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Is it Conservation, Efficiency, or the Economy? The Importance of Understanding Signals and Trends in Water Use

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Overview

- Background on the problem of differentiating among various factors affecting water use
- Relationship to Water Research Foundation Project 4458
- Show how time-series decomposition can assist in evaluating trends
- Summarize some inferences from a case study example

Background

- Over the last several years, many urban water systems have experienced a decrease in water demands
  - Some gradual
  - Some quick
- Lower demands can lead to net revenue problems, unused capacity, stranded capital, …(especially if demand reductions are acute and unexpected)
- Case for improved water efficiency becomes harder to sell
- In some cases, water efficiency is “blamed”

Background

- Water use is influenced by many factors, which operate over time more or less simultaneously
  - Weather
  - Price
  - Demographics
  - Economics
  - Attitudes
  - Technology
  - Regulation

Background

- What should we expect?
  - Advances in plumbing technology
  - Evolution of urban water service areas and management
    - Population growth
    - Change in structure of the economy and demand sectors
    - Change in development densities
    - Changes in costs and prices for water (and sewer) service
  - Active water efficiency programs
  - Weather spells
  - Periodic water shortages and restrictions
  - Economic cycles

Background

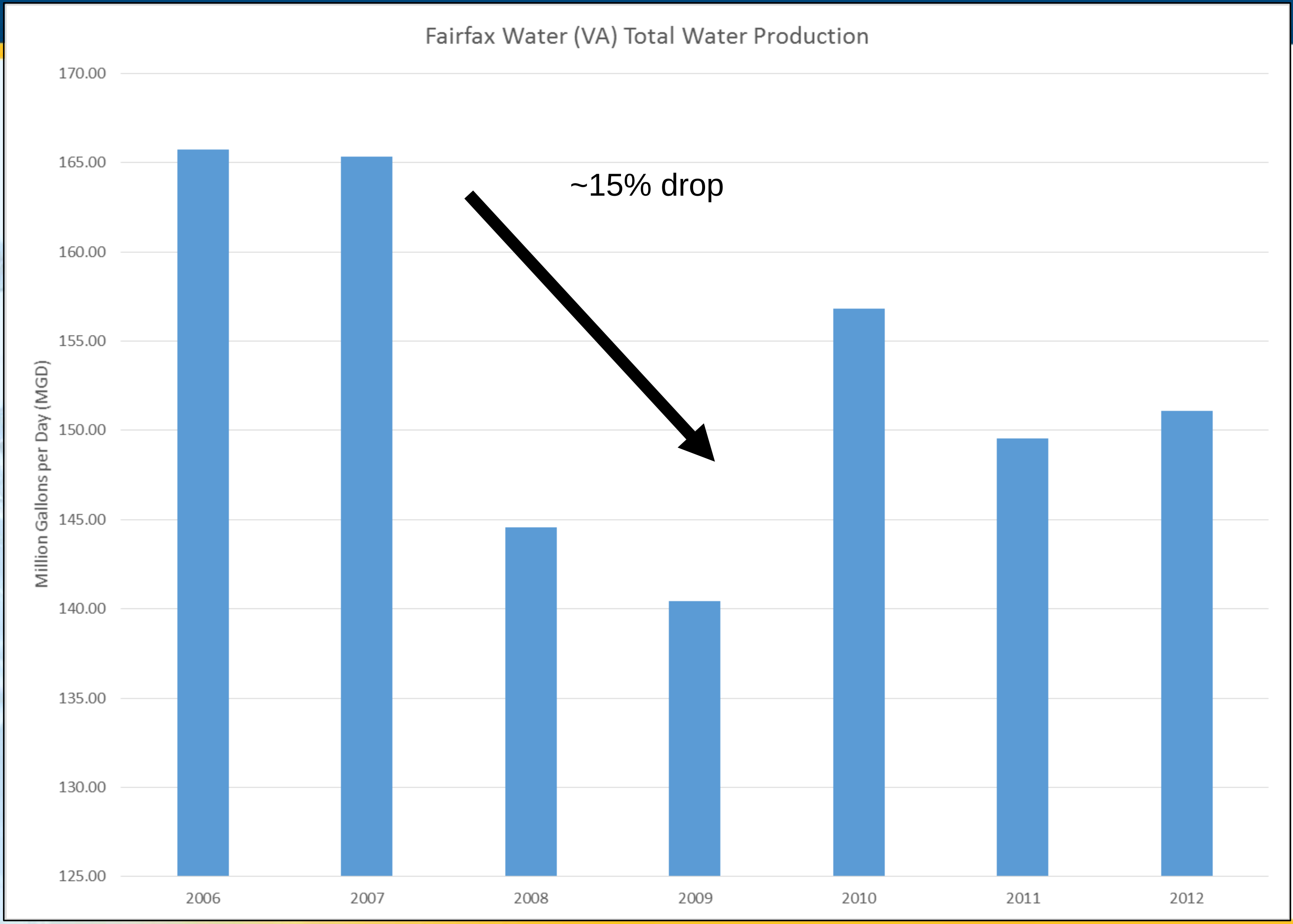
- Hypothesis
  - Some of the recent declines in water use are more closely tied to the condition of the economy than they are to increases in water efficiency
- Evaluating this hypothesis is not straightforward but supported by:
  - Visual analysis of water demand data
  - Collection and assessment of data for economic and other factors that change over time
  - Statistical estimation of demand models and inference

WaterRF Project 4458

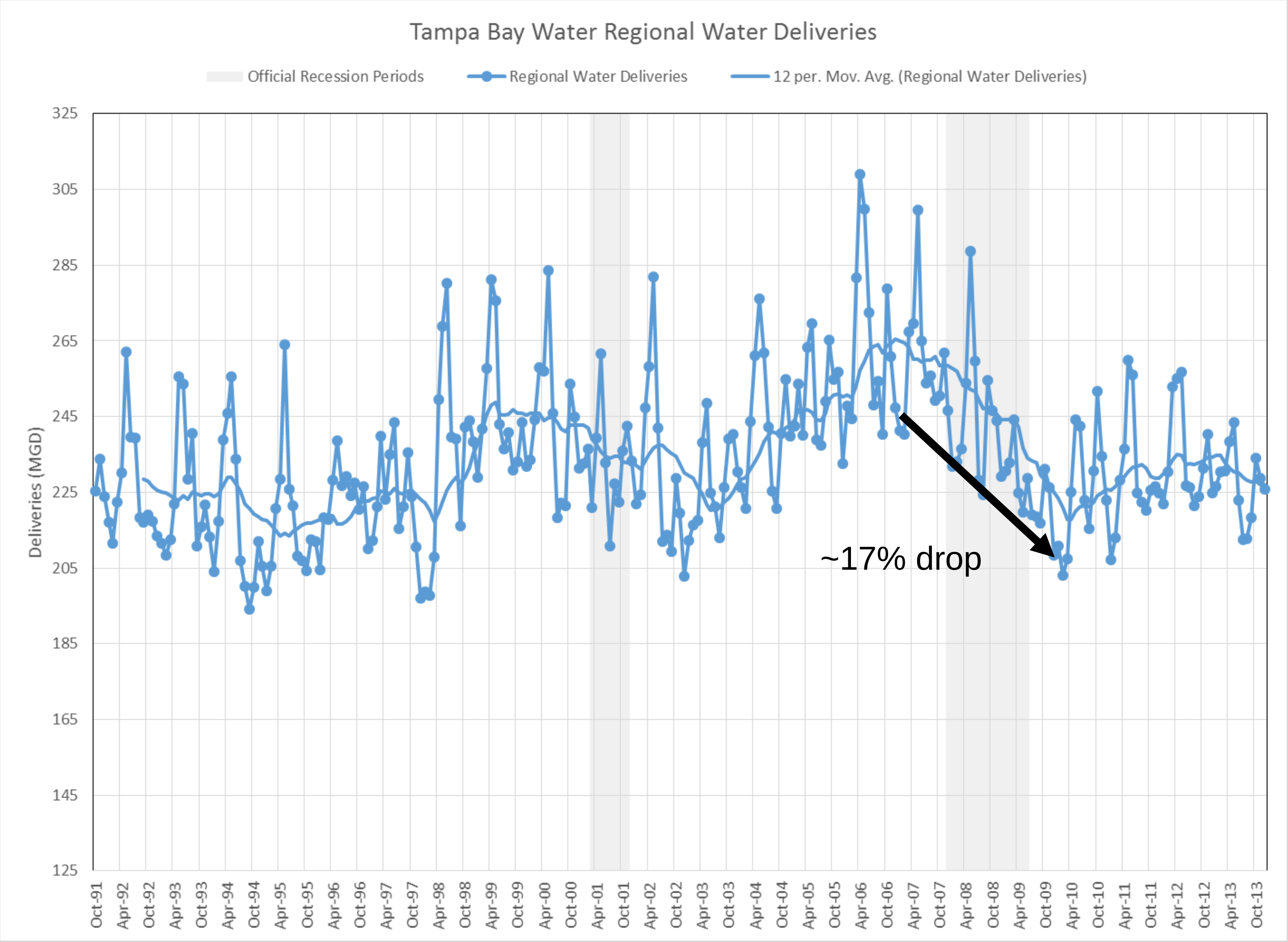
- Water Demand Forecasting in Uncertain Times: Isolating the Effects of the Great Recession

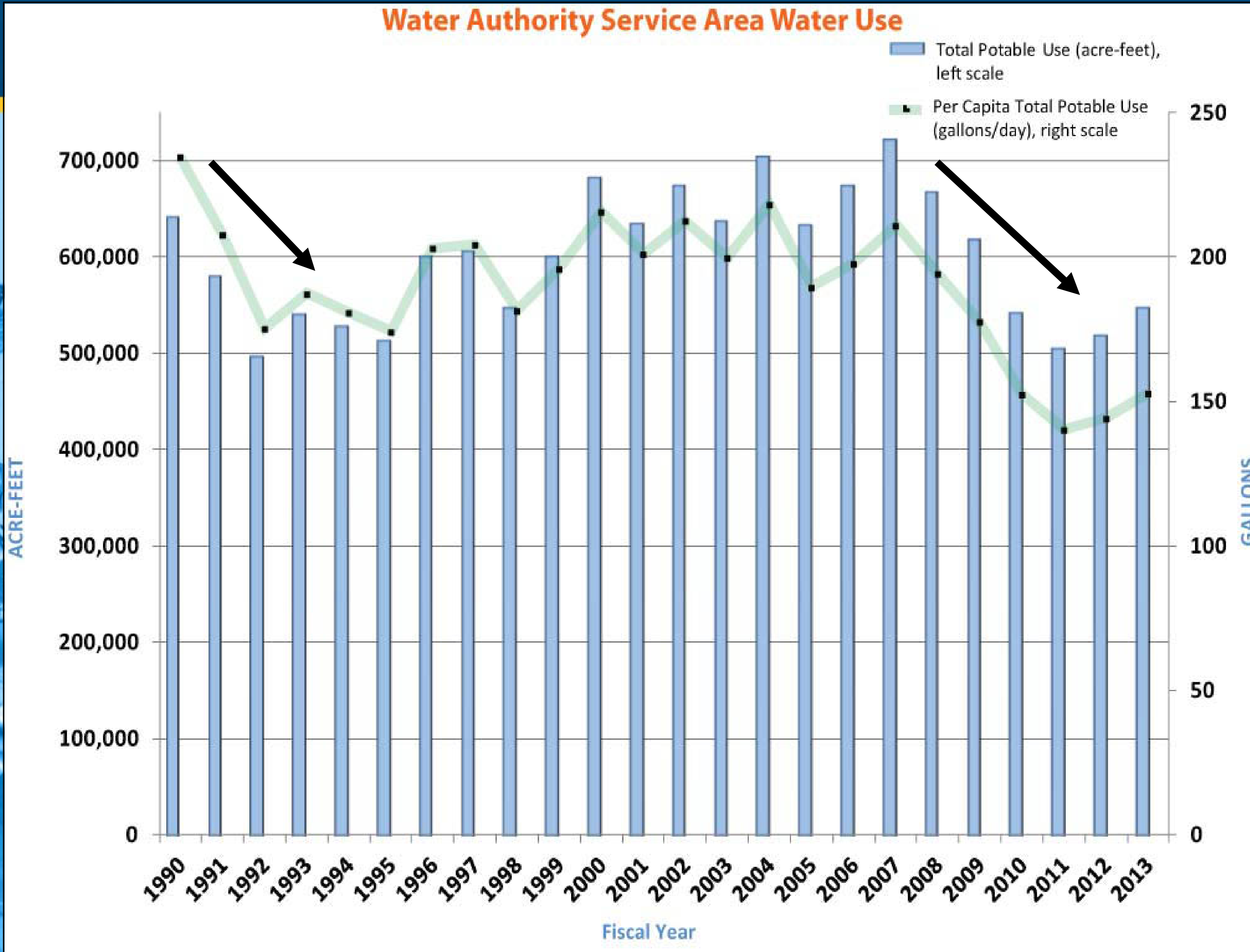
1. *Assess how water demand is affected by short-term economic shocks and through which economic channels*
2. *Evaluate how economic shocks can be differentiated from the many other factors known to have an impact on demand*
3. *Analyze how water utilities may be better able to anticipate, adapt to, and minimize impacts of future economic cycles on water demand planning*

Is water efficiency the cause of this?



Or this?


Tampa Bay Water Regional Water Deliveries
Official Recession Periods
Regional Water Deliveries
12 per. Mov. Avg. (Regional Water Deliveries)
Deliveries (MGD)
325
305
285
265
245
225
205
185
165
145
125
Oct-91
Apr-92
Oct-92
Apr-93
Oct-93
Apr-94
Oct-94
Apr-95
Oct-95
Apr-96
Oct-96
Apr-97
Oct-97
Apr-98
Oct-98
Apr-99
Oct-99
Apr-00
Oct-00
Apr-01
Oct-01
Apr-02
Oct-02
Apr-03
Oct-03
Apr-04
Oct-04
Apr-05
Oct-05
Apr-06
Oct-06
Apr-07
Oct-07
Apr-08
Oct-08
Apr-09
Oct-09
Apr-10
Oct-10
Apr-11
Oct-11
Apr-12
Oct-12
Apr-13
Oct-13
~17% drop


Water Authority Service Area Water Use
Total Potable Use (acre-feet), left scale
Per Capita Total Potable Use (gallons/day), right scale
ACRE-FEET
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
GALLONS
250
200
150
100
50
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
Fiscal Year

Example for San Diego County Water Authority

- ► Total regional water deliveries and population served 1975 to 2013
- ► Wholesale prices (inflation-adjusted) 1977 to present
- ► Regional weather characterization using PRISM gridded data
- ► Timing of mandatory water supply shortage restrictions
- ► Timing of recessions
- ► Selected economic indicator data

- ► Apply time series decomposition and evaluate trends and signals in water use and where they might be attributed

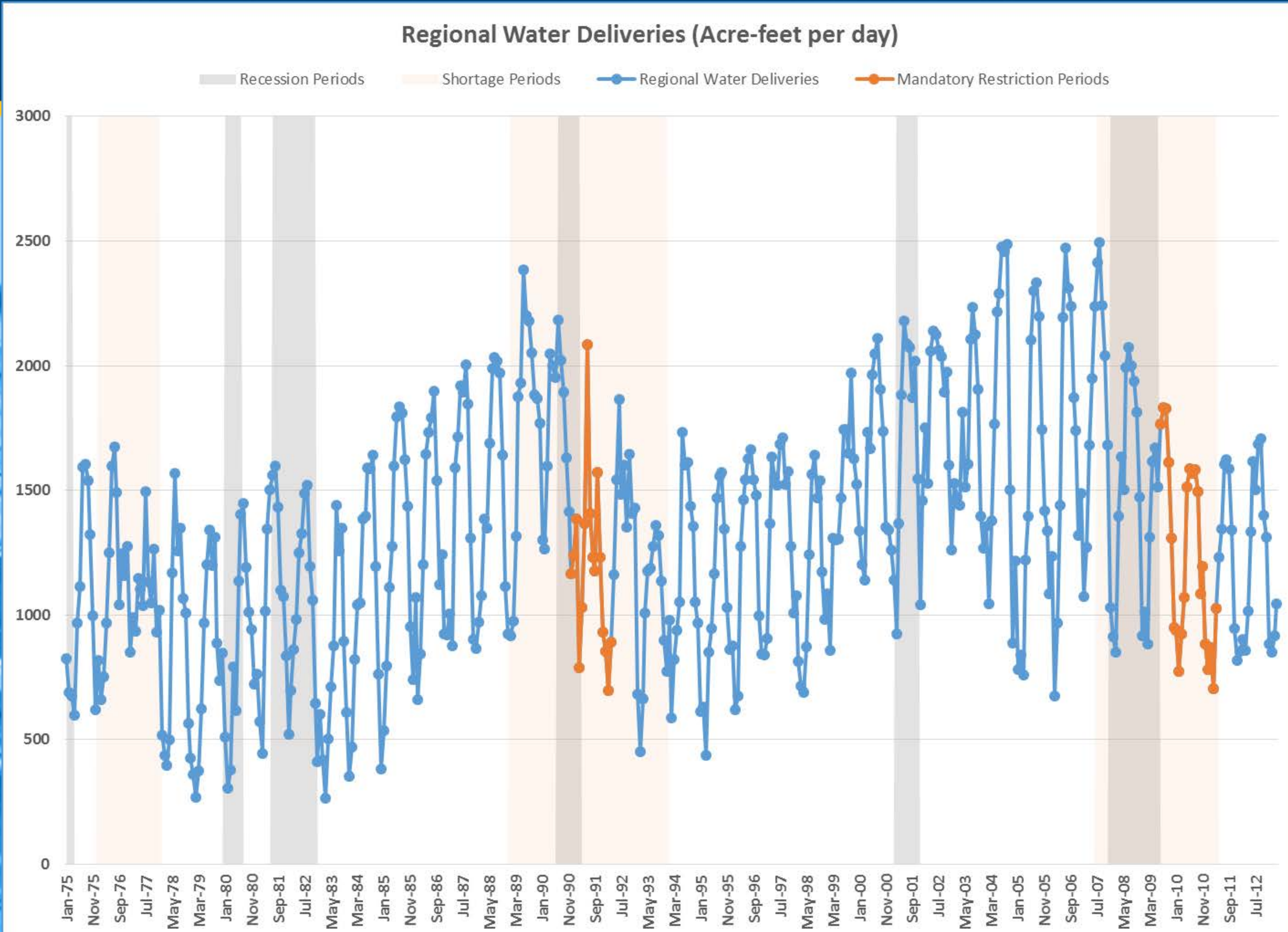
Time Series Decomposition

- In simple time series decomposition the original raw input time series (TS) can be defined (or decomposed into components) as:

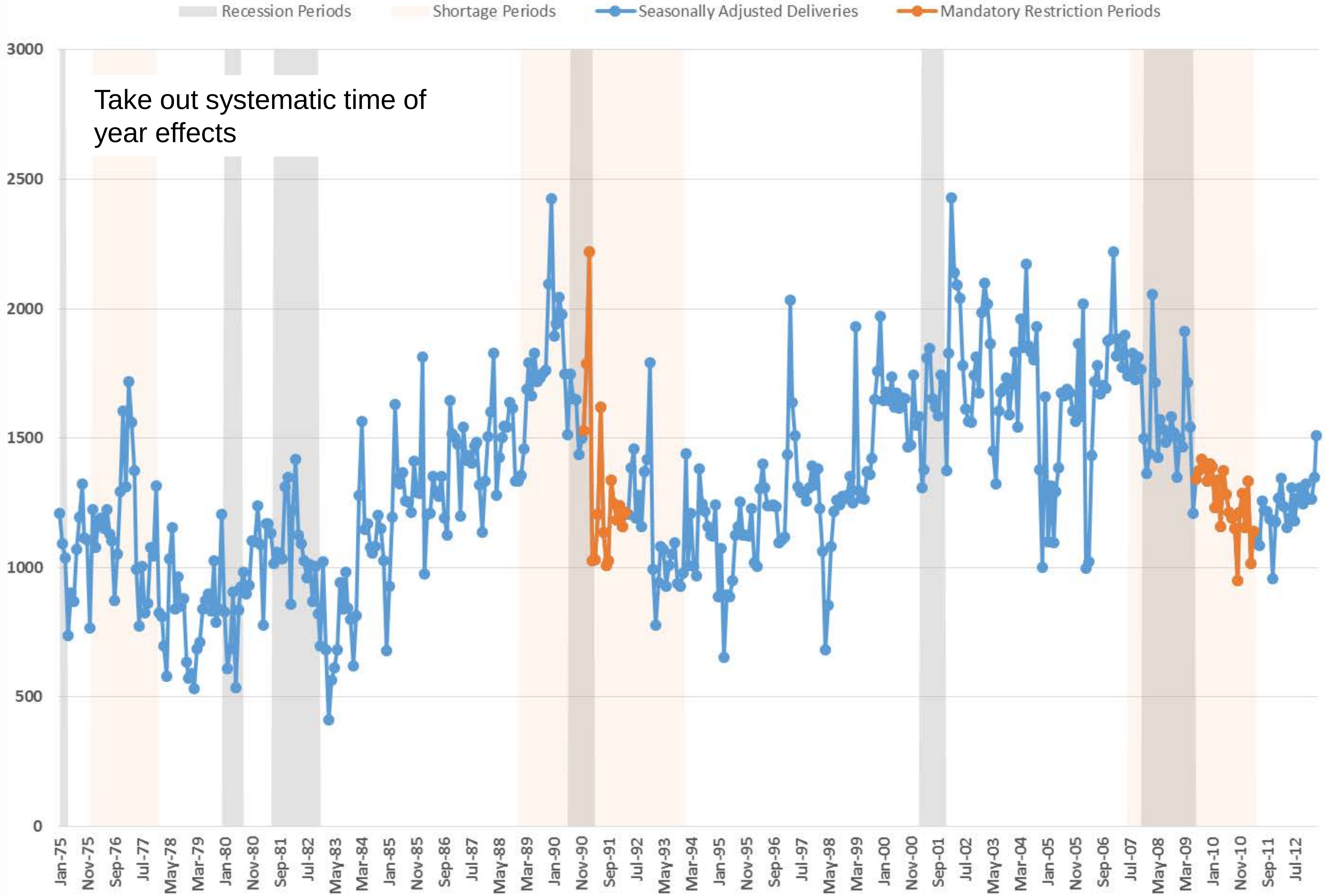
$$TS = S \times C \times I$$

  - *S* is the seasonal component
  - *C* is the trend cycle
  - *I* is the irregular component

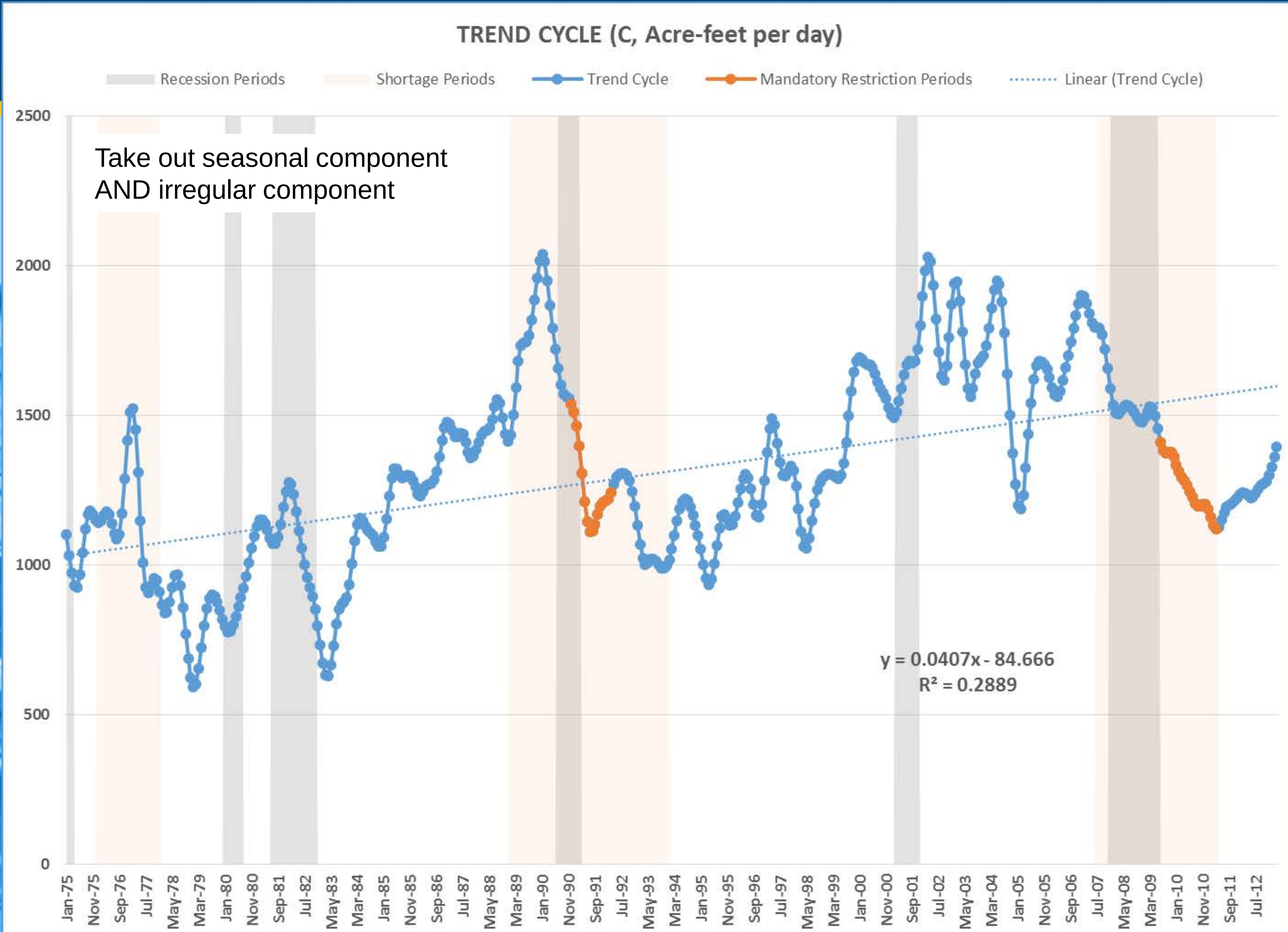
- Available in several statistical packages

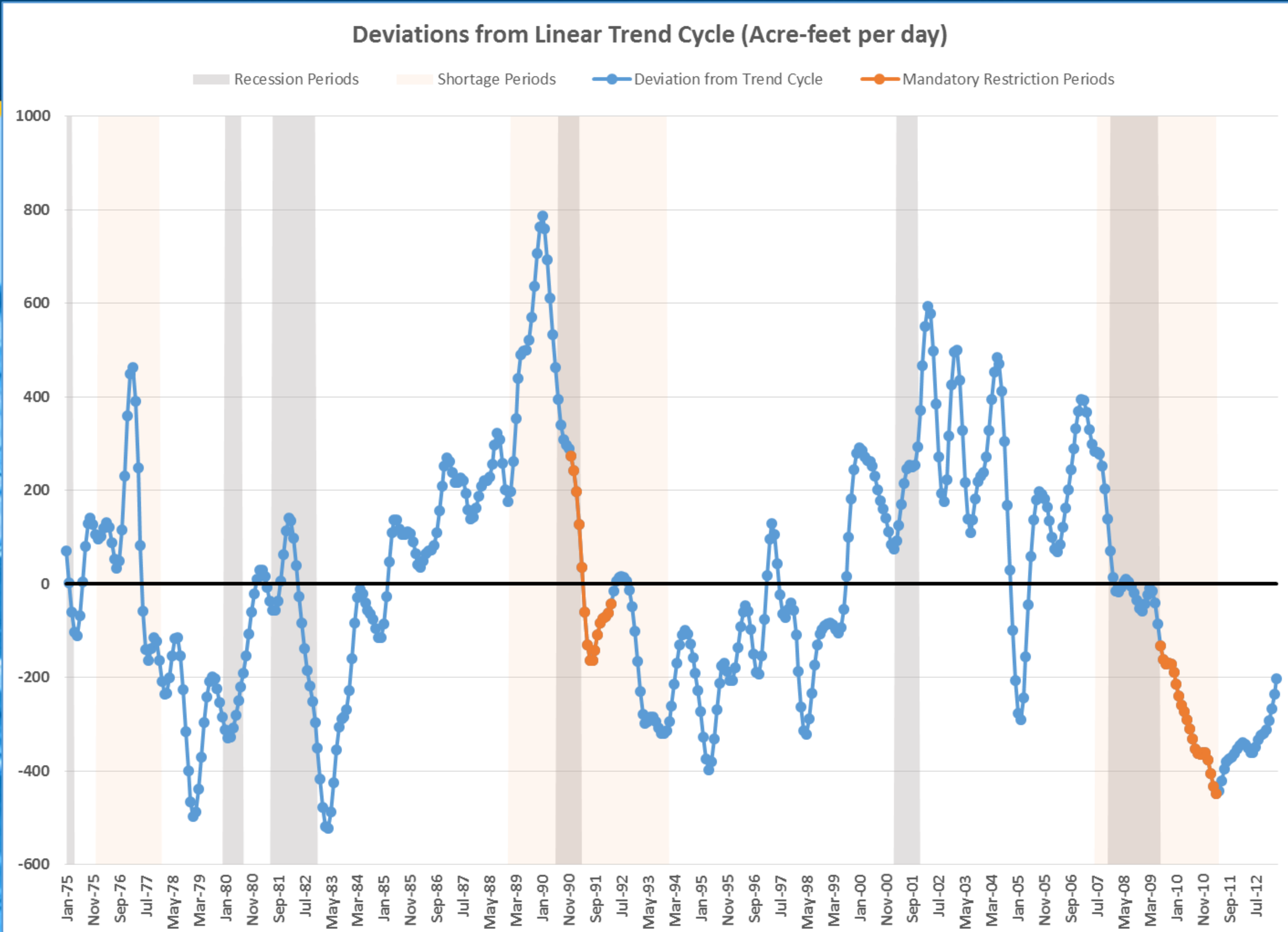

Regional Water Deliveries (Acre-feet per day)
Recession Periods
Shortage Periods
Regional Water Deliveries
Mandatory Restriction Periods
3000
2500
2000
1500
1000
500
0
Jan-75
Nov-75
Sep-76
Jul-77
May-78
Mar-79
Jan-80
Nov-80
Sep-81
Jul-82
May-83
Mar-84
Jan-85
Nov-85
Sep-86
Jul-87
May-88
Mar-89
Jan-90
Nov-90
Sep-91
Jul-92
May-93
Mar-94
Jan-95
Nov-95
Sep-96
Jul-97
May-98
Mar-99
Jan-00
Nov-00
Sep-01
Jul-02
May-03
Mar-04
Jan-05
Nov-05
Sep-06
Jul-07
May-08
Mar-09
Jan-10
Nov-10
Sep-11
Jul-12

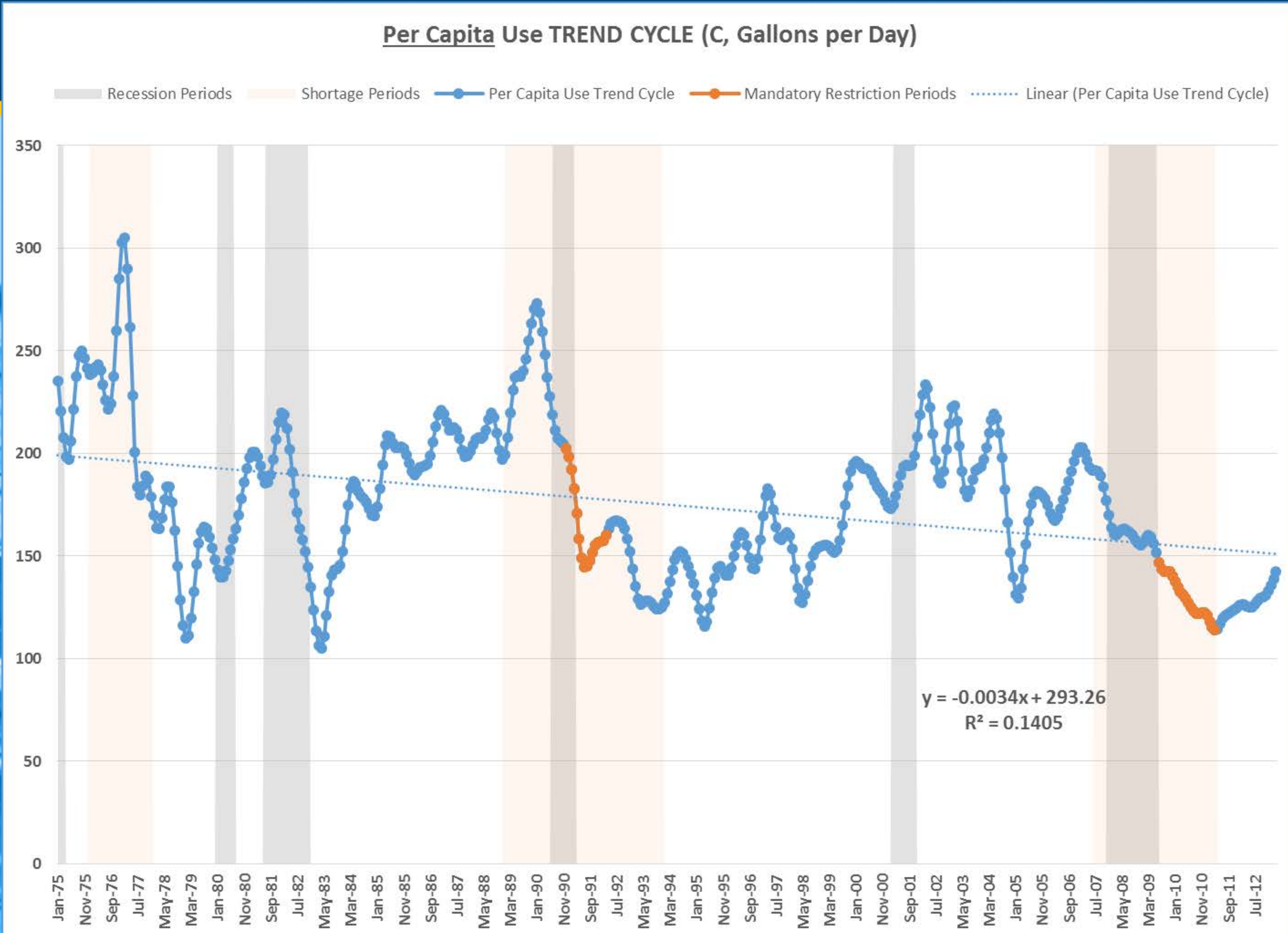
SEASONALLY ADJUSTED DELIVERIES (C x I, Acre-feet per day)



Take out systematic time of year effects


TREND CYCLE (C, Acre-feet per day)
Recession Periods
Shortage Periods
Trend Cycle
Mandatory Restriction Periods
Linear (Trend Cycle)
Take out seasonal component
AND irregular component
y = 0.0407x - 84.666
R² = 0.2889
2500
2000
1500
1000
500
0
Jan-75
Nov-75
Sep-76
Jul-77
May-78
Mar-79
Jan-80
Nov-80
Sep-81
Jul-82
May-83
Mar-84
Jan-85
Nov-85
Sep-86
Jul-87
May-88
Mar-89
Jan-90
Nov-90
Sep-91
Jul-92
May-93
Mar-94
Jan-95
Nov-95
Sep-96
Jul-97
May-98
Mar-99
Jan-00
Nov-00
Sep-01
Jul-02
May-03
Mar-04
Jan-05
Nov-05
Sep-06
Jul-07
May-08
Mar-09
Jan-10
Nov-10
Sep-11
Jul-12


Deviations from Linear Trend Cycle (Acre-feet per day)
Recession Periods
Shortage Periods
Deviation from Trend Cycle
Mandatory Restriction Periods
1000
800
600
400
200
0
-200
-400
-600
Jan-75
Nov-75
Sep-76
Jul-77
May-78
Mar-79
Jan-80
Nov-80
Sep-81
Jul-82
May-83
Mar-84
Jan-85
Nov-85
Sep-86
Jul-87
May-88
Mar-89
Jan-90
Nov-90
Sep-91
Jul-92
May-93
Mar-94
Jan-95
Nov-95
Sep-96
Jul-97
May-98
Mar-99
Jan-00
Nov-00
Sep-01
Jul-02
May-03
Mar-04
Jan-05
Nov-05
Sep-06
Jul-07
May-08
Mar-09
Jan-10
Nov-10
Sep-11
Jul-12

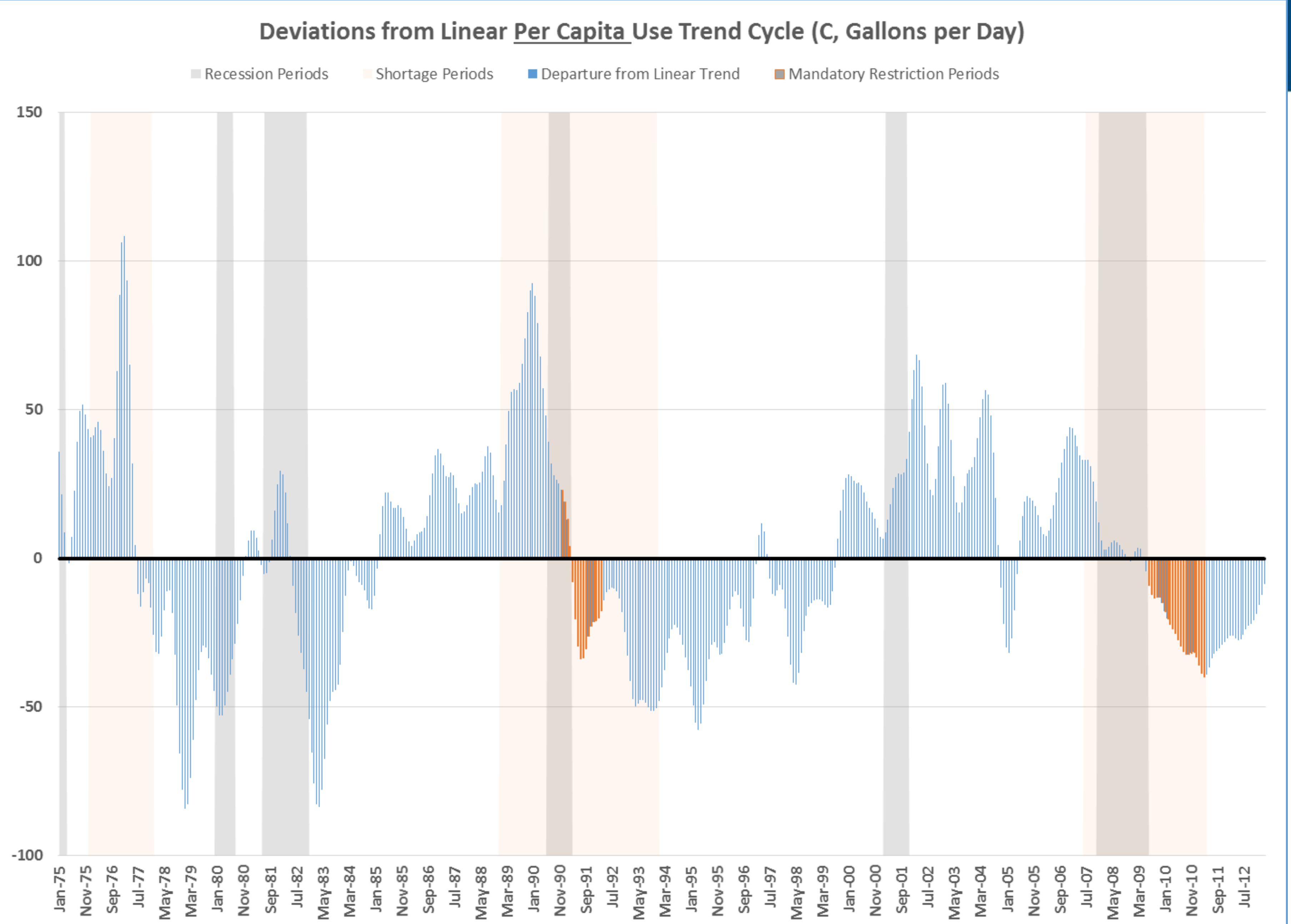

Per Capita Use TREND CYCLE (C, Gallons per Day)
Recession Periods
Shortage Periods
Per Capita Use Trend Cycle
Mandatory Restriction Periods
Linear (Per Capita Use Trend Cycle)
350
300
250
200
150
100
50
0
y = -0.0034x + 293.26
R² = 0.1405
Jan-75
Nov-75
Sep-76
Jul-77
May-78
Mar-79
Jan-80
Nov-80
Sep-81
Jul-82
May-83
Mar-84
Jan-85
Nov-85
Sep-86
Jul-87
May-88
Mar-89
Jan-90
Nov-90
Sep-91
Jul-92
May-93
Mar-94
Jan-95
Nov-95
Sep-96
Jul-97
May-98
Mar-99
Jan-00
Nov-00
Sep-01
Jul-02
May-03
Mar-04
Jan-05
Nov-05
Sep-06
Jul-07
May-08
Mar-09
Jan-10
Nov-10
Sep-11
Jul-12

Time Series Decomposition

- If you assume or estimate a deterministic time trend then time series decomposition of the original raw input (TS) is defined as:

$$TS = T \times S \times C \times I$$

- *T* is deterministic trend
- *S* is the seasonal component
- *C* is the cycle around the trend
- *I* is the irregular component

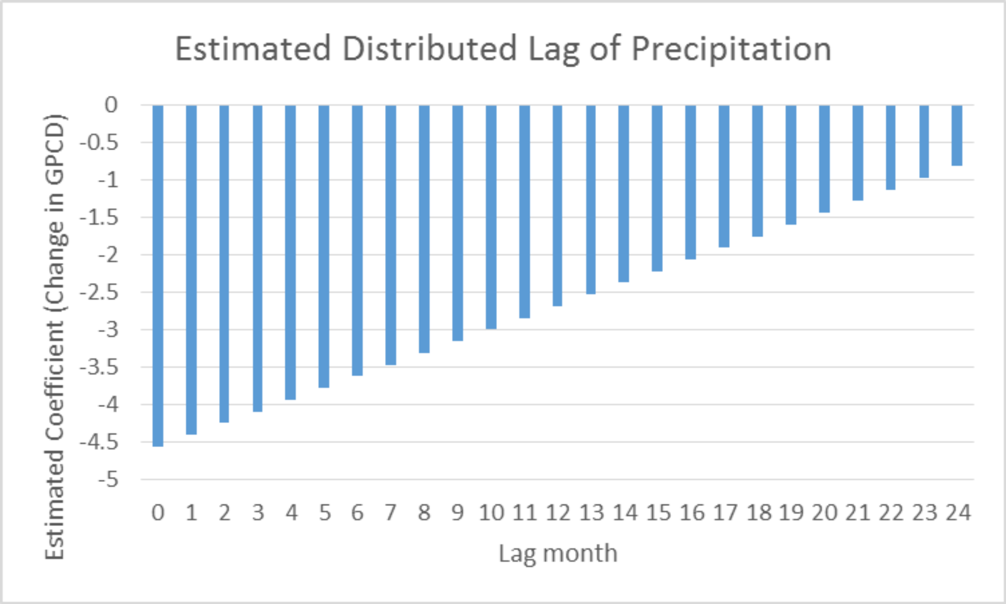

Deviations from Linear Per Capita Use Trend Cycle (C, Gallons per Day)
Recession Periods
Shortage Periods
Departure from Linear Trend
Mandatory Restriction Periods
150
100
50
0
-50
-100
Jan-75
Nov-75
Sep-76
Jul-77
May-78
Mar-79
Jan-80
Nov-80
Sep-81
Jul-82
May-83
Mar-84
Jan-85
Nov-85
Sep-86
Jul-87
May-88
Mar-89
Jan-90
Nov-90
Sep-91
Jul-92
May-93
Mar-94
Jan-95
Nov-95
Sep-96
Jul-97
May-98
Mar-99
Jan-00
Nov-00
Sep-01
Jul-02
May-03
Mar-04
Jan-05
Nov-05
Sep-06
Jul-07
May-08
Mar-09
Jan-10
Nov-10
Sep-11
Jul-12

Evaluation Approach 1

- Perform simple regression analysis of trend cycle in per capita on various variables:
  - Deterministic linear trend (time counter)
  - De-seasonalized weather
  - Dummy (0/1) variables for periods of mandatory watering restrictions
  - Dummy variables for recession periods
  - Regional wholesale water prices (treated water)

Selected Findings (preliminary)

- Relatively long memory with respect to de-seasonalized precipitation (up to 6 quarters!)
  - Weather variables are “regional”
  - Speculate this is capturing effects of dry spells or climate cycles
  - Trends in ambient soil moisture could create trends in per capita use



Selected Findings (preliminary)

- Estimated effect of mandatory restrictions on gpcd:
  - Early 1990s restrictions: ~ -19%
  - More recent (mid 2009-early 2011): ~ -17%

- Estimated effect of "official" recession periods on gpcd:
  - "Great Recession": ~ -11%
  - Average of others: ~ -7%

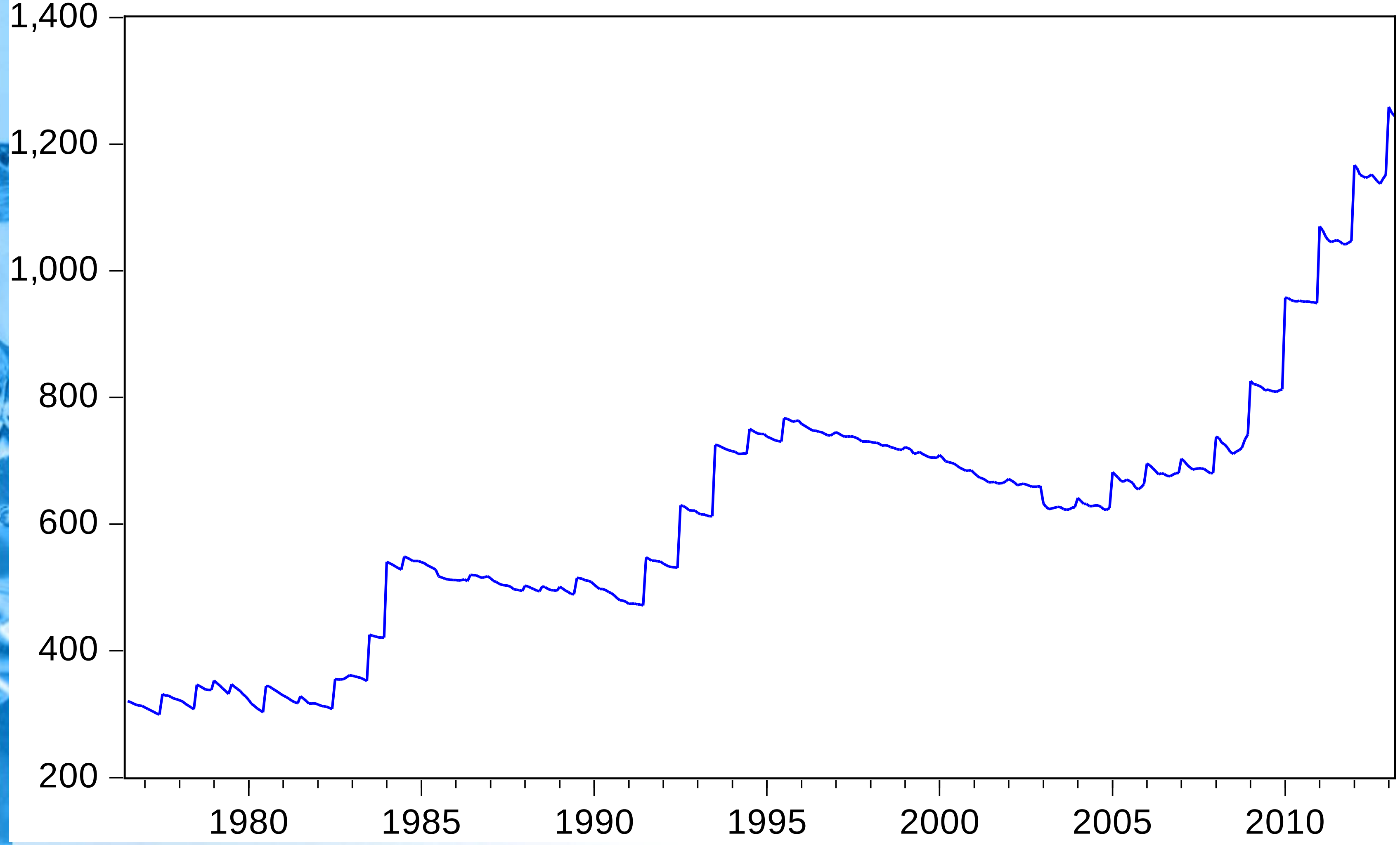
Selected Findings (preliminary)

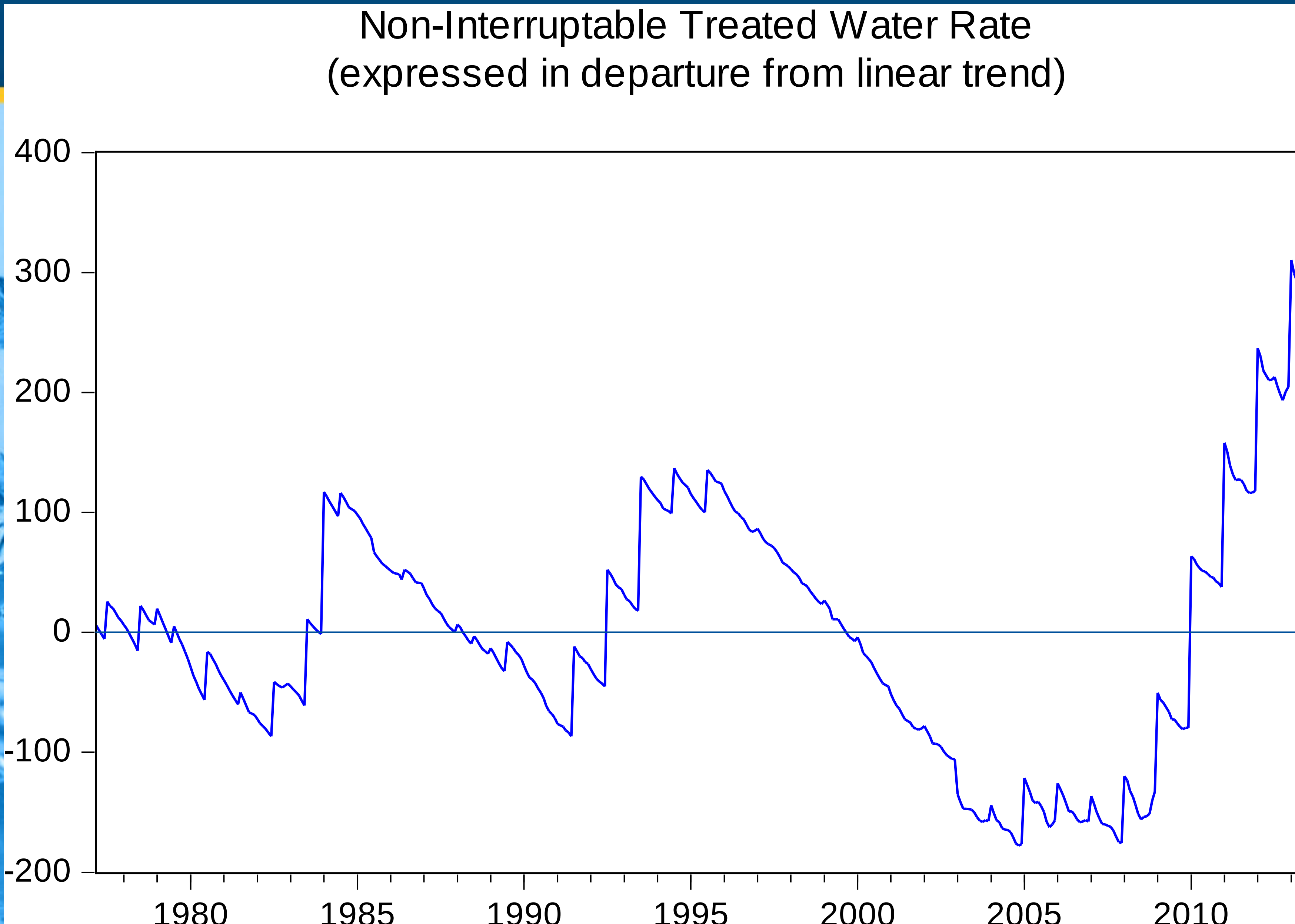
- Estimated price effects
  - Estimated price elasticity: -0.36
  - Consistent with other estimates of long-term price elasticity
  - 10% increase in treated water price per acre-foot yields about 3% decrease in per capita use
- Specification of price variable virtually eliminates significance of deterministic time trend
- High collinearity of price and trend variable—price has a strong increasing trend

Evaluation Approach 2

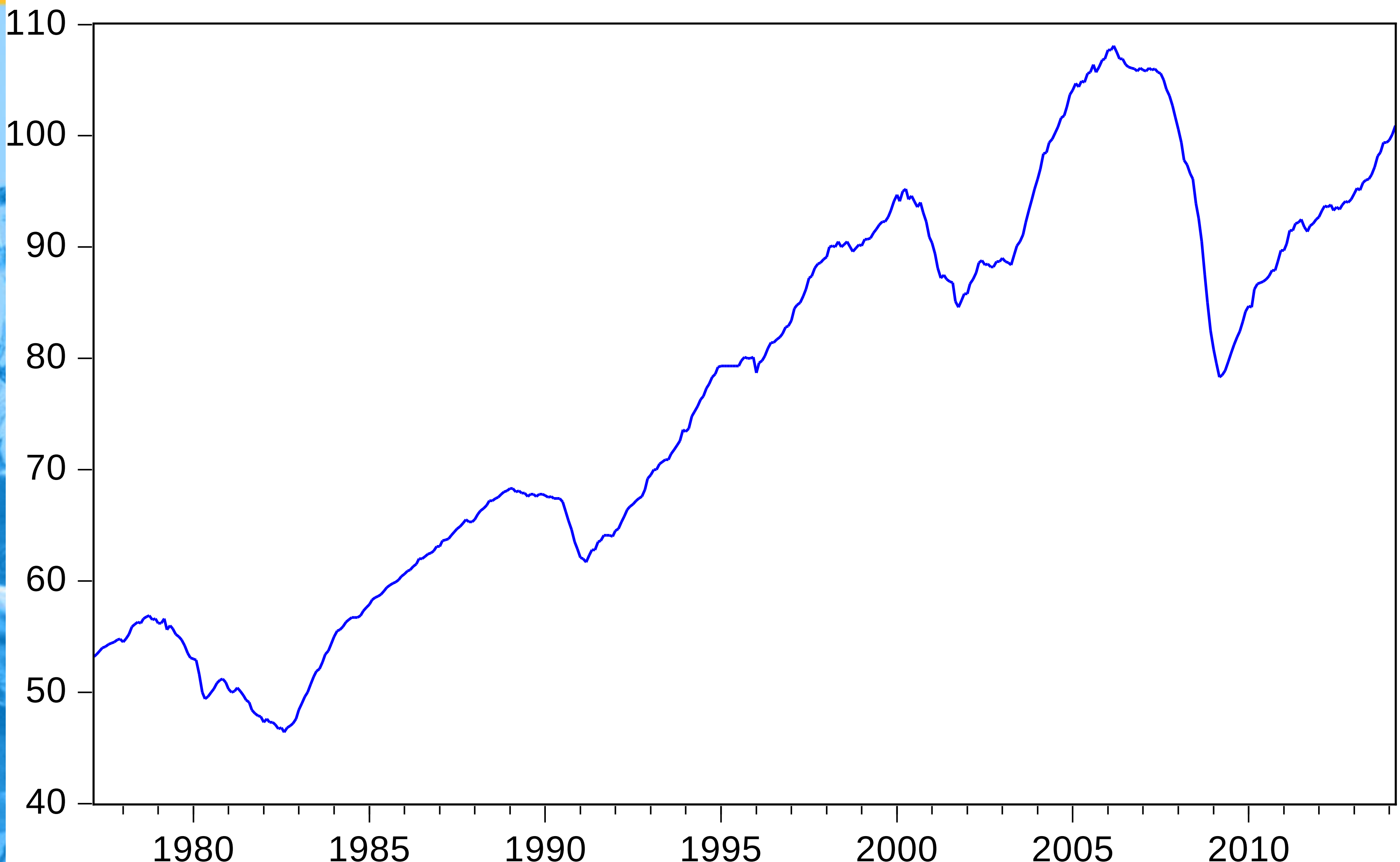
- Replace recession indicator (dummy) variables with economic metrics that describe the relative state of the economy
  - Limited availability of economic variables spanning back to 1975
  - The Conference Board economic indices available for entire series
- Make price and economic measures independent of linear trend effects
  - Dramatically reduce collinearity (“variance inflation”)
  - Evaluate long-term trend

Non-Interruptable Treated Water Rate
($/AF; Inflation-adjusted)

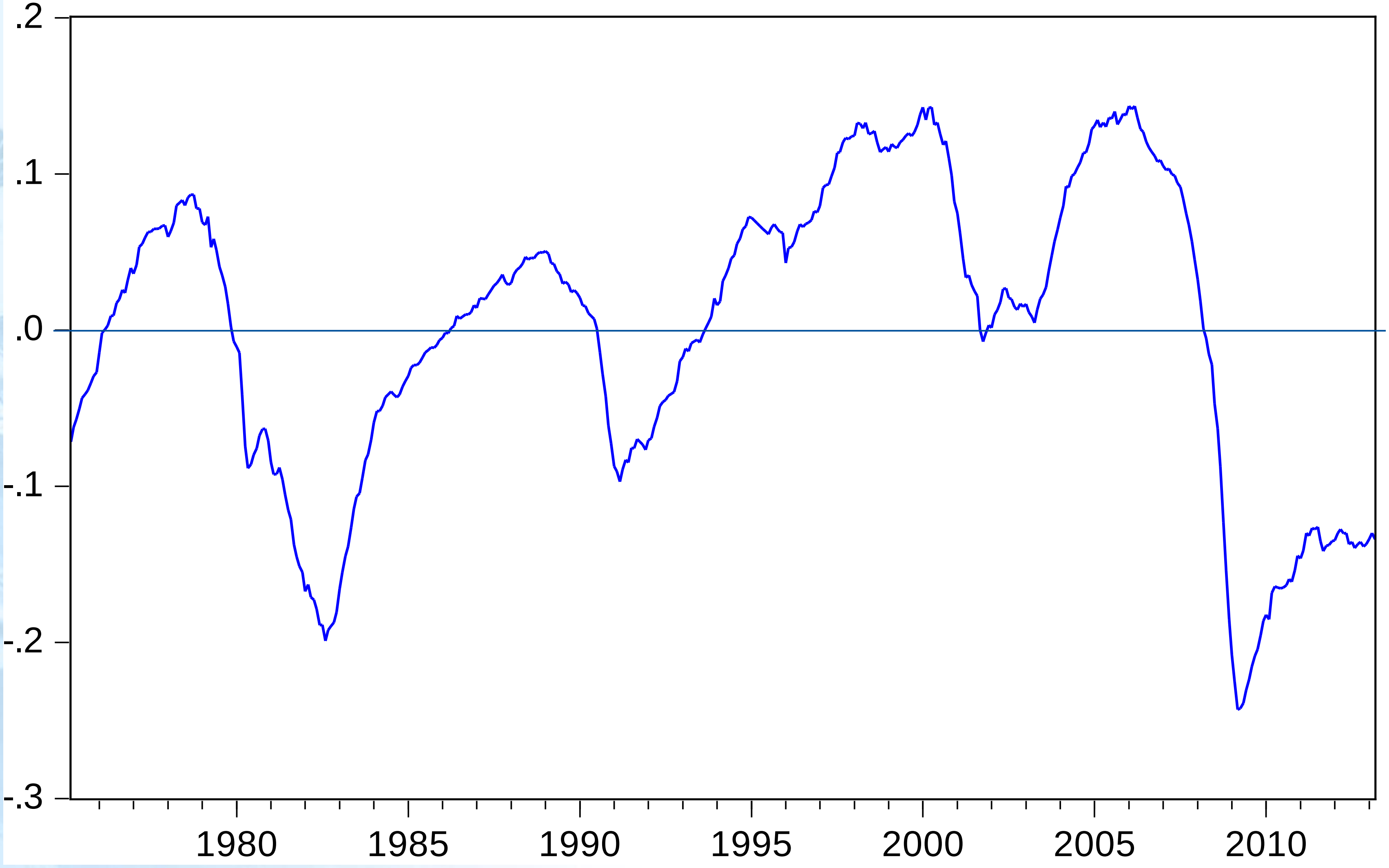



Non-Interruptable Treated Water Rate
(expressed in departure from linear trend)
400
300
200
100
0
-100
-200
1980
1985
1990
1995
2000
2005
2010

The Conference Board Index of Leading Economic Indicators



The Conference Board Leading Economic Indicator
(expressed in departure from linear trend)



Selected Findings (preliminary)

- Using The Conference Board Leading Index to measure "economy"
  - Estimate ~13% decrease in per capita trend cycle from peak to trough of "official" Great Recession period
  - Estimate ~5% decrease from peak to trough of early 1990s recession
  - Recent high index value of 107.7 in 2006M01; Recent low index value 78.3 in 2009M03
- Index still well below trend through end of estimation period
  - Lingering drag of recession
  - Lasting into 2009-2011 period of mandatory restrictions

Selected Findings (preliminary)

- More of the persistent downward deviations from per capita trend now attributed to economy
- Estimated reduction in use attributable to mandatory restrictions decline
  - Early 1990s: ~ -14%
  - More recent: ~ -4%
- Small relative reduction in estimated influence of price
  - Estimated price elasticity: -0.31 (instead of -0.36 before)
  - 10% increase in treated water price still generates about 3% decrease in gpcd

Selected Findings (preliminary)

- ▶ Independent estimate of linear time trend: ~1% decrease in gpcd per year
- ▶ From official start of Great Recession to last period of mandatory restrictions (Dec 2007 to Apr 2011) model suggests:
  - ~ 4% reduction associated with long-term trend (-6 gpcd)
  - ~ 6% reduction associated with "economy" (-10 gpcd)
  - ~13% reduction associated with increases in rates (-21 gpcd)

Evaluation Approach 3 (in progress)

- Utilize available quarterly economic data spanning from 1990 to present
  - Step 1: De-seasonalize water use (full record)
  - Step 2: Weather-normalize and make “brute force” adjustments for mandatory restriction periods
  - Step 3: Regress de-seasonalized, weather-normalized, per-capita use on alternative economic measures
- Make deliberate use of time series econometrics concept of co-integration to avoid spurious regressions

Selected findings (preliminary)

- Per capita use "co-integrated" with several economic variables
  - Real gross metro-area product (GMP) (+)
  - Real per capita disposable personal income (+)
  - Real retail sales (+)
  - Employment in NAICS Goods super-sector (+)
  - Unemployment rate (-)
  - Labor force participation rate (+)

- More to come on this in WaterRF project report…stay tuned

Summary and Conclusions

- Changes in efficiency should be separated from the effects of water shortage restrictions and the economy—especially if blamed for acute and unanticipated reductions in demand
- Attributing changes in water use to different factors requires a close look at water use and related data
- Several techniques that employ time-series decomposition and regression analysis are useful
- Care should be taken to deal with factors that are correlated in time and to avoid spurious regressions

Summary and Conclusions

- The economy can play a significant role in shaping trends in water use
- The effects of economic cycles should not be ignored
- Economic factors <u>and</u> how they are measured matter quite a bit
- Metrics other than binary indicators are preferable (unfortunately not much choice for specifying watering restrictions)

Summary and Conclusions

- ► In some places, the recent ("Great") recession was severe enough to force considerable short-term deviations from longer-term water use patterns

- ► Recessionary effects are among other effects associated with water efficiency, short-term conservation, and water pricing, all of which can and should be anticipated

Thank you!

Questions?

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