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SUSTAINABLE WATER MANAGEMENT AT MAJOR AUSTRALIAN REGIONAL AIRPORTS: THE CASE OF MILDURA AIRPORT

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Abstract. Sustainable water management is an essential aspect of all industries. This is particularly true in regional Australia, which in known for its harsh climate, with arid conditions. In this work we investigate the sustainable water management of major Australian regional airports. A specific case study of Mildura Airport, as the largest regional airport in the State of Victoria, is presented. Potable water is of particular importance, as it has the largest cost associated with its use. Sustainable means of supplying potable water can be significant to the operating costs of a regional airport. In an attempt to determine the potential for water harvesting at regional airports a novel image processing approach was taken to analyse the water capture area. This involved utilising satellite imagery and the image processing functionalities of Matlab, with some simple mathematics to estimate roofed areas. From here meteorological data gives rainfall data, in terms of depth, facilitating volume capture potentials. It was found that the average potable water harvesting potential for Mildura Airport is 3.964 megalitres per year.

Keywords: airports, regional aviation, sustainability, water management.

1. Introduction

The relationship between airports and the environment has been a constant challenge with strong historical ties (Hansen *et al.* 2013). The airport industry, similar to many other industries, is, thus, confronting the effects of increasing environmental pressure (Graham 2014). Airports are, therefore, working to make themselves more environmentally friendly. The airport's location, current situation, and available opportunities also play a key role in this situation (Vanker *et al.* 2013). Environmental management plans and eco-friendly policies and strategies are, therefore, being adopted increasingly by airports around the world (Giustozzi *et al.* 2012).

To maintain airport infrastructure, significant quantities of water are required (de Castro Carvalho *et al.* 2013). The push for environmental sustainability, coupled with the exponential increase in the aviation industry, means that assessing water consumption is essential, given the scarcity of the resource. At airports, water is mostly utilised for non-potable applications. As such, there is significant potential to implement water conservation strategies. This can include (de Castro Carvalho *et al.* 2013), water metering and installation of water saving fixtures, also, utilising alternative sources, for example rainwater and treated greywater or domestic sewage effluent. In addition to the significant improvements in environmental sustainability, the utilisation of reclaimed greywater or rainwater will also represent an improvement in economic sustainability (de Aguiar do Couto *et al.* 2013).

Airports consume substantial volumes of water in order to maintain their operations (Thomas, Hooper 2013). Airport operators, ground service providers, and passengers and staff require water for drinking, catering, retail, cleaning, flushing toilets, system maintenance, as well as for airport grounds maintenance and landscaping. The operational capacity of an airport and the level of service quality delivered to its customers and service partners can be severely constrained if it is unable to guarantee and deliver a secure, adequate, and low-cost supply of water to satisfy peak demand (Thomas, Hooper 2013).

2. Sustainable airport water management

For airports, satisfying the increasing demand for water is becoming more challenging due to the increased competition from other sectors, particularly in parts of the world where water supplies are under stress or are diminishing either as a result of over abstraction, excessive run-off, or a decline in rainfall resulting from the influence of a changing climate (Eurocontrol 2011 cited in Thomas, Hooper 2013).

The principle of an airport's sustainable water management involves a hierarchical approach, the most environmentally and economically effective being to minimize water at the source through (Thomas, Hooper 2013):

- raising awareness and promoting "turn-off" programs;
- fitting automatic switch-off and collection systems;
- the introduction of simple low-water operating practices, for example, the use of sand rather than water and detergents to deal with fuel spills;

– the use of low-water consumption equipment such as waterless apron sweepers.

Historically, airports have been designed to make use of ground water or water supplied from municipal authorities that satisfy appropriate quality standards. Where this water has only been used for non-industrial purposes (for example, washing, cleaning, and laundry), wastewater can be collected by the airport, treated, and reused for activities including toilet flushing, washing, and, in some instances, irrigation of plants. Such practices may require the airport to introduce a dual drainage system as well as water-purification facilities (Thomas, Hooper 2013).

A further source of water comes from harvesting (collecting) and storing rainwater. This approach can substantially reduce the volume of water sourced from conventional supplies and acts as a reservoir to guard against water shortages. The most sustainable approach to water management is for airports to seek to become self-sufficient in their water supply by optimizing opportunities for water harvesting, recycling, and minimizing consumption (Thomas, Hooper 2013).

3. Storm water management at airports

The construction of an airport and especially the construction of the runway(s) can disturb the ground water system not only in the airport precinct, but also in the wider surroundings of the airport (Horonjeff *et al.* 2010). Rain water drains quite rapidly from the paved airport areas, and can result in flooding in the water courses that are fed by the rain drains. Flood waters are consequently typically fed into retention tanks (Kazda *et al.* 2007).

An airport can be a significant contributor to water pollution if suitable facilities to treat airport wastes are not provided. Sources of water pollution from an airport include sewage from airport facilities, industrial wastes such as fuel spills, and high temperature water degradation from the various power plants located at the airport. Furthermore, runoff chemicals used in winter de-icing operations contribute to the collection of pollutants in the airport's surrounding water table (Young, Wells 2011). Major airports could also have a number of hydrocarbon-based contaminants that may appear in storm-water runoff (Fisher *et al.* 1995). Hence, managing storm water is critical for an airport's operations (Pazwash 2011).

Most countries have water quality standards, and many airports have standards that are normally more stringent (Kazda *et al.* 2007).

Airports also generate large volumes of waste water (Pitt *et al.* 2002). The water quality around airports is adversely impacted by the runoff of aircraft and airport de-icing operations, together with other sources such as fuel leaks, spills, and solid and liquid waste treatment and disposal. Since water sources are often connected to each other, any adverse impact on the local supply in terms of deterioration of water quality arising from airport operations can be felt in regions quite distant from the airport itself (Marais, Waitz 2009).

Therefore, prior to entering the sewer the airport's waste waters must be properly treated (Kazda *et al.* 2007). In an airport's operational area, run-off waters represent a significant environmental threat (Sulej *et al.* 2012a, 2012b) and could have a negative impact on both soil and groundwater, since they contain a relatively high concentration of contaminants (Vanker *et al.* 2013). Storm water runoff can be impacted by airport operations, for example, the use of chemicals for snow and ice removal, accidental fuel and oil spills on airport ramp areas, and the discharge of fire-fighting foam in the event of aircraft emergencies. Wastes associated with aircraft refuelling, operation and cleaning could potentially be carried to lakes and streams located nearby to the airport through the storm water drainage system. Other operational activities at the airport can also influence water quality through contaminants in storm water runoff, for instance, major aircraft overhauls that utilise toxic chemicals to remove paint and clean and re-chrome engine parts as well as other light-industrial type activities (Culberson 2011). The treatment of such wastes must satisfy health and safety requirements regarding the contents of heavy metals, chlorinated hydrocarbons, and sedimentation substances (Kazda *et al.* 2007).

Sewage water from an airport is cleansed in normal water treatment plants. Drainage from an airport's movement areas requires a special treatment due to the oil-products or de-icing chemicals used in winter (Kazda *et al.* 2007). This is a requirement because in regions where temperatures drop below freezing point aircraft surfaces must be de-iced prior to take-off to ensure that the wing control surfaces can function and the aerodynamic properties of the wing are not changed by ice (Marais, Waitz 2009). The safety of air transport operations also requires that runways/taxiways and aircraft are kept free of both ice and snow. In order to ensure the safe landing and take-off of aircraft, independent of the prevailing weather conditions at the airport, aircraft de-icing/anti-icing fluids (ADFs) and runway de-icing chemicals are often required (Breedveld *et al.* 2003). Consequently, de-icing and anti-icing are, critical for aircraft safety (Marais, Waitz 2009).

Rain water from the paved areas, especially from the apron, can be cleaned in a special treatment plant located at the airport, with separation of oil products, or alternatively, the collector can be connected to the local municipal treatment plant (Kazda *et al.* 2007).

Furthermore, especially dangerous areas of the airport, for instance, fuel storage, and aircraft hangars and maintenance facilities, need to be equipped with traps for oil products and be inspected regularly. Also, it is important for airports to pay attention to possible water or soil contamination arising from fire-fighting training. Such training activities should only be permitted within a specially designated area (Kazda *et al.* 2007).

4. Mildura Airport: a brief overview

"Mildura Airport" is strategically located in the far north west of Victoria, around 650 km north north-west from the state's capital, Melbourne (Fig. 1). "Mildura Airport" is Victoria's largest and busiest regional airport, serving not only the State of Victoria, but also a large part of rural New South Wales together with South Australia (Mildura Airport 2010).

The total area of the entire airport site is 240 hectares, of which around 102 hectares comprise the airport and its associated ancillary facilities (Table 1) (Mildura Airport 2010).

Fig. 1. Location of "Mildura Airport", in Victoria, Australia, and the surrounding region which it serves (Imagery ©2015 TerraMetrica, Map data ©GBRMPA Google)

Table 1. Land-use of Mildura Airport (Mildura Airport 2010: 4)

Location	Area (hectares)
Airside operations	77.85
Terminal operations	7.2
Hangars/Tenants	8.44
Motorsports	5.62
Undeveloped	137.27
Museum	0.54
MET/ESS	2.3
Total	**239.22**

The airport has a modern infrastructure, consisting of a modern main passenger terminal building, 2 runways, a small number of enclosed hangars, several open air hangars, a cargo terminal, and a sewage treatment plant (see Fig. 2).

Fig. 2. Aerial view of Mildura Airport (Imagery ©2015 CNES/Astrium, Cnes Spot Images, Digital Globe)

The airport is located on the south western side of the city of Mildura, around eight kilometres (km) from the central business district (Civil Aviation Safety Authority 2010). The predominant adjacent land use surrounding the airport in all directions is rural or undeveloped land. There is some residential use associated with the occupation of the rural land but the density of dwellings is very low (Mildura Airport 2010).

The airport was established as a training centre for the Royal Australian Air Force (RAAF) during World War II and became the largest training facility for fighter pilots in Australia (Civil Aviation Safety Authority 2010). Following service as a military training field, the airport operated for many years as a small rural airfield. The airport was serviced by several airlines, including Ansett Australia and government-owned Trans Australia Airlines (TAA). It was not until the 1980's that demand stimulated competition and a number of new airlines – Murray Valley Airlines, Southern Airlines, Kendall Airlines and O'Connor Airlines – commenced operations at the airport (Mildura Airport 2010).

Currently, three airlines, QantasLink, Regional Express (Rex), and Virgin Australia, provide regular passenger transport[1] (RPT) services to Adelaide, Broken Hill (South Australia), Melbourne and Sydney, utilising both turbo prop and jet aircraft. In addition to the RPT operators, the airport services charter, flight training, air cargo, air ambulance, aerial agriculture, parachuting, as well as military, and VIP flights. The airport is also used for the refuelling of transiting aircraft and provides a convenient calling point for diverting aircraft and those experiencing an on-board emergency (Mildura Airport 2010).

Over the past two decades, the airport has recorded quite a strong growth in both inbound and outbound scheduled RPT passenger traffic. This is shown in Figure 3. The indication here is that there will be continued

[1] In Australia, *regular passenger transport* (RPT) services are scheduled aircraft operations provided to the general public and operated on a commercial basis (Productivity Commission 2011).

growth over time. The drop in traffic after 2000 is primarily due to the collapse of Ansett Australia (the second largest airline in Australia at the time), and the drop in 2008 is primarily due to the global financial crisis.

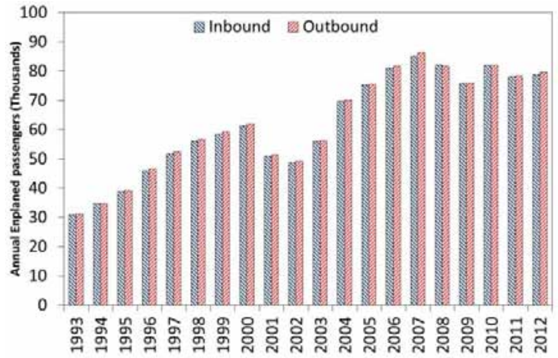

Fig. 3. Annual growth in Mildura Airport RPT inbound and outbound passenger traffic: 1993–2012 (Bureau of Infrastructure, Transport and Regional Economics 2014)

Figure 4 illustrates the annual RPT aircraft movements at the airport from 1993 to 2012. Although Figure 3 shows a growth in passenger numbers, there is no accompanied growth in aircraft movements. This can be explained by the increase in aircraft size. For example, the Virgin Embraer E190 currently serving the destination is in contrast to the typical Fairchild Metroliner serving many regional destinations, including Mildura.

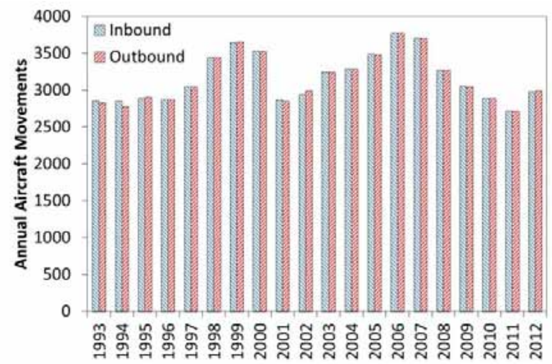

Fig. 4. Annual RPT aircraft movements at Mildura Airport: 1993–2012 (Bureau of Infrastructure, Transport and Regional Economics 2014)

The airport is managed by Mildura Airport Pty Ltd and was awarded the Australian Airports Association prestigious "Airport of the Year" award for the category "Regular Public Transport Airport with 50,000 to 500,000 Passengers Per Annum" in 2013 (Mildura Airport 2013).

5. Potential rainwater harvesting at Mildura Airport

5.1. Methodology

In order to assess the rainwater potential of "Mildura Airport", the total roof area of the airport needs to be measured. This involved writing an image processing script in Matlab. To do this, a digital map of Mildura airport was modified; this involved overlaying the building areas with black polygons. The underlying image was then removed, leaving the black polygons on a white background. This black and white image was then analysed in Matlab. Two reference measurements, ideally orthogonal, are used to scale the image pixel in terms of an area. The sum of the black pixels can then be used to determine the total area. The area estimation calculation requires the inputs of pixel coordinates for three points, *A*, *B* and *C*. We will denote the pixel coordinates of these points as (x_A, y_A), (x_B, y_B), and (x_C, y_C) respectively. Also, the distance from point *A* to point *B* (d_{AB}) and the distance from point B to point C (d_{AB}) are required. The goal is to determine the horizontal distance Δx, corresponding to the width of a pixel, and the vertical distance Δy, corresponding to the height of a pixel. Using right angle triangles, the following two equations were devised:

$$\begin{aligned} \Delta x^2\left(x_B - x_A\right)^2 + \Delta y^2\left(y_B - y_A\right)^2 &= d_{AB}^2 \\ \Delta x^2\left(x_C - x_B\right)^2 + \Delta y^2\left(y_C - y_B\right)^2 &= d_{CB}^2 \end{aligned}, \tag{1}$$

both of which can be solved simultaneously to yield:

$$\Delta x = \sqrt{\frac{d_{BC}^2\left(y_B - y_A\right)^2 - d_{AB}^2\left(y_C - y_B\right)^2}{\left(x_C - x_B\right)^2\left(y_B - y_A\right)^2 - \left(x_B - x_A\right)^2\left(y_C - y_B\right)^2}}$$

$$\Delta y = \sqrt{\frac{d_{BC}^2\left(x_B - x_A\right)^2 - d_{AB}^2\left(x_C - x_B\right)^2}{\left(y_C - y_B\right)^2\left(x_B - x_A\right)^2 - \left(y_B - y_A\right)^2\left(x_C - x_B\right)^2}}. \tag{2}$$

The area of the black regions in the figure is then estimated to be the number of black pixels, n, times the pixel dimensions:

$$Area \approx n\Delta x\Delta y\,. \tag{3}$$

5.2. Results

Figure 5 shows a screen shot of the area image processing tool which was created in Matlab. In it, a black and white map of "Mildura Airport" roofed buildings can be seen, which was utilised to determine the total rainfall capture area. The area was estimated to be 12,695m^2.

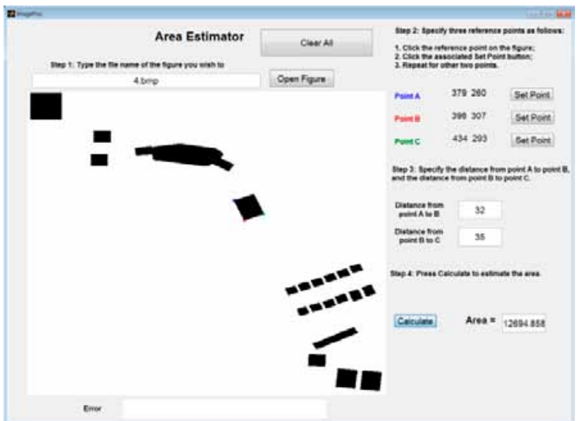

Fig. 5. Screen shot of image processing tool created in Matlab. The bitmap shows the roofed structure available at Mildura Airport

Rainfall information for "Mildura Airport" is readily available from the Australian Bureau of Meteorology. Daily information is provided, facilitating a detailed investigation of the rain water potential. From the information on rainfall and the building area the water volume can be obtained.

Figure 6 shows the annual rainfall for "Mildura Airport" since 1947. There is a significant degree of variation, with a range from 100mm to 600mm. The average is (291±26) mm. The number here utilises a 95% confidence interval, showing a relatively tight clustering of data, given the long time scale. The standard deviation is a little more significant, being at 105 mm. The average monthly rainfall (Fig. 7) shows a fairly consistent trend, with approximately 25mm per month. This is very promising for rainwater harvesting.

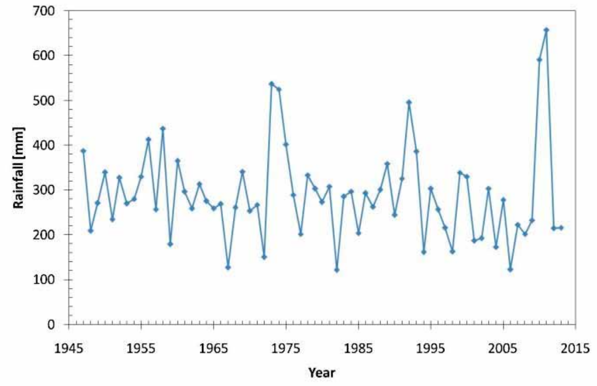

Fig. 6. Annual rainfall from 1947 until 2013 for Mildura Airport (source: Bureau of Meteorology 2014)

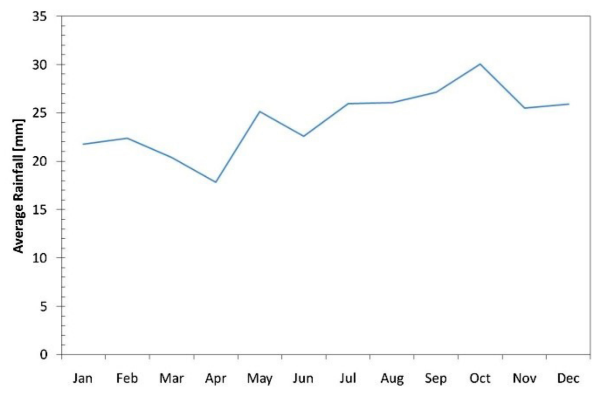

Fig. 7. The average monthly rainfall (averaged from 1947 until 2013) for Mildura Airport (Bureau of Meteorology 2014)

Combining the area estimate and the average annual rainfall gives a volume of 3964m^3. That is, 3.964 megalitres. It should be noted that this volume, although by no means trivial, does not come close to the demand of the airport; however, it can be used for multiple purposes. A similar analysis could be undertaken for water capture off the hard surfaces, which as grey water has more limited applications. Following this, the potential saving obtained by comparing the commercial cost of water purchased could to the cost of capturing and cleaning this grey water. This could have a significant benefit in terms of the long term economic and environmental sustainability of "Mildura Airport".

6. Conclusions

In conclusion, this work has presented a novel and relatively simple method of estimating potable water harvesting potentials of airport structures. This was done in the context of sustainable water management, as an essential aspect of regional airport operations in Australia. Due to the climatology of Australia many regional areas experience arid drought like conditions, potentially for long periods of time. Water management at an airport in general is an important consideration, given the need for large grassed areas airside, along with airside needs of aircraft and other vehicles, as well as landside facility usage (toilets, kitchens, passenger consumption, etc). To assess the aspects of sustainable water management at regional airports, "Mildura Airport" was selected as a case study. It is the largest regional airport in the State of Victoria, servicing a large regional population across three states in the south east of Australia.

Significant effort is put into the reclamation of greywater, which has applications for plant watering and other, airside; however, potable water is also significant as it has a larger cost associated with its use. As such, sustainable water management must also investigate potable water options in order to improve operational efficiencies of running a regional airport.

The method presented to determine the potential water harvesting capability at regional airports involved processing of satellite imagery, combined with the image processing functionalities of Matlab, and some basic mathematics. This provided an estimate to the total roofed area, which in combination with meteorological data, readily available at all major aerodromes, provided the volume capture potentials. For Mildura Airport, an average potable water harvesting potential of 3.964 megalitres per year was estimated using the method.

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