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Primary Data of Water Use Trends in Single Family Residences: Evidence from Research in Phoenix

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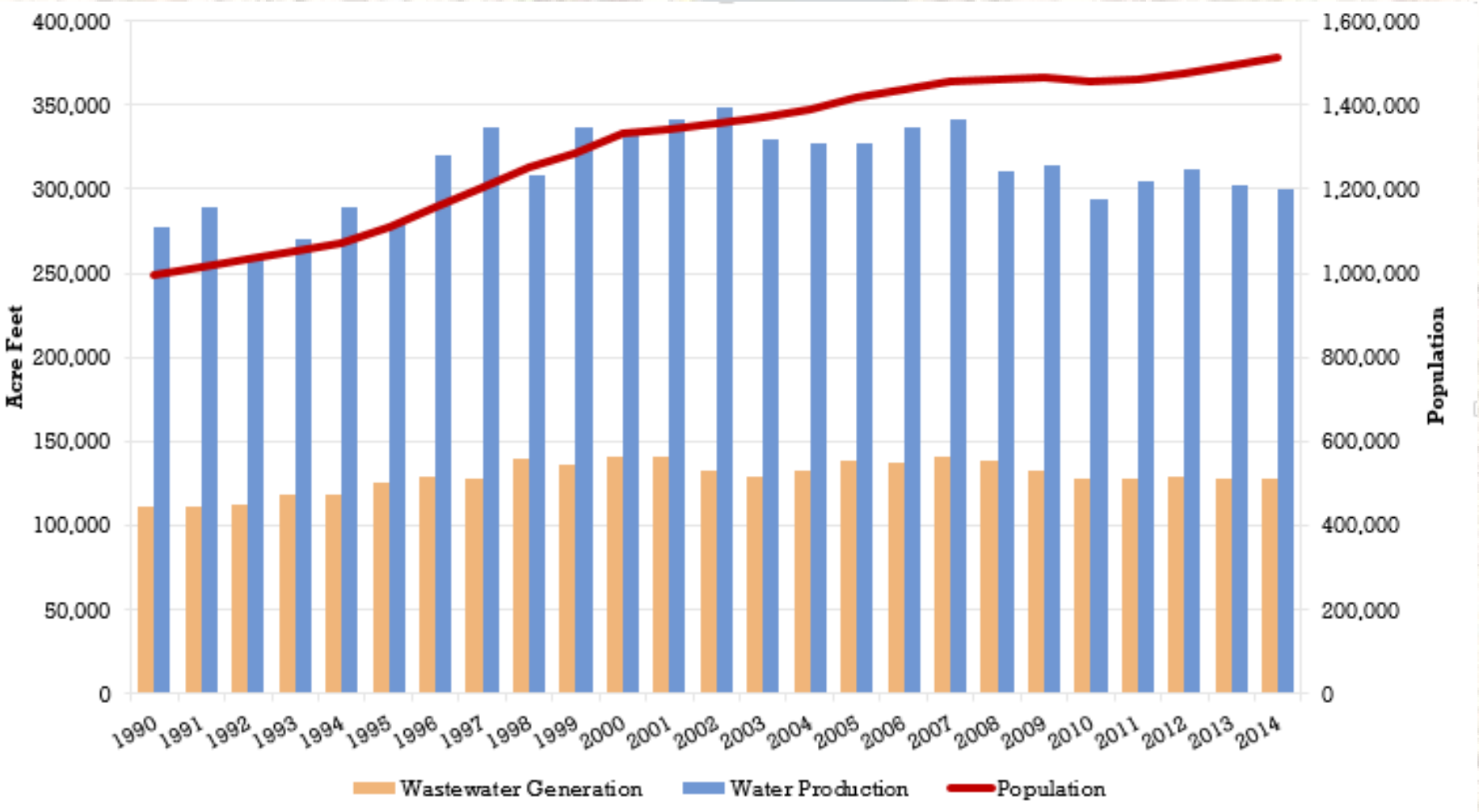
Overview

- Why study water use in Phoenix?
- How has Phoenix conducted water use studies in the past?
- Why code aerial imagery?
- What are the preliminary results of aerial imagery coding?
- Why use data loggers?
- What are the initial results of data logging?
- What is the next phase of research?

Why study water use in Phoenix?

- **Water resource planning**
  - **New sources and/or**
  - **Increased water efficiency initiatives**
- **Water and wastewater infrastructure design specifications/guidelines (developer and city)**
- **Water and wastewater infrastructure requirements (area and city-wide master plan)**
- **Financial planning (revenues partially based on volume)**
- **Impact fee calculations**

Water Production and Wastewater Generation



Reasons for Water Use Decline

- Gradual transition to more efficient plumbing fixtures and appliances
- Gradual conversion to less water intensive landscapes

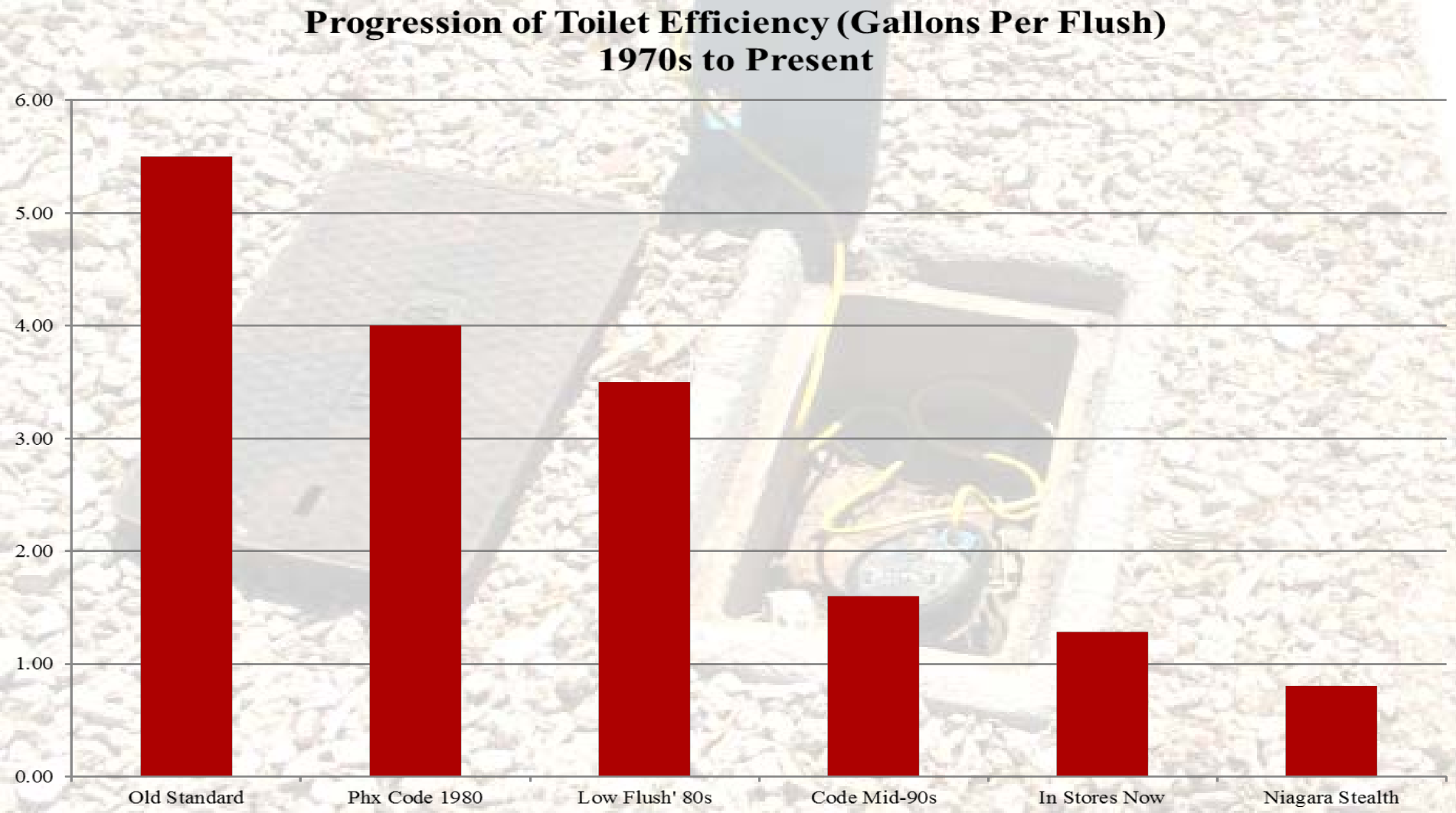
Phoenix Trend for Residential Devices

TREND IN USAGE RATES FOR RESIDENTIAL DEVICES Pre-1996 Homes		
Fixture / Appliance	1999 Use Rate (gal/day)	2009 Use Rate (gal/day)
Toilet	48.3 ★	35.2 ★
Clothes Washer	43.5 ★	27.9 ★
Shower	33.3	31.3
Faucet	24.7	28.0
Leak [1]	14.1	15.1
Other	10.1	11.7
Dish Washer	2.2	1.0
Bathtub	3.0	1.8
Total	179.2	152.0

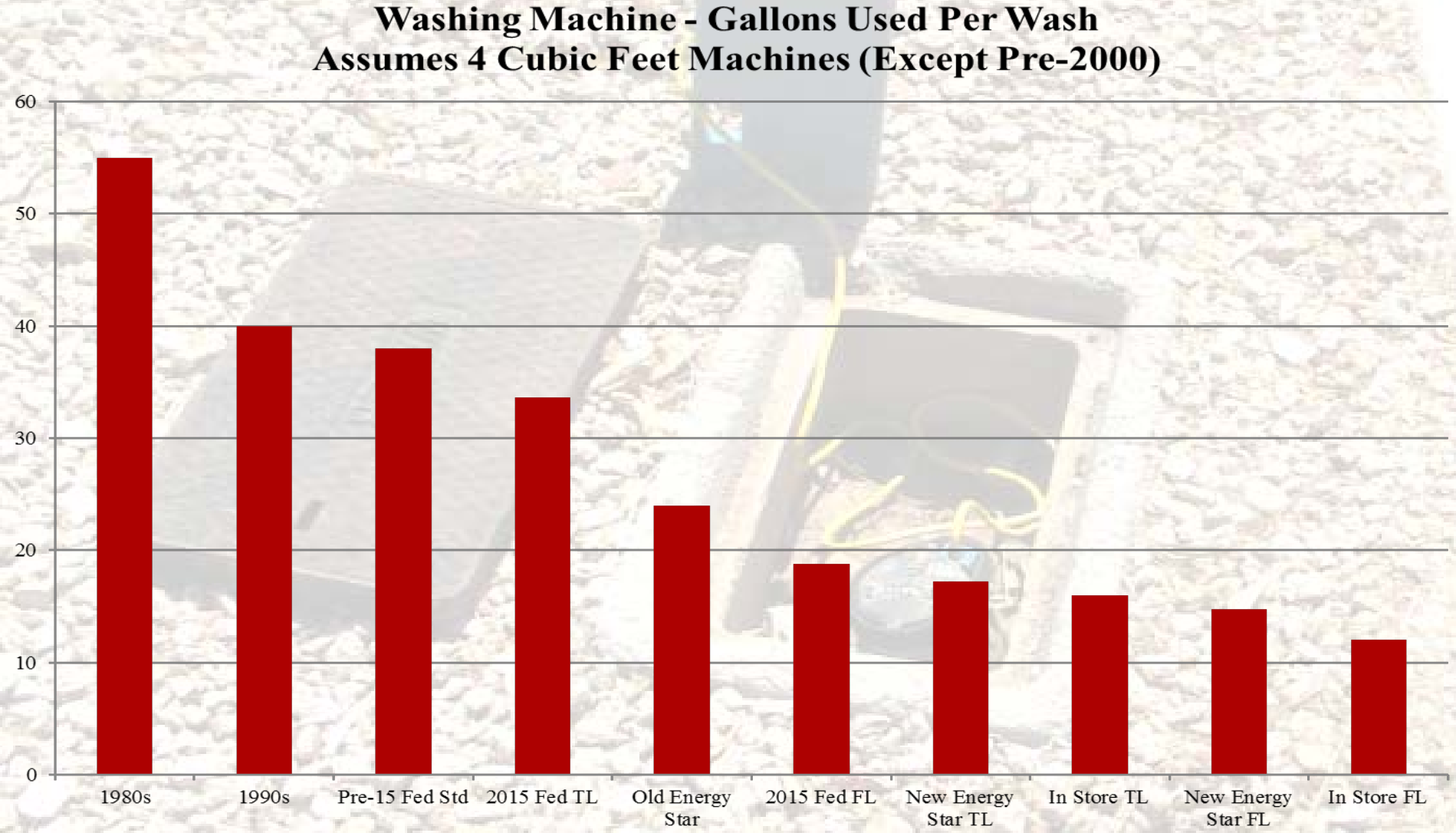
Data from the 1999 REUWS and the 2009 city of Phoenix ReLog Study

1. Data shown is mean daily use (gallons) except Leak data is median due to right-hand skew.

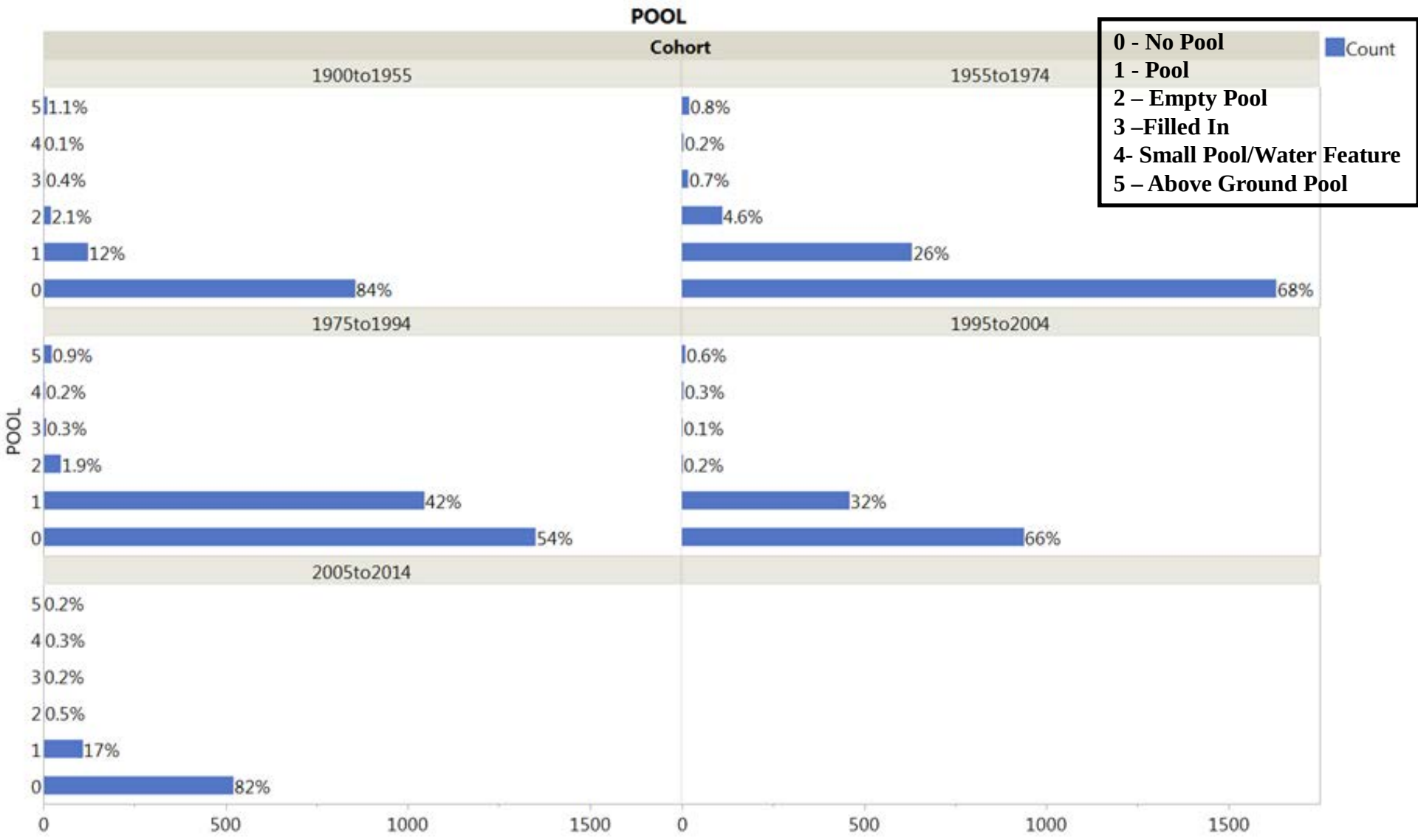
Toilet Efficiency



Clothes Washer Efficiency



Homes with Pools



Water Use Decline is Largely Independent of Human Behavior

Study Reference	Year	Laundry Loads (Daily per Person)	Showers (Daily per Person)	Shower Duration (Minutes)	Toilet Flushes (Daily per Person)
1999 REUWS (AVG)	1999	0.37	0.75	8.20	5.05
1999 REUWS Boulder	1999	0.34	0.81	7.90	4.79
1999 REUWS Denver	1999	0.37	0.80	8.10	5.10
1999 REUWS Eugene	1999	0.40	0.90	8.10	5.62
1999 REUWS Las Virgenes	1999	0.40	0.74	8.10	4.73
1999 REUWS Lompoc	1999	0.38	0.71	8.30	5.19
1999 REUWS Phoenix	1999	0.40	0.77	8.00	5.31
1999 REUWS San Diego	1999	0.42	0.63	7.90	5.20
1999 REUWS Seattle	1999	0.30	0.75	7.90	4.49
1999 REUWS Tampa	1999	0.36	0.70	8.20	4.85
1999 REUWS Tempe & Scotts	1999	0.36	0.82	7.90	5.12
1999 REUWS Walnut Valley	1999	0.34	0.74	8.20	4.69
1999 REUWS Waterloo	1999	0.35	0.63	6.80	5.51
REUWS Update Scottsdale	2012	0.31	0.74	6.50	5.28
CA SF Water Use (AVG)	2011	0.35	0.72	8.70	4.76
New SF Homes (Standard)	2011	0.31	0.66	8.20	4.45
New SF Homes (HE)	2011	0.32	0.88	9.60	4.60
AVERAGE		0.36	0.75	8.04	4.98
MIN		0.30	0.63	6.50	4.45
MAX		0.42	0.90	9.60	5.62
MEDIAN		0.36	0.74	8.10	5.05

Studies conducted by Aquacraft Water Engineering and Management

How has Phoenix conducted water use studies in the past?

- Analysis of single family monthly meter data back to 1986
- Data-logging as part of national studies
  - Aquacraft studies in 1996 and 2009
  - Focus on identifying & quantifying all uses in 100 homes
- Extensive commercial, industrial, and institutional (CII) studies and audits in ‘90s
- Site level single-family (SF) and multi-family (MF) research 2007-09
- Participation in national studies

Aerial Imagery

Phoenix Traditional Landscape Model

Phoenix Newer Landscape Model

An Example of Landscape Changes

- Landscapes are changing over time:
  - Overall landscapes are becoming dryer
  - Primary turf parcels are shifting to partially desert or mostly desert landscapes

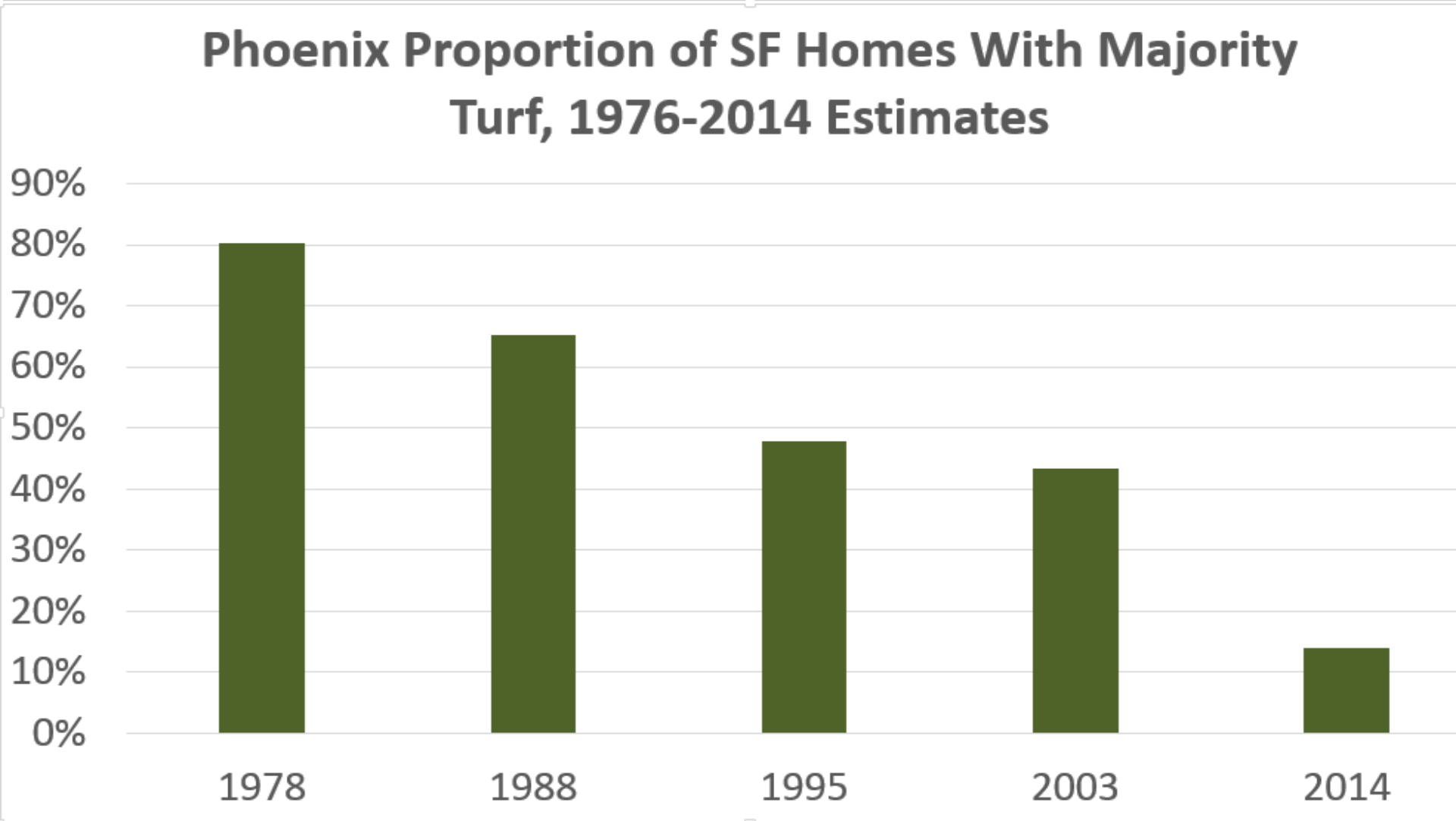
2010

Parcel has turf

2014

Turf is replaced with rocks and shrubs

Single Family Homes with Turf



Why code aerial imagery?

- The transition to desert landscaping was pervasive but unquantified
- Need the rate of transition for modeling purposes
- Coding of aerial landscapes is the most efficient means to date of understanding single family water use
- Coding aerial imagery is time-consuming but it provides a wealth of data

What are the preliminary results of aerial imagery coding?

- Demonstrated that landscapes are far more diverse than previously assumed
- Verified correlation between single family water use and landscape/pool codes
- In 1990s, most single family homes were ‘turf’ or ‘extensive’ but now they are less than 15%
- Largest landscape categories now are mostly desert or partially desert
- A coding system had to be developed to reflect huge diversity (different codes)

GIS Attribute Table : Used for Aerial Coding

Table

Landscape Single Family Parcels

FRONT	BACK	OVERALL_MIX	POOL	LOT_CONF	TURF_MEASURE	TURF_OVER	Supplementary Turf	Supplementary Overall	ImageYr	QUESTIONABLE	COMMENT
Turf	Sparse Pla	Moderate Plant C	None	Standard	1886	20% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	None	Pie Slice	1744	10% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	1713	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Sparse Pla	Moderate Plant C	None	Standard	389	10% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	4821	50% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Transition	Moderate Plant C	None	Standard	1078	20% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	None	Standard	1154	20% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Moderate	Extensive Plant C	Full	Irregullar	6188	20% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	2299	40% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	2154	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Moderate Plant C	None	Standard	1607	20% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	4888	40% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	3901	30% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	4293	60% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	Full	Standard	2011	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	28140	60% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Extensive	Extensive Plant C	None	Standard	3322	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	None	Standard	1837	30% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	24960	40% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Transition	Moderate Plant C	None	Standard	2124	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Sparse Pla	Moderate Plant C	None	Standard	1371	20% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	8117	70% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	11624	70% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	Full	Standard	5679	40% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	None	Standard	1690	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Transition	Moderate Plant C	None	Standard	271	10% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Transition	Moderate Plant C	None	Standard	758	10% Turf	High Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	Full	Standard	4520	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Arid	Moderate Plant C	None	Standard	975	10% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Sparse Pla	Moderate Plant C	None	Standard	1108	20% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	2502	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Turf	Turf	None	Standard	1712	30% Turf	Low Quality or Dying Tu	Well Defined	2013	No	<Null>
Turf	Turf	Turf	Full	Standard	8058	30% Turf	Medium Quality Turf	Well Defined	2013	No	<Null>
Turf	Moderate	Moderate Plant C	Filled In	Irregullar	1127	10% Turf	High Quality Turf	Well Defined	2013	No	<Null>

Landscape Classification

Primary Turf

- More than 35% of the total property is covered by turf.
- The most water intensive landscape

Extensive Vegetation

- Majority of the front, sides, and backyard are covered with various types of vegetation
- Second most water intensive landscape

Landscape Classification

Partially Desert

- Overall lot is a mixture of desert landscape which include numerous trees, shrubs, plants, and possible some turf
- Third most water intensive landscape

Mostly Desert

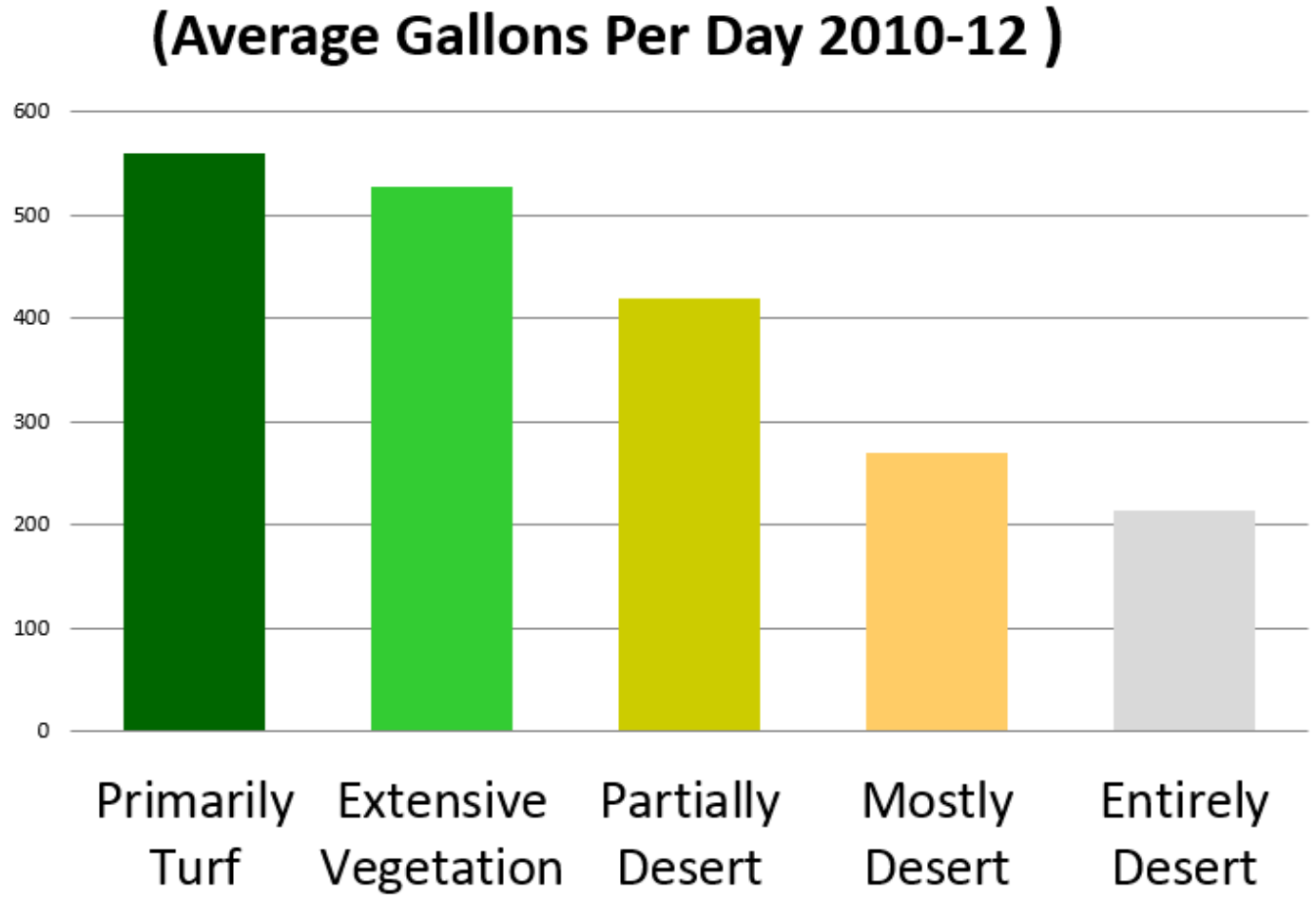
- Overall parcel has a mixture of desert landscape which includes some trees, plants, shrubs, etc.
- No turf present
- Fourth most water intensive landscape

Landscape Classification

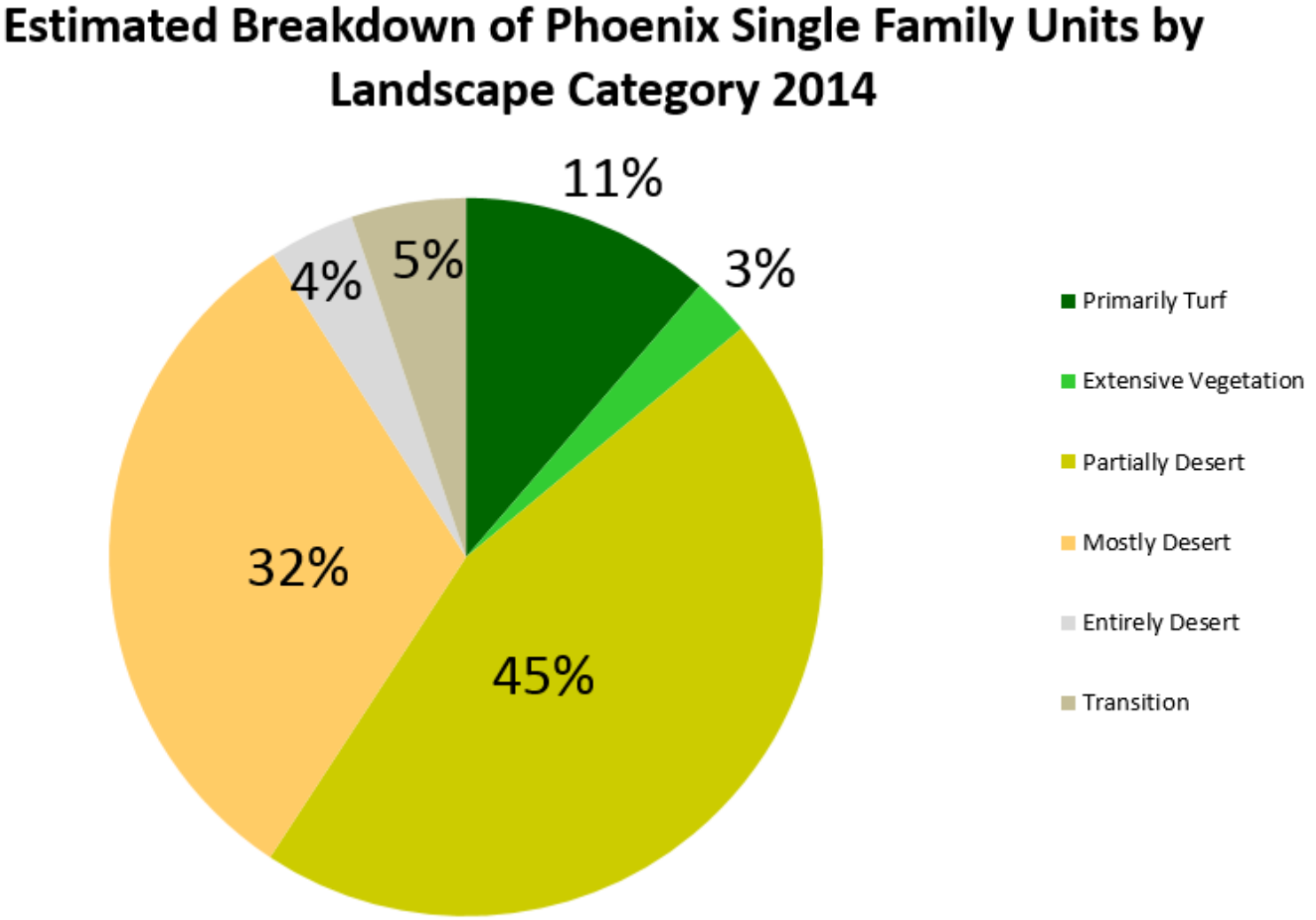
Entirely Desert

- **Overall parcel is dominated by gravel, pavement, dirt, and/rocks**
- **Irrigation free vegetation like cactus may be present**
- **Least most water intensive landscape**

Phoenix Single Family Total Water Use by Landscape Category



Single-Family Units by Landscape Category



Data Loggers

Why use data loggers?

- More efficient internal devices have been introduced since 1980s (tremendous diversity)
- Data loggers identify the types of appliances and fixtures present in single family homes without entering the resident's house
- Assist with the identification of the rate of transition for modeling purposes
- Data-loggers can (generally) identify signatures of different device types in single-family homes
- Data logging can be time-consuming and the sample size is often small
- It is still one of the most cost effective way to produce estimates

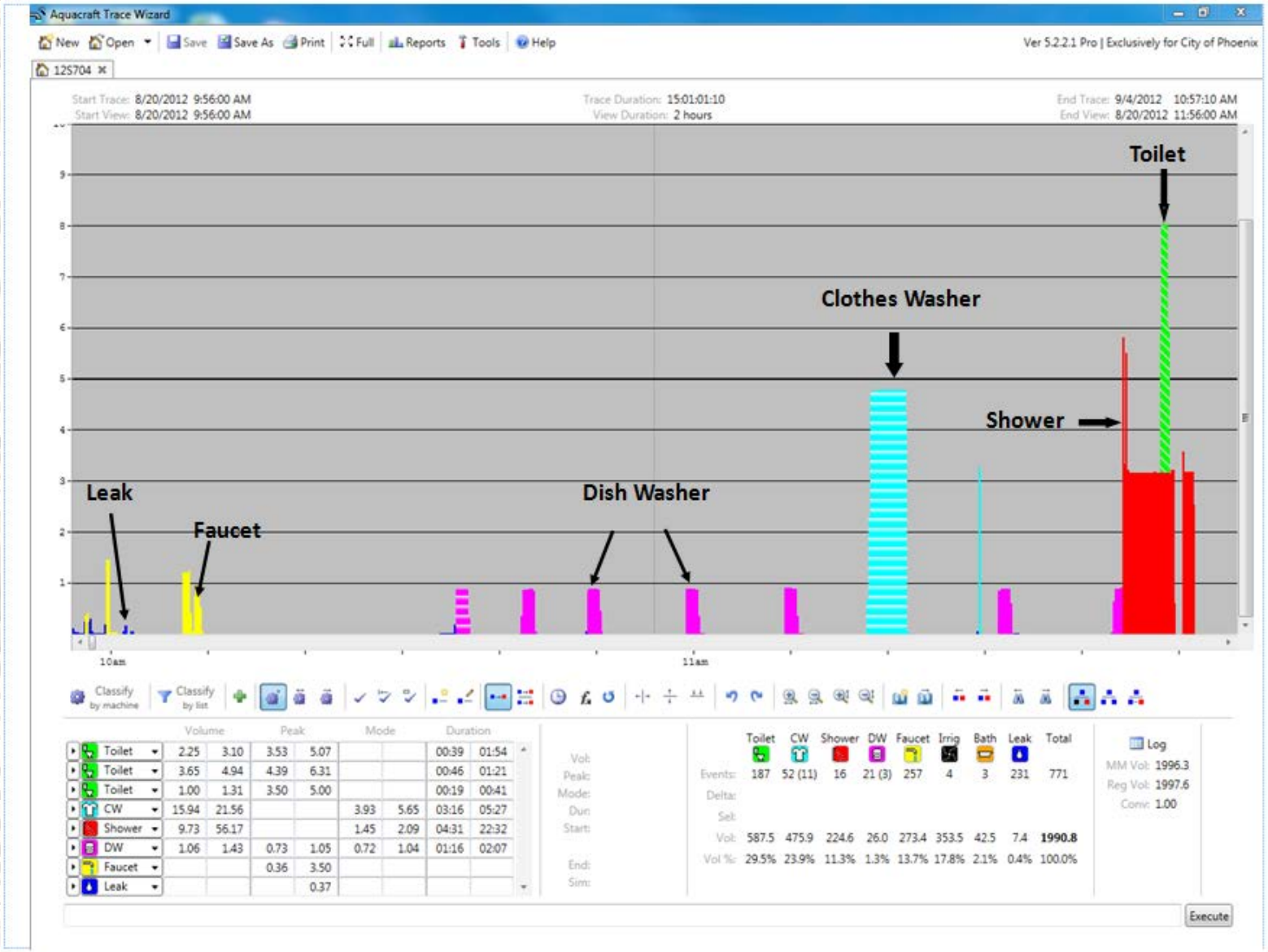
What are the initial results of data logging?

- Transition identified by previously national data logging studies
- Toilets are being replaced by more efficient ones. Reconstruction of homes is a driving factor and not age of the fixture
- Analysis of data in different age cohorts indicates that single family toilets replaced during upgrades
- Clothes washers appear to be replaced frequently
- Remaining older toilets and clothes washers indicate major efficiency opportunities

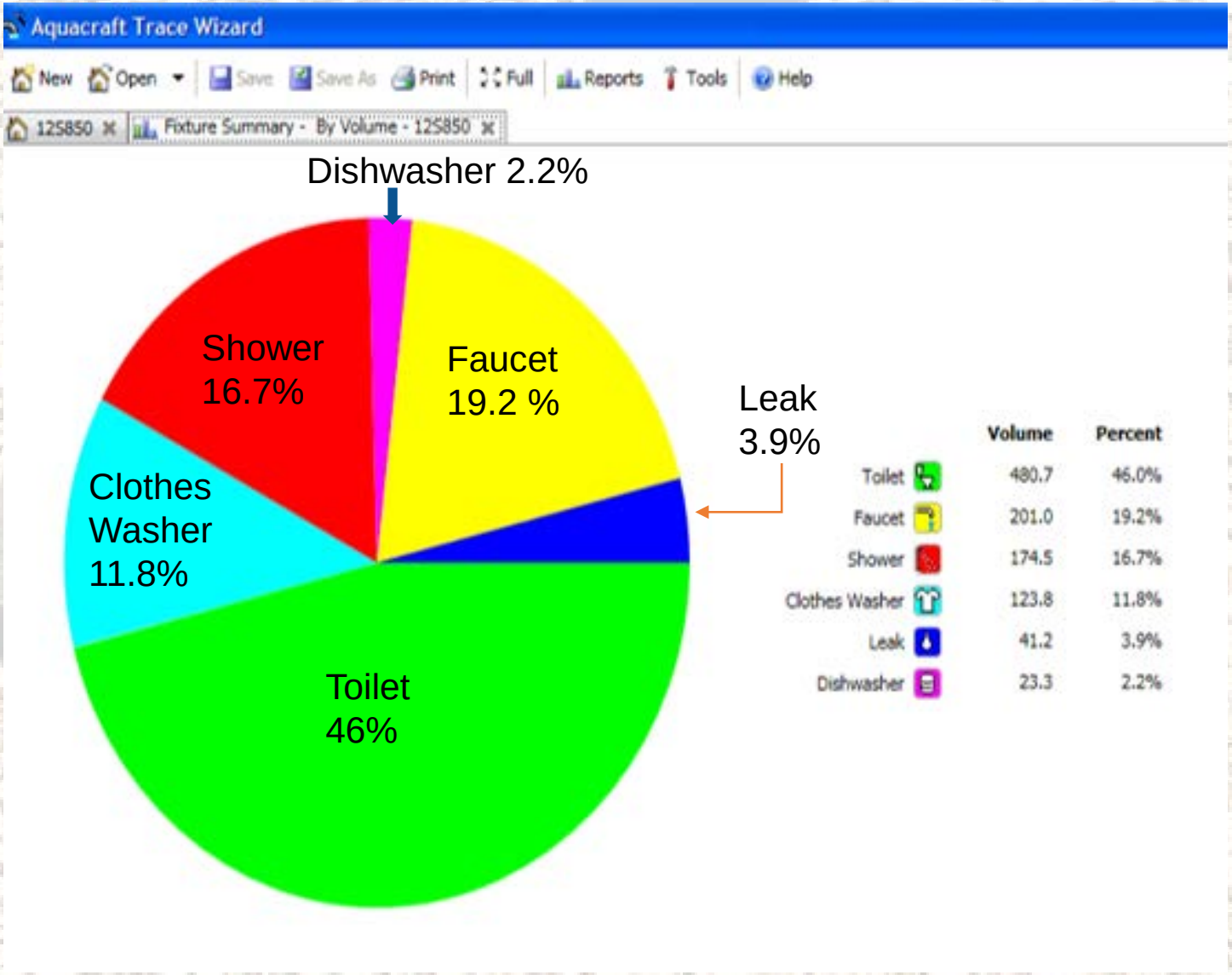
Data Logger Study

- Data logged 200 random parcels
- Set up data loggers on water meters for approximately 14 days
- Equipment malfunction for 6 parcels – no data received
- Information Received:
  - 194 parcels with toilet data
  - 163 parcels with clothes washer data
  - 167 parcels with shower data
- Other data was not present or could not be identified

Aquacraft Trace Wizard



An Example of a Fixture Summary by Volume



An Example of a Distribution Report

Aquacraft Trace Wizard

New | Open | Save | Save As | Print | Full | Reports | Tools | Help

125850 | Distribution - 125850

Toilet Events: 99

	Min	10%	50%	90%	Max
Vol:	3.12	4.46	4.66	5.32	5.93
Peak:	4.01	4.19	4.58	5.51	5.93
Mode:	0.02	4.16	4.23	5.51	5.51
Dur:	50s	01m00s	01m10s	01m20s	02m00s

Faucet Events: 530

	Min	10%	50%	90%	Max
Vol:	0.05	0.07	0.22	0.83	5.33
Peak:	0.26	0.31	0.75	1.46	3.12
Mode:	0.01	0.31	0.73	1.40	3.12
Dur:	10s	10s	20s	01m10s	05m30s

Shower Events: 12

	Min	10%	50%	90%	Max
Vol:	4.39	4.58	14.47	20.66	21.52
Peak:	1.44	1.89	1.95	2.08	2.18
Mode:	1.44	1.87	1.91	1.92	1.98
Dur:	02m50s	03m10s	07m40s	11m00s	11m30s

Clothes Washer Events: 9 1st Cycles: 3

	Min	10%	50%	90%	Max
Vol:	0.80	0.80	16.87	22.57	22.58
Peak:	1.64	1.64	1.66	1.87	1.98
Mode:	1.59	1.59	1.61	1.66	1.66
Dur:	30s	30s	10m40s	14m10s	14m10s

Leak Events: 614

	Min	10%	50%	90%	Max
Vol:	0.01	0.02	0.05	0.14	0.58
Peak:	0.01	0.02	0.10	0.21	0.24
Mode:	0.01	0.01	0.02	0.21	0.23
Dur:	10s	10s	02m00s	06m30s	18m40s

Dishwasher Events: 20 1st Cycles: 5

	Min	10%	50%	90%	Max
Vol:	1.08	1.10	1.17	1.20	1.22
Peak:	0.81	0.81	0.81	0.83	0.83
Mode:	0.81	0.81	0.81	0.83	0.83
Dur:	01m20s	01m20s	01m30s	01m40s	02m20s

Single- Family Resident Toilet Fixtures per Age Cohorts

Phoenix Data Logger Study for Toilets

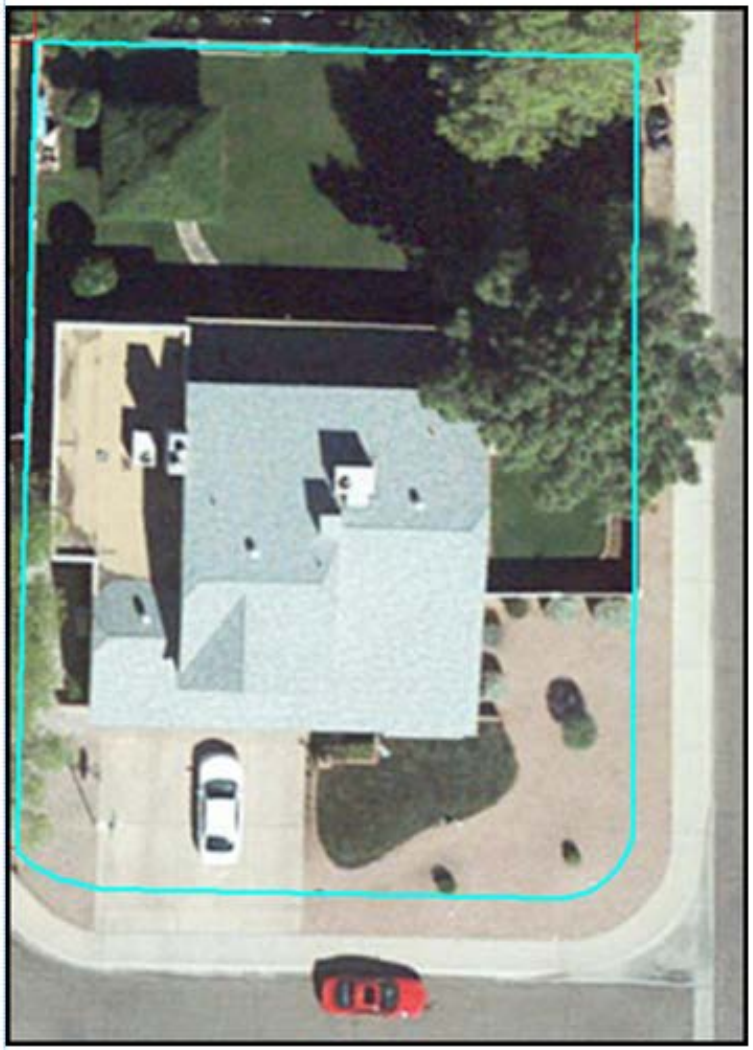
Cohorts	# of Toilets	Avg Flush Volume	1.28 or less	1.6 Only	Mix of Low Flow	Mix of Low Flow and 3.5	3.5 Only	Mix of Low Flow and 4.5+	Mix of 3.5 and 4.5+	4.5+ Only
1900-1954	29	2.36	13.79%	37.93%	10.34%	17.24%	17.24%	3.45%	0.00%	0.00%
1955-1974	58	2.47	8.62%	36.21%	18.97%	6.90%	10.34%	5.17%	8.62%	5.17%
1975-1994	58	2.85	6.90%	27.59%	10.34%	22.41%	18.97%	1.72%	0.00%	12.07%
1995-2004	26	2.58	7.69%	57.69%	0.00%	11.54%	11.54%	0.00%	3.85%	7.69%
2005-2015	23	1.8	13.04%	43.48%	30.43%	8.70%	4.35%	0.00%	0.00%	0.00%

Probably toilet malfunction of a 1.6

Single- Family Resident Clothes Washer per Age Cohorts

Phoenix Data Logger Study for Clothes Washer					
Cohorts	# of CW	Average Wash Volume	< 20 GPW	20-35 GPW	>35 GPW
1900-1954	24	29.73	25.00%	37.50%	37.50%
1955-1974	49	36.13	24.49%	18.37%	57.14%
1975-1994	46	31.2	32.61%	19.57%	47.83%
1995-2004	25	26.84	36.00%	24.00%	40.00%
2005-2015	19	29.4	21.05%	31.58%	47.37%

Aerial Imagery and Data Logger



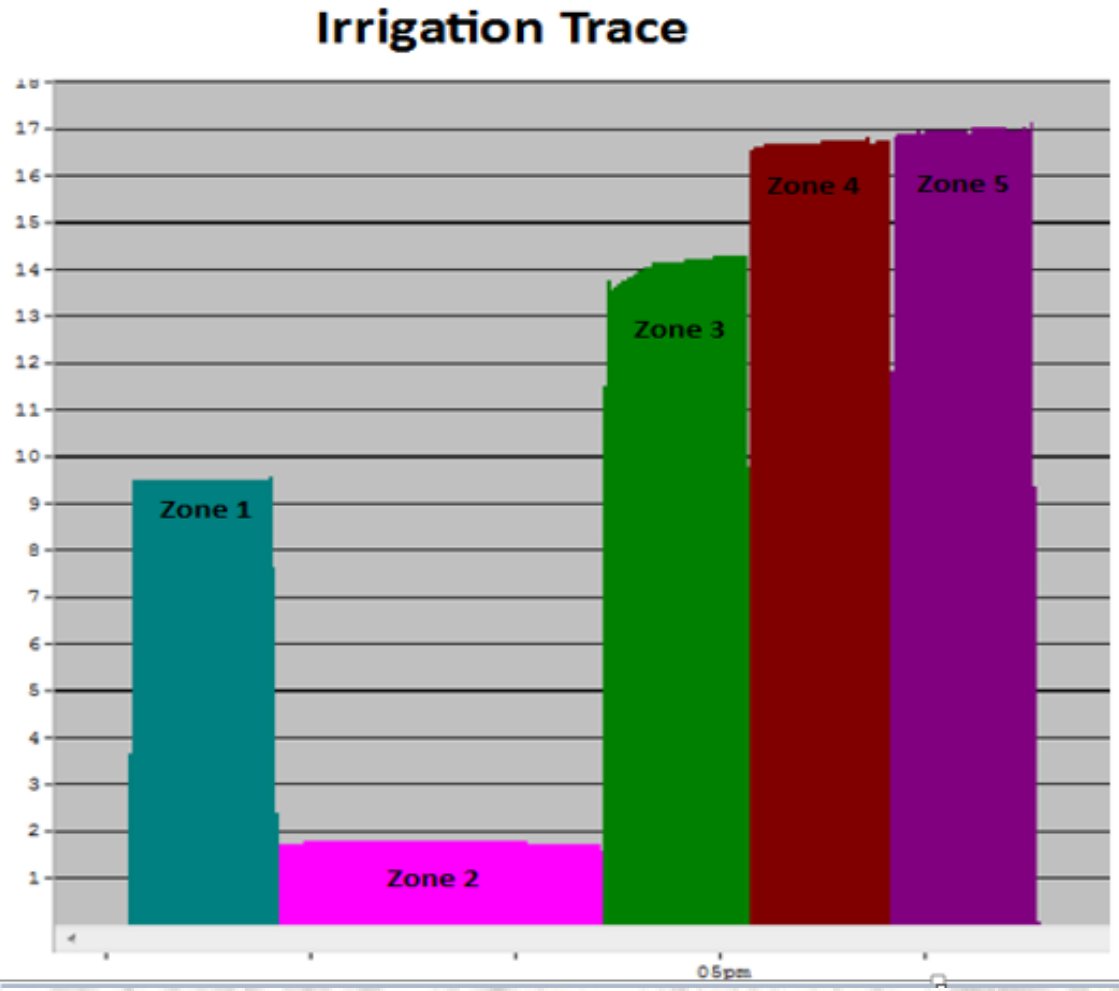
- **Set Up Month:** August
- **Overall Landscape Classification:** Turf
- **Turf Measurement:** Approximately 4000 Square Feet (40% of lot size)
- **Lot Size:** Approximately 10,000 Square Feet

An Example of a Data Logged Parcel with Turf

Duration Per Zone

Cycles	Irrigation Date	Time Started	Irrigation Day	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Cycle 3	8/8/2014	12:03:00 PM	Friday	7:30	7:50	10:00	10:00	10:10
Cycle 4	8/8/2014	4:30:00 PM	Friday	10:20	7:50	10:20	9:40	10:20
Cycle 1	8/10/2014	7:00:00 AM	Sunday	10:20	7:40	10:10	10:10	10:00
Cycle 2	8/10/2014	12:00:00 PM	Sunday	7:10	14:00	7:10	6:50	7:10
Cycle 3	8/10/2014	4:30:00 PM	Sunday	7:10	14:00	7:00	7:00	7:20
Cycle 4	8/10/2014	7:30:00 PM	Sunday	7:10	14:00	7:00	7:00	7:10
Cycle 1	8/11/2014	7:00:00 AM	Monday	7:10	14:00	7:00	7:00	7:20
Cycle 2	8/11/2014	12:00:00 PM	Monday	7:10	14:00	7:00	7:00	7:20
Cycle 3	8/11/2014	4:30:00 PM	Monday	7:10	14:00	7:00	7:00	7:20
Cycle 4	8/11/2014	7:30:00 PM	Monday	7:20	13:50	7:00	7:00	7:20
Cycle 1	8/13/2014	7:01:00 AM	Wednesday	7:10	13:50	7:00	7:00	7:20
Cycle 2	8/13/2014	12:01:00 PM	Wednesday	7:10	13:50	6:50	7:10	7:10
Cycle 3	8/13/2014	4:30:00 PM	Wednesday	7:20	13:50	7:10	6:50	7:20
Cycle 4	8/13/2014	7:31:00 PM	Wednesday	7:10	13:50	6:50	7:10	7:20
Cycle 1	8/16/2014	3:14:00 PM	Saturday	4:20	16:00	7:00	7:10	7:00
Cycle 1	8/17/2014	7:01:00 AM	Sunday	7:10	16:00	7:10	6:50	7:20
Cycle 2	8/17/2014	12:01:00 PM	Sunday	7:10	16:00	7:10	7:00	7:00
Cycle 3	8/17/2014	4:31:00 PM	Sunday	7:10	16:00	6:50	7:20	7:00
Cycle 4	8/17/2014	7:31:00 PM	Sunday	7:10	16:00	7:10	7:00	7:10
Cycle 1	8/18/2014	7:01:00 AM	Monday	7:10	16:00	7:00	7:00	7:20
Cycle 2	8/18/2014	12:01:00 PM	Monday	7:10	16:00	6:50	7:10	7:10
Cycle 3	8/18/2014	4:31:00 PM	Monday	7:20	15:50	7:10	6:50	7:20
Cycle 4	8/18/2014	7:31:00 PM	Monday	7:20	15:40	7:20	6:40	7:30
Cycle 1	8/20/2014	7:01:00 AM	Wednesday	7:10	15:50	7:20	6:40	7:20
Cycle 2	8/20/2014	12:01:00 PM	Wednesday	7:10	15:50	7:00	7:00	7:20
Cycle 3	8/20/2014	4:31:00 PM	Wednesday	7:10	15:50	7:00	7:10	7:00
Cycle 4	8/20/2014	7:31:00 PM	Wednesday	7:10	15:50	7:00	7:10	7:00

An Example of a Data Logged Parcel with Turf



In Gallons

Zones	Total Water Use Per Zone
1	1650.8
2	647.7
3	2488.4
4	2944.2
5	3016.8
Total	10747.9

A snap-shot of Aquacraft Trace Wizard signature for irrigation

Conclusion

- Why is water use declining?
- What have we learned about aerial imagery?
- How have data loggers benefitted us?

What is the next phase of research?

- ❖Ongoing single family data-logging
- ❖Use of automated aerial imagery (ecognition)
- ❖Ongoing commercial, industrial, and institutional studies (visits, specific sector review)
- ❖Ongoing multi-family studies (new data sets to overcome challenges)
- ❖Intensive study of specific areas (aerial coding, data-logging, audits, sewer metering, etc.)
- ❖Multi-city single family study
- ❖Eventually smart meter analysis

Ecognition Screenshot

Questions

Primary Data of Water Use Trends in Single Family Residences: Evidence from Research in Phoenix

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