Reduce, Reuse, Recycle

Applying Bob The Builder's philosophy to Victorian exploration data collection:

Reduce the effort,

Reuse the products,

Recycle the data

Suzanne Haydon

June 2023

GEOLOGICAL SURVEY OF VICTORIA

DISCOVER EARTH'S SECRETS

Reduce the effort for data submission by knowing what's required

Discover and Reuse existing data and products

Acquire high quality geoscience data that can be Recycled into new and improved products

GEOLOGICAL SURVEY OF VICTORIA

Reduce, Reuse, Recycle

Reduce the effort for data submission by knowing what's required

Where to look for help:

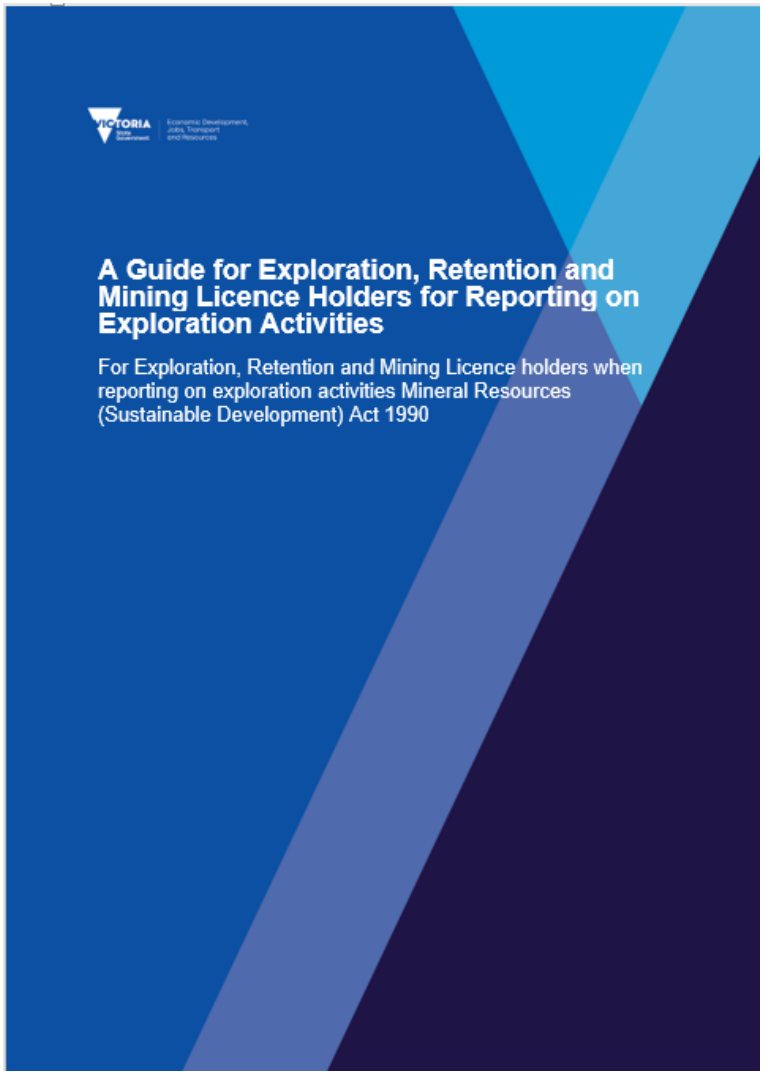
- Published Technical and Industry standards
- Government-survey contract specifications in public reports
- Seek guidance from GSV

GEOLOGICAL SURVEY OF VICTORIA

Reduce the effort

Technical and Industry standards

- Guide for Reporting MR(SD)A exploration activities (Department of Jobs, Precincts and Regions, 2021)
- Australian Requirements for the Submission of Digital Exploration Data (Government Geoscience Information Committee, 2018)
- Victorian Petroleum Regulations (Chief Parliamentary Counsel, 2021)



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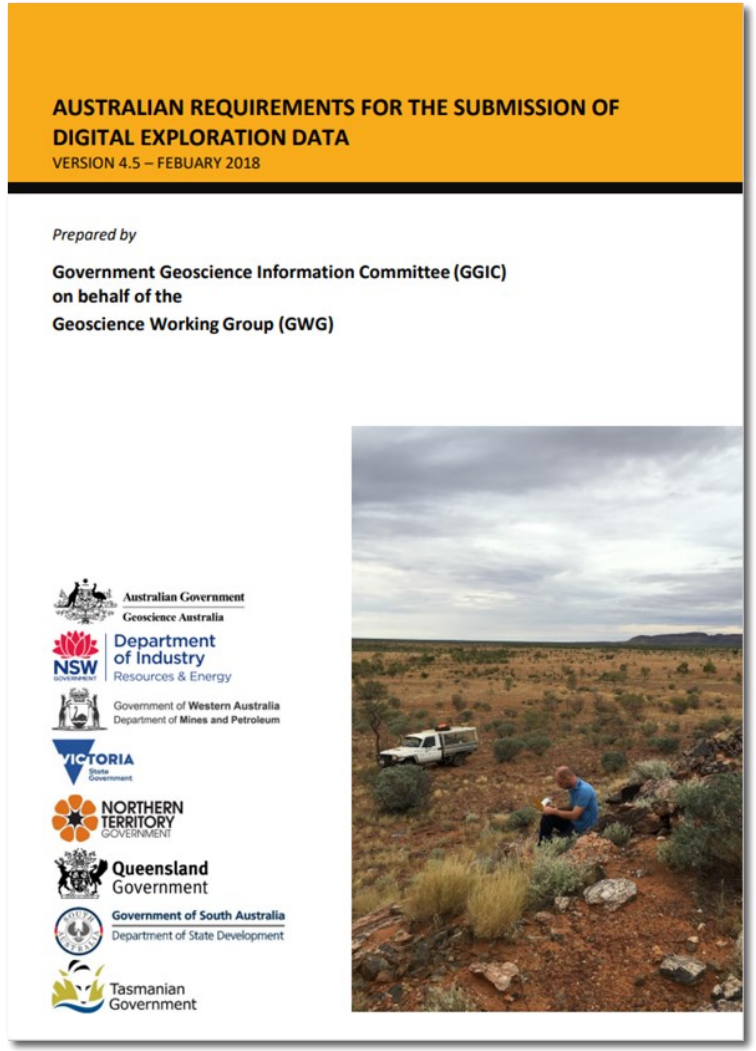

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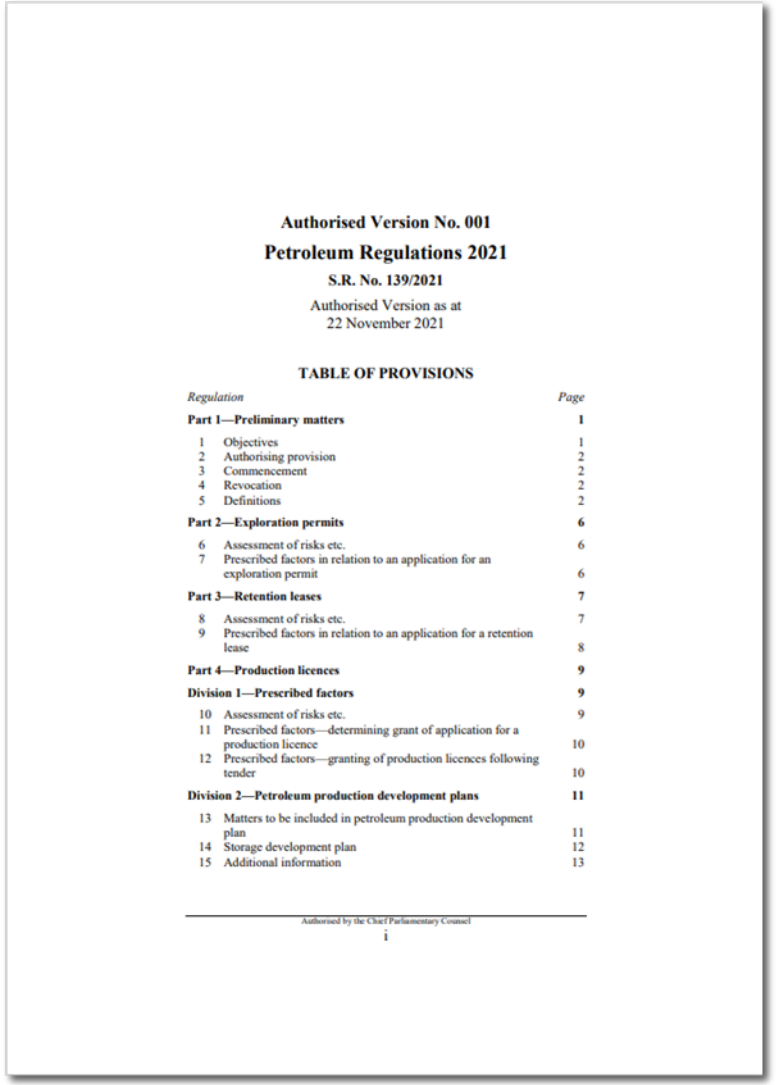

Authorised Version No. 001

Petroleum Regulations 2021

S.R. No. 139/2021

Authorised Version as at
22 November 2021

TABLE OF PROVISIONS

Authorised by the Chief Parliamentary Counsel

i

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Technical and Industry standards

- Airborne magnetic/radiometric surveys (Goodwin, 2023)
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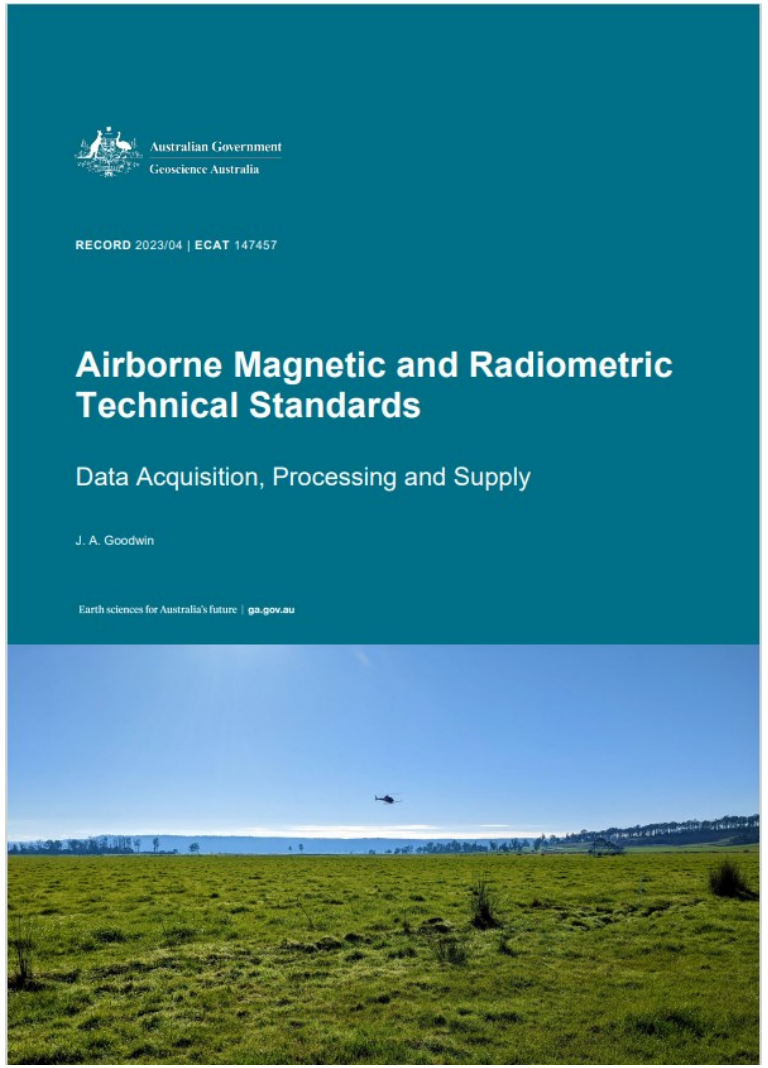

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BEST PRACTICE IN GRAVITY SURVEYING

by

Alice S Murray
Ray M. Tracey

2001

AAGD07: A new absolute gravity datum for Australian gravity and new standards for the Australian National Gravity Database

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SUMMARY

The current Australian gravity datum, Isogal84, is defined by the Australian Fundamental Gravity Network (AFGN). The AFGN consists of about 950 stations at over 250 locations throughout Australia with the first stations in the network being established in the early 1950s. Prior to Isogal84, the datum was based on relative ties to overseas sites. The Isogal84 datum is based on 5 absolute gravity sites within Australia that were established in 1979 using a Soviet absolute gravimeter.

Absolute gravity measurements conducted at 60 AFGN sites by Geoscience Australia using a portable absolute gravimeter have shown that the Isogal84 datum is 78 microgals (1 microgal = $1x10^{-8}$ m/s^2) higher than the absolute measurements. A new gravity datum, the Australian Absolute Gravity Datum 2007 (AAGD07), has been defined based on these absolute gravity measurements and the AFGN and the Australian National Gravity Database (ANGD) have been adjusted to this new datum.

Concurrent with implementing AAGD07, the formulae used for reducing gravity data in the ANGD have been reviewed and updated. These changes include using the 1980 International Gravity Formula, global horizontal and vertical datums, and a spherical cap Bouguer correction that accounts for the Earth's curvature. These new formulae provide more accurate anomalies, particularly in longer wavelengths which will be beneficial to regional studies.

Key words: gravity, geophysics, absolute gravity, geodesy.

INTRODUCTION

The datum and scale for gravity surveys conducted in Australia is provided by the Australian Fundamental Gravity Network (AFGN). The AFGN consists of about 950 stations at over 250 locations and was initially established in the early 1950s. The datum for this early network was defined by gravity ties, using a pendulum apparatus, to Cambridge in England (Dooley *et al*, 1961). Relative ties to other overseas gravity stations were made in later years to further define the datum prior to the establishment of the Isogal84 datum in 1984. The Isogal84 datum was constrained by ties to five absolute gravity sites established in Australia by a Soviet absolute gravimeter in 1979 (Arnautov *et al*, 1979).

Between 2003 and 2006 Geoscience Australia conducted absolute gravity measurements with a portable absolute gravimeter at 60 AFGN stations, shown in Figure 1, in order to ascertain the accuracy and precision of the AFGN and the Isogal84 datum. These measurements show that the Isogal84 datum is 78 microgals (1 microgal = $1x10^{-8}$ m/s^2) higher than the absolute measurements and that the accuracy of the AFGN is 30 microgals.

A new datum, the Australian Absolute Gravity Datum 2007 (AAGD07), has been defined based on these absolute gravity measurements and the AFGN and the Australian National Gravity Database (ANGD) have been adjusted to this new datum.

Concurrent with implementing AAGD07, the formulae used for reducing gravity data in the ANGD have been reviewed and updated. These changes include the adoption of global horizontal and vertical datums, the use of the 1980 International Gravity Formula, and a spherical cap Bouguer correction that accounts for the Earth's curvature. These new formulae and standards will avoid errors introduced by the use of local datums and provide more accurate anomalies, particularly in longer wavelengths for regional studies.

Figure 1. Absolute gravity measurement sites (red triangles) with all AFGN sites (black dots).

NEW GRAVITY DATUM

Absolute gravity measurements conducted in Australia since Isogal84 was introduced did not agree with the Isogal84 values and showed that measurements with modern absolute gravimeters produce values that were inconsistent with the Isogal84 datum. To identify the magnitude and distribution of these differences and to see if there were any systematic errors

Reduce the effort

Technical and Industry standards

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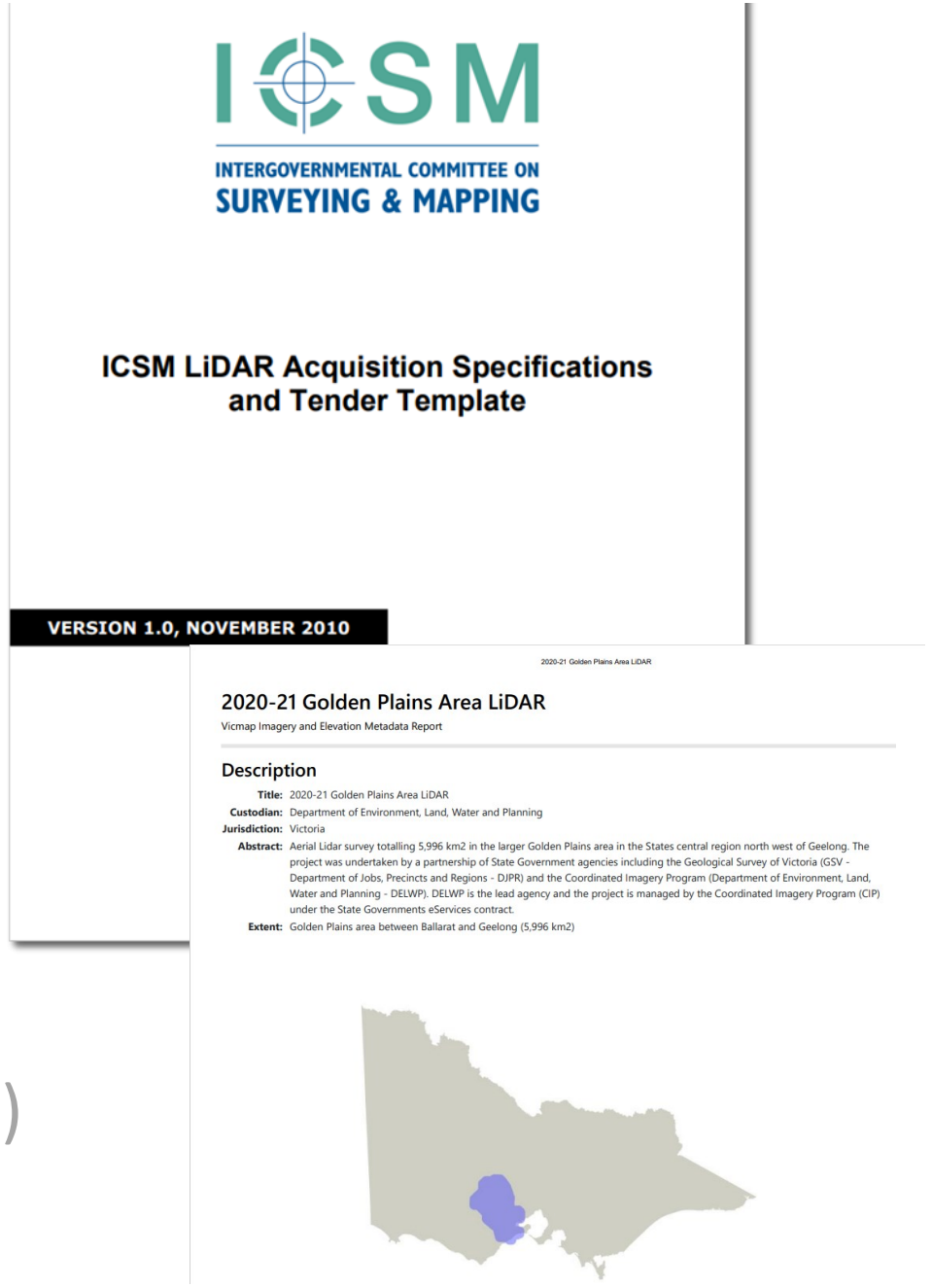

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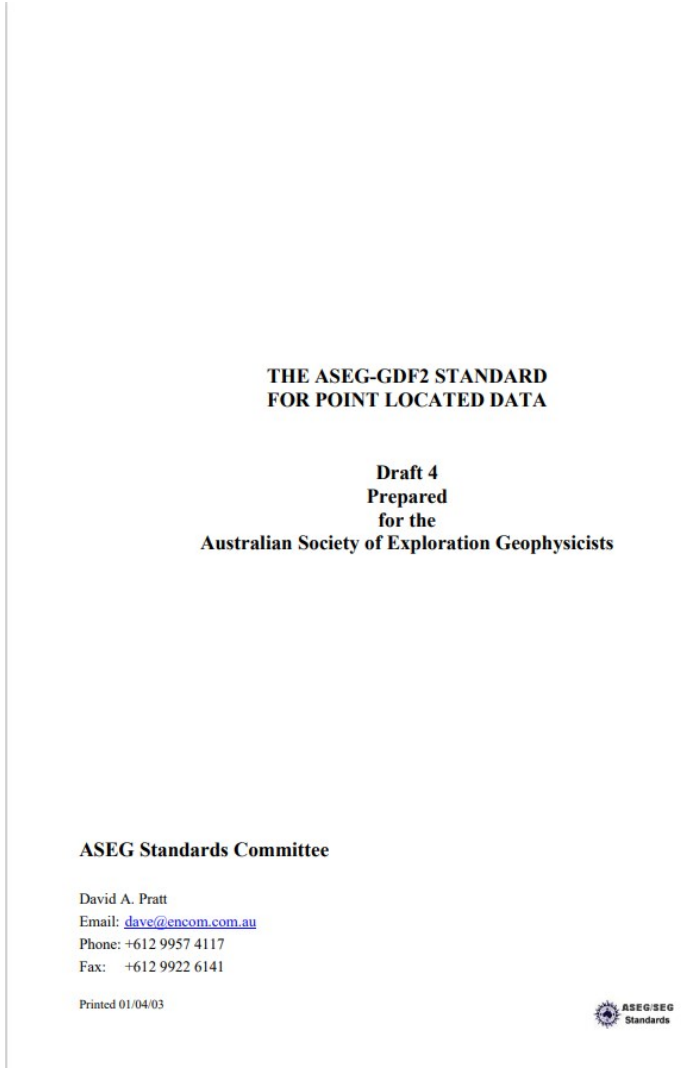

THE ASEG-GDF2 STANDARD
FOR POINT LOCATED DATA

Draft 4
Prepared
for the
Australian Society of Exploration Geophysicists

ASEG Standards Committee

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Printed 01/04/03

ASEG/SEG Standards

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Technical and Industry standards

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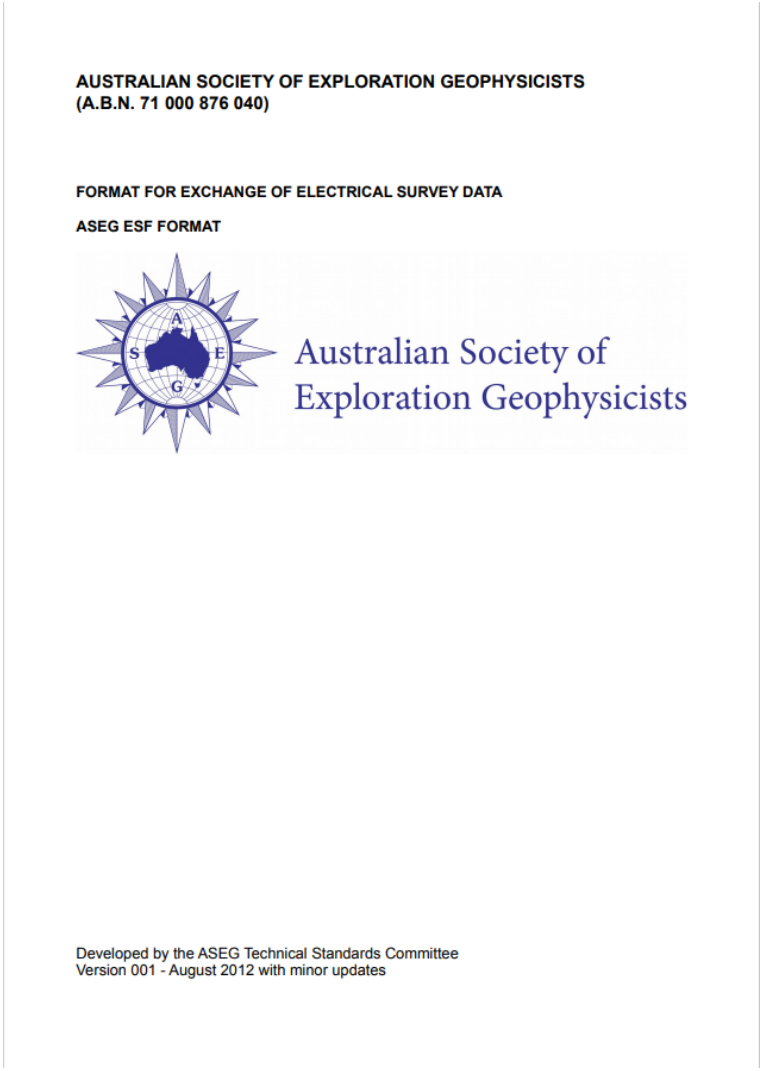
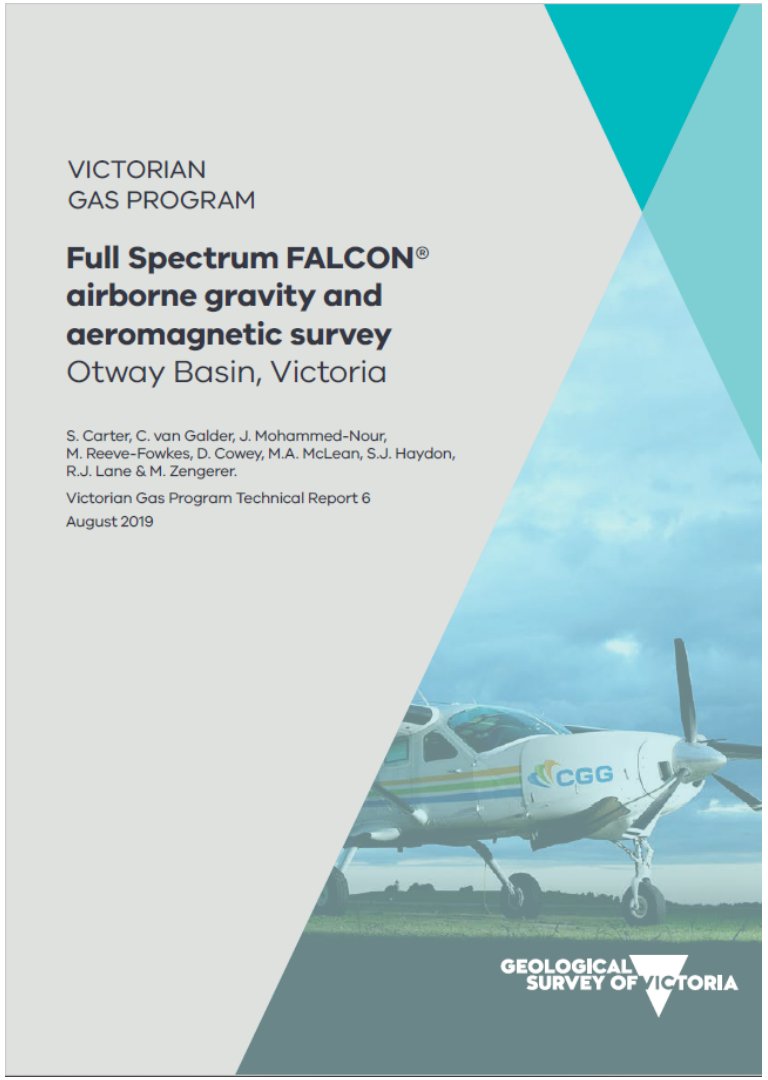


Reduce the effort

Government survey specifications

Refer to recent survey operations reports for acceptable procedures, reporting and formats

- Airborne gravity (Carter et al., 2019)
- Ground gravity (Haydon et al., 2017)
- Passive seismic (Holzschuh et al., 2022)
- Airborne Electromagnetics (Brodie, 2023)



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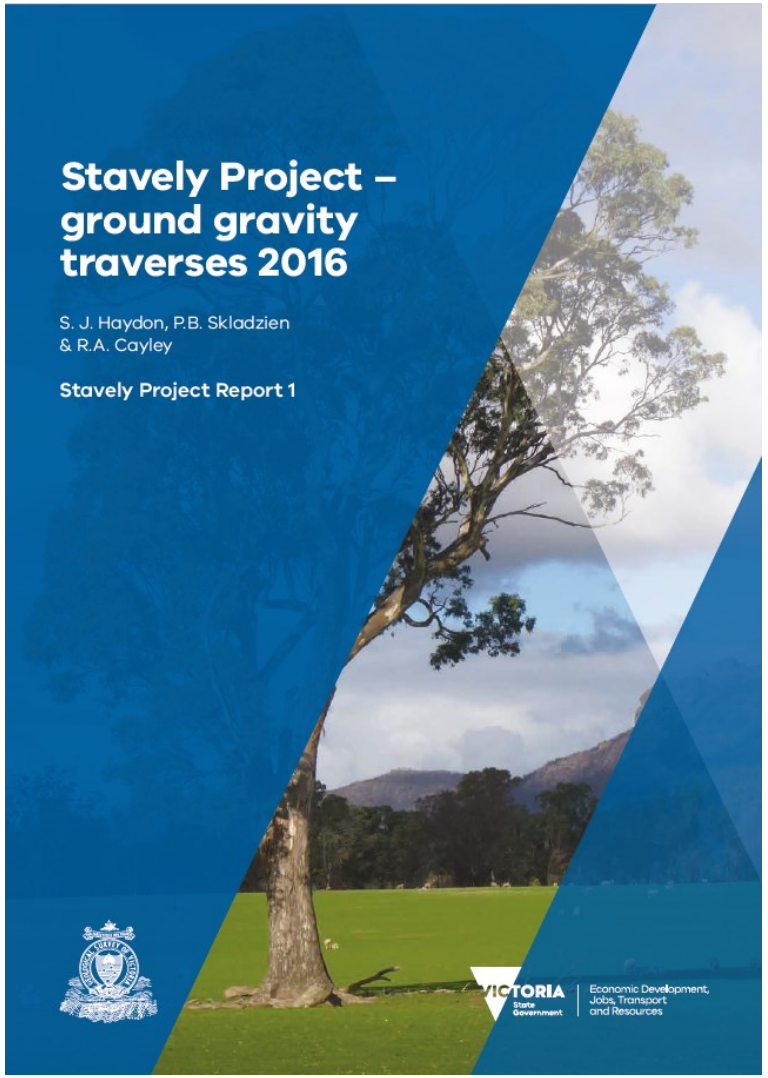

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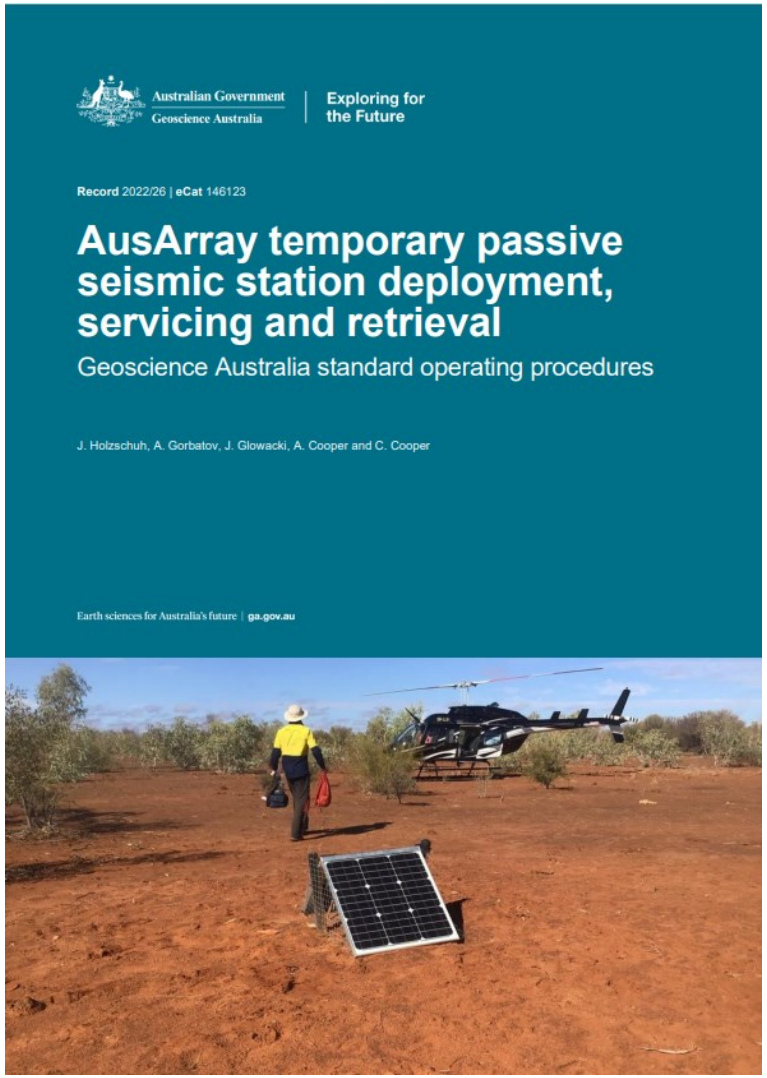

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Seek advice from GSV

Work with GSV to determine submission requirements for undocumented and emerging techniques

- Government reports published by other jurisdictions
- International working groups
- Research organisations and academia
- Liaise with instrument manufacturers and contractors
- Published papers

Reduce the effort

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Work with GSV to determine submission requirements for emerging and maturing mineral exploration geophysical techniques

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Guidelines for Drone Geophysics

Australian Research Data Commons

2030 Geophysics Collections

Reduce, **Reuse,** Recycle

Discover and Reuse existing data and products

Before acquiring new data – search the public catalogues

- Government survey data and reports
- Discover existing public-domain data
- Open-file tenement data

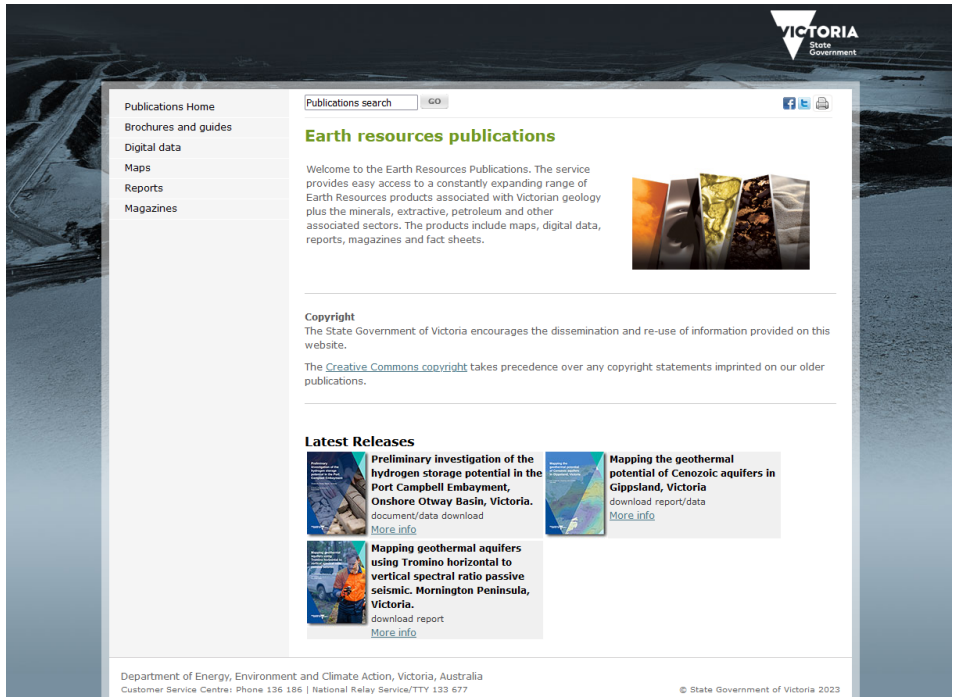
GEOLOGICAL SURVEY OF VICTORIA

Reuse the products

Government survey data and reports

Before acquiring new data – search the public catalogues

- Earth Resources Publications (Online Store)
- Geophysical Archive Data Delivery System (GADDS)
- Geoscience Australia Data and Publications Search



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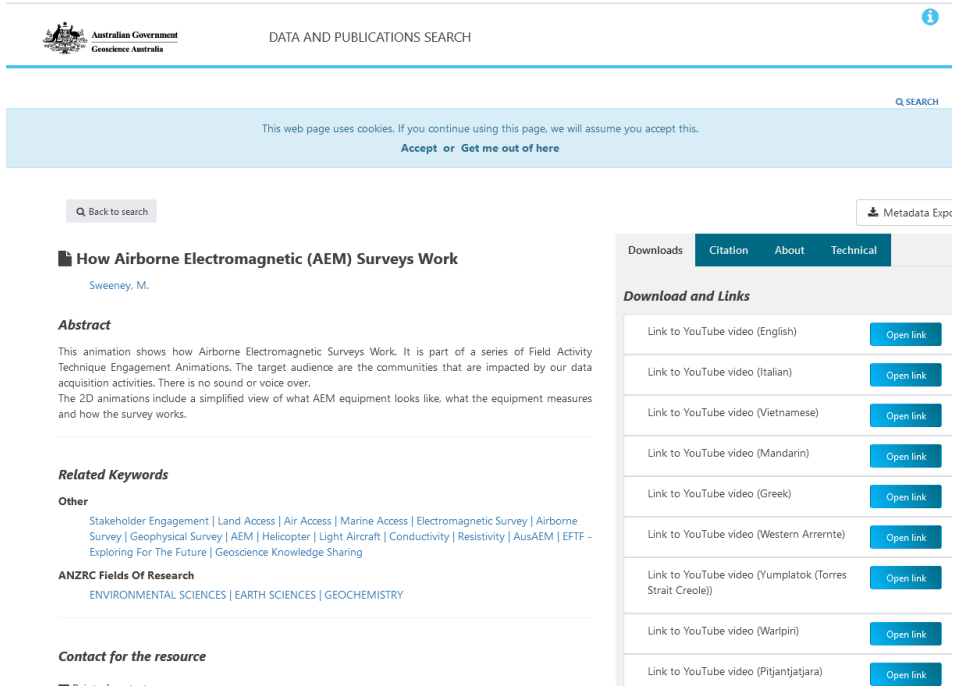
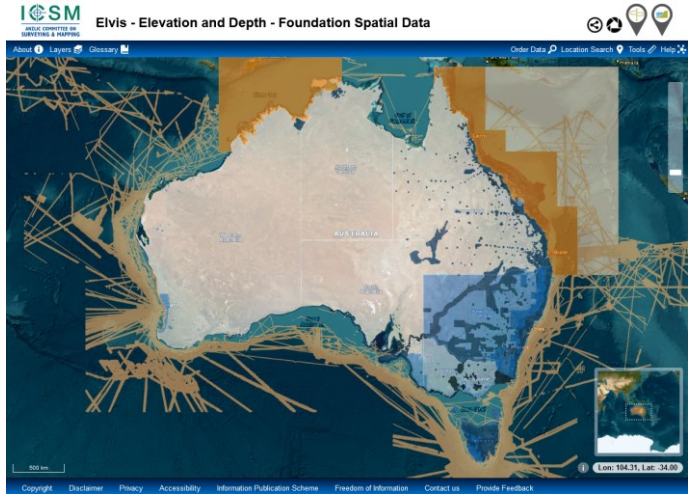


Discover existing public-domain spatial data

- ELVIS Elevation and Depth - Foundation Spatial Data
- VicMap Elevation
  (10 m DEM, 10-20 m contours)
- VicMap LiDAR points and LiDAR DEM
- VicMap Aerial Photography

Find out how to access licensed spatial data products at www.land.vic.gov.au/maps-and-spatial/spatial-data/how-to-access-spatial-data



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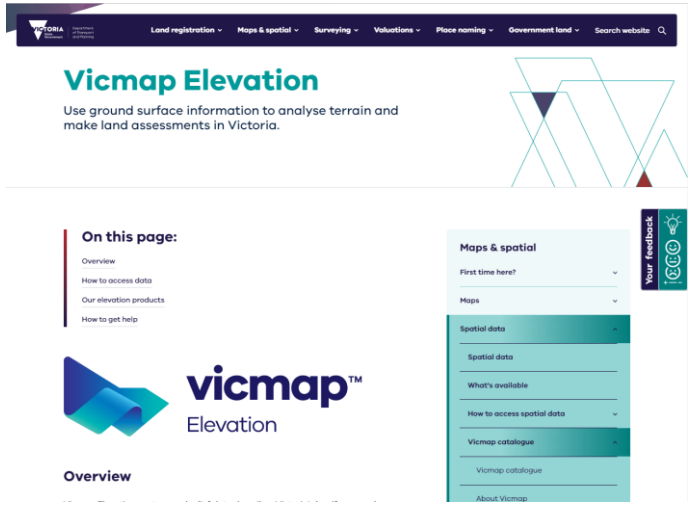

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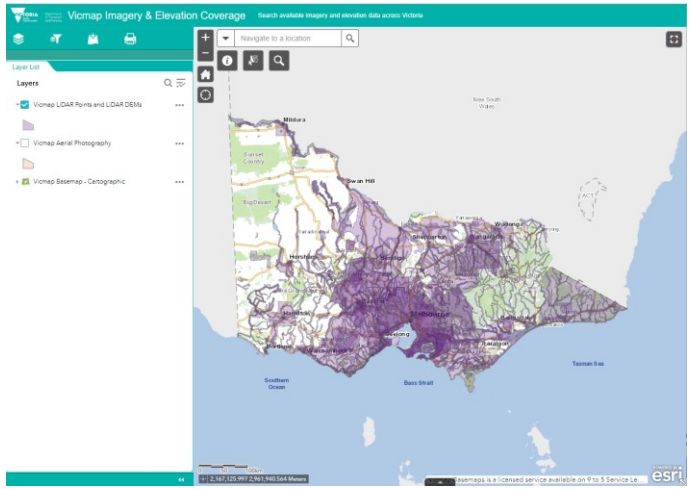
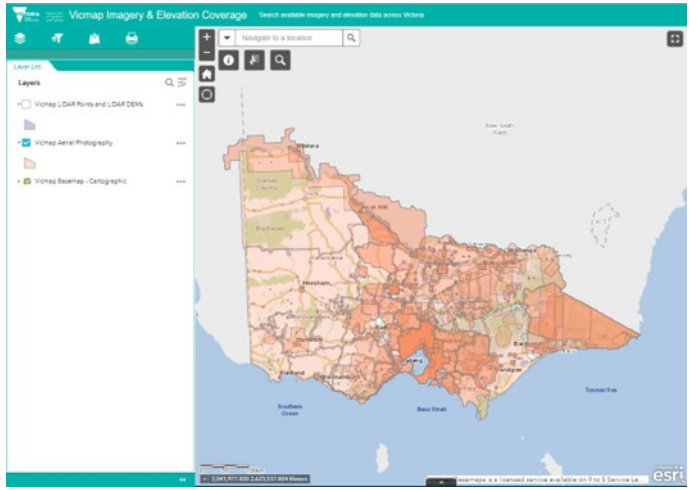
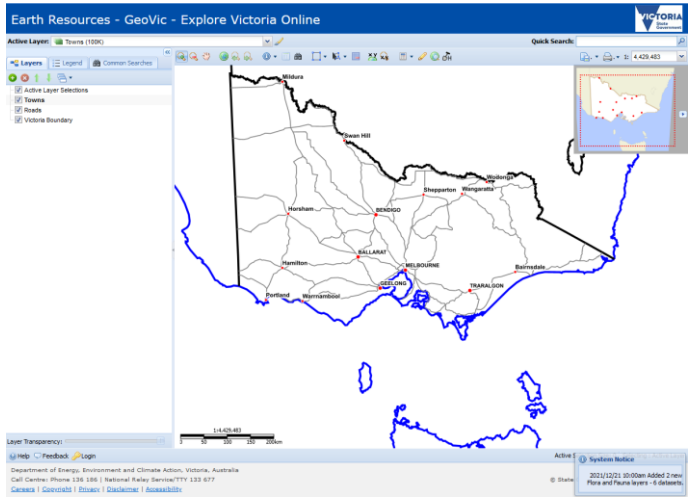




Open-File tenement data and GSV products

- GeoVic
- Geological Survey of Victoria Catalogue (Search Assistant)



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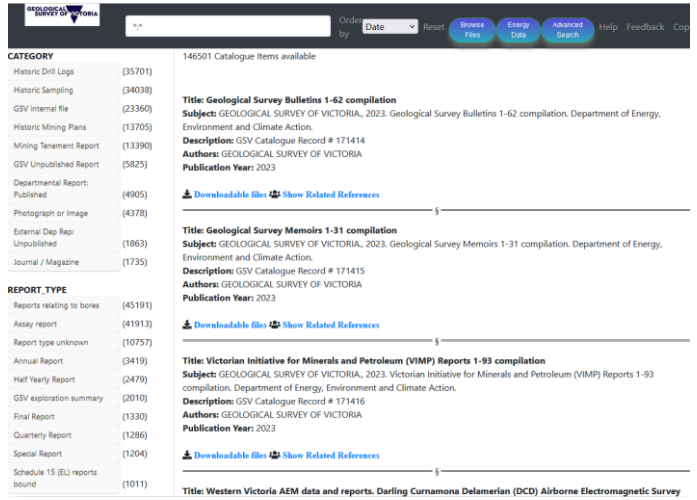

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Digital Airborne Geophysical Surveys Index demonstration

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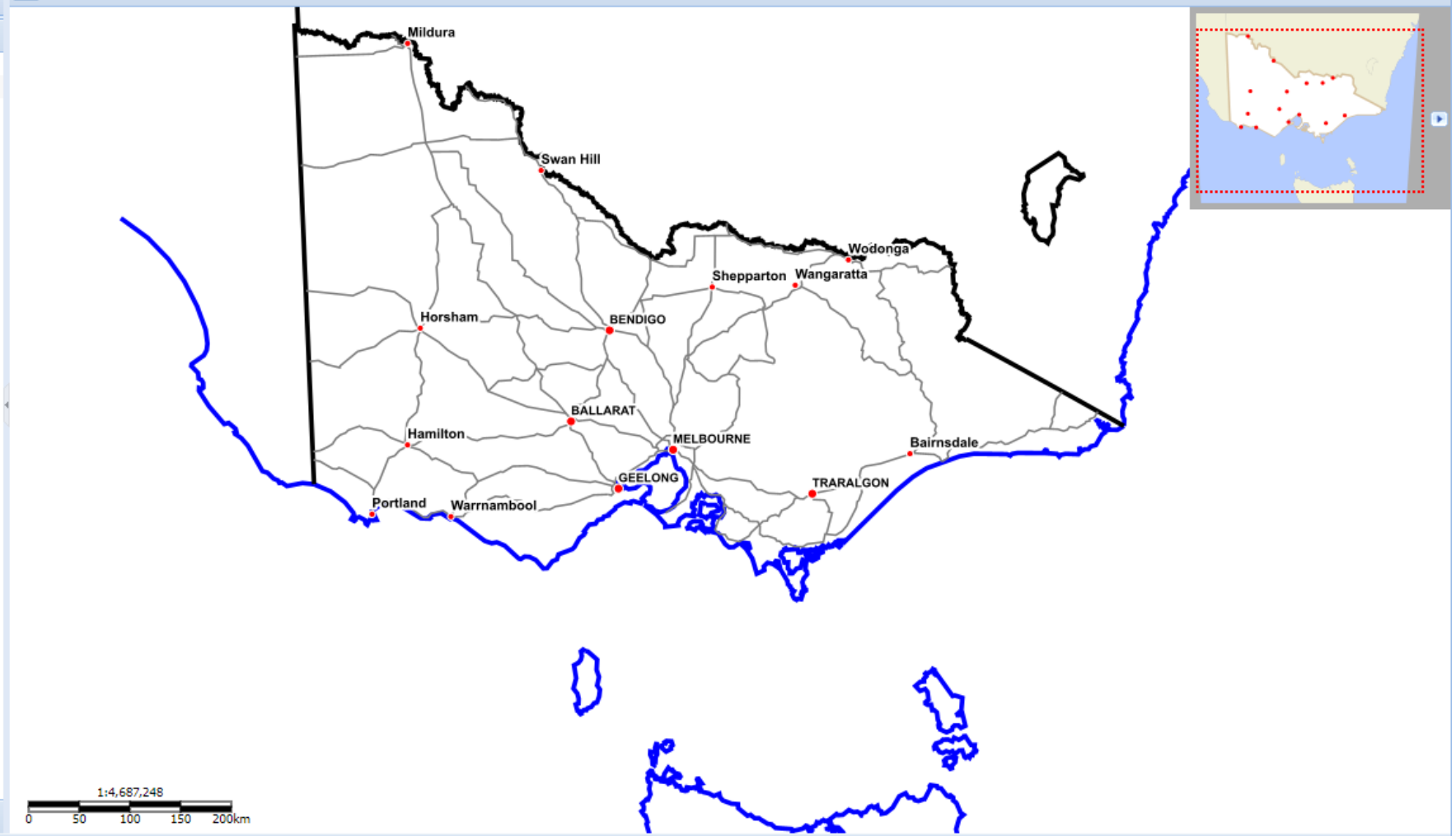

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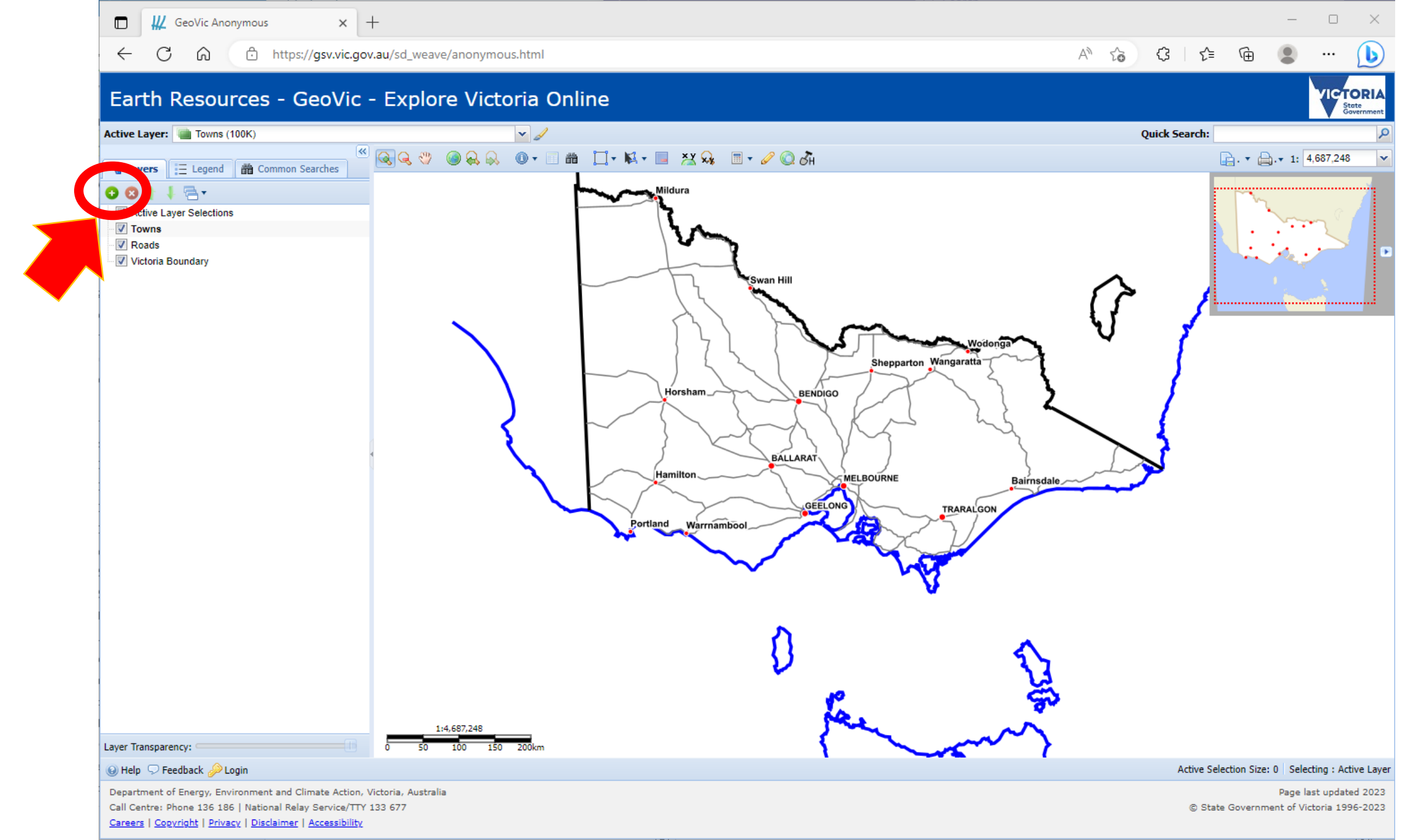
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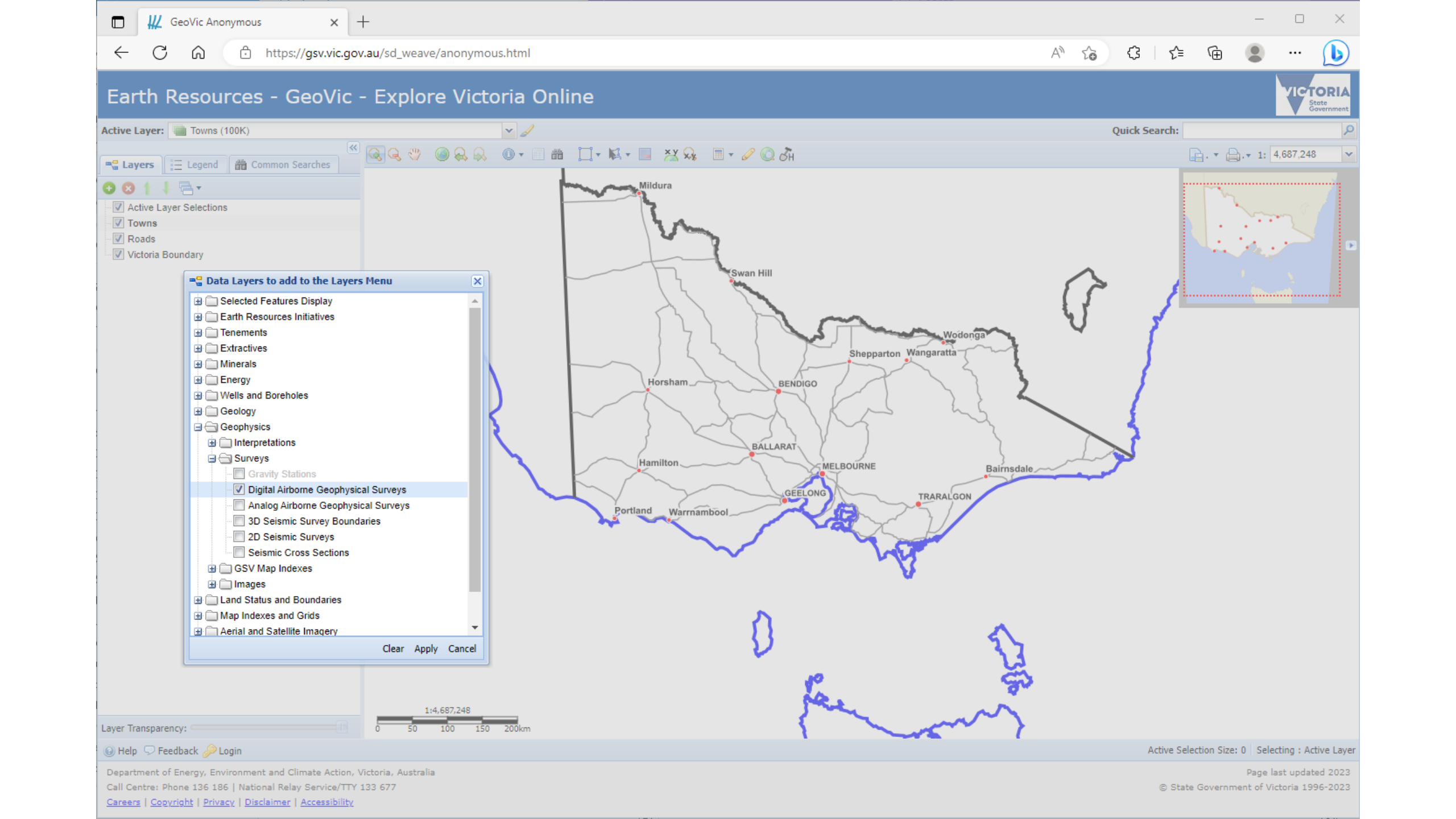
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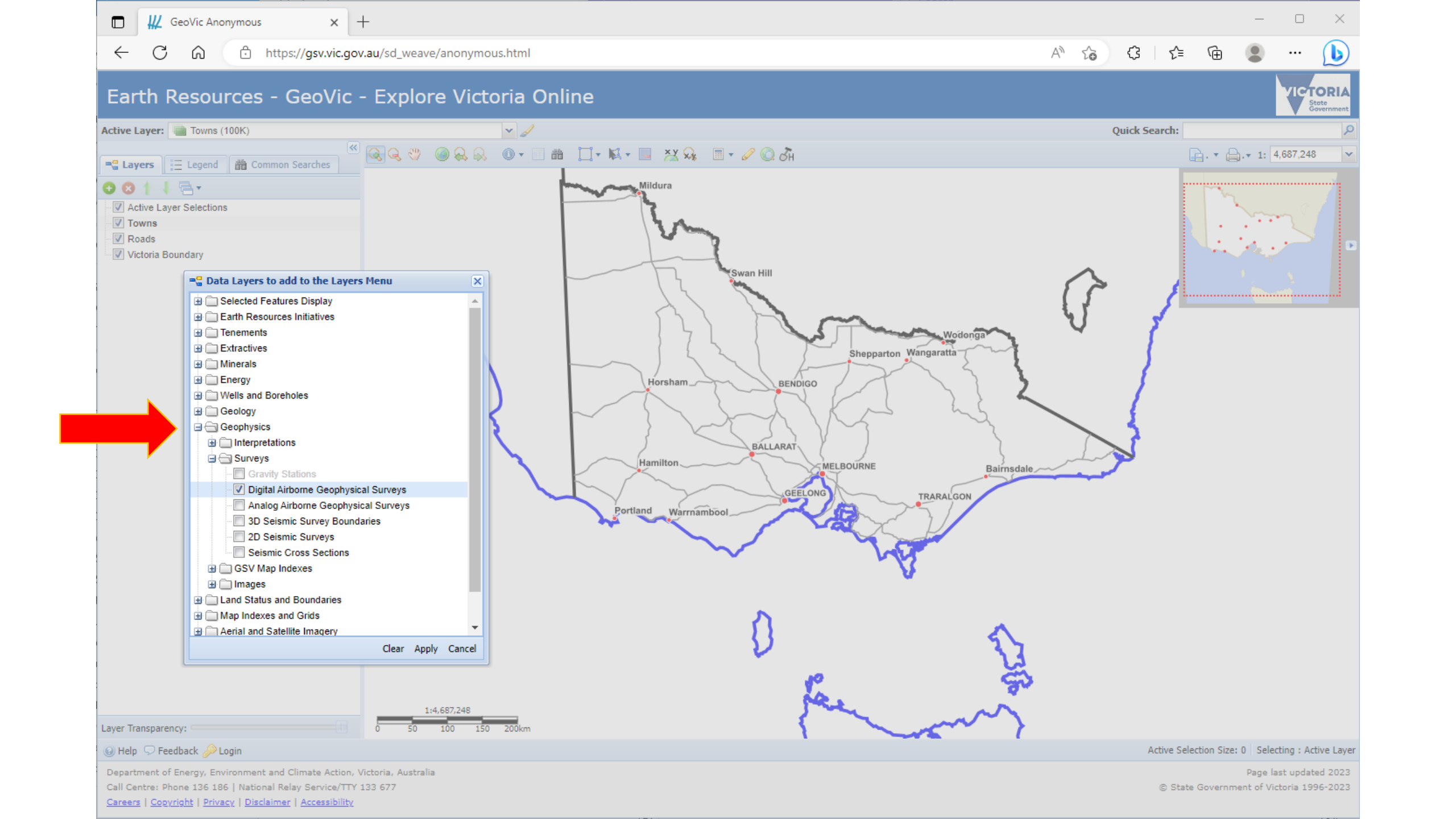
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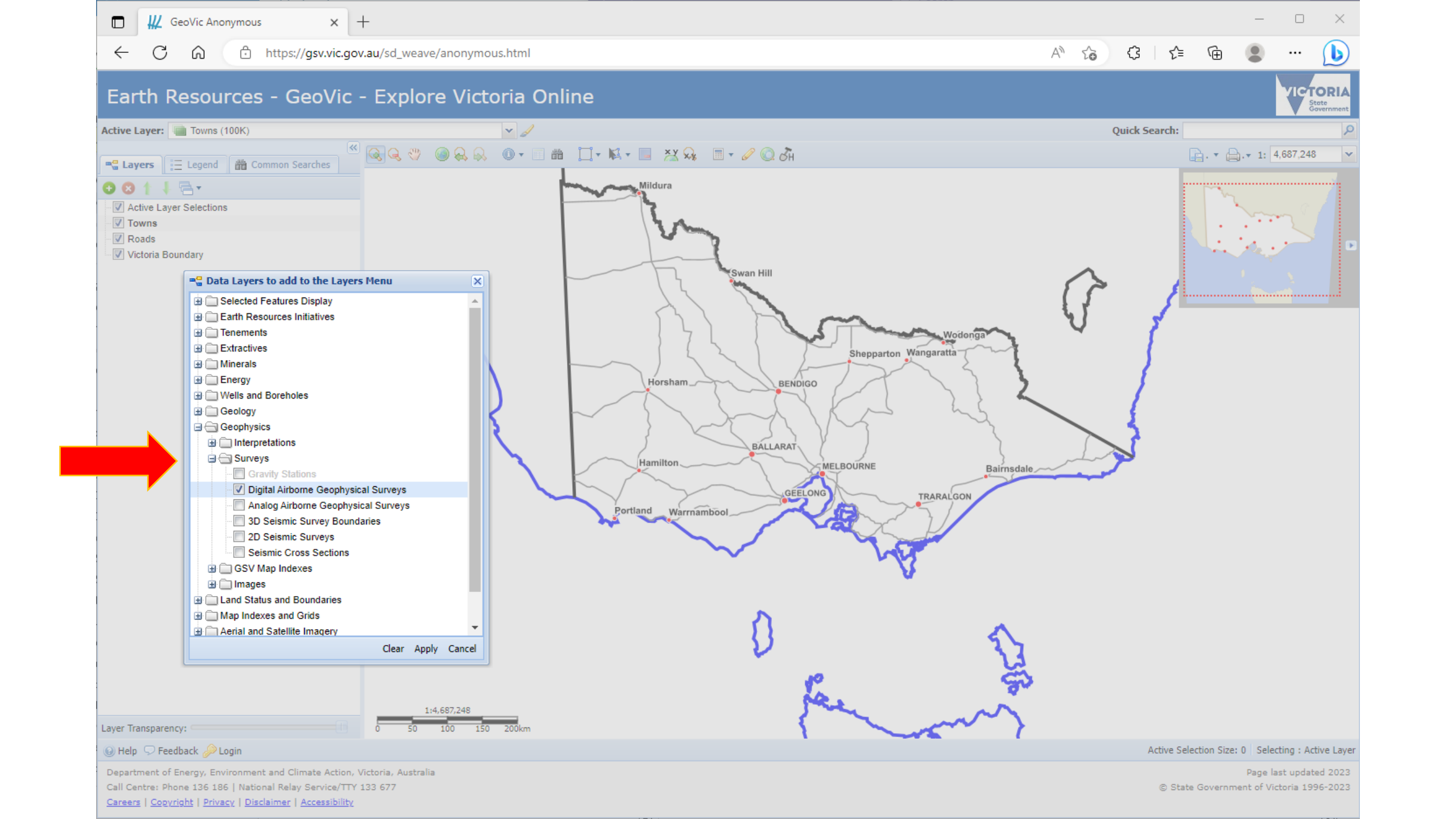
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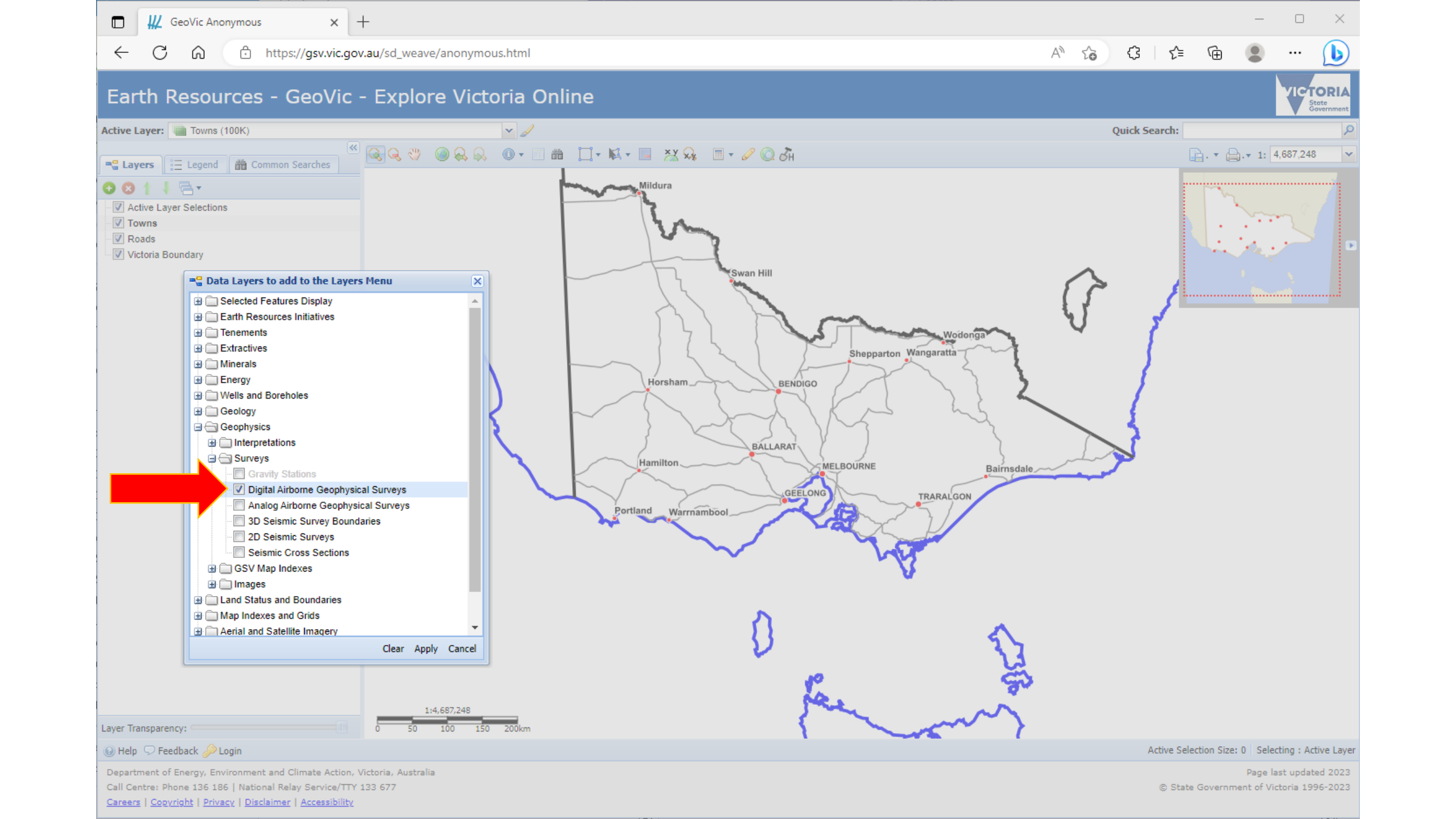
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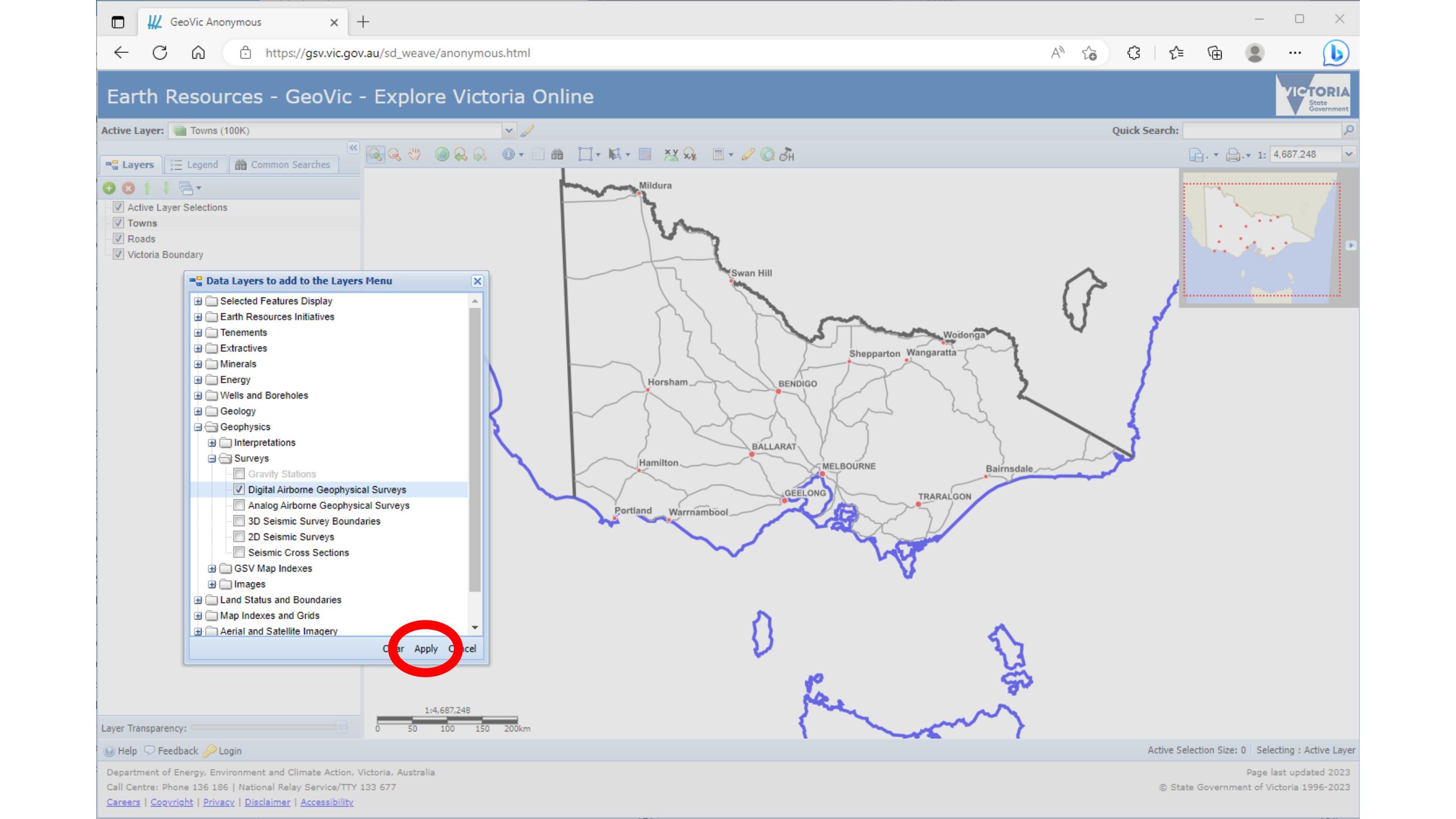
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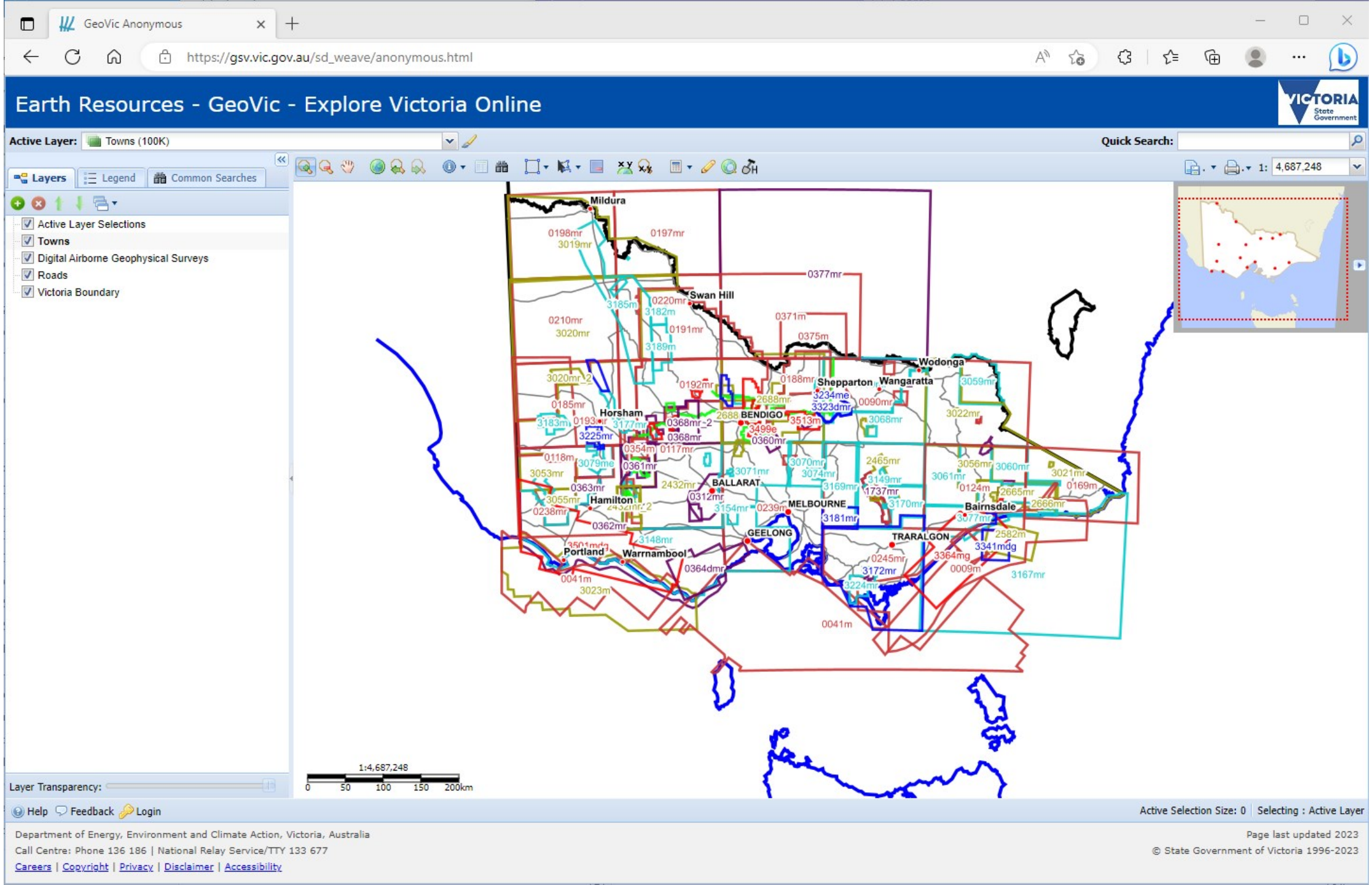
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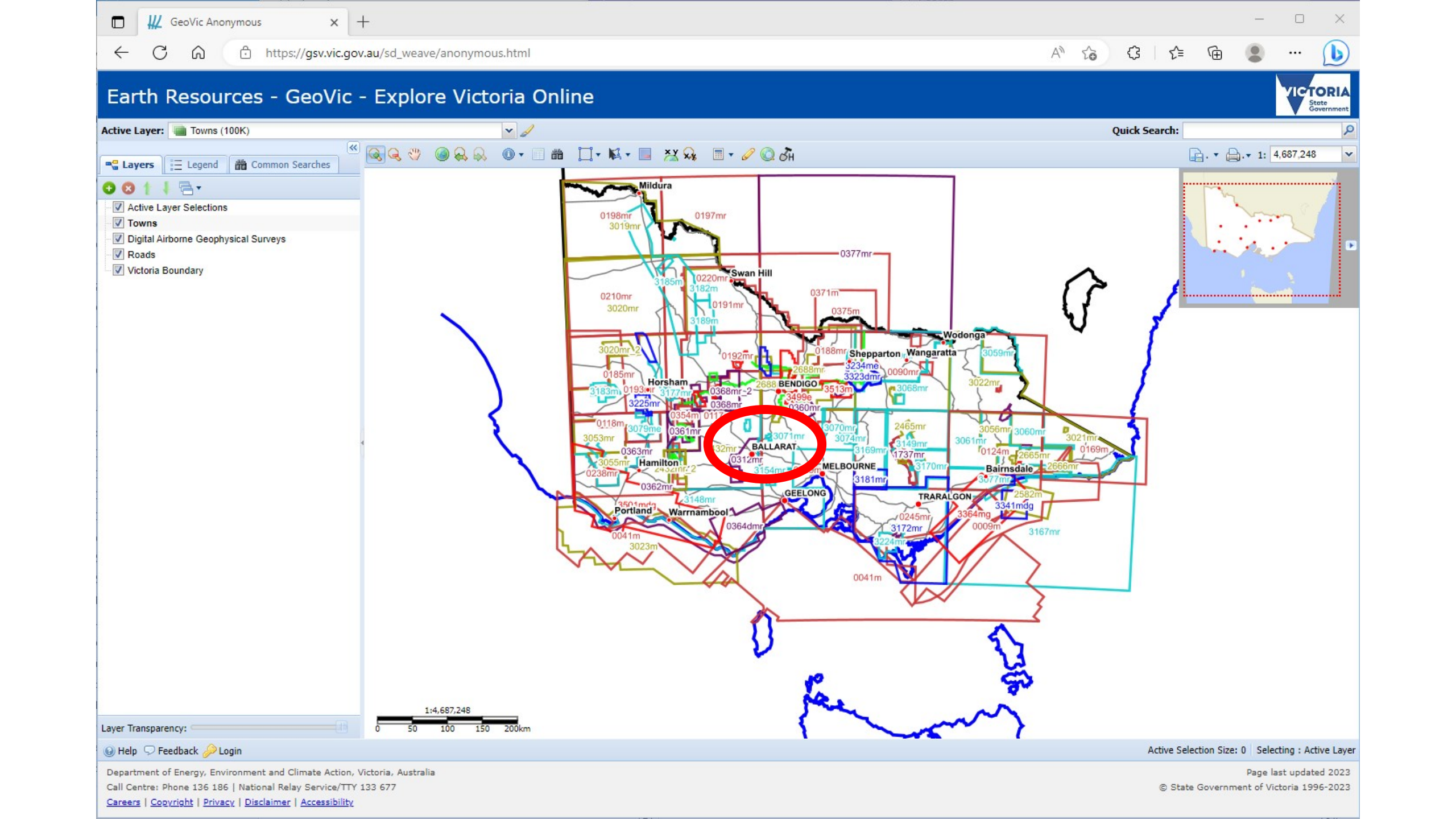
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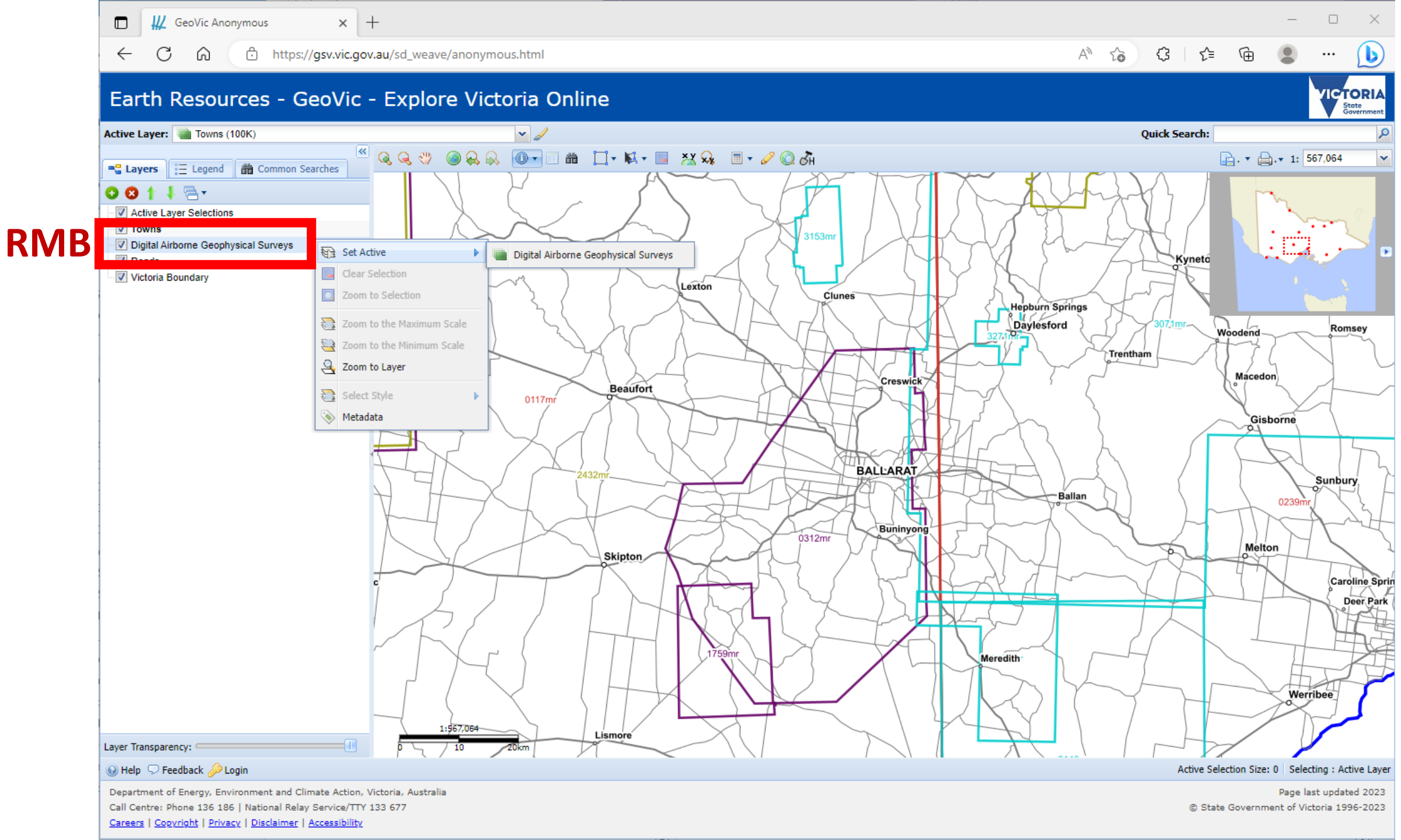
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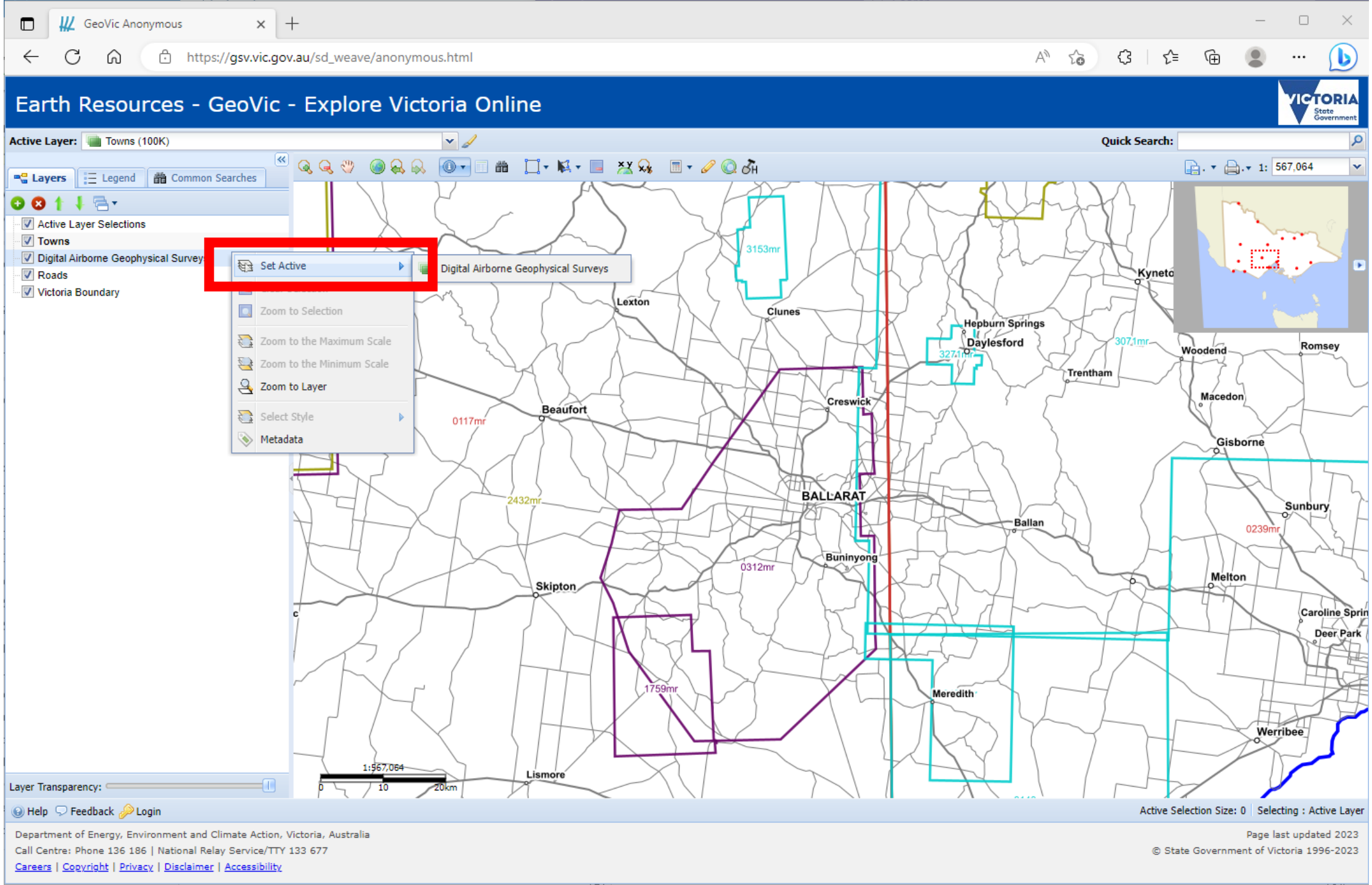
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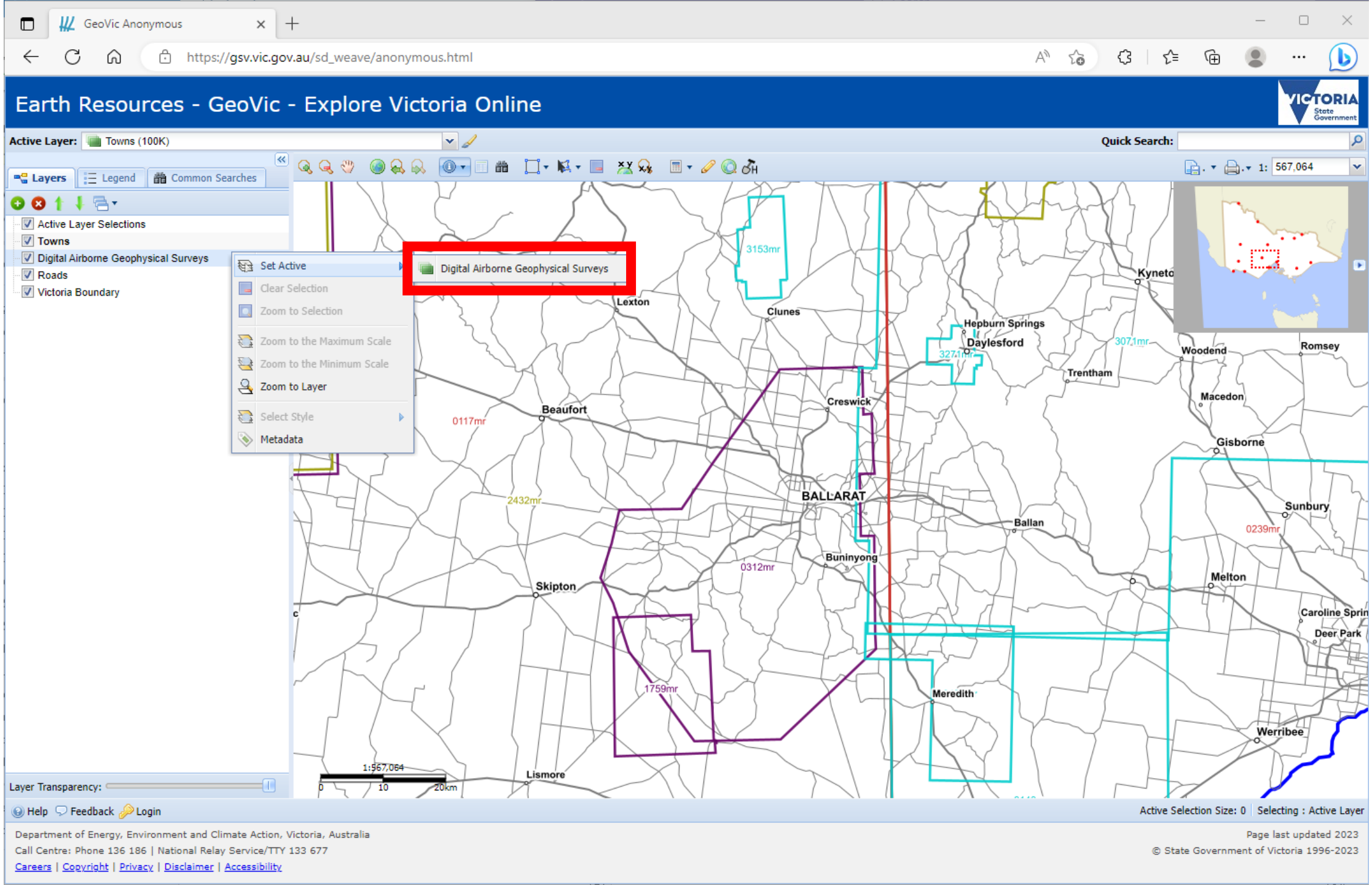
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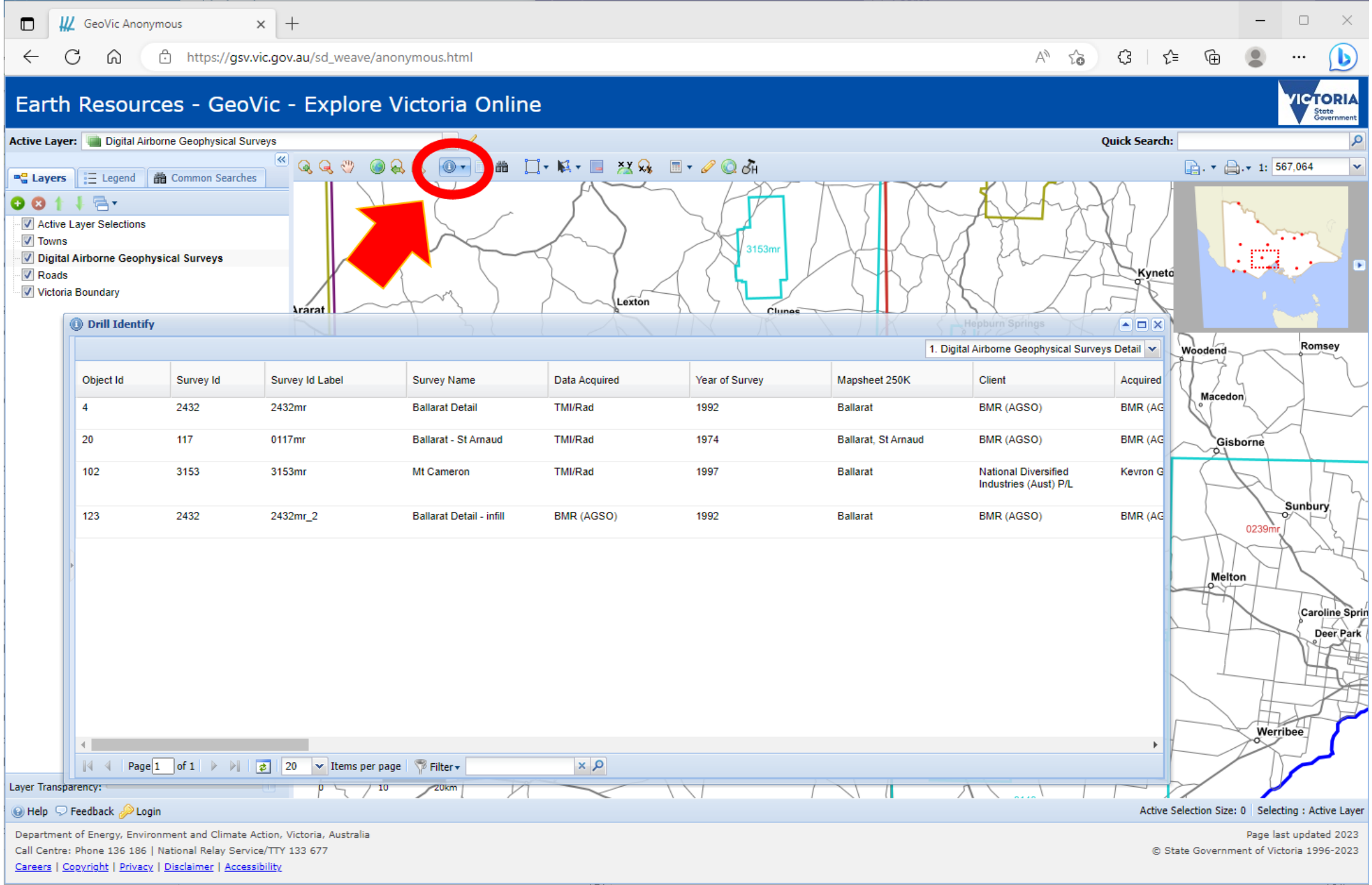
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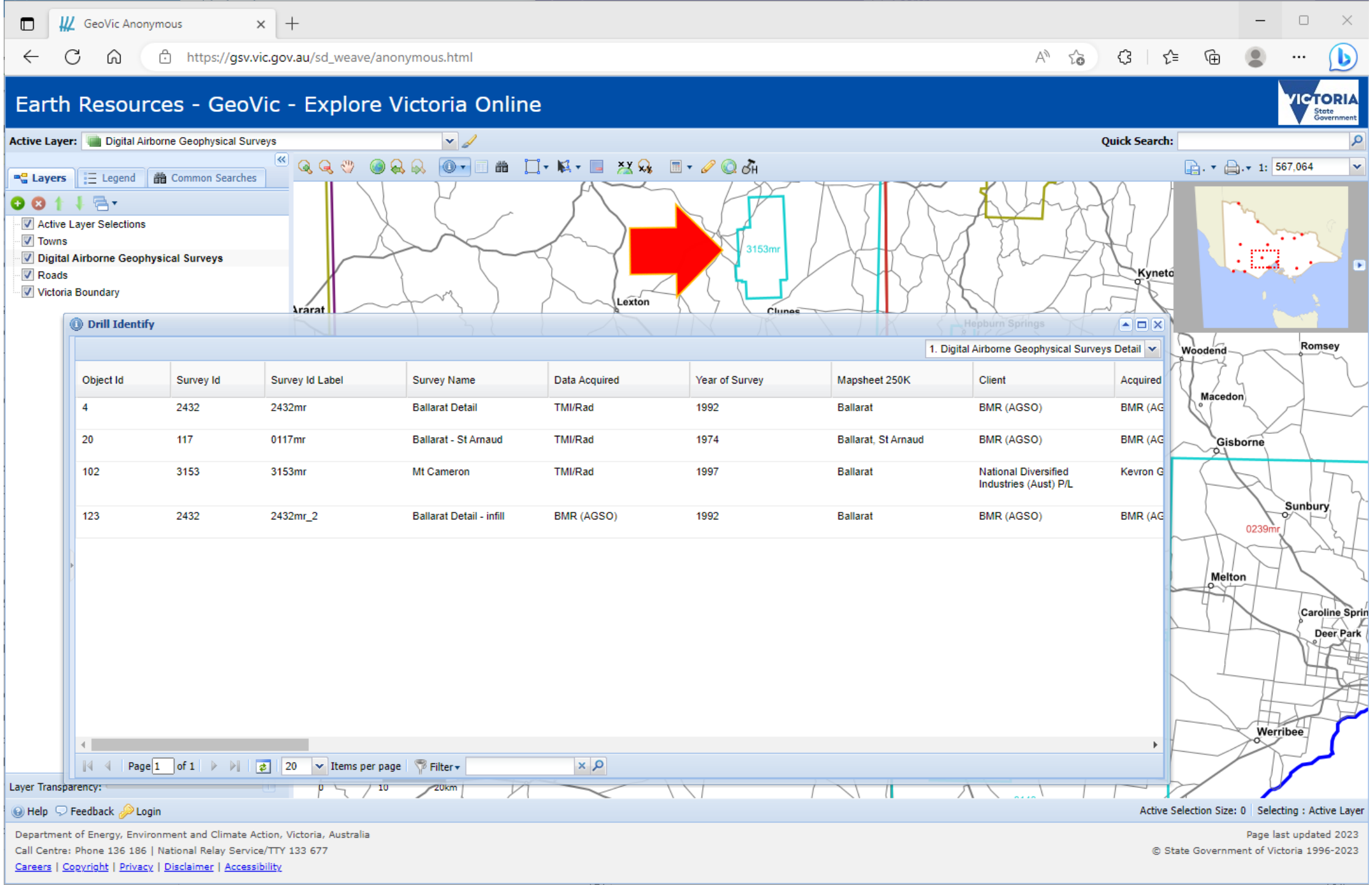
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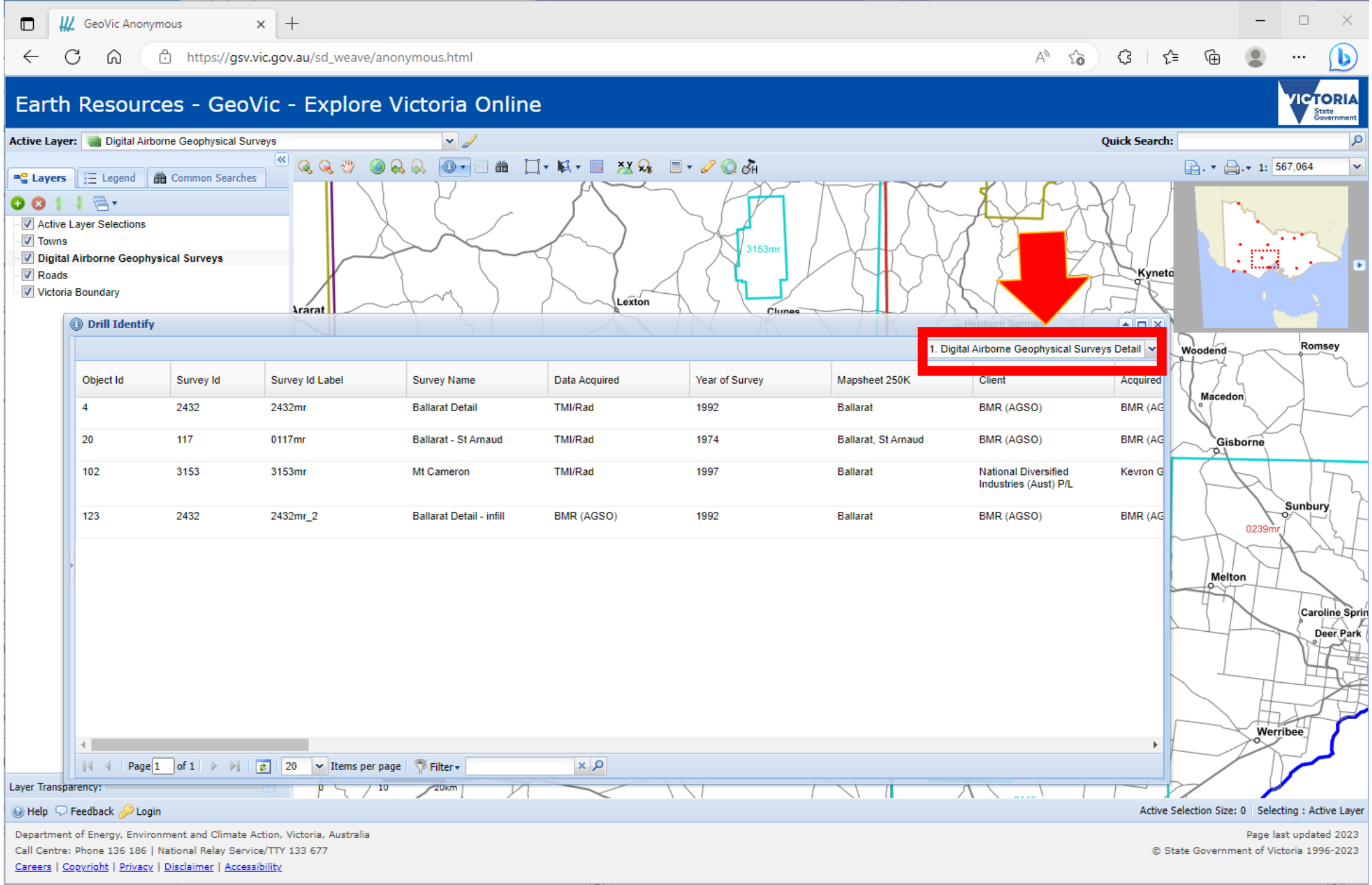
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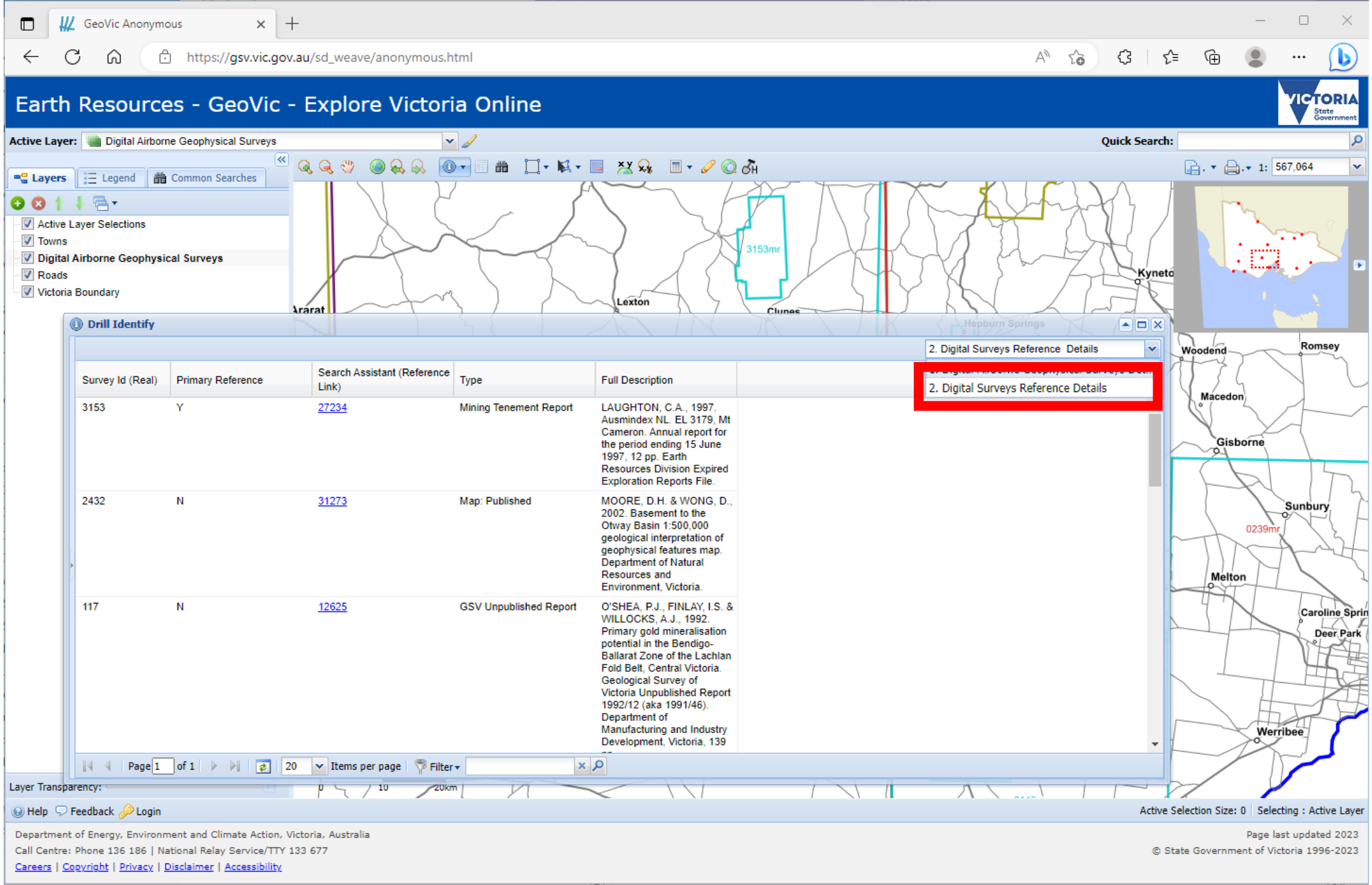
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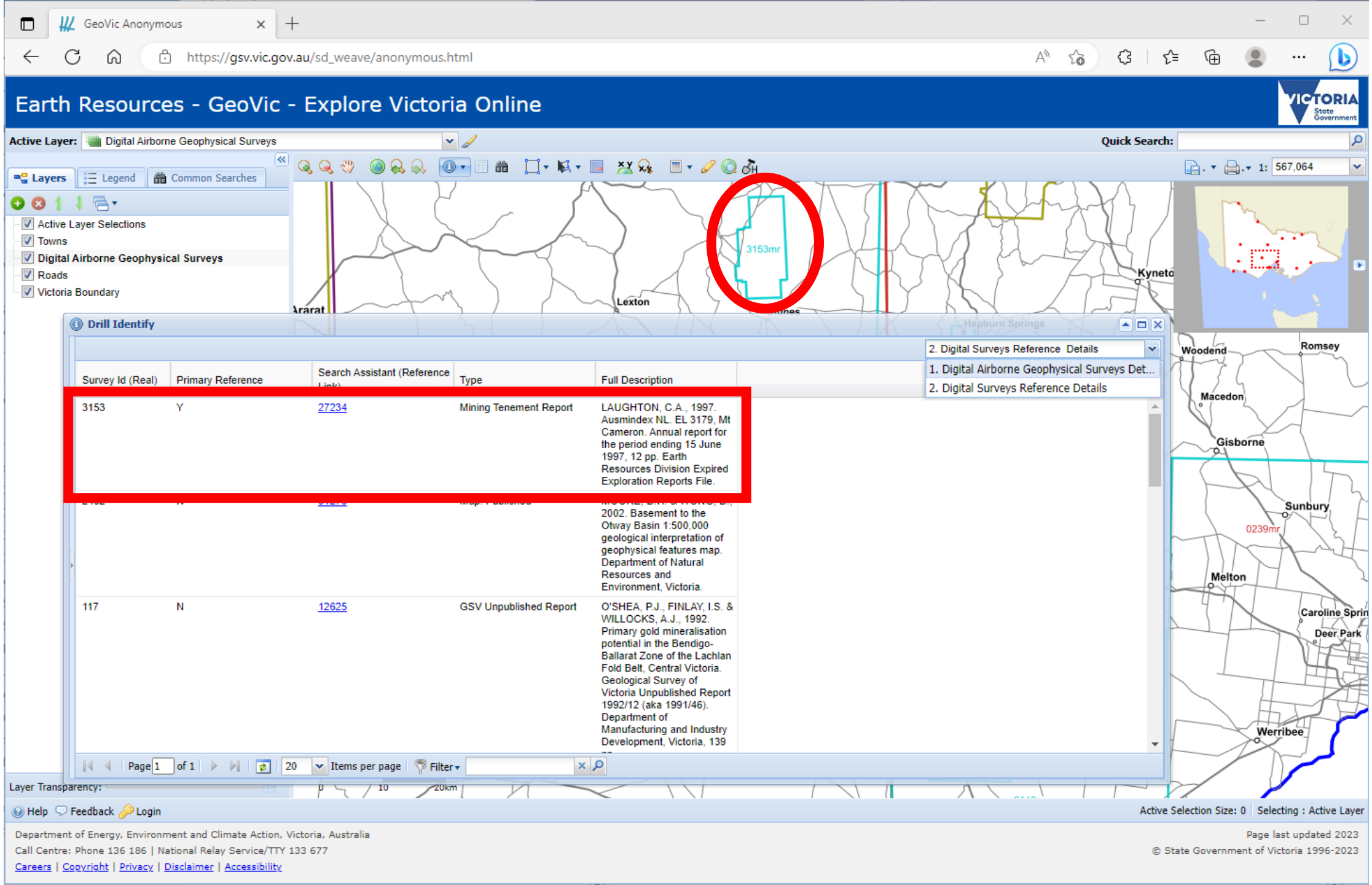
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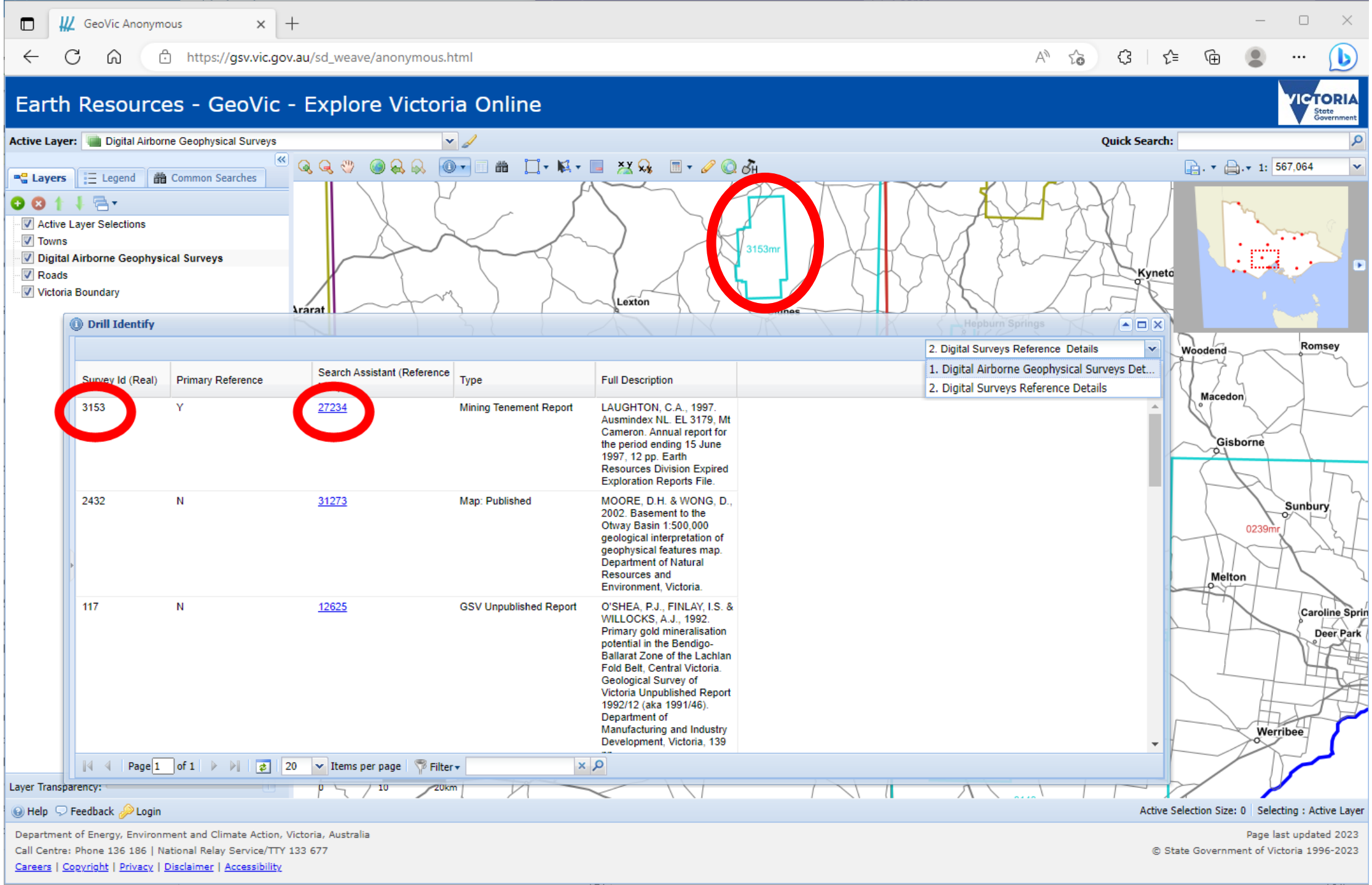
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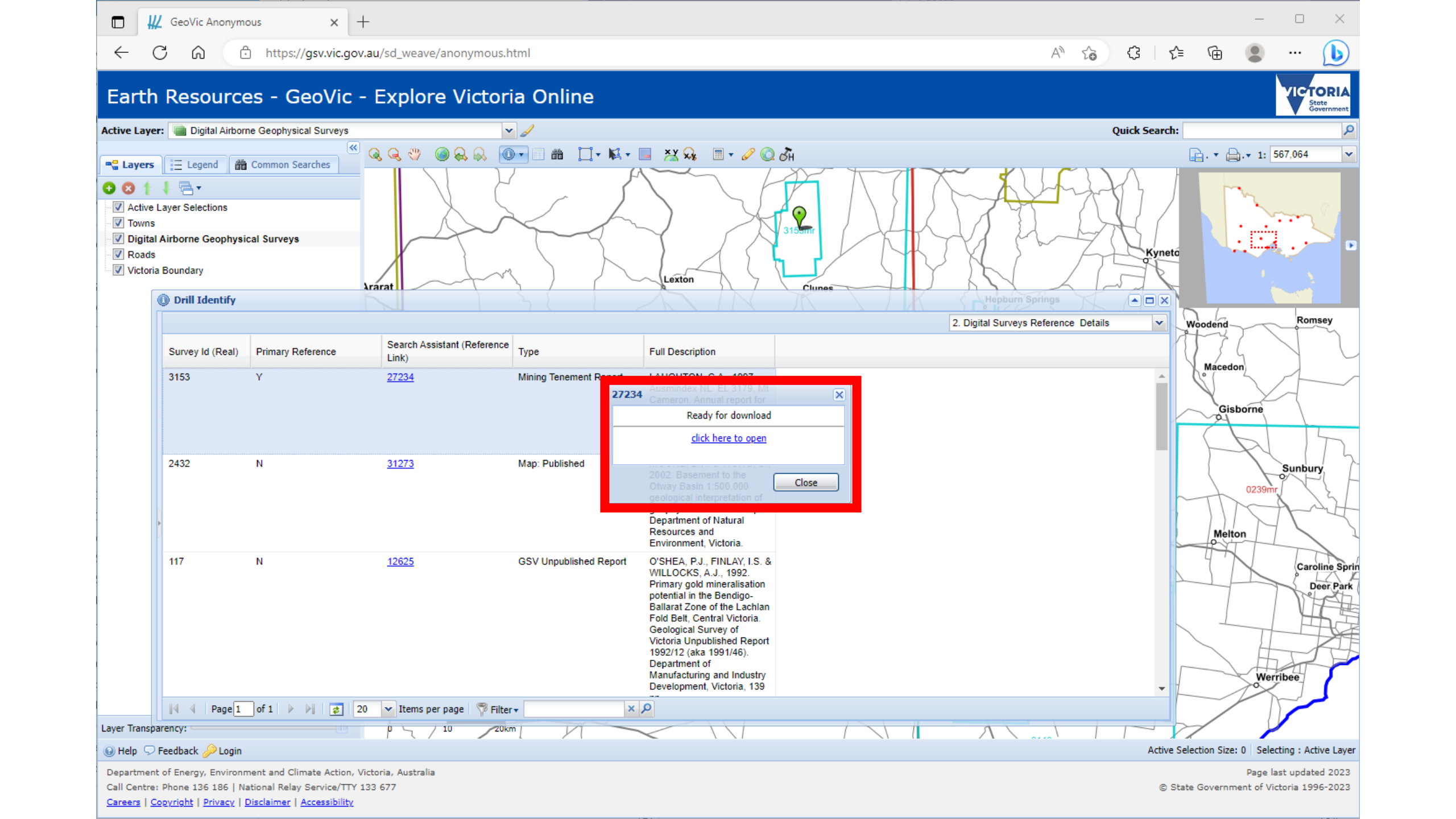
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Description: GSV Catalogue Record # 27234

Authors: LAUGHTON,C,A

Publication Year: 1997

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CATEGORY

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REPORT_TYPE

Annual Report (1)

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3.2 Aeromagnetic/radiometric survey

A 2233 line kilometre fixed wing aeromagnetic/radiometric survey was flown over all of the tenement area, except the northern two graticules, by Kevron Geophysics Pty Ltd, with dry ground conditions. The flight height above ground and flight line spacing were both 50 metres, with an effective magnetic ground sample interval of 3 to 4 metres, and sensor sensitivity of 0.001 nT. 256 channels of radiometric data were recorded with an "Exploranium" GR 820 self calibrating spectrometer to allow production of K, U, Th and Total Count data.

A trial TMI HSI image was produced, which showed the advantage of this data presentation method over the contoured format. Image processing of the magnetic data will be carried out by a consultant early in the next period to facilitate interpretation. Magnetic marker beds are evident in the Palaeozoic sequence, although the known auriferous reefs do not have a magnetic signature.

EL3179_G27234_199707_Annual.pdf (www.gsv.vic.gov.au/rid/27234)

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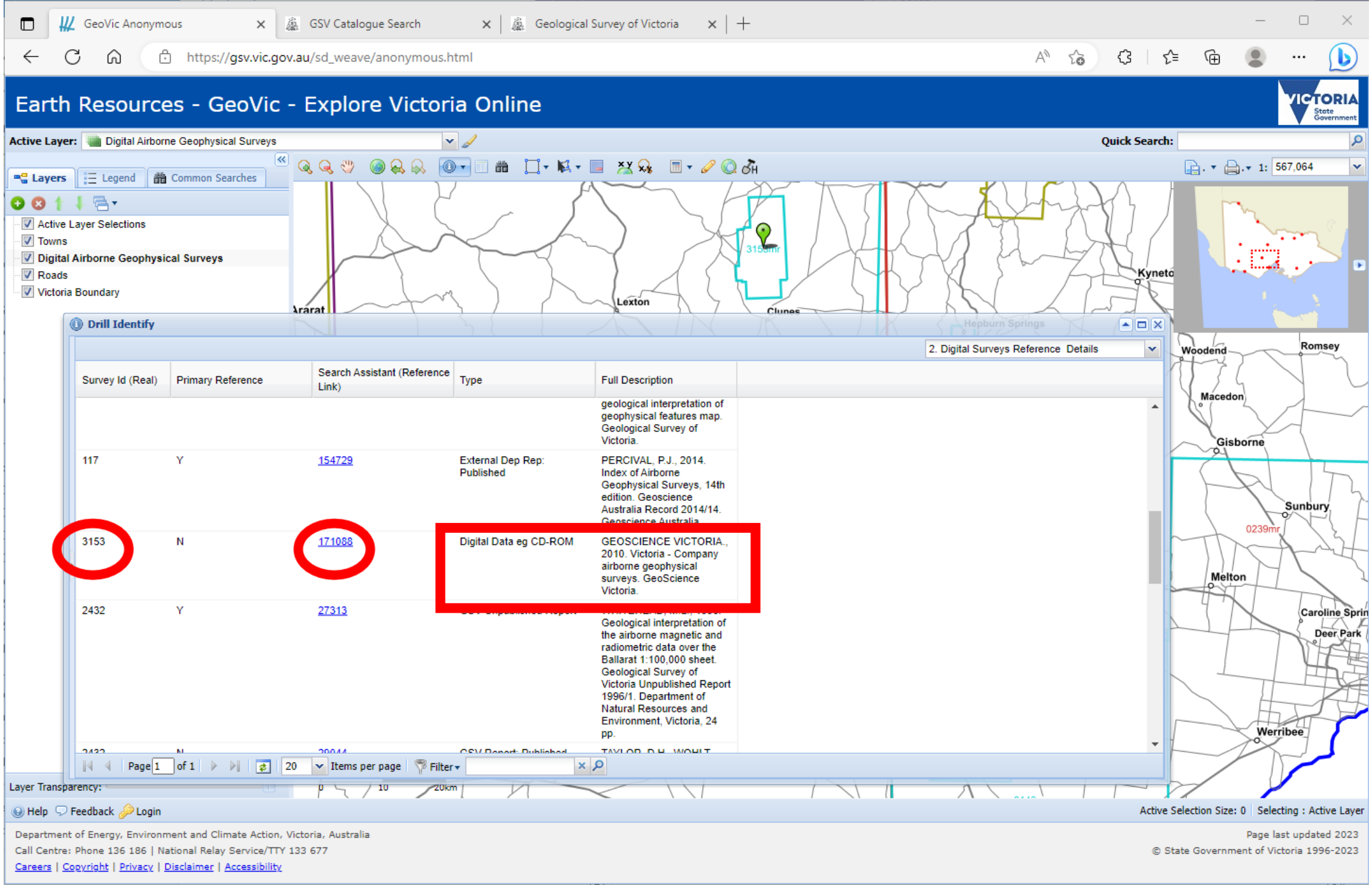
EL3179_G27234_199707_Annual.pdf (www.gsv.vic.gov.au/rid/27234)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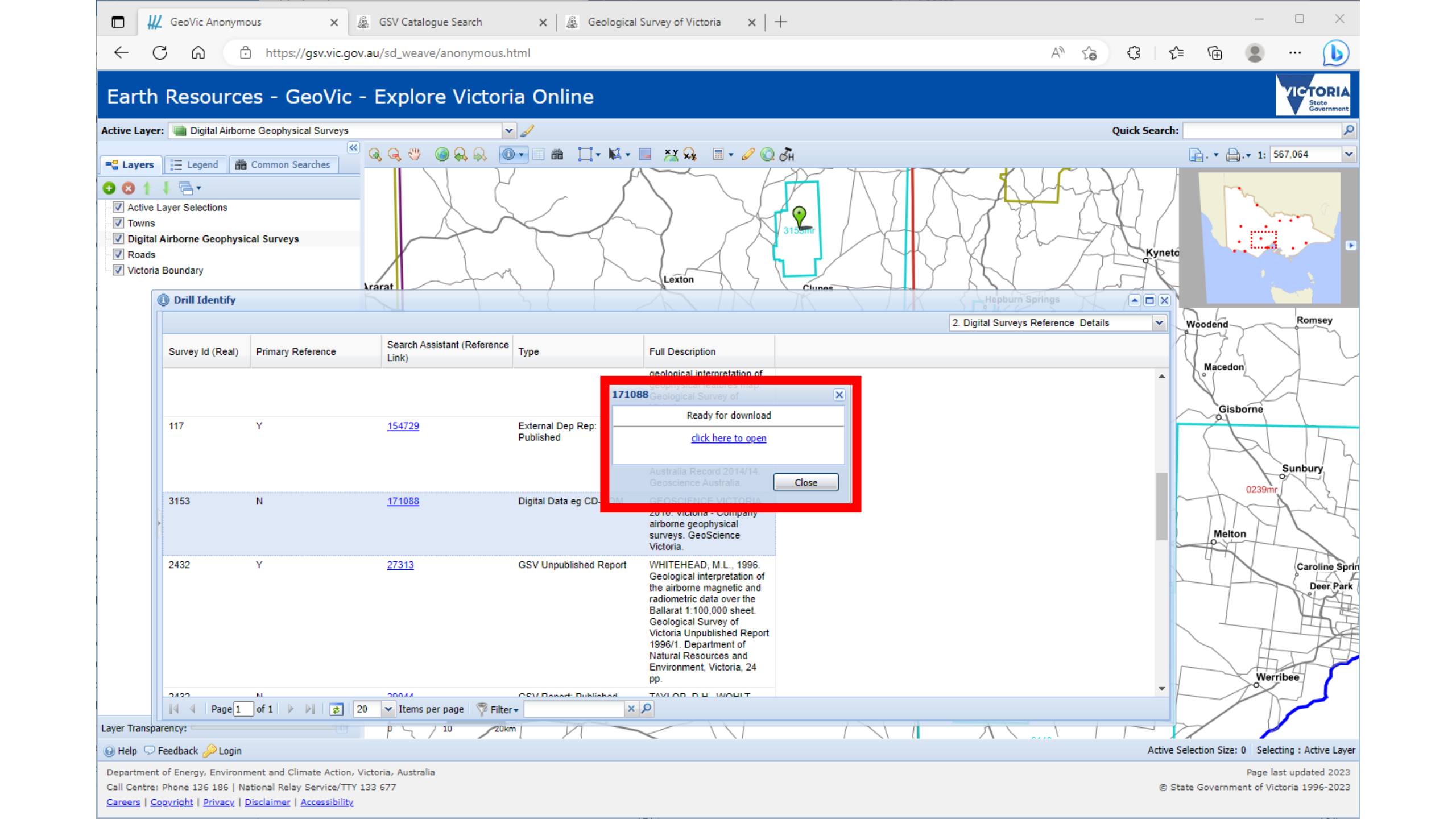
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Authors: GEOSCIENCE VICTORIA
Publication Year: 2010

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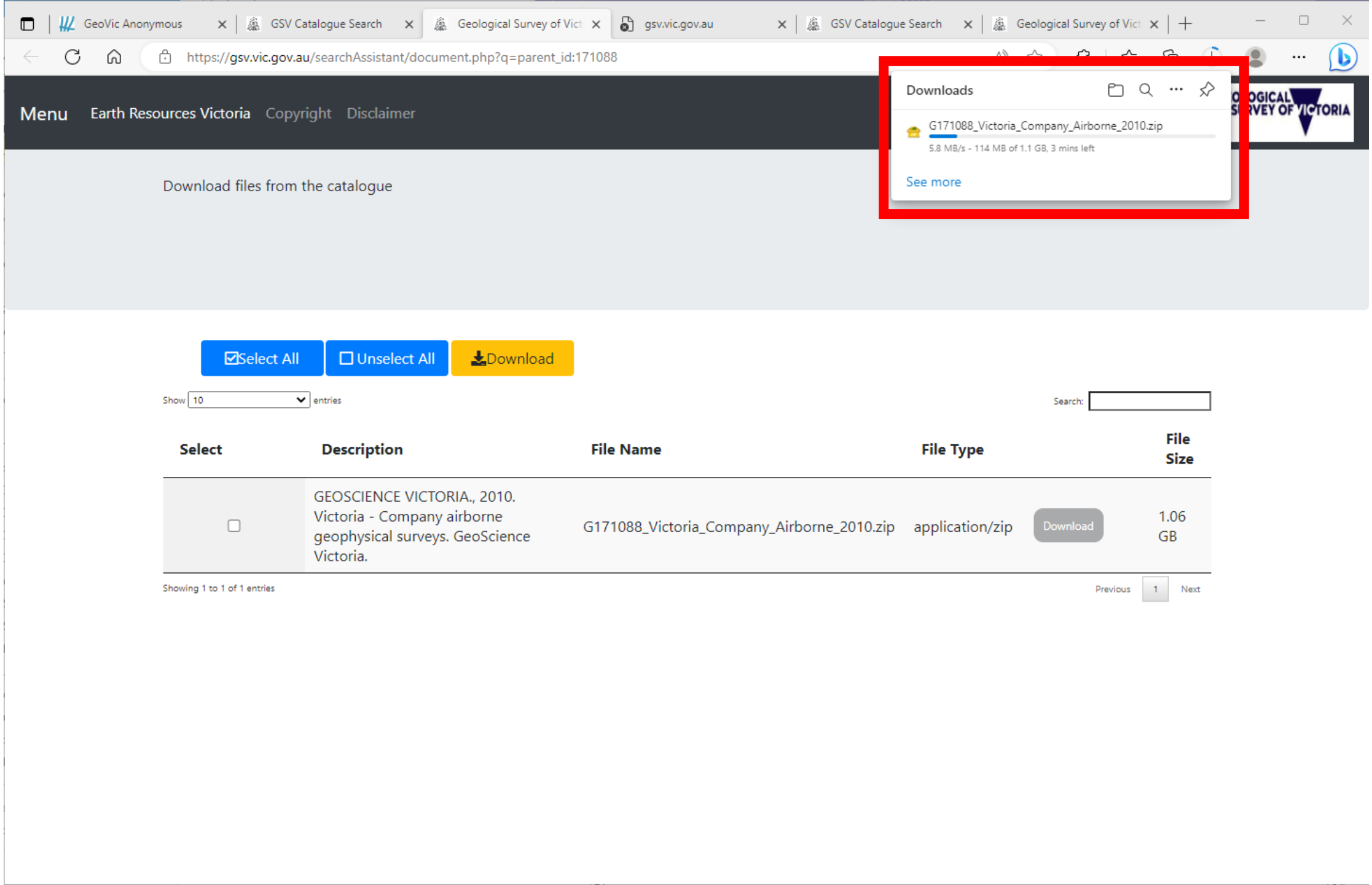
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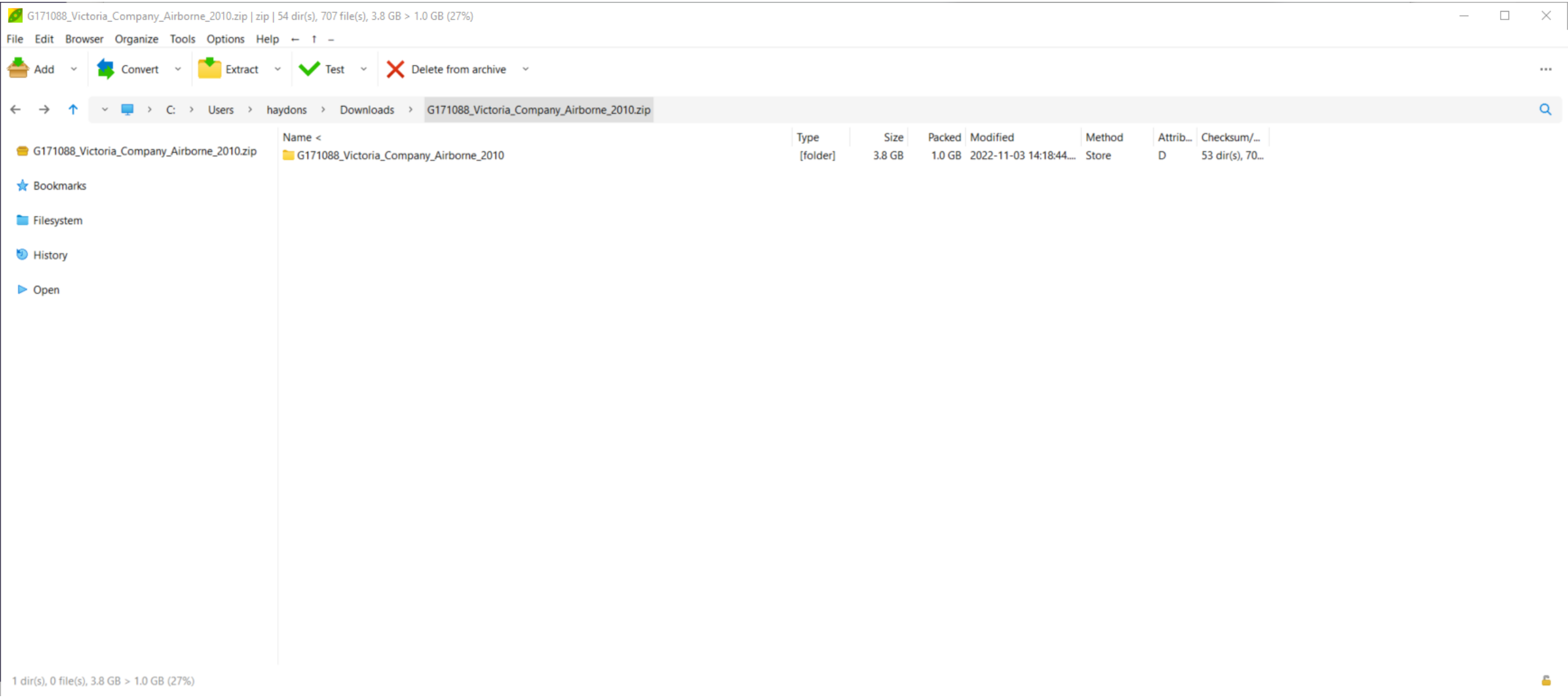
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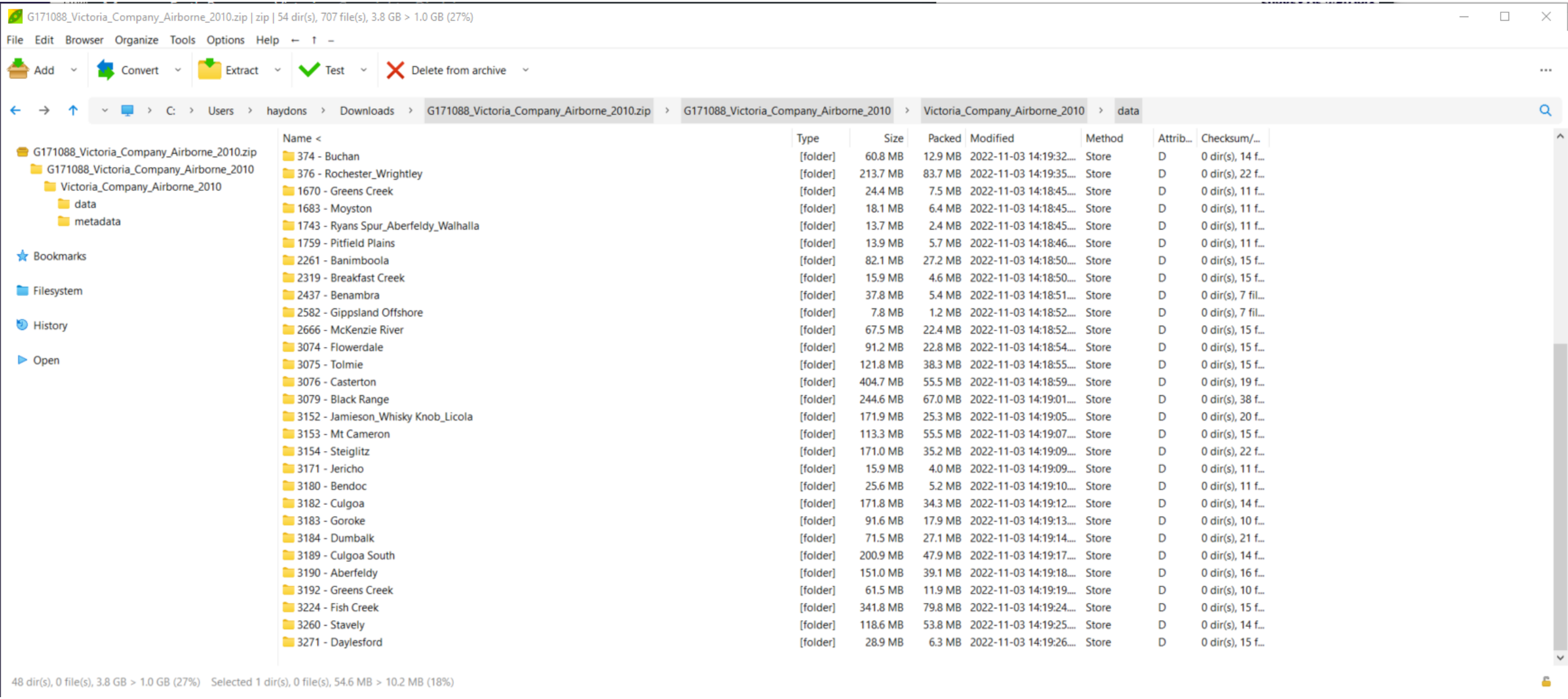
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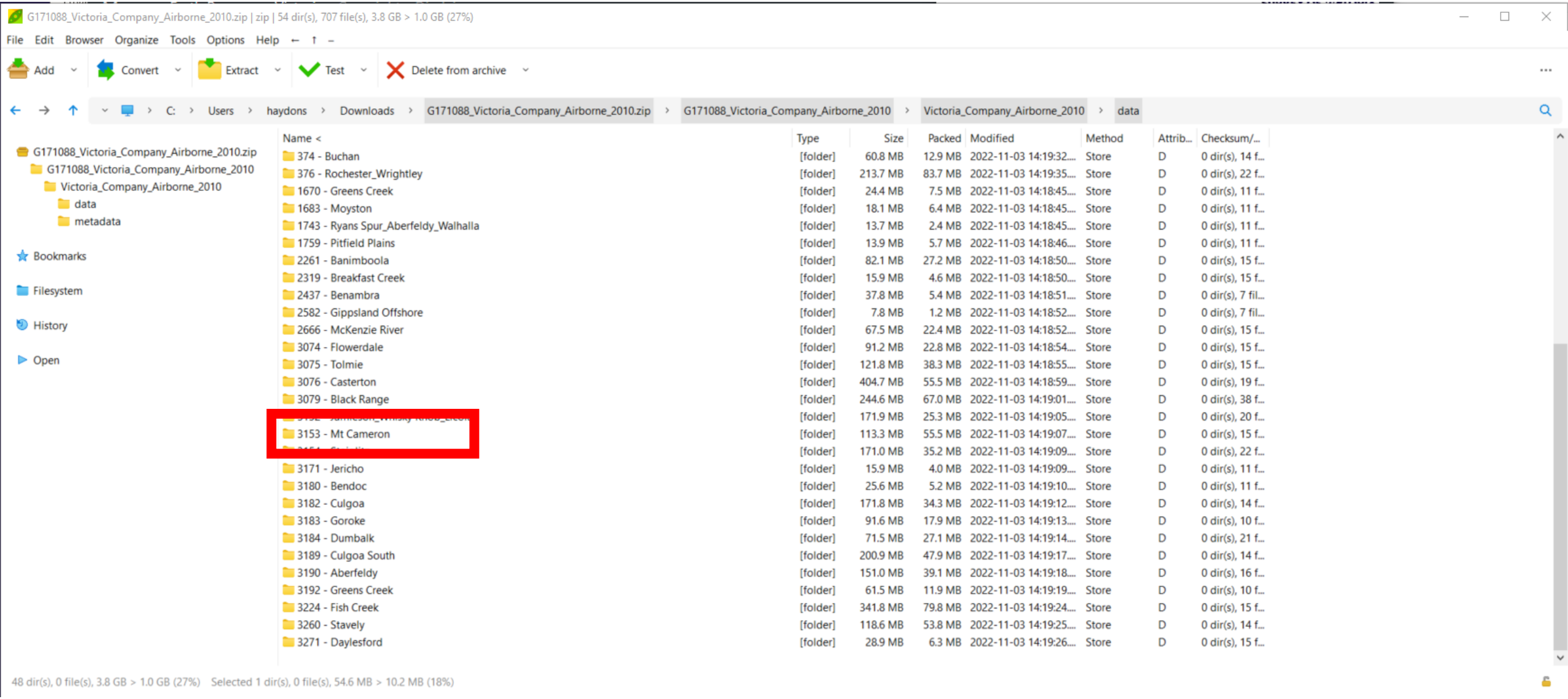
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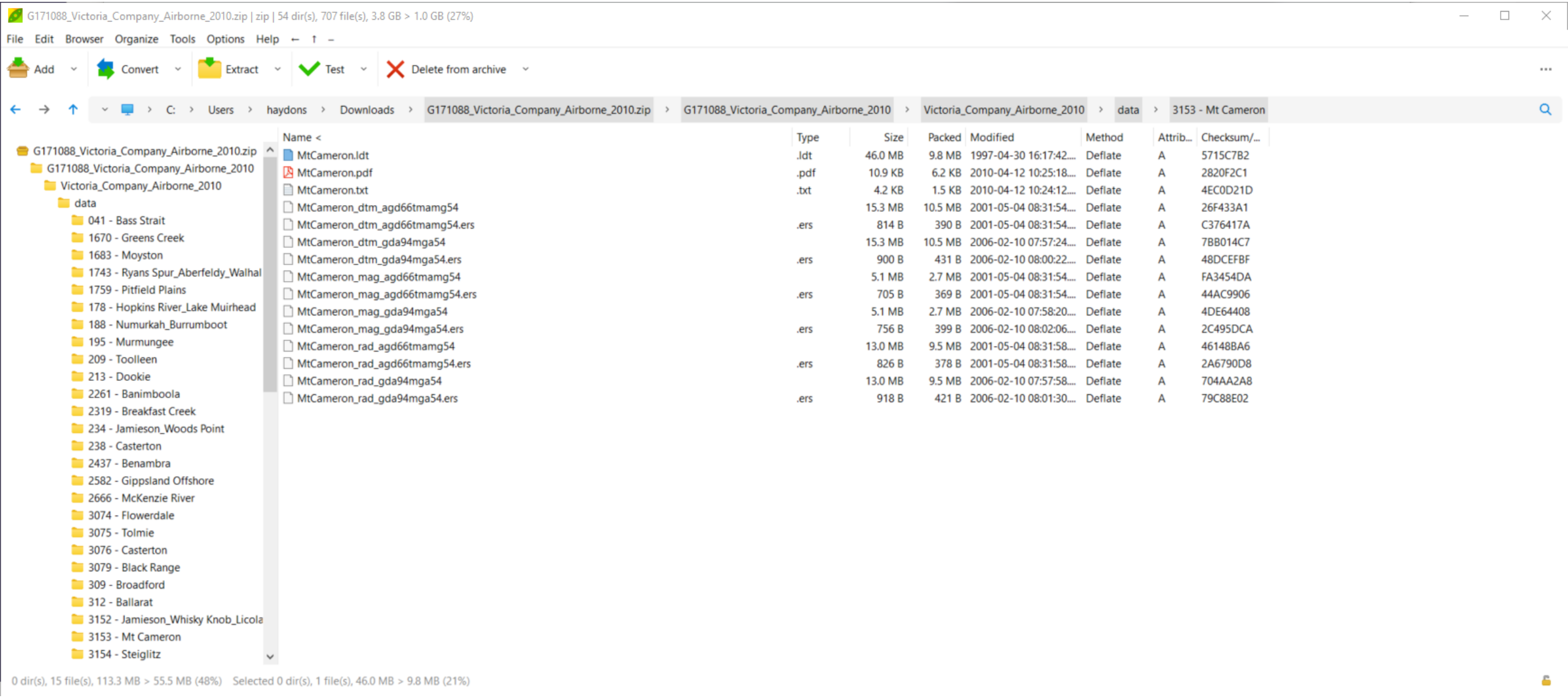
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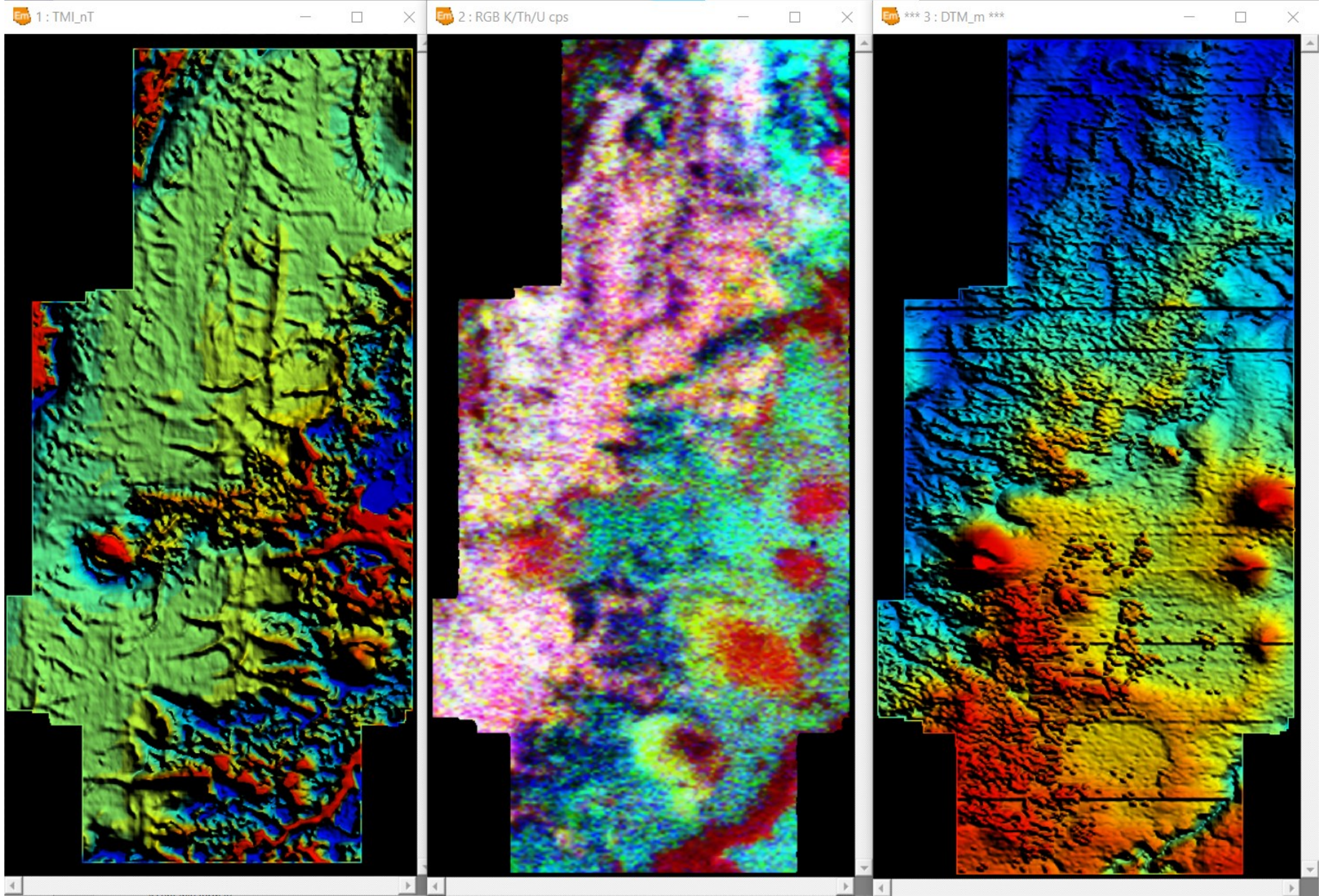
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Company Flown for: National Diversified Industries (Aust) Pty Ltd.
Company Processed: Kevron Geophysics Pty. Ltd.

AIRBORNE SURVEY EQUIPMENT:

Aircraft	Rockwell Aerocommander 500S VH-KAV
Magnetometer	Geometric G822A Cs Sensor
Magnetometer Resolution	0.001 nT
Magnetometer Compensation	RMS AADC operating in real time
Magnetometer Sample Interval	0.1 seconds (approx 7.0 metres)
Data Acquisition	RMS DAS-8
Data Recording	DC300 data cartridges
Spectrometer	Exploranium GR820
Crystal Size	33.6lt downward,4.2lt upward arrays
Spectrometer Sample Interval	1.0 Seconds (approx 70 metres)
Flight Path Record	VHS Colour Video System
GPS Navigation System	Ashtech XII GPS Receiver

AIRBORNE SURVEY SPECIFICATIONS:

Flight Line Direction	090 - 270 degrees
Flight Line Separation	50 metres
Tie Line Direction	000 - 180 degrees
Tie Line Separation	500 metres
Terrain Clearance	50 metres (MTC)

Survey flown	April 1997
Kevron Geophysics job number	1489

Data are in AGD66, UTM Grid Zone 54

GPS navigation data differentially corrected real time using Ashtech XII GPS and Omnistar receiver.

MAGNETIC DATA CORRECTIONS:

Diurnal variations removed
IGRF(1995) updated to 1997.27 removed
Average survey base station value and average
IGRF value of 5000 nT added to datum

RADIOMETRIC CORRECTIONS AND COEFFICIENTS:

Data has been corrected for aircraft and cosmic backgrounds.
Height corrected to a constant datum of 50 metres,
minimum height of 20 and a maximum of 300 metres.
Data has also been corrected for radon using an upward detector
and corrected for channel interaction.

	Tot.Count	Potassium	Uranium	Thorium	Uranium Up
Arcft Bkg	42.06	9.34	0.57	1.04	0.07
Cosmic Bkg	0.65315	0.03360	0.03050	0.03841	0.00405
Height Attn	-0.00729	-0.009370	-0.00821	-0.00742	0.0082

STRIPPING RATIOS:

---

alpha = 0.2575 beta = 0.4078 gamma = 0.781 delta = 0.077

CONCENTRATION COEFFICIENTS:

K40 = 91.81 bi214 = 6.538 tl208 = 4.6

RADON CORRECTIONS:

---

a1= 0.02564 a2= 0.02245 aI= 10.459 aK= 0.716 aU= 0.20000 aT= 0.0368

DATA TAPE FORMAT:

---	undefined	
line number	a8	
date	a8	
fiducial	f10.0	-999999999
easting	f11.0	-99999999
northing	f11.0	-99999999
raw magnetics	f9.2	-99999.00
diurnal	f9.2	-99999.00
levelled magnetics	f9.2	-99999.00
radar altimeter	f6.1	-999.0
baro altimeter	f6.1	-999.0
raw total count	f6.0	-99999
raw potassium	f5.0	-9999
raw uranium	f5.0	-9999
raw thorium	f5.0	-9999
corrected total count	f6.0	-99999
corrected potassium	f5.0	-9999
corrected uranium	f5.0	-9999
corrected thorium	f5.0	-9999
cosmic	f8.3	-9999.00
local time	f9.5	-99.00000

Reduce, Reuse, **Recycle**

Acquire high quality geoscience data that can be Recycled into new and improved products

- Detailed technical specifications
- Measure the quality to be confident in the results
- Receive and deliver complete, well-described data

GEOLOGICAL SURVEY OF VICTORIA

Fit-for-purpose, detailed technical specifications

- Ask an expert for advice
  - Local network
  - Australian Society of Exploration Geophysicists (ASEG)
  - ASEG Technical Standards Committee

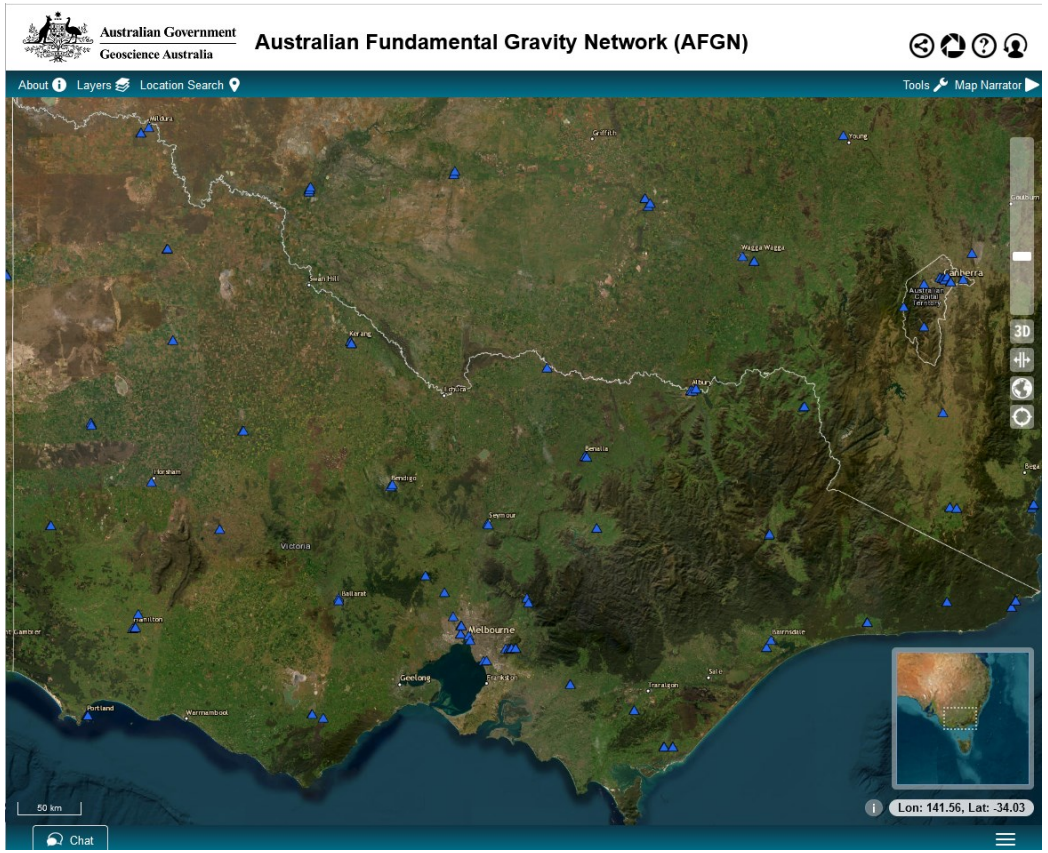
Australian Society of Exploration Geophysicists

- Use specifications included in technical/industry standards and government reports

OFFICIAL

Recycle the data

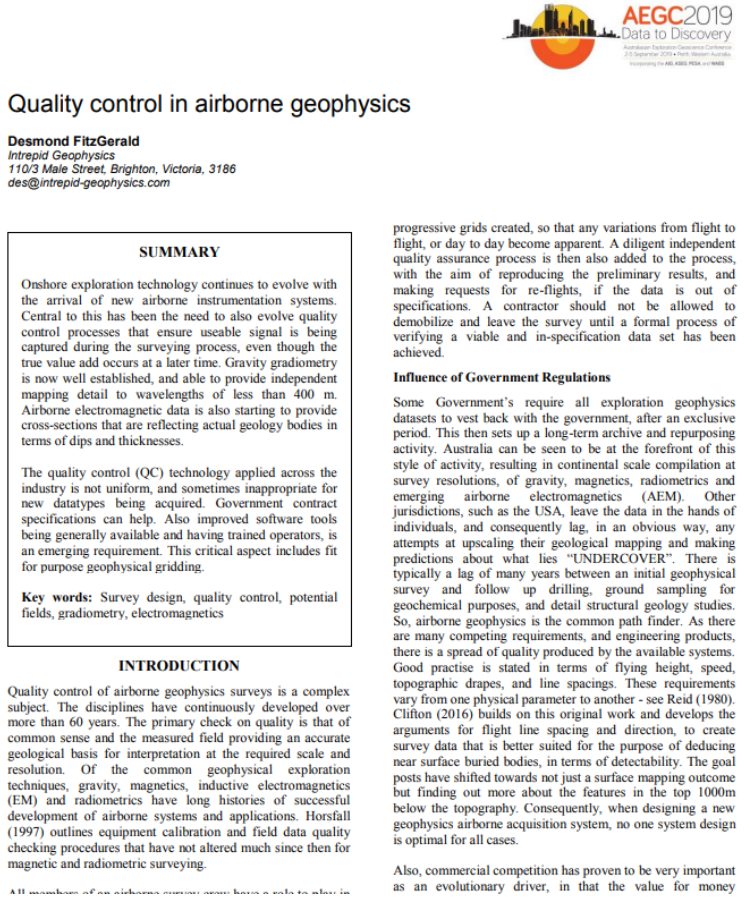
Technical specifications – gravity example



Local gravity base at Colac Colac, Victoria. Photo: Atlas Geophysics, 2019

Measure survey quality – QAQC procedures

- Professional Quality Assurance / Quality Control
- System calibration and validation
- Repeat observations



AEGC2019 Data to Discovery

Quality control in airborne geophysics

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SUMMARY

Onshore exploration technology continues to evolve with the arrival of new airborne instrumentation systems. Central to this has been the need to also evolve quality control processes that ensure useable signal is being captured during the surveying process, even though the true value add occurs at a later time. Gravity gradiometry is now well established, and able to provide independent mapping detail to wavelengths of less than 400 m. Airborne electromagnetic data is also starting to provide cross-sections that are reflecting actual geology bodies in terms of dips and thicknesses.

The quality control (QC) technology applied across the industry is not uniform, and sometimes inappropriate for new datatypes being acquired. Government contract specifications can help. Also improved software tools being generally available and having trained operators, is an emerging requirement. This critical aspect includes fit for purpose geophysical gridding.

Key words: Survey design, quality control, potential fields, gradiometry, electromagnetics

INTRODUCTION

Quality control of airborne geophysics surveys is a complex subject. The disciplines have continuously developed over more than 60 years. The primary check on quality is that of common sense and the measured field providing an accurate geological basis for interpretation at the required scale and resolution. Of the common geophysical exploration techniques, gravity, magnetics, inductive electromagnetics (EM) and radiometrics have long histories of successful development of airborne systems and applications. Horsfall (1997) outlines equipment calibration and field data quality checking procedures that have not altered much since then for magnetic and radiometric surveying.

progressive grids created, so that any variations from flight to flight, or day to day become apparent. A diligent independent quality assurance process is then also added to the process, with the aim of reproducing the preliminary results, and making requests for re-flights, if the data is out of specifications. A contractor should not be allowed to demobilize and leave the survey until a formal process of verifying a viable and in-specification data set has been achieved.

Influence of Government Regulations

Some Government's require all exploration geophysics datasets to vest back with the government, after an exclusive period. This then sets up a long-term archive and repurposing activity. Australia can be seen to be at the forefront of this style of activity, resulting in continental scale compilation at survey resolutions, of gravity, magnetics, radiometrics and emerging airborne electromagnetics (AEM). Other jurisdictions, such as the USA, leave the data in the hands of individuals, and consequently lag, in an obvious way, any attempts at upscaling their geological mapping and making predictions about what lies "UNDERCOVER". There is typically a lag of many years between an initial geophysical survey and follow up drilling, ground sampling for geochemical purposes, and detail structural geology studies. So, airborne geophysics is the common path finder. As there are many competing requirements, and engineering products, there is a spread of quality produced by the available systems. Good practise is stated in terms of flying height, speed, topographic drapes, and line spacings. These requirements vary from one physical parameter to another - see Reid (1980). Clifton (2016) builds on this original work and develops the arguments for flight line spacing and direction, to create survey data that is better suited for the purpose of deducing near surface buried bodies, in terms of detectability. The goal posts have shifted towards not just a surface mapping outcome but finding out more about the features in the top 1000m below the topography. Consequently, when designing a new geophysics airborne acquisition system, no one system design is optimal for all cases.

Also, commercial competition has proven to be very important as an evolutionary driver, in that the value for money

Recycle the data

Survey quality

System calibration and validation

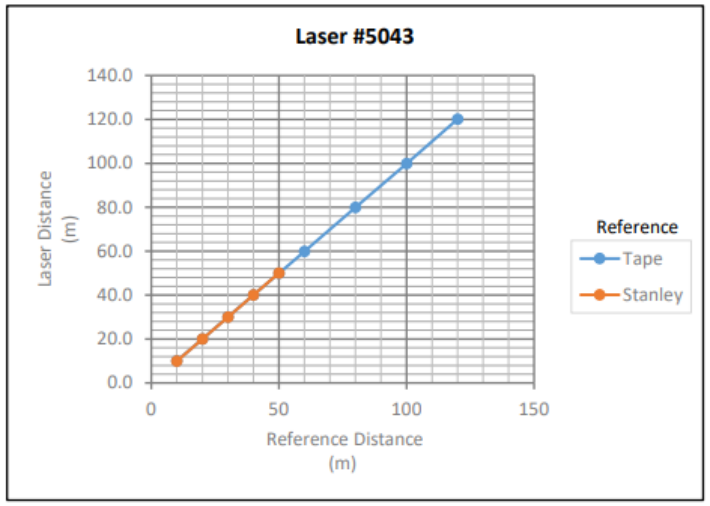


Figure 8A Results of Laser #5043 altimeter calibration

Laser altimeter calibration checks (Brodie, 2023)

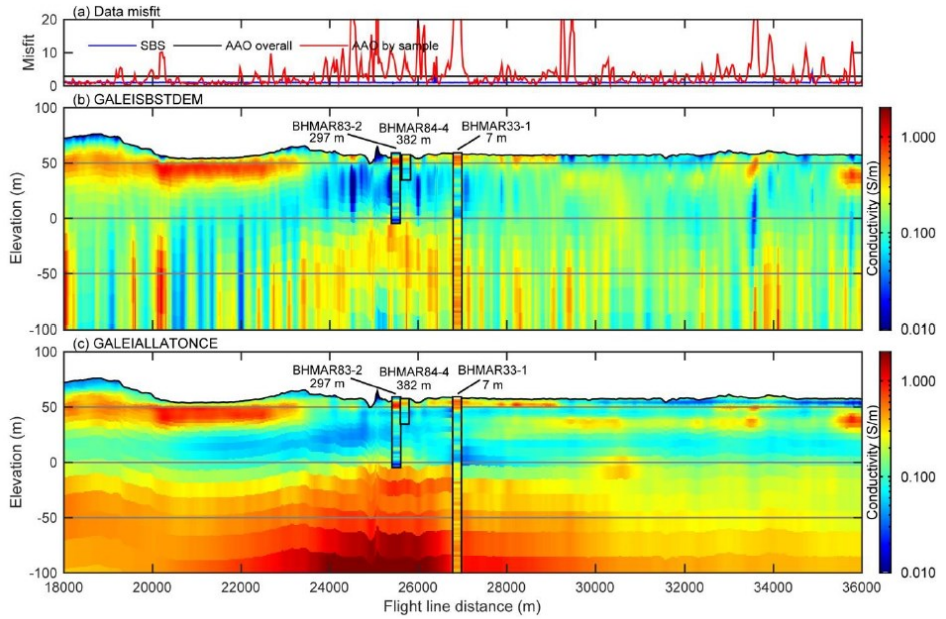


Figure 5: Comparison conductivity sections for flight line 23310 showing: (a) the data misfits for both inversions; (b) section for the conventional stitched sample by sample (SBS) inversion GALEISBSTDEM; and (c) section for the new all-at-once (AAO) inversion GALEIALLATONCE. The three adjacent borehole conductivity logs are superimposed on the sections with the same colour lookup table as the AEM conductivity section, along with their respective distance from the flight line.

Downhole conductivity logs and 1D AEM inversion (Brodie & Ley-Cooper, 2018)

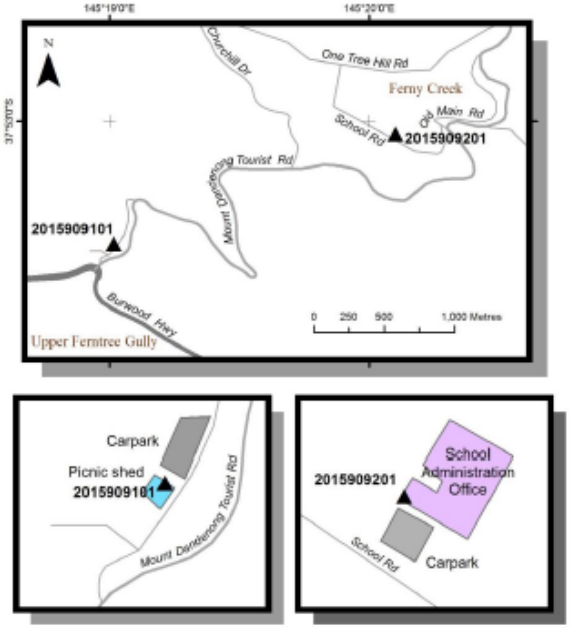


Figure 1 Location diagram of Ferntree Gully CS1 (2015909101) and Ferny Creek Primary School CS2 (2015909201).

Dandenong Gravity Meter Calibration Range (Haydon & McLean, 2016)

Recycle the data

Survey quality

Collect repeat observations

Left: Stavely ground gravity (Haydon et al., 2017)

Right :Otway Basin AGG (Carter et al., 2019)

Stavely ground gravity survey repeat differences (elevation, gravity)

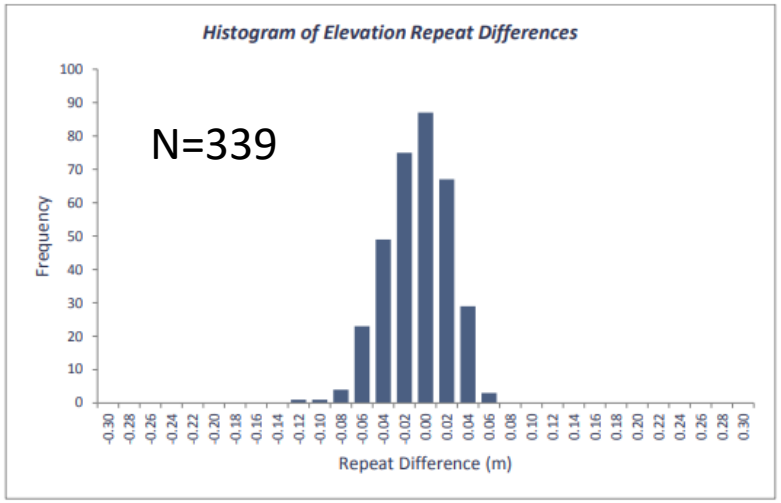


Figure 11: Histogram of GNSS Repeat Differences

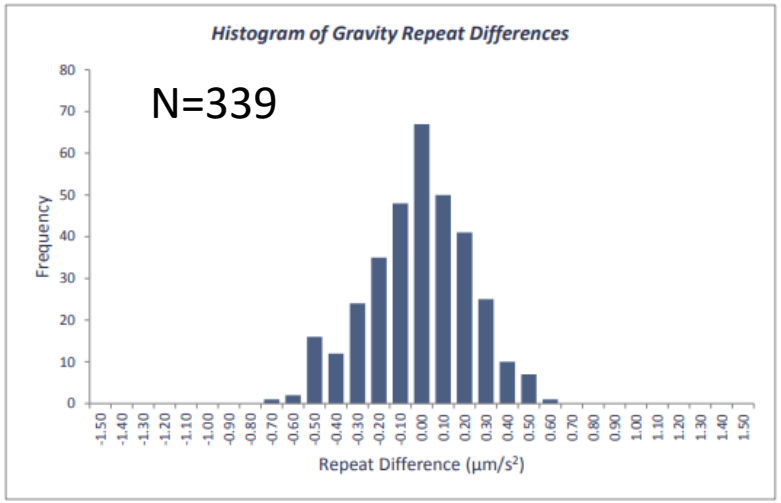


Figure 12: Histogram of Gravity Repeat Differences

Otway Basin AGG repeats and repeat differences

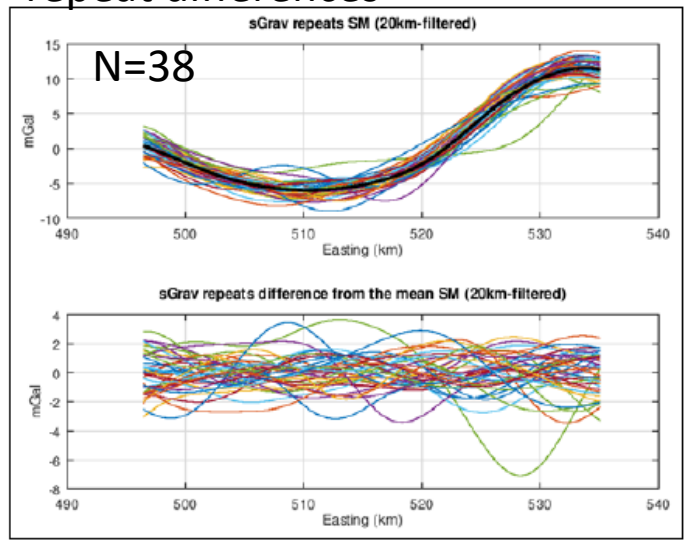


Figure A2.1 Repeat line 901 – Profile of sGrav gD and difference from the mean for each attempt.

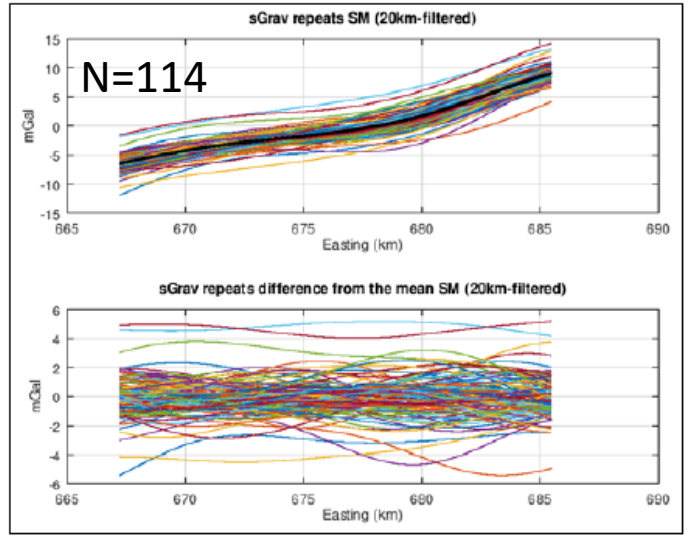


Figure A2.2 Repeat line 902 – Profile of sGrav gD and difference from the mean for each attempt.

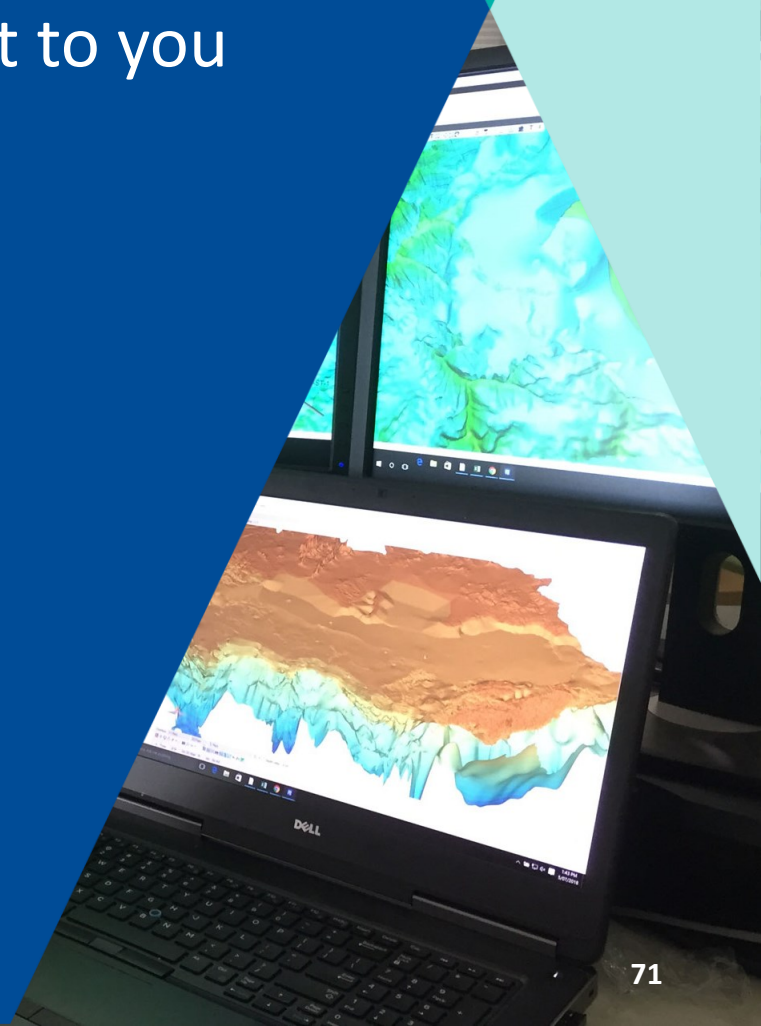
Well documented, complete data

- Record the acquisition parameters, comprehensive metadata
- Ancillary and raw data enables reprocessing in future
- Have greater confidence in the results of inversion
- Take full advantage of developments in processing, machine learning

Reduce, Reuse, Recycle

Collect and deliver high-quality data that is of benefit to you now and in the future

GSV is here to help



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Guidelines for Drone Geophysics. www.guidelinesfordronegeophysics.com/

VicMap Imagery and Elevation Coverage

How to Access Spatial Data https://www.land.vic.gov.au/maps-and-spatial/spatial-data/how-to-access-spatial-data

VicMap Elevation https://www.land.vic.gov.au/maps-and-spatial/spatial-data/vicmap-catalogue/vicmap-elevation

Vicmap Elevation products, www.data.vic.gov.au

VicMap DEM 10 m https://discover.data.vic.gov.au/dataset/vicmap-elevation-dem-10m

www.earthresources.vic.gov.au/geology-exploration/maps-reports-data/geophysics

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