This presentation premiered at WaterSmart Innovations

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Water Demand and Weather

Implications of Climate Change and Water Efficiency

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HAZEN AND SAWYER
Environmental Engineers & Scientists

Overview

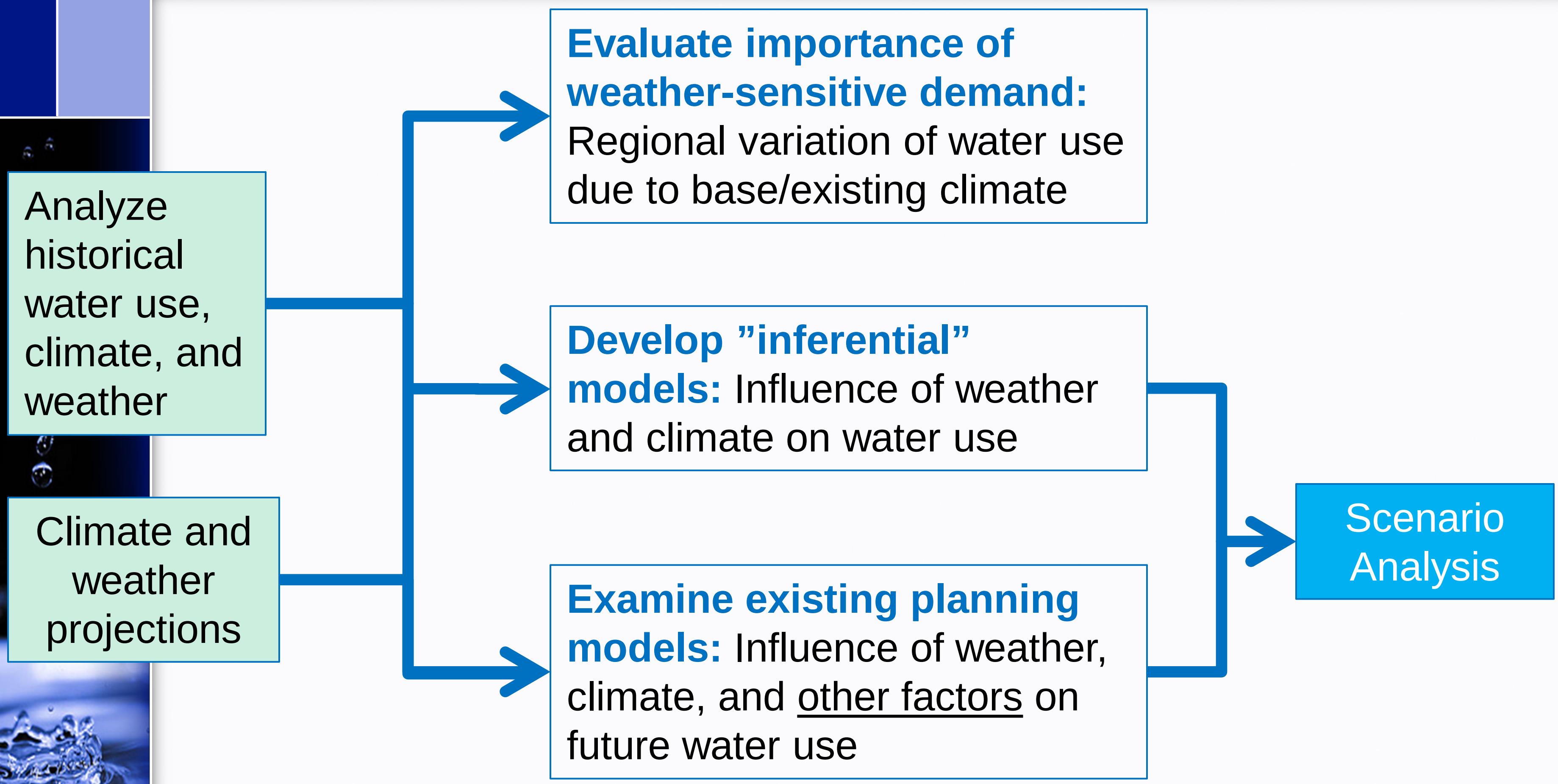
- Describe WaterRF Project 4263
- Compare and contrast regional water use patterns
- Provide example for evaluating weather and climate impacts on water use
- Provoke thoughts on alternative water futures
  - Climate change impacts
  - Water efficiency

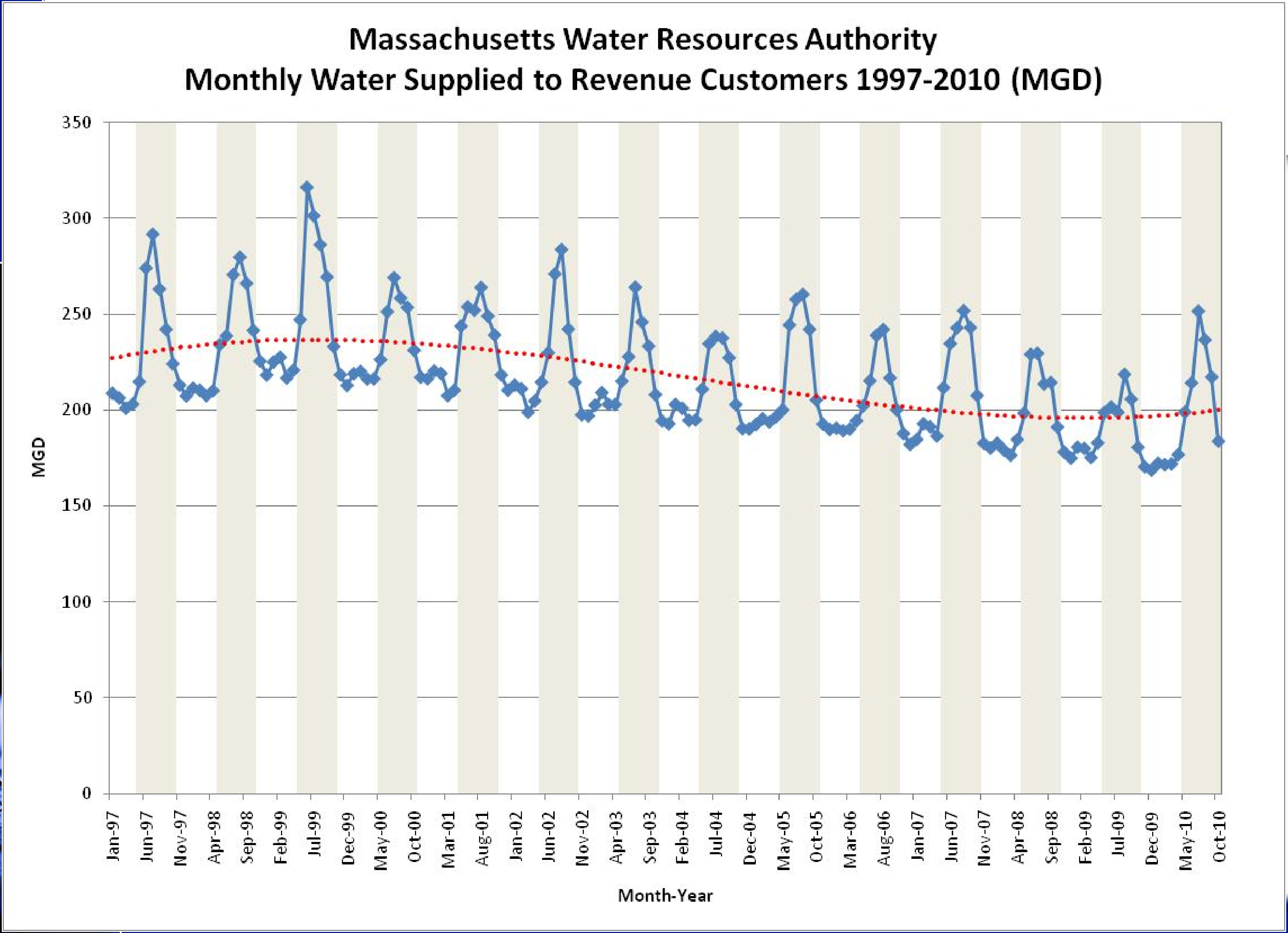
WaterRF Project 4263

- Analysis of Changes in Water Use Under Regional Climate Change Scenarios

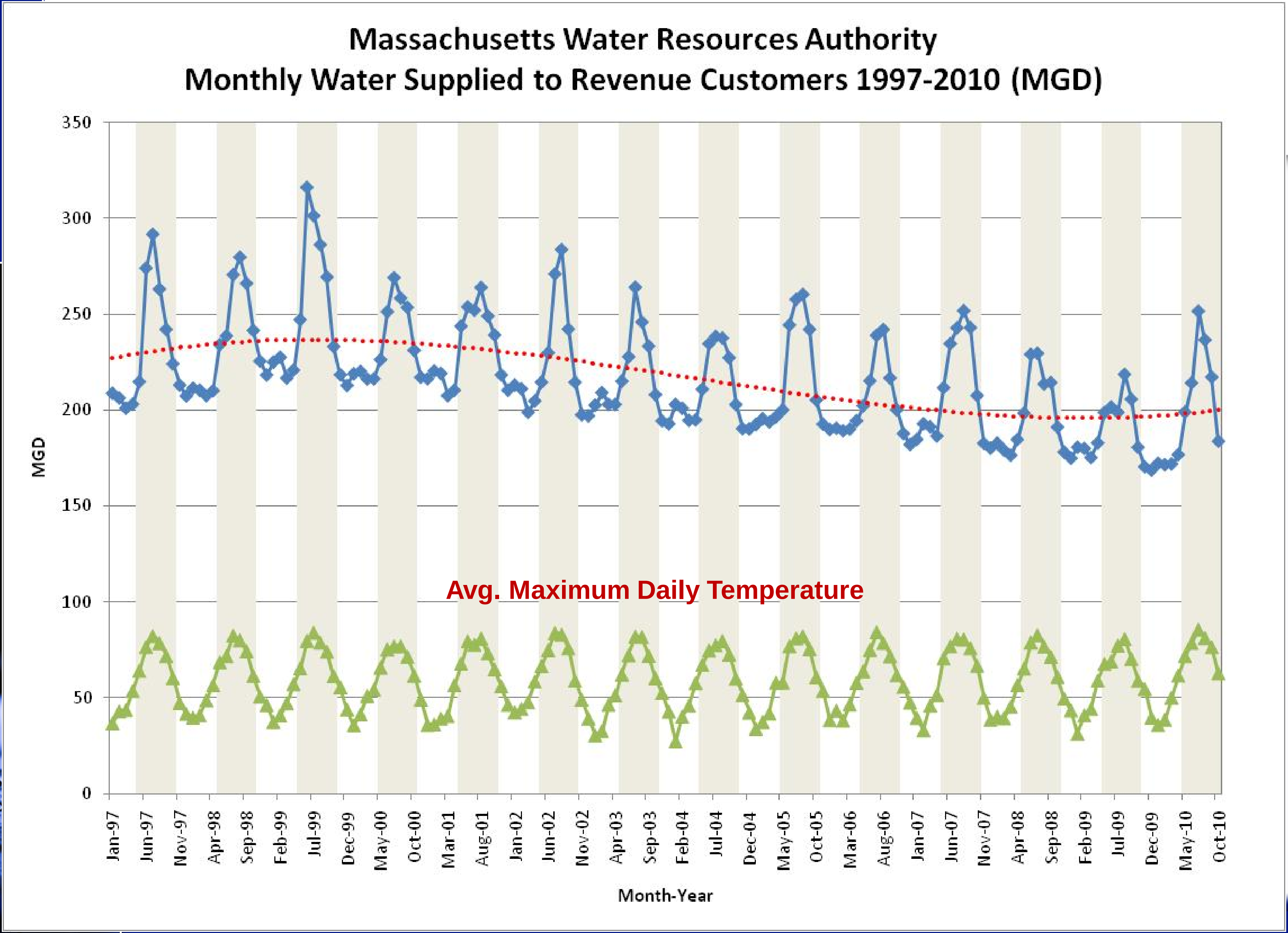
  1. Develop and demonstrate demand modeling/prediction methodologies
  2. Compile regionally downscaled climate projections
  3. Identify and quantify potential climate change impacts
  4. Evaluate demand-side planning and policy options

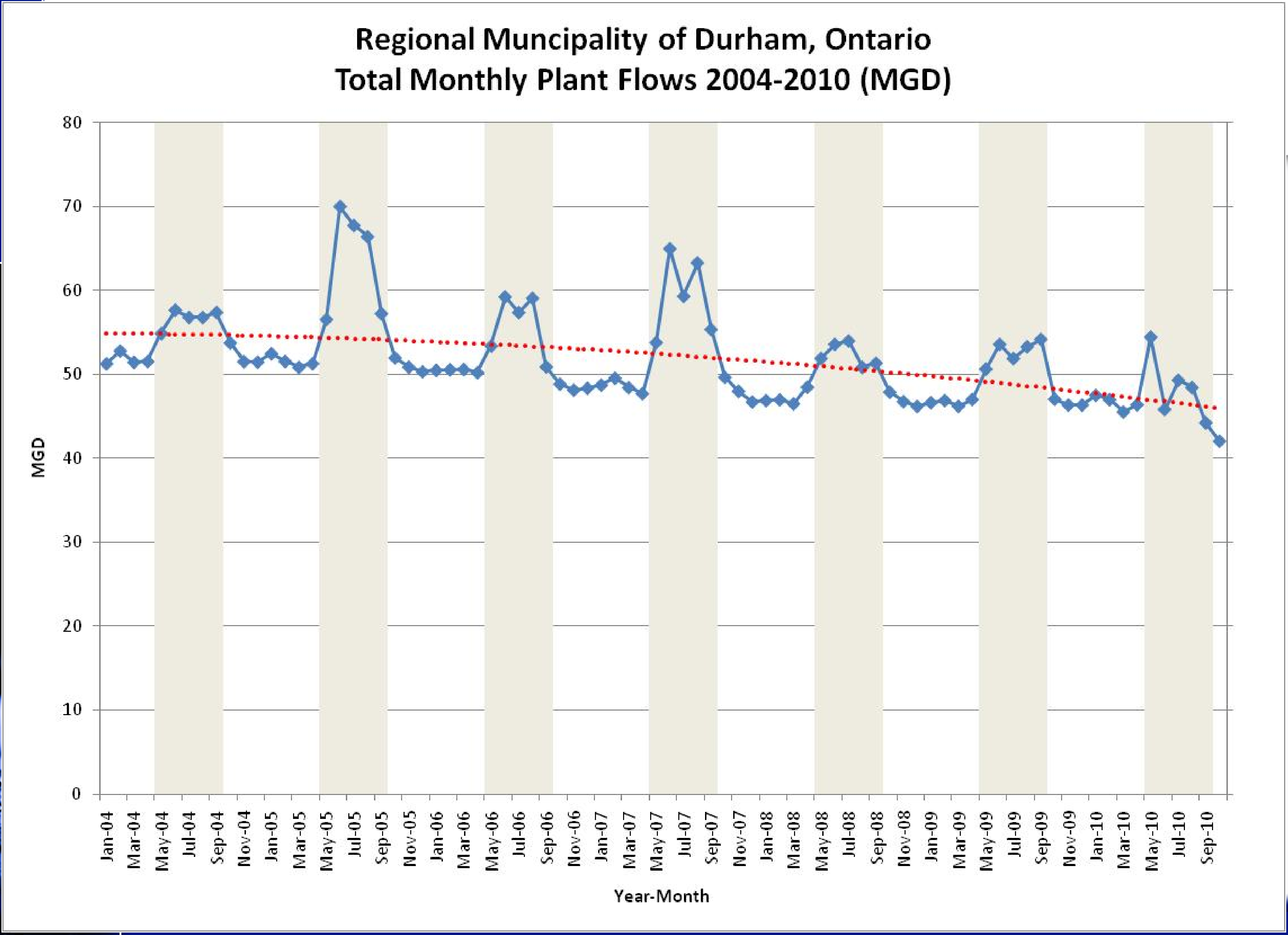
General Study Approach





Massachusetts Water Resources Authority
Monthly Water Supplied to Revenue Customers 1997-2010 (MGD)
MGD
Month-Year
350
300
250
200
150
100
50
0
Jan-97
Jun-97
Nov-97
Apr-98
Sep-98
Feb-99
Jul-99
Dec-99
May-00
Oct-00
Mar-01
Aug-01
Jan-02
Jun-02
Nov-02
Apr-03
Sep-03
Feb-04
Jul-04
Dec-04
May-05
Oct-05
Mar-06
Aug-06
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10


Massachusetts Water Resources Authority
Monthly Water Supplied to Revenue Customers 1997-2010 (MGD)
MGD
350
300
250
200
150
100
50
0
Avg. Maximum Daily Temperature
Jan-97
Jun-97
Nov-97
Apr-98
Sep-98
Feb-99
Jul-99
Dec-99
May-00
Oct-00
Mar-01
Aug-01
Jan-02
Jun-02
Nov-02
Apr-03
Sep-03
Feb-04
Jul-04
Dec-04
May-05
Oct-05
Mar-06
Aug-06
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Oct-10
Month-Year



Regional Muncipality of Durham, Ontario
Total Monthly Plant Flows 2004-2010 (MGD)
MGD
80
70
60
50
40
30
20
10
0
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
May-06
Jul-06
Sep-06
Nov-06
Jan-07
Mar-07
May-07
Jul-07
Sep-07
Nov-07
Jan-08
Mar-08
May-08
Jul-08
Sep-08
Nov-08
Jan-09
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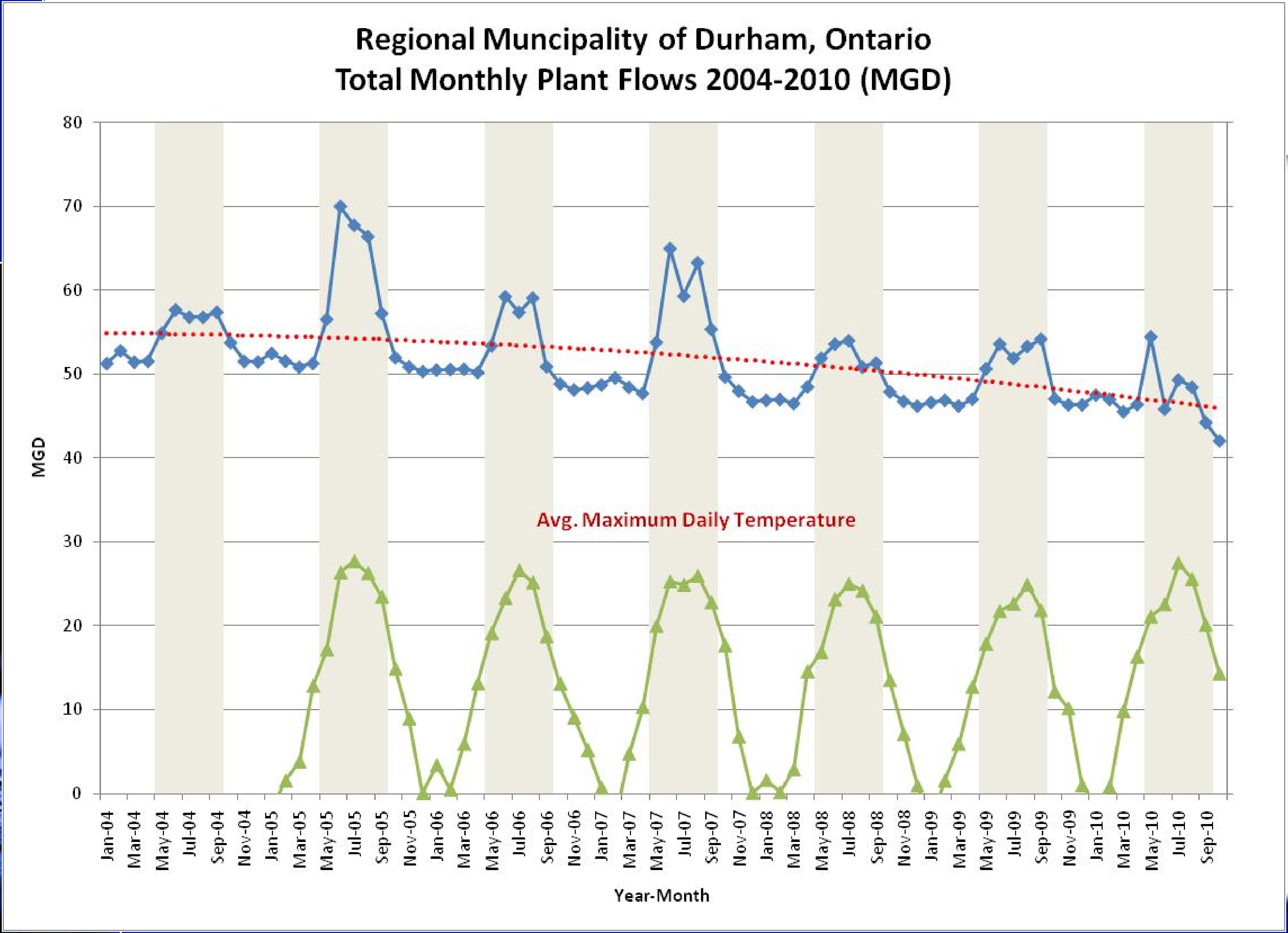
Jul-09
Sep-09
Nov-09
Jan-10
Mar-10
May-10
Jul-10
Sep-10
Year-Month



Regional Muncipality of Durham, Ontario
Total Monthly Plant Flows 2004-2010 (MGD)
MGD
80
70
60
50
40
30
20
10
0
Avg. Maximum Daily Temperature
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
May-06
Jul-06
Sep-06
Nov-06
Jan-07
Mar-07
May-07
Jul-07
Sep-07
Nov-07
Jan-08
Mar-08
May-08
Jul-08
Sep-08
Nov-08
Jan-09
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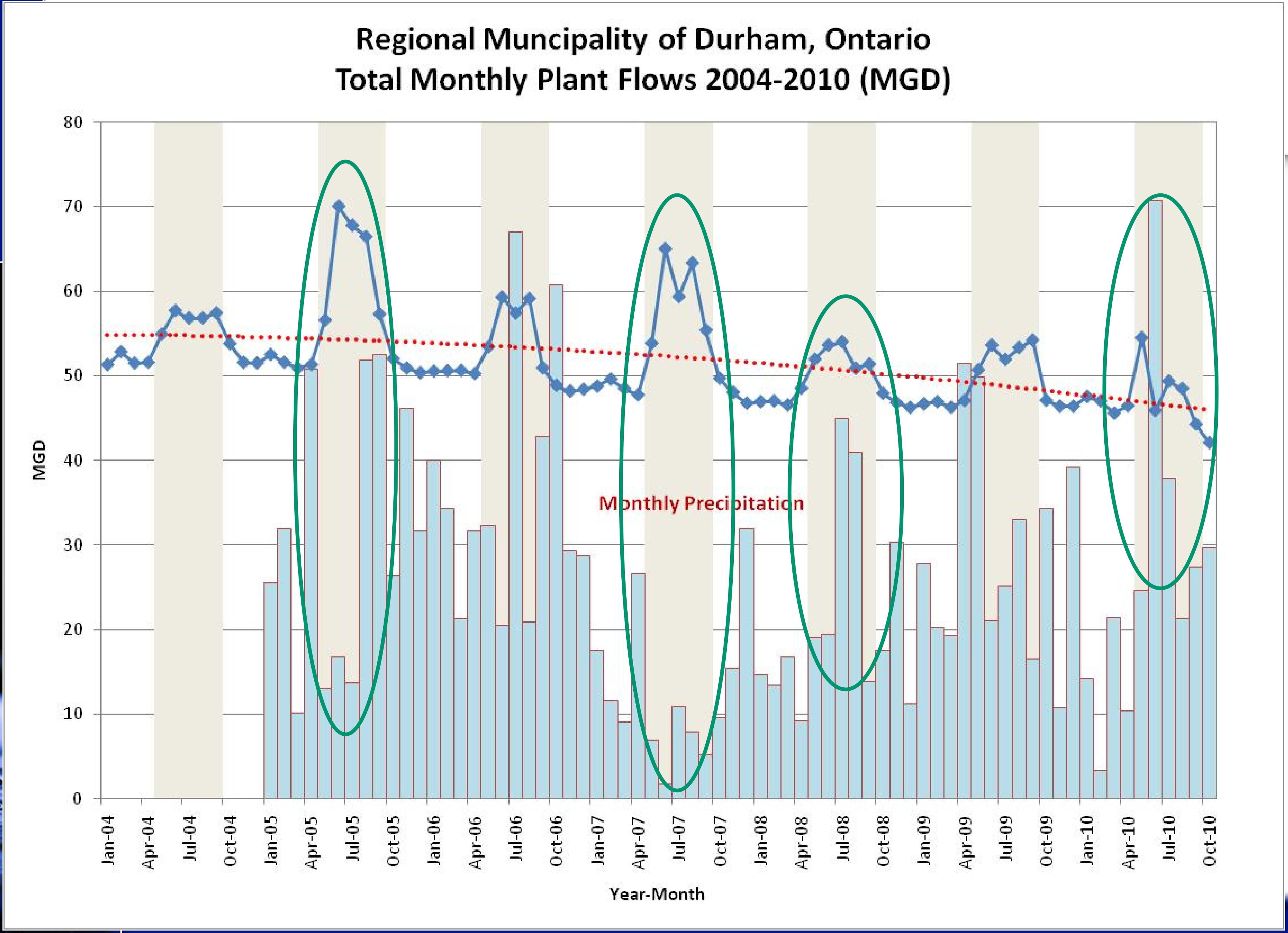
Nov-09
Jan-10
Mar-10
May-10
Jul-10
Sep-10
Year-Month


Regional Muncipality of Durham, Ontario
Total Monthly Plant Flows 2004-2010 (MGD)
MGD
Year-Month
Monthly Precipitation
80
70
60
50
40
30
20
10
0
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
Jul-06
Oct-06
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
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Apr-09
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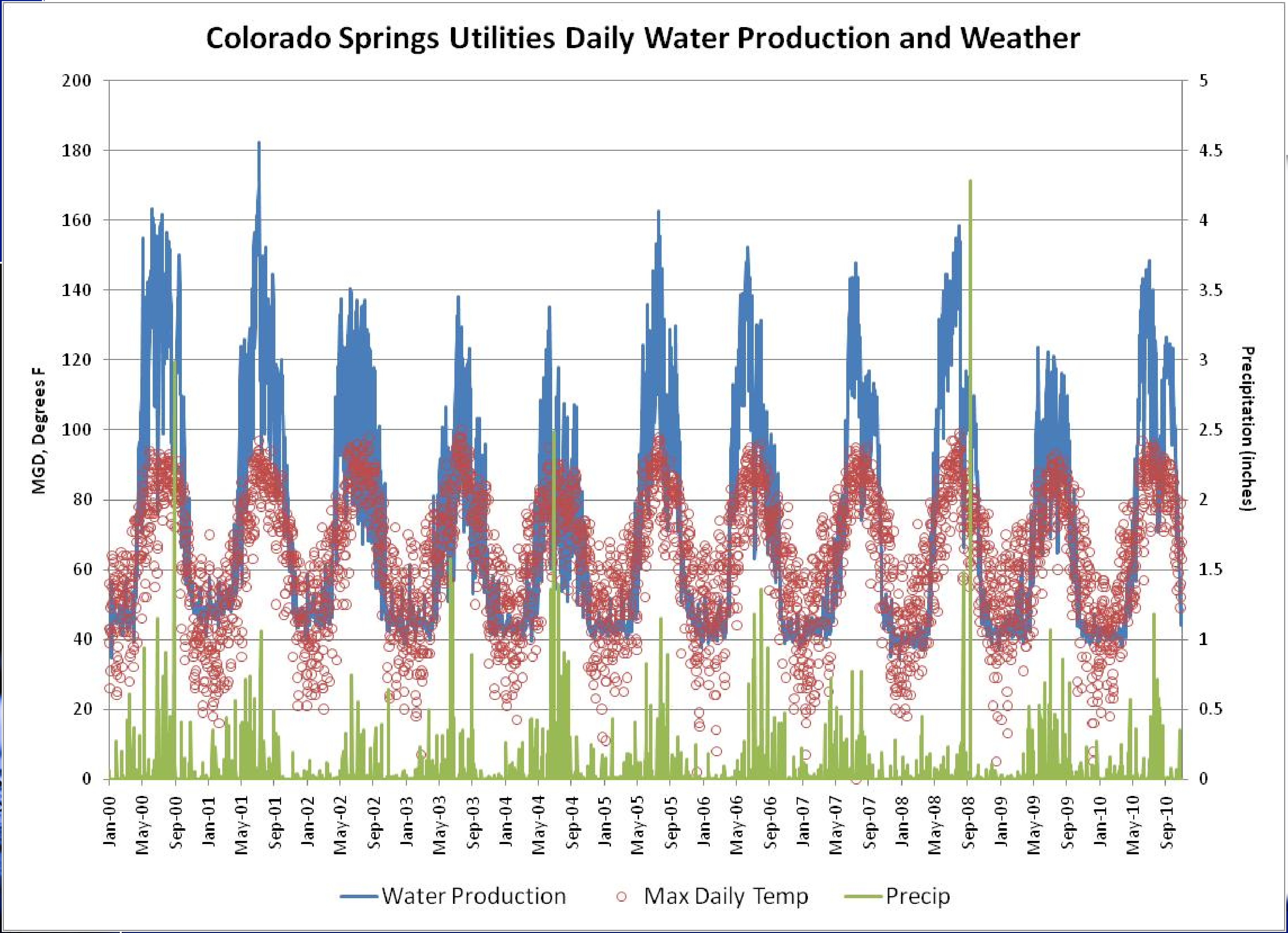
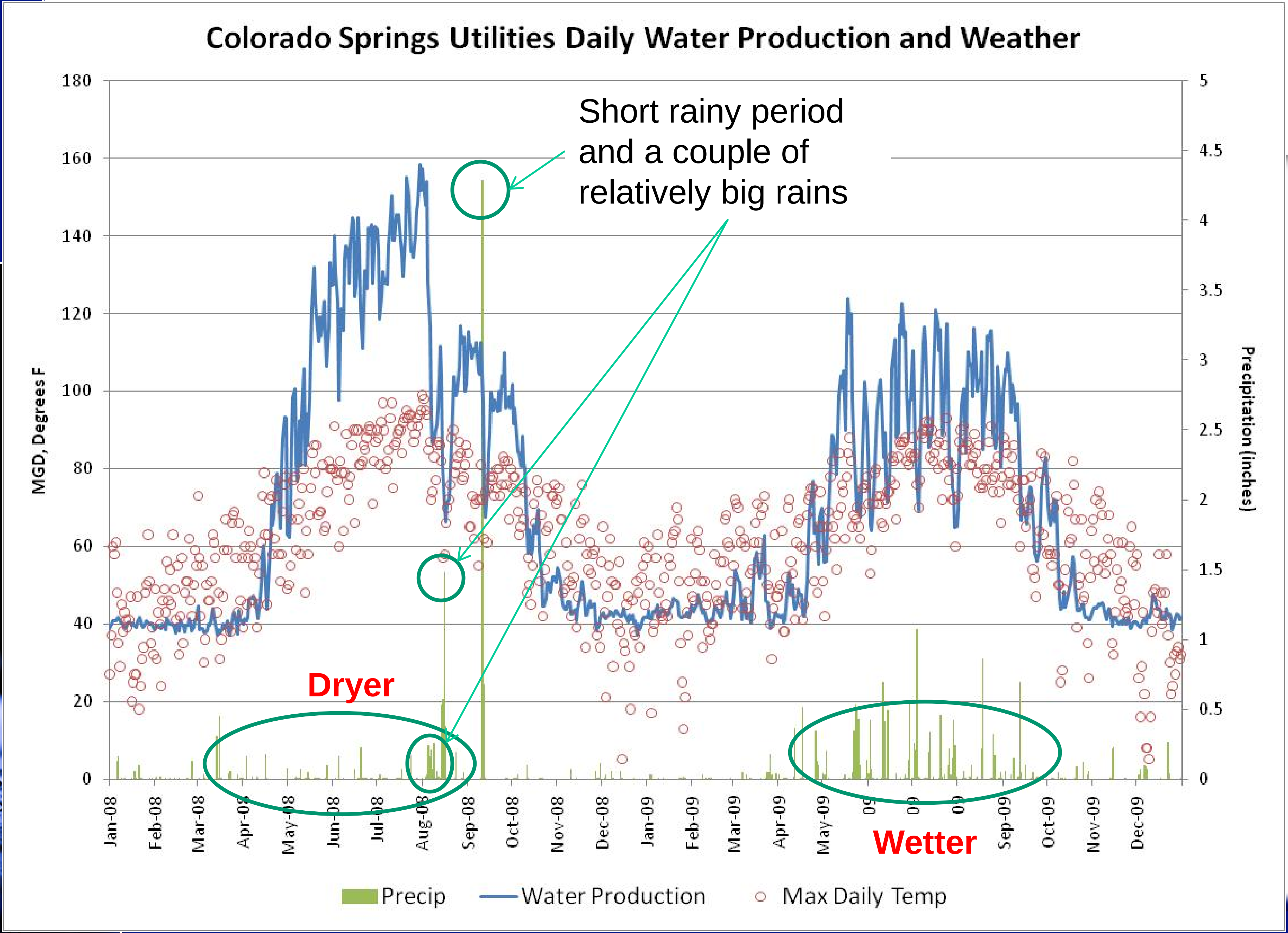
Jan-10
Apr-10
Jul-10
Oct-10



Colorado Springs Utilities Daily Water Production and Weather
MGD, Degrees F
Precipitation (inches)
0
20
40
60
80
100
120
140
160
180
200
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Jan-00
May-00
Sep-00
Jan-01
May-01
Sep-01
Jan-02
May-02
Sep-02
Jan-03
May-03
Sep-03
Jan-04
May-04
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Sep-06
Jan-07
May-07
Sep-07
Jan-08
May-08
Sep-08
Jan-09
May-09
Sep-09
Jan-10
May-10
Sep-10
Water Production
Max Daily Temp
Precip



Colorado Springs Utilities Daily Water Production and Weather
MGD, Degrees F
Precipitation (inches)
Short rainy period and a couple of relatively big rains
Dryer
Wetter
Jan-08
Feb-08
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08
Oct-08
Nov-08
Dec-08
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Sep-09
Oct-09
Nov-09
Dec-09
Precip
Water Production
Max Daily Temp

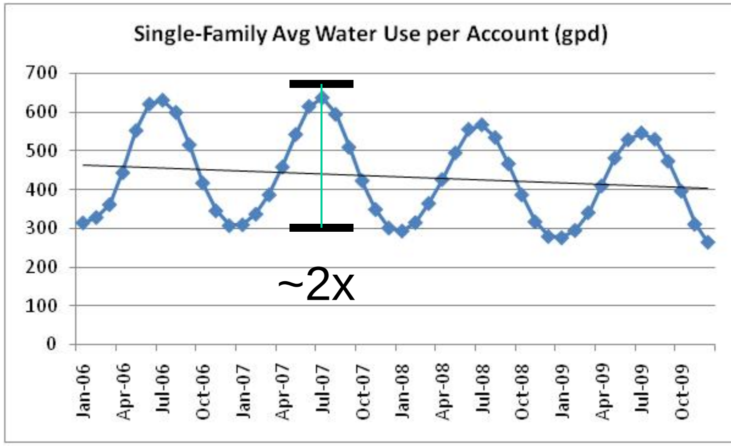
Seasonality in Different Water Use Sectors (Southern Nevada)

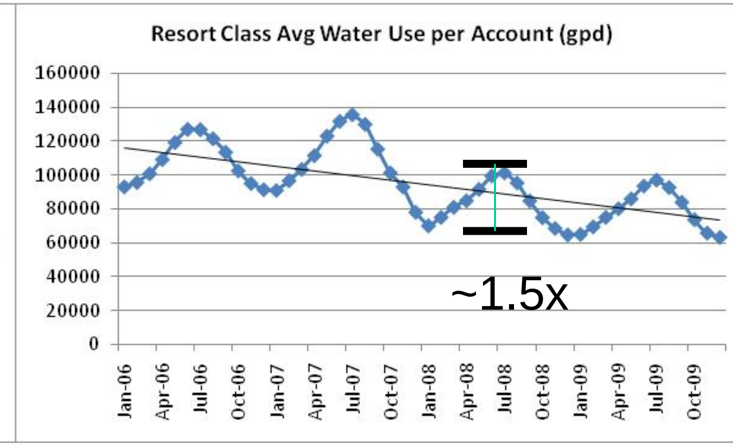
Lawn Irrigation

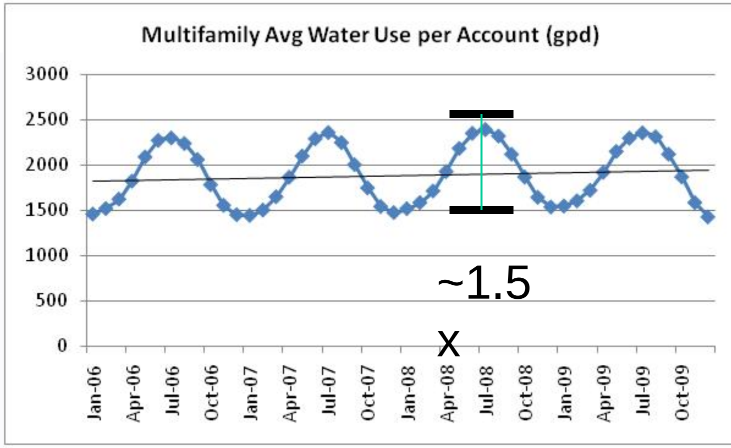
Swimming Pools

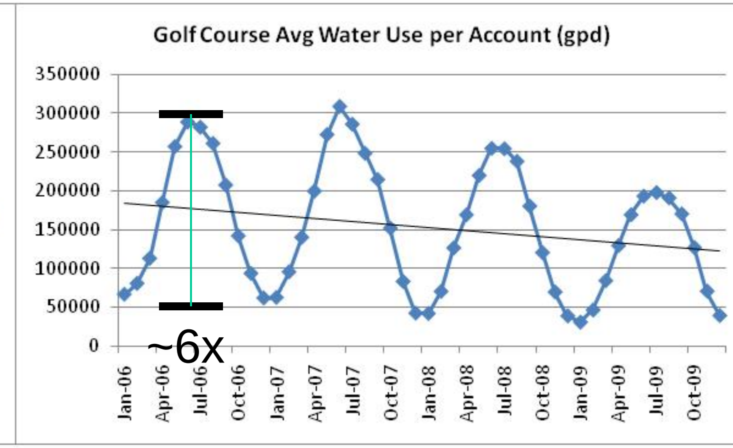
Cooling

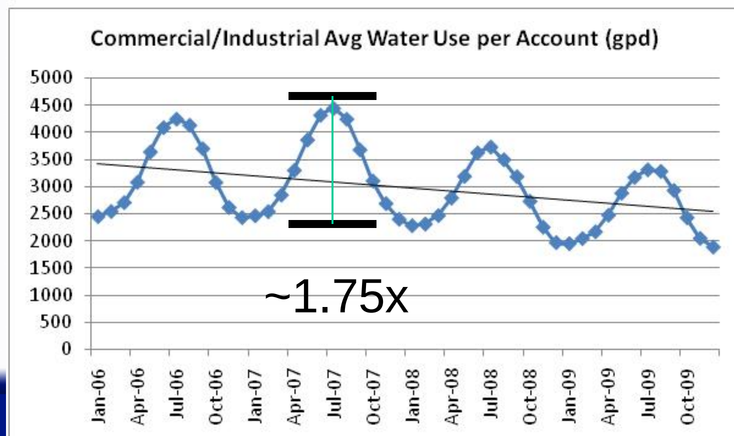
Other

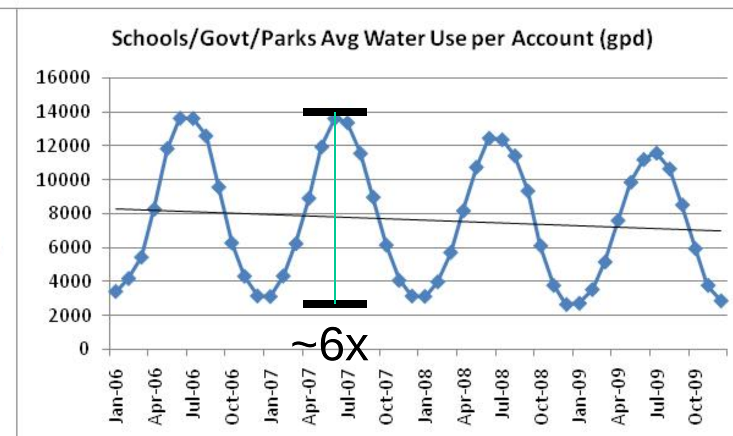


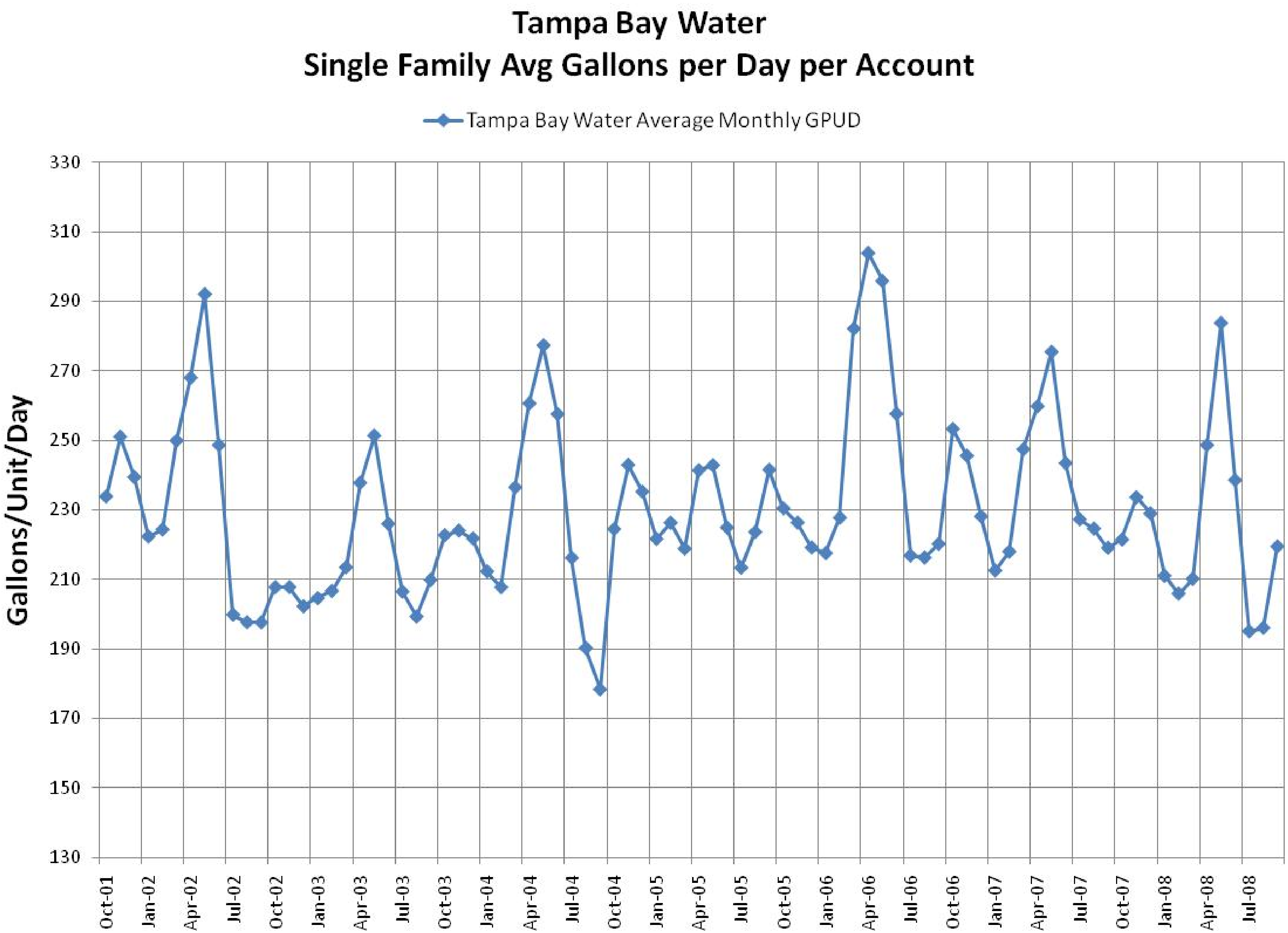











Tampa Bay Water
Single Family Avg Gallons per Day per Account
Tampa Bay Water Average Monthly GPUD
Gallons/Unit/Day
330
310
290
270
250
230
210
190
170
150
130
Oct-01
Jan-02
Apr-02
Jul-02
Oct-02
Jan-03
Apr-03
Jul-03
Oct-03
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
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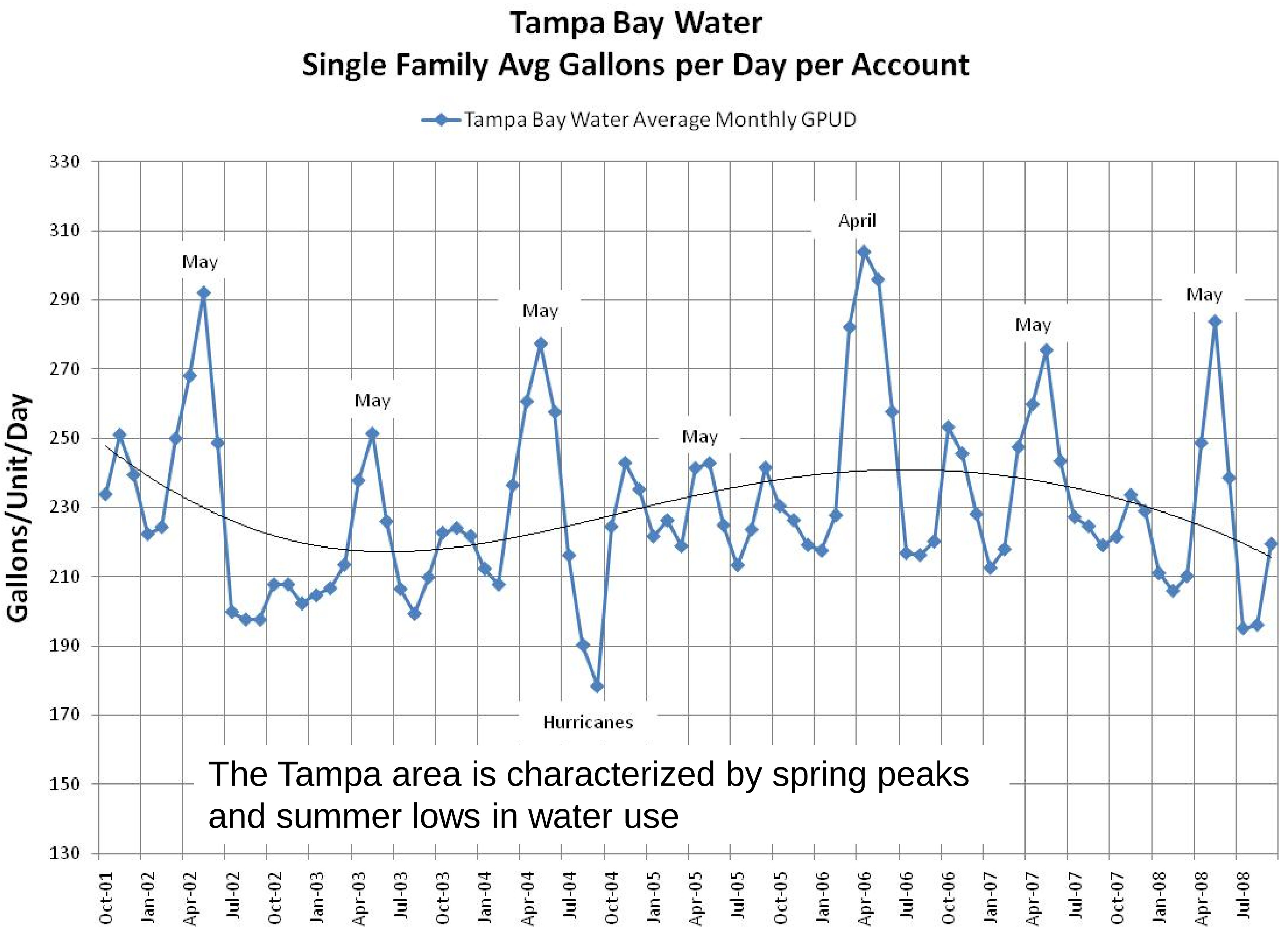
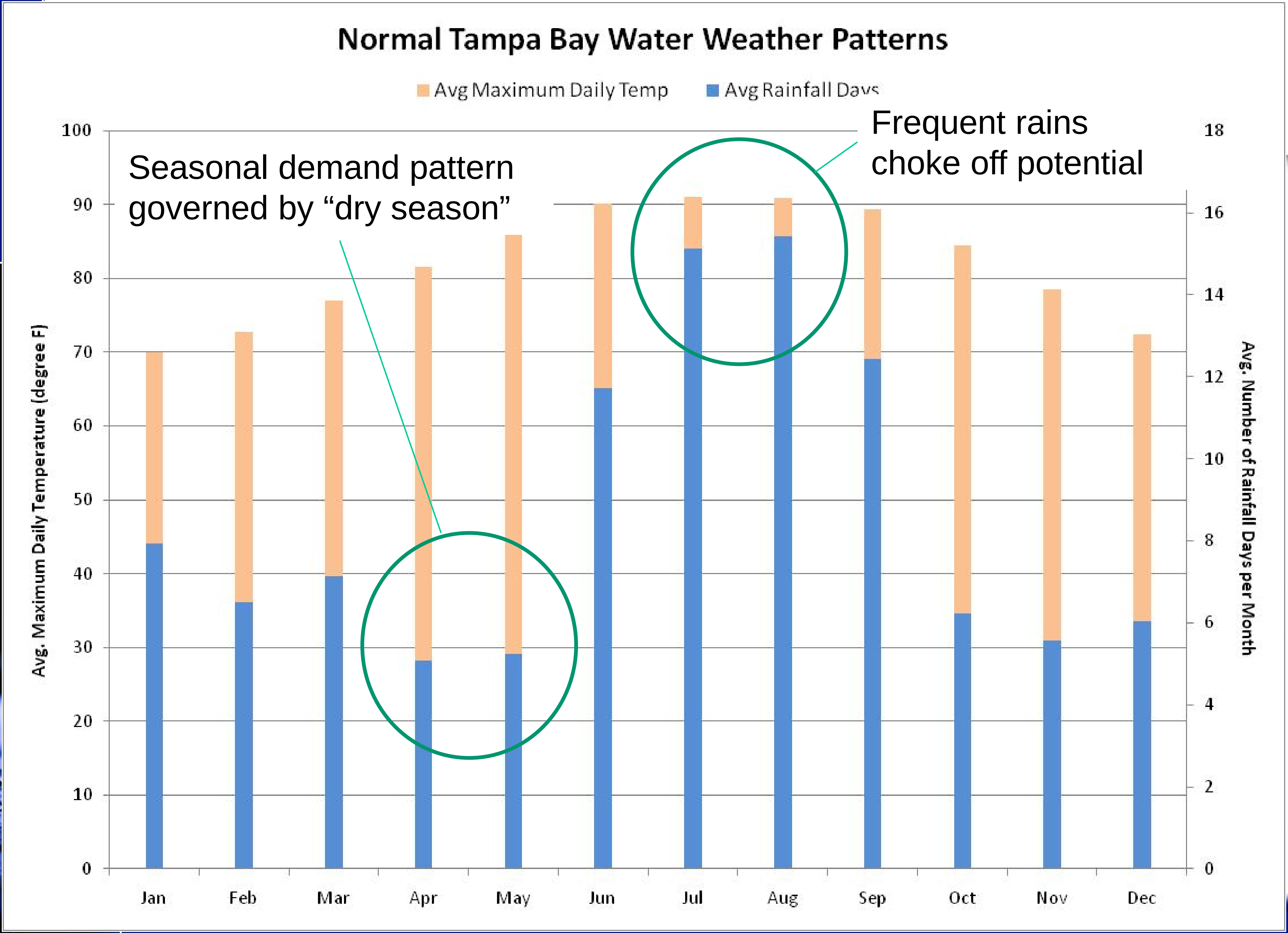
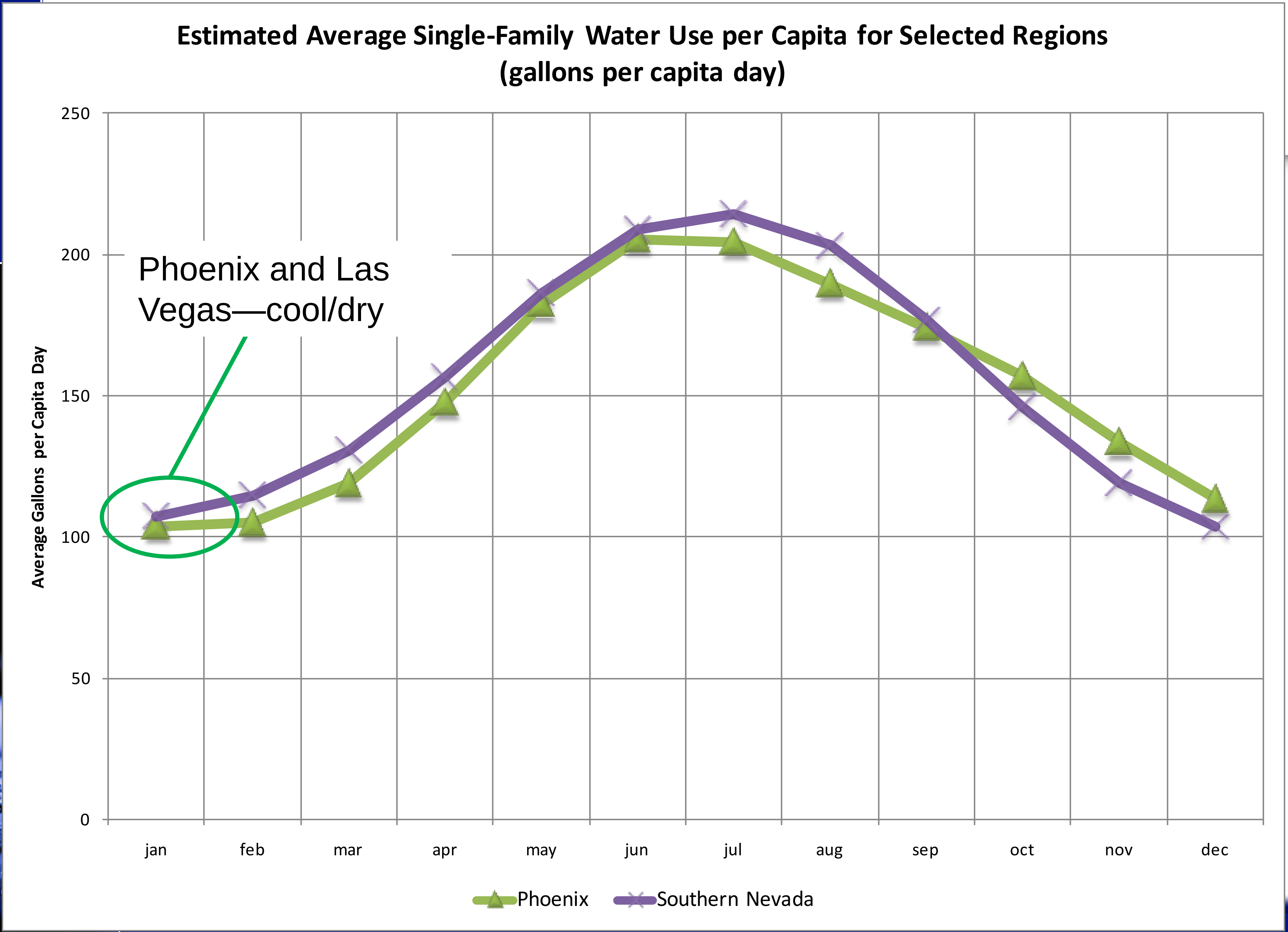
Jul-06
Oct-06
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08

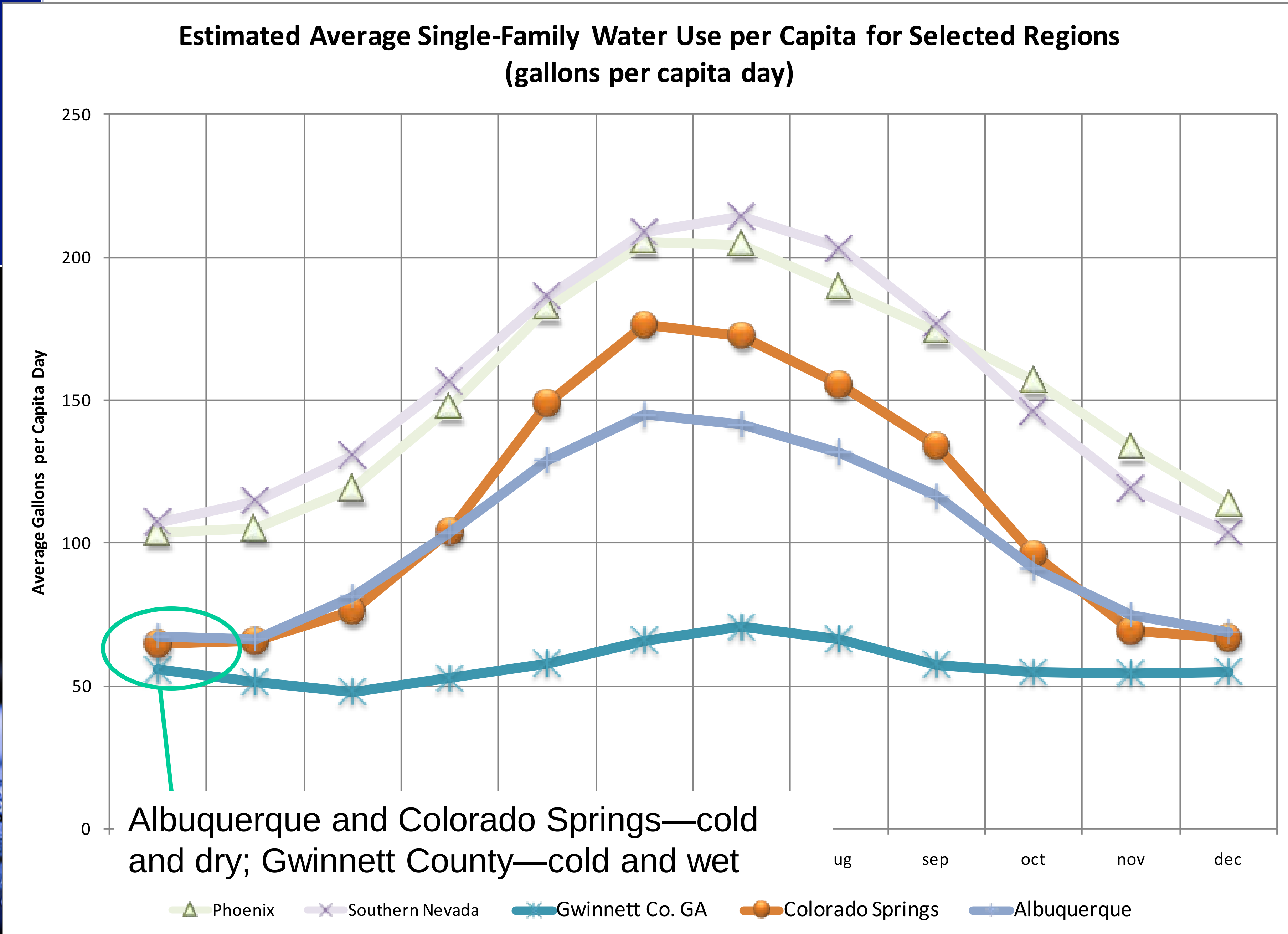


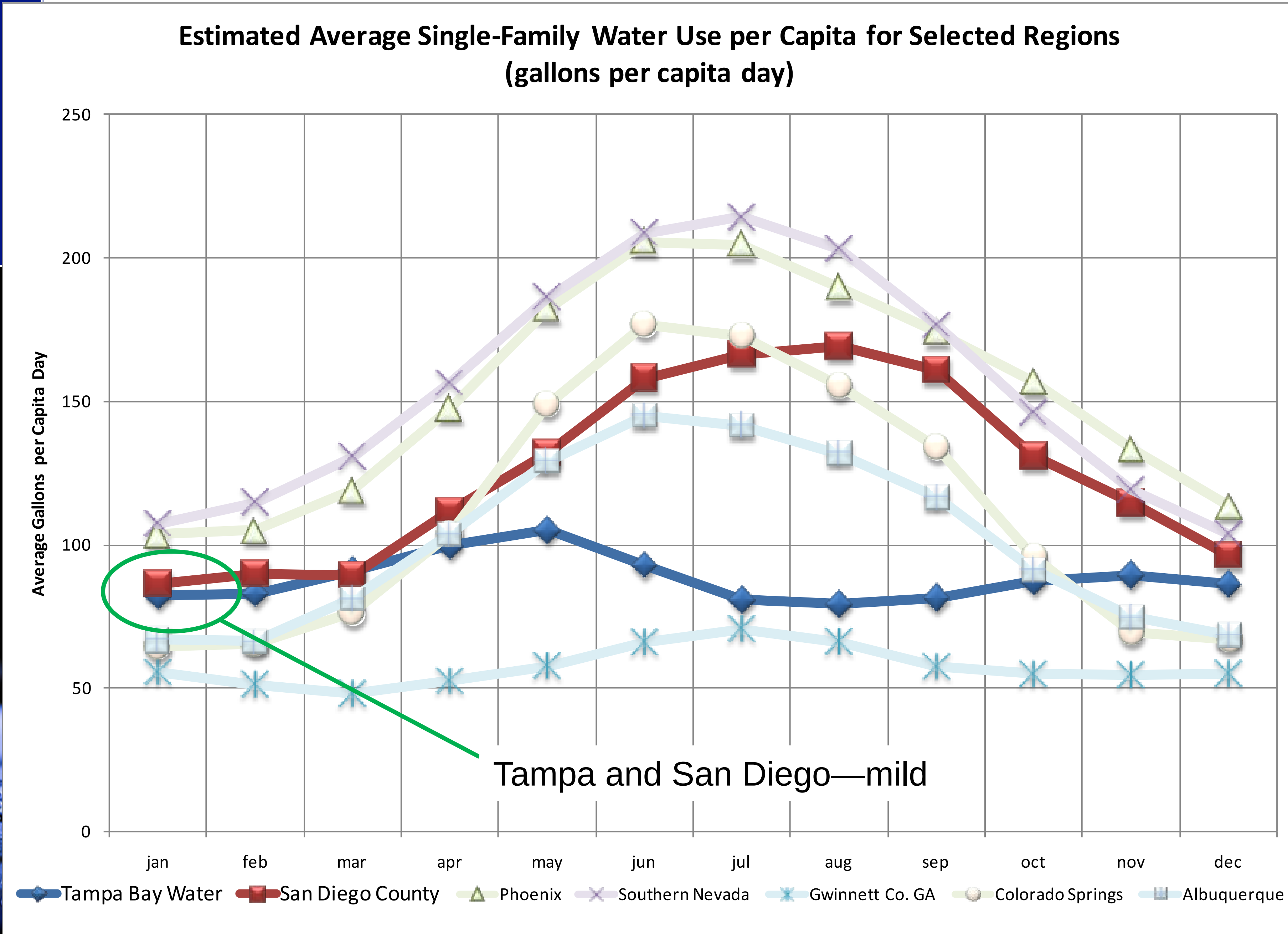
The Tampa area is characterized by spring peaks and summer lows in water use



Normal Tampa Bay Water Weather Patterns
Avg Maximum Daily Temp
Avg Rainfall Days
Seasonal demand pattern governed by "dry season"
Frequent rains choke off potential
Avg. Maximum Daily Temperature (degree F)
Avg. Number of Rainfall Days per Month
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Estimated Average Single-Family Water Use per Capita for Selected Regions
(gallons per capita day)
250
200
150
100
50
0
Average Gallons per Capita Day
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Phoenix and Las Vegas—cool/dry
Phoenix
Southern Nevada


Estimated Average Single-Family Water Use per Capita for Selected Regions
(gallons per capita day)
Average Gallons per Capita Day
250
200
150
100
50
0
ug
sep
oct
nov
dec
Phoenix
Southern Nevada
Gwinnett Co. GA
Colorado Springs
Albuquerque
Albuquerque and Colorado Springs—cold and dry; Gwinnett County—cold and wet


Estimated Average Single-Family Water Use per Capita for Selected Regions
(gallons per capita day)
Average Gallons per Capita Day
250
200
150
100
50
0
jan
feb
mar
apr
may
jun
jul
aug
sep
oct
nov
dec
Tampa and San Diego—mild
Tampa Bay Water
San Diego County
Phoenix
Southern Nevada
Gwinnett Co. GA
Colorado Springs
Albuquerque

Measuring Response to Weather

- Several different measures/specifications of weather and climate
  - Temperature
  - Precipitation
  - ET_0
  - Precipitation event thresholds
  - Spells
    - Dry/wet
    - Hot/cool
  - Treatment of systematic seasonal effects
  - Departures from “normal”

Measuring Response to Weather

- Several statistical estimation methods
  - Generally involves regression analysis
  - Choice of technique depends on both technical and practical factors
    - Amount of available data
    - Dimensions of available data (e.g., time-series, spatial, cross-sectional)
    - Amount of time to invest in complexities of statistical inference and forecasting

Example Sector Long-Term Planning Model

Parameter Estimates

Variable	Estimate	Standard Error	t Value	Pr > |t|
Intercept	-7.60602	0.6297	-12.08	<.0001
ln (normal avg. daily maximum temperature)	1.87741	0.1067	17.59	<.0001
ln (avg. maximum daily temperature) - ln (normal avg. daily maximum temperature)	0.87102	0.1252	6.96	<.0001
1-month lag of {ln (avg. maximum daily temperature) - ln (normal avg. daily maximum temperature)}	0.63362	0.1272	4.98	<.0001
ln (normal total precipitation + 1)	-0.28773	0.0226	-12.71	<.0001
ln (total precipitation + 1) - ln (normal total precipitation + 1)	-0.06350	0.0076	-8.4	<.0001
1-month lag of {ln (total precipitation + 1) - ln (normal total precipitation + 1)}	-0.05023	0.0074	-6.82	<.0001
2-month lag of {ln (total precipitation + 1) - ln (normal total precipitation + 1)}	-0.02011	0.0069	-2.93	0.0035
ln (average household income)	0.55467	0.0253	21.88	<.0001
ln (number of single-family units per developed single-family acre)	-0.33820	[illegible]	[illegible]	[illegible]
ln (inflation adjusted marginal price of water)	-0.39627	0.053	-7.48	<.0001
ln (average persons per household)	0.30809	0.1034	2.98	0.003
ln (number of occupied single-family units per single-family account)	0.13775	0.0487	2.83	0.0048

Weather Component

Socioeconomic Component

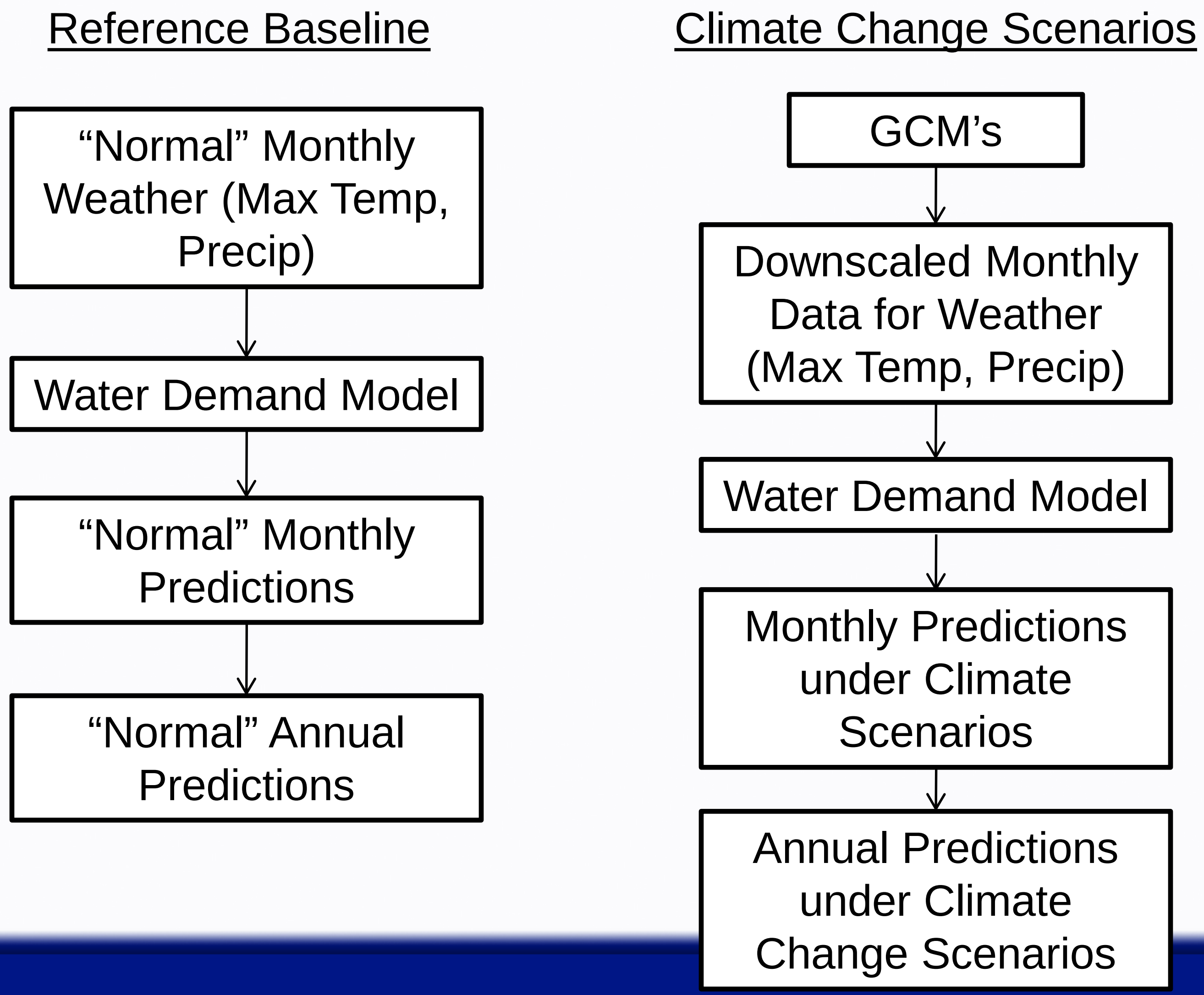
Example of Estimating Climate Change Impact on Demand

- Use weather component of model
- Downscale climate projections
- Substitute new climate/weather into model
- Compare with “baseline”
  - Relative to historical normal climate
  - Relative to “without climate change” socioeconomic futures
- Evaluate change in predicted water use

Notes on Example

- Single sector (SF)
- Illustrative purposes only
  - Based on actual predictive demand model and projections of future climate
  - Limited number of GCM’s used
  - Liberal use of climate projection traces out to 2099
- More work to be done
  - Conceptual framework
  - Demand modeling approaches
  - Process for interpreting and screening downscaled data

Process


Reference Baseline
“Normal” Monthly Weather (Max Temp, Precip)
Water Demand Model
“Normal” Monthly Predictions
“Normal” Annual Predictions
Climate Change Scenarios
GCM’s
Downscaled Monthly Data for Weather (Max Temp, Precip)
Water Demand Model
Monthly Predictions under Climate Scenarios
Annual Predictions under Climate Change Scenarios

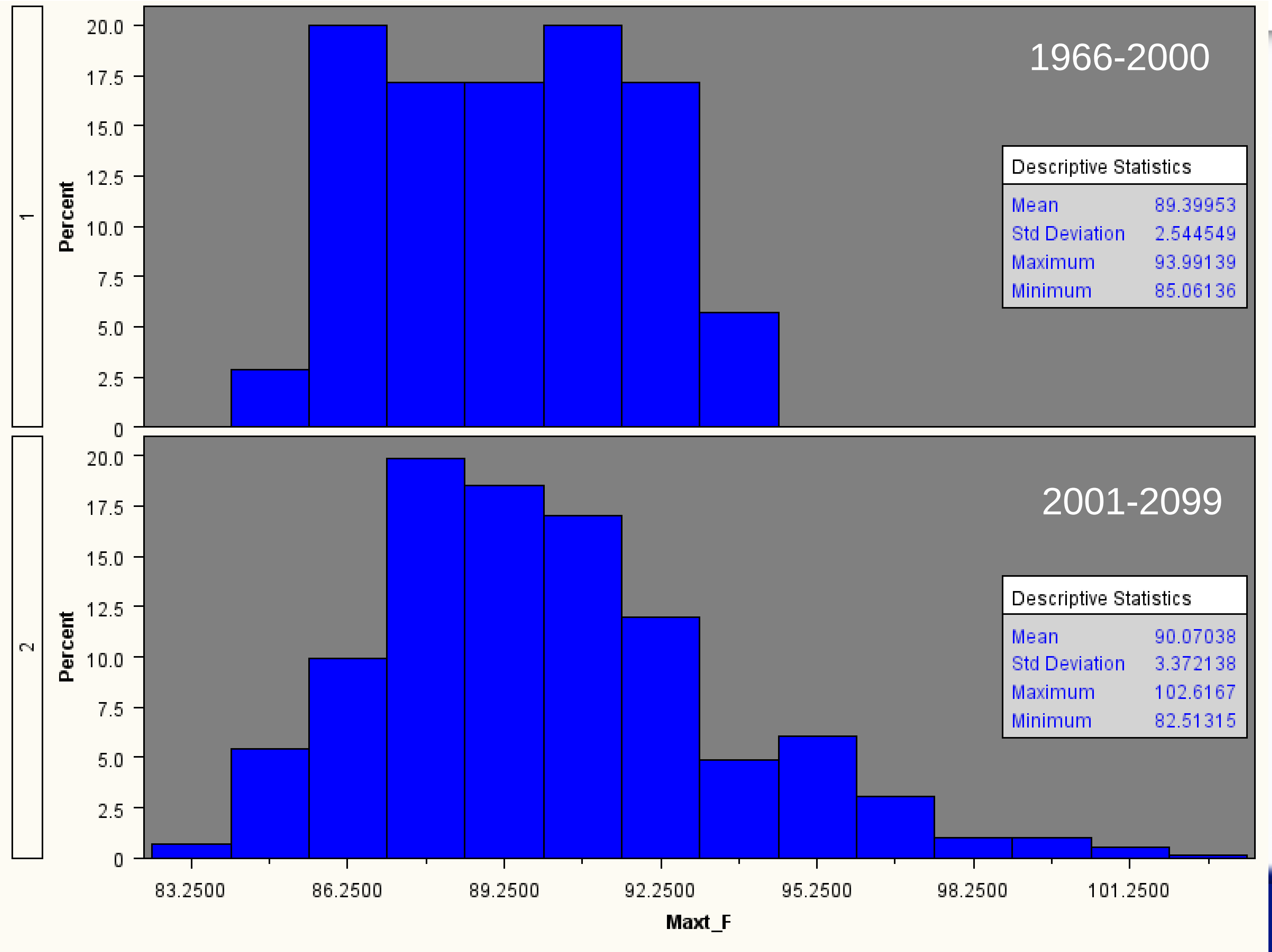
Example of Estimating Climate Change Impact on Demand

- Change in projected 2035 annual water use given
  - 2035 projection of weather/climate
  - 2050 projection of weather/climate
  - 2099 projection of weather/climate

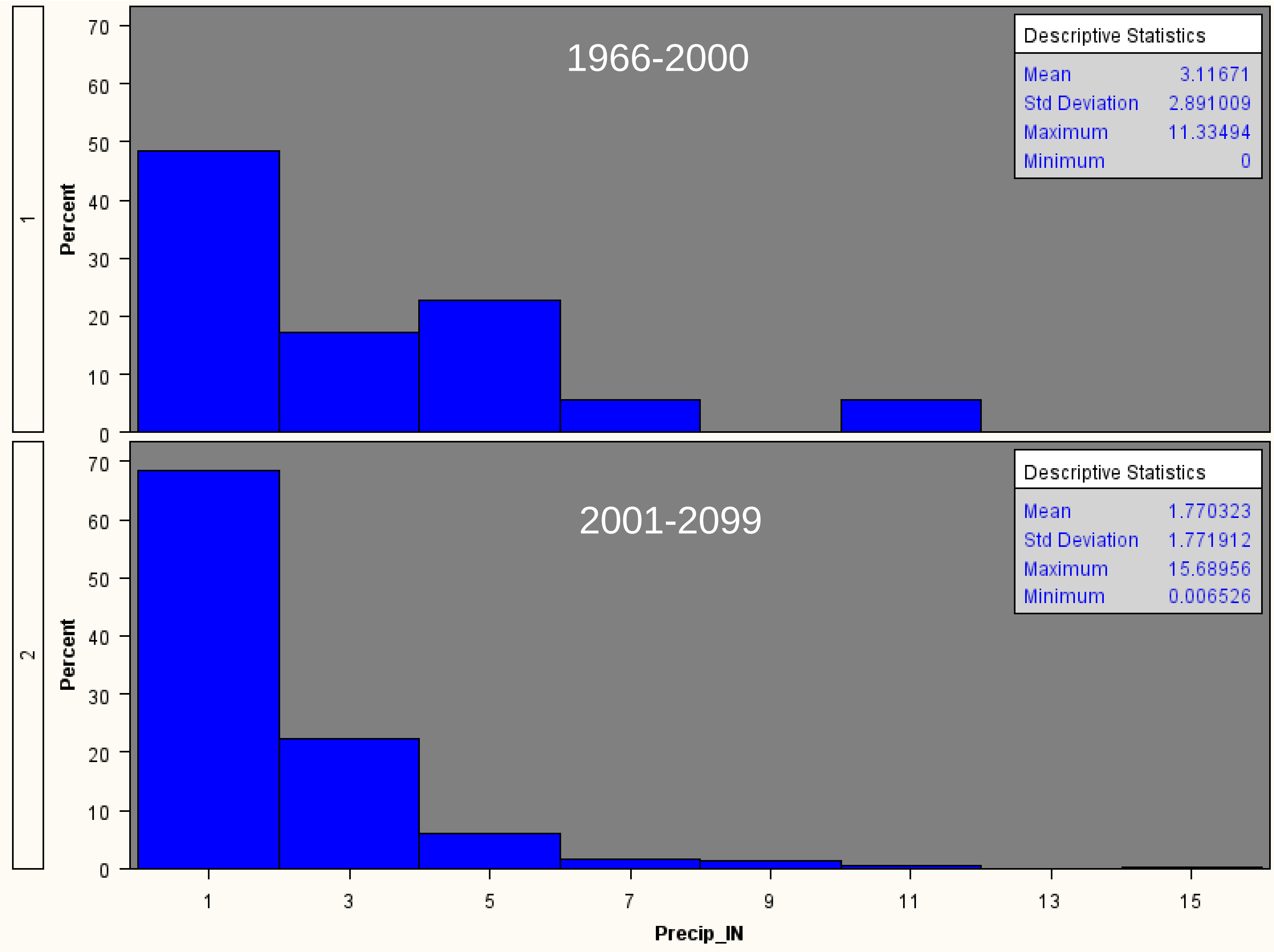
	Single Family Percent Difference from Baseline							
	Emissions Scenario 1			Emissions Scenario 2				
Reference Year	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3	Mean	Median
2035 Weather	1.7%	0.5%	1.8%	-1.1%	6.1%	2.4%	1.9%	1.8%
2050 Weather	3.0%	6.5%	6.3%	4.4%	9.9%	0.9%	5.2%	5.4%
2099 Weather	-0.8%	4.3%	6.9%	4.3%	14.2%	13.5%	7.1%	5.6%

- Hides monthly trends
- Does not incorporate variability over climate traces

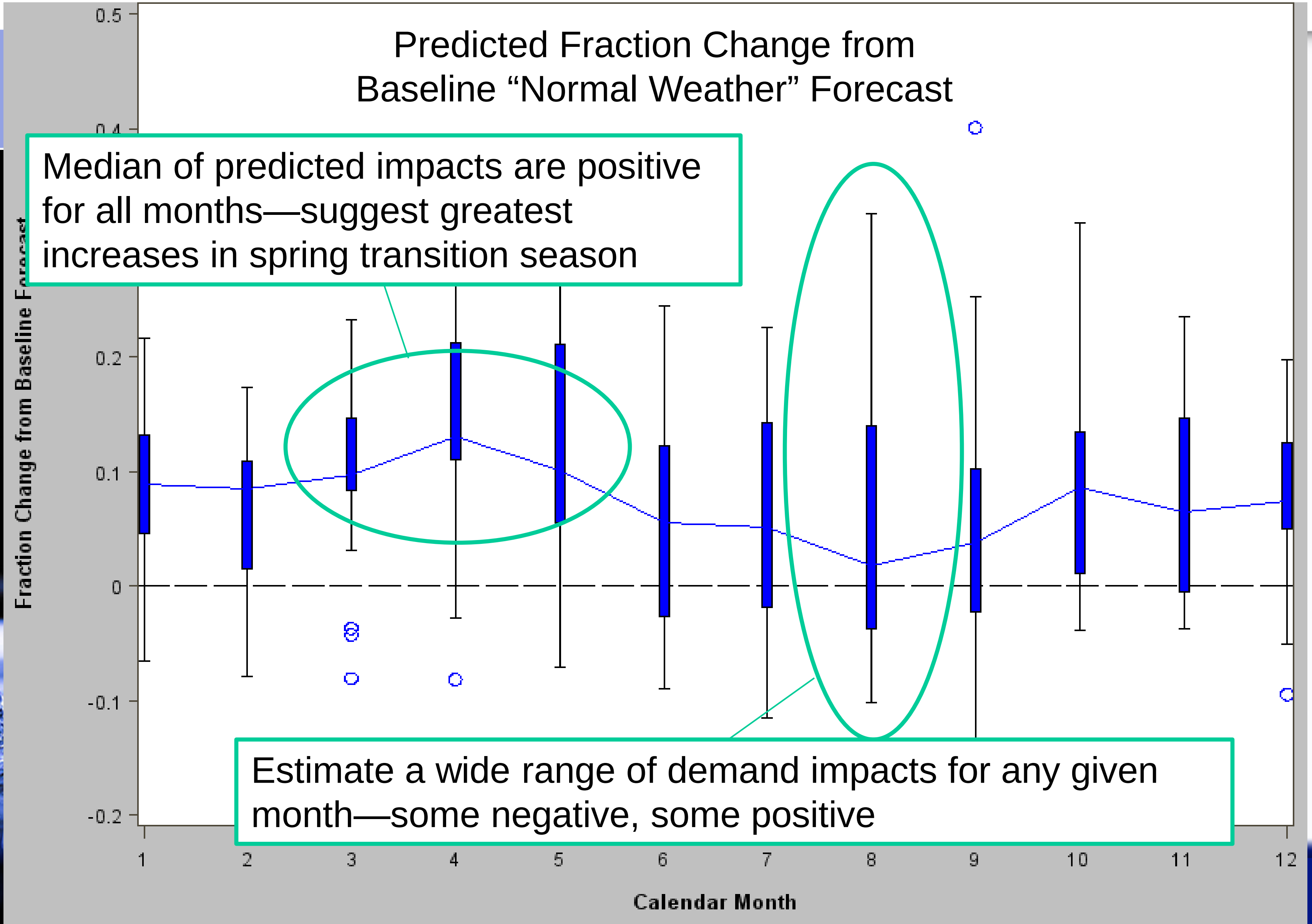
Distributions of August Average Maximum Daily Temperature



Distributions of March Precipitation

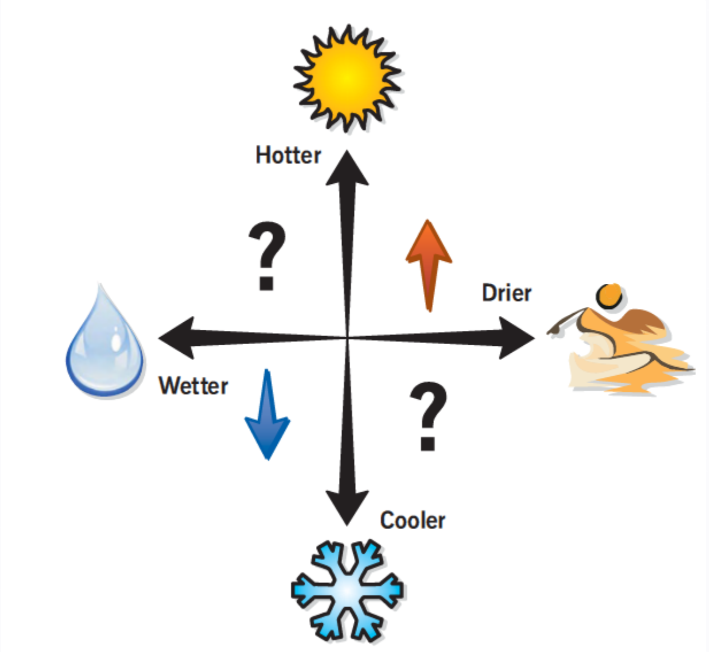


Example Ensemble of Potential Monthly Demand Impacts



Important Points

- Its probably going to get warmer
- It may get dryer
- It may get wetter
- Seasonal trends may be amplified
- Seasonal trend may be altered



- Impacts on demand are uncertain and projections are variable

Regional-Scale Vulnerabilities

- Climate change will likely exacerbate existing demand pressures in some regions and municipal systems that have
  - High rates of population growth
  - Competition for sources of water supply
    - Municipal
    - Agriculture
    - Power
    - Ecological
  - Heavy reliance on surface water sources
- Some water resources “hot spots” are going to get “hotter”…

Important Open Questions/Issues about Role of Efficiency

- Can investments in water efficiency reduce potential risks?

- Can increasing efficiency in indoor plumbing mitigate potential climate change impacts as an alternative source of supply?

  - Some initial simulations suggest so on <u>annual average basis</u>
  - Variability in initial annual and monthly projections cause concern

Important Open Questions/Issues about Role of Efficiency

- Increases in outdoor use may be projected in some places under “current” circumstances
- There may be additional future societal benefits from increasing outdoor plantings
- Cooling with water may become more cost-effective

- Can irrigation and cooling efficiency measures offset potentially more outdoor and cooling uses of water?
- Can “surplus” irrigation be reduced without inducing more irrigation from deficit irrigators?

Important Open Questions/Issues about Role of Efficiency

- Does uncertainty and potential for increased weather variability focus more attention on curtailment potential than long-term efficiency?

- Restrict demand when you need to?
- Preserve a "soft demand" buffer?

- More of a supply/operational perspective
- Implications for servicing demands

Indirect Adaptations?

- Increasing development density would generally decrease water use in residential sectors

- Example of changes in development patterns
  - Assume elasticity with respect to housing density (units per acre) = -0.33
  - Current density = 1 acre lots
  - Future scenario = 2 units per acre
  - Estimated reduction in water use = -20%

Indirect Adaptations?

- Increasing cost of water and higher prices may lead to reductions in long-term water use
- Example of higher prices
  - Assume elasticity with respect to inflation-adjusted volumetric prices = -0.40
  - Assume marginal prices increase by 50%
  - Estimated reduction in water use = -15%

Summary and Conclusions

- Understanding demand-side impacts of climate change and adaptation opportunities is important
  - Fundamental mission of “on demand” delivery of water
  - Predictions of future (unrestricted) demand drive investment decisions
  - Scenario planning requires consistent and simultaneous analysis of supply and demand

Summary and Conclusions

- Weather and climate-sensitive water uses are a sizeable component of water demands in most urban systems
- Understanding demand response to weather and climate is fundamental to climate change evaluation
- There is certainly a role for water efficiency adaptations but uncertainty makes planning complex
- Indirect utility adaptations and market/economic signals could mitigate (or exaggerate) climate change impacts
- More research is needed on climate-induced drought and potential characteristics of future droughts

Thank you

Questions?

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