A Stratified Random Sampling Plan for an Irrigation Customer Telephone Survey

May 1986

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A STRATIFIED RANDOM SAMPLING PLAN FOR AN
IRRIGATION CUSTOMER TELEPHONE SURVEY

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SUMMARY

This report describes the procedures used to design and select a sample for a telephone survey of individuals who use electricity in irrigating agricultural cropland in the Pacific Northwest.^(a) The survey is sponsored by the Bonneville Power Administration (BPA) and is intended to gather information on the irrigated agricultural sector that will be useful for conservation assessment, load forecasting, rate design, and other regional power planning activities.

The sample is a stratified two-stage sample. Eight strata were defined to correspond to geographic agricultural production areas (APAs). In these eight strata, the irrigated farms in the Pacific Northwest are grouped into areas with similar cropping and climatic characteristics. The first-stage primary sampling units (PSUs) are utilities with an irrigation load in a geographic strata. Utilities serving customers in two or more APAs were correspondingly partitioned into two or more PSUs. At the second stage, irrigation accounts from the selected utility's billing records were sampled.

Distributional analysis of the MWh billed by each PSU showed that a cut point at 30,000 MWh was appropriate for separating the PSUs into high and low MWh groups. About 91 percent of the total regional irrigation load was used by high group utilities with irrigation loads exceeding 30,000 MWh. All 29 PSUs in the high group were selected for the sample.

Another 23 PSUs in the low MWh group were randomly selected from among all remaining PSUs with irrigation loads. The final PSU sample for the survey included 40 utilities partitioned into 52 PSUs that accounted for 97 percent of 1980 Pacific Northwest regional irrigation load. The sample represents every geographic area in the region where electricity is used for irrigation and includes both public and private (investor-owned) utilities.

(a) For purposes of this study, the Pacific Northwest is defined as Washington, Oregon, Idaho, Montana (west of the Continental Divide) and very small parts of Wyoming, Utah, Nevada and California where the service areas of utilities supplied by BPA power cross into these states.

Approximately 1700 telephone responses were allocated to the selected PSUs based on the relative sizes of their 1984 irrigation loads. As a result of this process, 1500 responses were allocated to the high group PSUs and 200 responses were allocated to the low group. Allocations to individual PSUs ranged from 6 to 200.

Elementary sampling unit (ESU) customers were selected for the sample by first partitioning the PSU's irrigation loads into six customer usage strata (U-strata). Based on an analysis of the distribution of irrigation loads, the highest usage stratum (high U-stratum) was usually defined as any irrigation customer using in excess of 500 MWh in a year. The other five usage strata each accounted for 20 percent of the utility's remaining irrigation load after the high U-stratum load had been subtracted. All customers in the high U-stratum were selected for the sample. Equal numbers of customers from each of the five remaining U-strata were also selected until the number of responses allocated to the PSU was reached.

In some cases, utilities were unable to provide MWh consumption data by customer because of the format of their billing record system. In such cases, sample selection was based on the distribution of irrigation meter kWh consumption, with consideration for the potential for multiple meters per customer incorporated in the sampling calculations. Cross-checking the sampled meters for duplicate customers was also necessary when metered data were used in sampling.

The stratified random sampling methods used in this study will provide better precision in estimating the parameters of interest to BPA in the irrigation sector than would simple random sampling methods. The process of developing and implementing stratified random sampling methods for 40 utilities with different billing record formats was time-consuming and difficult. However, the validity of the survey results will be significantly enhanced because these methods were used.

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GLOSSARY

DEFINITIONS

UNIVERSE (to be sampled)	All "irrigated farms" located in the Pacific Northwest region. [Operationally: all "irrigation accounts" listed in utility records]. For purposes of this study, the Pacific Northwest region is defined as the states of Washington, Oregon, Idaho, Montana (west of the Continental Divide), and very small parts of Wyoming, Utah, Nevada and California where the service areas of public utilities supplied by BPA power cross into these states.
ELIGIBLE RESPONDENTS	Farm managers or irrigation managers for farms.
ELEMENTARY SAMPLING UNITS (ESU)	Irrigation accounts listed in Pacific Northwest utility records; about 55,200 in 1982 count of irrigation customers or meters. Many utilities do not have the capability to efficiently aggregate multiple meter charges billed to the same irrigation operation. That is, they cannot conveniently produce a "customer" listing that contains the total annual usage (kWh) per customer, since multiple bills (one for each meter), are sent to the "customer." Thus, depending on the utility, an ESU may be either an irrigation customer or an irrigation meter. Adjustments in sampling procedures were necessary when utilities were only able to provide consumption data by meter.
PRIMARY SAMPLING UNITS (PSU)	Partitioned utilities that include those farms in a utility's service area that are located in a specific agricultural production area (APA). By this definition, the 78 utilities with irrigation loads produce 103 PSU.
AGRICULTURAL PRODUCTION AREA (APA)	A geographical partitioning of the BPA service area into eight areas that have similar cropping and climatic patterns. The eight APAs will be treated as geographic strata in the sampling.
SAMPLING PROPORTIONATE TO SIZE	Here, size is defined as MWh delivered to all irrigation customers by a PSU and, at the customer (ESU) level, by the MWh billed to the farm or meter.

1.0 INTRODUCTION

The purpose of this report is to specify a sample design for a survey to determine the irrigation system characteristics, irrigation practices, and attitudes regarding them, of operators of irrigated farms in the Pacific Northwest region. The Bonneville Power Administration (BPA) requested that Pacific Northwest Laboratory (PNL) design, manage and analyze the results of this survey as part of an effort to gather information for conservation planning, load forecasting and other purposes within BPA. One important product of the survey will be an extensive computerized data base on the characteristics of irrigation operations in the Pacific Northwest for use by BPA conservation planners and others. Energy use (MWh) for irrigation and number of irrigation accounts at the utility level will be used in defining the sampling frame for the survey.

This report is divided into five chapters. Chapter 2.0 summarizes the results of the sample design and selection process. The third chapter describes the procedures that were used to select utilities for inclusion in the irrigation survey sample and to allocate the 1700 total required responses among the sampled utilities. Chapter 4.0 presents the general methodology developed for selecting irrigation customers from within the various utilities for inclusion in the irrigation survey sample. The final chapter of the report describes the sampling procedures that were implemented at each utility included in the survey sample.

2.0 RESULTS AND CONCLUSIONS

In designing the sample for the irrigation customer telephone survey, BPA and PNL project staff identified several requirements:

1. Financial resources for the survey required that the number of customer telephone responses to the survey be limited to approximately 1700 and the number of utilities in the sample to approximately 50
2. The utilities and irrigation customers selected for the sample should represent a high proportion of Pacific Northwest irrigation electrical demand
3. The sample should be as representative as possible (given requirement 2) of the total population of irrigators in the Pacific Northwest.

The sample design described in this report fulfills these requirements. It is a stratified two-stage sample that includes both large and small utilities (in terms of irrigation loads) and large and small irrigation customers from within utility service areas. It covers all of the geographic areas in the Pacific Northwest where electricity is used for irrigation and includes both public and private utilities.

The eight geographic strata (G-strata) used in partitioning Pacific Northwest utilities with irrigation loads into primary sampling units (PSUs) range from western Montana to the Oregon/Washington coast, and represent every geographic area in the region where electricity is used for irrigation. The 29 high group PSUs that were selected with probability one for inclusion in the sample (based upon a 1980 irrigation load within a G-strata in excess of 30,000 MWh) represented 91 percent of 1980 regional irrigation load. The 23 low MWh group PSUs that were selected for the sample based on the relative size of their irrigation load within a G-strata (from among PSUs with irrigation loads less than 30,000 MWh) raised the percentage of total regional 1980 irrigation load contained in the survey PSU sample to approximately 97 percent.

The 52 PSUs selected for the sample equate to 40 different utilities because some of the selected utilities span multiple APAs. All of the private (investor-owned) utilities in the Pacific Northwest with irrigation loads were included in the survey, except Puget Sound Power and Light. A total of 35 public utilities were included in the sample.

Initial survey response allocations to PSUs based on the relative sizes of their irrigation loads resulted in Idaho Power Company receiving the largest allocation (500 responses) among all utilities. Allocating almost 30 percent of the survey responses to one utility seemed to be a clear over-allocation of resources that would not allow for other utilities to be adequately represented in the study. Thus, Idaho Power's final response allocation was reduced to 200. This allocation was still the largest among all selected utilities, but it allowed for an additional 300 responses to be available for allocating to other PSU utilities. Grant County Public Utility District received the largest response allocation among public utilities at 175.

Private utilities received 35 percent of the final total response allocation (627 responses) and public utilities received 65 percent (1182 responses). As stated previously, private and public high MWh group PSUs were initially allocated 1500 total responses while low MWh group PSUs were initially allocated 200 responses. However, where possible, the sampling procedure required a minimum of two responses per MWh usage strata (U-strata) within each utility. This led to a final total response allocation of 1809.

Seven utilities representing approximately 13 percent of 1984 regional irrigation load required that customers' permission be received either through a signed consent form or a telephone call before the customers' names could be released for inclusion in the survey sample. This requirement resulted in unforeseen reductions in sample sizes for these utilities. Irrigation customers from these utilities will be under-represented in the survey compared to the representation that would have been obtained from response levels initially allocated to them. However, the significance of the problem introduced by the permission requirements cannot be assessed until response levels to the survey are known, billing records for survey respondents are obtained, and statistical weights for the survey responses are developed.

Selection of ESUs (irrigation accounts) for the sample was based on the stratification of billed electric loads within the selected utilities into six usage strata (U-strata). Based on an analysis of load (MWh) distribution by account from 19 purposely selected PSUs representing all eight APAs, it was decided that all irrigation accounts with annual loads in excess of 500 MWh should be included in the survey sample. This cut point defined the highest U-strata for 38 of the 40 utilities in the sample. It allowed for a significant proportion of the selected utilities' total loads to be included in the sample while also allowing for adequate representation of lower MWh consumption customers.

The five lower U-strata were defined based on 20 percent increments in the utilities' load that remained after the load of all high stratum customers was subtracted out. An equal number of customers were then selected for the survey sample from each of the five lower U-strata. For the majority of the irrigation load contained in the survey sample, it was possible to define utility-specific cut points, but in some cases, it was necessary to use the "representative" cut points calculated from the purposely selected PSUs for each G-strata because of a lack of utility-specific MWh distribution data.

The lack of individual customer consumption data for some utilities required the use of meter data for approximately 30 percent of the irrigation load contained in the study sample. This introduced some statistical problems into the stratified sample selection process. These problems were dealt with by using sampling procedures that incorporated data on the number of meters per customer in the sampling steps. After the survey is taken and customer consumption data are available from all utilities, survey participants for which only metered data were available can be more accurately classified into their correct usage strata.

SUMMARY

The sampling methods used in this study will provide much more precise estimates for the regional irrigation sector than would result from using a simple random sample of the same size. Selecting high usage PSUs and ESUs with certainty, while selecting low usage PSUs and ESUs proportional to size, will

provide for a much higher percentage of PNW regional irrigation load to be included in the survey. In addition, at each stage of sampling, high usage units are effectively censused, so they do not contribute to sampling error at their aggregation level. An example analysis was performed to characterize the potential improvement in estimation precision resulting from the use of the sampling methods described in this report. In this example, the relative standard deviation of an estimate of total MWh used for irrigation in Grant County PUD was reduced from 18.9 percent in a purely random sample to 2.6 percent for the sampling plan described in this study.

3.0 SAMPLE SELECTION AND RESPONSE ALLOCATION AT THE UTILITY (PSU) LEVEL

This chapter describes the procedures used to select utilities for the irrigation survey sample in such a way that a high level of Pacific Northwest regional irrigation load would be represented in the sample while also achieving a high level of geographic and usage diversity within the sample. It also presents the procedures used to allocate approximately 1700 successful telephone responses requested by BPA to the utilities in the sample.

3.1 PSU SAMPLING FRAME

Previous studies (Harrer, Lezburg and Wilfert 1985) on the irrigation sector in the Pacific Northwest have separated the region into the 11 agricultural production areas (APAs) illustrated in Figure 3.1. These APAs are designed to broadly group irrigation customers into areas that have similar climates and cropping patterns. In this study, BPA desired that particular emphasis be given to APAs 2, 3, 6 and 10 in constructing a sample framework for the survey because these APAs comprise the major portion (over 80 percent) of

FIGURE 3.1. Pacific Northwest Agricultural Production Areas (APAs)

the regional irrigation load. The remaining seven "lower load" APAs were combined into four geographic strata. This process resulted in the geographic strata (G-strata) designations for this study listed in Table 3.1.

Data on the MWh delivered to irrigation accounts by utilities in 1980^(a) provided the basis for defining the sampling plan. These data were augmented by the 1982 data on number of irrigation accounts.^(b) These data showed that the combined load of utilities with individual loads greater than 30,000 MWh comprised about 90 percent of total regional irrigation load. Thus, a load of 30,000 MWh was designated as a cut point for sampling, with all utilities with loads greater than 30,000 MWh in a G-strata classified into a high MWh group and all utilities with loads less than this amount classified into a low MWh group.

TABLE 3.1. Geographic Strata Designations Defined For This Study

<u>Strata Designation For This Study</u>	<u>Previous APA Designation (From Figure 1)</u>	<u>Emphasis Level Requested For Sampling</u>
1	10 - Southern Idaho	High
2	3 - Columbia Basin	High
3	6 - North Central Oregon	High
4	2 - Yakima Valley	High
5	7 - Southern Oregon 8 - Northeast Oregon	Low
6	4 - Eastern Washington	Low
7	9 - Northern Idaho 11 - Western Montana	Low
8	1 - Western Washington 5 - Western Oregon	Low

-
- (a) Unpublished data developed by Northwest Economic Associates and supplied by Fred Gordon, Conservation Planning, Bonneville Power Administration.
 (b) Unpublished data supplied by Cam Downing, Power Forecasting, Bonneville Power Administration.

Some characteristics of the primary sampling unit (PSU) utilities in the high and low MWh groups are listed in Tables 3.2 and 3.3. The PSU defined by Idaho Power Company serving farms in Stratum 1 (APA 10) delivered about 4.5 times as many MWh as the next largest PSU (Utah Power and Light, also in Stratum 1), so a special stratum was created for it.

3.2 UTILITY (PSU) SAMPLE SELECTION

According to the sampling strategy developed for use in this project, all utilities in the high MWh group are included with a probability of one. The utilities selected on this basis are shown in Table 3.4.

TABLE 3.2. Characteristics of Irrigation Survey Sampling Frame,
High MWh Group^(a)

I. HIGH EMPHASIS						
G-Stratum Number	0	1	2	3	4	Total
APA Number	10	10	3	6	2	
APA Name	Idaho Power Co.	Southern Idaho	Columbia Basin	No. Central Oregon	Yakima Valley	
No. of PSU Utilities	1	2	8	3	4	18
No. of ESU Accounts	10,102	1,875	9,471	3,061	5,349	29,858
1980 MWh Irrigation Load	1,414,611	453,222	1,051,468	425,138	217,615	3,562,054
% of Total PNW Load	30.9	9.9	23.0	9.3	4.8	77.9
of High Group Load ^(b)	--	16.6	38.4	15.5	8.0	78.5
No. of Respondents	200	215	502	203	102	1,222

II. LOW EMPHASIS					
G-Stratum Number	5	6	7	8	Total
APA Number	7&8	4	9&11	1&5	
APA Name	So. + NE Oregon	Eastern Washington	No. Idaho W. Montana	W. Oregon W. Wash.	
No. of PSU Utilities	5	2	2	2	11
No. of ESU Accounts	5,230	732	1,249	4,876	12,087
1980 MWh Irrigation Load	328,750	109,703	62,154	87,337	587,944
% of Total PNW Load	7.2	2.4	1.4	1.9	12.9
% of High Group Load ^(b)	12.0	4.0	2.3	3.2	21.5
No. of Respondents	156	52	29	41	278

(a) High MWh group is defined as any utility within an APA that had an irrigation load of 30,000 MWh in 1980.

(b) Represents percentage of total 1980 Pacific Northwest regional load comprised by all high group utilities in each geographic stratum, excluding Idaho Power Co.

TABLE 3.3. Characteristics of Irrigation Survey Sampling Frame,
Low MWh Group^(a)

I. HIGH EMPHASIS					
G-Stratum	1	2	3	4	Total
No. of PSU Utilities	10	2	6	5	23
No. of ESU Accounts	1,241	46	881	647	2,815
1980 MWh Load	63,455	12,228	20,873	31,924	128,480
% of Total PNW Load ^(b)	1.4	0.3	0.5	0.7	2.8
% of Low Group Load ^(c)	15.1	2.9	5.0	7.6	30.5
No. of Respondents	30	6	9	16	61

II. LOW EMPHASIS					
G-Stratum	5	6	7	8	Total
No. of PSU Utilities	7	8	18	18	51
No. of ESU Accounts	1,741	1,241	4,381	3,060	10,423
1980 MWh Load	69,556	48,975	135,391	38,561	292,484
% of Total PNW Load ^(b)	1.5	1.1	3.0	0.8	6.4
% of Low Group Load ^(c)	16.5	11.6	32.2	9.2	69.5
No. of Respondents	34	23	64	18	139

- (a) Low MWh group is defined as any utility within an APA that reported an irrigation load of less than 30,000 MWh in 1980.
 (b) Represents percentage of total 1980 Pacific Northwest regional irrigation load comprised by all low group utilities in each geographic stratum.
 (c) Represents percentage of total 1980 low group regional irrigation load comprised by all low group utilities in each geographic stratum.

Initial specifications were that "about 50" utilities in total should be contacted. Since 29 PSUs were sampled in the high group, about 20 utilities need to be sampled from the low MWh group to meet this requirement. It is advisable to have at least two utilities selected in each of the G-strata. The first step was to allocate among G-strata the approximately 20 utilities to be sampled based on "% of Low MWh Group" figures in Table 3.3, with the additional constraint of at least two utilities in each stratum. This gives the following allocation, requiring 23 PSUs.

G-Stratum	1	2	3	4	5	6	7	8
No. of PSUs	3	2	2	2	3	2	7	2

TABLE 3.4. Utilities With Irrigation Loads Exceeding 30,000 MWh Selected for the Irrigation Survey

<u>Utility Name</u>	<u>G-Stratum Number</u>	<u>Agricultural Production Area</u>
Idaho Power Company	0(1)(a)	Southern Idaho
Utah Power and Light	1	Southern Idaho
Raft River Coop.	1	Southern Idaho
Grant County PUD	2	Columbia Basin
Big Bend Electric	2	Columbia Basin
Benton County PUD	2	Columbia Basin
Franklin County PUD	2	Columbia Basin
Columbia REA	2	Columbia Basin
Pacific Power and Light	2	Columbia Basin
Benton REA	2	Columbia Basin
Washington Water Power	2	Columbia Basin
Umatilla Electric Coop.	3	North Central Oregon
Pacific Power and Light	3	North Central Oregon
Columbia Basin Coop.	3	North Central Oregon
Pacific Power and Light	4	Yakima Valley
Okanogan PUD	4	Yakima Valley
Benton REA	4	Yakima Valley
Chelan County PUD	4	Yakima Valley
Pacific Power and Light	5	Southern and N.E. Oregon
Harney Electric Coop.	5	Southern and N.E. Oregon
Idaho Power Co.	5	Southern and N.E. Oregon
Central Elec. Coop.	5	Southern and N.E. Oregon
Midstate Coop.	5	Southern and N.E. Oregon
Lincoln Coop. (WA)	6	Eastern Washington
Washington Water Power	6	Eastern Washington
Lost River Coop.	7	Northern Idaho - W. Montana
Vigilante Electric Coop.	7	Northern Idaho - W. Montana
Pacific Power and Light	8	W. Washington - W. Oregon
Portland General Electric	8	W. Washington - W. Oregon

(a) Idaho Power Company's irrigation load is primarily located in Geographic Stratum 1, but its relative irrigation load is so large that it was assigned its own stratum.

The required number of low-range PSUs allocated to each G-stratum were then selected with probability proportional to size within the G-stratum. The 2 to 18 PSUs in each stratum were ordered from highest to lowest MWh usage, the cumulative percentage of the total MWh usage within each stratum used by each utility in the stratum was calculated. Then, the required number of sampled PSUs was selected by using computer-generated random numbers between 0 and 100. The first PSU selected was the one whose cumulative usage percentage included the first selected random number. This process was continued in each G-stratum by skipping random numbers that fell in the range of utilities already selected until the required number of PSUs in each stratum was reached. The utilities initially selected by this method are listed in Table 3.5.

More random numbers were generated than the required number of utilities for each stratum so that alternate utilities would be available if we were unable to get a selected utility to participate in the study. These alternates are also listed in Table 3.5 and were used in the following cases:

1. East End Mutual was substituted for Rural Electric Company in Geographic Stratum 1 because the Board of Directors of Rural Electric Company voted not to participate in the irrigation study, citing a "lack of staff time" as the reason for refusal.
2. At the request of BPA staff, Fall River Electric Cooperative was substituted for South Side Electric Lines in Geographic Stratum 1 because of Fall River's more extensive involvement in BPA-sponsored programs.
3. South Side Electric Lines was substituted for Unity Power and Light in Geographic Stratum 1 because Unity Light and Power was unable to deliver requested sampling data within the time period required to construct the survey sample.
4. C.P. National in Geographic Stratum 5 was dropped from the study because its Oregon operations are now being acquired by Idaho Power and a considerable amount of sensitivity would be associated with any requests for data. Individuals from Umatilla Electric Cooperative

TABLE 3.5. Utilities in Low MWh Group^(a) Initially Selected for Sample

Utility	Geographic Strata	1980 MW Hour Load	Selection Order ^(b)
Fall River Cooperative	1	24,559	5 ^(c)
South Side Electric Lines	1	12,914	3
Rural Electric Company	1	10,916	2
Unity Light and Power Company	1	7,081	1
East End Mutual	1	3,856	4 ^(c)
Richland Energy Service	2	8,442	2
Lincoln Electric Coop.	2	3,756	1
Wasco Electric Coop.	3	9,430	2 ^(c)
Hood River Electric Coop.	3	1,391	4 ^(c)
North Wasco PUD	3	1,257	1
Columbia Power Coop.	3	5,800	3 ^(c)
Klickitat County PUD	4	22,888	1 ^(c)
Nespelem Valley Electric Coop.	4	3,950	3 ^(c)
Kittitas County PUD	4	2,075	2 ^(c)
Puget Sound Power and Light	4	1,394	4 ^(c)
C.P. National	5	22,815	3
Surprise Valley Elec. Corp.	5	22,713	1
Umatilla Electric Coop.	5	15,966	5 ^(c)
Columbia Power Coop.	5	5,800	2 ^(c)
Wasco Electric Coop.	5	1,665	4 ^(c)
Douglas County PUD	6	28,977	1
Inland Power and Light	6	10,077	2
Columbia REA	6	4,534	3 ^(c)
Pacific Power and Light	6	2,030	4 ^(c)
Idaho Power Company	7	28,145	6 ^(c)
Washington Water Power	7	27,520	8 ^(c)
Utah Power and Light	7	18,983	1
Montana Power Company	7	11,613	10 ^(c)
Salmon River Coop.	7	9,589	5
Flathead irrig. Power Project	7	8,587	2
Ravalli County Elec. Coop.	7	6,432	7
Kootenai REA	7	6,405	4 ^(c)
Flathead Electric Coop.	7	4,330	9 ^(c)
Pacific Power and Light	7	1,611	3
Puget Sound Power and Light	8	12,543	1 ^(c)
Consumers Power Inc.	8	5,982	3 ^(c)
Douglas Electric Coop.	8	2,251	2 ^(c)
Wahkiakum County PUD	8	721	4 ^(c)

(a) Low MWh Group = Utilities that have a megawatt hour (MWh) load of less than 30,000 MWh within a given geographic stratum.

(b) Selection order based on the order in which the random numbers, corresponding to cumulative PSU usage percentages, were drawn.

(c) Alternates to be included in the sample only if randomly selected designated utilities choose not to participate in the study.

whose operations are located in G-stratum 5 were substituted in the sampling process for C.P. National irrigation customers.

5. Idaho Power's response allocation in Geographic Stratum 7 was replaced by Washington Water Power because of uncertainty about whether Idaho Power could provide customers from this G-stratum for inclusion in the survey sample.
6. Clallam County Public Utility District was substituted in G-stratum 8 because for various reasons, cooperation in the study could not be obtained from Puget Sound Power and Light, Consumers Power Incorporated and Wahkiakum Public Utility District.

After these modifications to the initial PSU utility selection, the utilities selected for the irrigation survey sample were those listed in Table 3.6. Note from Table 3.6 that several PSUs, in different G-strata were selected for some utilities. The 40 utilities (52 PSU) selected for the irrigation survey sample comprised approximately 97 percent of 1980 irrigation electrical demand in the Pacific Northwest region. They represent every irrigation area in the region, include both private (investor-owned) and public utilities, and include both small and large utilities.

3.3 INITIAL ALLOCATION OF CUSTOMER INTERVIEWS (ESUs) AMONG UTILITIES (PSUs)

In this study, allocation of a desired level of 1700 successfully completed telephone interviews among selected utilities was performed based on the relative sizes of the utilities' regional irrigation loads.

3.3.1 High and Low MWh Group Interview Allocations

A preliminary allocation of interviews was performed using 1980 irrigation load data.^(a) This allocation resulted in Idaho Power Company receiving over 500 of the total responses. Allocating over 500 responses to Idaho Power would

(a) Unpublished data developed by Northwest Economic Associates and supplied by Fred Gordon, Conservation Planning, Bonneville Power Administration.

TABLE 3.6. Utilities Selected for Irrigation Survey Sample

Utility Selected	MWh Group ^(a)	G-Strata Covered ^(b)
1. Idaho Power Co.	High	0 (1) ^(c)
2. Utah Power and Light	High	1, 7
3. Raft River Coop.	High	1
4. South Side Electric Lines	Low	1
5. Fall River Cooperative	Low	1
6. East End Mutual	Low	1
7. Grant County PUD	High	2
8. Big Bend Electric	High	2
9. Benton County PUD	High	2
10. Franklin County PUD	High	2
11. Columbia REA	High	2
12. Pacific Power and Light	High	2, 3, 4, 5, 7, 8
13. Benton REA	High	2, 4
14. Washington Water Power	High	2, 6, 7
15. Richland Energy Service	Low	2
16. Lincoln Electric Coop.	High	2, 6
17. Umatilla Electric Coop.	High	3, 5
18. Columbia Basin Electric	High	3
19. Wasco Electric Coop.	Low	3
20. North Wasco PUD	Low	3
21. Okanogan PUD	High	4
22. Chelan County PUD	High	4
23. Klickitat County PUD	Low	4
24. Kittitas County PUD	Low	4
25. Harney Electric Coop.	High	5
26. Central Electric Coop.	High	5
27. Midstate Electric Coop.	High	5
28. Surprise Valley Electric	Low	5
29. Columbia Power Coop.	Low	5
30. Douglas County PUD	Low	6
31. Inland Power and Light	Low	6
32. Lost River Coop.	High	7
33. Vigilante Electric Coop.	High	7
34. Salmon River Coop.	Low	7
35. Flathead Irrig. Power Project	Low	7
36. Ravalli County Elec. Coop.	Low	7
37. Kootenai REA	Low	7
38. Portland General Elec.	High	8
39. Douglas Electric Corp.	Low	8
40. Clallam County PUD	Low	8

(a) Utilities with 1980 irrigation loads within a geographic strata that exceeded 30,000 MWh were placed in the high MWh group, and utilities with loads less than 30,000 MWh were placed in the low MWh group.

(b) The G-stratum with the largest usage for the utility is underlined.

(c) Idaho Power Company's irrigation load is primarily located in Geographic Stratum 1, but its relative irrigation load is so large that it was assigned its own stratum.

not allow for other utilities to be adequately represented in the surveys, so this utility's response allocation was specified at 200. Even at 200, Idaho Power's interview allocation remained the largest in the irrigation survey sample.

The remaining 1500 required successful responses for the survey were divided between the high MWh group and the low MWh group based on the percentage of total 1980 regional irrigation load (excluding Idaho Power Company's load) that the two groups comprised. This resulted in approximately 1300 successful responses being allocated to the remaining high MWh group utilities because these utilities comprised 87 percent of total irrigation load in 1980 (excluding Idaho Power). The remaining 200 successful responses were allocated to utilities in the low MWh group.

3.3.2 Individual Utility Interview Allocations

Analysis of 1984 irrigation load data obtained from utilities in conjunction with selecting customers (ESUs) for the survey sample (ESU sampling procedures are discussed in Chapter 4.0 of this report) revealed that billed irrigation loads for some utilities had decreased significantly from those reported to BPA for 1980, while other utilities' irrigation loads had increased. Thus, it was decided that 1984 data should be used to allocate survey responses to individual utilities within the high MWh and low MWh groups.

Total utility 1984 irrigation load data for 35 of the 40 utilities selected for the survey sample were obtained either through a listing provided by the utilities or over the telephone. The only utilities for which 1984 irrigation load data could not be obtained prior to response allocation were the following:

- Midstate Electric Cooperative
- Portland General Electric
- Clallam County PUD
- Douglas Electric Cooperative
- Flathead Irrigation and Power Project

When combined, these five utilities comprise less than four percent of Pacific Northwest regional irrigation load. Irrigation load data from 1980 was used to approximate the proper sample allocation for these utilities.

After 1984 irrigation load data had been collected, initial survey response allocations to utilities within the high group were made based on the percentage of total 1984 high group irrigation load comprised by each utility. The only exception to this allocation method was Idaho Power Company, which continued to receive an allocation of 200 successful responses. The initial response allocations for the selected high group utilities are presented in Table 3.7. As will be explained in Chapter 5, it was necessary in some cases to modify these initial response allocations when irrigation account load distribution data were received from the various utilities.

As reported in Table 3.6, six of the utilities selected for inclusion in the irrigation survey sample cover multiple G-strata. For three of these utilities, it was not possible to separate 1984 customer loads into different G-strata prior to sample selection. These utilities and the G-strata that they cover are as follows:

- Utah Power and Light - high MWh group for G-stratum 1, low MWh group for G-stratum 7
- Lincoln Electric Coop. - high MWh group for G-stratum 6, low MWh group for G-stratum 2
- Umatilla Electric Coop. - high MWh group for G-stratum 3, low MWh group for G-stratum 5

Although sample allocations representing both high and low MWh group PSUs were made for these utilities, the lack of customer data by G-stratum precluded sample selection by G-stratum. Thus, the low MWh group PSUs were combined with the high MWh group PSUs for these utilities, resulting in a reduction of three in the number of PSUs. When customer responses are obtained for these utilities, any customers found to lie in a low MWh group G-stratum will be placed in that stratum.

TABLE 3.7. Initial Allocated Successful Telephone Responses for High Group Utilities in Irrigation Survey Sample

Utility	G-Stratum	MWh Consumption Used in Sample Allocation ^(a)	Initial Allocated Responses
Idaho Power Co.	0	1,489,502	200
Utah Power and Light	1	290,506	148
Raft River Coop.	1	94,253	51
Grant County PUD	2	321,985	175
Big Bend Electric	2	216,041	117
Benton County PUD	2	234,182	127
Franklin County PUD	2	93,308	51
Columbia REA	2	107,400	58
Pacific Power and Light	2	30,683	17
Benton REA	2	21,582	12
Washington Water Power	2	31,918	17
Umatilla Electric Coop.	3	234,380	127
Columbia Basin Electric	3	30,748	17
Pacific Power and Light	3	84,118	46
Okanogan PUD	4	43,786	24
Pacific Power and Light	4	97,182	53
Benton REA	4	37,292	20
Chelan County PUD	4	31,472	17
Pacific Power and Light	5	118,234	64
Surprise Valley Electric	5	33,634	20
Central Electric Coop.	5	36,291	20
Midstate Electric Coop.	5	34,576	16
Harney Electric Coop. (Nevada)	5	40,941	22
Washington Water Power	6	44,477	22
Lincoln Electric Coop.	6	54,492	30
Lost River Electric	7	20,530	12
Vigilante Electric	7	35,637	19
Portland General Electric	8	38,000	21
Pacific Power and Light	8	20,934	12
TOTAL INITIAL RESPONSE ALLOCATION		3,968,084	1,535

- (a) MWh consumption levels for sample allocation are equal to 1984 irrigation loads for all utilities except Portland General Electric.
- (b) Idaho Power Company was assigned a response allocation of only 200 because, based on the relative size of its irrigation load (1.5 million MWh), over 500 of the 1700 total responses would have been allocated to Idaho Power.

Initial response allocations for PSUs in the low MWh group were made in two steps. First, the percentages of total 1980 low MWh group consumption comprised by all low group utilities in each G-stratum were calculated. These percentages were used to allocate the 200 required responses for the low group among G-strata. The second step was to allocate the required responses for each G-stratum among selected utilities in each G-stratum using 1984 load data.

The calculations used in initially allocating responses to low MWh group utilities are illustrated in Table 3.8. The percentages of total low group 1980 MWh load comprised by all low group utilities in each G-stratum are shown

TABLE 3.8. Allocated Successful Telephone Responses for Low Group Utilities in Irrigation Survey Sample

G-Stratum	% of Total 1980 Low Group Load in G-Stratum ^(a)	Low Group G-Stratum Allocation	Selected Utility Name	% of 1984 Selected Load ^(b)	Initial Utility Response Allocation
1	15.3	31	Fall River East End Mutual South Side Electric	45.2 11.9 42.9	14 4 13
2	2.9	6	Richland Energy Service Lincoln Electric Coop.	58.4 41.8	4 3
3	5.0	10	Wasco Electric North Wasco PUD	86.6 13.4	9 1
4	7.9	16	Klickitat PUD Kittitas PUD	85.0 15.0	14 2
5	16.8	34	Umatilla Electric Harney Electric (Oregon) Columbia Power Coop.	41.2 47.1 11.8	14 16 4
6	11.4	23	Douglas County PUD Inland P and L	81.3 18.7	19 4
7	31.8	64	Washington Water Power Utah Power and Light Salmon River Coop. Flathead Power Project Ravalli Electric Kootenai REA Pacific Power and Light	35.0 21.0 11.2 12.0 9.7 9.0 1.9	22 13 7 8 6 6 2
8	8.9	18	Douglas Electric Coop. Clallam County PUD	30.7 69.3	6 12
TOTALS	100.0	202			203

(a) Total 1980 irrigation load for low group utilities was 420,964 MWh.

(b) Represents percent of total load for all utilities selected in a G-stratum comprised by each selected utility.

in the second column of Table 3.8. These percentages were used to derive the low group G-strata allocations shown in the third column using a total response allocation for all low group G-strata of 200. The percentages comprised by each selected utility of the combined 1984 load for all selected low group utilities in each G-stratum are shown in the fifth column of Table 3.8. These were used in dividing the G-strata allocations among selected utilities. The initial response allocations based on these percentages for the selected low group utilities are shown in the last column of Table 3.8. In many cases, adjustments to the initial response allocations shown in Table 3.8 were necessary in order to obtain a sample with improved statistical properties that conformed to the irrigation account MWh distribution characteristics of the various utilities. A description of these adjustments is presented in Chapter 5.

4.0 GENERAL SAMPLE SPECIFICATION AND SELECTION AT THE ESU (IRRIGATION CUSTOMER) LEVEL

Proper selection of irrigation customers for the irrigation survey sample required that the following tasks be performed:

1. specification of sampling criteria for selecting customers for the sample
2. development of sampling methods for identifying/selecting customers for the sample according to the sampling criteria.

The specific activities involved in performing these tasks are described in this chapter.

4.1 ESU (IRRIGATION CUSTOMER) SAMPLE SPECIFICATION

The sampling methods developed in this study are based on a sampling theory described by Roger L. Wright (Wright 1982). This article demonstrates the improvement in precision of estimation (of MW demand) when the population (customers of a utility) is separated into usage strata (U-strata) that account for equal percentages of the total utility MWh usage. This theory was combined with sampling the high MWh usage stratum customers with probability one (i.e., all high usage stratum customers are selected for the sample) in developing the sampling methodology for the BPA irrigation customer survey.

After performing some preliminary investigation, it was found that not all utilities would be able to construct a listing of their individual irrigation customers' kWh consumption. Therefore, sampling for these utilities had to be done from a listing of billed meters. This complicated the theory, but after the survey has been administered, the billing record information needed for "post-stratification" based on customer usage will be available to classify the respondents into their appropriate U-strata.

In order to develop a basis for sampling irrigation customers according to load, 1984 irrigation account load data for 14 utilities were obtained. These

data provided listings for 19 PSUs with at least one utility listing of individual customer kWh consumption for every G-stratum except Stratum 8. The data also provided at least one listing of metered account kWh consumption for every G-stratum. Thus, these data allowed for design of the customer sampling frame to incorporate load data from every G-stratum and to be flexible enough to be applied to either individual customer or metered account data.

Data from these 19 purposely selected PSUs were used to define the cut points for six MWh usage strata. The sixth stratum is the high MWh usage stratum, consisting of all customers using at least 500 MWh or metered accounts above 300 MWh for some G-strata. The low-usage group was defined as consisting of all customers or meters not in the high-usage stratum. This group was partitioned into five low-usage strata. Each of the five low U-strata accounted for 20 percent of the total MWh remaining in the purposely selected utilities after the MWh in the high stratum were taken out.

The cut points for U-strata change for different G-strata, but all have an upper limit that defines the high-usage stratum of 500 MWh for customers and 300 or 500 MWh for metered accounts. The 500-MWh limit was selected because it provided some large customers for all utilities that were analyzed without exceeding the tentative sample size allocation for the utilities.

Table 4.1 presents definitions of the upper limits (in MWh) for the low U-strata calculated in each G-stratum for both the customer (C) data and the meter (M) data. These definitions were used as the criteria for selecting irrigation accounts for the irrigation survey sample from among the utilities listed at the bottom of Table 4.1. The definitions presented in Table 4.1 were also used as sampling criteria for utilities for which MWh load data were not available to derive utility specific cut points based on 20 percent increments in load. In addition to the 14 utilities listed at the bottom of Table 4.1, the utilities for which cut points specific to their customers' load characteristics were defined include:

- Idaho Power Company
- Benton Rural Electric Association
- Chelan County PUD
- Ravalli County Electric Coop.

TABLE 4.1. Definition of Upper Limits in MWh for Low Usage Strata in Each Geographical Stratum

U-St. (a)	Cumulative Percentage	G-Stratum							
		1		2		3		4	
		C ^(b)	M	C	M	C	M	C	M
1	20%	125 ^(c)	70	70	25	45	25	30	15
2	40%	225	150	120	50	125	100	65	30
3	60%	300	250	200	100	240	200	125	50
4	80%	400	350	300	170	375	350	240	110
5	Max	500	500	500	500	500	500	500	500
	Based on Utility ^(d)	RFTR	UTAH	GRNT COLR	PP&L	UMAT WASC	PP&L	OKP	PP&L

U-St.	Cumulative Percentage	G-Stratum							
		5		6		7		8	
		C	M	C	M	C	M	C	M
1	20%	70	25	30	100	65	15	30	10
2	40%	125	50	92	200	110	35	65	20
3	60%	200	85	184	275	175	60	125	40
4	80%	275	160	320	375	285	250	240	70
5	Max	500	500	500	500	500	300	500	300
	Based on Utility	SRPV HRNY	PP&L	WWP	LINC DOUG	VIGL	PP&L	OKP	PP&L

(a) U-St. = Usage Stratum

(b) C is for customer data and M is for meter data.

(c) Numbers shown represent maximum MWh limits for placing an irrigation account within a geographic stratum into its proper usage stratum.

(d) The letter codes refer to the following utilities:

RFTR - Raft River Coop.	OKP - Okanogan PUD
UTAH - Utah Power and Light	SRPV - Surprise Valley
GRNT - Grant County PUD	HRNY - Harney Elec. Coop.
COLR - Columbia REA	WWP - Washington Water Power
PP&L - Pacific Power and Light	LINC - Lincoln Coop (WA)
UMAT - Umatilla Electric Coop.	DOUG - Douglas County PUD (WA)
WASC - Wasco Electric Coop.	VIGL - Vigilante Elec. Coop.

For the other 22 utilities included in the sample, "representative" cut points were defined based on the G-stratum cut points listed in Table 4.1 and used in sample selection. The assumption used is that the usage distributions for utilities where representative cut points were used in sample selection are similar to those for the utilities within the same G-stratum upon which the cut-points were based. The utilities for which utility-specific cut points were defined represented 78 percent of Pacific Northwest regional irrigation load and the use of "representative" cut points was necessary for utilities comprising 22 percent of regional load.

The only exception to the cut point for the high U-strata shown in Table 4.1 was for Idaho Power Company, where the total number of customers using 500 MWh or more was 700, exceeding the utility's response allocation of 200 by 500 customers. Idaho Power's high stratum cut point was raised to 2000 MWh, which resulted in 121 customers being included in this stratum and sampled with probability one. The other U-strata cut points for ESU stratification within Idaho Power were as follows:

- U-stratum 5, maximum = 2000 MWh
- U-stratum 4, maximum = 1270 MWh
- U-stratum 3, maximum = 800 MWh
- U-stratum 2, maximum = 500 MWh
- U-stratum 1, maximum = 250 MWh

PNL could not obtain preliminary customer kWh consumption data from Portland General Electric, the utility selected to represent G-stratum 8. Therefore, customer cut points from G-stratum 4 were used to define ESU U-strata for G-stratum 8. G-stratum 8 is expected to have smaller usage per customer than most G-strata and the distribution for G-stratum 4 indicates that relatively low-usage customers are predominant.

4.2 GENERAL DESCRIPTION OF SAMPLING METHODS FOR ESU SELECTION

In general, the sampling methods developed for use in this study require that the person doing the sampling (PNL or utility) have: a listing of accounts (customer or meter), the appropriate G-strata cut points from Table 4.1, and n_p , the allocated sample response size for the utility from

Table 3.7 or 3.8. The sampling task becomes more complicated as the listings change from the ideal customer listing sorted by (aggregated) total MWh usage of individual customers to unsorted meter data. The methods have step-by-step procedures for partitioning the total adjusted sample size to the U-strata and systematically (with a random start) selecting accounts from the listing. When accounts are for individual meters, cross-checking of names and addresses associated with the billings for the meters is required to come up with a sample listing free of duplicates. In addition, some information about the number of meters per customer in each of the MWh load strata is necessary in order to select the appropriate number of customers from each stratum for the survey sample.

The general procedures incorporated in the sampling methods are as follows:

Let n_r be the total number of allocated responses for a utility. Let n_H be the number of customers using at least 500 MWh. These customers will be selected with probability one. Then

$$n_L = n_r - n_H$$

is the number of responses needed from the five low-usage strata. In order to account for non-response and listing errors, let

$$n_{LS} = [1.333n_L]_I + 1$$

truncated to the whole number. Then the required equal sample size in each of the five low-usage strata is

$$n_u = n_L'/5$$

where

$$n_L' = n_{LS} + c_5$$

and

c_5 is an integer, (0, 1, 2, 3, or 4) that makes n'_L exactly divisible by 5.

The adjustment for listing and non-response error of $[1.333n_L]_I + 1$ truncated to the whole number was chosen based on an expected response rate of 80 percent and a listing error rate of 5 percent. Given these assumptions, the sample size, n_S , required to assure n_r responses is

$$n_S = n_r / 0.75 = 1.333 n_r.$$

To clarify these ideas, consider an example using data from Umatilla Electric Cooperative. This utility had a total usage in 1984 of 234,380 MWh; and 1003 irrigation usage meters billed to 448 customers. The preliminary customer respondent allocation for Umatilla (before CP National's allocation in G-stratum 5 was added) was:

$$n_r = 120 \text{ customers.}$$

There were $n_H = 51$ high-usage stratum customers so that

$$n_L = 120 - 51 = 69 \text{ low-usage group customers}$$

and

$$n_{LS} = [(1.333)69]_I + 1 = 91 + 1 = 92.$$

There are then 397, (448 - 51), customers available for sampling for the low group representatives. Then

$$n'_L = 92 + 3 = 95$$

and

$$n_U = 95/5 = 19$$

customers to be sampled in each low-usage stratum.

A modification to n_U for Umatilla is required since the 60 to 80 percent and 80 to 100 percent low-usage strata have 14 and 10 customers instead of the required 19. The resolution is made through several adjusting calculations. The adjusting calculations are based on sampling the strata with NCUST less than n_U with probability one, thus reducing the upper limit for the high group to customers with consumption in excess of 240 MWh. For Umatilla Electric,

$$n_L (\text{adj}) = 120 - 75 = 45$$

and

$$n_{LS} (\text{adj}) = [(1.333)45] + 1 = 60$$

Then

$$n_U' = 60/3 = 20$$

since the 60 sampled customers for the low group now represent only 3 strata. Thus, for Umatilla, all 75 customers with usage of 240 MWh or greater will be selected, and at least 20 customers will be selected from each of the 3 lowest usage strata (see Table 4.2).

The mechanism for selecting customers from strata where all customers are not sampled is to calculate the required sampling interval for each U-stratum as

$$I_U = [NCUST_U/n_U']$$

truncate to the whole number, and enter the result in the Sampling Interval column. Then every I_U -th customer in the listing that falls in the U-stratum is selected. For Umatilla, the sampling interval is 1 for the 40 to 60 percent U-stratum, (25/20), 2 for the 20 to 40 percent U-stratum, and 14 for the 0 to 20 percent U-stratum. This procedure is applicable to sorted customer listings, and, by skipping customers not in the U-stratum being sampled for, to unsorted customer listings.

TABLE 4.2. Example of Sample Allocation for Customer Data (Umatilla Electric)

Usage Stratum	MWh U-St. Limit	NCUST	n_U	n_{RU}	n'_{RU}	n'_U	Sampling Interval (I_U)
0 - 20%	45	295	19	14	15	20	14
20 - 40%	125	53	19	14	15	20	2
40 - 60%	240	25	19	14	15	20	1
60 - 80%	300	14	19	14	(14)	0	--
80 - 100%	500	10	19	14	(10)	0	--
Low Stratum Total		397	95	70	45	60	
High Stratum Total		51	51	51	75	75	
Total All Strata		448	146	121	120	135	

where NCUST = Number of customers in each U-stratum.

n_U = Preliminary number of customers from each U-stratum to be included in the survey sample.

n_{RU} = Preliminary number of customers from each U-stratum for which successful responses to the telephone survey are required.

n'_{RU} = Adjusted number of required successful responses from each U-stratum.

n'_U = Adjusted number of customers from each U-stratum to be included in the survey sample.

Grant County PUD in geographical stratum 2 provides a more straightforward example. It had a more equal split of total MWh usage to the high (43%) and low (57%) MWh usage groups than did Umatilla (where 90.7% of the total MWh was accounted for by the high group). For Grant, the total MWh usage in 1984 was 321,986 by 2,148 customers through 3,324 meters. The allocated sample size was 175 customers. There were $n_H = 120$ customers using at least 500 MWh, leaving $n_L = 55$ customers to represent the low group. Then

$$n_{LS} = [1.333(55)] + 1 = 75 = n'_L$$

and

$$n_U = 75/5 = 15$$

customers to be sampled in each low-usage stratum. Each low-usage stratum had enough customers to cover a sample size of 15.

It should be noted that the sampling method described above were the ideal method that was used whenever individual customer consumption data were available to PNL. Such data were available for 28 utilities included in the sample. However, the specific sampling method used for each utility was determined by the type of account listing available to PNL.

When a utility could not list consumption by customers, the potential for multiple meters per customer, and consequently, multiple sampling of the same customer, was high. For eight utilities that provided both customer and meter data, the average number of meters per customer ranged from 1.55 to 2.79, and the average for all 8 utilities was 2.3 meters per customer. Individual customers had as many as 43 meters, but most customers had only one meter. Having to use meter, rather than customer listings as the sampling list creates theoretical statistical problems, and requires that different sampling methods than those applied to customer consumption data be used.

The sampling procedures developed in this study for selecting customers for the survey sample from metered data account for the problems introduced by multiple meters by utilizing assumptions about the number of meters per customer in the calculations.

Data from seven utilities that provided both meter and customer data were used to determine factors for expanding customer sample sizes to the number of meters expected to be typically required to provide the needed individual customers. The average number of meters per customer in each U-stratum is given in Table 4.3 for the seven utilities. The last column has the expansion weights (E_u) used for each stratum. These expansion weights are approximately the same as the (weighted by NCUST) U-strata averages for the number of meters per customer.

The general procedures developed for sample selection from metered data will be described using an example for Pacific Power and Light in G-stratum 4.

TABLE 4.3. Average Meters per Customer

U-Stratum	Utility ^(a)							Stratum Average	Weight Used, E_u ^(b)
	GRNT	UMAT	WASC	OKP	SPRV	HRNY	VIGL		
1	1.08	1.11	1.34	1.19	1.28	1.66	1.49	1.31	1.3
2	1.34	1.64	2.18	2.00	2.00	2.62	2.14	1.97	2.0
3	1.68	2.93	3.54	2.31	2.71	3.08	2.38	2.66	2.5
4	2.16	3.67	3.12	3.48	3.07	5.22	3.74	3.49	3.5
5	2.55	3.62	6.40	4.55	4.06	5.50	5.65	4.32	4.3
6	4.94	9.02	12.0	4.50	13.6	10.17	8.57	8.47	8.5
Utility Average	1.55	2.24	2.04	1.66	2.07	2.79	2.28		
NCUST	2,148	448	161	842	394	127	387		
NMETER	3,324	1,003	329	1,395	814	354	883		

(a) See Table 4.1 for definition of utility codes.

(b) E_u = Weighting factors for deriving number of meters to be selected for sample corresponding to the required number of customers in each stratum.

Pacific Power and Light (PP&L) provided PNL with listings of meter billing data ordered by usage (MWh) for each of our G-strata 2, 3, 4, 5, 7 and 8. The listing for G-stratum 4 included accounts from PP&L's Yakima, Sunnyside and Toppenish Service Districts. There were 4,548 meter accounts with total billed usage of 97,182 MWh.

The process for allocating the required customer sample size using metered account data is given in Table 4.4. The upper MWh limits for the U-strata were determined by counting the number of meters with billed usage in each of 27 MWh ranges for usage less than 500 MWh and listing the exact usage for meters with at least 500 MWh billed. This frequency distribution was input to the computer, along with the MWh midpoints, and the cumulative MWh distribution calculated. Then, the MWh limits shown in Table 4.4 that split the usage less than 500 MWh into the 5 U-strata, each accounting for about 20 percent of the low usage, were calculated.

The numbers in column NMET of Table 4.4 are the number of meters with usage in the range of MWh determined by the limits; e.g., there were 2814

meters billed between 0.1 and 15 MWh, 926 meters billed between 15 and 29 MWh, etc., up to 87 meters billed between 115 and 500 MWh. There were $M_H = 6$ meters with billing greater than 500 MWh.

The rest of Table 4.4 is based on the calculations defined at the bottom of Table 4.4. First, the estimated number of customers in the high stratum, n_H , was calculated. This calculation was performed by multiplying the actual number of meters in the high stratum, M_H , by a conversion factor computed using data from Table 4.3. Then, the number of customers, n_U , required to assure the number of responses in each of the low MWh strata was calculated. This is 14, and is entered in the n_U column.

The number of meters to be sampled, M_U , were then derived, using the expansion factors, E_U , given in Table 4.3. The sampling interval was calculated, and a random sample of metered accounts within each U-stratum was selected using a computerized random sampling method (MINITAB, SAMPLE command). Finally, the last column, n_{rU} , gives the number of distinct customers that must be contacted and respond to obtain the required number of responses. For example, in U-stratum 5, we want at least 14 (n_U) distinct customers from the 61 meter accounts selected for checking, and need 10 responses from these 14.

The end product of the sampling procedures used in this study will be 1) a listing of the required number (n_U) of irrigation customer names, 2) addresses, and 3) phone numbers (if available) that will almost certainly be more representative of the areas of interest to BPA than would a simple random sample of irrigators. As stated previously, it is necessary that the sampling methods used in this study be as scientifically valid as possible without imposing excessive data collection burdens on utility staff or creating any data confidentiality problems. The specific sampling methods used to select customers from each utility in the survey sample are designed to meet these requirements. These methods are described in the final chapter of this report.

TABLE 4.4. Example of Sample Allocation for Meter Data,
(PP&L, G-stratum 4 data)

Usage Stratum	MWh Limit	NMET	n_u	E_u	M_u	SI_u	Meters Selected	n_{ru}
0 - 20%	15	2,814	14	1.3	19	148	19	10
20 - 40%	29	926	14	2.0	28	33	28	10
40 - 60%	56	474	14	2.5	35	13	35	10
60 - 80%	115	241	14	3.5	49	4	49	10
80 - 100%	500	87	14	4.3	61	1	61	10
Low Strata Total		4,542	70		192		192	50
High Strata Total		6	3	(0.385)	6		6	3
Total All Strata		4,548	73		198		198	53
Total '84 MWh		97,182						

$$\begin{aligned}
 n_r &= 53 \\
 n_H &= [M_H(0.3846)]_I + 1 = 3 \\
 n_L &= n_r - n_H = 50 \\
 n_{LS} &= [1.33n_L]_I + 1 = 67 \\
 n'_L &= n_{LS} + c_5 = 70 \\
 n_u &= n'_L/5 = 14 \\
 n_{ru} &= [(n_L + c'_5)/5]_I = 10 \\
 M_u &= [E_u n_u]_I + 1 \\
 SI_u &= [NMET_u/m_u]_I
 \end{aligned}$$

where

NMET = Number of meters in each U-stratum.

n_r = Number of required responses for PSU.

n_H = Estimated number of customers in high stratum, calculated as a function of the actual number of meters in the high stratum (M_H) and a conversion factor (0.3846) for the estimated number of meters belonging to the same customer in the high stratum.

M_u = Estimated number of meters necessary to be selected for each strata to obtain the required response levels (n_{ru}).

All other parameters = As defined previously in Tables 4.1 and 4.2.

5.0 UTILITY SPECIFIC SAMPLING METHODS

Significant differences in billing record formats and data processing capabilities were found by contacting the 40 utilities included in the irrigation survey sample. These differences included the utility's ability to:

- readily provide an ordered listing of annual consumption data by individual irrigation customer
- readily provide annual consumption data by individual irrigation customer, but not readily order these data from highest to lowest or lowest to highest
- readily provide and order only annual consumption data for metered irrigation accounts
- readily provide only unordered annual consumption data for metered irrigation accounts.

Several alternative sampling methods were developed for this study to deal with these differences. These methods are described in this chapter. Information on the specific sampling method used on each of the 40 utilities included in the study sample is presented. Adjustments in initial response allocations that were used in deriving final response allocations are described. The chapter concludes with a discussion of several problems that were incurred by using utility billing record data as the basis for sampling in the study and how these problems were addressed.

5.1 SAMPLING METHOD ALTERNATIVES

The sampling methods used in this study can be broadly separated into five alternative types. These alternatives are described in this section.

5.1.1 Method 1 - Sampling from an Ordered Customer List

This method was used when a utility could provide annual kWh consumption data by individual irrigation customer and could order these data from highest consumption to lowest or lowest to highest. Utilities with these characteristics provided PNL with an ordered listing of their irrigation customers' 1984

irrigation consumption. Identities of the customers were masked from PNL to protect customer confidentiality.

When an ordered list sorted by customer kWh consumption was provided, lines were drawn at the appropriate U-stratum limits for the utility. The counts for the number of customers (NCUST) in each of the six U-strata were then easily obtained. After these counts were made, sampling was able to proceed exactly like the Umatilla Electric and Grant County PUD examples discussed in Section 4.2. That is, n_u (the number of customers from each low U-stratum to be included in the survey sample), the sampling interval, and other necessary elements of the sampling procedure were calculated, and customer identification numbers corresponding to the appropriate customers were selected.

The MWh consumption listings were then returned to the utilities, along with a request for the names, addresses and telephone numbers (if available) of the customers corresponding to the customer identification numbers. The requested information was then provided by the utilities and input into the survey sample records. More detailed information on the procedures used in Method 1 are presented in Appendix A, in the form of the worksheet that was used to implement Method 1 or Method 2 on all utilities that provided customer kWh consumption data to PNL.

5.1.2 Method 2 - Sampling From a Customer List Not Sorted by kWh Usage

This method was used when utilities were able to provide individual customer consumption amounts but did not have the capability to readily sort their kWh listings by amounts consumed. The selection results from using this method are similar to those of Method 1. However, slightly more effort was required by the PNL staff members performing the sampling because of the difficulty involved in tallying customers into six U-strata from an unsorted listing. The sampling was done a stratum at a time, skipping customers not falling within the limits for the stratum being worked on while counting to the I_u -th customer. After sampling was completed, the selected customer identification numbers were sent to the utilities with a request for the names, addresses and telephone numbers (if available) of the selected customers. The MWh consumption listings were also returned to the utilities at this time.

5.1.3 Method 3 - Sampling from an Ordered Meter Listing

This method was used when a listing of metered irrigation account MWh consumption ordered either from lowest to highest or highest to lowest was available from data supplied by a utility. A line was drawn at the appropriate meter cut points and the number of meters (rather than the number of customers) in each U-Stratum was counted. Sampling then proceeded in the manner described in Section 4.2 for sampling from metered data. That is, weights based on the number of meters per customer in each U-stratum, the utility's required response allocation, an allowance for listing error, and other parameters were used to select metered accounts from the listing for inclusion in the survey sample. More detailed information on the procedures used in Method 3 are presented in Appendix A in the form of the worksheet that was used to implement Method 3 or Method 4 on all utilities that provided metered kWh consumption data to PNL.

After sampling was completed, listings of the selected meter accounts and the kWh consumption data were returned to the utilities with a request for the names, addresses, and telephone numbers (if available) corresponding to the selected accounts. In some cases, the utilities were asked to supply a specified number of names and addresses equal to n_U (the number of customers to be included in the sample) chosen from among the selected metered accounts for each U-stratum. In other cases, the utilities provided names and addresses for all selected metered accounts and PNL staff checked for duplicates and reduced the number of customers for each strata to the desired number (n_U).

5.1.4 Method 4 - Sampling from a Metered List Not Sorted by kWh Usage

This method was used when utilities kept their billing records in metered accounts, were unable to aggregate these metered accounts to an individual customer, and did not have the capability to readily provide a sorted meter MWh consumption listing. The results of using this method were similar to those of Method 3. However, more effort was required on the part of the PNL staff members who performed the sampling because of the difficulty associated with tallying metered accounts into their appropriate U-stratum from an unsorted listing.

5.1.5 Method 5 - Utility Sampling from Specified U-Strata

Constraints related to aggregation of MWh consumption data and distribution of this data to PNL resulted in development of a sampling method which was implemented by the individual utility's staff. Five of the 40 utilities selected for the survey sample could not or would not provide PNL with a listing of customer or metered account data and it was not feasible for PNL personnel to visit the utility. Thus, it was necessary to use a sampling method that could select the most appropriate customers for the survey sample within the limits of these constraints.

In Method 5, the utility was provided with the representative U-strata cut points for customer or metered accounts within their G-stratum and instructed to select a specified number of customers from each U-stratum. Since PNL had no way of calculating a sampling interval based on how many accounts fell into a specific U-stratum, the utility was instructed to take a "geographically dispersed" sample. This helped to reduce the probability that the first accounts encountered were automatically selected.

Since PNL had no specific knowledge of the customer load MWh distribution, it was necessary to ask each of the six utilities which customers had the largest kWh consumption and an idea of the dispersion of remaining accounts. If the utility did not have the requested number of customers in a specified U-stratum, PNL staff reallocated the sample and requested more customer names and addresses from the smaller accounts. It should be noted that the five utilities from which customers were selected using Method 5 comprise a very small percentage (1.6 percent) of total regional irrigation load and of the irrigation survey sample.

5.2 SAMPLING METHODS USED ON IRRIGATION SURVEY UTILITIES

In this section, utilities have been grouped by the type of irrigation kWh consumption account listing they were able to provide. A distinction is made between:

- Customer consumption data provided by the utility (Methods 1 and 2).
- Metered consumption data provided by the utility (Methods 3 and 4).

- The individual utility performed the sampling procedure according to specified U-strata provided by PNL (Method 5).

5.2.1 Customer Consumption Data Provided by the Utility

The utilities discussed in this section provided PNL with per-customer kWh consumption figures corresponding to individual irrigation customers. These utilities were sampled using either Method 1 or 2 and are listed in Table 5.1. They represent all geographic strata in the region and also comprised the majority (68 percent) of the total 1984 irrigation kWh load of all utilities selected for the sample. Although more effort was required of PNL staff to sample from an unordered listing using Method 2, the results were similar to those obtained from sampling from an ordered listing using Method 1.

For these utilities, an accurate identification of customers falling into the specific U-strata should have been obtained, since there were no multiple metered accounts to consider.

5.2.2 Metered Consumption Data Provided by the Utility

The utilities which did not have the capability to provide per-customer irrigation kWh consumption listing were asked to provide a listing of metered irrigation accounts. These utilities were sampled using either Method 3 or 4 and are listed in Table 5.2. The 9 utilities that provided metered data comprised approximately 30 percent of the total 1984 irrigation load of selected utilities. There will usually be a less accurate account of which U-stratum a customer belongs to using this data compared to individual customer consumption data.

5.2.3 Utilities That Performed the Sampling Procedure According to Specified U-Strata (Method 5)

In special cases where the utility was unable to provide PNL with an account/kWh consumption listing and it was not possible for PNL staff to visit the utility, the sampling procedure was performed by the utility. Five utilities fell into this category. They comprised about 2 percent of the total 1984 irrigation kWh for selected utilities. These utilities are listed in Table 5.3. As mentioned previously, this method posed the most difficult control problem because the sampling procedure was performed by the utility rather than PNL.

TABLE 5.1. Utilities Providing Customer Irrigation Consumption Data
(Method 1 or 2)

Geographical Stratum	Utility	1984 Irrigation MWh Usage
0(1)(a)	Idaho Power Company	1,489,502
1	Fall River Rural Electric Cooperative	17,219
	Raft River Rural Electric Cooperative	94,253
2	Columbia Rural Electric Association, Inc.	107,400
	Franklin County PUD	93,308
	Grant County PUD	321,985
	Richland Energy Service, City of	5,280
3	Columbia Basin Cooperative	30,748
	Umatilla Electric Cooperative Association	234,380
	Wasco Electric Cooperative, Inc.	8,832
	N. Wasco County PUD	1,372
4	Kittitas County PUD	2,935
	Klickitat County PUD	16,646
	Okanogan County PUD	43,786
5	Central Electric Cooperative, Inc.	36,291
	Columbia Power Cooperative	4,264
	Surprise Valley Electrification Corporation	33,634
5,5	Harney Electric Cooperative	58,697
6	Douglas County PUD	30,182
6,2	Washington Water Power Company	76,395
7	Kootenai REA	6,425
	Lost River Electric Cooperative, Inc.	20,530
	Salmon River Electric Cooperative, Inc.	8,020
	Vigilante Electric Cooperative, Inc.	35,637
8	Douglas Electric Cooperative	1,887
	Portland General Electric	38,000
TOTAL		2,817,608

(a) Idaho Power Company's irrigation load is primarily located in Geographic Stratum 1, but its relative irrigation load is so large that it was assigned its own stratum. In addition, the usage number shown is for the 1985 irrigation season, because this was the number used in defining the sampling method for this utility.

TABLE 5.2. Utilities Providing Metered Irrigation
Consumption Data (Method 3 or 4)

<u>Geographical Stratum</u>	<u>Utility</u>	<u>1984 Irrigation MWh Usage</u>
1,7	Utah Power and Light	290,506
2	Benton County PUD	234,182
	Big Bend Electric Cooperative, Inc.	216,041
2,3,4,5,7,8	Pacific Power and Light company	352,519
4	Chelan County PUD	31,472
4,2	Benton Rural Electric Association	58,874
6	Lincoln Electric Cooperative Incorporated (WA)	54,492
7	Ravalli County Electric Cooperative Incorporated	6,923
	Washington Water Power Company	6,939
8	Clallam County PUD	<u>1,363</u>
	TOTAL	1,253,311

TABLE 5.3. Utilities Which Performed Sampling Procedures According
to Specified U-Strata Provided by PNL

<u>Geographical Stratum</u>	<u>Utility</u>	<u>1984 Irrigation MWh Usage</u>
1	East End Mutual Electric Company	4,093
	South Side Electric Lines, Inc.	17,129
5	Midstate Electric Cooperative, Inc.,	34,576
6	Inland Power and Light	6,940
7	Flathead Irrigation and Power Project	<u>22,885</u>
	TOTAL	85,623

5.3 RESPONSE ALLOCATION ADJUSTMENTS

It is statistically desirable to interview at least two customers from each MWh usage stratum defined for each utility. Adjustments in the initial

sample allocation for many of the utilities included in the sample were necessary in order to accomplish this objective. In some utilities, the number of customers in the high stratum were large enough that additional responses had to be added to the response allocation in order to obtain two responses in each stratum. For example, Raft River had 59 customers in the high stratum in 1984, while its sample allocation was 51. In order to obtain all responses in the high stratum and two responses from each of the other stratum, it was necessary to raise Raft River's sample allocation to 69.

The initial response allocations in some of the low group utilities were not large enough to obtain two responses in each stratum. Thus, wherever possible, the response allocations for these utilities were increased above their initial levels.

The final adjusted response allocations for the utilities in the survey sample are shown in Tables 5.4 and 5.5. The only exceptions to the practice of allocating two successful responses to each U-stratum in each utility occurred where two irrigation accounts did not exist in a specified U-stratum or the utility required that customer permission be obtained before it would release customer names.

Also shown in Tables 5.4 and 5.5 are the numbers of distinct customer names returned by the utilities from which the allocated number of responses are intended to be obtained for each utility. The difference between the number of allocated responses and the size of the sample list varies primarily because of three factors:

1. Utilities where a large number of irrigation customers are in the high stratum will have a small differential between allocated responses and sample list size because the goal is to survey all high stratum customers.
2. Utilities that required customer permission before releasing the names for the survey sample will normally have a lower total sample list size than their response allocation because such permission could not be obtained within the time frame of the study.

TABLE 5.4. Final Allocated Successful Telephone Responses for High Group
Primary Sampling Units in Irrigation Survey Sample

G-Stratum	Utility	Adjusted Allocation	Size of Sample List ^(a)
0	Idaho Power Company	200 ^(b)	224
1	Utah Power and Light	139 ^(c)	250
	Raft River Cooperative	69	81
2	Grant County PUD	175	64 ^(d)
	Big Bend Electric	117	148
	Benton County PUD	127	154
	Franklin County PUD	50	54
	Columbia REA	58	71
	Pacific Power and Light	19	51
	Benton REA	12	26
	Washington Water Power	20	4 ^(d)
3	Umatilla Electric Cooperative	134 ^(c)	150
	Columbia Basin Electric	21	21
	Pacific Power and Light	46	83
4	Okanogan PUD	23	27
	Pacific Power and Light	51	160
	Benton REA	25	37
	Chelan County PUD	17	30
5	Pacific Power and Light	65	138
	Surprise Valley Electric	20	29
	Central Electric Cooperative	20	25 ^(d)
	Midstate Electric Cooperative	16	14
	Harney Electric Cooperative (Nevada)	35	40
6	Lincoln Electric Cooperative	34 ^(c)	25 ^(d)
	Washington Water Power	22	4 ^(d)
7	Lost River Electric	14	14
	Vigilante Electric	22	30
8	Pacific Power and Light	12	42
	Portland General Electric	21	27
TOTALS		1584	2023

(a) Number of distinct customer names returned by utility.

(b) Idaho Power Company was assigned a response allocation of 200 because, based on the relative size of its irrigation load (1.5 million MWh), over 500 of the 1700 total responses would have been allocated to Idaho Power.

(c) Adjusted allocations for Utah Power and Light, Umatilla Electric Cooperative and Lincoln Electric include allocations for Low Group PSUs in alternative G-Strata 7, 5 and 2 respectively.

(d) Customer permission required before names released.

TABLE 5.5. Final Allocated Successful Telephone Responses for Low Group
Primary Sampling Units in Irrigation Survey Sample

<u>G-Stratum</u>	<u>Selected Utility Name</u>	<u>Adjusted Response Allocation</u>	<u>Size of^(a) Sample List</u>
1	Fall River	16	24
	East End Mutual	6	6
	South Side Electric	17	26
2	Richland Energy Service	6	6 ^(b)
3	Wasco Electric	12	17
	North Wasco PUD	7	7
4	Klickitat PUD	17	17
	Kittitas PUD	9	12
5	Harney Electric (Oregon)	16	17
	Columbia Power Cooperative	7	12
6	Douglas County PUD	19	32
	Inland Power and Light	6	9 ^(b)
7	Washington Water Power	22	12 ^(b)
	Salmon River Cooperative	11	11
	Flathead Power Project	8	11
	Ravalli Electric	12	17
	Kootenai REA	5	5 ^(b)
	Pacific Power and Light	10	14
8	Douglas Electric Cooperative	7	12
	Clallam County PUD	12	23
TOTALS		225	290

(a) Number of distinct customer names returned by utility.

(b) Customer permission required before names released.

- Utilities where metered data was used as the basis for sample selection will generally have relatively large sample list sizes compared to their allocation due to use of the expansion weights based on the number of meters per customer (Table 4.3) in selecting the meter samples.

5.4 PROBLEMS OCCASIONED BY SAMPLING BILLING RECORDS

There are several problems that must be resolved in order to use the survey results to estimate population totals, percentages and other quantities of interest. The "population" of interest is irrigated farms in the BPA service area. However, a listing of irrigated farms from which to sample was not available. Instead, listings of billing records for the accounts classified as irrigation accounts by the utilities were used to define and select the sample. In addition to irrigated farms, these listings are likely to include accounts that are not "farms," for example, school districts, municipalities (for park watering or water treatment plants), and cemeteries.

The number of nonirrigated farms contained in the utilities' irrigation accounts will vary depending upon the various utilities' account classification methods and their customer characteristics. A preliminary analysis of the level of nonirrigated farms included in utilities' irrigation billing records has already been conducted. In this analysis, the nonirrigated farm load was calculated as a percentage of the total irrigation load. The non-farm load included school districts, municipal water facilities, cemeteries and correctional facilities. The results of this analysis are shown in Table 5.6.

The results shown in Table 5.6 were developed using two types of data sources. When a listing of total irrigation account and kWh consumption was available, the MWh usage corresponding to the identified non-farm accounts was tabulated and the proportion of non-farm usage for the utility found. Since the entire population of accounts was evaluated, the most accurate measure of non-farm usage was possible. The six utilities evaluated in this manner are marked with an A in Table 5.6.

In other cases, only the names and addresses selected according to the stratified random sampling methods described in this report were available. The non-farm accounts were identified and, since we had no specific consumption figure, assigned the MWh consumption for the midpoint of the usage strata in order to estimate the proportion of non-farm usage for the utility. The utilities analyzed using this method are marked with a B in Table 5.6.

TABLE 5.6. Sample Data on Nonirrigated Farm Loads Contained in Irrigation Billing Records

Stratum	Data Used ^(a)	Utility Sampled	1984 Irrigation Load (MWh)	Nonirrigated Farm Load (MWh) ^(b)	Nonirrigated Farm Load (%)
1	B	Raft River	94,253	0	0
	A	South Side	17,129	0	0
2	B	Benton County	234,182	150 ^(c)	0.06
	B	Franklin County	93,308	0	0
	B	PP&L	30,683	135 ^(c)	0.44
3	B	Columbia Basin	30,748	0	0
	B	North Wasco	1,372	0	0
	B	Wasco Electric	8,832	0	0
	A	Umatilla	234,380	51	0.02
	B	PP&L	84,118	0	0
4	A	Klickitat	16,646	151	0.90
	B	PP&L	97,182	0	0
5	B	Central Electric	36,291	0	0
	B	Surprise Valley	40,941	0	0
	B	PP&L	118,234	0	0
	B	Harney Electric	58,274	0	0
6	B	Douglas PUD	30,182	15 ^(c)	0.05
7	B	PP&L	1,368	32.1 ^(c)	2.35
	A	Vigilante	35,637	33	0.09
	A	Salmon River	8,020	54	0.67
	A	Lost River	20,530	17	0.08
8	B	PGE	37,000	30 ^(c)	0.08
	B	PP&L	20,934	0	0
0	B	Idaho Power	1,489,502	2,000	0.13
TOTALS			2,839,746	2,668.1	0.09

- (a) A = 1984 "irrigation" kWh listing provided by the utility; B = sample of "irrigation" accounts selected for the utility using the stratified random sampling methods described in this report.
- (b) Sum of loads identified in irrigation billing records as school districts, municipal water facilities, cemeteries and correctional facilities.
- (c) Derived using the average MWh usage for the strata.

Note from Table 5.6 that, for the utilities analyzed, nonirrigated farm accounts (as defined by school districts, municipal water plants, cemeteries and correctional centers) are generally less than 1 percent of the selected utilities irrigation load. Thus, the results of this preliminary analysis indicate that the problem of nonirrigated farms being included in billed irrigation demand may not be large for most utilities.

In addition to those accounts that obviously do not represent irrigated farms (such as those upon which Table 5.6 is based), there are a number of accounts designated as "irrigation districts" in the billing records that represent a grey area as to whether they represent irrigated farms or not. In some cases, a farmer or group of farmers may form an irrigation district that does represent a farm where electricity is being used to deliver water directly to croplands. In other cases, irrigation districts only use electricity to distribute water within surface water delivery systems (canals, ditches, etc.) and do not represent irrigated farms. The problems associated with the eligibility of irrigation districts and other nonfarm "irrigators" will likely be dealt with through the use of an operational definition of "irrigated farm" and subsequent classification of some sampled accounts as "ineligible." Then the "case weights" for estimating population totals would be based on the eligible population and MWh used by it, similar to the method used in other studies (Lou Harris and Associates, 1984 and WESTAT 1982). Some screening of "ineligibles" was done for the sample listing and at the start of the telephone interviews.

Other problems that were associated with the required use of billing record data for developing a sample for the irrigation survey include:

- the need to use metered load data that could not aggregate MWh consumption to an individual customer in selecting a sample for some utilities
- a requirement by seven utilities that customers' permission be received either through a signed consent form or a telephone call before the customers' names could be released for inclusion in the survey sample.

The goal of the study is to sample irrigated farms, but the probability of selecting a farm from a meter listing is not known unless we know how many meters are billed to the farm. If a utility provided us with a meter listing that had customers identified by a customer account number, we aggregated the billed meters to a customer total and sampled customers.

The multiple listing problem arising from the use of metered accounts can be resolved by calculating inclusion probabilities similar to the handling of multiple meter problems in other studies (WESTAT 1982). However, for the utilities that provided only meter data, we will have to await the survey results to determine appropriate case weights for estimation purposes.

The seven utilities which required that customers' permission be received (either through a signed consent form or a telephone call) before the customers' names could be released for inclusion in the survey sample represented approximately 12 percent of 1984 regional irrigation load. These utilities are listed in Table 5.7. Also shown in Table 5.7 are the utilities initial response allocations and the number of customers whose names were actually released.

TABLE 5.7. Initial Response Allocations for Utilities Requiring Customer Permission for Name Release and Names Actually Received

<u>Utility Requiring Permission</u>	<u>Initial Response Allocation</u>	<u>Customer Names Actually Received</u>
Grant County PUD	175	64
Washington Water Power	64	22
Lincoln Electric Cooperative	34	24
Midstate Electric Cooperative	16	14
Inland Power and Light	4	9
Kootenai REA	6	5
Richland Energy Services	6	6

Every effort was made to obtain the names of the customers from these utilities for inclusion in the survey sample. The utilities involved were requested to either make reminder telephone calls or send reminder letters when

permission was not received from the customers within a month. The utilities conducted these activities to the degree that their staff resources would allow. However, in most cases, it was not feasible for the utilities to attempt to contact every customer who did not return a permission form. The process of collecting waivers was conducted for approximately two months and was discontinued only when the time constraints of conducting the survey required that it be stopped.

It is obvious from Table 5.7 that the listed utilities will not be as well represented in the results of the irrigation survey as they would have been if their desired sample allocations had been reached. This is particularly true for Washington Water Power and Grant County PUD. Appropriate statistical adjustments for responses obtained from the customers of these utilities will be particularly necessary when the survey results are received.

5.5 SUMMARY OF SAMPLING METHODOLOGY

Despite the problems introduced by sampling from billing records, the sample produced by the methods described in this report will lead to a significant improvement in the precision of estimation compared to a simple random sample. Sampling decisions were based on what theory indicated would produce good precision in estimating MWh load, irrigated acres and other parameters of interest. These decisions included:

- selecting high-usage utilities with certainty
- selecting high-usage customers with certainty
- selecting low-usage utilities with probability proportional to size
- randomly selecting low-usage customers within "strongly stratified" usage strata.

The resulting sample will provide the theoretically best precision for those survey items that are well-correlated with usage when ratio or other regression-based estimates are used, given the fixed sample size we allocated to the utilities.

The improvement in precision that will be obtained from using the sampling plan described in this report as opposed to other plans can be illustrated through the use of an example for a selected utility. For purposes of illustration, Grant County PUD was selected for analysis, although the principles of the example are applicable to any of the utilities for which customer MWh consumption data were available for sampling.

Grant County PUD delivered 321,985 MWh to 2148 customers in 1984. It was allocated a completed response (n_r) of 175. It was found that 120 customers used more than 500 MWh, leaving 2028 customers from which to draw a sample and obtain 55 responses from the sample. In order to compare sampling plans, the plans are evaluated in reference to their precision in estimating the total MWh billed in 1984. Since we know the MWh for each customer such evaluation is possible.

If a simple random sample of 175 customers were drawn from the 2148 customers, then the standard deviation for an estimate of total MWh would be

$$sd (T \text{ MWh}) = 60,911 \text{ MWh}$$

which is 18.9 percent of the total 1984 MWh of 321,985. If we selected the 120 high-usage customers with probability one and used simple random sampling for drawing 55 from the remaining 2028, then

$$sd (T \text{ MWh}) = 25,750 \text{ MWh}$$

which is 8 percent of total 1984 MWh. For the sampling plan described in this report, which involves selecting the high-usage customers with probability one and randomly selecting the same number of customers from each low-usage stratum, the standard deviation is

$$sd (T \text{ MWh}) = 8,530.96$$

or

2.64% of total 1984 MWh

These figures show a marked improvement; the standard deviation of estimates (the statistical measure of precision) improves from 18.9 percent of the total to be estimated using a purely random sample to 2.54 percent for the sampling plan described in this report. These results are for simple inverse probability of selection estimators for variables that have distributions similar to MWh. Even better precision can be expected when ratio estimates, using MWh, are made for variables that are correlated with MWh.

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APPENDIX A

SAMPLING WORK SHEETS

TABLE A.1. Worksheet for Sampling From Customer kWh Load
Data Using Sampling Method 1 or 2

- Given:
1. Utility irrigation customer kWh consumption listing
 2. Upper limits for the low MWh usage stratum for the geographical Stratum the utility is in
 3. The allocated sample size, n_r

Step 1. List all customers using at least 500,000 kWh in Sample Listing.

Step 2. Count customers listed in Step 1, getting n_H , and calculate as follows:

$$n_r = \underline{\hspace{2cm}} \quad \text{sample size}$$

$$n_H = \underline{\hspace{2cm}} \quad \text{number of customers using at least 500 MWh}$$

$$n_L = n_r - n_H = \underline{\hspace{2cm}} \quad \text{number of respondents for low group}$$

$$n_{LS} = [1.333 n_L]_{I+1} = \underline{\hspace{2cm}} \quad \text{approximate number to sample in low group}$$

$$n_L' = n_{LS} + c_5 = \underline{\hspace{2cm}} \quad \text{number to sample in low-usage group}$$

$$n_U = n_L' / 5 = \underline{\hspace{2cm}} \quad \text{number to sample in each of the five low-usage strata}$$

$$n_{ru} = (n_L + c_5') / 5 = \underline{\hspace{2cm}} \quad \text{number of respondents in each low-usage stratum.}$$

Notes:

$[\cdot]_I$ means truncate to the inter part. c_5 and c_5' are integers, (0, 1, 2, 3, or 4) that make n_L or n_{ru} exactly divisible by 5.

TABLE A.1. (contd)

Utility _____

G-Stratum _____

Sample Size n_r _____

SUMMARY TABLE FOR CUSTOMER LOAD DATA

		(Stratum 2, e.g.,)		If Needed ^(a)				Sampling Interval
u	Usage Stratum	Upper MWh Limit	Number of Customers	n_u	n_{ru}	$\frac{n'_{ru}}{n'_{ru}}$	$\frac{n'_u}{n'_u}$	
1.	0-20%	MWh(1)=70	_____	_____	_____	_____	_____	_____
2.	20-40%	MWh(2)=120	_____	_____	_____	_____	_____	_____
3.	40-60%	MWh(3)=200	_____	_____	_____	_____	_____	_____
4.	60-80%	MWh(4)=300	_____	_____	_____	_____	_____	_____
5.	80-100%	MWh(5)=500	_____	_____	_____	_____	_____	_____
Low Total			_____	_____	_____	_____	$=n_{LS}(\text{adj})$	NA
6.	High	$\frac{\text{MWh(6)=}}{\text{Maximum}}$	$n_H =$ _____	$=$ _____	$=$ _____	_____	$=n_H(\text{adj})$	
Grand Total			NA	_____	_____	_____	_____	
Total 1984 MWh Usage								

(a) These columns are needed if n_u is greater than the number of customers for any usage strata. (See Table 4.2 for an example.) Then

$$n_L(\text{Adj}) = n_r - n_H - \text{NCUST}(5) - \text{NCUST}(4) - \dots - \text{NCUST}(\text{HI})$$

where the adjustment to n_L is to subtract off NCUST for each usage stratum that has n_u greater than NCUST and NCUST (HI) is the last such stratum

$$n_H(\text{Adj}) = n_H + \text{NCUST}(5) + \dots + \text{NCUST}(\text{HI})$$

$$n_{LS}(\text{Adj}) = [1.333 n_L(\text{Adj})] + 1$$

$$n'_u = (n_{LS} + c_5)/S, \text{ where } S \text{ is the number of low-usage strata with}$$

n_u less than NCUST.

$$n'_{ru} = [n_r - n_H(\text{Adj}) + c_5]/5.$$

TABLE A.2. Worksheet for Sampling From Meter kWh Load Data
Using Sampling Method 3 or 4

Given: Listing of meter consumption. U-ST MWh limits for G-ST. n_r

Step 1. Count NMET in each U-ST.

Step 2. Let M_H be the number of meters in U-ST6.

Step 3. Calculate the expected number of customers in U-ST6 as

e.g., for $n_r = 17$, $M_H = 5$

$$n_H = [M_H(0.3846)]_I+1 \quad [5(0.3846)]_I+1 = 2$$

and

$$n_L = n_r - n_H \quad 17-2 = 15$$

$$n_{LS} = [1.333 n_L]_I+1 \quad [1.333(15)]_I+1 = 20$$

$$n'_L = n_{LS} + C_5 \quad 20 + 0 = 20$$

$$n_U = n'_L/5 \quad 20/5 = 4$$

also

$$n_{ur} = [n_L + c'_5]_I \quad 15/5 = 3$$

Step 4. Calculate the number of meters to sample for U-ST 1-5 as

e.g.

	1	2	3	4	5
E_U	1.3	2.0	2.5	3.5	4.3
M_U	5	8	10	14	17

$$I_U = [NMET_U/M_U]_I$$

Step 5. Space to do these calculations is provided at the bottom of Summary Table for Meter Data. Enter the results on the appropriate lines in the table.

TABLE A.2. (contd)

Utility _____

G-Stratum _____

Sample Size n_r _____

SUMMARY TABLE FOR METER LOAD DATA

<u>u</u>	<u>UL%</u>	<u>MWh</u> <u>Limit</u>	<u>NMET</u>	<u>n_u</u>	<u>E_u</u>	<u>M_u</u>	<u>I_u</u>	<u>Selected</u>	<u>n_{ur}</u>
1.	20	_____	_____	_____	1.3	_____	_____	_____	_____
2.	40	_____	_____	_____	2.0	_____	_____	_____	_____
3.	60	_____	_____	_____	2.5	_____	_____	_____	_____
4.	80	_____	_____	_____	3.5	_____	_____	_____	_____
5.	100	_____	_____	_____	4.3	_____	_____	_____	_____
Low Total		_____	_____	_____		_____		_____	_____
High		M_H _____		_____	0.385	_____		_____	_____
Max MWh		_____							
Total meters		_____		_____		_____		_____	_____
Total '8H MWh		_____							

$$n_r = \underline{\hspace{2cm}}$$

$$n_H = [M_H(0.3846)]_{I+1} = \underline{\hspace{2cm}}$$

$$n_L = n_r - n_H = \underline{\hspace{2cm}}$$

$$n_{LS} = [1.333n_L]_{I+1} = \underline{\hspace{2cm}}$$

$$n'_L = n_{LS} + c_5 = \underline{\hspace{2cm}}$$

$$n_u = n'_L/5 = \underline{\hspace{2cm}}$$

$$n_{ur} = [(n_L + c'_5)/5]_I = \underline{\hspace{2cm}}$$

$$M_u = [E_u n_u]_{I+1}$$

$$I_u = NMET_u/M_u$$

APPENDIX B

ALPHABETICAL LISTING OF UTILITIES INCLUDED IN SAMPLE

APPENDIX B

ALPHABETICAL LISTING OF UTILITIES INCLUDED IN SAMPLE

Utility	UID (a)	1984 ^(b)	
		MWH SUM	PSUs
Benton PUD	24	234,182	1
Benton REA	27	58,874	2
Big Bend Elec. Coop.	30	216,041	1
Central Elec. Coop.	64	36,291	1
Chelan Co. PUD	79	31,472	1
Clallam PUD	98	1,363	1
Columbia Basin Coop.	110	30,748	1
Columbia REA	113	107,400	1
Columbia Power Coop.	116	4,264	1
Douglas PUD	140	30,182	1
Douglas Elec. Coop.	143	1,887	1
East End Mutual	152	4,093	1
Fall River Coop.	170	17,219	1
Franklin PUD	191	93,308	1
Grant PUD	197	321,985	1
Harney Coop.	203	58,697	2
Idaho Power Co.	215	1,489,502	1
Inland P&L	221	6,940	1
Kittitas PUD	224	2,935	1
Klickitat PUD	227	16,646	1
Kootenai REA	230	6,425	1
Lincoln Coop. (WA)	243	54,492	1
Lost River Coop.	246	20,530	1
Midstate Coop.	262	34,576	1
N. Wasco PUD	295	1,372	1
Okanogan PUD	304	43,786	1
Pacific P&L	326	352,519	6
Portland Gen'l Elec.	353	38,000	1
Raft River Coop.	366	94,253	1
Ravalli Coop.	369	6,923	1
Richland City Light	372	5,280	1
Salmon River Coop.	390	8,020	1
South Side Elec. Lines	409	17,129	1
Surprise Valley Coop.	424	33,634	1
Umatilla Elec. Coop.	439	234,380	1
USIS-Flathead	451	22,885	1
Utah P&L	457	290,506	1
Vigilante Elec. Coop.	459	35,637	1
Wasco Elec. Coop.	467	8,832	1
Washington Water Power	470	83,334	3
Total for 40 Utilities		4,156,542	49

(a) Utility Identification Number from BPA Historical Sales Data Files.

(b) 1984 Data except for Idaho Power Co. (1985 data), Clallam PUD and 25,000 MWh for WWP (1980 data).

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