The resiliency of urban water systems

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Presented by: Kathleen Low

Water Stress in California

Delta Smelt

- Inter-basin transfer
  - Ecosystem collapse of Sacramento-San Joaquin Delta
  - Energy and GHG emissions (19% electricity and 30% natural gas of total state's usage, 88 billion gallons of diesel fuel+/yr)
  - Diminished resiliency (climate, earthquakes, terrorism)
- Population growth (15.7 to 37.3 million from 1960 to 2010)
- Climate change (drought, climate variability)

Pic. source: http://en.wikipedia.org/wiki/Sacramento%E2%80%93San_Joaquin_River_Delta

California Water Conservation Act of 2009

- In response to 2007-2009 Drought
- 20 x 2020 Plan
  - Reduce per capita potable water use 20% by 2020

Learning from Melbourne, Australia

- Long history of droughts
- Urban water management is more advanced in drought management
- Response to Millennium Drought (1997-2009) considered successful in some ways
  - 46% decrease per capita potable water consumption (458 to 247 L/person-day)

Purpose of study

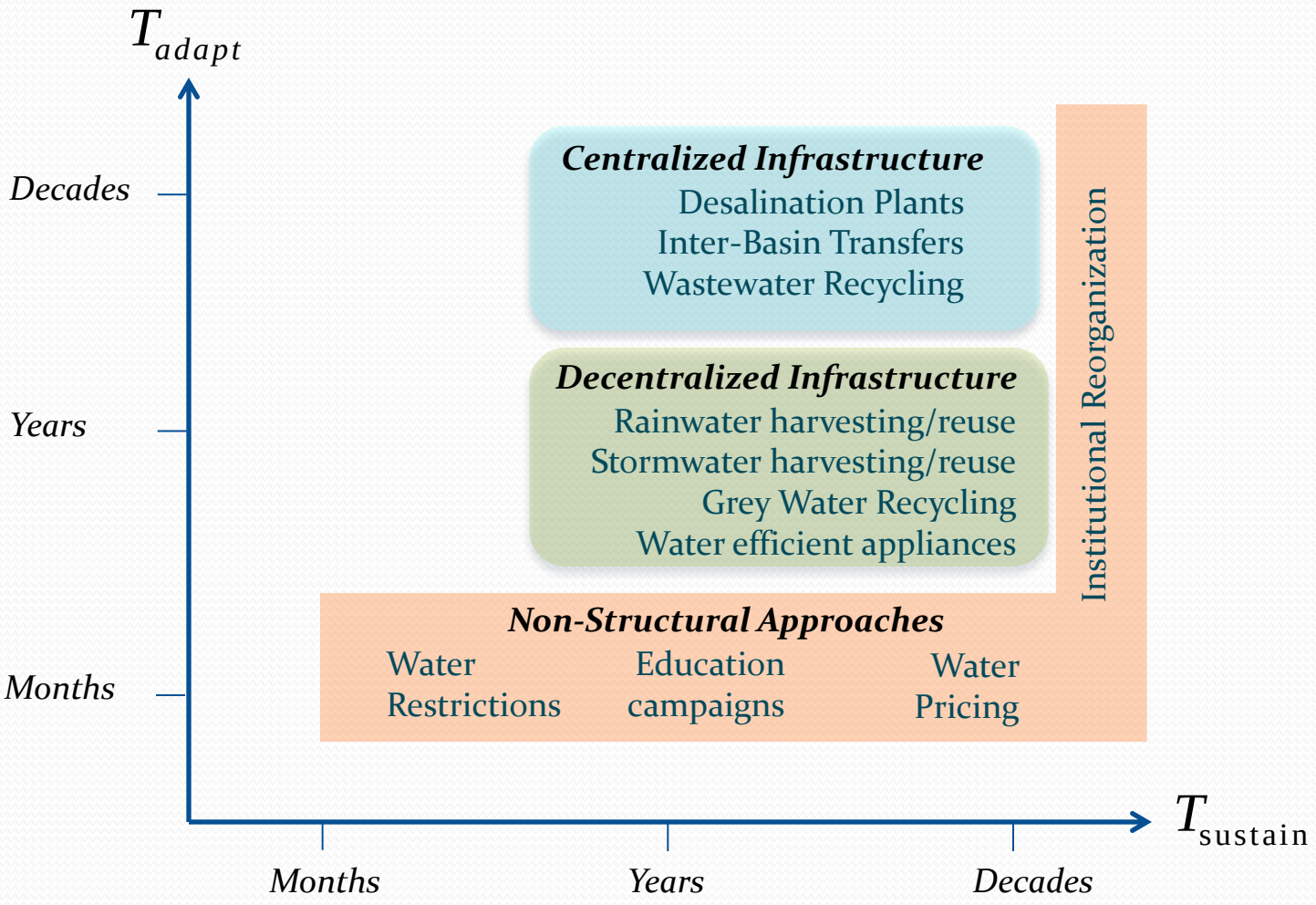
- Characterize drought management response
- Model water consumption changes during drought
  - Case study: Melbourne, Australia
- Implications for integrated water management for a resilient system

Characterizing Drought Management Response

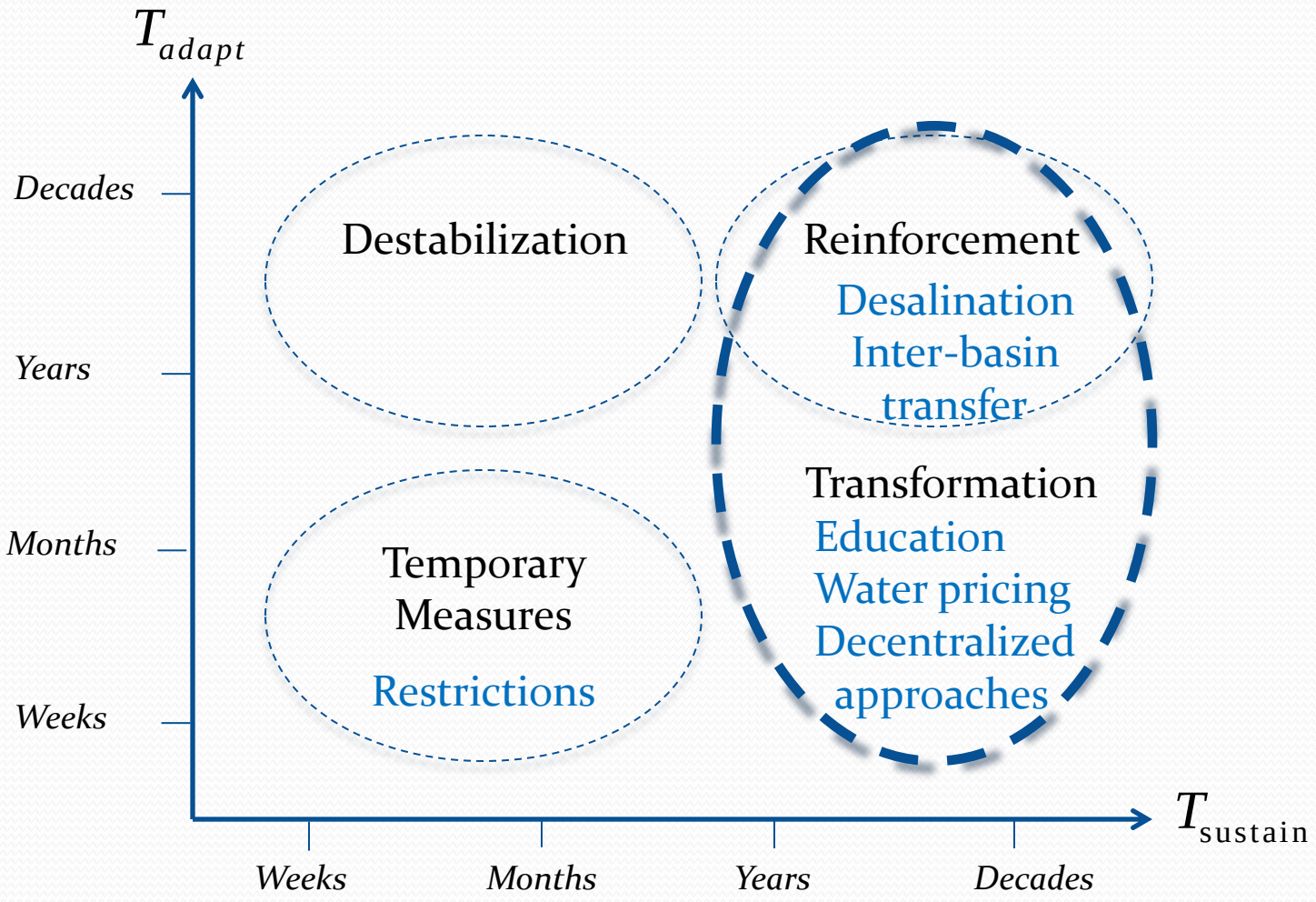
Propose characterizing response by:

- T_{adapt} : Time it takes for the socio-hydrological system to reduce water consumption after the onset of drought
- T_{sustain} : Time a socio-hydrological system continues to practice reduced water consumption after the drought has passed
- V_{security} : Storage volume of water to feel “water secure”

Drought Management Response



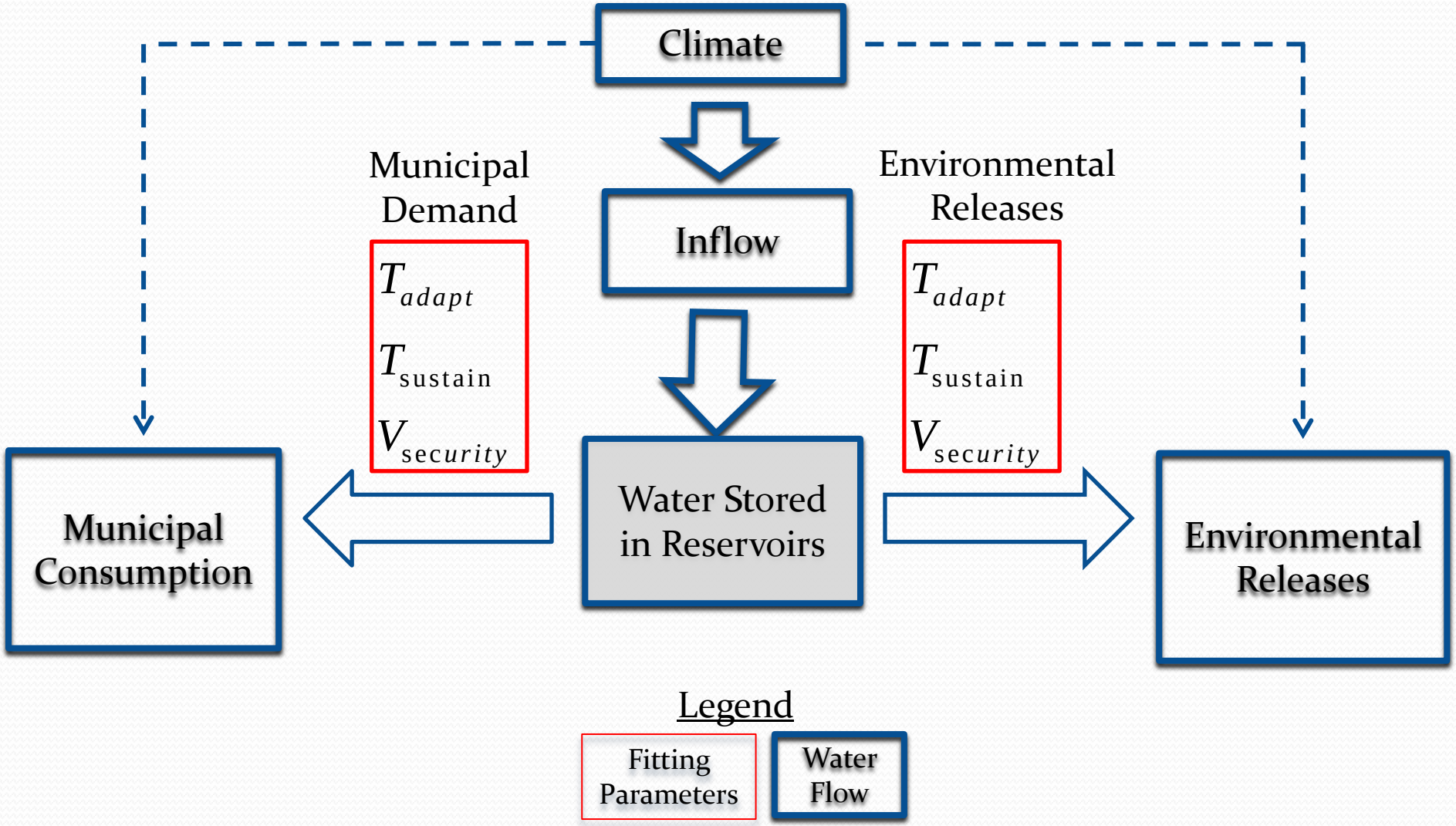
Drought Management Response



Modeling Approach

- Two-state water demand: drought vs. non-drought
- Convolution integral models transitions between drought and non-drought states
- Volume balance:
  - reservoir levels
  - municipal demand
  - environmental releases
- Model outputs:
  - $T_{adapt}, T_{\text{sustain}}, V_{\text{security}}$ for municipal demand and environmental releases
- Applied to Melbourne, Australia

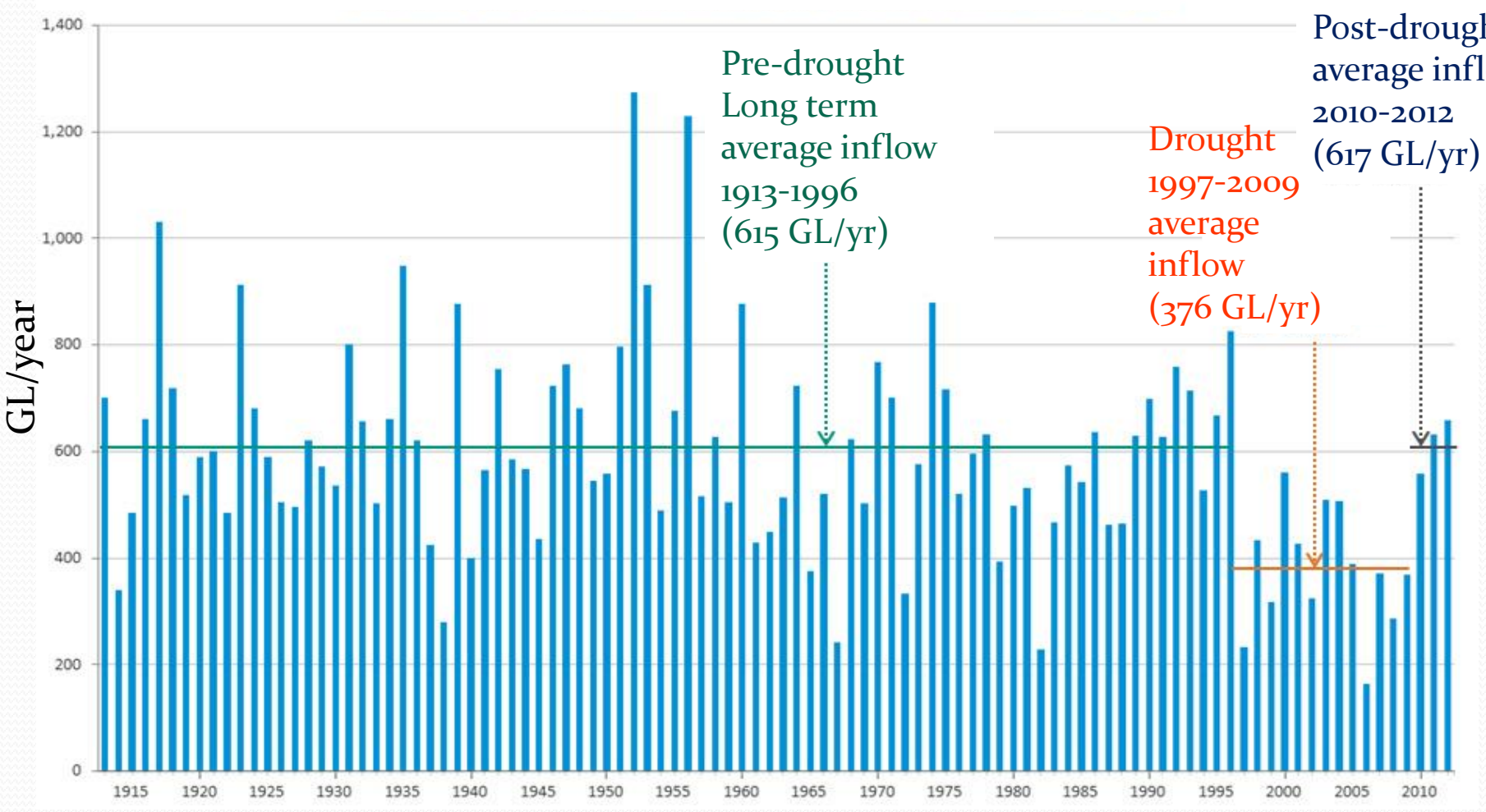
Modeling Gradual Water Conservation



Modeling applied to Melbourne

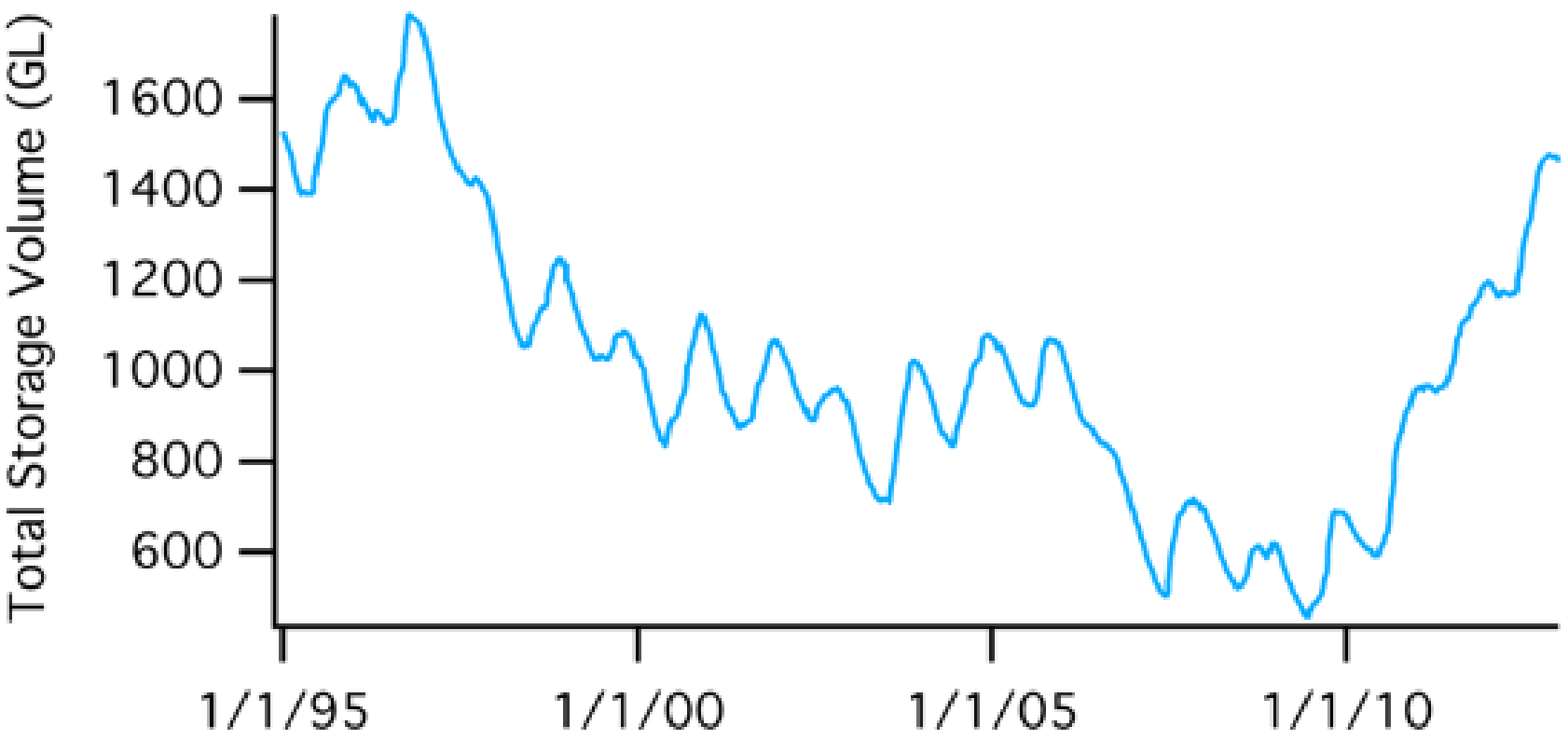
- Use Millennium Drought to determine the values of timescales and security volume
- Model application to Millennium Drought
  - Monthly time step
  - Years 1995-2012
  - Water data from Melbourne Water
  - Climate data from Australian Bureau of Meteorology
  - Population data from Australian Bureau of Statistics

Melbourne Millennium Drought: Decreased Inflow from 1997-2009



Source: www.melbournewater.com.au

Melbourne Millennium Drought: Reservoir Storage



Reservoirs dropped to historic lows of below 20% capacity in 2007

Fig Source: Grant et al. 2013

Melbourne Drought Response

- Public Education ($\downarrow T_{adapt}$, $\uparrow T_{sustain}$, transformative)
  - Water storage levels on TV, radio, newsprints, billboards

Pic source: www.theage.com.au

Melbourne Drought Response

- Restrictions: ($\downarrow T_{adapt}$, $\downarrow T_{\text{sustain}}$, temporary measure)
  - Stages from 1 to 4 based on water levels in reservoirs

Pic. Source: Melbourne Water, Managing Water Supplies for Climate Change and Variability—Melbourne, Aus.

Melbourne Drought Response

- Substitution Targets ($\downarrow\uparrow T_{adapt}$, $\uparrow T_{sustain}$, transformative)
  - Reused 22.8% of wastewater inflows by 2009/2010
  - Stormwater and rainwater harvesting (3% of annual municipal demand)

Rainwater collection water tank. Pic. Source: http://www.sustainablemelbourne.com/tag/rainwater-harvesting/

Pic. Source: Grant et al. 2013

Melbourne Drought Response

- Pricing ($\downarrow T_{adapt}$, $\uparrow T_{\text{sustain}}$, transformative)
  - 5% environmental levy
  - Introduction of 3-tier block tariff pricing (from 2-tier system)

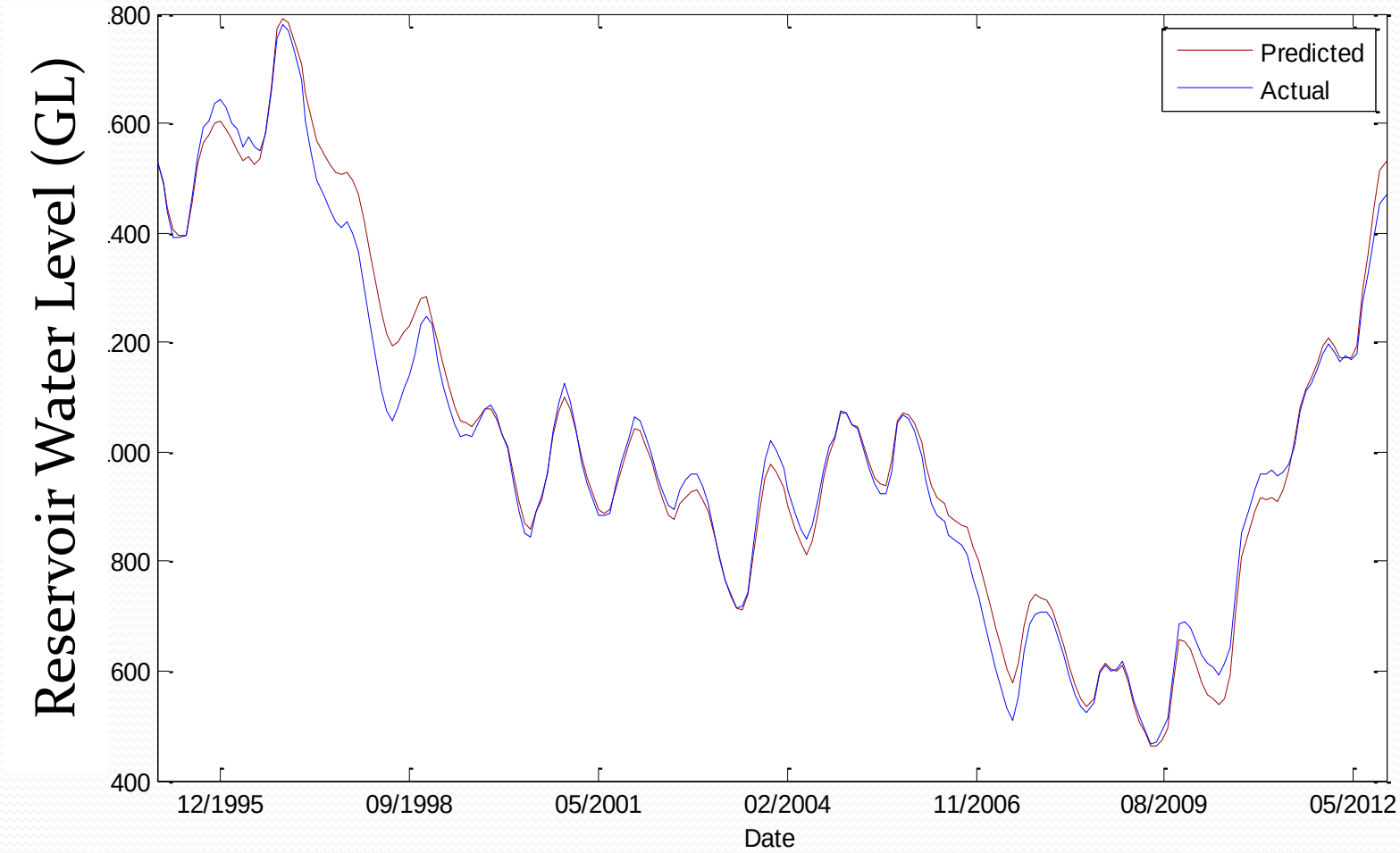
Yarra Valley Water

2013/2014 Residential Usage Charges

Step 1	0 - 440 litres of water per day	$2.5970 per kilolitre
Step 2	441 - 880 litres of water per day	$3.0469 per kilolitre
Step 3	881+ litres of water per day	$4.5017 per kilolitre
Recycled water	All usage	$2.2074 per kilolitre

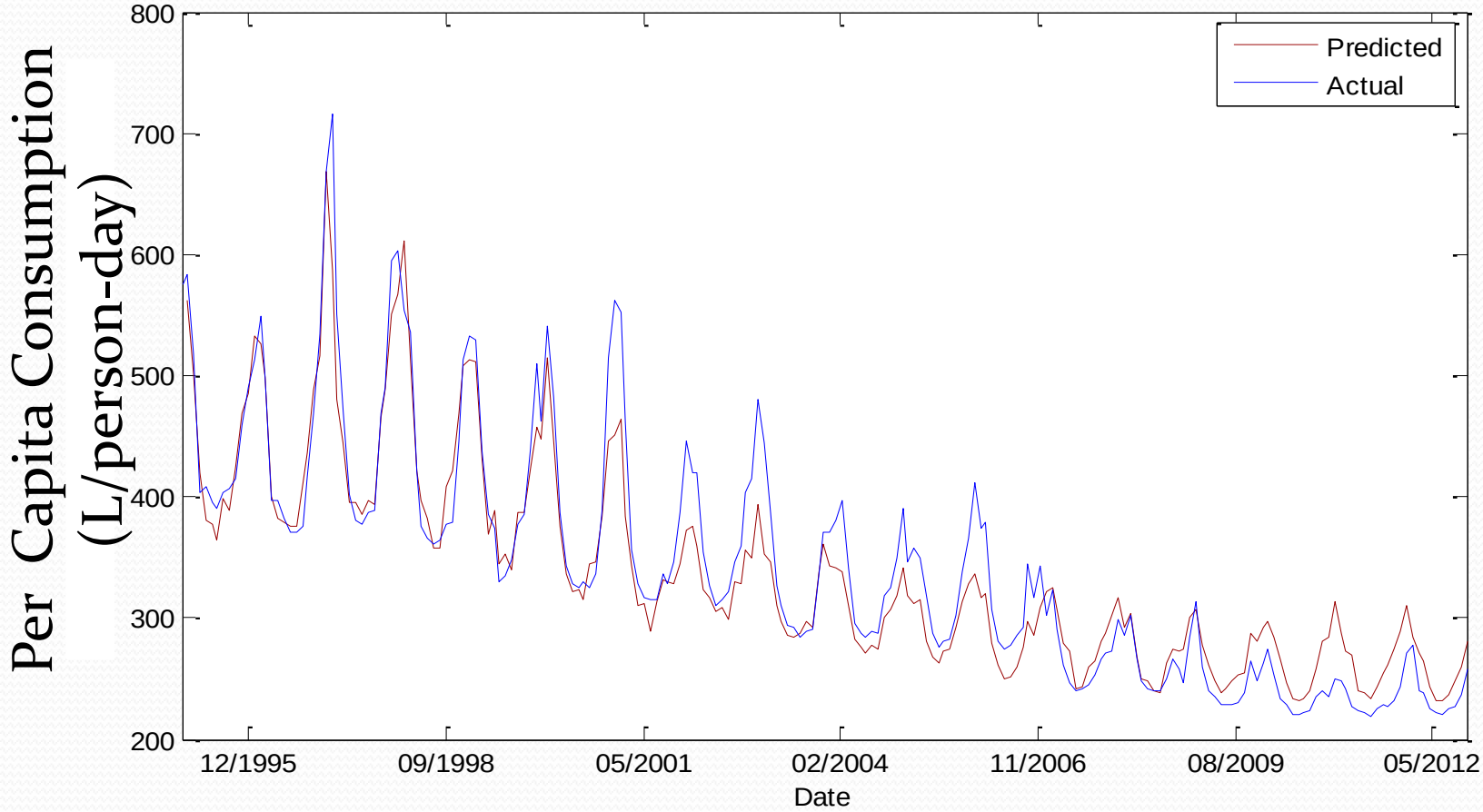
Fig. source: Yarra Valley Water, www.yvw.com.au

Results: Reservoir levels



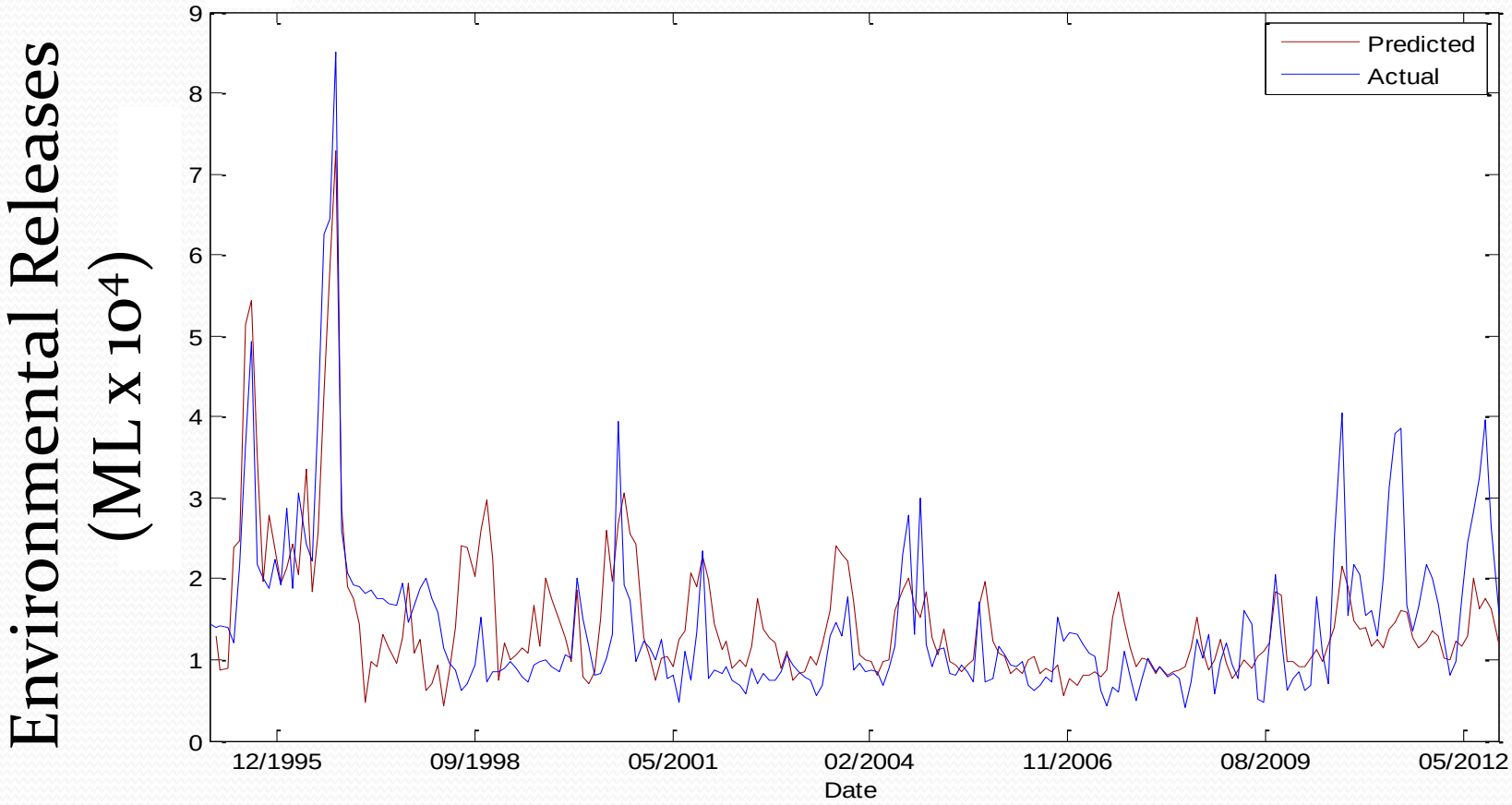
Actual and predicted reservoir water levels. R^2 for Reservoir Water Level is 0.98.

Results: Per capita municipal consumption



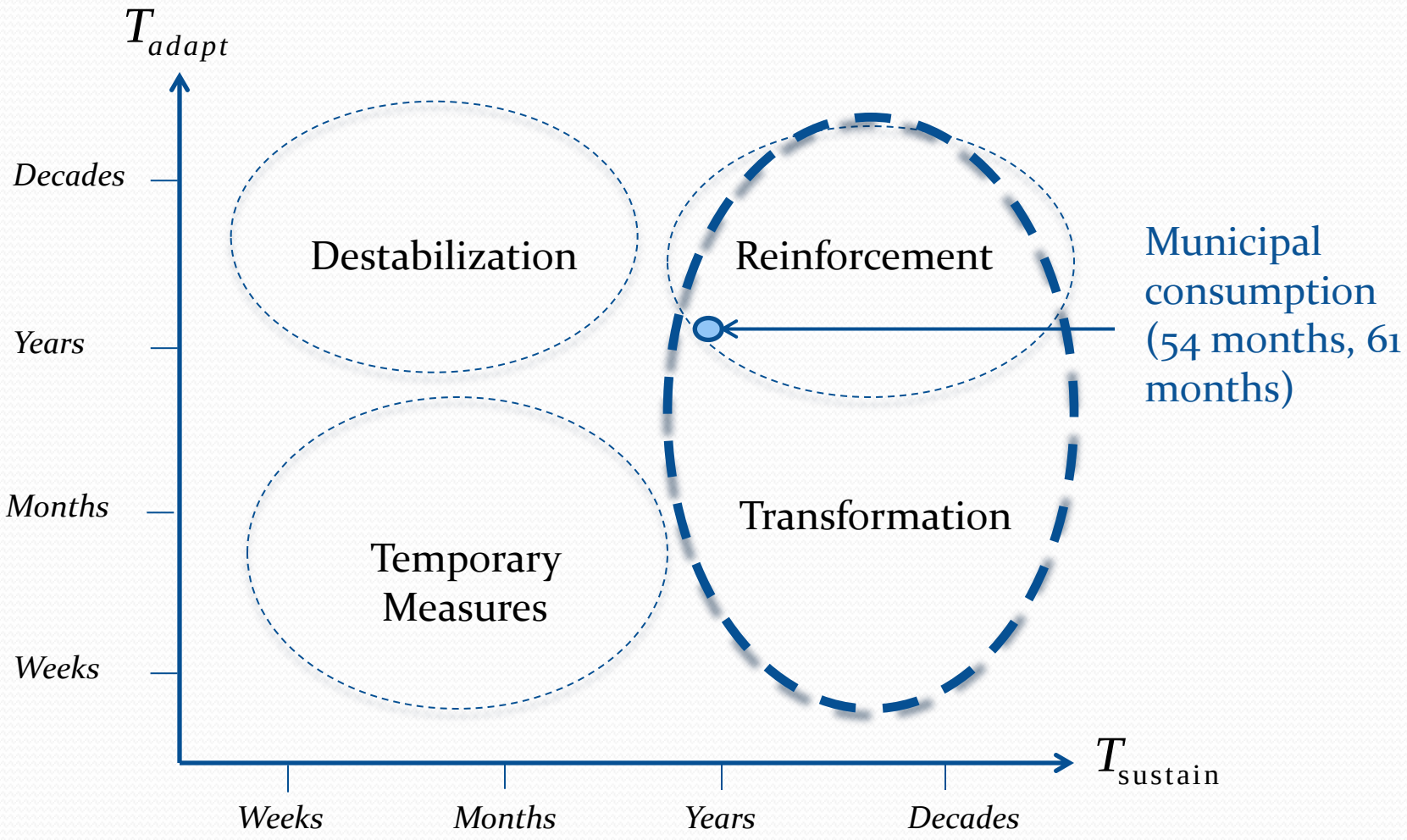
Monthly time series of Per capita Water Consumption model results from Jan 1997-Nov 2012. R^2 is 0.90. Non-drought and drought periods defined by Jan 1995- Dec 1996 and Jan 2010-Nov 2012, respectively.

Results: Environmental Release



Monthly time series of Environmental Release model results from Jan 1997-Nov 2012. R^2 is 0.50. Non-drought and drought periods defined as Jan 1995-Dec 1996 and Jan 1999 to Dec 2009.

Drought Management Response



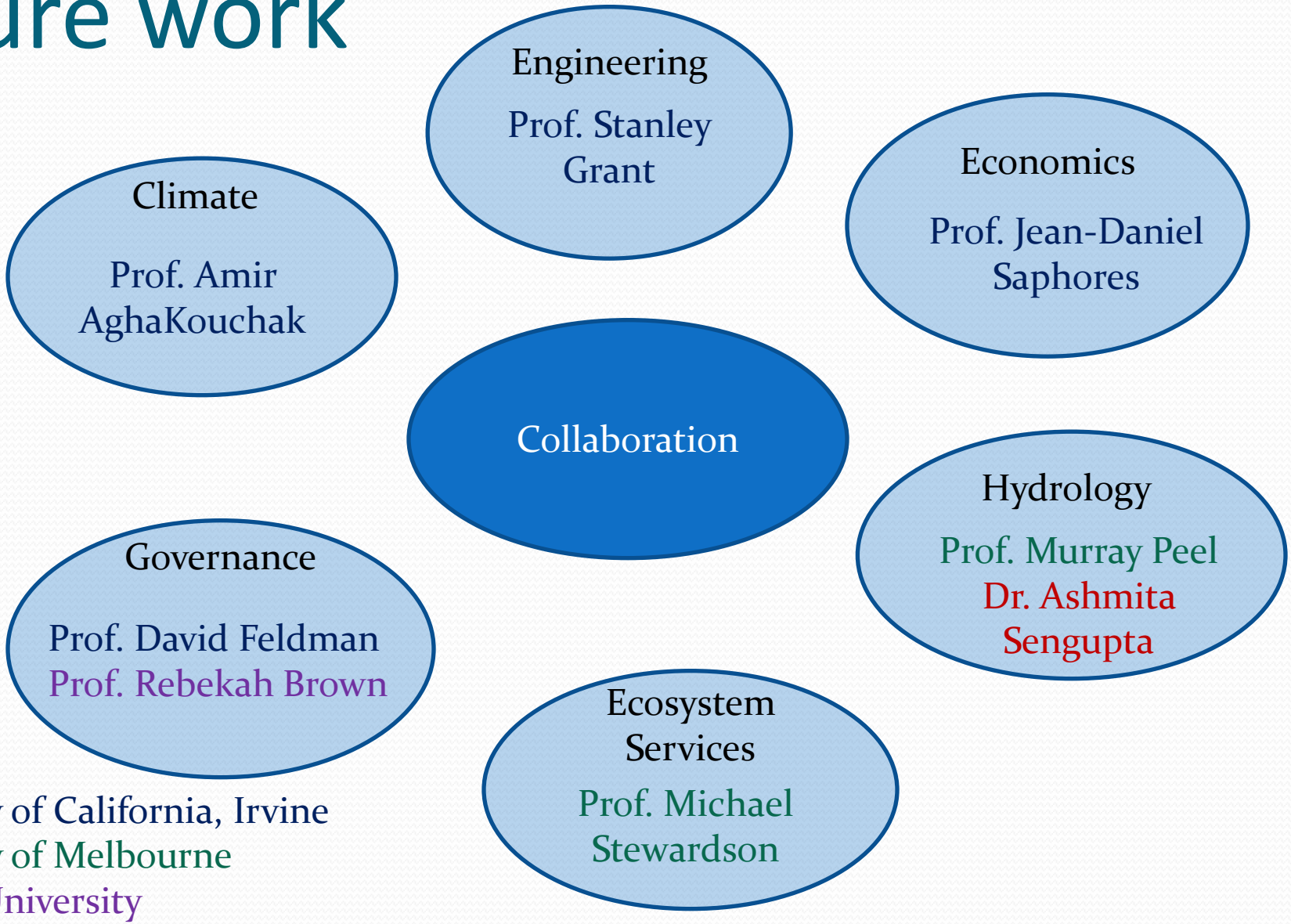
Summary of model results

- Simple model does reasonable job of fitting data
- Reservoir security volume is the same for environmental releases and per capita consumption

Future work

- Use climate predictions for the next 100 years to explore:
  - How values of T_{adapt} and $T_{sustain}$ interact with climate predictions to predict "vulnerabilities" and "opportunities"
  - Relate T_{adapt} and $T_{sustain}$ to fine-scale decisions about water use in in urban communities (collaborating with researchers at Monash University who are using agent based models to study water use choices).

Future work



Legend

University of California, Irvine

University of Melbourne

Monash University

Southern California Coastal Water Research Project

Conclusion

Sacramento-San Joaquin Water System
Pic Source: CA Drying Up, KPBS.org

- California is water stressed and needs to incorporate more sustainable practices
  - Potable water conservation is a top priority
  - 20x2020 Plan meant to conserve water or find savings from non-traditional sources

Conclusion

- Proposed model:
  - captures water usage change over time
  - characterizes management practices for meeting immediate short falls vs. cultivating sustained actions
  - is a tool to evaluate policy and strategic planning to increase resiliency in urban water systems

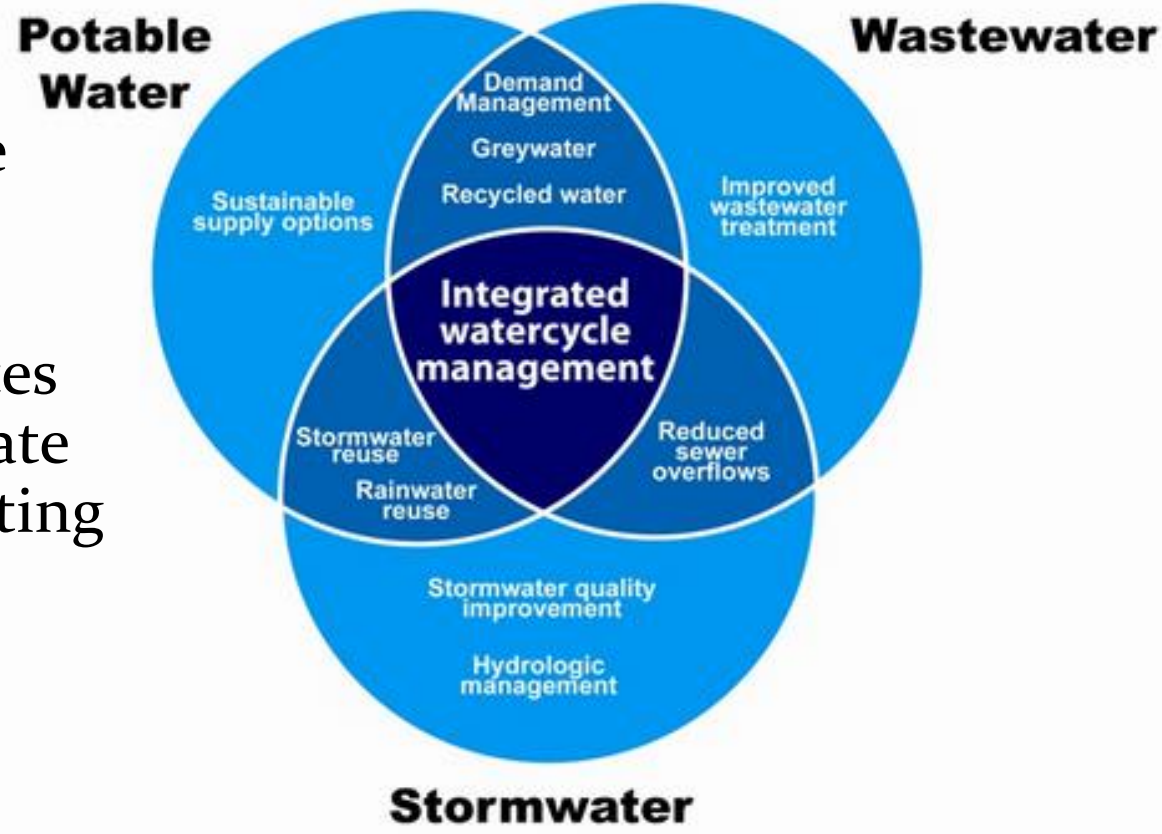


Fig. Source: Hoban and Wong (2006), www.waterbydesign.com.au

Thank you! Questions?

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Extra slides

Urban Water Management Transitions: Resiliency for meeting today's and tomorrow's challenges

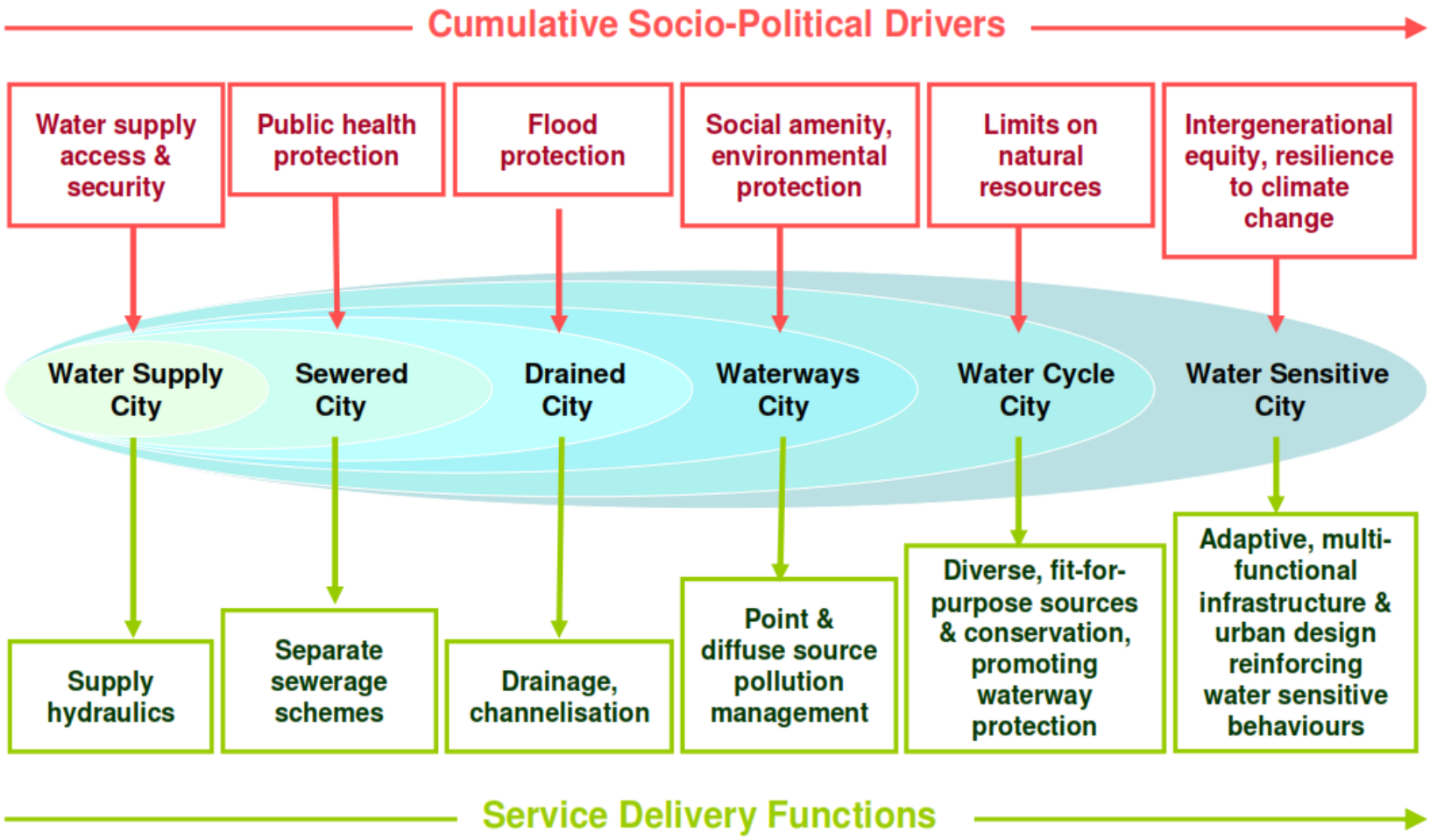

Fig Source: Brown et al. (2008) 11th International Conf. on Urban Drainage, Edinburgh, UK

Melbourne Water Budget

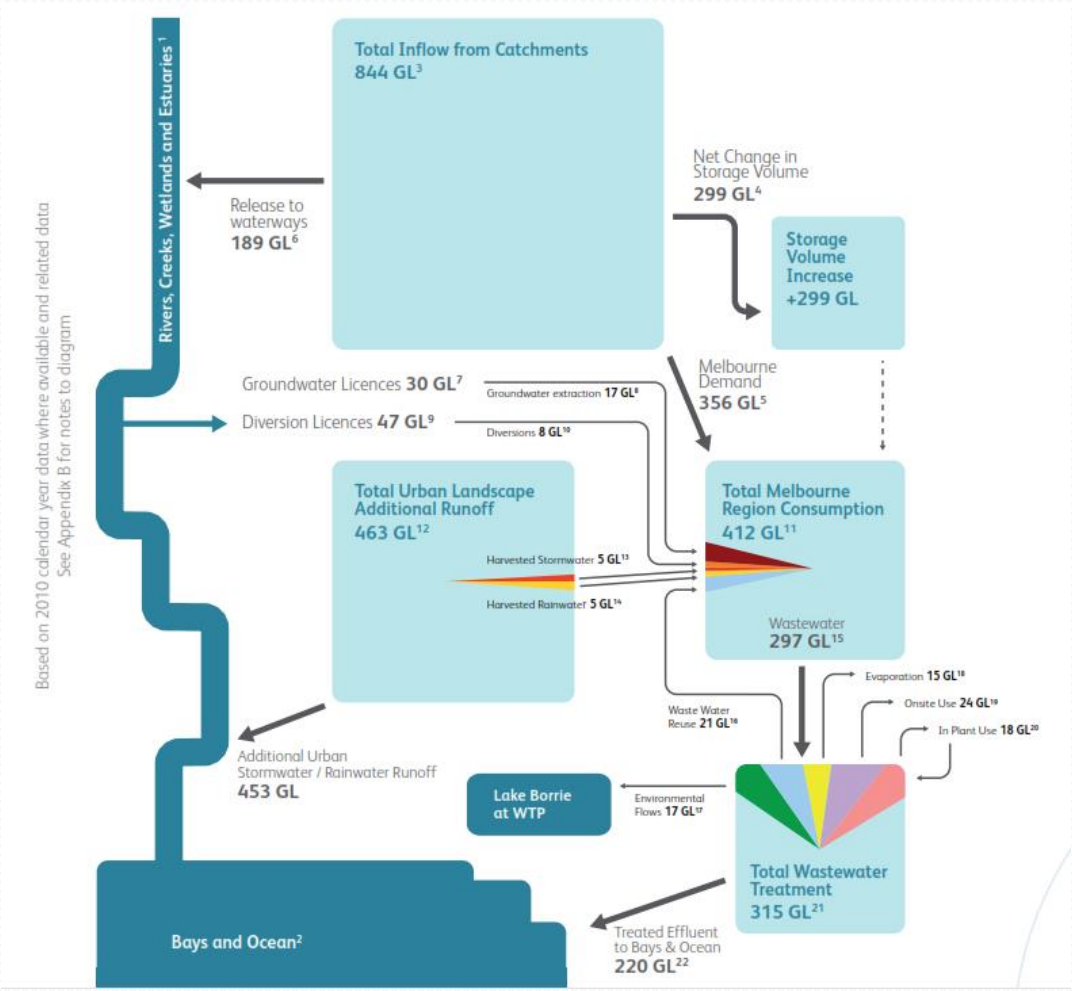

Fig. Source: Victoria State Government, DSE, Living Melbourne, Living Victoria Roadmap (2011)

Melbourne water restrictions

5.1 Water Restriction Levels and Duration

Water Restrictions Stage	Start Date
Stage 1	November 2002
Stage 2	August 2003
PWSR	March 2005
Stage 1	September 2006
Stage 2	November 2006
Stage 3	January 2007
Stage 3a	April 2007
Stage 3a + T155	December 2008
Stage "3" + T155	April 2010
Stage 2	September 2010
Stage 1	December 2011

Source: Appendix from Yarra Valley Water , Residential Water Use Study, V2: summer 2012

Melbourne water restrictions

Level of Drought Response	Triggers as Volume in Total System Storage (Gigalitres)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Early Warning	1,167	1,141	1,089	1,063	1,055	1,036	1,055	1,092	1,141	1,167	1,197	1,182
Voluntary Reduction	1,006	980	927	901	894	875	894	931	980	1,006	1,036	1,021
Stage 1	925	899	847	821	813	795	813	851	899	925	955	940
Stage 2	790	773	738	720	715	703	715	740	773	790	810	800
Stage 3	655	646	629	620	618	611	618	630	646	655	665	660
Stage 4	520	520	520	520	520	520	520	520	520	520	520	520

Source: Yarra Valley Water Drought Response Plan 2010, http://www.docstoc.com/docs/40604924/DROUGHT-RESPONSE-PLAN-FOR-YARRA-VALLEY-WATER