LOAD RESEARCH

Irrigation Load Study

Utah Cost of Service Task Force
August 25, 2005

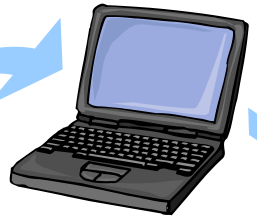
What is Load Research?

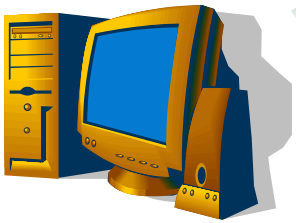
- The study of how and when our customers use energy so that PacifiCorp can most effectively:
  - Allocate Fixed Costs per Regulatory Mandates
  - Design or Maximize Customer Rates
  - Forecast Loads
  - Service Customer Data Requests
  - Size Distribution Circuits
  - Provide Customer Service

Load Research Data Process

Short Interval Data
Manually Collected

Short Interval Data
Remotely Collected





Customer Service
Tariff Option Analysis, Facilities Planning, Bill Complaints

Large Customer Billing
Special Contracts, Load Totalization

Cost Allocation
Intra-Class Allocation & Rate Design

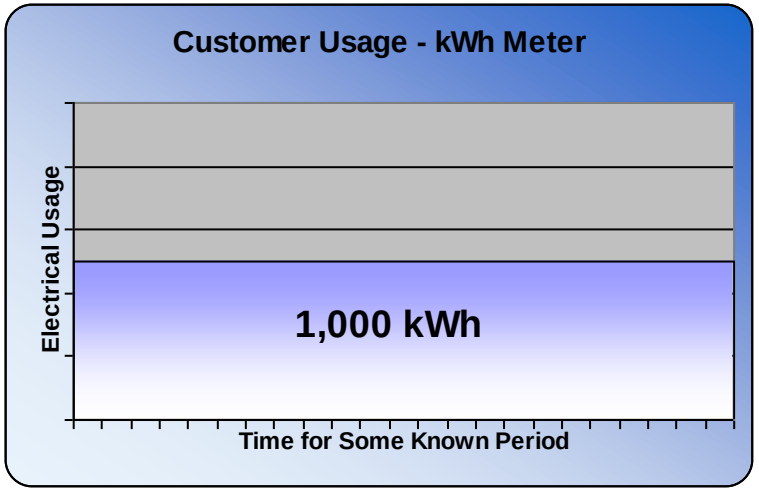
Retail Access
Scheduling/Billing/Settlement

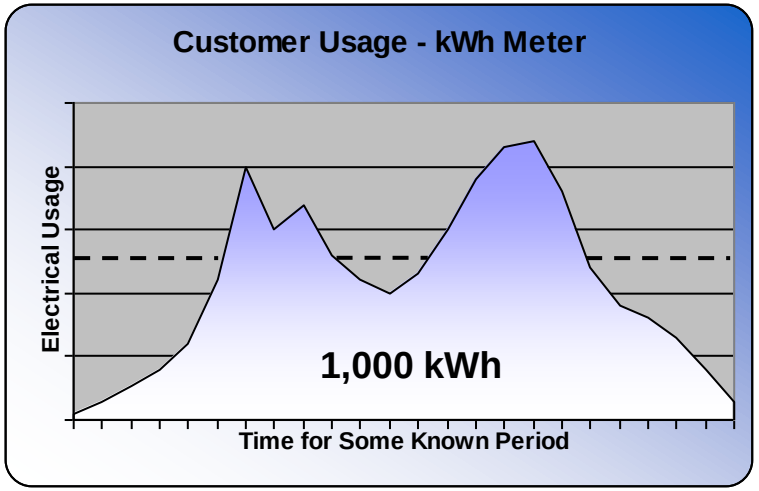
Energy Profiler Online
New Products/Services

Distribution Planning
Outage Management & Transformer Sizing

Load Shape Analysis

- Electric usage varies over time and by customer type
- PacifiCorp is obligated to provide electricity (load) when the customer demands (kW) and for the length of time that the customer needs it (kWh).
- Load research (interval) data provides an important data input into planning, regulatory and financial decision making processes… $$$$$

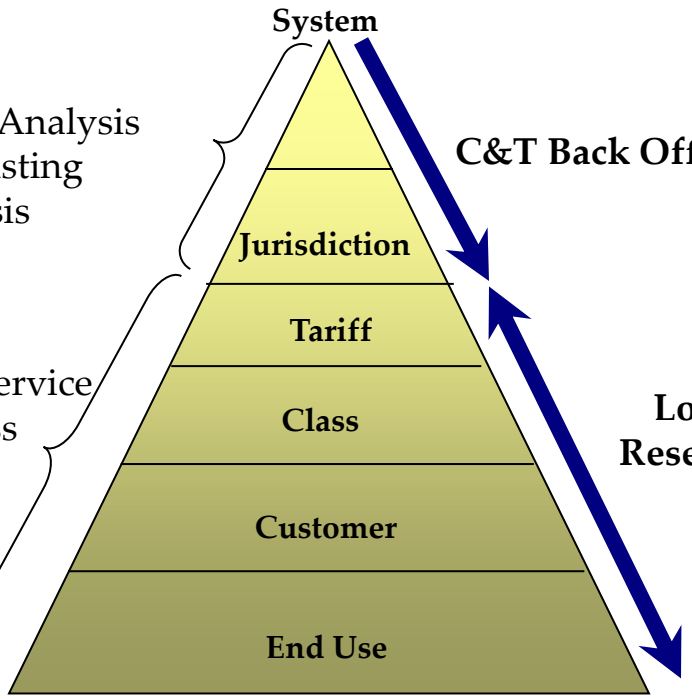




Regulatory Support

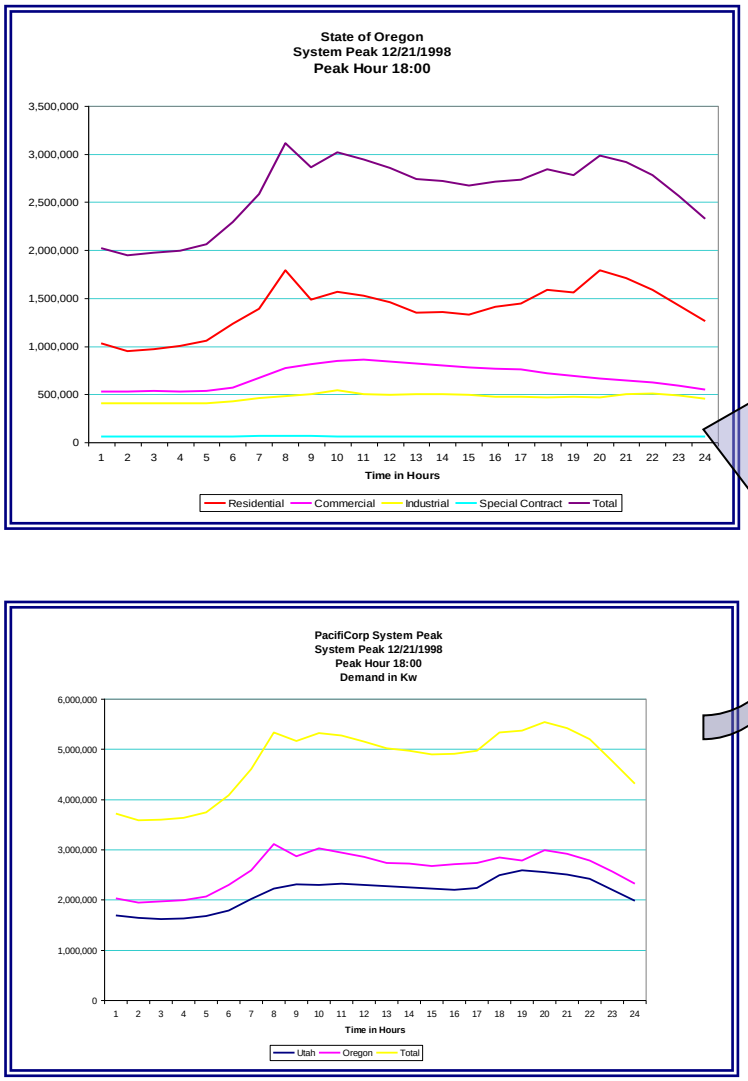
Regulatory Analysis
Peak Forecasting
Loss Analysis

Customer Service
Retail Access
Billing
EPO



C&T Back Office

Load Research

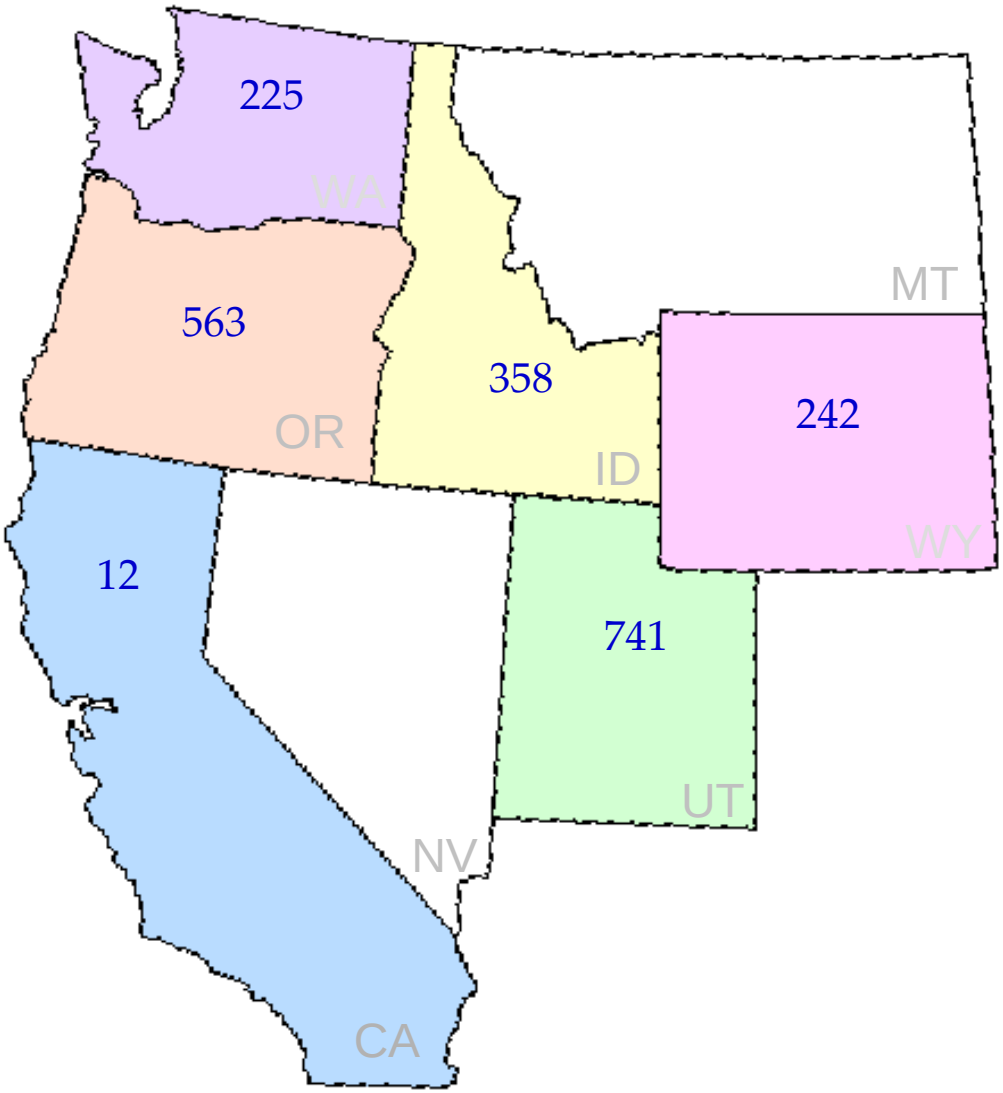


Load Research Meters

State	Class	# Recorders
Utah	Residential	169
	Rate 023	63
	Rate 006	142
	Rate 008	190
	Rate 009	20
	Large Load	157
		741
Idaho	Rate 001	52
	Rate 036	45
	Rate 006	89
	Rate 008	4
	Rate 009	12
	Rate 023	56
	Irrigation	88
	Large Load	12
		358

State	Class	# Recorders
Oregon	Residential	91
	Rate 025	85
	Large Load	387
		563
Washington	Residential	53
	General Service	61
	Large Load	111
		225
Wyoming	Residential	44
	General Service	96
	Large Load	102
		242
Other (DSM, FinAnswer, etc.)		75
Total		2,204

Load Research Meters



Irrigation Load Study - Issues

- 1991-1993 3-year average for current reporting.
- Issues
  - Crop rotation
  - Weather impacts
    - Growing season
    - Access to water
  - Smaller family owned farms (vs. Corporations in Idaho)
- Options
  - Conduct new load studies
  - Use Idaho Data
  - Use system average costing/pricing

Sample Design

Bill Frequency Analysis Summary

Utah Irrigation Schedule 010
Five Strata

Range			Customer Count f	Interval Factor (1K) μ	μf	$\sqrt{\mu f}$	cum $\sqrt{\mu f}$	
0	to	25	1066	1.0	1,066.0	32.6	32.6	1,066
26	to	50	423	1.0	406.1	20.2	52.8	423
51	to	75	204	1.0	195.8	14.0	66.8	
76	to	100	140	1.0	134.4	11.6	78.4	344
101	to	125	99	1.0	95.0	9.7	88.1	99
126	to	150	57	1.0	54.7	7.4	95.5	
151	to	175	49	1.0	47.0	6.9	102.4	
176	to	200	27	1.0	25.9	5.1	107.5	
201	to	225	25	1.0	24.0	4.9	112.4	
226	to	250	11	1.0	10.6	3.2	115.6	
251	to	275	3	1.0	2.9	1.7	117.3	
276	to	300	1	1.0	1.0	1.0	118.3	
301	to	325	4	1.0	3.8	2.0	120.3	
326	to	350	5	1.0	4.8	2.2	122.5	
351	to	375	1	1.0	1.0	1.0	123.4	
376	to	400	2	1.0	1.9	1.4	124.8	
401	to	450	1	2.0	2.0	1.4	126.2	
451	to	475	1	1.0	1.0	1.0	127.2	
476	to	550	1	3.0	3.0	1.7	128.9	
551	to	600	1	2.0	2.0	1.4	130.3	
601	to	800	2	8.0	15.9	4.0	134.3	
801	to	1,000	1	8.0	8.0	2.8	137.1	
1,001	to	2,000	1	40.0	40.0	6.3	143.5	
2,001	to	2,750	1	30.0	30.0	5.5	148.9	194
		Total N	2,126					2,126

BOUNDARIES INDICATED FOR STRATA:	3	4	5	6
1	49.6	37.2	29.8	24.8
2	99.3	74.5	59.6	49.6
3		111.7	89.4	74.5
4			119.1	99.3
5				124.1

SAMPLING STATISTI	Avg. kWh[2]	Mean kW[2]	Res. Variance[2]
1	0	3.503	5.571
2	0	23.371	14.814
3	0	39.910	25.513
4	0	35.208	40.642
5	0	189.051	187.652

[1] Billing records for the twelve months ended June 2005

[2] Load Research estimates based on Idaho Schedule 010 sample data

Utah Irrigation Sample Designs

3 Strata – 235 recorders

4 Strata – 203 recorders

5 Strata – 175 recorders

6 Strata – 169 recorders

Sample Design - Stratification

UTAH SCHEDULE 010 LOAD STUDY DESIGN OPTION FOR 2005
THREE STRATA, MEAN-PER-UNIT DESIGN

		a	b	c	d	e	f	g	h	i	j
		Sample Mean kW	Sample Mean kWh	2004 Pop N	Variance of Mean	Standard Deviation	Wtd. Devtns. c*e	Proprtn. row f/ sum f	Optimal Allocation g*h total	Optimal with Attrition	Final with Attrition
STRATUM 1	0 - 50 kW	7.4760	0	1,489	125.6417	11.2090	16690	0.2130	45	45	50
STRATUM 2	51- 100 kW	39.9100	0	344	650.9132	25.5130	8776	0.1120	23	23	26
STRATUM 3	GT- 100 kW	162.2950	0	293	32590.7198	180.5290	52895	0.6750	142	142	159
EST POP MEAN (wtd by N)		34.0608	0	2,126			78362	1.0000	210	210	235

Sample Estimate	**Adj Sample Estimate**
210	**235**

RELATIVE PRECISION OF SAMPLE KW ESTIMATE

	TOTAL KW Optimal n (col. h)	TOTAL KW Adjusted n (col. i)	MEAN KW Adj. n
Variance contributed by strata: 1	6,139,641	6,139,641	1.358365
2	3,267,111	3,267,111	0.722832
3	10,226,321	10,226,321	2.262522
Total Variance	19,633,072	19,633,072	4.343719
Standard Error	4430.922259	4430.922259	2.0841591
Desired Conf. Level	90%	90%	90%
(z two tailed)	1.645	1.645	1.645
Conf. Interval	7288.867115	7288.867115	3.4284417
MPU Est of kW	72413.239	72413.239	34.0608
Relative Conf. Int.	10.07%	10.07%	10.07%

Sample Design - Stratification

UTAH SCHEDULE 010 LOAD STUDY DESIGN OPTION FOR 2005
FOUR STRATA, MEAN-PER-UNIT DESIGN

		a Sample Mean kW	b Sample Mean kWh	c 2004 Pop N	d Variance of Mean	e Standard Deviation	f Wtd. Devtns. c*e	g Proprtn. row f/ sum f	h Optimal Allocation g*h total	i Optimal with Attrition	j Final with Attrition
STRATUM 1	0 - 50 kW	7.4760	0	1,489	125.6417	11.2090	16690	0.2593	47	47	53
STRATUM 2	51 - 75 kW	25.5910	0	204	327.8634	18.1070	3694	0.0574	10	10	11
STRATUM 3	76 - 125 kW	48.9570	0	239	1008.1260	31.7510	7588	0.1179	21	21	24
STRATUM 4	GT- 125 kW	189.0510	0	194	35213.2731	187.6520	36404	0.5655	103	103	115
EST POP MEAN (wtd by N)		30.4464	0	2,126			64377	1.0000	182	181	203

Sample Estimate	**Adj Sample Estimate**
182	**203**

RELATIVE PRECISION OF SAMPLE KW ESTIMATE

	TOTAL KW Optimal n (col. h)	TOTAL KW Adjusted n (col. i)	MEAN KW Adj. n
Variance contributed by strata: 1	5,864,566	5,864,566	1.297506
2	1,441,725	1,441,725	0.318974
3	2,626,269	2,626,269	0.581049
4	6,094,658	6,094,658	1.348413
Total Variance	16,027,218	16,027,218	3.545942
Standard Error	4003.40078	4003.40078	1.88306716
Desired Conf. Level	90%	90%	90%
(z two tailed)	1.645	1.645	1.645
Conf. Interval	6585.594284	6585.594284	3.09764548
MPU Est of kW	64728.945	64728.945	30.4464
Relative Conf. Int.	10.17%	10.17%	10.17%

Sample Design - Stratification

UTAH SCHEDULE 010 LOAD STUDY DESIGN OPTION FOR 2005
FIVE STRATA, MEAN-PER-UNIT DESIGN

		a Sample Mean kW	b Sample Mean kWh	c 2004 Pop N	d Variance of Mean	e Standard Deviation	f Wtd. Devtns. c*e	g Proprtn. row f/ sum f	h Optimal Allocation g*h total	i Optimal with Attrition	j Final with Attrition
STRATUM 1	0 - 25 kW	3.5030	0	1,066	31.0360	5.5710	5939	0.0967	15	15	17
STRATUM 2	26 - 50 kW	23.3710	0	423	219.4546	14.8140	6266	0.1020	16	16	18
STRATUM 3	51 - 100 kW	39.9100	0	344	650.9132	25.5130	8776	0.1429	22	22	25
STRATUM 4	101 - 125 kW	35.2080	0	99	1651.7722	40.6420	4024	0.0655	10	10	11
STRATUM 5	GT- 125 kW	189.0510	0	194	35213.2731	187.6520	36404	0.5928	93	93	104
EST POP MEAN (wtd by N)		31.7548	0	2,126			61410	1.0000	156	156	175

Sample Estimate	**Adj Sample Estimate**
156	**175**

RELATIVE PRECISION OF SAMPLE KW ESTIMATE

		TOTAL KW Optimal n (col. h)	TOTAL KW Adjusted n (col. i)	MEAN KW Adj. n
Variance contributed by strata:	1	2,483,695	2,483,695	0.549505
	2	2,518,768	2,518,768	0.557265
	3	3,433,350	3,433,350	0.759612
	4	1,617,085	1,617,085	0.357772
	5	7,499,662	7,499,662	1.659263
Total Variance		17,552,559	17,552,559	3.883416
Standard Error		4189.577478	4189.577478	1.970638512
Desired Conf. Level		90%	90%	90%
(z two tailed)		1.645	1.645	1.645
Conf. Interval		6891.854951	6891.854951	3.241700353
MPU Est of kW		67510.657	67510.657	31.7548
Relative Conf. Int.		10.21%	10.21%	10.21%

Sample Design - Stratification

UTAH SCHEDULE 010 LOAD STUDY DESIGN OPTION FOR 2005
SIX STRATA, MEAN-PER-UNIT DESIGN

		a Sample Mean kW	b Sample Mean kWh	c 2004 Pop N	d Variance of Mean	e Standard Deviation	f Wtd. Devtns. c*e	g Proprtn. row f/ sum f	h Optimal Allocation g*h total	i Optimal with Attrition	j Final with Attrition
STRATUM 1	0 - 25 kW	3.5030	0	1,066	31.0360	5.5710	5939	0.1003	15	15	17
STRATUM 2	26 - 50 kW	23.3710	0	423	219.4546	14.8140	6266	0.1058	16	16	18
STRATUM 3	51 - 75 kW	25.5910	0	204	327.8634	18.1070	3694	0.0624	9	10	11
STRATUM 4	76 - 100 kW	59.9560	0	140	437.1026	20.9070	2927	0.0494	7	10	11
STRATUM 5	101 - 125 kW	35.2080	0	99	1651.772164	40.6420	4024	0.0680	10	10	11
STRATUM 6	GT- 125 kW	189.0510	0	194	35118.76	187.4000	36356	0.6141	90	90	101
EST POP MEAN (wtd by N)		31.7009	0	2,126			59205	1.0000	146	151	169

Sample Estimate	**Adj Sample Estimate**
146	**169**

RELATIVE PRECISION OF SAMPLE KW ESTIMATE

		TOTAL KW Optimal n (col. h)	TOTAL KW Adjusted n (col. i)	MEAN KW Adj. n
Variance contributed by strata:	1	2,483,695	2,483,695	0.549505
	2	2,518,768	2,518,768	0.557265
	3	1,630,301	1,441,725	0.318974
	4	1,356,475	883,919	0.195563
	5	1,617,085	1,617,085	0.357772
	6	7,961,305	7,961,305	1.761399
Total Variance		17,567,629	16,906,496	3.740478
Standard Error		4191.375492	4111.750948	1.9340315
Desired Conf. Level		90%	90%	90%
(z two tailed)		1.645	1.645	1.645
Conf. Interval		6894.812684	6763.830309	3.1814818
MPU Est of kW		67396.021	67396.021	31.7009
Relative Conf. Int.		10.23%	10.04%	10.04%

Sample Design

Bill Frequency Analysis Summary

Utah Irrigation Schedule 010
Six Strata

Range			Customer Count f	Interval Factor (1K) μ	μf	$\sqrt{\mu f}$	cum $\sqrt{\mu f}$	
0	to	25	1066	1.0	1,066.0	32.6	32.6	1,066
26	to	50	423	1.0	406.1	20.2	52.8	423
51	to	75	204	1.0	195.8	14.0	66.8	204
76	to	100	140	1.0	134.4	11.6	78.4	140
101	to	125	99	1.0	95.0	9.7	88.1	
126	to	150	57	1.0	54.7	7.4	95.5	
151	to	175	49	1.0	47.0	6.9	102.4	
176	to	200	27	1.0	25.9	5.1	107.5	
201	to	225	25	1.0	24.0	4.9	112.4	
226	to	250	11	1.0	10.6	3.2	115.6	268
251	to	275	3	1.0	2.9	1.7	117.3	
276	to	300	1	1.0	1.0	1.0	118.3	
301	to	325	4	1.0	3.8	2.0	120.3	
326	to	350	5	1.0	4.8	2.2	122.5	
351	to	375	1	1.0	1.0	1.0	123.4	
376	to	400	2	1.0	1.9	1.4	124.8	
401	to	450	1	2.0	2.0	1.4	126.2	
451	to	475	1	1.0	1.0	1.0	127.2	
476	to	550	1	3.0	3.0	1.7	128.9	
551	to	600	1	2.0	2.0	1.4	130.3	
601	to	800	2	8.0	15.9	4.0	134.3	
801	to	1,000	1	8.0	8.0	2.8	137.1	
1,001	to	2,000	1	40.0	40.0	6.3	143.5	
2,001	to	2,750	1	30.0	30.0	5.5	148.9	25
		Total N	2,126					2,126

BOUNDARIES INDICATED FOR STRATA:				
	3	4	5	6
1	49.6	37.2	29.8	24.8
2	99.3	74.5	59.6	49.6
3		111.7	89.4	74.5
4			119.1	99.3
5				124.1

SAMPLING STATISTI	Avg. kWh[2]	Mean kW[2]	Res. Variance[2]
1	0	3.503	5.571
2	0	23.371	14.814
3	0	25.591	18.107
4	0	59.956	20.907
5	0	95.052	67.321
6	0	404.370	257.663

[1] Billing records for the twelve months ended June 2005

[2] Load Research estimates based on Idaho Schedule 010 sample data

Sample Design - Stratification

UTAH SCHEDULE 010 LOAD STUDY DESIGN OPTION FOR 2005
SIX STRATA, MEAN-PER-UNIT DESIGN

		a Sample Mean kW	b Sample Mean kWh	c 2004 Pop N	d Variance of Mean	e Standard Deviation	f Wtd. Devtns. c*e	g Proprtn. row f/ sum f	h Optimal Allocation g*h total	i Optimal with Attrition	j Final with Attrition
STRATUM 1	0 - 25 kW	3.5030	0	1,066	31.0360	5.5710	5939	0.1371	15	15	17
STRATUM 2	26 - 50 kW	23.3710	0	423	219.4546	14.8140	6266	0.1447	15	15	17
STRATUM 3	51 - 75 kW	25.5910	0	204	327.8634	18.1070	3694	0.0853	9	10	11
STRATUM 4	76 - 100 kW	59.9560	0	140	437.1026	20.9070	2927	0.0676	7	10	11
STRATUM 5	101 - 250 kW	95.0520	0	268	4532.117041	67.3210	18042	0.4166	44	44	49
STRATUM 6	GT- 250 kW	404.3700	0	25	66390.22157	257.6630	6442	0.1487	16	16	18
EST POP MEAN (wtd by N)		29.5474	0	2,126			43309	1.0000	106	110	123

Sample Estimate	Adj Sample Estimate
106	123

RELATIVE PRECISION OF SAMPLE KW ESTIMATE

		TOTAL KW Optimal n (col. h)	TOTAL KW Adjusted n (col. i)	MEAN KW Adj. n	Weighted St.Dev	Weighted Variance
Variance contributed by strata:	1	2,483,695	2,483,695	0.549505	2.793361	15.56182
	2	2,705,311	2,705,311	0.598537	2.94747	43.66383
	3	1,630,301	1,441,725	0.318974	1.737454	31.46009
	4	1,356,475	883,919	0.195563	1.376754	28.78381
	5	6,327,257	6,327,257	1.399874	8.486373	571.3111
	6	995,853	995,853	0.220328	3.029904	780.694
Total Variance		15,498,892	14,837,759	3.282780	20.37132	1471.475
Standard Error		3936.863223	3851.981227	1.8118444	V =	3.22631
Desired Conf. Level		90%	90%	90%		
(z two tailed)		1.645	1.645	1.645		
Conf. Interval		6476.140001	6336.509119	2.9804841		
MPU Est of kW		62817.721	62817.721	29.5474		
Relative Conf. Int.		10.31%	10.09%	10.09%		

Utah Irrigation Sample Designs

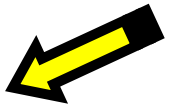
3 Strata – 235 recorders + 24 (10%) = $78,218

4 Strata – 203 recorders + 20 = $67,346

5 Strata – 175 recorders + 18 = $58,286

6 Strata – 169 recorders + 17 = $56,172

6 Strata (adjusted) – 123 + 20 = $43,186



Data acquisition merged with FieldNet Pro operations for summer months only.

Sample Expansion

The expansion of sample data using mean-per-unit procedures are simple and straight forward. The estimate of the population mean ($\hat{Y}$) is derived by multiplying the sample mean ($\ddot{y}$) against the total number of customers in the target group (N), as indicated below:

$$\hat{Y} = N\ddot{y} = N \sum_{n} y_i/n$$

If the sample mean ($\ddot{y}$)is derived from a stratified sample, the population mean ($\hat{Y}$) is derived by performing the above outlined procedure on the individual strata basis (h) and summing the strata totals to derive the estimate for the total population, as outlined below:

$$\hat{Y} = \Sigma N_h \ddot{y}_h = N \sum_{n} y_{hi}/n_h$$

Sample Design

Random Sample Selection

Wyoming Small General Service Sample Parameters
Secondary Voltage Level

Active Customers with kWh Meters
March 2004 History

Stratum	1	2	3	4	5
Sampling Frame	9,239	6,933	1,537	450	137
Sample	10	16	15	10	10
Interval	923.90	433.31	102.47	45.00	13.70
Random Starts					
Primary					
Random No.[(1)]	0.58586	0.09998	0.14346	0.74103	0.24200
Start	541	43	15	33	3
Alternate 1					
Random No.[(1)]	0.87308	0.07351	0.96423	0.26432	0.66432
Start	807	32	99	12	9
Alternate 2					
Random No.[(1)]	0.26422	0.94305	0.77341	0.56170	0.55293
Start	244	409	79	25	8
Alternate 3					
Random No.[(1)]	0.88640	0.12908	0.30134	0.49127	0.49618
Start	819	56	31	22	7
Alternate 4					
Random No.[(1)]	0.78171	0.81263	0.64270	0.82765	0.46473
Start	722	352	66	37	6

[(1)] Random numbers from Probability and Statistics in Engineering and Management Science, Hines & Montgomery, 2nd Ed, Pg. 628, beginning at row 19, col 4.