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USING DIGITAL EARTH AUSTRALIA WATERBODIES TO SUPPORT AERIAL FIREFIGHTING

Evaluating the suitability of Digital Earth Australia Waterbodies v1 to support decision making processes of command centres and pilots

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EXECUTIVE SUMMARY

Up to date information about the spatial distribution of water that is suitable for use by firefighting aircraft is required to:

- Provide pilots with pre-flight information about the availability of water close to the fire ground. This allows pilots to source water more quickly and therefore reach the fire ground with water more rapidly, and minimise the travel time between pick-up and drop when multiple drops are required.
- Contribute to information used by fire authorities to optimise the distribution of their firefighting aircraft throughout the firefighting season, to optimise the efficiency of the aerial firefighting fleet.

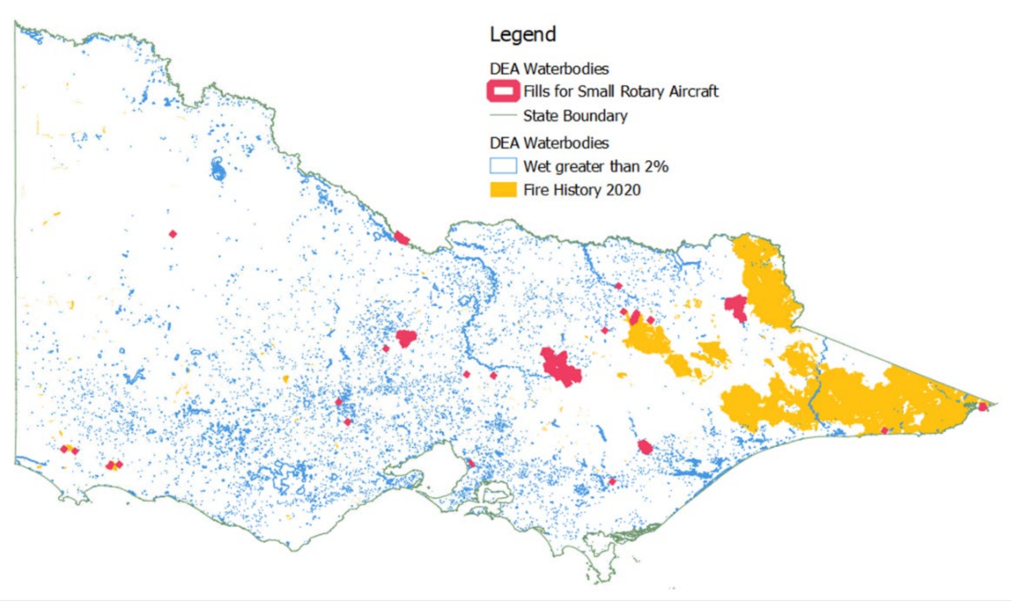
The Digital Earth Australia (DEA) Waterbodies tool provides information water in waterbodies bigger than four Olympic swimming pools. This information is updated with every cloud free satellite overpass (satellite revisit every 16 days).

The aim of this project was to:

- Evaluate the extent to which the current DEA Waterbodies product can be used to provide both start-of-season and near-real-time pre-flight information.
- Deliver a proof-of-concept web feature service that includes up-to-date fill levels and waterbody suitability for different types of firefighting aircraft and to ensure that the web service could be accessed via NAFC's Arena spatial platform.
- Identify improvements to the DEA Waterbodies product that would be required to further increase its utility to the National Aerial Firefighting Centre, state and territory firefighting agencies and aircraft operators.

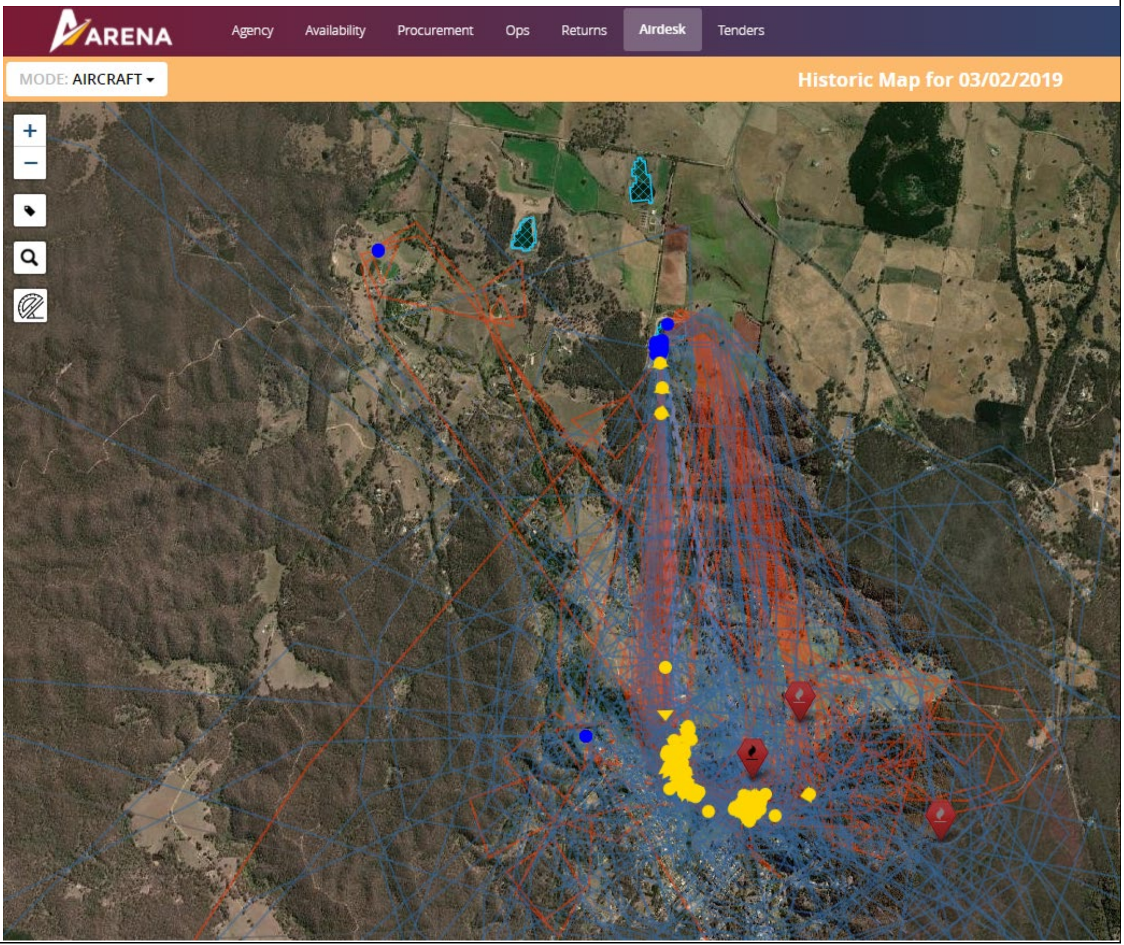
START OF SEASON WATER AVAILABILITY

DEA Waterbody information about water availability during the Black Summer fire season with waterbodies used by small rotary wing aircraft highlighted in magenta



SPECIFIC FIREGROUND DATA (DEA WATERBODIES WEB FEATURE SERVICE INTEGRATED INTO ARENA)

DEA waterbodies web feature service integrated into Arena (DEA Waterbodies shown here in hatched cyan polygons)



FINDINGS

DEA Waterbodies v1 was found to be suitable for start-of-season, severe fire danger period and start-of-fire information for command centres seeking to identify water availability within range of Helitak airpads (both permanent and temporary airpads). However, at present, its utility for pre-flight information for pilots was minimal based on the following limitations.

Waterbody size limitations

<u>Limitations of DEA Waterbodies v1</u> Noting that the 25 metre pixel size provides a fundamental constraint on the minimum size of waterbodies that can be reliably detected using Landsat. A waterbody must be larger than 3125m^2 (5 Landsat pixels) to be included in the DEA Waterbodies v1 polygon set. The water surface area in these polygons will be tracked down to 625m^2 (a single Landsat pixel). This means that there will be many waterbodies that are suitable for access by small rotary wing aircraft that are not captured in the DEA Waterbodies v1 product. A future version of the DEA Waterbodies product could include smaller waterbodies to improve its utility for aerial firefighting stakeholders. This could be achieved by:

- relaxing the minimum size constraint of DEA waterbodies (capture waterbodies as small as a single pixel), and/or
- applying the DEA Waterbodies workflow to Sentinel 2 imagery (10 metre pixel size).

Timeliness limitations

Waterbody fill level information is of greatest utility to firefighting agencies when it is as up-to-date as possible. The timeliness of DEA waterbodies fill level information is determined by two elements:

- Latency (the time between when a waterbody is observed by satellite and when the fill level information is available in the firefighting agencies spatial information system *i.e.* Arena for NAFC or EMAP for Victorian CFA). This is determined by the level of automation of the IT systems that sit between the satellite itself, and the DEA waterbodies web service.
- Observation frequency (how frequently a satellite observes that waterbody). This is determined by the number of satellites operating and the presence/absence of cloud/smoke/haze. At the time of writing the observation frequency for DEA Waterbodies is ~16 days (Landsat 8 only), but has the potential to be ~ 3 days (Landsat 8 and 9, Sentinel 2a and 2b).

Polygon attributes

Waterbody fill level information is of greatest utility to firefighting agencies when presented in the context of whether that waterbody is suitable for use by a specific aircraft type. Waterbody-aircraft suitability can be determined either via matching the historical fill activity for a particular aircraft type (demonstrated in this study) or via a spatial analysis of constraints (workflow described here for future implementation).

Web services

The two tables below describe the current and desired future state of DEA Waterbodies web services in terms of its current timeliness and polygon attribution. The desired future state is based on stakeholder consultation with the National Aerial Firefighting Centre and Victorian Country Fire Authority.

Current service

Service Type	Web Map Service with click query for time series
Latency (satellite overpass to web service update)	2 weeks
Observation frequency (how often the satellite revisits a particular location)	16 days
Service update frequency	Monthly
Polygon source	Landsat derived vectors
Attribute	Time series of % of wet surface area

Desired future service

Service Type	Web Feature Service with queriable attributes
Latency (satellite overpass to web service update)	24 Hours
Observation frequency (how often the satellites revisits a particular location)	3-5 Days
Polygon source	Best available open source linework
Attribute 1	Last observed wet %
Attribute 2	Time since last clear observation (days)
Attribute 3	Previously used by small rotary wing aircraft (y/n)
Attribute 3	Previously used by large rotary wing aircraft (y/n)
Attribute 4	Previously used by fixed wing aircraft (y/n)
Attribute 5	Waterbody likely suitable for aircraft class x*

* based on spatial analysis of vertical obstructions within proximity of the waterbody

END-USER STATEMENT

Andrew Matthews, *Manager Capability, National Aerial Firefighting Centre*

This study demonstrated the ability for a DEA Waterbodies web service to provide pre-flight information for pilots, when fully implemented as an operational web service, this capability would allow NAFC and jurisdictional fire-fighting agencies to provide pilots with pre-flight information about the availability of water close to the fire ground and the suitability (based on previous use) of those water sources.

Danielle Wright, *Remote Sensing Analyst, Victorian Country Fire Authority*

The Victorian CFA is evaluating DEA Waterbodies to identify how much water is within range of Helitak zones at the start of the fire season. The current size limitations on DEA Waterbodies are not a major concern from this perspective because 3125m^2 represents a water point with a bit of size to it, not just a dot of water.

INTRODUCTION

Australia has a long history of severe bushfire activity. Aerial firefighting is a critical capability in responding to bushfires. However, aerial firefighting aircraft are costly to operate and capturing water to fight fires can place pilots into risky situations. Aerial firefighting aircraft typically operate at low altitudes, with fields of view that are limited by both altitude and smoke. Having pre-flight information about all water sources that are close to the active fire provides pilots with more options.

Up to date information about water availability and the suitability of those waterbodies for retrieval by different aircraft types have the potential to:

- Provide the National Aerial Firefighting Centre and the State and Territory firefighting agencies with start-of-season information about the amount of water available for use within range of their airbases (both fixed and temporary).
- Provide pilots with pre-flight information about water sources that are close to the active fires that they're being dispatched to.

Satellite remote sensing has the ability to provide information about current fill levels in waterbodies across Australia as demonstrated by DEA Waterbodies (Krause et. al. 2020). The Victorian Country Fire Authority is currently trialling the use of DEA Waterbodies to assist with start-of-season planning. The team at Digital Earth Australia (DEA) liaised with the National Aerial Firefighting Centre during the Black Summer fire season and identified that there was potential to provide pilots with pre-flight information by combining up-to-date information about fill levels with historical patterns of waterbody utilisation. Based on the rationale that waterbodies that have historically been accessed by aircraft of a particular class are likely to still be suitable for that aircraft class.

The research approach described in the following section outlines how the historical aircraft activity data was combined with the DEA Waterbodies polygon set to identify waterbodies that had been previously used by aircraft of different classes.

RESEARCH APPROACH

The research approach consisted of the following key steps:

1. Identify available aircraft activity data and surface water information products (DEA Waterbodies and best available spatial data for describing waterbody extent)
2. Revise the DEA Waterbodies linework to maximise the chance of matching a fill event to a specific waterbody
3. Match fill events that occurred during the Black Summer fires from different aircraft types to the revised DEA Waterbodies linework (results from this step provide an estimate of the suitability of particular waterbodies for different aircraft types)
4. Generate time-specific maps using DEA Waterbodies fill time series data to identify where water was available during the Black Summer Fires (results from this step identify available water sources detected from DEA Waterbodies, and compares these waterbodies with actual fill events)
5. Deliver the resultant polygons with attributes of fill levels and aircraft utilisation to NAFC as web feature services to compare with observed aircraft activity for two epochs:
    a. Black Summer Fire season (to match with aircraft activity observed at the time in Arena)
    b. Current* waterbody fill levels (to illustrate what up to date information would look like as part of an on-going decision support capability.

DATASETS AND PRE-PROCESSING

Aircraft activity datasets (National Aerial Firefighting Centre)

2019-2020 Drops report NSW Vic v001.zip - Contains flight data from aircraft operators for the period of summer 2019-2020.

Waterbody datasets

DEA Waterbodies

DEA Waterbodies from space - Polygon geometry dataset derived from satellite images

The tool uses a water classification for every available Landsat satellite image and maps the locations of water bodies across Australia. It provides a time series of wet surface area for water bodies that are present more than 10% of the time and are larger than 3125m2 (5 Landsat pixels).

https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/132814.

Digital Mapping Australia Hydrology layer

GA DMA Hydro - Australia wide Cartographic representation of inland water bodies represented by points, lines and polygons. Derived from state jurisdiction topographic datasets.

Open Street Map

Water Layers - Data was captured from multiple layers and themes from the Open Street Map - Australia.pkb downloaded from www.geofabrik.de.

METHODS

Data was processed using the FME Workbench software which allows for reading of multiple GIS and data formats. Within FME Workbench a number of Transformers (processing tools) were used to integrate, transform and merge the required datasets together. Spatial Filters were used to overlay the datasets together to form the outputs required as part of the project objectives. The Detailed FME workflows used to process the data are captured in Appendix 1. These FME workflows have been simplified into flowcharts that show both the main processing steps and the symbology used to characterise the results.

The initial method attempted to identify the following:

1. Aircraft fill data = true *and* DEA Waterbodies = wet during Black Summer
2. Aircraft fill data = true *and* DEA Waterbodies = dry during Black Summer (indicating that there was water there below the Landsat detection limit)
3. Aircraft fill data = true *and* no waterbody present in DEA Waterbodies (to identify how many waterbodies were being accessed that were not detected in DEA Waterbodies, i.e. small farm dams, narrow river channels etc)

The matches associated with point 1 are shown in the Figure 4, and no cases of point 2 were observed. Point 3 proved highly problematic, as there was a combination of 'multiple-fills-per-single-waterbody' and a variety of data collection accuracy issues. Consequently, the comparison of counts for these different cases is not presented.

Revising DEA Waterbodies linework

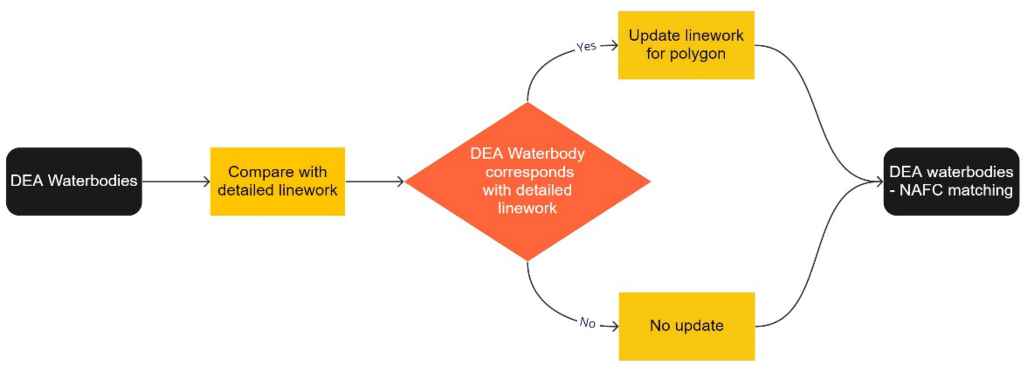


FIGURE 1 – WORKFLOW FOR UPDATED VECTOR LINEWORK TO MATCH FILLS WITH WATERBODIES

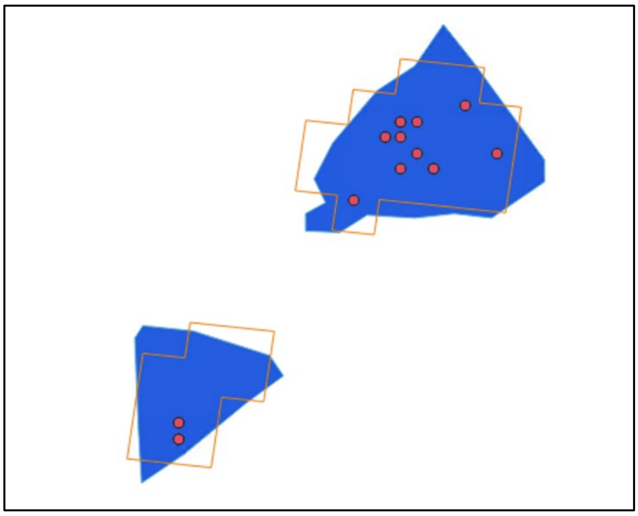


FIGURE 2 EXAMPLE OF FILL DATA (RED DOTS) MATCHED WITH DEA WATERBODIES (ORANGE OUTLINES) AND DETAILED LINEWORK (BLUE SOLID POLYGONS)

This step is necessary as DEA Waterbodies v1 has linework derived from 25 metre resolution satellite imagery, hence the edges of the waterbody are blocky 'pixel' edges rather than more detailed linework. The blocky nature of the DEA Waterbodies v1 polygons is clearly shown in Figure 2. The workflow outlined in Figure 1 was undertaken in FME Workbench and the detailed FME workflow is captured in Appendix A. The updated DEA Waterbodies with revised linework was used in all subsequent spatial analysis steps.

Identifying DEA Waterbodies used by small roatary wing aircraft during Black Summer

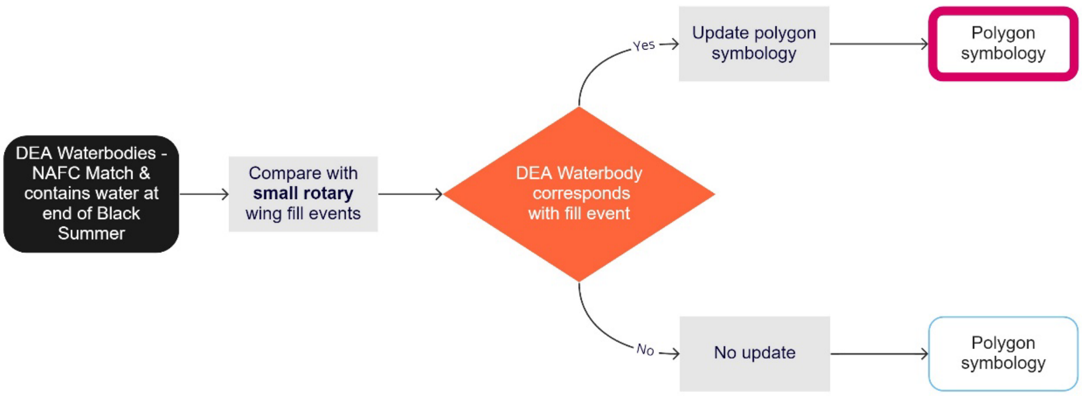


FIGURE 3 WORKFLOW FOR ATTRIBUTING DEA WATEBODIES WITH SMALL ROTARY WING AIRCRAFT UTILSATION

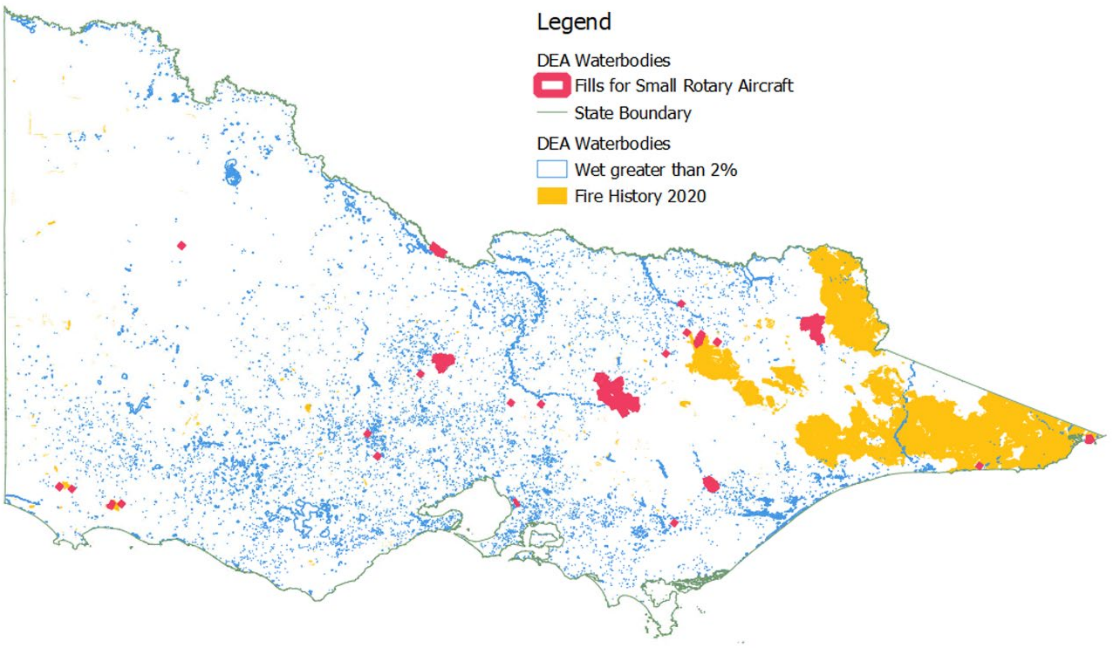


FIGURE 4 VICTORIA-WIDE VIEW OF DEA WATERBODIES THAT CONTAINED WATER DURING THE BLACK SUMMER FIRE SEASON (BLUE), WATERBODIES USED BY SMALL ROTARY AIRCRAFT DURING THE BLACK SUMMER FIRE SEASON (MAGENTA) AND FIRE EXTENTS (YELLOW)

The simplified workflow in Figure 3 was undertaken in FME, and the full FME workflow is shown in Appendix A. The results of that workflow are shown in Figure 4. The example shown here consists of both waterbody fill levels and aircraft activity from the Black Summer fire season. This epoch-specific analysis serves to illustrate that match ups are possible and can be used to identify patterns of use. However a more comprehensive analysis based on all available aircraft fill activity Australia wide is recommended to provide a more complete picture of aircraft suitability.

Identifying DEA Waterbodies used by large roatary wing aircraft during Black Summer

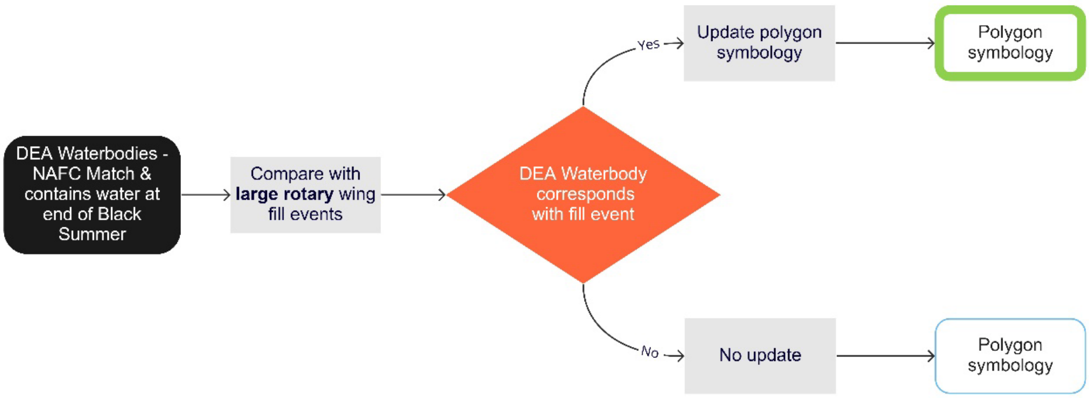


FIGURE 5 WORKFLOW FOR ATTRIBUTING DEA WATEBODIES WITH LARGE ROTARY WING AIRCRAFT UTILSATION

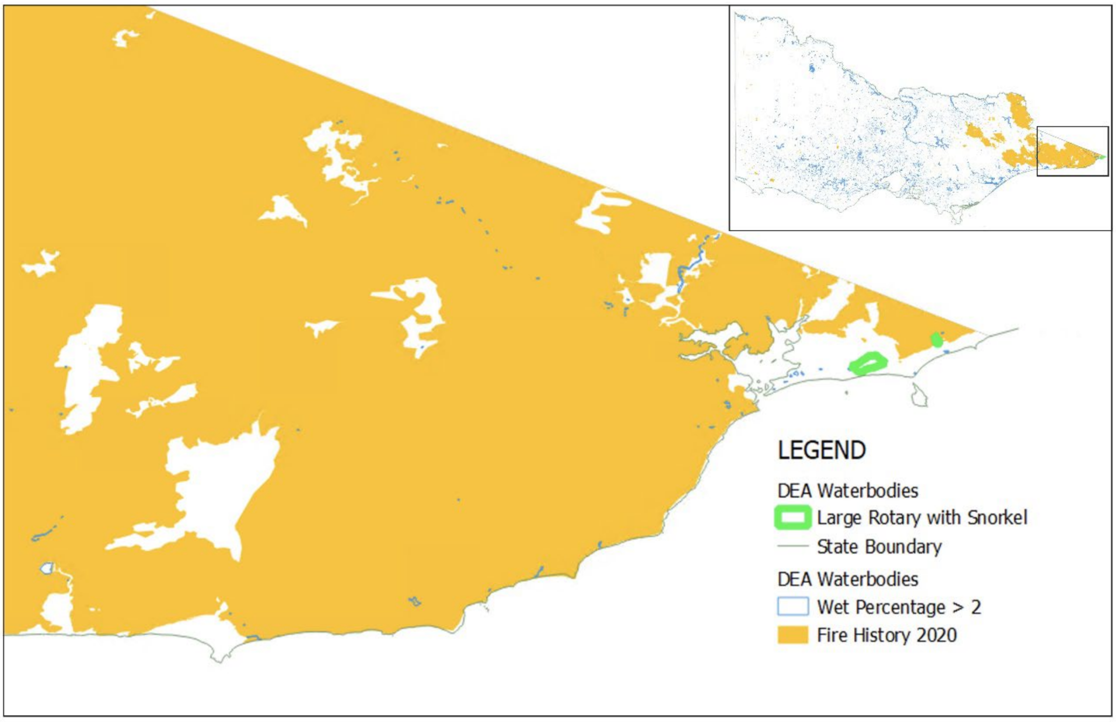


FIGURE 6 EASTERN VICTORIAN INSET VIEW OF DEA WATERBODIES THAT CONTAINED WATER DURING THE BLACK SUMMER FIRE SEASON (BLUE), WATERBODIES USED BY LARGE ROTARY AIRCRAFT WITH SNORKEL DURING THE BLACK SUMMER FIRE SEASON (GREEN) AND FIRE EXTENTS (YELLOW)

The workflow for match ups between DEA Watebodies v1 and large rotary wing aircraft activity during the Black Summer fire season in Victoria is shown in Figure 5 and the results of those match ups are shown in Figure 6. Based on these data, the large rotary wing aircraft were primarily active around the Mallacoota fire grounds. In addition to the comprehensive 'match up' process highlighted in the previous example, it is also possible to infer aircraft suitability 'rules' based on an analysis of patterns of aircraft utilisation as outlined in the following example.

Proposed method for identifyin waterbody suitability in the absence of previous aircraft acivitiy data

Required input data

Streamlines, Vertical Obstructions (Powerlines, Buildings), up-to-date water levels, detailed tree cover

Spatial analysis

FIGURE 7 SHOWS JUST THE FILL EVENTS RECORDED IN ARENA ON A PARTICULAR DAY

If we can understand why the pilot used this dam, rather than other nearby dams, this rationale can be used to inform a spatial analysis rule set to identify other similar dams that meet the same criteria. These sorts of rule sets could be applied in the future to estimate aircraft suitability in areas where previous aircraft activity data was not available.

FIGURE 8 LOCATION SHOWING BOTH FILL EVENTS AND ALL MAPPED NEARBY WATERBODIES (FILL LEVEL UNKNOWN)

FIGURE 9 LOCATION SHOWING BOTH FILL EVENTS AND ALL MAPPED NEARBY WATERBODIES (FILL LEVEL UNKNOWN - BLUE), WATERBODIES CONTAINING WATER AS PER DEA WATERBODIES ARE SHOWN IN ORANGE

With four waterbodies that contain water in close proximity, why did the pilot select that one?

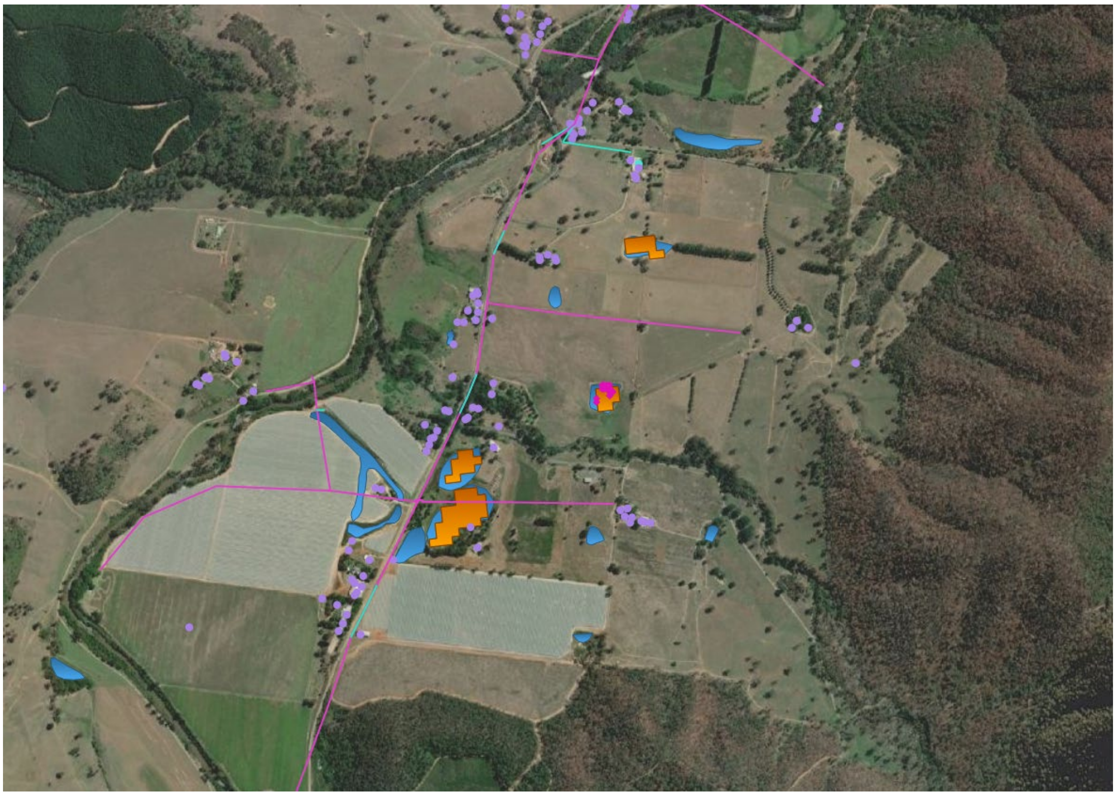


FIGURE 10 LOCATION SHOWING WATERBODIES THAT CONTAIN WATER (ORANGE), AND INCLUDES THE LOCATION OF POWERLINES (MAGENTA LINES) AND BUILIDNGS (MAUVE DOTS)

The bottom two waterbodies have powerlines in close proximity, rendering them unsuitable for access.

FIGURE 11 LOCATION NOW WITH THE INCLUSION OF TREE COVER (SHOWN IN GREEN BUFFERS)

Trees close to the top dam render it unsuitable for access.

FINDINGS

UTILITY OF CURRENT DATA AND DELIVERY MECHANISM

Utility for start-of-season planning

The waterbody fill information contained within DEA Waterbodies is reasonably well suited to 'start-of-season' planning as shown in Figure 12 from the Victorian CFA trial of DEA Waterbodies. The fortnightly-monthly refresh rate of the water level information is not a 'show stopper' for this type of analysis. Similarly the infrequent nature of 'start of season' means that a manual analysis of which polygons contained water at the start-of –season is not a major barrier to utilisation.

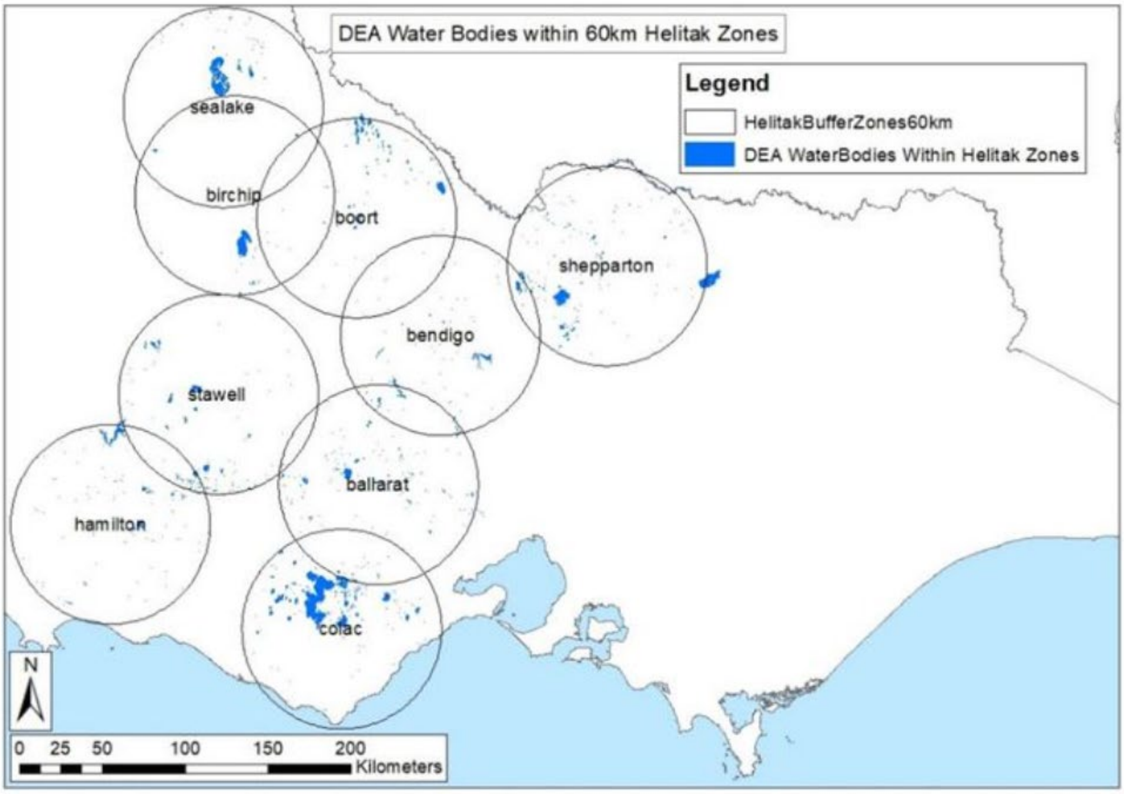


FIGURE 12 DEA WATERBODIES WITHIN 60KM OF VICTORIA COUNTRY FIRE AUTHORITY HELITAK ZONES

Utility for pilor pre-flight information pack

Whilst pilots can definitely benefit from having appropriate pre-flight information about water sources in the proximity of active fire zones. DEA Waterbodies v1 is not well suited to supporting pilot pre-flight information due to limitations in its timeliness (both latency and revisit), it's spatial accuracy, it's thematic accuracy, and it's delivery format. The following section outlines the improvements required to increase the utility of DEA Waterbodies for pre-flight pilot information packs.

IMPROVEMENTS REQUIRED TO ENHANCE UTILITY

Improved spatial accuracy

Sensor pixel size

The pixel size of the sensor determines the smallest area of water that can reliably be detected. In the case of DEA Waterbodies v1 it also determines the size of the smallest waterbody included in the product (5 pixels / 3125m^2). A visual assessment of the small rotary aircraft fill data shows that that this aircraft class often uses waterbodies smaller than this. This would indicate that DEA Waterbodies v1 is not capturing water availability information for some of the smaller waterbodies that pilots are making use of. To address this limitation in the immediate term the minimum size constraint could be relaxed in a future version of Landsat based DEA Waterbodies products to allow information about the presence/absence of water in smaller waterbodies (2 pixels / 1250m^2) to be captured. This would be accompanied by a plain language description of these size constraints so that pilots were aware of the limitations of the information they're being provided with.

Upgrading DEA Waterbodies to run on Sentinel 2 data, and keeping a 'minimum waterbody size' of 2 pixels would allow water presence/absence to be determined down to waterbodies of 200m^2. This would greatly increase the utility of the DEA Waterbodies product suite for pre-season/pre-flight information products.

In areas where good quality hydrological linework exists (waterbody maximum extent is determined from sources other than Landsat/Sentinel) it would be possible to use data from commercial high resolution sensors that acquire on a routine basis *i.e.* Planet. The 3 metre resolution of the Planet Dove constellation would allow presence/absence of water to be identified down to 18m^2. It is worth noting that the absence of a shortwave infra-red band on the Planet Dove sensors can limit the reliability of water detection where the waterbodies are highly turbid (which is not unusual in small farm dams).

The high cost of Planet data would likely constrain its use to targeted use of high priority fire grounds. A Planet data based DEA Waterbodies workflow could be developed and tested to establish the limitations of this approach. This could be done using historical data for previous fire seasons.

Vector accuracy

The vector accuracy of the waterbody polygons enables all fill events that have occurred at a waterbody to be matched to that waterbody. This improves the reliability with which waterbody suitability for particular aircraft sizes can be determined. Improved vector accuracy (linework) also provides a nicer cartographic product when including water availability information into decision support platforms such as Arena.

Improved timeliness

Latency

The term 'latency' in this report refers to the time between satellite overpass and the avialabilty of DEA Waterbodies information in a decision support tool such as Arena/EMAP (based on the assumption that these systems are picking up their data from DEA web services). The latency of DEA Waterbodies v1 web services ranges between 2-4 weeks. This latency is acceptable for 'start-of-season' analysis, however it limits the utility of information for pilot pre-flight information as the water availability information could be a month out of date. Further automation of the DEA Waterbodies workflow, and the availability of 'near-real-time' Landsat and Sentinel 2 have the potential to reduce this latency down to 24-48 hours.

Revisit

The revisit of the Landsat constellation is 8 days, however the scan-line-corrector gaps in Landsat 7 data can reduce the effective revisit to 16 days (the DEA Watebodies algorithm needs to be able to observe at least 80% of the waterbody to determine fill extent). The launch of Landsat 9 in 2021, and subsequent retirement of Landsat 7 will overcome this limitation, but the revisit of the DEA Watebodies v1 inputs will remain at 8 days. It's worth noting that *revisit* does not equate to *ground observation frequency*, because cloud, cloud shadow and smoke can all obscure the ground surface. During periods of wide spread fire activity, such as those experienced during the Black Summer, the combination of smoke and clouds can severly impact the ground observation frequency.

The revisit of the Sentinel 2 constellation is 5 days. When used in combination with the Landsat constellation, the combined revisit is 2-3 days. The inclusion of Sentinel 2 into a future DEA Waterbodies workflow would therefore reduce the revisit from ~16 days down to 2-3 days (noting the constraints of cloud/smoke would still apply).

The Sentinel 1 constellation provides all-weather (synthetic aperture radar (SAR) can 'see' through cloud/smoke) revisit every 6 days. SAR data can be used to detect the presence/absence of water. However significant development, testing and evaluation is required before Sentinel 1 based surface water information can be integrated into the DEA Waterbodies product.

Improved thematic accuracy

Aircraft suitability

The aircraft suitability data calculated in this project was based on aircraft activity data from the Black Summer fire season in Victoria. A systematic analysis of all available aircraft activity data from all jurisdictions would be required to provide a more comprehensive picture of waterbody suitability. This approach, however would still be limited to areas where aircraft activity data have previously been recorded. The spatial analysis approach outlined in the methods section (filter available available water sources based on their proximity to vertical obstructions such as powerlines, buildings and trees) would allow estimation of waterbody suitability in areas without previous aircraft activity data.

Waterbody type

DEA Waterbodies v1 does not distinguish different 'types' of waterbodies. This is because, being a satellite based product, all waterbodies are identified solely based on the presence/absence of water. However, the suitability of water for aerial firefighting activity is constrained by the 'type' of waterbody. The salt water versus fresh water question can determine both aircraft accessibility as well as suitability for use in particular locations. The potability of the water (sewerage treatment plants versus drinking water storages) can constrain the suitability for use as well. Likewise the 'ownership' of the water (private storages versus public storages/waterways) can also be a consideration.

In future, the integration of a 'waterbody type' attribute in the DEA Waterbodies product would enhance its utility for aerial firefighting decision support.

Improved delivery method

The DEA Waterbodies v1 web service is of limited utility for aerial firefighting decision support. Whilst waterbody fill level information is available in the service, a user needs to click on a particular waterbody to identify current fill level. Current fill levels can also be captured for a range of waterbodies, however the process is a manual one. Whilst this can be used for 'start-of-season' analysis it is not suitable for time critical applications such as pre-flight information packs where up-to-date information needs to be available without the need to run scripts and check results. To support the needs of aerial firefighting decision support, DEA Waterbodies web services would ideally consist of two elements.

Web Map service

The purpose of the WMS would be provide pilots with succinct pre-flight information. Waterbodies information with symbology that shows water availability (presence/absence) and suitability (previously used by same aircraft type, likely suitable, unknown, unsuitable). Delivery via WMS is preferred to optimise service reliability in areas with limited internet coverage.

Web Feature Service

The purpose of the WFS is to provide command centres with a richer suite of information to inform decision making processes. This would also allow the command centre to refine the suitability criteria of the WMS (above) based on feedback from pilots. This would include attributes such as:

- Current fill level
- Currency of information (how many days since satellite overpass)
- Waterbody type (salt/fresh, private/public, reservoir, river, wetland etc)
- Suitability for specific aircraft type
    - Based on previous utilisation by that aircraft type

    - Based on spatial analysis for that aircraft type
- Proximity/type of nearest vertical obstruction.

UTILISATION AND IMPACT

DEA WATERBODIES V1

Victorian CFA trial for pre-season planning

Utilisation impact

The DEA Waterbodies v1 data is being trialled by the Victorian Country Fire Authority for their pre-season planning to evaluate water availability within range of HeliTak airfields (Figure 12). The impact of this is to provide Victorian CFA with greater situational awareness about the availability of water within range of Helitak bases at the start of the fire season.

Utilisation potential

There is potential for other State and Territory fire fighting authorities to make use of DEA Waterbodies v1 data to inform their pre-season planning activities. The potential for utlisation is more likely to be realised if the web services are upgraded to make it easier for command centres to integrate the services into their decision support environments.

NAFC pre-flight information packs

Utilisation impact

There is limited impact at this point as the spatial resolution, latency, update frequency and web service delivery of DEA Waterbodies v1 are not suitable for the routine and timely generation of pre-flight information products for pilots.

Utilisation potential

If the improvements outlined in the findings are actioned then there is significant utilisation potential. For this potential to be realised up-to-date water availability/suitability information needs to be delivered to pilots via their command centres in a timely, accessable manner, with sufficient plain language caveats for the pilots to understand the capabilities and limitations of the information.

UTILISATION AND IMPACT

Valuable up-to-date information about water availability is currently being captured by satellite imagery constellations, however that information is not being delivered in a decision ready form to the pilots of fire fighting aircraft. Satellite imagery based water information has been successfully trialed by Victorian CFA to provide information about start-of-season water availability within range of HeliTak airbases. Making this data easier for command centres to access would facilitate its adoption across other jurisdictions.

NEXT STEPS

Geoscience Australia will continue to refine and improve the DEA Waterbodies product, including the integration of Sentinel 2 over the coming years. However there are some aerial firefighting specific elements of the recommendations that would require additional resourcing. These are outlined under the subheadings below.

Aircraft utilisation

Spatial analysis is required to a. match historical aircraft activities with specific waterbodies and b. establish and apply spatial analysis rules for waterbodies for which no aircraft activity exists. The workflows required to undertake these spatial analyses have been demonstrated in this paper. Additional resourcing is required to apply these analyses to all available aircraft activity data, and to identify and maintain a catalogue of suitable datasets for the rule set approach. The spatial data sources required are up-to-date representations of different types of vertical obstruction (powerlines, buildings and windfarms as well as detailed maps of tree cover), and hydrology layers (waterbodies, streams, rivers).

Pilot specific requirements

Whilst richly attributed web feature services are required to support the decisions being made in the command centres, the decision support tools being made available to the pilots need to be:

a. supported by web services that have minimal reliance on network connectivity,

b. able to continue to display spatial data after network connectivity is lost (i.e. geoPDF)

c. based on symbology that allows pilots to identify available water sources and assess their suitability ‘at-a-glance’.

The delivery and reliability of the web services, network-connectivity-robust spatial data capabilities and pilot-focussed symbology will need to be developed, tested and refined in consultation with end users. These activities would require additional resourcing as part of the next phase of this project.

Planet data trial

The 3 metre spatial resolution and daily revisit of the Planet Dove constellation mean that it has the potential to provide significantly improved situational awareness for firefighting aircraft operators (both command centres and pilots). Resourcing would be required to evaluate this potential. This could be done using archival Planet data acquired during the Black Summer fire season, using the spatial analysis techniques applied in this report. The Planet data would also be shared with command centre operators and pilots to identy whether there was additional insight to be gained from it, and to establish what type of image analysis would be required to routinely capture that insight.

Web service integration into Command Centres

The spatially enabled decision support tools used by the command centres are likely to have different requirements when it comes to integrating web services. Resourcing would be required to ensure that newly developed web services were integrated and tested for each jurisdiction.

TEAM MEMBERS

RESEARCH TEAM

Leo Lymburner (Digital Earth Australia, Geoscience Australia)

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END-USERS

Andrew Matthews (NAFC)

Danielle Wright (Victorian Country Fire Authority)

End-user organisation	End-user representative	Extent of engagement (Describe type of engagement)
National Aerial Firefighting Centre	Andrew Matthews	Frequent video conferences, identify stakeholder requirements, discuss potential solutions, evaluate preliminary results, provide key datasets
Victorian Country Fire Authority	Danielle Wright	Early adopter of DEA Waterbodies, consulted a number of time via video conference re: preliminary results and barriers to adoption

REFERENCES

1 Krause, C.E.; Newey, V.; Alger, M.J.; Lymburner, L. Mapping and Monitoring the Multi-Decadal Dynamics of Australia's Open Waterbodies Using Landsat. *Remote Sens.* 2021, *13*, 1437. https://doi.org/10.3390/rs13081437.

APPENDIX 1

CORE PROJECT DATASETS

NAFC supplied datasets

2019-2020 Drops report NSW Vic v001.zip - Contains flight data from aircraft operators for the period of summer 2019-2020

Aircraft tracks.zip - Contains flight data from aircraft operators for the period of 2020-2021 Western Australia bushfires

Geoscience Australia / Digital Mapping Australia supplied datasets

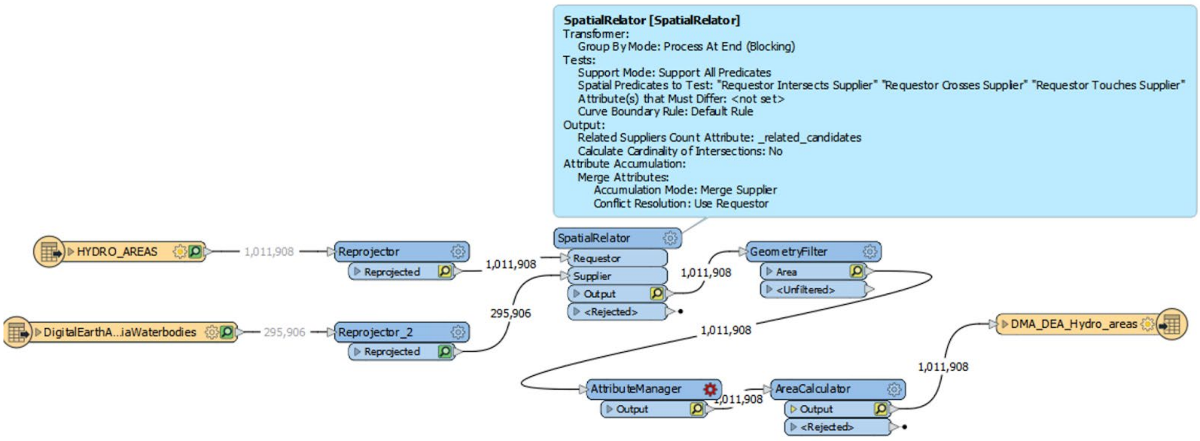
DEA Waterbodies

The tool uses a water classification for every available Landsat satellite image and maps the locations of water bodies across Australia. It provides a time series of wet surface area for water bodies that are present more than 10% of the time and are larger than 3125m2 (5 Landsat pixels) (Krause et al. 2021)

https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/132814.

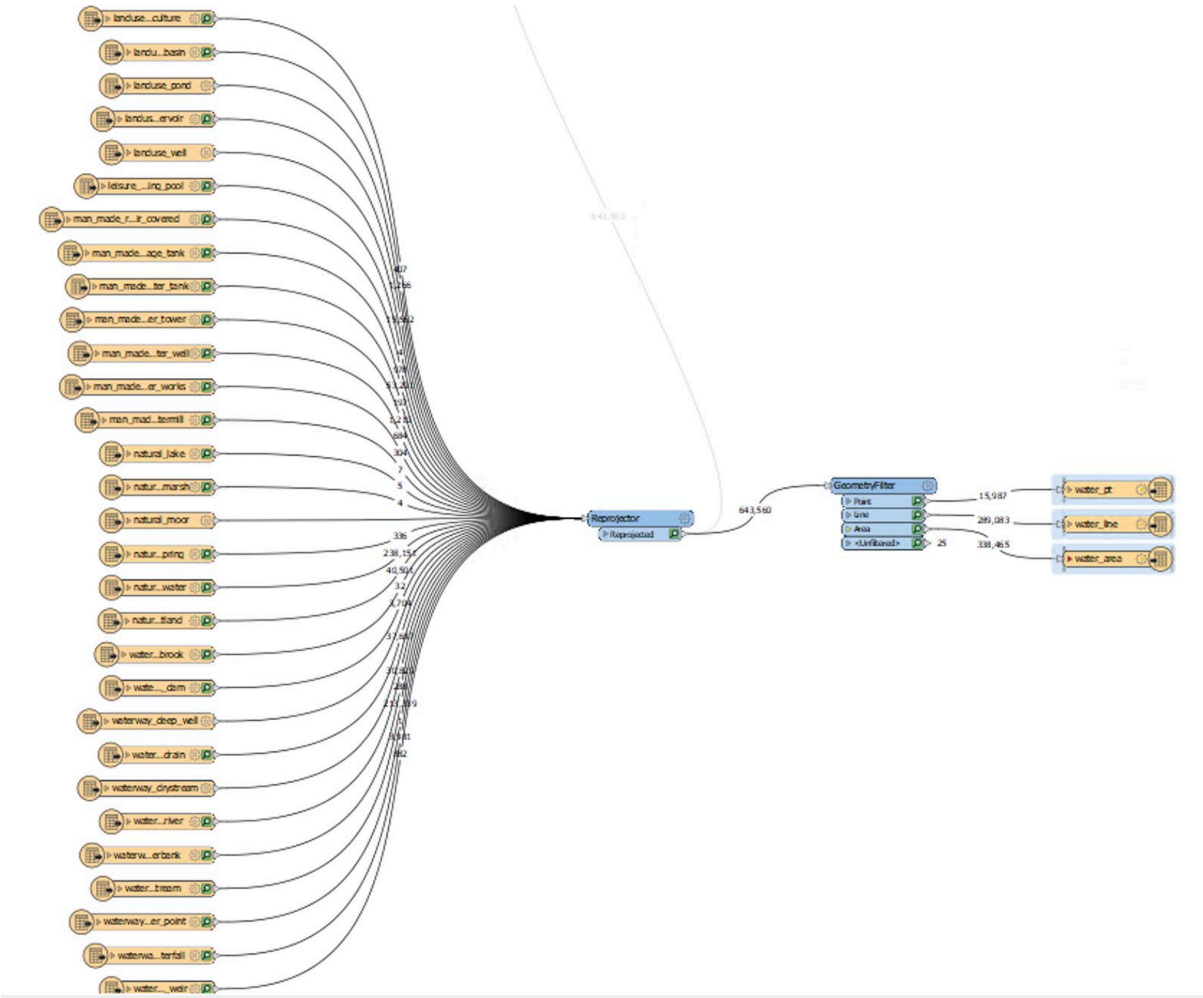
GA DMA Hydro

Australia wide Cartographic representation of inland water bodies represented by points, lines and polygons. Derived from state jurisdiction topographic datasets.



OPEN STREET MAP

Water Layers - Data was captured from multiple layers and themes from the Open Street Map - Australia.pkb downloaded from www.geofabrik.de.



VERTICAL OBSTRUCTION DATA

Sourced from DMA Foundation Datasets - Physical Infrastructure GDB.

PREPROCESSING DATA

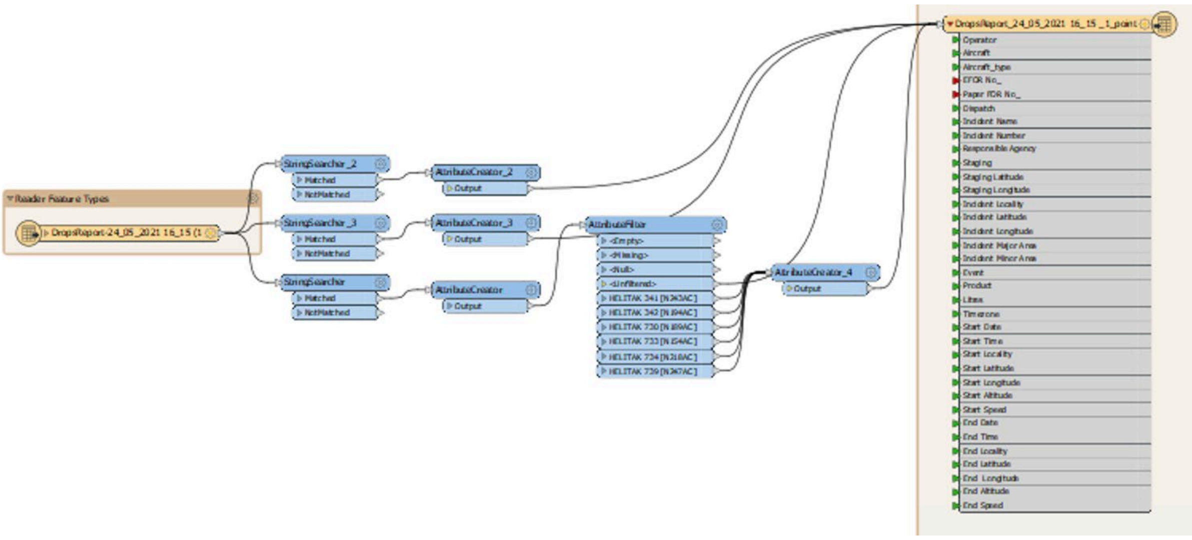
VIC/NSW dataset

The data was supplied as XLSR spreadsheet and needed to be converted into a GIS based format. Data was imported into FME and transformed into points using the Start_X and Start_Y values. Data was output for further use as OGC Geopackage.

A new attribute is added to show the aircraft type for use in the defining where fills are made by certain aircraft types.

The aircraft type is added to the Hydro polygon layer to show where fills have been made previously.

The output schema is the same has the input with the addition of the aircraft type field.



Western Australia sample (used to develop method subsequently applied to Victorian data, results now shown in main report)

The Western Australia sample allowed the project to be used as a starting point.

Water datasets were sourced from OSM as the GA Hydro dataset did not have the coverage.

NAFC Flight data introduced multiple types of helicopters and fixed wing aircraft together with vehicles.

Data was separated out of the json file

Data captured 31/1 to 6/2 2021

The FME script shown below deconstructs the NAFC aircraft data to allow better understanding and overlay of the water features.

Data results showed that flight data recorded with the FILL event shown as an attribute allowed the overlay with the waterway objects to identify those lakes or dams that have had aircraft fill from them previously.