The Lower Fortescue Hedland region

CSIRO has completed, for the Government of Western Australia and industry partners, an overview of the current and future climate and water resources of the Pilbara to aid water planning and management. These resources included regional surface water, groundwater and environmental water, and allowed local studies to be placed into a regional context. The Pilbara Water Resource Assessment covers an area of 288,479 km², which is about 11% of the state of Western Australia. This is one of the world’s most important resource regions for high-grade iron ore deposits and offshore gas reserves. Irrigated agriculture may also expand to augment the area’s long-term grazing industries.

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The Lower Fortescue Hedland region provides major ports and support for much of the iron ore industry in the Pilbara. It is also important for tourism, with a coastal network of attractions, as well as Millstream Chichester and Karijini national parks. It has a resident population of more than 35,000, not including workers who travel to work in the region on a regular basis.

The region has high temperatures for much of the year, and each summer there is a chance that a tropical cyclone will cross the coast and cause wind and flood damage, while bringing widespread rain to replenish aquifers and support flora and fauna.

The Hamersley Range in the south-west of the region has an orographic effect, with some peaks having an annual rainfall almost twice that of adjacent flatter areas. However, the area is semi-arid, with maximum temperatures in summer often exceeding 40 °C. The annual rainfall deficit (rainfall – Class A pan evaporation) ranges from 2400 mm in the Hamersley Range to more than 3100 mm in low-lying areas. Potential evaporation exceeds rainfall by 6 to 11 times, depending largely on elevation.

There is a trend of increasing annual mean and extreme rainfall in the region, as well as number of rain days, during the 52-year historical period. The 7-year period between 1995 and 2001 was 56% wetter than the historical mean. A larger number of tropical cyclones affected the region during this period, and these years were used to assess the potential impact of a future wetter climate on water resources and groundwater-dependent ecosystems (GDEs).

The physiography is dominated by its underlying geology. The north and east of the region is underlain by an ancient granite–greenstone terrane, which is usually topographically low, with rounded hills, and has few aquifers.

The remainder of the region is part of the Archean–Proterozoic Hamersley sedimentary basin, which comprises the Fortescue Group (mainly associated with the Chichester Range) and the Hamersley Group (associated with the Hamersley Range). The Wittenoom Formation, which contains the often karstic dolomite, is mainly associated with the Fortescue Valley and underlies some valleys in the Hamersley Range. Erosion and deposition in the Cenozoic formed deep paleochannels, which
contain important aquifers and channel iron deposits (CIDs) such as the Solomon Hub. More recent shallow alluvial deposits coincide with the modern stream network. Part of the Carnarvon sedimentary basin extends into the westernmost part of the region. This includes the Birdrong Sandstone, which is overlain by recent alluvial deposits. They are more extensive in the Ashburton Robe region.

Soil profiles in the region are weakly developed because of the hot, arid climate and sparse vegetative cover. Upland soils in particular are skeletal, which enhances runoff during high-intensity rainfall events. More developed soil profiles are associated with alluvial deposits in the lower valleys.

**Water resources of the Lower Fortescue Hedland region**

Rainfall intensities exceeding infiltration capacities is probably the main mechanism for runoff initiation in the region, with saturation excess only a factor low in hillslopes, after prolonged events, or in riverbeds and riparian areas. Localised recharge during streamflow is the main recharge mechanism.

Karst dolomites of the Wittenoom Formation and CIDs have potential as aquifers when hydraulically connected with overlying alluvial aquifers and where located beneath the present-time stream network. Other formations include low-permeability fractured rocks with limited groundwater storage, which include non-economic banded iron formations (BIFs). Mineralised zones in the BIFs are good local aquifers that require dewatering to access ore deposit. Mine dewater volumes are much less in this region than in the Upper Fortescue and Ashburton Robe regions.

Unlike other regions, the Lower Fortescue Hedland region contains a very valuable surface water resource: Harding Dam. This reservoir supplies water to the West Pilbara Water Supply Scheme, along with the Millstream aquifer and, more recently, the Bungaroo borefield (CID) in the adjacent Ashburton Robe region. In addition to being a water supply source, the Millstream calcrete aquifer provides substantial cultural and environmental values, given that it is a permanent source of water in a very hot and normally dry region. The development of Harding Dam and now the Bungaroo CID has taken a lot of pressure off this resource.

The region also contains the Yule borefield, which accesses groundwater from alluvial deposits in the Lower Yule River. This supplies residential and industrial water to the East Pilbara Water Supply Scheme, which services Port Hedland and South Hedland.

Pastoral properties access water for stock and domestic use from shallow alluvial aquifers and fractured rock aquifers.

**Hydrogeological provinces in the Lower Fortescue Hedland region**

There are five hydrogeological provinces in the region: Hamersley Range, Lower Fortescue Valley, Chichester Range, Granite Greenstone Terrane and Coastal Plain.

The **Hamersley Range** province has relatively high elevations and resultant rainfall, which results in a milder climate than in surrounding areas. River valleys within the Hamersley Range contain alluvial aquifers with varying thickness, depending upon the history of landscape erosion or eroded material deposition. They are also crossed by paleochannels, including some with very highly transmissive CIDs, which constitute major iron ore deposits.

Average annual runoff is only 8 mm. Important aquifers are associated with paleochannels and the dolomite of the Wittenoom Formation. Under projected climate changes, mean runoff could increase by about 16% under a wet future climate or decrease by about 43% under a dry future climate. Very low runoff years (<10th percentile) could more than double, indicating that recharge to alluvial aquifers and their GDEs could be impacted were this climate to eventuate.

The **Lower Fortescue Valley** province is contained between the Hamersley and Chichester ranges, and overlying the Wittenoom Formation and Marra Mamba Iron Formation. The Oakover Formation has in places undergone...
calcretisation, which has formed calcrete with a very high hydraulic conductivity just below the watertable, resulting in a flat watertable that responds in a limited way to climate and pumping. The projected change in runoff under a dry future climate is –39%, which is much larger than the projected increase under a wet future climate (+15%).

In the Chichester Range province, the Chichester Range only has a small orographic effect on rainfall compared with the much higher Hamersley Range. Most rivers in the Lower Fortescue Hedland region arise from this province. The projected change in runoff under a dry future climate is –38%, which is more than double the projected increase under a wet future climate (+15%).

The Granite Greenstone Terrane province contains areas of granite and greenstone north of the Chichester Range. Being weakly weathered and comprising crystalline bedrock, they contain few aquifers. Most of the rivers that arise in the Chichester Range flow across the terrane, including the Harding River, which is a major water source for the West Pilbara Water Supply Scheme. Weathered material from the granite plutons form sandy soils and alluvium downstream. Under a dry future climate, runoff is projected to decrease by about 36%, and under a wet future climate it is projected to increase by about 16% compared with the baseline.

The Coastal Plain province is low lying and contains important alluvial aquifers near the discharge to the Indian Ocean. These are used to supply drinking water to the East Pilbara Water Supply Scheme (Lower Yule) and to mining operations (Lower Fortescue). Under a wet future climate, the runoff in this province may increase by about 27% but it may decrease by about 40% under a dry future climate.

**Basis of the Assessment**

Weather observations were more plentiful and widespread in the 1950s and 1960s, when there were sheep stations throughout the region. More recently, iron ore mining companies have been recording climate data and streamflows at mine sites. However, these latter monitoring data are not yet long term and may not have the longevity of past gauging if they cease when mining moves or ends. Long-term surface water gauging is especially limited.

Groundwater and GDE investigations are intensive where they are associated with valuable drinking water resources associated with alluvial aquifers and at mine locations. The Assessment has used the available long-term data and specific studies to draw a regional picture, to put the more intensive studies into a broader context.
Key points

- The Lower Fortescue Hedland region has an extreme climate, characterised by extremely hot summers, high potential evaporation and intermittent intense rainfall.
- Groundwater is the main water resource in the Lower Fortescue Hedland region. It is contained within coastal alluvial aquifers, the Millstream calcrete, dolomite of the Wittenoom Formation and deeper paleochannel aquifers. Some of the latter are associated with CIDs. The region also contains the main surface water resource in the Pilbara: Harding Dam.
- Future climates are expected to become 1.3 to 2.2 °C hotter (by 2030 and 2050, respectively) than the 1961 to 2012 climate, but it is not clear whether it will be wetter or drier. In general, an ensemble of 18 global climate models (GCMs) suggests that a drier future climate is more probable than a wetter one. The above-average rainfalls in recent decades may result from natural variability, aerosols emanating from South-East Asia or climate change.
- Streamflow is initiated after rainfall exceeds 19 to 30 mm per event. Only 11 to 41 mm of annual rainfall becomes runoff in most years.
- Leakage from streambeds (localised recharge) is the main mechanism for recharging alluvial and underlying aquifers. The area and duration of riverbed inundation largely determine the amount of localised recharge.
- Net recharge estimated from rainfall–runoff models is between 1.7 and 5.1 mm, which represents 8 to 54 GL/year when calculated for hydrogeological provinces. Mean recharge volumes are only about 12% of mean streamflow volumes because large events result in large runoff that occurs over a short period of time and does not allow time for water to recharge aquifers, which may also be full near the streambed.
- Much of the Lower Fortescue Hedland region is underlain by fractured rock formations, which can form local aquifers. Groundwater recharge to these aquifers is mainly associated with rainfall infiltration (diffuse recharge), which has been estimated to vary between 1% and 5% of annual rainfall, mainly associated with rainfall events greater than 20 mm/day. This is a similar-sized event to initiative runoff.
- Runoff increases by up to 18% in 2050 under a wet future climate scenario but decreases by up to 45% under a dry future climate scenario, relative to the historical baseline period of 1961 to 2012. For each 1% change in rainfall, runoff changes by about 3%. A dry future climate may impact Harding Dam, which is a water source for the West Pilbara Water Supply Scheme.
- Because of climatic conditions, groundwater resources in the Lower Fortescue Hedland region have an important environmental value, supporting multiple terrestrial ecosystems.
- GDEs, including springs and groundwater-dependent terrestrial vegetation, comprise less than 0.5% of the region but have important environmental, social and cultural values. Analysis of satellite remote sensing over a 24-year period (1988 to 2011) indicates that GDEs generally showed limited variability.
- GDEs are ultimately groundwater discharge zones and can be supported by various groundwater systems: those that form aquifers (e.g. karstified dolomites or paleochannels, such as Millstream or pools supported by coastal aquifers) and those that do not (e.g. shallow alluvial systems or fractured zones along faults or dykes).
- When they rely on localised discharge from regional or local aquifers, GDEs can withstand prolonged dry periods with limited impact.
- GDEs supported by groundwater systems that do not form aquifers (e.g. shallow alluvial aquifers that can be filled by streamflow leakage during most years, such as in the Granite Greenstone Terrane) are more sensitive to climate variability. GDEs formed over groundwater discharges within seepage zones on scree slopes are the most sensitive to climate variability.
- The strong interdependence of geology, topography, soil and vegetation associations, hydrology and aquifers has enabled five hydrogeological provinces to be defined to help identify repeating patterns in the water resources of the region (see Figure 1).
- Most water resources in the region are low salinity, and there is sufficient fresh-to-marginal quality water in this and adjacent regions to meet residential, mining, dust suppression and stock watering needs. The availability of water in coastal alluvial aquifers and some paleochannels in the Hamersley Range is of increasing interest for irrigated agriculture as a new industry to support higher populations in the coastal towns of Karratha and Port Hedland.