



Critical examination of the ability of alternative fresh water sources to assist sustainable growth of Australian agricultural sector

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“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

Brundtland Commission, 1983²

1. Sustainability of the fresh water supply to the Australian agricultural sector

Australia is the world driest inhabited continent. In accordance with the Encyclopedia of Climatology³ 50% of Australian land receives less than 300 mm of precipitation per annum and 80% of the land receives less than 600 mm per annum. This is well below the average annual rainfall of 812.8 mm on the Earth, and much lower than the average annual rainfall of 4548 mm in Asia. Furthermore, in over 75% of the territory the potential evaporation is greater than 2500 mm/p.a. and in central Australia the evaporation potential is around 4500 mm/p.a. – 20 times the actual annual rainfall. Not surprisingly, the most productive agricultural areas of Australia are located within the zones of highest precipitation (with an exception of the most northern uninhabited parts of Western Australia, Northern Territory and Queensland), Figure 1. Therefore, the possibilities of the future development of the Australian agricultural sector and the prosperity of the Australian people in general, depend largely on the vital question of ensuring sustainable fresh water supply.

The natural sources of fresh water include surface water, under river flow, ground water and frozen water (not available in Australia). The surface water is the water in rivers, lakes, fresh water wetland and, in some countries – the glaciers runoff. Precipitation and discharge to the oceans, evaporation, and sub-surface seepage are elements of the natural balance of the surface water. The under river water is a component of the total flow that is transported downstream through sub-surface rocks and gravels that underlie the river and its floodplain. For many rivers in large valleys

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² Report of the World Commission on Environment and Development: Our Common Future, UN Documents, Annex to document A/42/427 – Development and International Co-operation: Environment [online] <http://www.un-documents.net/wced-ocf.htm> [accessed 27 April 2009].

³ Encyclopedia of Climatology (Encyclopedia of Earth Sciences Series), Oliver J.E.; Fairbridge, R.W. (Eds.), Springer; 1987.

the under river flow may greatly exceed the visible flow. The groundwater is located in the pore space of soil and rocks, and the water that is flowing within aquifers below the water table.

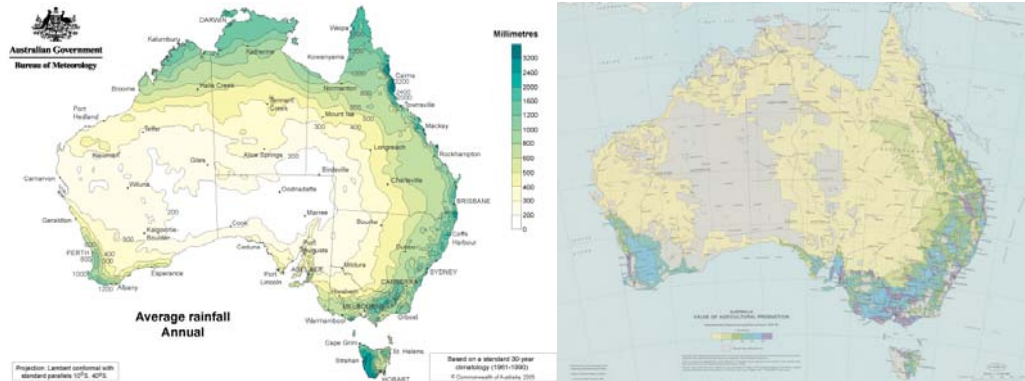


Figure 1. Maps of the annual average rainfall across Australia, based on a standard 30 year climatology record (1961-1990)¹ and the distribution of the value of agricultural production in Australia².

Three widely accepted operational rules define the condition of ecological (thermodynamic) sustainability³: (i) renewable resources (e.g. fish, soil, water) must be used no faster than the rate at which they regenerate; (ii) non-renewable resources (e.g. minerals and fossil fuels) must be used no faster than renewable substitutes for them can be put into place; and (iii) pollution and wastes must be emitted no faster than natural systems can absorb them, recycle them, or render them harmless. These basic ecological rules can be redefined to formulate the general conditions for sustainability of the water supply to households and to all aspects of the Australian economy, including the agricultural sector:

1. *Australian surface water, under river and ground water supplies must not be used faster than the rate at which they regenerate;*
2. *Increased energy demands for redirecting the natural (gravitational) water flow, waste water treatment and artificial water desalination must be satisfied by renewable energy sources;*
3. *If there are no renewable energy sources sufficient to satisfy Condition 2, then the exploitation of additional non-renewable energy sources should not significantly affect existing carbon dioxide, pollutants and waste balances.*

¹ Australian government, Bureau of Meteorology, annual average rainfall across Australia, based on a standard 30 year climatology record (1961-1990) [online] http://www.bom.gov.au/climate/map/rainfall/IDCJCM0004_rainfall.shtml [accessed 27 April 2009].

² Australian government, Geoscience Australia, Historical Atlas of Australian Resources - Agriculture (1982 edition) [online] http://www.ga.gov.au/nmd/mapping/atlas_agriculture.jsp [accessed 27 April 2009].

³ The Entropy Law and the Economic Process, Nicholas Georgescu-Roegen, iUniverse Inc, 1999.

Explanations that clarify these three criteria follow:

First criterion: Australian Bureau of Meteorology¹ reports 364 mm average annual rainfall for the years 2004-05. This results in total 2,789,424 gigalitres (GL) of rainfall across the country². Considering that the precipitation is the only natural replenishing source of fresh water, the absolute annual water consumption for all sectors of the Australian economy cannot exceed the total annual rainfall across the country. Then, the first reformulated sustainability condition can be satisfied in terms of the whole country. Indeed, this is a gross oversimplification of the problem, since most of the surface water (2,497,471 GL) is lost through evapotranspiration³ and the run-off is only 242,779 GL. Furthermore, the geography of the country is such that rainfall distribution is extremely non-uniform. For example, most of the 2004-05 rainfall in Australia fell in Queensland (865,973 GL), Western Australia (639,609 GL) and the Northern Territory (505,623 GL)⁴, mostly in their uninhabited northern parts. This is to indicate that the first criterion for sustainability of the water supply must be applied in respect to the water balance of smaller territorial units, preferably to the individual Australian drainage divisions (these divisions include the Indian Ocean, the south-west coast and Timor Sea drainage divisions in Western Australia, the Gulf of Carpentaria drainage division, the north-east and south-east coast drainage divisions, the Murray-Darling Basin, the South Australian gulf drainage division, the Lake Eyre Basin, Western Plateau, Bulloo-Bancannia drainage division and Tasmania). Then, the first criterion must be rewritten to the following final formulation:

1. The surface water, under river and ground water supplies of an individual drainage division must not be used faster than the rate at which they regenerate.

Second criterion: Consider some of the theoretically feasible technical solutions on how to supplement the water resources in areas where Criterion 1 cannot be satisfied: (i) catchment of the massive rainfalls in the northernmost parts of the country and transportation of water to the agricultural areas in the south (this would require creation of policies for and adoption of an internal water trade scheme); (ii) import of fresh water from neighbouring countries with abundant supply (e.g. import from Papua New Guinea); (iii) towing huge icebergs from Antarctica (iv) agricultural use of recycled water; and (v) desalination of ocean water. The apparent advantages and disadvantages of these methods will be considered in details in the next sections. For the moment, we will concentrate on the conditions for satisfaction of the second criterion for sustainability of the water supply. The second criterion can be partly satisfied if, for instance, the electricity needed to pump the massive water flow from north to south or to drive the water desalination plants comes from renewable energy sources (e.g. from wind farms). Similarly, if the ships towing icebergs or tankers transporting water are fuelled by renewable substitutes of the standard diesel fuel (e.g. pyrolysis oil or biodiesel), then the second criterion is also partially satisfied. This criterion would be fully satisfied only if the energy required for building the new

¹ Australian government, Bureau of Meteorology, 2004-05 summary of rainfall, evapotranspiration, deep drainage, runoff and land use area of Australia [online], http://www.water.gov.au/WaterAvailability/Whatisourtotalwaterresource/Rainfalldistribution/index.aspx?Menu=Level1_3_1_2 [accessed 27 April 2009].

² Ibid.

³ Ibid.

⁴ Ibid.

infrastructure also comes from renewable sources (e.g. heavy machineries and cement plants utilise renewable fuel).

Third criterion: Criterion 2 is probably the most difficult to satisfy since most of the aforementioned technical projects are extremely energy demanding and the potential of the Australian renewable energy industry to grow is not unlimited. Therefore, non-renewable energy may need to supplement the renewable sources in a way that is the least harmful to the environment. For instance, if the electricity generated in wind farms is not sufficient to drive a water desalination plant, then energy from thermal power plants that burn natural gas instead of coal can be used. If adverse changes to the carbon dioxide balance of the country are undesirable, then building and utilisation of nuclear power stations to supply the huge extra energy demands must be considered.

2. Sustainability of water supply in individual Australian drainage divisions

This section provides an overview of the sustainability of water supply in individual Australian drainage divisions and assesses the necessity of taking measures to artificially supplement these supplies¹. Detailed maps of these divisions are shown in Annex 1. A summary is provided at the end of the section.

2.1. North-east coast drainage division



The north-east coast drainage division is located between the Great Dividing Range and the Pacific ocean in Queensland. The southern border of the division is an arbitrary line drawn along the Queensland/New South Wales border. The population in 2006 was 3,537,605 with Brisbane and Gold Coast being the major cities. Average rainfall varies from about 500 mm in the driest sections (notably the area surrounding Townsville) to almost 4 metres in the wettest districts (the section between

Cooktown and about Innisfail). The major rivers are Suttor River, Belyando River and Nogoia River. The rivers tend to be short but have high flow volumes, particularly during the wet season. The major water storages are Burdekin Falls (Lake Dalrymple) and Fairbairn. The largest irrigation areas are Burdekin and Dawson. On a per-area basis, the northeast coast division is the wettest of any in Australia. If an internal water trade scheme is adopted, then the northern part of the north-east coast drainage division could be selected as one of the water donors to the dryer parts of Queensland. At the moment, a water desalination plant is under construction near Tugun in Queensland to supply the fast growing Gold Coast metropolitan area and the relatively dry South East Queensland. The daily output is expected to reach 167,000 m³.

¹ Most of the information shown in this section is taken from the websites of the Bureau of Meteorology, CSIRO, the Bureau of Rural Sciences and the webpage of the BIRD (Biodiversity Information, Resources and Data). The population data is provided by the Australian Bureau of Statistics (2006 Census).

2.2. South-east coast drainage division



The south-east coast drainage division includes all of coastal Victoria and coastal New South Wales between the Great Dividing Range and the ocean. It also includes a small part of south-eastern South Australia which lies to the east of the Murray-Darling Basin. The northern boundary is arbitrarily defined as the New South Wales/Queensland border. This is the most populous area of Australia with population of 10,054,054 (2006 census) and heavily urbanised and industrialised areas around the cities of Sydney and Melbourne. The major rivers are Glenelg River, Hunter River and Snowy River. The major water storages are Eucumbene and Warragamba. The largest irrigation areas are the Southeast Region and Macalister. Much of the division has experienced a decrease in annual rainfall since 1997. A second, more widespread downturn in annual rainfall started during 2002 and has severely affected the area. Most commonly these low annual rainfalls are attributed to El Niño events that occurred during 1997, 2002 and 2006. Normally droughts caused by El Niño are followed by good, drought-breaking rains. However the rainfall in the years after 1997 has been insufficient to fully alleviate the water deficiencies, which resulted in lowering the level of water stored in the dams and severe water restrictions in the affected areas. States government are taken measures to divert fresh water from agricultural areas and to build water desalination plants to supplement the water supply of the large metropolitan centres. For example, the Victorian North/South pipeline is to transfer 75 GL per year from the Goulburn Valley to Melbourne. A desalination plant in Kurnell, New South Wales is planned to supplement Sydney's water requirements and there are plans to build a large desalination plant (150 GL) near Wonthaggi in Victoria. These plans face strong opposition from the local communities and the environmentalists¹.

2.3. Tasmania



Tasmania is characterised by relatively uniform rainfall throughout the year with the maximum falling during the winter and the low summer. 461,244 people were living in Tasmania in 2006, with the largest towns being Hobart and Launceston. The area of the main island is 62,409 km². The major rivers are South Esk River, River Derwent, and Macquarie River. The major water storages are Gordon (Lake Gordon) and Miena Rockfill (Great Lake). The largest irrigation areas include Cressy Longford and Coal River Valley. The long term (1961-1990) average annual rainfall of Tasmania is twice as high as the long term average rainfall of Victoria – 1,168 versus 654 mm²,

¹ Stamatov V., Stamatov A., Long-term impact of water desalination plants on the energy and carbon dioxide balance of Victoria, Australia: a case study from Wonthaggi, *Water and Environment Journal*, in press.

² Australian government, Bureau of Meteorology, 2004-05 summary of rainfall, evapotranspiration, deep drainage, runoff and land use area of Australia [online],

which makes the island a potential water donor to the nearby south-east coast drainage division. Plans are already under consideration to deliver 350 GL of fresh water a year from Burnie on the northwest coast of Tasmania to Melbourne through 350 km long pipeline under the Bass Strait¹. The water would be drawn from the Forth River, which is already dammed and tapped for hydroelectricity and has an annual flow of 1300 GL.

2.4. Murray-Darling Basin



The Murray-Darling Basin is by far the most significant agricultural area of country. Although the Murray-Darling Basin receives only 6% of Australian rainfall, 42% of country's farmland and 70% of the irrigated areas (including the areas of Berriquin and Central Goulburn) are located there to produce 40% of the nation's food. 2,007,121 people used to live in this area in 2006, with the nation capital being located there. The second major town is Toowoomba in South East Queensland. Most of the 1,072,000 km² basin (roughly one-seventh of the Australian territory) is flat, low-lying and far inland. Rainfall is unpredictable and varies from place to place as well as year to year, but is typically around 250 or 300 mm a year on average, except in the elevated south-east corner where the rainfall is typically about 500 mm a year. The major rivers are Murray River, Darling River and Lachlan River. They tend to be long and slow-flowing, and carry a volume of water that is large only by Australian standards. The major water storages are Lake Dartmouth and Lake Eildon. Total water flow in the Murray-Darling basin averages 14,000 GL per year. 11,500 GL yearly are removed for irrigation (95%), industrial use, and domestic supply. This is one of the divisions that most desperately need extra fresh water supplies, although extreme care must be taken to prevent over irrigation, since salinisation of the soil is a major issue in many areas.

2.5. South Australian gulf



The south Australian gulf drainage division shares many problems with the neighbouring Murray-Darling Basin and south-east coast divisions. It is a home of 1,293,107 people (2006 census) concentrated mainly in the metropolitan area of Adelaide. Rainfall over the area varies between 200 and 750 mm per year. It occurs primarily in winter and tends to be concentrated on the highest and most southerly districts. There are no permanent fresh water lakes in the region and the rivers are short. The only significant irrigation area is in

http://www.water.gov.au/WaterAvailability/Whatisourtotalwaterresource/Rainfalldistribution/index.aspx?Menu=Level1_3_1_2 [accessed 27 April 2009].

¹ Neales S., \$2bn pipeline could bring supplies in from Tasmania, Herald Sun dated 18 July 2008 [online], <http://www.news.com.au/heraldsun/story/0,21985,24038330-2862,00.html> [accessed 27 April 2009].

Barossa Valley. The major water storages are Horndale Flume and Mount Bold Reservoir. In most years the flow to these reservoirs is supplemented by water pumped from the Murray River. The contribution of this water is about 40% to 90% of Adelaide's water needs. Constant water shortages forced the SA government to consider building a solar-powered desalination plant near Port Augusta and a second one in Port Stanvac to supply the city of Adelaide with fresh water.

2.6. South-west coast drainage division



The South-west coast drainage division lays on the most fertile part of Western Australia. The weather resembles the one in the temperate Mediterranean areas. Most of the rain falls in the mountains near the coast, with parts of the extreme south-western corner receiving as much as 1,400 mm per year. Away from the coast, however, precipitation drops rapidly, with inland areas averaging about 250 mm per year. The area experiences rapid population growth.

The total population is 1,772,146 (2006 census), most of them living in Perth and in the second largest town of Rockingham. The major rivers are Blackwood River, Avon River and Frankland River. The major water storages are the South Dandalup Dam (Lake Banksiadale River) and the Wellington Reservoir. The only significant irrigation areas is Harvey Water. A SWRO (Seawater Reverse-Osmosis) plant has been recently built south of Perth in Kwinana. There are plans to build a second plant in Binnigup to boost the city supply with fresh water. One of the major environmental issues is the severe dry land salinity, which could reduce the benefits of supplying extra fresh water to some of the agricultural districts.

2.7. Indian Ocean drainage division



The Indian Ocean drainage division extends over 520,000 km² of arid Western Australia. The rainfall is low and conditions harsh. The division falls naturally into two main areas – Pilbara to the north and the Gascoyne-Murchison to the south. Yearly rainfall averages up to 400 mm in Pilbara, however, as with most parts of outback Australia, yearly average figures are misleading since dry periods with little rain can last for months or years, yet a cyclone can deliver most of the rain in a few hours causing severe erosion of the soil.

The agricultural activities are limited and overgrazing has degraded much of the land area. The Gascoyne-Murchison area and the Lyndon-Minilya system further north in the Pilbara, is regarded as the most degraded pastoral catchment in Western Australia.

2.8. *Timor Sea drainage division*



The Timor Sea drainage division covers an area of 450,000 km². Average rainfall in the division varies from less than 400 mm in the south to about 1500 mm in the north. Nearly all rain falls during the short summer wet season, often in association with spectacular thunderstorms and tropical cyclones. The population was 164,436 people in 2006, 120,000 of them living in Darwin. The major rivers are Victoria River, Fitzroy River and Ord River. Rivers run generally north or west to the Indian Ocean and the Timor sea and can be very large by Australian standards. On a stream flow/area basis, it is the second-wettest division in Australia (after the northeast coast drainage division), however, its extreme remoteness from the major agricultural areas prohibits the inclusion of the water surplus to the country's balance.

2.9. *Gulf of Carpentaria drainage division*



This division encloses the Gulf of Carpentaria on three sides. The climate is hot and humid with two seasons per year. Almost all rain falls during the period from December to March. Average annual rainfall varies from about 1500 mm in the north to less than 300 mm further inland. The major rivers are Flinders River, Gilliat River, and Roper River. Most rivers flow only during the short tropical wet season and although being relatively short, carry almost a quarter of the continent's total yearly stream flow. With no large towns and few smaller settlements, the key environmental issue for the division is the sustainable management of grazing. Similarly to the neighbouring Timor Sea drainage division, the remoteness of the excess water resources of the Gulf of Carpentaria prohibits their delivery to the major agricultural areas.

2.10. *Lake Eyre Basin*



The Lake Eyre Basin is the largest internal drainage system in the world and covers roughly 1.2 million km². All the riverbeds in this mostly flat, arid and semi-arid area lead inland towards Lake Eyre in central South Australia. The lake lies 15 metres below sea level and usually contains only salt. The average annual rainfall in the area surrounding Lake Eyre is 125 mm and none of the creeks and rivers in the Basin are permanent. At the same time, even the entire flow of the Murray-Darling would be insufficient to fill Lake Eyre – it would merely keep pace with evaporation rate of 3500 mm a year. These extremely harsh climate conditions and the remoteness of the area prohibit almost all economic activities.

2.11. *Bulloo-Bancannia drainage division*



The Bulloo-Bancannia is an isolated central Australian drainage system. The total area is 98,824 km² with a population of only 1,462 (2006 census). Bulloo River is the only river in this region, flowing into a number of ephemeral lakes. Annual rainfall throughout the basin ranges from 330 mm in the north to 200 mm in the south. The area is used almost exclusively for the extensive grazing of sheep and cattle.

2.12. *Western Plateau*



The Western Plateau is the largest drainage division in Australia. It covers a vast arid land of 2,700,000 km². There are no permanent watercourses. The rainfall is highly unpredictable and insufficient to produce any marked drainage pattern.

Summary: Unfortunately, the areas of the highest agricultural productivity that are situated in the southern parts of the north-east coast drainage division, Murray-Darling Basin, south Australian gulf and south-east and south-west coast drainage divisions, are also those with the most distorted water balance. Those areas are most sensitive to any adverse deviations from the average rainfall values and in case of prolonged drought cannot satisfy the first of the criteria for sustainability of the water supply:

1. *The surface water, under river and ground water supplies of an individual drainage division must not be used faster than the rate at which they regenerate.*

Except for the Murray-Darling Basin, the aforementioned areas also have the highest population density. All existing projects for artificial supplement of the water supply are designed to satisfy the needs of the large metropolitan areas only. Furthermore, there are examples showing that the State governments are willing to diverge water resources from agricultural to urban areas (e.g. the Victorian North/South pipeline).

Because of geographical factors (close proximity and suitable relief) only one of the divisions with excess water supply could be considered as economically and technically viable donor: that is Tasmania which could supply fresh water to the closely situated parts of the south-east coast drainage division in Victoria and, potentially, to parts of South Australia.

3. Assessment of technical, economic and environmental viability of alternative water sources

This section provides an assessment of the technical, economic and environmental feasibility of different alternative sources to supply Australian agriculture with sufficient amount of fresh water. A summary is provided at the end of the section.

3.1. Transportation of water from zones with excessive supply to agricultural areas

3.1.1. Transportation in channels and/or pipelines

Transportation of water in open channels from the northern to the southern drainage divisions could be automatically ruled out since the channels should pass through zones with extremely high evaporation potential.

Delivering water by pipelines from the zones with excessive supply may require moving it uphill and inland to reach the agricultural areas. Delivering the water to the consumers will mean enormous infrastructure costs for piping, but relatively minor operating costs for pumping. The energy requirements for pumping could be satisfied by the available renewable sources (wind farms). So far, building of a pipeline to deliver fresh water from Tasmania to Victoria is the most technically and financially realistic project of this kind.

3.1.2. Tankers and towed water-bags

Transportation of water in tankers is a technically feasible but economically not viable option. This method, being too expensive for agricultural use, could be used in emergency situations for delivering relatively minor quantities of water. A Canadian study¹ shows that the cost per m³ of water payload per day of transport has a broad range of \$0.12-\$0.60 per m³ per day², depending on current fuel prices and the size of tanker involved. The transport cost would double because there would be no suitable return-trip cargo.

The concept of towed water-bag transport may reduce the operating costs, but the technology has not yet been proven for long distances in the open ocean. So far, water is shipped in towed bags for short distances, typically on the order of 100 km, to serve islands in the eastern Mediterranean.

3.1.3. Towing icebergs

This is a rather exotic option with not successful large scale tests provided. Although there are no any significant technical obstacles for slow towing of large ice

¹ Policy Research Initiative, Exporting Canada's Water Outside of NAFTA [online], http://policyresearch.gc.ca/doclib/BN_SD_ExportingWater_200501_e.pdf [accessed 27 April 2009].

² Canadian dollars for 2004.

masses from Antarctica to Australia, it is impossible to evaluate the financial viability of such projects. Furthermore, there are substantial environmental concerns that thawing large masses of fresh water ice near the coast of Australia may cause local climate changes and serious damage to the seawater ecosystems.

3.2. Agricultural use of storm and recycled waste water

This is a technically and economically viable method, which is widely used. Power provided by renewable sources (from wind farms and from burning biomass decomposition gases) is sufficient to satisfy the energy requirements, which makes this method extremely environmentally friendly. The only real obstacle is the lack of sufficient quantities of feedwater. For instance, the Western Treatment Plant at Werribee, Victoria, treats about 52% of Melbourne's sewage, which makes about 180 GL a year. This is a substantial amount of water on local level, however it is not sufficient to provide solution to large scale water shortages in the agricultural sector.

3.3. Desalination

The economical and political decisions of whether to build a desalination plant in particular areas are influenced by 3 major factors: (i) the relative economic value of fresh water; (ii) the availability of excessive energy reserves; and (iii) the possibility to co-generate fresh water (a co-generating water desalination plant utilises the residual heat coming from power stations or from other sources of thermal energy). At the moment, only countries with severe water scarcity and extensive energy reserves like some of the Middle-East countries, or countries being in desperate need for fresh water like Israel, Malta and Singapore produce desalinated water in sizable proportions.

3.3.1. Stationary water desalination plants

There are about 12,500 desalination plants around the world with a total capacity of nearly 30 million m³ per day of fresh water¹. Two leading desalination methods are used: reverse osmosis (RO) and multi-stage flash distillation (MSFD). By the year 2004, these two provided 47.2% and 36.5% of the installed worldwide capacity. In general, RO plants are more cost-effective, while MSFD plants produce purer water. There are other desalination methods that are used in small number of plants like multi-effect distillation, vapour compression, reversal electrodialysis, forward osmosis, solar humidification, MSFD-RO hybrid process, and others.

All industrial water desalination methods are extremely energy intensive. A RO plant needs about 4-6 kWh/m³. The energy requirements of a MSFD plant are substantially higher, about 25-200 kWh/m³, although a variety of low-temperature heat sources may be supplementary used, including solar energy². The actual energy consumption depends on many factors including the salinity and temperature of the

¹ World Nuclear Association (WNA) [online]. www.world-nuclear.org_info_inf71.html [accessed 18 May 2008]

² Ibid.

feedwater, the salt permeation constant of the membranes (for the RO process) and the quality of the water produced. For instance, using of municipal wastewater as a feed substantially reduces the energy required for RO processes¹ to only about 1 kWh/m³.

An important consequence of using high energy demanding desalination processes is that the price of the water becomes instantaneously linked with the price of the electrical energy. Any fluctuations and crises in the energy market will be inevitably reflected by the water market. Aside from the high initial capital cost for building the desalination plant, the high cost of the electricity will also contribute to the increased price of the water to the final consumers.

There are several desalination plants built around Australia with few more proposals announced in the mass media. In most of the cases State governments declare that the energy required for the water desalination process will come from renewable sources like wind farms or solar energy, therefore, the extension of the water desalination programs will not affect the carbon dioxide balance of the country. An analysis on the availability of renewable energy sources² shows that these sources would be insufficient to satisfy the energy requirements of desalination plants in a long-term. There are two contributing factors: firstly, the potential for generating electricity from renewable sources is limited, and secondly, the energy consumption nationwide grows steadily every year with the current level being 2.1%. All alternative energy sources (hydro, biomass, geothermal, wind, tidal and photovoltaic cells) have inherent drawback. For instance, in the state of Victoria all hydro-electric facilities were commissioned pre-1980 (the reason for not extending the hydro-electric program is the general unavailability of new conveniently located water sources); photovoltaic (solar) cells are still extremely expensive; the wind farms potential to grow is not unlimited, etc.

Therefore, the long term perspective for the work of the desalination plants (which at the current level are anyway not sufficient to produce sizable quantities of water for the agricultural sector) is to be powered by the only reliable conventional source of energy in Australia – the coal burning thermal power stations. This will immediately violate the second and the third conditions for sustainability of the water supply that were formulated earlier in this paper:

2. Increased energy demands for redirecting the natural (gravitational) water flow, waste water treatment and artificial water desalination must be satisfied by renewable energy sources;

3. If there are no renewable energy sources sufficient to satisfy Condition 2, then the exploitation of additional non-renewable energy sources should not significantly affect existing carbon dioxide, pollutants and waste balances.

Hence, despite the unwillingness of the current government of Australia to discuss building of nuclear power stations in the country, this remains the only available

¹ Ibid.

² Stamatov V., Stamatov A., Long-term impact of water desalination plants on the energy and carbon dioxide balance of Victoria, Australia: a case study from Wonthaggi, *Water and Environment Journal*, in press.

option for developing large scale water desalination projects without violating the last of the aforementioned conditions.

3.3.2. Floating nuclear desalination plants

There are technical and safety issues related to the future of the nuclear energy in Australia that have not been addressed so far. For instance, one of the major problems is the location of a future nuclear reactor. – while many would appreciate the benefits of the nuclear energy, only few would like a nuclear reactor nearby their living areas. An interesting solution to this issue can be provided by the so-called Floating Nuclear Power Generating and Water Desalinating Units. These units are nuclear power stations combined with desalination plants. They can be towed to the destination point in coastal waters near a town, an industrial enterprise or agricultural district which needs the water or the energy. Alternatively, these units can be anchored outside the territorial waters of the country and connected with pipelines to the mainland.

The concept of the floating nuclear power and desalination plants is not new. Historically, the first floating nuclear power station had been an American MH-1A nuclear power reactor used to supply electricity and fresh water to the Panama Canal Zone from 1968 to 1975. In 2007, Russian Federal Atomic Energy Agency announced plans to launch six floating nuclear power stations that could generate electricity and desalinate water¹. The first station will be based on a KLT40S nuclear reactor with a planned output of 300 MW of heat and 70 MW of electrical power. The cost of the first station is US\$200 million. The station can work without refuelling for 12-15 years. The engineers designing the floating nuclear stations claim that the reactors are highly protected and normally there would not be any radiation impact on the environment.

3.3.3. Solar updraft towers (SUT)

Solar Updraft Towers work on the basic principle that hot air rises. As it is shown in Figure 2, the SUT has a large collector area at the base. The collector absorbs solar radiation, which heats up the air beneath it. As the air heats up, it becomes less dense and begins to rise towards the chimney in the SUT's centre. This generates a flow of cool air from outside the collector to be drawn into the system. The energy from the flow can be harnessed by the use of a turbine at the chimney base, which runs a generator that outputs electricity.

The energy stored in the ground allows the tower to work overnight, although at a decreased level. Thermal storage provided by, for example, concrete slabs or water tubes/channels can be used to improve overnight performance by accumulating heat during the day and releasing it at night; however, at the cost of reduced maximum output during the day. To optimise power output of a solar tower, it should be located

¹ Vzgljad Business Gazette (VBG) dated 15 April 2007, Russia will build floating nuclear power stations [online] <http://www.vz.ru/news/2007/4/15/77501.html> [accessed 01 December 2008]

in an area which experiences high annual solar irradiation. Most areas in Australia receive high solar energy input, which makes the country perfectly suited for utilising this type of solar power plants.

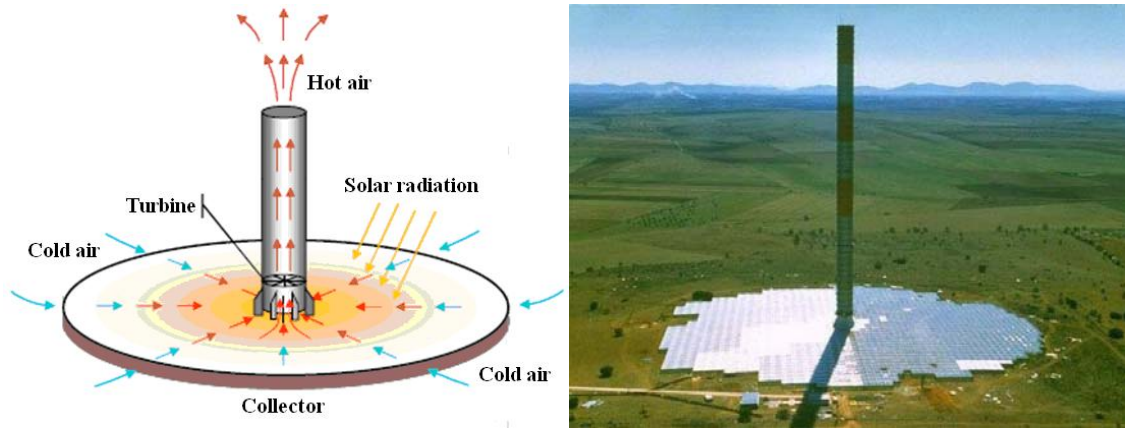


Figure 2. SUT's principle design¹ and a photographic image of a prototype solar tower built in Manzanares, Spain in 1982².

Scientists from the Los Alamos National Laboratory and the University of Denver in the USA have proposed using of SUT for extracting fresh water from the atmosphere³. The idea is to use an expansion cyclone separator that would be placed at the base of the chimney for condensing and removing atmospheric water. Power consumed in the expansion and separation would be offset by the energy generated by the SUT. The authors of the proposal provided a theoretical basis for the feasibility of the Solar Cyclone Distillers and suggested that an experimental study of the separation device would be worthwhile. It was later commented⁴ that a better performance of the water desalination function of a SUT could be achieved if the collector is partially built over reservoirs, channels or shallow lakes of salty, industrial or gray waters. The water reservoirs would provide the vapour for condensation and, at the same time, the reservoirs will store the day-time solar energy for the night-time electricity generation. The desalinated water can be used for irrigation of the crops that are grown under the rest of the collector.

A limitation of the method is the relatively insignificant amount of water that could be distilled, which makes it suitable for small scale agricultural activities only.

¹ Schlaich J., Bergermann R., Schiel W., Weinrebet G., Design of Commercial Solar Updraft Tower Systems – Utilization of Solar Induced Convective Flows for Power Generation [online]. http://www.sbp.de/de/html/contact/download/The_Solar_Updraft.pdf [accessed 02.02.2009].

² Ibid.

³ Kashiwa B.A., Kashiwa B.C., The solar cyclone: A solar chimney for harvesting atmospheric water, *Energy*, Volume 33, Issue 2, pp. 331-339, 2008.

⁴ Stamatov V.A., Utilisation of solar updraft towers for electricity generation and improvement of air quality near closed landfills in Australia, *Solar Energy*, ISSN: 0038-092X, submitted March 2009.

Summary: There is no perfect technical, economic and environmental solution to the problem of supplying Australian agricultural sector with sufficient fresh water from alternative to the natural precipitation sources. Table 1 shows a summary of the advantages and disadvantages of different methods for supplementing agricultural water supply. Some of the methods, like transporting water in tankers or towed water-bags, are technically feasible but too expensive for agricultural use (not to mention the impact of the tankers to the carbon dioxide balance of the country). Some other methods, like towing large Antarctic icebergs to the coast of Australia or using Solar Updraft Towers for water desalination, have not been technically examined so far, or may have negative environmental impact to the local ecosystems (icebergs). Utilising storm and recycled waste water for agricultural purposes is an excellent environmentally friendly option. Unfortunately, because of the limited supply of feedwater, this option may only be of local importance. Water desalination plants using conventional power supply from coal-burning thermal power stations and (partially) from wind farms are feasible for partial supply of urban centres with water. Because of the enormous energy and environmental cost this option is non feasible for agricultural use.

There are only practical options to supplement agricultural water supply in sizable quantities:

1. Redirection of excess water from parts of the northern drainage divisions and Tasmania to the agricultural areas via systems of reservoirs, pipelines and pumps. The realisation of this option requires massive capital investments and adoption of an acting water trade scheme;
2. Building and exploitation of stationary or floating nuclear powered desalination plants. For example, one or more large stationary or floating nuclear desalination plants could be suitably located somewhere along the coast line of southern Queensland, NSW or eastern Victoria. Alternatively, they could be built on ocean platforms. The plants could be connected with pipelines to the sources of the rivers of the Murray-Darling Basin to boost the water flow there and to provide much needed fresh water to this extremely important agricultural region. Major drawback to the realisation of such project is the general unpreparedness of the public to adopt the idea of using nuclear power on Australian soil. In this case, using of floating nuclear powered desalination plants could provide a compromise between the cultivated antinuclear notions and the practical needs of the Australian economy.

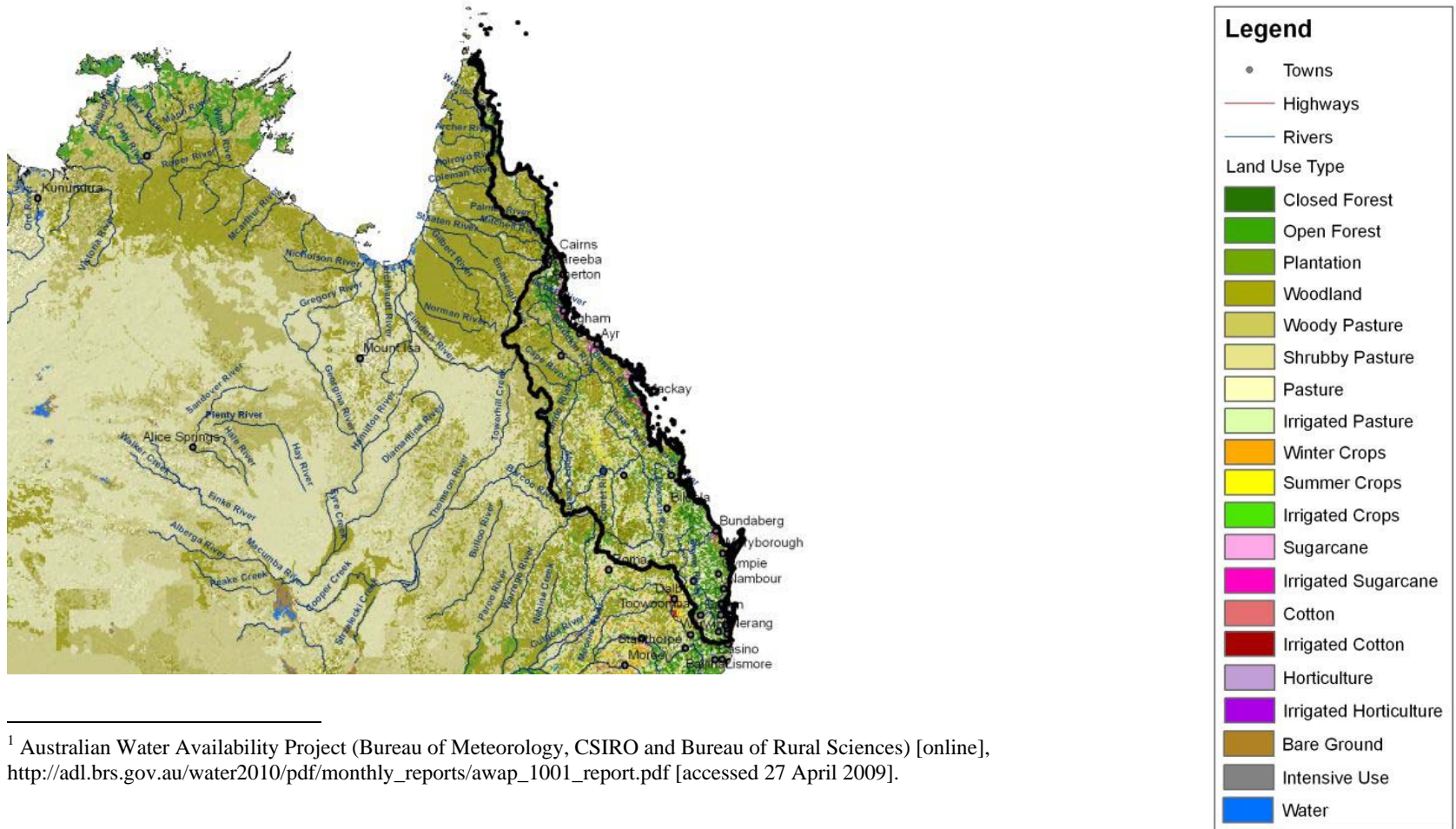
Table 1: Summary of the advantages and disadvantages of different methods for supplementing agricultural water supply.

Method	Technical feasibility	Feedwater	Available infrastructure/Initial capital cost/Transport cost ¹	Energy required for exploitation/Transport	Sufficiency of renewable power supply/Negative envir. impact	Overall estimation
Transportation of water from zones with excessive supply to agricultural areas: -In channels and/or pipelines	Feasible	Abundant	Part. avail./Enorm./Moder.	None/Moder.	Suff./Min.	Feasible, requires enormous initial capital expenses and acting water trade scheme Non feasible for agricultural use Non feasible
-In tankers and towed water-bags	Feasible		Non-avail./Moder./Sign.	None/Sign.	Suff./Min.	
-Towing icebergs	Unknown		Non-avail./Moder./Sign.	None/Sign.	Suff./Sign.	
Agricultural use of recycled and storm water	Feasible	Limited	Part. Avail./Moder./Min.	Min./Min.	Suff./Min.	Feasible for local agricultural use
Desalination:		Unlimited				
-In stationary water desalination plants using conventional power supply	Feasible		Avail. but not for agricultural use/Sign./Moder.	Enorm./Moder.	Non-suff./Enorm.	Feasible for partial supply of urban centres, although at enormous energy and environmental cost, non feasible for agricultural use
-In stationary water desalination plants using nuclear power supply	Feasible		Non-avail./Sign./Moder.	Enorm./Moder.	n.a./Moder.	
-In floating nuclear desalination plants	Feasible		Non-avail./Sign./Moder.	Enorm./Moder.	n.a./Moder.	Feasible
-In solar updraft towers	Unknown	Non-avail./Sign./Min.	None/Min.	Suff./None	Possible feasibility for minor agricultural projects	

¹ Gradation scale starts from Enormous and goes to Significant, Moderate and Minimal.

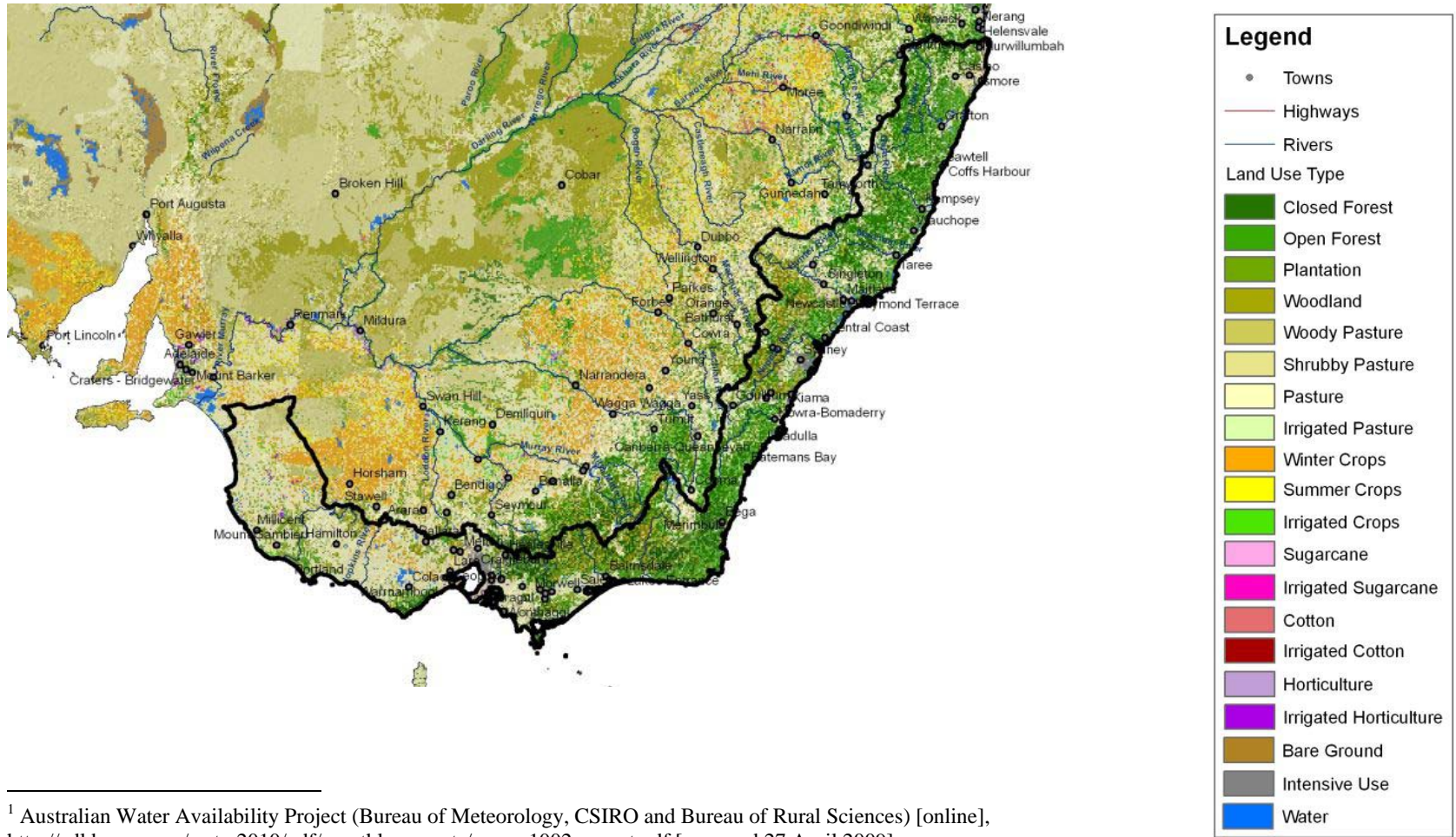
Annex 1: Maps of the Australian drainage divisions

1. North-east coast drainage division¹



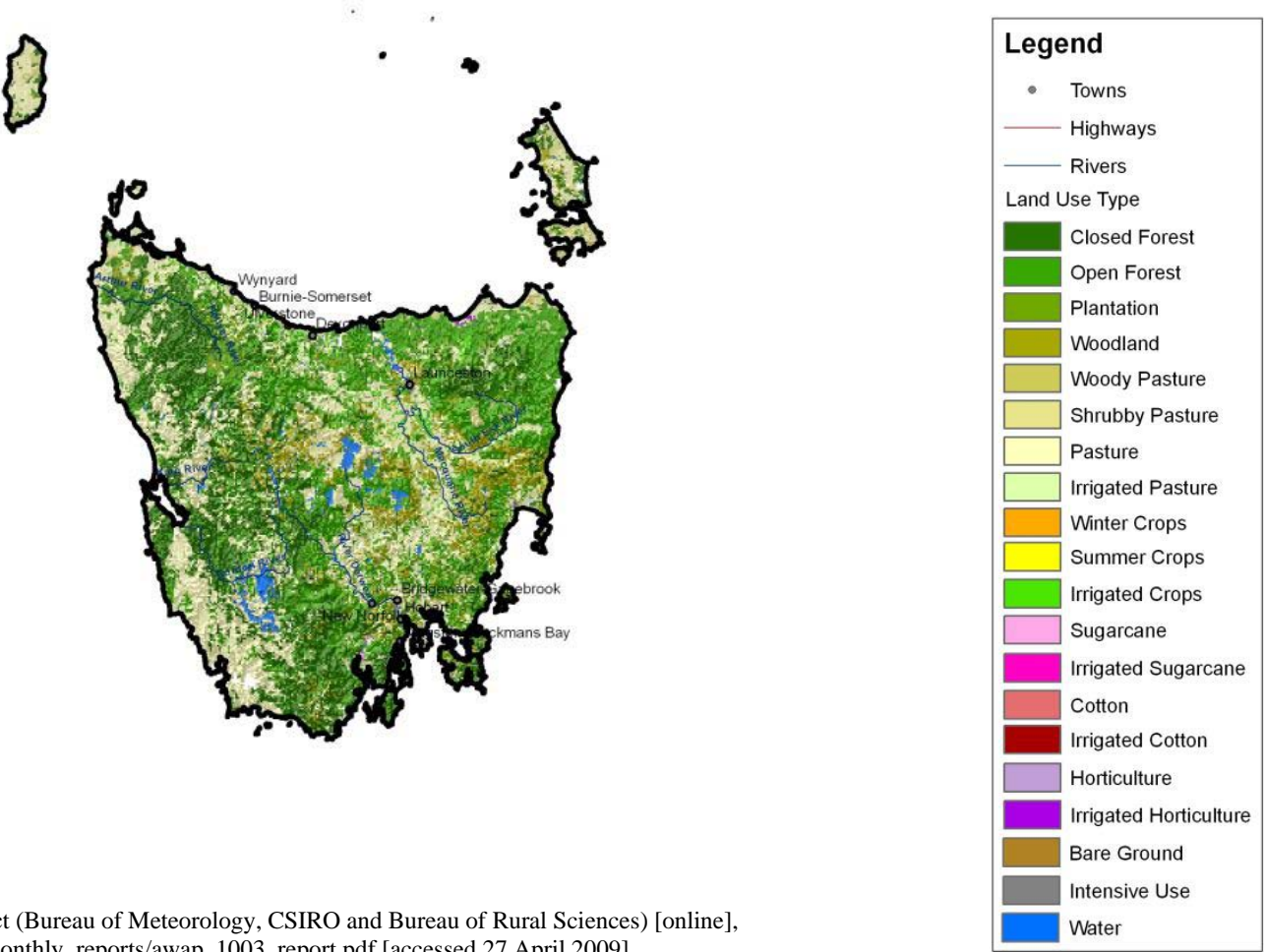
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1001_report.pdf [accessed 27 April 2009].

2. *South-east coast drainage division*¹



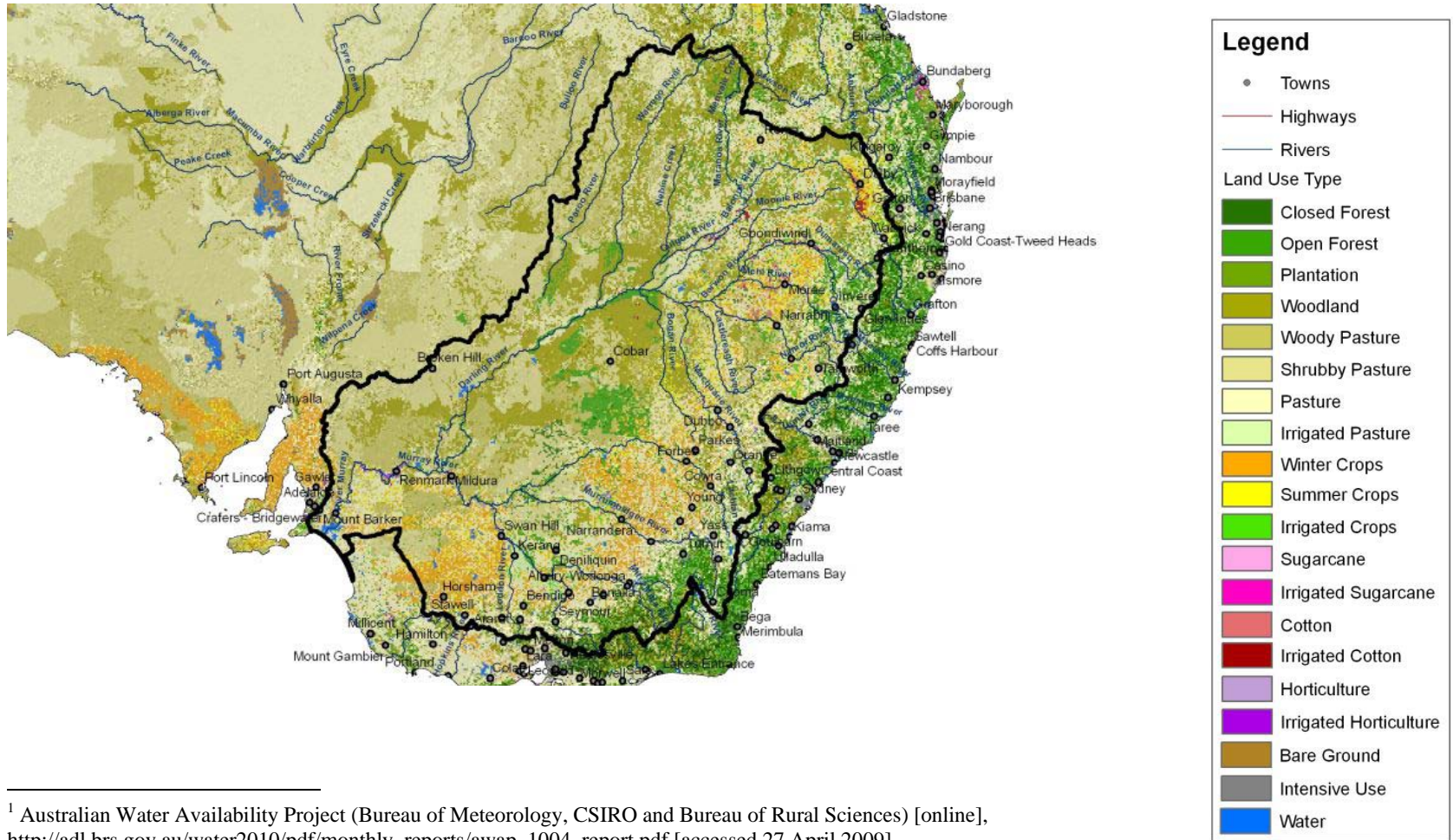
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1002_report.pdf [accessed 27 April 2009].

3. *Tasmania*¹



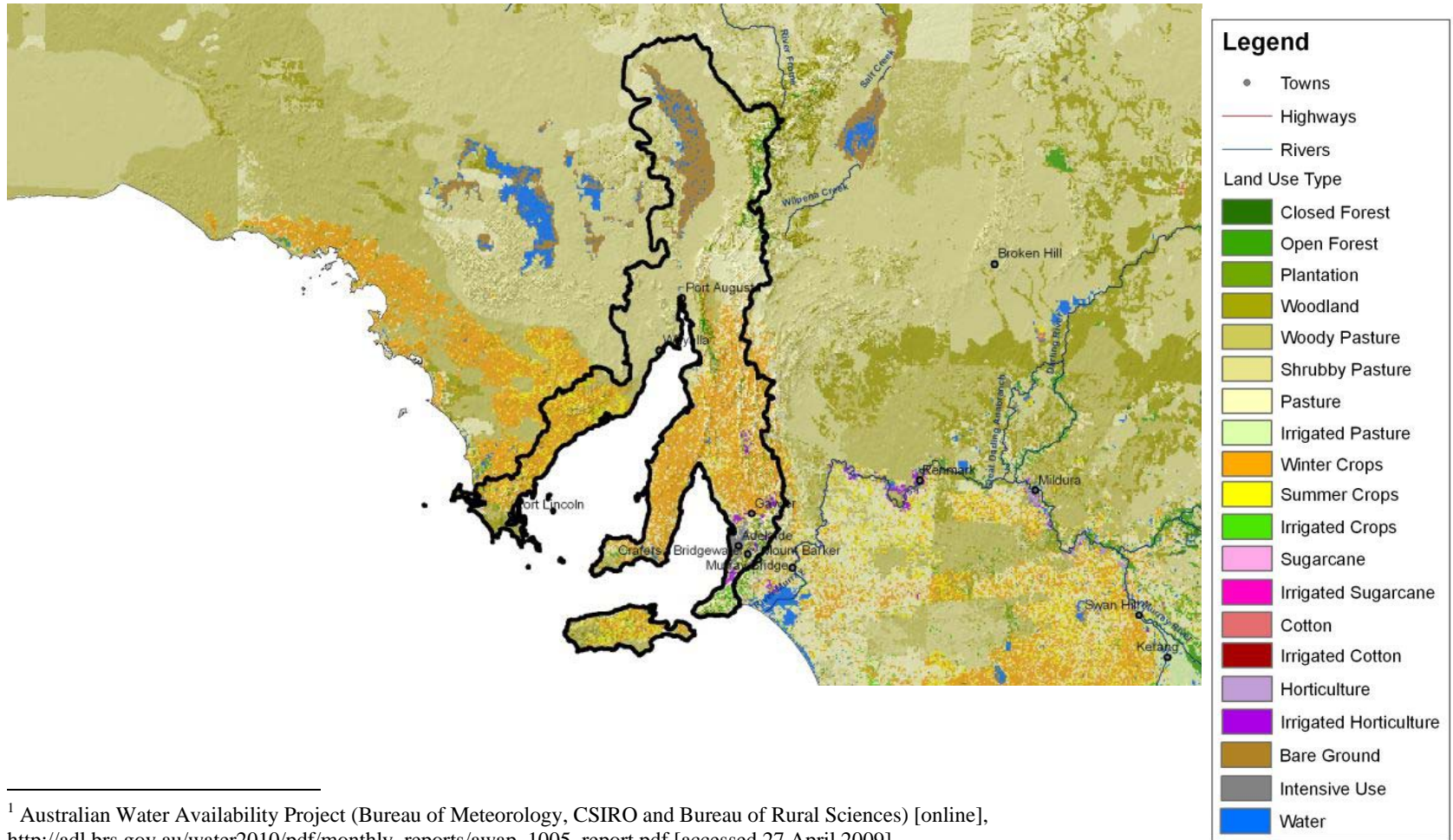
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1003_report.pdf [accessed 27 April 2009].

4. Murray-Darling Basin¹



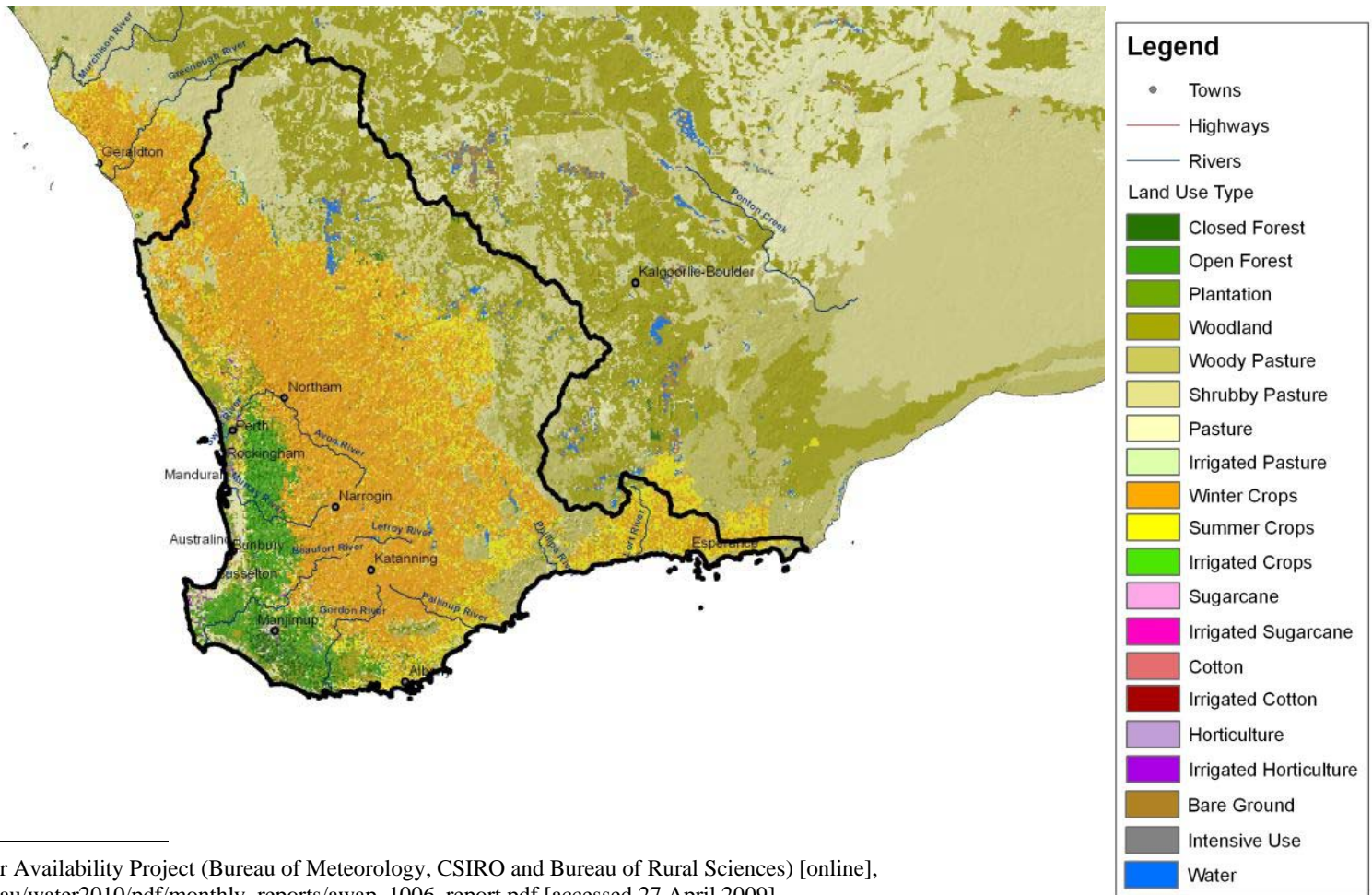
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1004_report.pdf [accessed 27 April 2009].

5. *South Australian gulf*¹



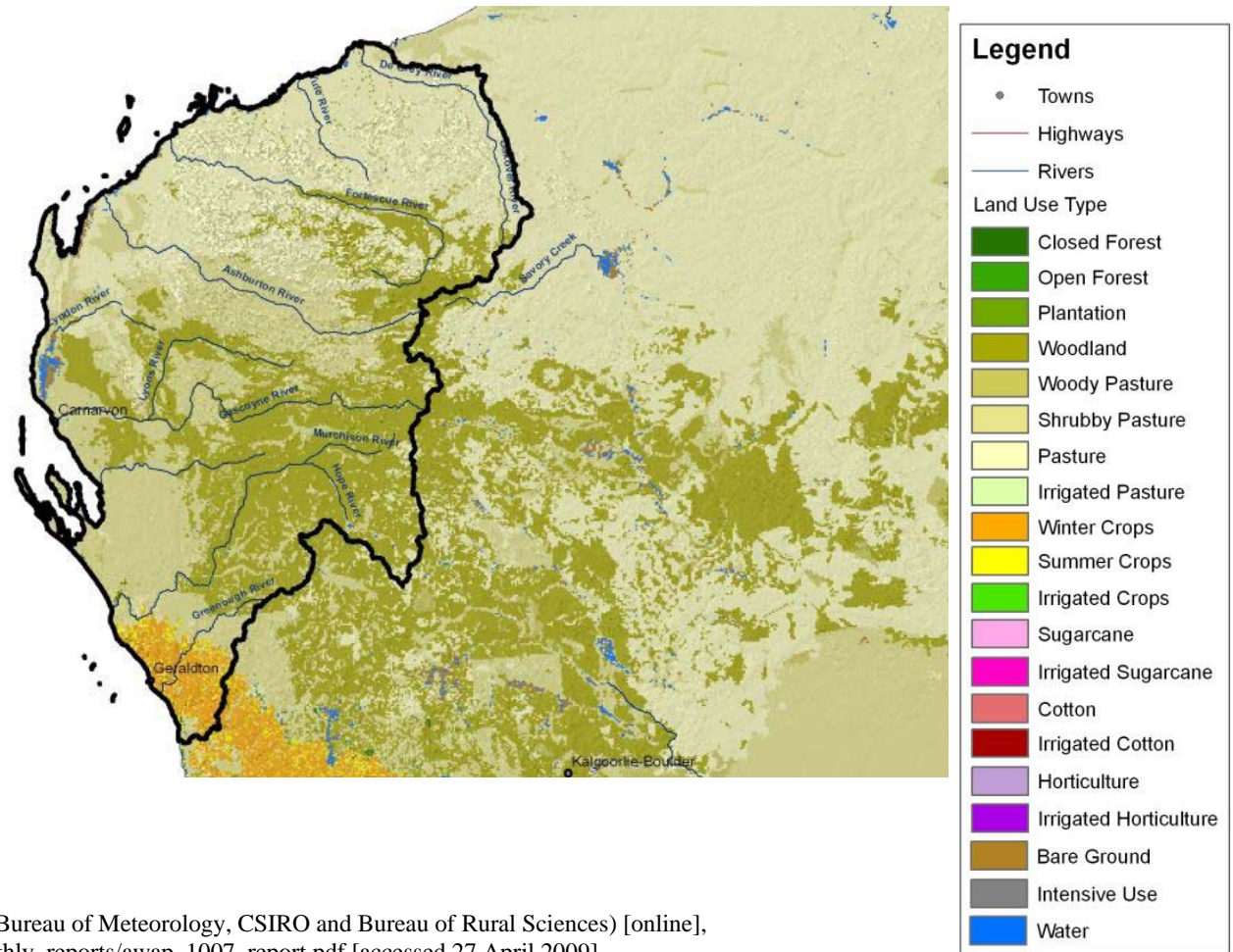
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1005_report.pdf [accessed 27 April 2009].

6. *South-west coast drainage division*¹



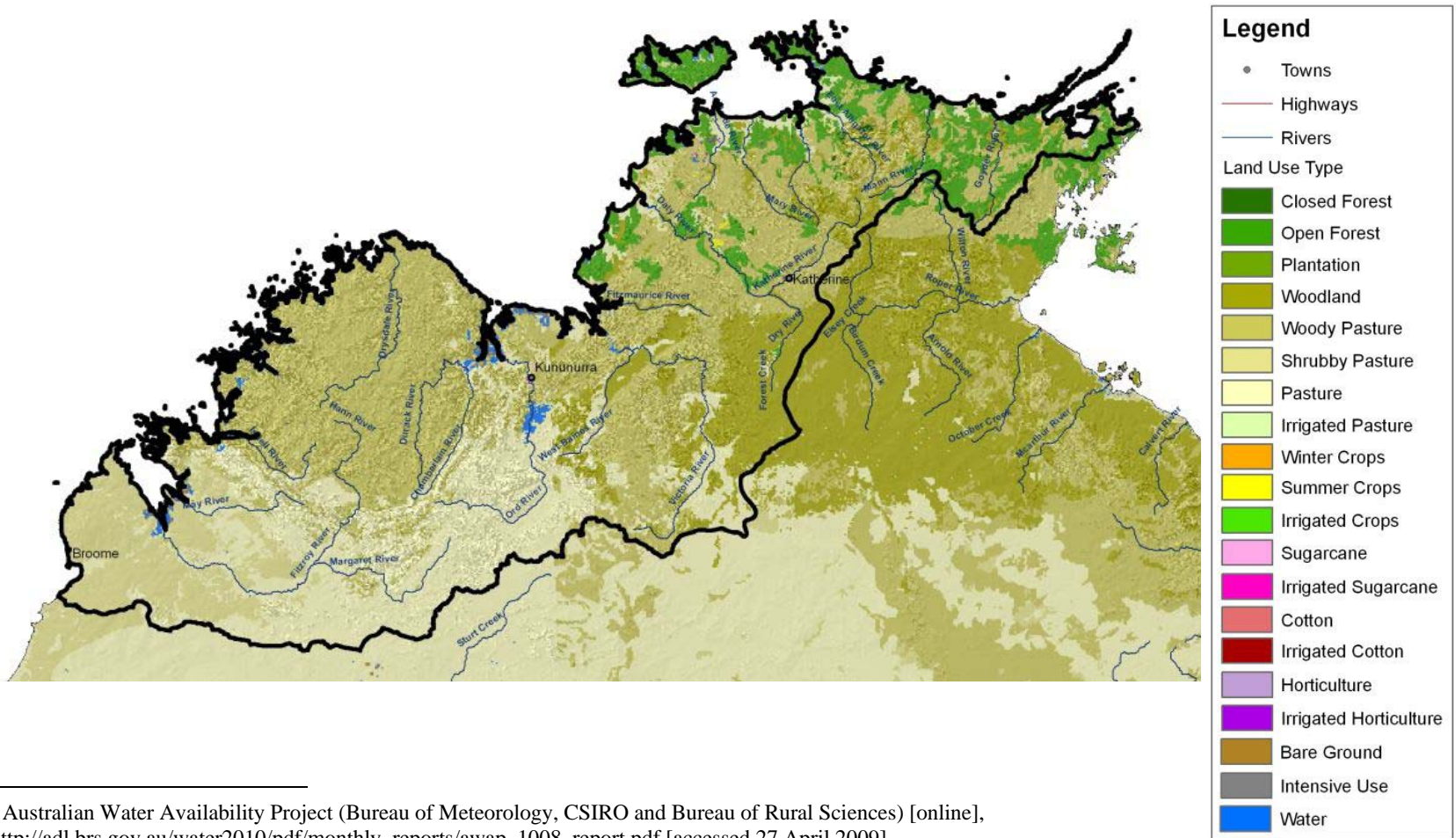
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1006_report.pdf [accessed 27 April 2009].

7. *Indian Ocean drainage division*¹



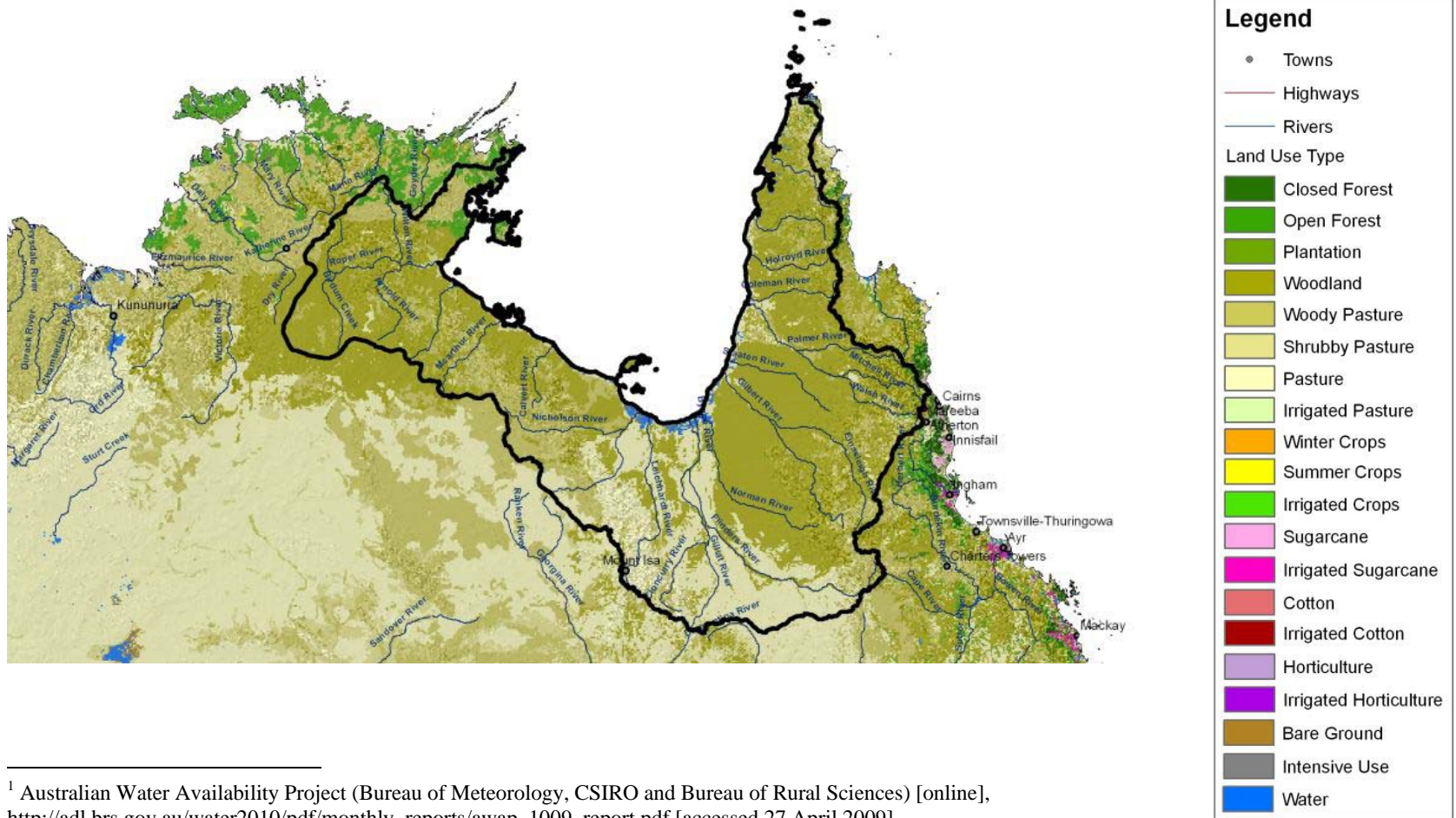
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1007_report.pdf [accessed 27 April 2009].

8. *Timor Sea drainage division*¹



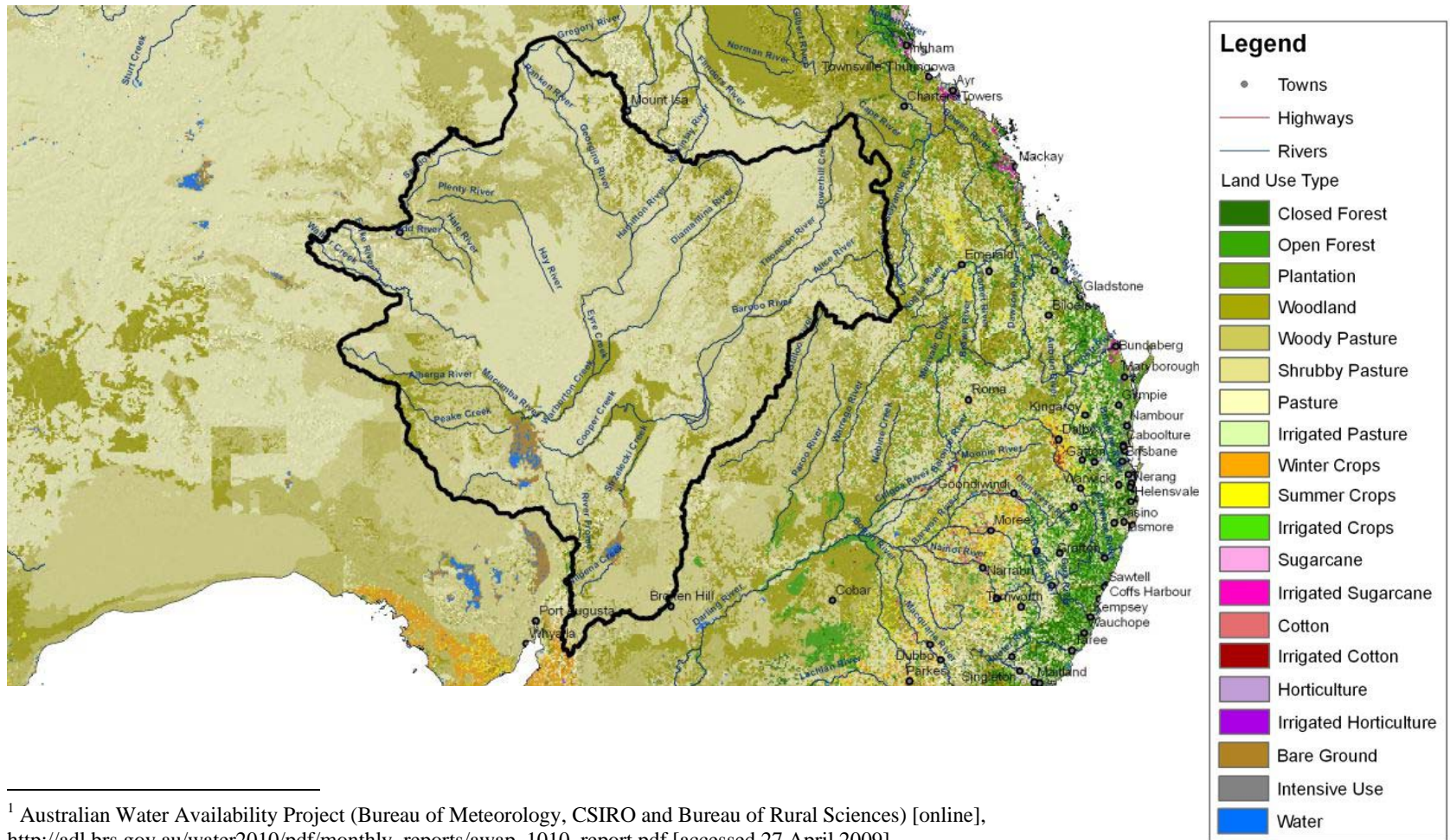
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1008_report.pdf [accessed 27 April 2009].

9. *Gulf of Carpentaria drainage division*¹



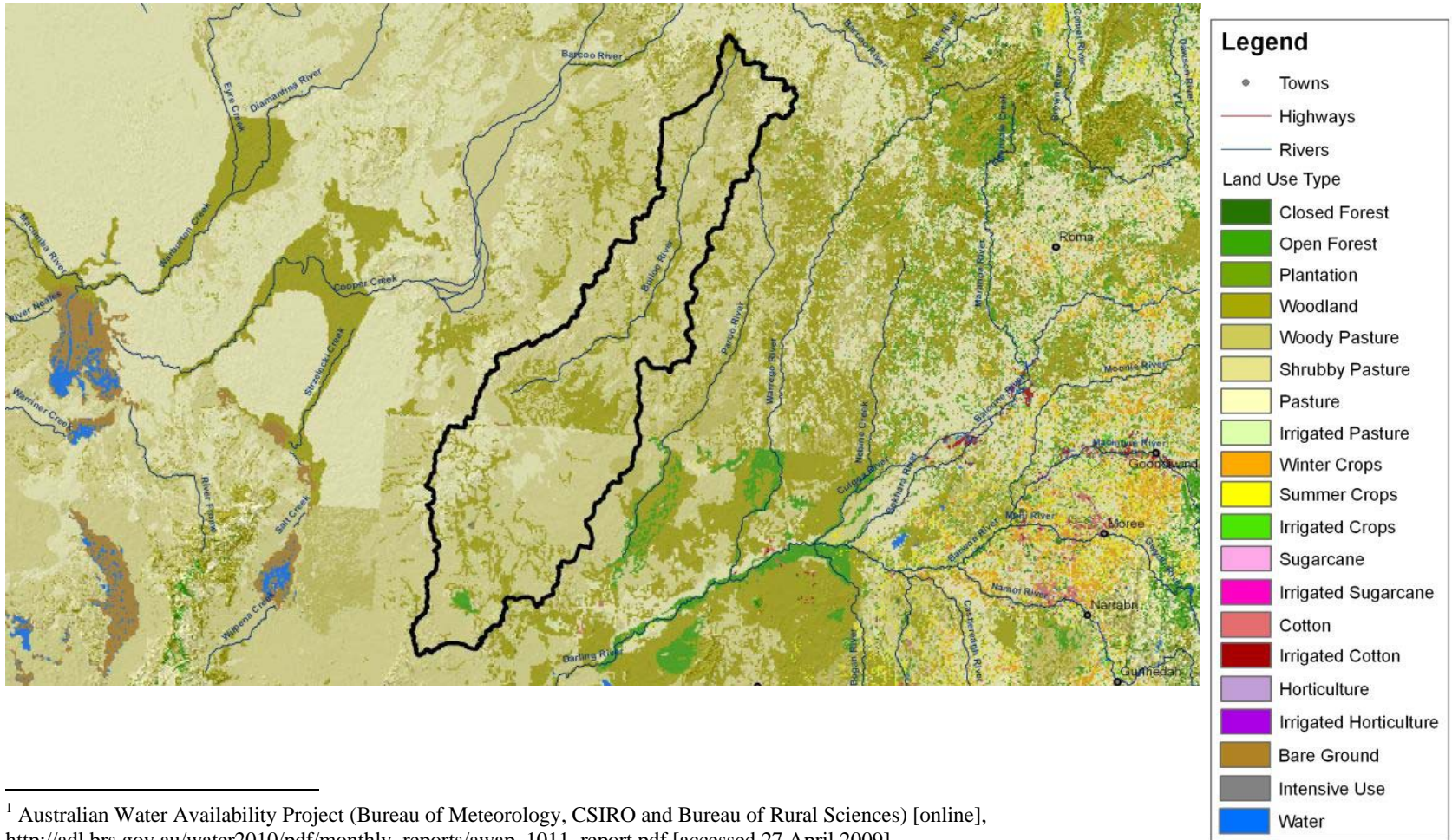
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1009_report.pdf [accessed 27 April 2009].

10. Lake Eyre Basin¹



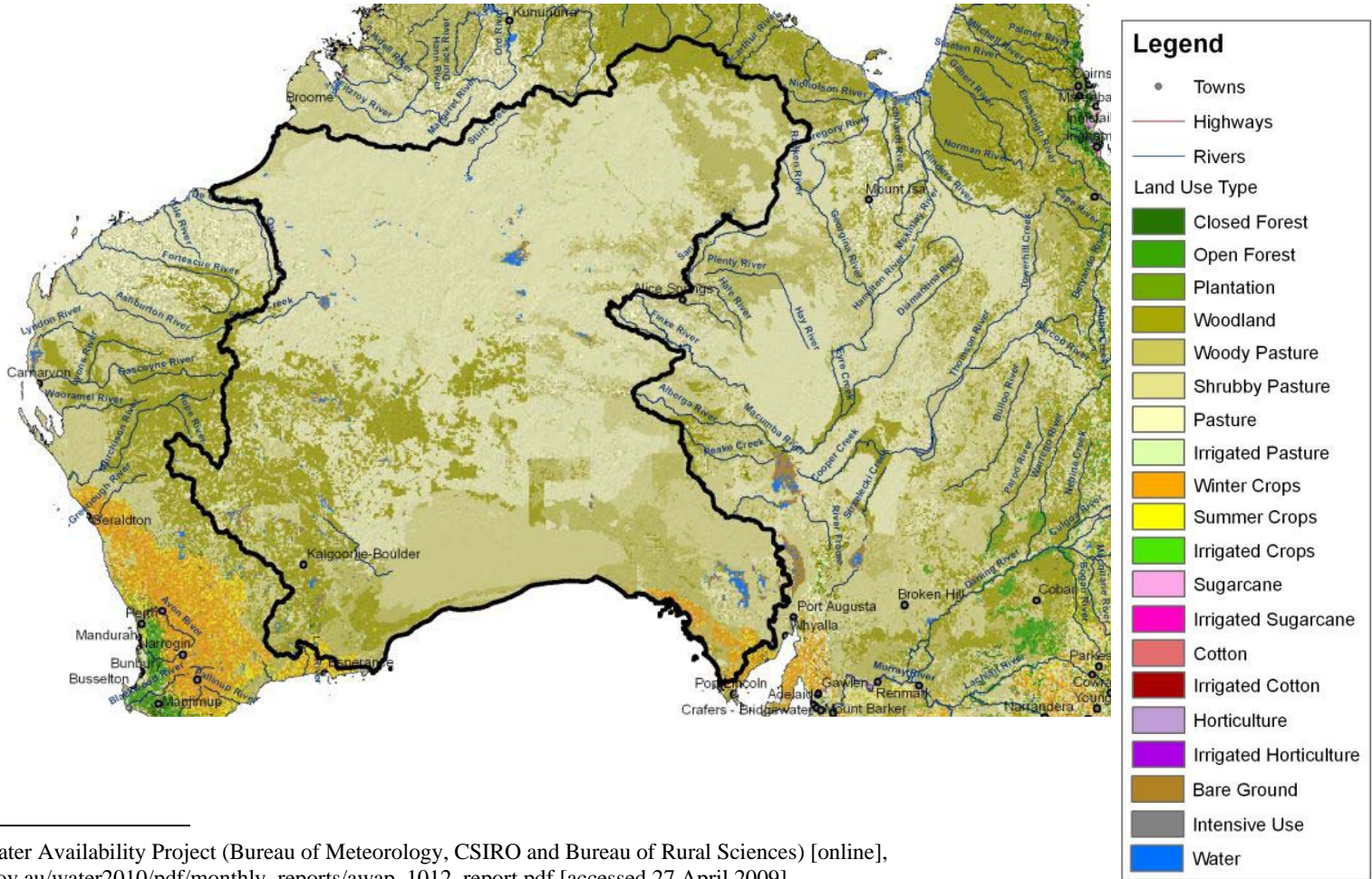
¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1010_report.pdf [accessed 27 April 2009].

11. *Bulloo-Bancannia drainage division*¹



¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1011_report.pdf [accessed 27 April 2009].

12. Western Plateau¹



¹ Australian Water Availability Project (Bureau of Meteorology, CSIRO and Bureau of Rural Sciences) [online], http://adl.brs.gov.au/water2010/pdf/monthly_reports/awap_1012_report.pdf [accessed 27 April 2009].