South-West Western Australia Sustainable Yields Project

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Project Leader
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  • Resource Economics Unit – demand estimation
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  Murray Peel (University of Melbourne)
Broad terms of reference

• Estimate the current and 2030 yield of water in catchments and aquifers for the south-west of WA considering climate change and development (plantations, farm dams, groundwater abstraction)

• Compare the estimated current and future water yields to those needed to meet the current levels of extractive use, future demands and environmental needs
Publications

Main reports

Executive summaries

Factsheets

Web:
www.csiro.au/partnerships/SWSY.html

USB Sticks
Project context

- The project does not determine sustainable yields or set new allocation limits
- The project is regional and doesn’t address local issues
- The results are scenarios based on assumptions about the future climate, landuses, abstraction levels and demands
Location of the project area

- All fresh, marginal and brackish surface water catchments between Gingin Brook and the Hay River
- All aquifers within the Perth and Collie basins, plus the western Bremer Basin
- Area = 62,500 km²
• Short streams that arise in the Darling Ranges are fresh

• Darling Fault separates Perth Basin from Darling Plateau

• Coastal plains are flat and low lying – Swan Coastal Plain; Scott Coastal Plain; South Coast

• Perth Basin Plateaux are higher in elevation
Land cover

• Surface water catchments are mainly forested

• About 60% of the Perth Basin is cleared about 56% of this being under dryland agriculture

• The uncleared areas include coastal areas north of Perth, the Gnangara Mound and the Blackwood Plateau
South-west WA has had reduced rainfall since 1975

The 1975 to 2007 period is the baseline for all subsequent comparisons.
Scenarios

• The ‘historical climate’ or Scenario A assumed that the climate of the last 33 years (1975 to 2007) would continue. This was used as a base case for comparison of other climate scenarios.

• The ‘recent climate’ or Scenario B assumed that the climate of the last 11 years (1997 to 2007) would continue.

• The ‘future climate’ or Scenario C used 15 GCMs with 3 GHG emission levels which would result in 0.7, 1.0 and 1.3°C of warming by 2030 = 45 possible climates. They are reported as
  • wet extreme future climate (Cwet)
  • median future climate (Cmid) and
  • dry extreme future climate (Cdry)

• Current levels of abstraction and land use were assumed to continue for all scenarios above.

• The ‘future climate and development’ or Scenario D assumed a median future climate and full groundwater abstraction, new plantations and farm dams (where important).
14 of 15 GCMs predict it will get drier

- Median future climate: -7%
- Wet extreme future climate (90 percentile): -1%
- Dry extreme future climate (10 percentile): -14%

Change in annual rainfall (%)
Geographic scope

- 13 surface water basins covering 39,000 km²
Rainfall runoff modelling

- Runoff simulated using five simple conceptual models
  - Sacramento
  - IHACRES
  - SIMHYD
  - AWBM
  - SMARG

- One catchment model
  - LUCICAT (in about half the catchments)

- The calibrated model output was compared with observed data and an average of runoff from Sacramento and IHACRES was the best
Catchment representation

- 0.05° x 0.05° grid (~ 5 x 5 km)
- Each cell mapped into a catchment
- Flow accumulated for 204 defined streamflow reporting nodes
Calibration results – examples

Average model efficiency = 0.84, >0.8 in 80% of catchments

NSE = 0.82

NSE = 0.87
Averaged across the surface water basins, 15 global climate models project less runoff. Runoff change across all basins:

- Wet future climate: -10%
- Median future climate: -25%
- Dry future climate: -42%

Mid warming, High warming, Low warming.
Rainfall, runoff and runoff coefficient under historical climate
Projected change in mean annual rainfall relative to the historical climate

- Rainfall declines by 8% under median future climate and 14% under dry climate.
- Proportion of area receiving over 900 mm is: 37% under historical climate, 34% under recent and wet future, 22% under median future, and 16% under dry future climate.
Projected change in mean annual runoff relative to the historical climate

- Runoff declines by 25% under median future climate and 42% under dry climate.
- Proportion of area generating 110 mm runoff is: 37% under historical climate, 34% under recent and wet future, 22% under median future, and 16% under dry future climate.
Projected changes in rainfall and runoff

<table>
<thead>
<tr>
<th>Surface water modelling area</th>
<th>Historical</th>
<th>Percent change relative to historical climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean annual rainfall</td>
<td>837</td>
<td>Recent: -2%</td>
</tr>
<tr>
<td>Mean annual runoff</td>
<td>98</td>
<td>Recent: -7%</td>
</tr>
<tr>
<td>Frequency of rainfall</td>
<td></td>
<td>exceeding 900 mm generating more than 130 mm runoff</td>
</tr>
<tr>
<td></td>
<td>1 in 5 years</td>
<td>1 in 9 years</td>
</tr>
</tbody>
</table>
Percent decline in runoff in all basins

- Decline under recent climate is greatest Gingin to Collie
- Decline under median future climate more uniform across the area
Surface water – Key Findings

Relative to the historical climate, under the median future climate:

• Rainfall declines by an average of 8% and runoff by 25%
• Climate impact on projected streamflows is much greater than that of increase in plantations and farm dams after 2007
• Across all surface water basins, there is a decline in mean annual runoff of 24 mm and streamflow of 800 GL in addition to the decline that has occurred since the mid-1970s
• Declines in runoff are proportionally greater in the northern surface water region but greater volumetrically in the central and southern regions
Groundwater results

Geomorphic landforms affect groundwater response to climate change
Groundwater models

- All together 24 GWAs considered for groundwater modelling and/or assessment
- Recharge modelling in GWAs of the Northern Perth Basin and Albany area
- Recharge and groundwater modelling for all remaining GWAs
Groundwater models

- The PRAMS model as used in the Gngangara Sustainability Strategy was used.
- A new model (PHRAMS) was developed for the Peel Harvey area.
- The SWAMS model was linked to a recharge model and recalibrated.
- The Collie model was linked to a recharge model and recalibrated.
Groundwater objectives

- Project groundwater levels in 2030 under future climate and development scenarios
- Understand why some areas and aquifers may be less sensitive to climate change than others
- The groundwater results are later used to:
  - assess the impacts of levels on groundwater dependent ecosystems (GDEs); and
  - estimate future groundwater yields
Land cover likely to affect recharge / discharge

Groundwater areas
- 56% dryland agriculture
- 38% native vegetation
- 6% plantations, urban, irrigated, open water
Maximum depth of the watertable in the southern half of the Perth Basin in 2007

- Coloured areas are potential GDEs if not cleared
- Coastal plain soils have very shallow watertables except Gnangara and Spearwood Dunes
- Plateaux areas mainly have deep watertables
Change in groundwater levels between 2008 and 2030 under climate and development scenarios
South to North cross section across the Southern Perth Basin
Change in superficial aquifer levels between 2008 and 2030

Historical climate

Median Future Climate

Long term monitoring bores

CLSC CLBW CLNW CLNC

Red: > 10 m decline
Brown: 6 to 10 m decline
Orange: 3 to 6 m decline
Light orange: 0.5 to 3 m decline
Light green: no change
Light grey: 0.5 to 3 m rise
Dark grey: 3 to 6 m rise
Blue: 6 to 10 m rise
Dark blue: > 10 m rise
Groundwater trends on the Blackwood Plateau since 1987

CL2C

CL6W

CL7W

CL8C

CSIRO South-West Western Australia Sustainable Yields Project – Bunbury
Change in groundwater levels in the Leederville Aquifer 2008 to 2030
Change in groundwater levels in the Yarragadee Aquifer 2008 to 2030
Groundwater levels are less affected near rivers.
Level of confidence in the 2030 projections of groundwater levels

- Central and Southern Perth Basin groundwater models are generally better than others.
- Northern Perth Basin and Albany Area require models.
Groundwater – Key Findings

• A future drier and hotter climate is likely to lower groundwater levels, especially where there is perennial vegetation.

• Groundwater levels under cleared, sandy coastal plains are expected to be fairly resilient except under the dry extreme climate and high abstraction.

• As groundwater levels fall in these areas, evapotranspiration and drainage losses decrease and there is room in the aquifer to accept recharge.
Groundwater – Key Findings (cont.)

- Interactions between surface water and groundwater may change in both volume and direction as a result of lower water levels in rivers and surrounding aquifers.

- Confidence in model predictions varies depending on calibration error, hydrogeology, data quality, model maturity and other factors.
Environmental assets in the project area

- Ramsar listed wetlands
- Wetlands of national significance
- Conservation category wetlands
- Wild rivers
- Caves
CSIRO South-West Western Australia Sustainable Yields Project – Bunbury

<table>
<thead>
<tr>
<th>Ecological significance</th>
<th>Ecological function flow threshold (ML/day)</th>
<th>Flow threshold exceeded (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintain pool habitat in summer</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Minimum flow to maintain pool quality</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Upstream migration of small native fish</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Summer habitat for invertebrates</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Winter habitat for invertebrates</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>Inundate trailing vegetation</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>Inundate low elevation benches</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>Inundate high elevation benches</td>
<td>1080</td>
<td></td>
</tr>
</tbody>
</table>

Based on data from DoW

Frequencies of daily river flow under the historical climate: $f_{\text{hist}}$
Change in the frequencies of daily river flow under future climate scenarios: \(f_{\text{hist}} - f_{\text{scenario}}\)

<table>
<thead>
<tr>
<th>Ecological significance</th>
<th>Ecological function flow threshold (ML/day)</th>
<th>Difference (%)</th>
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</thead>
<tbody>
<tr>
<td>Maintain pool habitat in summer</td>
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<td>-4</td>
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<tr>
<td>Minimum flow to maintain pool quality</td>
<td>6</td>
<td>-8</td>
</tr>
<tr>
<td>Upstream migration of small native fish</td>
<td>10</td>
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Recent climate, Wet extreme future climate, Median future climate, Dry extreme future climate
### Ecological Significance

<table>
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<th>Ecological Significance</th>
<th>Ecological Function Flow Threshold (ML/day)</th>
<th>Relative Difference</th>
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Relative frequency difference under dry extreme future climate (relative to historical climate): \((f_{\text{hist}} - f_{\text{scenario}})/f_{\text{hist}}\)
More than 80% percent of annual runoff is generated during the high runoff period.
Runoff during this period decreases under future climates relative to historical data.

**Runoff Decrease for All Rivers**

- **Historical climate**: No significant decrease
- **Recent climate**: Slight decrease
- **Wet extreme future climate**: 5–20% decrease
- **Median future climate**: 20–30% decrease
- **Dry extreme future climate**: 40–50% decrease
Climate impacts on runoff are greater in southern (Kent and Denmark) and northern rivers (Gingin).

There is a slightly greater percentage decrease in summer runoff compared to winter.
3. Change in “no-flow” days

No-Flow days

Change in number of no-flow days

Historical climate

Recent climate

Median future climate

Dry extreme future climate

Perennial rivers
Areas of potential GDEs

- Only regional risk assessments were undertaken
- The analyses were carried out where groundwater models were available and where potential GDEs may occur (coloured areas)
GDEs ecological risk assessment

*Depth to watertable

(Froend and Loomes, 2004)
Risks to GDEs in the Peel Harvey area under a median future climate (in addition to current conditions)

The risk to some wetlands is moderate but other categories are low to nil.
Risks to GDEs in the Southern Perth Basin under a median future climate (in addition to current conditions)

The risk to GDEs from a median future climate is mainly low or non existent.
Key findings

• For surface water dependent ecosystems
  • Runoff during both the wet and dry seasons is expected to decrease by 20 to 30 percent under a median future climate
  • The impact of a drier climate is greater for low frequency-high flow events, but ecosystems are less sensitive to such conditions

• For groundwater dependent ecosystems
  • About 40% of potential GDEs may be affected to some degree under a median future climate
  • There are some localised high risk areas under the dry future climate and development scenarios
Water use in the project area

• Total use is about 1200 GL/y of which 71% is self supplied (on-site bores and farm dams) and three quarters is groundwater

• About 35% is used for irrigated agriculture – elsewhere in Australia it is 66 to 75%

• There is relatively little ‘low value’ agricultural water use compared with elsewhere in Australia

• Can be competition for water between water sectors – residential, industry, mining and agriculture

• The fact that so little agricultural water is in schemes, most is groundwater and it is used on high value crops, makes transfers and trading less feasible
Water demand was assumed to grow because of:

- population growth;
- economic growth; and
- industry growth – some industries have high water use coefficients.
Yield and demand areas

- 21 surface water management areas
- 23 groundwater areas
- 8 demand regions

Perth Demand Region
Surface water use is highest in central catchments and these will grow in future

Current use = 299 GL/y

Growth in demand

Metro basins are fully used and growth in demand was assumed to be zero
Current surface water yields

Total yield = 425 GL/y

- Public Water Supply 24%
- Irrigation schemes 27%
- Self supply 49%
- Harvey and Collie contribute 43% of total yield
Surface water yields are projected to change by -24% under a median future climate. Range of -4 to -49%.

IWSS yields reduced by 18% to 77 GL/y under a median future climate.
Gaps in surface water yields and demands in areas where irrigation is important

Recent climate-2030 gap

Median future climate-2030 gap

Dry extreme future climate-2030 gap

Harvey

Warren

ML/km²/yr

>20  10  5  2  -2  -5  -10  <20

Surplus  Deficit
Current groundwater yields as estimated by adding the 2009 Allocation Limits

Total yield = 1556 GL/y
(3.6 x surface water yield)

Main aquifers:
• Superficial 58%
• Leederville 12%
• Yarragadee 26%
Groundwater use and future demand is highest near Perth and Bunbury

Current use = 808 GL/y
(2.2 x surface water)

Growth in demand
Current groundwater use

SWARMS abstraction mm depth equivalent (ML/sq km/y)
- > 10
- 5 - 10
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1
- Subareas not determined
Current Allocation Limits

SWRMS allocation limit mm depth equivalent (ML/sq km/yr)

- > 10
- 5 - 10
- 4 - 5
- 3 - 4
- 2 - 3
- 1 - 2
- 0 - 1
- Subareas not determined
Future groundwater yield method

• Almost all groundwater areas are proclaimed and have an annual allocation limit set under an allocation plan

• This limit was assumed to be the best estimate of the aquifer’s current yield

• The limit was assumed to be related to the historical climate (Scenario A) and 2008 aquifer storage volumes (groundwater levels)
Groundwater yields are projected to change by -2% under a median future climate. Range = +2 to -7%

Yield reductions are low because
1. Drain and ET losses reduce as watertables fall
2. Areas under dryland agriculture (56% of Perth Basin) have rising levels
3. Allocation Limits account for a future drier climate
Groundwater deficits may develop near Perth, Collie and Albany.
Yields and demands in the Harvey to Preston surface water region

Available SW/GW yield (GL/y)

Current yield A B Ow et Cmid Cdry

Available SW/GW yield (GL/y)

Total demand v Total available yield (GL/y)

Maps and data analysis showing yields and demands in the Harvey to Preston surface water region.
Yields and demands in the Preston Demand Region
Yields and demands in the Southern Perth Basin
The project area can meet all except high demands until 2030 under a median future climate.

- A 250 GL/y deficit may develop under a dry extreme climate and high demand.
Key findings

1. South-west Western Australia has experienced a significant climate shift since 1975 which is thought to be mainly climate change. Climate models project that rainfall could decline further by about 7% by 2030 (up to 14%)

2. Surface water yields are projected to decrease by about 24% (up to 49%)
   - The yields have already decreased in northern catchments and may decrease further by 2030
   - Central catchments are higher yielding and the decrease could be less
   - Streamflows are projected to decrease the most in the Southern catchments
Key Findings (cont.)

3. Groundwater levels are projected to fall most under areas of perennial vegetation, e.g. Gnangara, Blackwood Plateau, Collie and Albany.

Levels are least affected in areas with high watertables such as coastal areas under dryland agriculture, e.g. Swan and Scott Coastal Plains; Dandaragan Plateau

As watertables fall, drainage and evaporation from GDEs fall and allows more recharge to enter

4. Water dependent ecosystems have already been impacted and these impacts are projected to worsen, especially for high streamflows and GDEs with a watertable depth of 6 to 10m
5. Water deficits between yields and demands are likely in:
   • Surface water irrigation catchments
   • Aquifers near Perth, Collie and Albany

6. Overall there is enough water to meet all except high demands under a median future climate. However if there is a dry extreme climate and a high demand the deficit may be as much as 250 GL/y
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