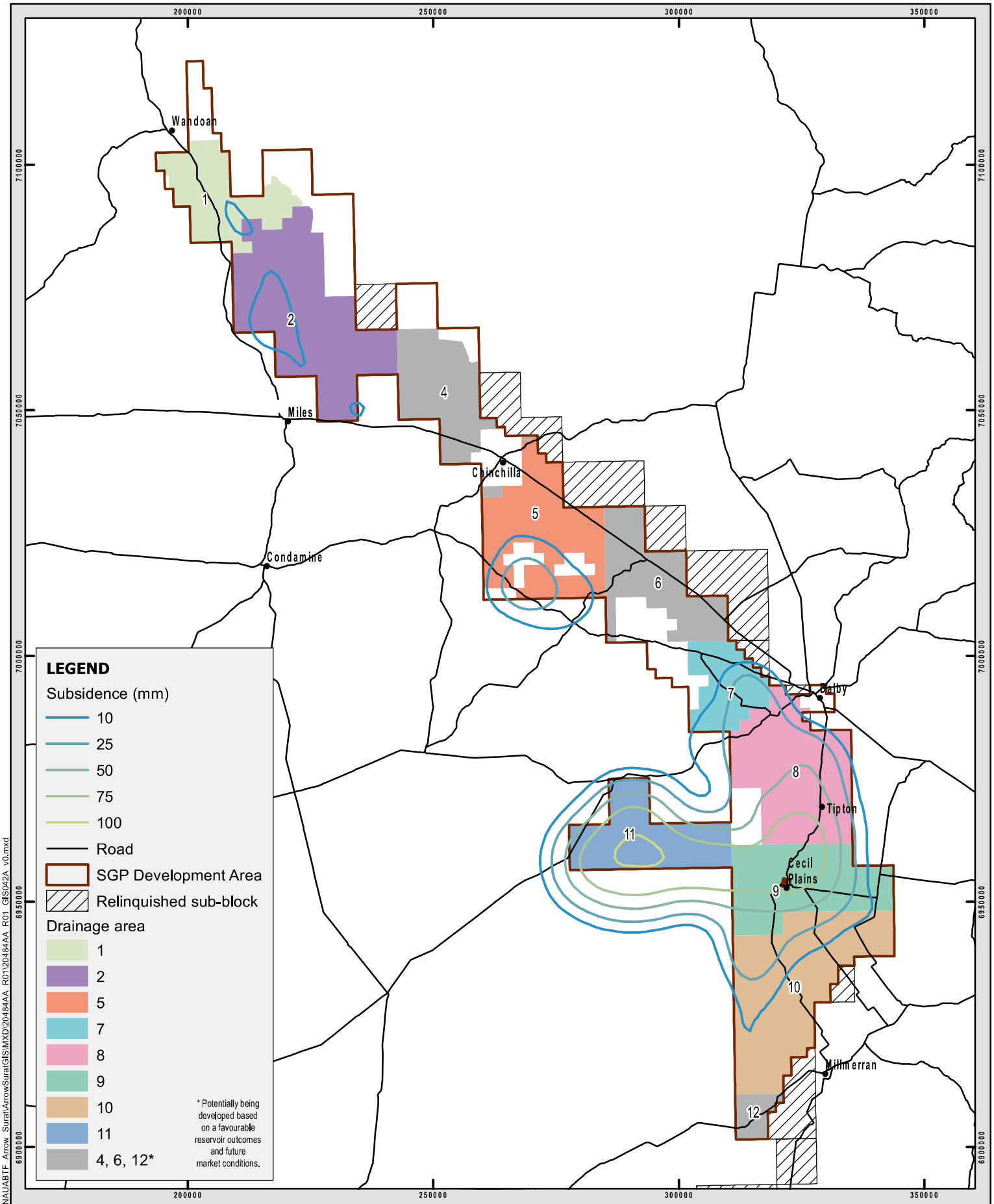

Figure 7.3 **Predicted subsidence 2030 High assessment - Arrow only case**

Source:
Arrow Energy Pty Ltd
Coffey

Date: 8/11/2017
Issued To: Arrow Energy
Author: Helen.Unkovich

0 5 10 20 30 40 50 60
Kilometres
Scale: 1:1,000,000 @ A4
Coordinate System: GDA 1994 MGA Zone 56

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arrow energy go further

Document: \\Abtfarcv01\data$\GIS\20484_ENAUABTF_Arrow_Surat\ArrowSuratGIS\MXD\20484AA_R01\20484AA_R01_GIS042A_v0.mxd

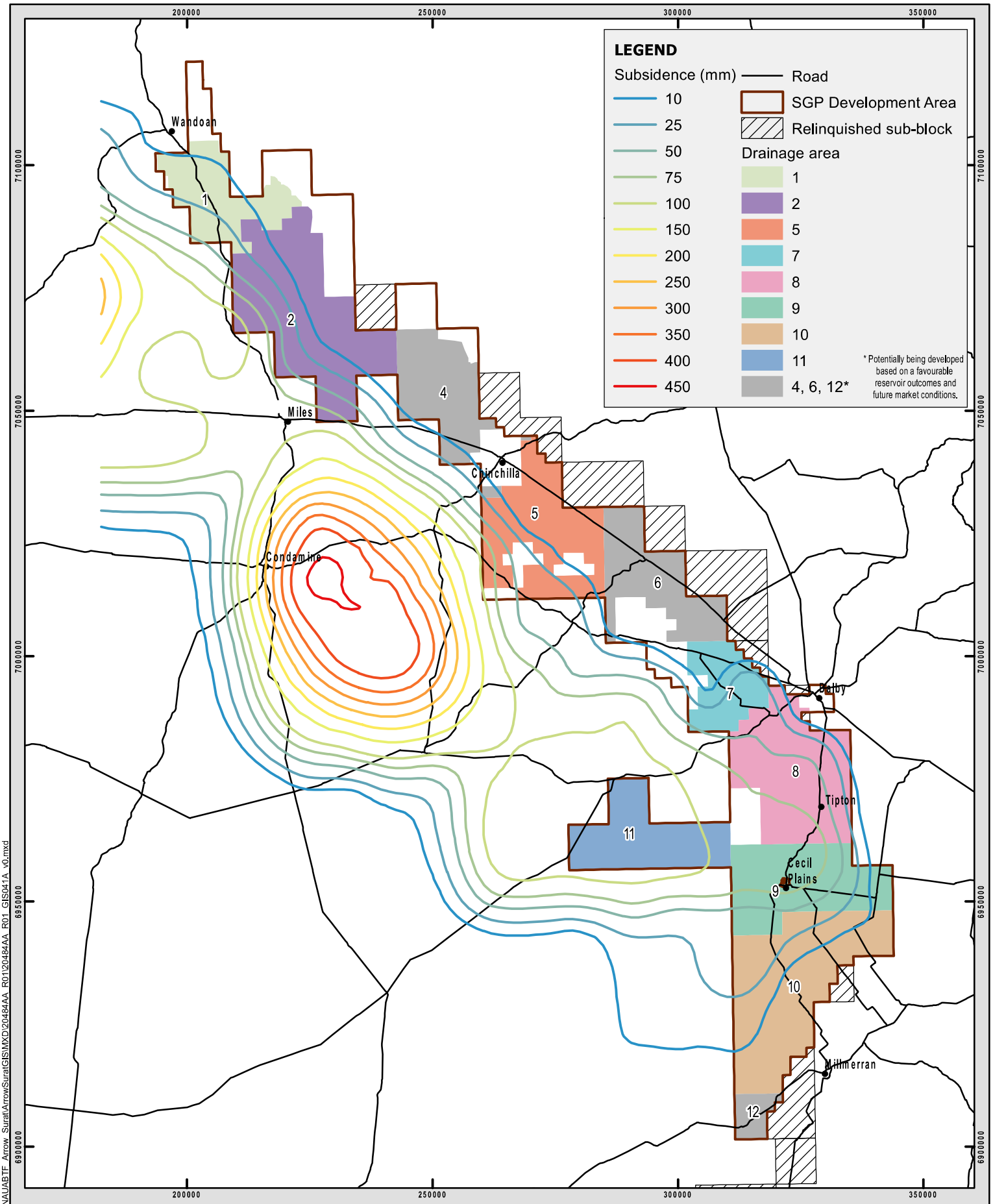

Figure 7.4 **Predicted subsidence 2030 High assessment - Cumulative case**

Source:
Arrow Energy Pty Ltd
Coffey

Date: 27/11/2017
Issued To: Arrow Energy
Author: Helen.Unkovich

0 5 10 20 30 40 50 60
Kilometres
Scale: 1:1,000,000 @ A4
Coordinate System: GDA 1994 MGA Zone 56

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arrow energy go further

7.3 Risk assessment

Risks associated with subsidence caused by CSG extraction were assessed using the approach set out in the Australian and New Zealand Standards Association Handbook SA/SNZ HB 89:2013. Under this approach, an 'event' is considered as CSG induced subsidence movement affecting an existing asset.

The likelihood of subsidence of a particular magnitude was assessed by reference to the subsidence measured to date, and the predictions for future subsidence. The consequence of an event of particular magnitude was assessed based on the nature of an asset and its sensitivity to movement.

7.4 Subsidence trigger thresholds

Trigger thresholds have been developed for CSG induced [22]subsidence as required by approval condition 13(g). They are derived from calculated risk assessments of potential subsidence, and taking into account the outcomes of the risk assessment process.

An initial screening level has been set to identify areas for targeted further assessment of settlement and evaluation of whether the trigger thresholds have been exceeded. The general assessment process that will be implemented is presented in Figure 7.5.

7.4.1 Screening level

Initial screening will involve identification of areas where significant subsidence is occurring based upon the annual rate of subsidence reported from InSAR monitoring results. This initial screening will involve identification of areas of 1 km by 1 km where more than 50% of the InSAR monitoring points indicate an annual subsidence rate of more than 8 mm/yr (a movement rate discernible using InSAR methods). In areas where this level of movement is recorded, further assessment will be carried out to assess whether the investigation levels as nominated in section 7.4.2 are exceeded.

7.4.2 Investigation Levels

In areas where the screening level is exceeded, further assessment of relevant data relating to subsidence will be undertaken. This will include an assessment of the CSG-related subsidence component of the reported InSAR measurements with consideration for the cumulative industry impact and reported subsidence since the commencement of the Action.

Investigation levels have been defined as set out in Table 7.1. Where the CSG-related subsidence exceeds the investigation levels set out in Table 7.1, further assessment will be carried out to assess the site-specific infrastructure that may be impacted and identify whether an impact has occurred as a result of the Action.

[22] Subsidence rates that have non-CSG influences (i.e. natural fluctuation and other anthropogenic influences) removed

7.4.3 Trigger threshold

Where the investigation levels nominated in Table 7.1 are breached additional investigation of the affected area will be carried out using conventional survey methods for a period of six months. The results of the survey will be tested against asset-specific thresholds (refer Appendix K for further detail). For example in the case of structures, assessment of damage categories as a result of ground movement would be based upon the guidance presented in Burland, 2012.

Where adverse impacts are identified to have occurred based on the results of the site-specific investigation, a trigger threshold is considered to have been exceeded and mitigation measures will be employed following the approach set out in Section 7.4.3.

7.4.4 Trigger threshold exceedance response actions

Approval condition 13(g) requires the development and implementation of an action plan to address identified subsidence impacts within 90 calendar days of a trigger threshold being exceeded.

Trigger threshold exceedance response actions are dependent on the evaluation of the cause of the exceedance, and if the potential for detrimental impacts is confirmed, a mitigation (action) plan will be developed and implemented within 90 days to minimise impact. The mitigation plan will:

- Identify potential mitigation measures and response actions.
- Select suitable response actions, tailored to site-specific conditions, impact cause, timing and magnitude.
- Evaluate time frames within which impacts would be expected to occur and within which mitigation actions would need to be successful.
- Schedule mitigation implementation, with consideration for the anticipated timing of the indicated impact.
- Contain procedures to evaluate the effectiveness of the mitigation measures.

Where an action plan is not developed and implemented within 90 calendar days of the identified trigger threshold exceedance this represents a non-compliance and the Minister will be notified.

Item	Description	Criteria	Relevant assets	Basis for selection / comment
Screening level	Settlement rate	8 mm/year (for >50% of sampling points in 1 km by 1 km block)	All natural features, man-made features and built infrastructure	Areas where this criterion is exceeded will be subject to investigation of subsidence (refer Appendix K).
Investigation levels	Gradient change	0.03 % (300 mm per 1,000 m)	Irrigation system (laser levelled)	Based upon half the slope of minimum grades recommended by the Cotton Research and Development Corporation for furrow irrigation. Areas where this criterion is exceeded will be subject to investigation of subsidence (refer Appendix K), including review of laser levelling practices.
	Differential settlement (built infrastructure)	0.001 m/m	Buildings, structures	• Selected for buildings as the most sensitive item in this group (refer Appendix K). • Not relevant to linear infrastructure (roads, rail, transmission lines and pipelines) as predicted differential settlement is well within the tolerance of these facilities. • Not relevant to bushland or farmland.
	Change in slope (natural features)	25 mm/1,000 m	Flood flow in watercourses	• Taken as 5% of topographic gradient of the Condamine Plain. • Applies only to the main channel of the Condamine River. • Review of effects on flow and conventional survey would be carried out to assess the significance of the change.
Trigger threshold	Outcome of site specific monitoring using conventional survey and review of risk to asset.	Individual threshold based on the local conditions	Irrigation system, structure or watercourse	• Site specific assessment based upon conventional survey of identified asset. In the case of potential impacts on structures within populated areas the assessment will be based upon selected structures considered to be most vulnerable.

Table 7-1. Subsidence monitoring screening level, investigation levels and trigger threshold

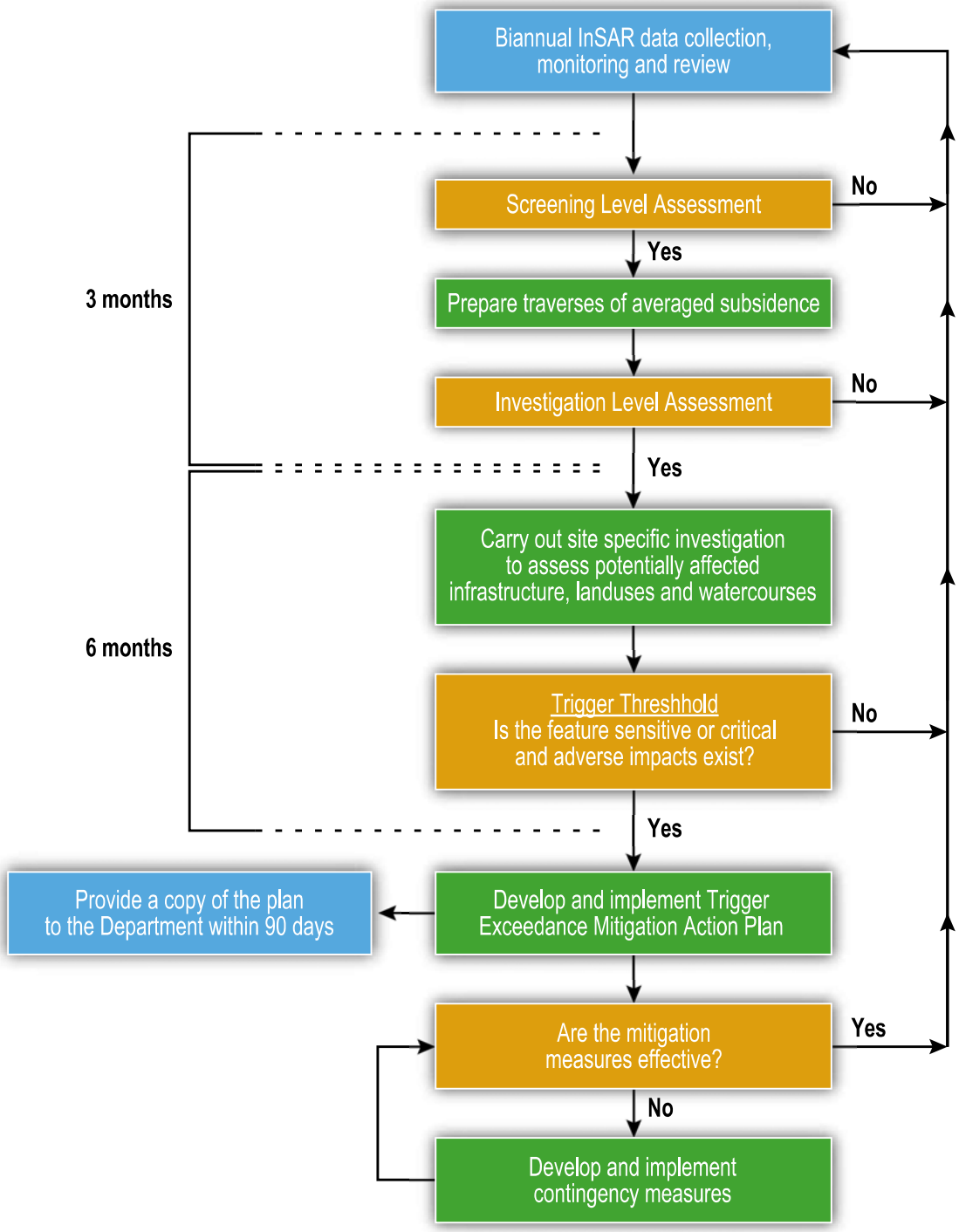

Figure 7.5 **Subsidence monitoring assessment flow chart**

Source:
Coffey

Date: 19/09/2018
Issued To: Arrow Energy
Author: Helen.Unkovich / Richard.heath

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7.5 Monitoring program

The current monitoring program provides groundwater level monitoring, and monitoring of subsidence using InSAR technology. InSAR technology provides high resolution and wide coverage, however separate geodetic measurement of ground movement will be taken at selected locations to provide a ground-truthing check and control on the InSAR results.

7.5.1 Measurement techniques and subsidence monitoring stations

Measurement techniques that can contribute to the assessment of subsidence impacts include:

- Tiltmeters, to measure small changes in ground slope.
- Survey using traditional or GPS methods.
- Extensometers in boreholes.
- Condition assessments of structures at risk.

Of these methods, the use of extensometers and survey to ground truth-the results of InSAR monitoring are considered most useful. Extensometers allow identification of the horizons in the ground profile contributing to surface settlement.

Locations for geotechnical ground movement monitoring will be co-located with groundwater monitoring bores where possible to provide coverage of the full ground profile potentially influenced by the SGP. Instrumented sites will be preferentially located at the centre of selected SGP well-fields, and will be installed to provide baseline information prior to the initiation of water production. The timing of monitoring location installation will reflect the FDP sequencing.

Figure 7.6 sets out locations recommended for establishment of subsidence monitoring stations that would comprise:

- Groundwater monitoring at multiple locations including within, above and below the WCM.
- Geodetic ground movement (vertical) monitoring monument (installed to avoid shrink swell movement of the upper soils).

In addition, at one station (SMS1 in Drainage Area 11, refer Figure 7.6) an extensometer array will be installed to separately record compression within the Juandah Coal Measures and the Taroom Coal Measures (member of the WCM subgroup).

7.5.2 Ongoing monitoring

Measurement of settlement and extensometers is proposed on an initially monthly frequency. Ongoing reviews of the baseline established will determine when changeover to monitoring commences on a quarterly basis (with associated continuous groundwater level measurement using data loggers).

A program for ongoing monitoring will be implemented to confirm that subsidence is within the predicted behaviour of the strata over time. Where deviation from predictions is observed, revised predictions will be prepared and assessment of the significance of the predictions made.

InSAR data updates will be received on a bi-annual basis. Review of the updated InSAR data will be undertaken within 3 months of the data being received.

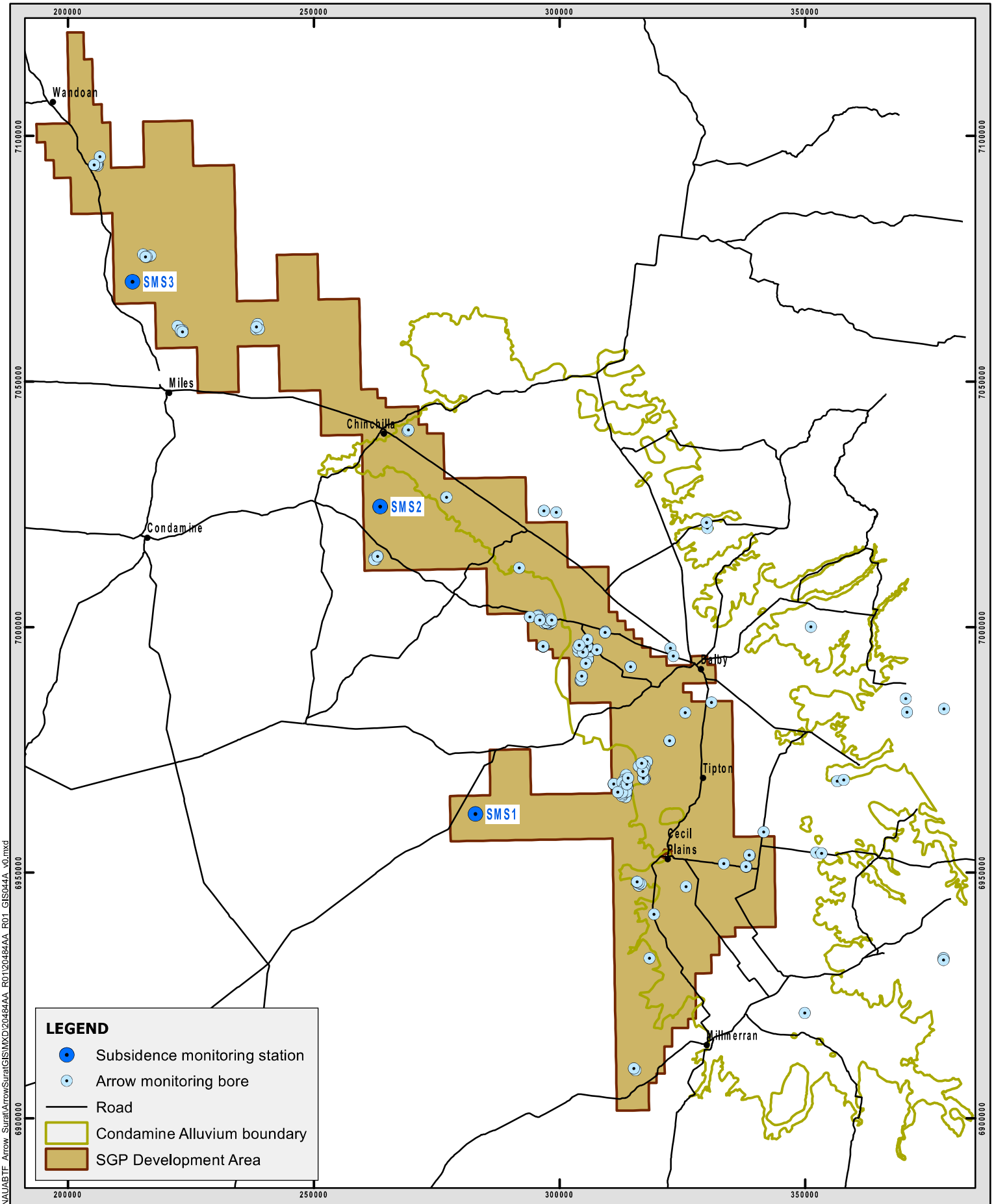

Figure 7.6 **Subsidence monitoring stations**

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Arrow Energy Pty Ltd
Coffey

Date: 27/11/2017
Issued To: Arrow Energy
Author: Helen.Unkovich

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Coordinate System: GDA 1994 MGA Zone 56

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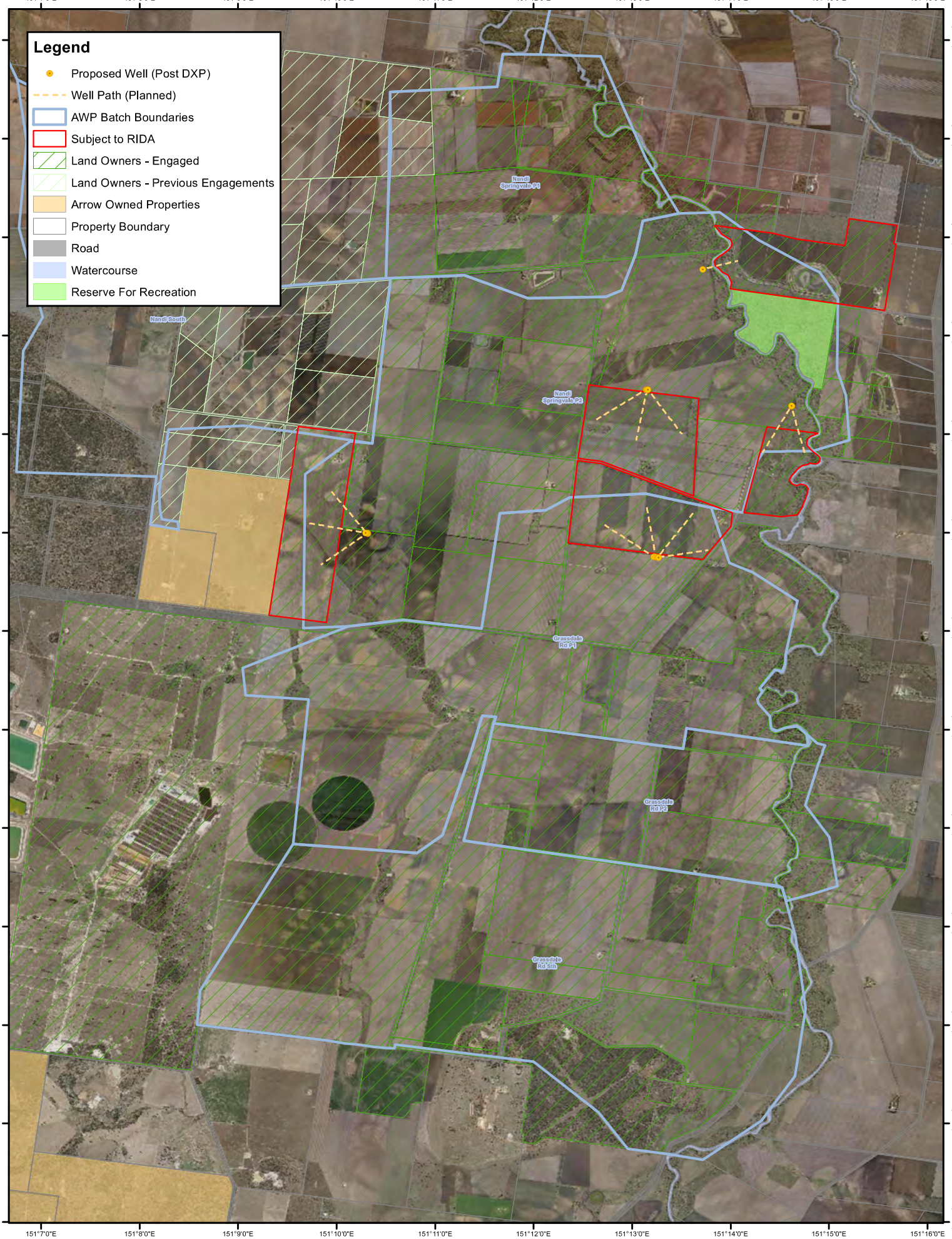
Appendix I – Confidential Stakeholder Engagement Map



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Source:
Arrow Energy Limited, Geosciences Australia
Dept. Envir. and Resource Mgmt.

Status: IFI
Issued To: S. Ferguson
Author: coellermann

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Nandi Springvale Grassdale Road and Grassdale Road South

Engagement Map

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