MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

AwwaRF Tailored Collaboration Proposal

Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

June 22, 2007

This page intentionally left blank.

TABLE OF CONTENTS

TAILORED COLLABORATION PROPOSAL COVER WORKSHEET **1**

PROPOSAL TITLE: EMPIRICAL DEMAND ANALYSIS OF AMR DATA FOR DISTRIBUTION AND SYSTEMS PLANNING 1

PROJECT ABSTRACT **2**

EMPIRICAL DEMAND ANALYSIS OF AMR DATA FOR DISTRIBUTION AND SYSTEMS PLANNING 2

PROJECT DESCRIPTION **3**

RESEARCH OBJECTIVES **3**

THE RESEARCH TEAM **3**

RESEARCH APPROACH **4**

APPLICATIONS POTENTIAL **9**

SUMMARY OF RELATED RESEARCH **10**

AMR MEASURES OF WATER DEMAND 10
WATER DEMAND 10
TYPES OF DEMAND MODELS 10
PURPOSE OF THE DEMAND FORECAST 11
1. SHORT-TERM DEMAND FORECASTING 11
2. LONG-TERM DEMAND FORECASTING 12
3. DEMAND LOAD FORECASTING 12

REFERENCES **14**

QUALITY ASSURANCE/QUALITY CONTROL **18**

SCHEDULE **19**

MANAGEMENT PLAN AND STATEMENT OF QUALIFICATIONS **20**

MANAGEMENT PLAN 20
QUALIFICATIONS OF RESEARCH TEAM 21

TAILORED COLLABORATION BUDGET **22**

TC CO-FUNDING SUPPORT FORMS **23**

CASH AND IN-KIND SUPPORT FORM **26**

APPENDIX A **32**

This page intentionally left blank.

TAILORED COLLABORATION PROPOSAL COVER WORKSHEET

Proposal Title: Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

Sponsoring Utility: The Metropolitan Water District of Southern California

Contact at Sponsoring Utility:
Name: Warren Hagstrom
Address: P.O. Box 54153, Los Angeles, California 90054-0153
Phone: (213) 217-6963 Fax: (213) 217-6949 e-mail: whagstrom@mwdh2o.com

Co-Funding and In-Kind Summary:

Organization Name	Cash Co-Fund Amount	In-Kind Contribution Amount
Metropolitan Water District of Southern California	$50,000	$25,000
The Municipal Water District of Orange County		$10,000
The City of Portland Bureau of Water Works	$50,000	$45,000
Tualatin Valley Water District	$50,000	$10,000
Contractor Contribution		$31,680
TOTAL	**$150,000**	**$121,680**

PROJECT PERSONNEL
Principal Investigator (i.e., researcher responsible for conducting research):
Thomas W. Chesnutt, Ph.D.
A & N Technical Services, Inc.
839 Second Street, Suite 5
Encinitas, CA 92024
760-942-5149, 760-942-6853 (fax), tom@antechserv.com.
Person responsible for finalizing *Funding Agreement* (i.e., research contract):
Warren Hagstrom
Person responsible for accounting matters of contractor:
Warren Hagstrom

AwwaRF Funds Requested:	$150,000
Amount of Funds eligible for AwwaRF match:	$150,000
Amount of Funds not eligible for AwwaRF match:	$ 0
Total Cash Budget:	$300,000
Total In-Kind Contributions	$121,680
TOTAL PROJECT BUDGET:	**$421,680**

PROJECT ABSTRACT

Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

Many utilities have begun to assess automated meter reading (AMR) technologies for collecting more reliable and precise measures of water demand. Given the large economic stakes involved in meeting future water demand– to say nothing of infrastructure replacement needs and water quality requirements–empirically driven engineering decision models have a high payoff.

Research Objectives

- To further the understanding of technical analyses– statistical, engineering, and economic–that require high-resolution AMR measures of water demand.
- Define how AMR data can best be used to shed light on questions of distribution and systems planning.
- Assess how utilities have validated and used AMR demand measures in integrated planning through methodologically rigorous case studies.
- Demonstrate how the framework can be applied in different utility settings
- Provide a structure for assessing data requirements for integrating precisely measured demand into integrated water planning.

Research Approach

We will initiate the research with a preliminary review of the literature, summarizing topics and issues of relevance, and then meeting with the PAC to finalize research objectives and prioritize issues. A sketch of the topical structure we envision might look as follows:

(1) Water Demand and AMR measures
   a. Need for better measures
   b. Validation – contrast w/consumption measures
   c. Types of Inference Based on Demand Sampling Using AMR
   d. Integrated Planning

(2) Planning and Operational Issues
   a. System Planning – dynamic demand forces
   b. Distribution Planning – search for the right peaking factor

(3) Models – Specification and Estimation
   a. Descriptive Models – data assessment and validation
   b. Structural Models – prediction of dynamic forces
   c. Spatial Demand Tracking Models (comparing demand behavior across households and/or service areas.)

(4) Applications
   a. Utility Case 1 – Descriptive models of demand, spatial and temporal variation
   b. Utility Case 2 – Distribution planning, tracking changing spatial demand load
   c. Utility Case 3 – Structural models of real time demand by class

(5) Decision Framework—engineering better decisions

(6) Recommended Planning Practices

Quality assurance will be coordinated through the AwwaRF PAC. Initial draft work products will be submitted for review as part of the periodic reports. Following the work product revision, the second draft work product will be submitted to the PAC for review. Following PAC review, a final draft work product will be prepared.

Anticipated Results: This research will produce a reference document compiling information on uses of AMR demand measures. A spreadsheet tool to assist in model selection decision-making, along with associated documentation, will be offered. Last, documentation of case studies in empirical demand analysis of AMR measures including illustrations of distribution and systems planning will be concisely summarized. Case studies will be organized by five or six major topics of immediate relevance and concern to the domestic water industry. The final report will provide a concise review of utility experience with collecting AMR data, validating the measures, illustrations of various models for different planning inference, and integrated planning applications. In addition to the final report, research findings will be submitted for presentation at relevant AWWA conferences and submitted for journal publication.

The Research Team: The project team is composed of Thomas Chesnutt, Ph.D. and David Pekelney, Ph.D. of A&N Technical Services Inc., and joint investigators from the participating utilities. Participating utilities include: **The Metropolitan Water District of Southern California, Municipal Water District of Orange County, the City of Portland Bureau of Water Works** and **Tualatin Valley Water District**.

Schedule and Budget: This research will be conducted over 18 months at a proposed cash budget of $300,000 with $121,680 provided by in-kind donations and $150,000 requested from the AWWA Research Foundation. The plan is to solicit participation of other interested AWWA member utilities in which case the budget and request for funding from AwwaRF will be adjusted accordingly.

PROJECT DESCRIPTION

Many utilities have begun to assess automated meter reading (AMR) technologies for collecting more precise or valid measures of water demand. Given the large economic stakes involved in meeting future water demands–to say nothing of infrastructure replacement needs and water quality requirements–empirically driven engineering decision models have a high payoff. This research proposes to examine the empirical challenges faced by three early adaptations of AMR water demand measuring technology. The implementing utilities faced the challenge of converting the monumental amount of data created into usable planning information. The sample of early AMR implementations covers different types of planning problems (system tracking, end-use consumption tracking, better customer service and revenue generation) and different parts of water utility systems (production, delivery, and end-use). This research seeks to document the range of problems addressable by innovative AMR applications, the implementing challenges, and the science-based methods and models required for rigorously defensible planning.

RESEARCH OBJECTIVES

- Further the understanding of technical analyses – statistical, engineering, and economic – require making use of high-resolution AMR measures of water demand.
- Define how AMR data can best be used to shed light on questions of distribution and systems planning.
- Assess how utilities have validated and used AMR demand measures in integrated planning through methodologically rigorous case studies.
- Demonstrate how the framework can be applied in different utility settings
- Provide a structure for assessing data requirements for integrating precisely measured demand into integrated water planning.

THE RESEARCH TEAM

To address the complex and multidimensional challenges posed by this research, we have assembled a team of experts that spans the relevant economic, engineering, institutional, financial, and management elements relevant to the study. Our team consists of an array of consulting researchers, empirical modelers, and utility practitioner experts to address the full range of AMR data collection, modeling, and planning issues. The team members' credentials are detailed in the Statement of Qualifications section of this proposal.

The research will be led by ***Dr. Thomas Chesnutt*** (A&N Technical Services) and ***Mr. Warren Hagstrom*** (Metropolitan). As project manager, Mr. Hagstrom will coordinate the project with AwwaRF, the project team, and the participating utilities. As Principal Investigator, Dr. Chesnutt will focus on defining the modeling tasks, data requirements, expected results, and project documentation. Dr. Hoessein Parandvash (City of Portland) will lead the econometric modeling of water consumption data in the City of Portland.

Thomas Chesnutt, Ph.D. and ***David Pekelney, Ph.D.*** (A&N Technical Services) are experts in empirical policy analysis specializing in water utilities. They have worked on water resource issues including water resource planning, statistical modeling of consumption and production data, and have provided technical support to water agencies in water demand modeling, water resource economics, and valuation. A & N has developed a national reputation for their work in empirical models, in explaining the use and practical import of empirical methods, and in integrating cutting edge methods into utility plans. They were the lead researchers for AwwaRF's *Spatial Demand Allocation for Distribution System Design* and *Water Efficiency Programs for Integrated Water Management.* Dr. Chesnutt is a member of the AWWA Planning and Evaluation Committee of the Conservation Division. Dr. Pekelney is a member of the AWWA Rates and Charges subcommittee of the Management Division.

RESEARCH APPROACH

We will initiate the research with a preliminary review of the literature, summarizing topics and issues of relevance, and then meeting with the PAC to finalize research objectives and prioritize issues. A sketch of the topical structure we envision might look as follows:

(1) Water Demand and AMR measures
   a. Need for better measures
   b. Validation – contrast w/consumption measures
   c. Types of Inference Based on Demand Sampling Using AMR
   d. Integrated Planning

(2) Planning Issues
   a. System Planning – dynamic demand forces
   b. Distribution Planning – search for the right peaking factor
   c. Planning for Customer Service

(3) Data Sampling, Collection, and Validation
   a. Sample Design
   b. Data Collection
   c. Data Validation

(4) Models – Specification and Estimation
   a. Descriptive Models – data assessment and validation, sampling, validation
   b. Structural Models – prediction of dynamic forces
   c. Spatial Demand Tracking Models (comparing demand behavior across households and/or service areas.)

(5) Applications
   a. Utility Case Study 1 – Descriptive models of demand, spatial and temporal variation
   b. Utility Case Study 2 – Distribution planning, tracking changing spatial demand load
   c. Utility Case Study 3 – Structural models of real time demand by class

(6) Decision Framework—engineering better decisions

(7) Recommended Planning Practices

Scope of Work

The following statement of work provides a detailed summary for the research approach to be followed in this project.

Task 1 - Project Management and Administration

This task includes all project management activities and administration; including meetings, quality control and assurance, budgeting and scheduling, and other general project management activities.

Task 2 - Literature Search and Review of Existing Practices

In addition to existing knowledge provided by project participants and work cited in this proposal, other knowledge and studies will be researched in this task. A comprehensive literature review will be conducted to obtain information on AMR demand analysis methods and prevalent practices.

Task 3 - Conceptual Framework for Planning Issues

This task focuses on developing a conceptual framework that connects AMR measurement with the different planning issues confronting water utilities. The conceptual framework will examine three types of planning problems that require demand forecasting applications:

1. Short-Term Demand Forecasts—needed for operations optimization and revenue planning
2. Long-Term Demand Forecasts—needed for resource planning, including demand side management (DSM)
3. Demand Load Forecasts—needed for treatment and distribution system planning

While the data collection, statistical modeling, and case studies will tend to emphasize the second and third planning problems–due to the interests of the participating utilities–the conceptual framework necessarily includes discussion of short-term demand forecasting applications: operations optimization and revenue planning. The research project is open to adding an additional participating utility to develop a third case study focused on these issues if one can be identified and resources secured. Since revenue management is one of the key drivers behind large scale adoption of AMR technology, this would be a valuable addition to the research results.

Task 4 - Data Collection, Manipulation, and Validation

In many water demand and systems modeling, too little attention is paid to what can and cannot be done with available data. This research project pays special attention to the strengths and limits of data typically available to water utilities, a set that increasingly includes AMR data. The different types of AMR measures and data that participating utilities have compiled illustrate both the production and consumption side of water systems. This research emphasizes scientific inference. Hence scientific sampling issues lay at the heart of working with both sets of data.

A sample design will be developed for historical water demand data, data for the sample will be acquired from AMR and billing systems, and these data will be validated and cleaned. Spatial categories of interest will be identified and used to develop what scientific sampling terms "strata." In the following discussion the term "strata" and "category" will be used interchangeably. A stratified sample will then be designed where the sampling strata come from the desired spatial aggregation. Appropriate stratification weights will be developed to permit scientific inference from the sampled connections to the entire population of service connections. In this way, a formal basis is preserved for inference about the means and distributions surrounding spatial parameters.

The next subtask involves validation of the demand data. "Validity" in scientific inference refers to the question of how a measure (demand or flow) relates to the object of interest (demand load). Due to line loss and other measurement error, customer consumption data will imperfectly reflect flow requirements. To quantify this difference, consumption data for sub-areas will be aggregated and compared with corresponding demand (flow meter) data to quantify differences in sample consumption and demand data. Completion of this task will result in the creation of a consistent data source for the study (consumption time series containing data for all compared sub-areas).

The most important deliverable from this task will be the documentation of data strengths, limits, and workarounds.

a) Design Data Sample

- Determine Sample Time Period and Region
- Select Spatial Data Categories (Strata) – Land Use, Customer Class, etc.
- Develop Stratification Weights

b) Acquire Spatial Category (Strata) Data (Historic and Existing)
   - Identify individual Parcels, Tracts, Land Areas in Data Sample
   - Perform GIS and database analysis to join data to Sample

c) Acquire Consumption Data (Download from Mainframe Tapes)

d) Create Consistent Consumption Histories/Time Series (Data cleaning)

e) Develop Data Documentation

Task 5 - Statistical Demand Models: Specification and Estimation

Task 5 involves the formal estimation of all consumption factors associated with categories (strata) identified in Task 4. This task will explain the estimation task in terms assessable to working water professionals. This work involves development of a computerized statistical consumption model, which can be used to predict consumption for alternative sets of spatial categories. There are three different types of water demand models to be developed.

a) Define Model Development Process
   - Specification
   - Estimation
   - Testing
   - Limitations/Applicability
   - Model Form

b) Types of Models
   - Descriptive Models – data assessment and validation
   - Structural Models – prediction of dynamic forces
   - Demand Tracking Models – comparison to planning thresholds

c) Develop Mathematical Consumption Model
   - Formally Aggregate Individual Connection Consumption Data to Spatial Categories (Strata)
     - Land Use Categories
     - Customer Class Categories
     - Climate Zone Categories
     - Combinations
   - Test Sample for Service Connection Heterogeneity
   - Incorporate the Effect of Weather

d) Develop Model Documentation

Task 6 - Applications

a) Utility Case Study 1 – Distribution System Planning Applications

Decisions about the timing and sizing of infrastructure expansions turn on an understanding of average demand growth, supply capacity, and demand shape (peaking behavior). Water utility AMR measures of historical production can provide the empirical basis to better inform decision makers of the risks and rewards of system delivery or treatment capacity alternatives. This module will empirically examine how models using AMR data can improve estimates of risk and variability—the risks of not meeting future demand can then be balanced against the costs of system expansion.

AMR measures constitute a higher resolution source for demand analysis. One set of measurement issues concerns how the analysis should combine high time resolution AMR data with other lower resolution data collected by older methods. Another planning issue is how historical sample data can be combined with known future changes to inform today's decisions.

b) Utility Case Study 2 – Structural Models of real time Customer Demand by Class

In 1997 Portland Bureau of Water Works embarked upon a pilot AMR deployment in order to be able to collect high resolution consumption data on mainly single family residential (SFR) and other customer classes. Prior to this Customer Demand Monitoring (CDM) project, the data available were the quarterly billing data for SFR and monthly billing data for multifamily residential, commercial, industrial, institutional, and wholesale customers. The only other data available were the daily system production measures of water delivered to all retail and wholesale customers. These data are clearly not conducive to any meaningful demand analysis of customer classes. The basic idea behind CDM was to use AMR technology and collect high resolution (15-minute reads) consumption data on statistically representative samples of customers in each class in the retail service area. The next step was to expand the project and collect similar data in the wholesale service area. The high resolution data could then be used to implement:

- Micro level demand analysis based on socioeconomic factors, weather, and location and land-use patterns.
- Load profiling and peaking behavior based on different parts of the service area which could be of important use for operation purposes.
- Monitoring the response to conservation messages and possible mandatory curtailments under draught conditions.
- Disaggregating the total demand by customer class.
- Spatial comparison of demand behavior in retail and wholesale (urban and suburban) service areas.

In July 1997, the Bureau started the first phase of the CDM project with recruitment of the 500 single-family residential dwellings, spread over the retail service. The sites were randomly selected from the entire population of SFR accounts to statistically represent the customer class. Each site was equipped with a water meter with digital encoder, a meter interface unit, and a connection to the residence phone line. The AMR system was to collect 15-minute reads from the meter and report the reads to the host computer on preset intervals.

The SFR deployment phase of the project was completed in 1999. Meanwhile, deployment in other customer classes, as result of budget issues was postponed indefinitely. However, three commercial sites and two multifamily sites were implemented as well. The multifamily sites were two similar complexes with 120 units each in the same neighborhood. All 120 units of one complex was sub-metered both for hot and cold water and equipped with AMR. The other complex was equipped with AMR at master meter level. The purpose was to estimate the effect of sub-metering on consumption.

In the next phase, again as a result of budget issues, the project was expended to only one of the wholesale service areas. Tualatin Valley Water District (TVWD) is the largest wholesale customer of the Bureau. A sample of 300 SFR sites were randomly selected and equipped with AMR in order to collect similar interval data.

Task 7 - Decision Framework and Recommended Planning Practices

Task 7 will provide a Decision Framework and a set of Recommended Planning Practices that derive from the AMR case studies. The Decision Framework will identify key decision points in applying AMR measures of water demand for application to planning issues. The Recommended Planning Practices seeks to derive applicable lessons for taking better planning advantage of newly emerging AMR capabilities.

Task 8 - Documentation

The final report for this project will document the findings of the tasks outlined above in an accessible and reader-friendly fashion. An outline of the final report will be presented at the project kickoff meeting with suggested task responsibilities. Drafts of report sections will be included in periodic reports to the AwwaRF project advisory committee in order to elicit early feedback on the direction of the project research. This early PAC input has proved invaluable in the past as a means of avoiding blind alleys, focusing on the most difficult issues, and communicating research findings in an accessible and understandable manner. Adequate time has been budgeted for the AwwaRF editorial review process.

Interim work products of this project will be quarterly report submitted every three months (after the start of the project) to the AwwaRF Project Manager. These reports are then shared with the Project Advisory Committee (PAC). It is the intention of the researchers to begin the process of writing the final report for this project as soon as work begins and continue this effort through the entire 18 month research period. Sections of the final report such as the literature review, methodology, bibliography, glossary, and other sections can be completed early on. These will be included as part of the quarterly reports.

Quarterly progress reports will provide specific work products as well as detailed information about completed, on-going work efforts, and upcoming tasks expected to begin during the next 3-month period. Table 1 outlines the anticipated schedule of project interim and final work products assuming a project start date of July 2, 2007.

Table 1: Quarterly Report Schedule, Project Work Products and Due Dates

Report #	Due Date*	Description and Products Included
Quarterly Report #1	10/1/2007	Work completed during first three months of project – Literature review, description of AMR inception and relevant planning issues for each case study.
Quarterly Report #2	1/1/2008	Work completed during first six months of project – draft Conceptual Framework
Quarterly Report #3	4/1/2008	Work completed during first 9 months of project – draft data and modeling chapters
Quarterly Report #4 – Annual Report #1	7/1/2008	Work completed during first year of project – literature review, description of AMR inception and relevant planning issues, draft Conceptual Framework, draft chapters on draft data and modeling chapters, Draft write ups of each case study
Quarterly Report #5	10/1/2008	Work completed during first 15 months of project – draft Decision Framework and Recommended Planning Practices
Draft Final Report	1/1/2009	Draft final report summarizing findings and methodology.
Completed Final Report	4/1/2009	A three-month review and revision period is provided.

*Assumes a project start date of July 2, 2007

APPLICATIONS POTENTIAL

This research will produce a reference document compiling information on uses of AMR demand measures. Documentation of case studies in empirical demand analysis of AMR measures including illustrations of distribution and systems planning will be concisely summarized. Case studies will be organized by major topics of immediate relevance and concern to the domestic water industry. The final report will provide a concise review of utility experience with collecting AMR data, validating the measures, illustrations of various models for different planning inference, and integrated planning applications. In addition to the final report, research findings will be submitted for presentation at relevant AWWA conferences and submitted for journal publication.

SUMMARY OF RELATED RESEARCH

AMR Measures of Water Demand

Automatic meter reading (AMR) was first tested in trials conducted by a group of energy utilities, AT&T, and Westinghouse more than 40 years ago. Though proving the technical feasibility, the initial economics of phone-based AMR systems precluded widespread adoption. Tamarkin (1992) provided a summary of this history and went on to point out that cost-justification of AMR adoption required documentation of the multiple benefits of better measurement to the utility.

The last decade has seen dramatic reductions in the cost of installed AMR capability and a widespread testing of AMR alternatives for the water industry. Evidence of this is born out by the recent AwwaRF project 4000 *Automated Meter Reading - Best Practices for Selection, Acquisition and Implementation*. A central theme of this research concerns how the quality and quantity of AMR data currently outpace the availability of necessary analytic methods to make sense of these data. Thus, this research focuses on developing the analytic tools to allow the water demand data measured by AMR to be used to benefit water utility planning and, ultimately, decision-making.

Water Demand

There are different meanings given to "water demand" that need to be clarified to avoid misunderstandings (Merritt 2004).

- Engineer – may view demand in terms of "demand load" – a production requirement, need
- Water Planner – water demand as supply provided, use
- Wastewater Planner – concerned with water use not consumed, but disposed
- Financial Planner – demand as revenue-producing consumption;
- Economist – demand as a choice-based relationship between quantity and price, sometimes conditional on quality and reliability

AMR can be used to measure water produced (supply) or water consumed (customer demand). These two types of measures can differ; instantaneous production can differ from instantaneous customer demand due to delivery system losses and the buffering effect of storage. This research will examine both production and consumption types of water utility problems.

Water demand models serve many purposes within water utilities. From a system planning perspective, demand models can *explain* how water use reacts to factors such as weather, price changes, conservation, income growth and other factors such as demographic change. The explanation of how these factors determine water demand can be used to *predict* how water demand can be expected to change. Improved measures and models of water demand have the potential to shed light on many of the planning problems confronting water utilities. Formal water demand models can also provide a framework for analyzing the forecast uncertainty, helping planners make rational decisions and manage risk.

Types of Demand Models

Even a cursory review of water demand forecasting literature shows that utilities use a wide variety of models for water demand forecasting, ranging from simple percent growth methods to sophisticated econometric models[1]. Times series analysis is appropriate for many forecasting applications, and researchers are beginning to explore advanced mathematical techniques such as genetic algorithms, fuzzy programming and artificial neural networks to forecast water demand. GIS-based forecasting systems are becoming increasingly popular, and provide a powerful tool for spatially disaggregated demand forecasting.

[1] Standard water demand references include Billings and Jones (1996), *Forecasting Urban Water Demand*, AWWA, and Baumann, Boland, and Hanemann (1988) Urban Water Demand Management and Planning.

Purpose of the Demand Forecast

The first question that must be asked is; what is the purpose of the water demand forecast? The answer will suggest a model type. A forecast designed for predicting short-term peaking might look an hour to several weeks in the future, and may include a high degree of spatial disaggregation, while a forecast used for resource planning might span 20 years and feature a low degree of spatial disaggregation. Forecast designed for developing spatially varying water rates may forecast one year out and feature a completely different level of geography. Each of these forecasts suggests a different type of model and level of spatial disaggregation. This will research will examine three types of demand forecasting applications:

- Short-Term Demand Forecasts—needed for operations optimization and revenue planning
- Long-Term Demand Forecasts—needed for resource planning, including DSM
- Demand Load Forecasts—needed for treatment and distribution system planning

1. Short-Term Demand Forecasting

Short-term demand models produce forecasts anywhere from one hour ahead to several years in the future, and are typically used for short-term system operations and optimization, but are also used for peak forecasting, reservoir operations, and revenue prediction.

Most short-term demand models tend to use aggregate demand measures that have a high temporal resolution (a daily or weekly time step). When spatial disaggregation is used in short-term models varies according to purpose, ranging from pressure zones, and treatment areas to other utility-specified load areas. Many short-term forecasting applications employ time-series or trending models such as exponential smoothing, which can be applied with minimal data needs to a large number of demand nodes. These simplistic forecasting methods, summarized in Billings and Jones (1996), are not the focus of this study and therefore are not described here.

There are several studies of daily water demand in the literature that specify short-term models using predictor variables. These include Maidment (1985) Maidment and Miaou, (1986), Smith (1988) Miaou (1990), Zhou (2000), Jain (2001), and Aly and Wanakule (2004). These short term water demand models can be used to predict peaking behavior tend to focus on predicting daily variations in water demand using measures of weather (precipitation, air temperature, evapotranspiration) and indictors for the day of the week. The model parameters are derived statistically using standard linear regression, transfer function (a nonlinear regression), or automated model selection such as a neural network or “boosting” approach (both of which can be depicted within a regression framework).

High-resolution AMR measures of water demand are more than planning tools for infrastructure investments. Importantly, demand models are a fundamental underpinning of any method to predict utility revenues. Simple revenue prediction models assume growth next year is the same as growth last year—or perhaps the average of the past five or ten years. Although still a common practice, these methods fail to account for the influence of climate or changing water rates, personal income or the business cycle. Short-term aggregate demand models sometimes also include some subset of the determinants of demand that are the focus of long term models of urban water demand: price of water, personal income, measures of conservation programs, and measures of the business cycle (see Hanemann (1998)).

Even when demand models account for climate and water rates, revenue prediction requires an understanding of the distribution of water use, especially in the presence of any kind of block rate structures. (See the AwwaRF study Chesnutt 1995). Although incentive rate structures are commonly thought to result in revenue deficits, the reverse can occur as well (Beecher, et al. 1994). Further, although demand variation affects both costs and revenues, it may do so in very different ways. (Moreau 1997). Any prediction of utility revenue can be as misleading as it is enlightening without a thorough understanding of its uncertainty Boland (1982). Chesnutt et al. (1994, 1995, and 1996) develop the means to measure revenue instability and to develop coping mechanisms that allow explicit tradeoffs between revenue stability, equity, and rate incentives for water conservation.

2. Long-Term Demand Forecasting

Long-term water demand forecasts are generally used for long-range system planning, resource development and rate planning, and range anywhere from several years to 20 years in the future. Some land-use based water demand forecasts will project system demands to a "build-out" state, representing the theoretical limits of development based on a general plan.

In functional form, long-term forecasting models range from relatively simple per capita models to data-intensive cross-sectional times-series econometric models. Most long-term models are based on "explanatory" or "driving" variables, such as population, households and land-use; and "coefficients" or "factors" which connect the drivers back to water demand. In these model formulations, long-term projections of the driving variables (population or acreage for instance) typically obtained from an outside agency or source, are combined with annual or seasonal water use factors. The water use factors may be fixed over time (gallons per acre per day) or vary based on projected changes in explanatory variables such as weather, household demographics, price, and conservation.

3. Demand Load Forecasting

Demand analysis constitutes one of the main steps as documented in AWWA M32 "Distribution Network Analysis for Water Utilities" though AMR is not specifically addressed. The study mentions the use of meter-read books as a base for nodal demands within a network. Customer meters are usually read bi-monthly or quarterly so an average annual use value can be obtained for each customer. When appropriate peaking factors are applied along with diurnal curves, a model will be ready for calibration against field data.

AWWA sponsored a research study by Lee Cesario titled "Modeling, Analysis, and Design of Water Distribution Systems" in which the importance of demand allocation was emphasized. One section of the book mentions that in order for a model to be simulated properly, water demand must be accurately distributed geographically and over time. These studies along with others (Lowry and Porter 1994, Orr, et. al 1994, Purves and Cesario 1992) have emphasized the importance of accurately distributing nodal demands within a network. The AwwaRF study by Chesnutt (2003) "Spatial Demand Allocation for Distribution System Design" set for the formal demand methodology for determining load shape from consumption data but did not have access to AMR data. Thus it was limited to measures of seasonal load shape.

Several other important studies have focused on residential water use. These studies were useful to the water industry from a consumption and time-pattern standpoint but do not constitute a comprehensive picture of water demand. AwwaRF has sponsored two studies within the recent past. A 1993 study (Bowen, et. al) is titled "Residential Water Use Patterns". Five cities were studied where electronic meters were installed at various residencies to determine a 24-hour demand pattern during the summer and winter months. Their main conclusions focused on the amount of water used by an individual residence and when the 24-hour peak demands occurred. It was a useful study where these patterns could be incorporated into a distribution model for an extended-period simulation.

The second study was headed by Aquacraft Inc. where they set out to create the most extensive database on end uses of residential customers in North America—the "North American Residential End Use Study". The main focus of the progress report was to determine how water is used by single-family residential households, that is, where are the end uses of water? A follow-up study did analyze a limited number of commercial customers. The study has been widely cited but inference outside the sample sites is limited since the scientific sampling was not used in the sample selection process. End use modeling does offer great potential to shed light on long term trends in demand load.

Various other studies have been conducted in the past (Kuranz 1942, Graeser 1958, Hudson 1964, Sisco 1967, Neilsen 1969, Brittain 1974, Newman and Noss 1982, Yanov and Koch 1987). The main focus of these articles was to determine residential end uses by developing diurnal curve patterns, actual usage within a structure, or comparing usage patterns from different parts of the country. These studies can be useful in hydraulic modeling but differ in scope from this proposal.

None of these studies looked into developing a methodology to analyze water consumption or production data using current automatic meter reading technology (AMR). This research, by contrast, is designed to help utilities develop

an analytic strategy for transforming the large volume of data created by automated metering into information useful for utility decision making.

Electricity utilities have performed much more research on demand load (See AEIC, 2001), largely through necessity. Electrons are expensive and difficult to store. The research from AMR applications with energy utilities--produced by EPRI, AEIC, and the AMRA--will be examined to assess its applicability to the water industry. Thomas and Hall (1992) provide a simulation based approach to least cost planning for electricity. The daily load and load duration curves for electricity (Charts 1 and 2) reveal an interesting contrast with one taken from the water industry (Figure 1).

Chart 1: Daily Load Curve

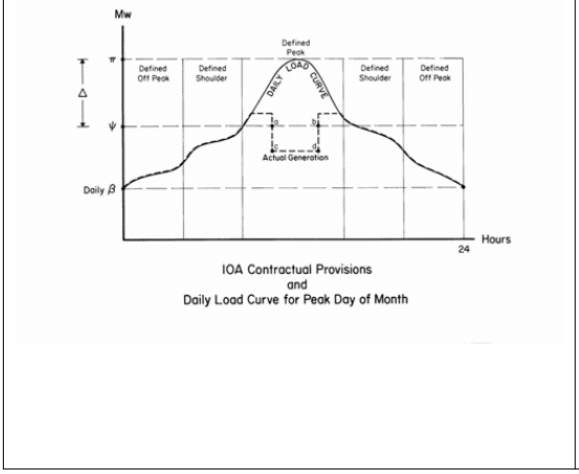
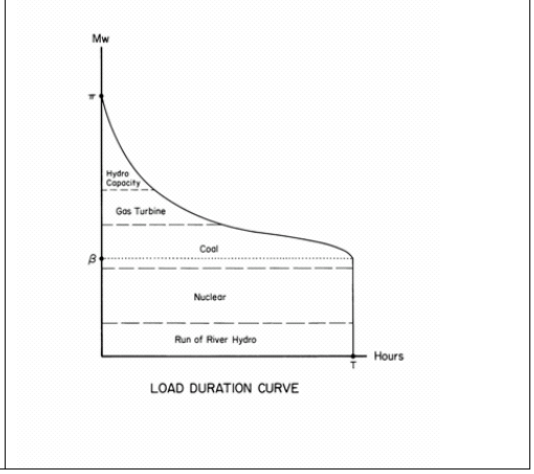
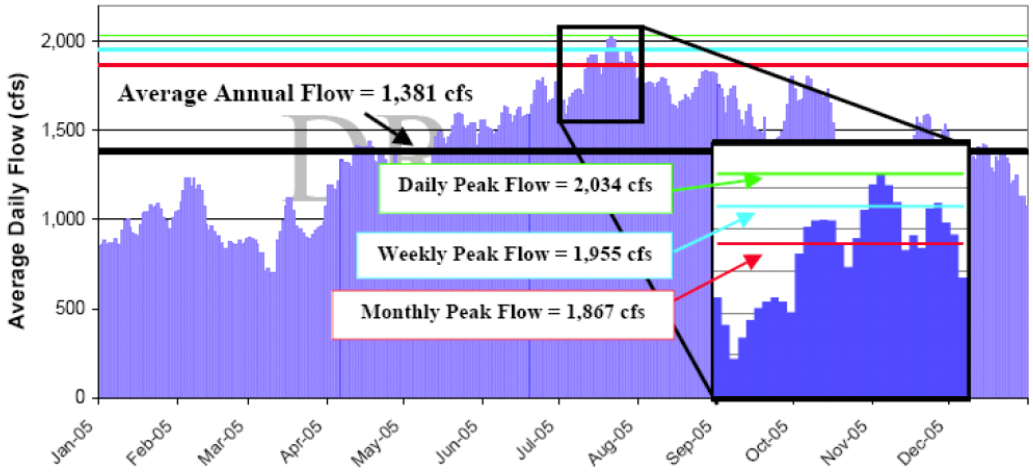


Chart 2: Load Duration Curve



Source: Thomas and Hall (1992).

Figure 1 – Central Pool Average Daily Flow Calendar Year 2005
(Unadjusted Flows - Replenishment and Agricultural Deliveries included)



AMR measures of the type of production data displayed in Figure 1 have been used to estimate peaking factors and inform the timing of major investments in treatment and distribution system infrastructure. This research will explore formal demand load models that require AMR data to better inform major investment decisions in the North American water industry.

REFERENCES

AEIC, 2001, *Load Research Manual*, 2nd Edition. The Association of Edison Illuminating Companies. http://www.aeic.org/load_research/lrpubs.html

AWWA, 1989. American Water Works Association Manual M32. AWWA.

AwwaRF, 1992. *Automatic Meter Reading for the Water Industry* Report No. 90594.
Examines the state-of-the-art and the economic feasibility of automatic meter reading (AMR). Evaluates AMR standardization needs and impacts.

Aly, A.H. and N. Wanakule. 2004. Short-term Forecasting for Urban Water Consumption. *Journal of Water Resources Planning and Management, ASCE*. 130:5(405). September/ October.

Baleriaus, H., E. Jamoulle and Linard de Guertechin (1967), "Simulation de l'Exploitation d'un Parc de Machines Thermiques de Production d'Electricite Couple a des Station de Pompage," *Extrait de la Revue E* (edition SRBE), Vol. 5: 3-24.

Beecher, et al., "Revenue Effects of Water Conservation and Conservation Pricing: Issues and Practices," National Regulatory Research Institute, September 1994.

Chesnutt, T.W. et al, "Designing, Evaluating, and Implementing Conservation Rate Structures," California Urban Water Conservation Council, July 1997.

Chesnutt, T.W., C.N. McSpadden, and J. Christianson, "Revenue Instability Induced by Conservation Rate Structures", Journal of the American Water Works Association, January 1996, pp. 52-63.

Chesnutt, T.W., A. Bamezai, C.N. McSpadden, J. Christianson, and W. M. Hanemann, Revenue Instability and Conservation Rate Structures, A report for American Water Works Association Research Foundation and the United States Bureau of Reclamation, 1995.

Chesnutt, T.W., A. Bamezai, C. N. McSpadden, J. Christianson, and W. M. Hanemann, "Revenue Instability Induced by Conservation Rate Structures: An Empirical Investigation of Coping Strategies", Proceedings of the American Water Works Association Conference in New York, June 1994.

Boland, J. J., R. W. Wentworth, and R. C. Steiner. 1982. Forecasting short-term revenues for water and sewer utilities. Journal American Water Works Association, 74(9): 460—465.

Boland, J.J., 1998.Chapter 3: Forecasting Urban Water Use: Theory and Principles. pp. 77-94. In (D.D. Baumann, J.J. Boland, M. Hanemann, Eds.) *Urban Water Demand Management and Planning.* McGraw-Hill Publishers.

Bowen, P.T. 1993. Residential Water Use Patterns. AWWA Research Foundation.

Cesario, L. 1995. Modeling, Analysis, and Design of Water Distribution Systems. AWWA.

Chesnutt, T.W. 2003. *Spatial Demand Allocation for Distribution System Design*, Report No. 1P-4C-9093402/03-CM, Awwa Research Foundation,

Chesnutt, T.W. and C.N. McSpadden. 1995. *Determinants of Phoenix Water Demand*, A report for the City of Phoenix, February.

Chesnutt, T.W., C.N. McSpadden, and J. Christianson. 1996, "Revenue Instability Induced by Conservation Rate Structures", *Journal of the American Water Works Association*, January, pp. 52-63.

Chesnutt, T.W., A. Bamezai, C.N. McSpadden, J. Christianson, and W. M. Hanemann, 1995, *Revenue Instability and Conservation Rate Structures*, A report for American Water Works Association Research Foundation and the United States Bureau of Reclamation, 1995.

Chesnutt, T.W., A. Bamezai, C. N. McSpadden, J. Christianson, and W. M. Hanemann, 1994. "Revenue Instability Induced by Conservation Rate Structures: An Empirical Investigation of Coping Strategies", *Proceedings of the American Water Works Association Conference in New York*, June.

Christianson, R., (1994) "What utilities love and hate about AMR .(automatic meter reading)", *Public Utilities Fortnightly.* Vol. 138; pp. 26-29.

Clark and Grayman, 1998, *Modeling Water Quality in Drinking Water Distribution Systems*, AWWA, Denver Co.

Dziegielewski, B. 1996. Long-Term Forecasting of Urban Water Demands, pp. 33-49. In: Darwin C. Hall (Ed.), *Advances in the Economics of Environmental Resources*. Volume 1: JAI Press Inc., Greenwich, CT, London, England. 1996.

Dziegielewski, B. and J. J. Boland. 1989. Forecasting urban water use: the IWRMAIN model. *Water Resources Bulletin,* 25(1): 101—119.

Dziegielewski B. and E. Opitz. 2004 .Chapter 1: Water Demand Analysis. In: Urban Water Supply Management Tools. Larry W. Mays (editor). McGraw-Hill
Ford, L. R. and D. R. Fulkerson, 1962, Flows in Networks, Princeton University Press.

Frey, McCuller, Henke, Spackman, and Murphy (2001). "Optimizing a water master plan." *Journal AWWA*, Vol. 93, No. 5, p. 86.

Graeser, H.J. 1958. Detecting Lost Water at Dallas. *Journal. AWWA*, 50(7):925-932.

Hanemann. W.M. 1998.Chapter 2: Determinants of Urban Water Use. pp.31-75, In (D.D. Baumann, J.J. Boland, M. Hanemann, Eds.) *Urban Water Demand Management and Planning.* McGraw-Hill Publishers.

Hsiao (1986) *Analysis of Panel Data,* Cambridge University Press.

Hudson, W.D. 1964. Reduction of unaccounted-for Water. *Journal. AWWA*, 56(2):143-148.

James L. D. and R.R. Lee. 1971. *Economics of Water Resources Planning*. McGraw-Hill Book Company: New York.

Jones, C. V,J.J. Boland,J. B, Crews, C. F. DeKay, and J. R. Morris. 1984. *Municipal Water Demand: Statistical and Management Issues*. Boulder, CO: Westview Press.

Jain, A., A.K. Varsheney, and U. C. Joshi. 2001. Short-term Water Demand Forecast Modeling at IIT Kanpur Using Artificial Neural Networks. *Water Resources Management* 15: 299-321.

Kuranz, A.P. 1942. Meter Maintenance Practice. *Journal. AWWA*, 34(1):117-120.

Lowry, S.G. and Porter, R.S. 1994. Automated Demand Allocating, Updating, and Forecasting Through Integration of GIS, Distribution System Model and Erie County, New York, Water Authority Customer Database. In *Proc. Computers in the Water Industry Computer Conference*. AWWA.

Maidment, D.R., S.P. Miaou; and M.M. Crawford. 1985. Transfer Function Models of Daily Urban Water Use. Water Resources Research 26(2), 425-432

Maidment, D.R. and S.P. Miaou. 1986. Daily Water Use in Nine Cities. *Water Resources Research* 222(6), 845-851.

Mayer, P.W., and DeOreo, W.B., 1997. North American Residential End Use Study: Progress Report. 1997 AWWA Annual Conference.

Merritt, S. 2004. "The Demand for Water: Four Interpretations," *Water International*, Vol. 29, No. 1, pp. 27–29.

Miaou, S.P. 1990. A Class of Time Series Urban Water Demand Models with Non-linear Climatic Effects. Water Resources Research 26(2), 169-178

Moreau, D.H., "Trends in Revenues and Expenditures for Water and Sewer Services: Implications for Demand Management," Chapter 8 in Bauman D.D., J.J. Boland, and W.M. Hanneman, Urban Water Demand Management and Planning, 1997, McGRaw-Hill.

Nielsen, N. 1969. Determination of Proper Age for 5/8 Inch Meters in the Hackensack and Spring Valley Systems. *Report for the Hackenstack Water Co*., Harrington Park, NJ.

Newman, G.J., and Noss, R.R. 1982. Domestic 5/8 Inch Meter Accuracy and Testing, Repair, and Replacement Programs. In *Proc. Of the 1982 AWWA Annual Conference*, Part 1, Paper No. 11-7. Denver, CO: AWWA.

Opitz, E.M., J.F. Langowski, B. Dziegielewski, N. Hanna-Somers, S.Willet and R. Houer. 1998. Chapter 4. Forecasting Urban Water Use: Models and Applications. pp. 95-136, In (D.D. Baumann, J.J. Boland, M. Hanemann, Eds.) *Urban Water Demand Management and Planning.* McGraw-Hill Publishers. 1998.

Orr, C.H., Alegre, H., and Coelho, S.T. 1994. System Analysis and Modeling for a Water Information System. In *Proc. Computers in the Water Industry Computer Conference*, AWWA.

Sisco, R.J. 1967. The Case of Meter Replacement Programs. *Journal. AWWA*, 59(11):1149-1455.

Smith, J.A. 1988. A Model of Daily Municipal Water Use for Short-term Forecasting. Water Resources Research 24(2), 201-206.

Tamarkin, Tom & Starkey, Gene, (1989) *The Complete Handbook of Automatic Meter Reading*, Technopress, Boulder, CO.

Tamarkin, T. 1992 "Automatic Meter Reading," Public Power , Volume 50, Number 5.

Thomas, B.G., and Hall, D.C. (1992), "Probabilistic production costing under integrated operation agreements and joint power agency financing," Energy Economics, July: 200-208.

Wooldridge (2002) *Econometric Analysis of Cross Section and Panel Data.*

Yanov, D.A., and Koch, R.N. 1987. A Modern Residential Flow Demand Study. Session 27 of AWWA Annual Conference, Kansas City, KS.

Zheng Y. W., P. F. Boulos, C. H. Orr, and J. J. Ro, (1998), "Using Genetic Algorithms to Rehabilitate Distribution Systems," *Journal AWWA*, Vol. 98, No. 11, p. 74.

Zhou, S. L. T.A. McMahon, A. Walton, and J. Lewis. 2000. Forecasting Daily Urban Water Demand: A Case Study of Melbourne. *Journal of Hydrology*, 236, 153-164

QUALITY ASSURANCE/QUALITY CONTROL

Measures will be taken throughout the project to maintain quality to assure accurate project results. At each stage of data acquisition, data will be acquired and checked for accuracy prior to use. Data verification will include both spot checks and complete computerized comparisons with original data sources. All project data and calculated results will also be reviewed by the project team and subsequently by the Project Advisory Committee for validation checks. Typical quality control steps will occur as follows:

1. Data/information obtained for original source
2. Data/information is put in proper computer format
3. **QA/QC** – Computer data verified/checked against original source data
4. Computer analysis used to calculate new data
5. **QA/QC** – Calculated data is reviewed and spot verified
6. Calculated data is published
7. **QA/QC** – Published data is reviewed by Project Advisory Committee

The steps outlined here to maintain quality control and quality assurance will be strictly followed at all times to assure the accuracy of project results. In this way, data obtained through this research will be of the highest quality.

SCHEDULE

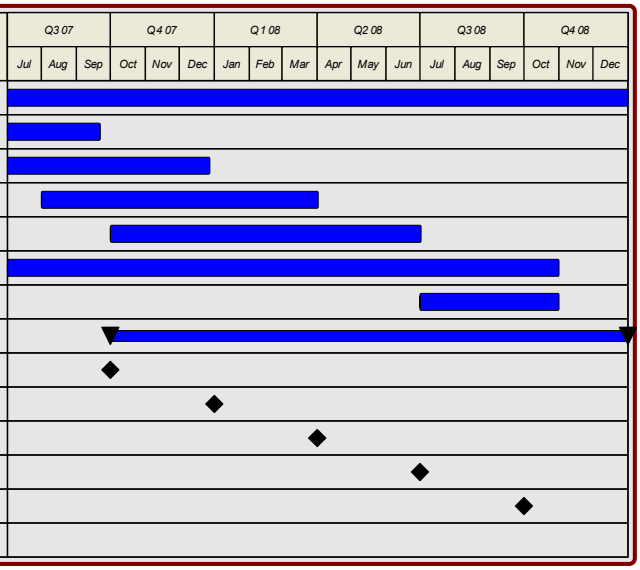
Quarterly report schedule, project work products and due dates

Report #	Due Date*	Description and Products Included
Quarterly Report #1	10/1/2007	Work completed during first three months of project – Literature review, description of AMR inception and relevant planning issues for each case study.
Quarterly Report #2	1/1/2008	Work completed during first six months of project – draft Conceptual Framework
Quarterly Report #3	4/1/2008	Work completed during first 9 months of project – draft data and modeling chapters
Quarterly Report #4 – Annual Report #1	7/1/2008	Work completed during first year of project – literature review, description of AMR inception and relevant planning issues, draft Conceptual Framework, draft chapters on draft data and modeling chapters, Draft write ups of each case study
Quarterly Report #5	10/1/2008	Work completed during first 15 months of project – draft Decision Framework and Recommended Planning Practices
Draft Final Report	1/1/2009	Draft final report summarizing findings and methodology.
Completed Final Report	4/1/2009	A three-month review and revision period is provided.

*Assumes a project start date of July 2, 2007

Project Schedule by Task

ID	Task Name	Start	Finish	Duration
1	Task 1 Project Management	7/2/2007	4/1/2009	458d
2	Task 2 Literature Search and Review	7/2/2007	9/21/2007	60d
3	Task 3 Conceptual Framework	7/2/2007	12/27/2007	129d
4	Task 4 Data Collection, Manipulation	8/1/2007	4/1/2008	175d
5	Task 5 Statistical Demand Models	10/1/2007	7/1/2008	197d
6	Task 6 Applications	7/2/2007	10/31/2008	350d
7	Task 7 Decision Framework	7/1/2008	10/31/2008	89d
8	**Task 8 Documentation**	**10/1/2007**	**1/1/2009**	**328d**
9	Quarterly Report #1	10/1/2007	10/1/2007	0d
10	Quarterly Report #2	1/1/2008	1/1/2008	0d
11	Quarterly Report #3	4/1/2008	4/1/2008	0d
12	Annual Report #1	7/1/2008	7/1/2008	0d
13	Quarterly Report #5	10/1/2008	10/1/2008	0d
14	Draft Final Report	1/1/2009	1/1/2009	0d



MANAGEMENT PLAN AND STATEMENT OF QUALIFICATIONS

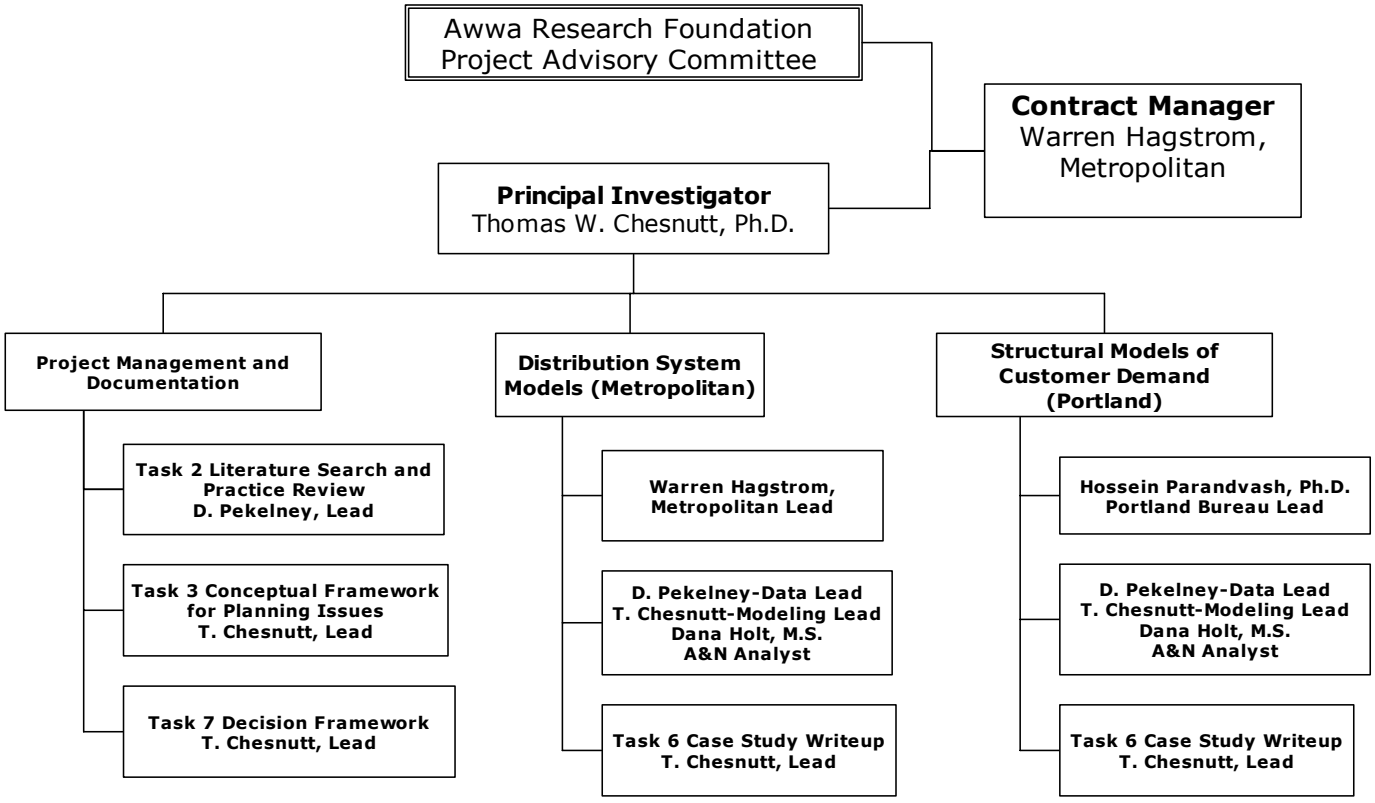
Management Plan

This section describes the management plan, the roles and responsibilities of the key team members, and the qualifications of the investigators. The proposed research will be led by the Metropolitan Water District of Southern California in conjunction with A&N Technical Services (A&N). Other project participants include:

- The Municipal Water District of Orange County,
- The City of Portland Bureau of Water Works, and
- The Tualatin Valley Water District.

An organizational chart is shown in Figure 2. The project will be administered by AWWARF, and the Project Advisory Committee (PAC) will report directly to the designated AWWARF Project Manager. The principal investigator for this project is Dr. Thomas W. Chesnutt from A & N Technical Services. Dr. Chesnutt will interface directly with AWWARF. Other Metropolitan participants include Mr. Robert Harding, Mr. Brandon Goshi, and Mr. Warren Hagstrom. Coordination and communication between the participants will be accomplished by periodic working meetings, conference calls, and Internet communications. Fortunately, all case study participants are within close vicinity to make frequent project meetings possible.

Figure 2. Organization Chart and Management Plan



The project team assembled for this research is uniquely qualified to conduct this work. Extensive water use studies have been performed by A & N. Additionally, numerous relevant water demand and system planning studies have been conducted by team participants. Resumes for the project team are included in Appendix A. A brief description of the qualifications for each team member is presented below.

Qualifications of Research Team

To address the complex and multidimensional challenges posed by this research, we have assembled a team of experts that spans the relevant economic, engineering, institutional, financial, and management elements relevant to the study. Our team consists of an array of consulting researchers, empirical modelers, and utility practitioner experts to address the full range of AMR data collection, modeling, and planning issues. The team member's credentials are detailed in the Statement of Qualifications section of this proposal.

The research will be led by ***Dr. Thomas Chesnutt*** (A&N Technical Services) and ***Mr. Warren Hagstrom*** (Metropolitan). As project manager, Mr. Hagstrom will coordinate the project with AwwaRF, the project team, and the participating utilities. As Principal Investigator, Dr. Chesnutt will focus on the defining the modeling tasks, data requirements, expected results, and project documentation. ***Dr. Hossein Parandvash*** (City of Portland) will lead the econometric modeling of water consumption data in the City of Portland.

Thomas Chesnutt, Ph.D. and ***David Pekelney, Ph.D.*** (A&N Technical Services) are experts in empirical policy analysis specializing in water utilities. They have worked on water resource issues including water resource planning, statistical modeling of consumption and production data, and have provided technical support to water agencies in water demand modeling, water resource economics, and valuation. A & N has developed a national reputation for their work in empirical models, in explaining the use and practical import of empirical methods, and in integrating cutting edge methods into utility plans. They were the lead researchers for AwwaRF's *Spatial Demand Allocation for Distribution System Design* and *Water Efficiency Programs for Integrated Water Management.* Dr. Chesnutt is a member of the AWWA Planning and Evaluation Committee of the Conservation Division. Dr. Pekelney is a member of the AWWA Rates and Charges subcommittee of the Management Division.

Dana Holt, M.S. Dana Holt is the resident information scientist at A & N Technical Services. She has over 17 years experience in software and hardware project lifecycle development, software implementation, project management, technical writing, and training. She is responsible for database, programming, web development, and financial analyses under tight time and budget constraints.

TAILORED COLLABORATION BUDGET

Project Budget Form						
Direct Cost				**Cash Funds (including AwwaRF)**	**In-Kind Contribution**	**Total**
Personnel	**# of Hours**	**Hourly Rate**	**% of Time Allocated to Project**	**US $**	**US $**	**US $**
Thomas Chesnutt	560	$200	19%	$112,000	$11,491	$123,491
David Pekelney	480	$150	17%	$72,000	$8,000	$80,000
Dana Holt	450	$110	16%	$49,500	$5,500	$55,000
A & N Analyst	540	$96	19%	$51,840	$5,760	$57,600
Clerical	220	$38	8%	$8,360	$929	$9,289
Personnel Subtotal				$293,700	$31,680	$325,380
Metropolitan Water District of Southern California				$50,000	$25,000	$75,000
The Municipal Water District of Orange County					$10,000	$10,000
The City of Portland Bureau of Water Works				$50,000	$45,000	$95,000
Tualatin Valley Water District				$50,000	$10,000	$60,000
Contractor contribution					$31,680	
Utility and Other Organization Cash and In-kind					$121,680	$240,000
Subtotal Direct Labor				$293,700		$565,380
Travel				$6,300		$16,025
TOTAL PROJECT BUDGET				**$300,000**	**$121,680**	**$421,680**

TC CO-FUNDING SUPPORT FORM

Note: Each co-funding organization (including the sponsoring utility) must complete a separate Co-Funding Support Form and include it in the proposal.

Co-Funding Organization: Metropolitan Water District Of Southern California

Type of Organization: _X_water utility ____consulting firm ____ manufacturer ____other (describe)

Is your organization eligible to participate in one of AwwaRF's subscription programs? _X_ Yes ___ No

Is your organization requesting that AwwaRF match its funds? _X_ Yes ____No

Is your organization eligible for AwwaRF matching funds? _X_ Yes ____No

Cash co-funding amount being provided by your organization (in USD) $ 50,000

Person responsible for contract matters for your organization:
Name: Setha Schlang, Sr Deputy General Counsel

Address at which FedEx packages can be received: 700 North Alameda Street, Los Angeles, CA 90012

Phone/Fax/e-mail: 213.217.6329/213.217.6949/sschlang@mwdh2o.com

Person responsible for accounting matters for your organization:

Name: Drew Boronkay

Address at which FedEx packages can be received: 700 North Alameda Street, Los Angeles, CA 90012

Phone/Fax/e-mail: 213.217.6748/213.217.6949/dboronkay@mwdh2o.com

What approvals will be required in order for your funds to be released to AwwaRF? (e.g., City Council, Board of Commissioners)
None

Have these approvals been obtained? __X_ Yes ____ No

Can approvals be obtained and co-funding agreements be signed within 120 days of award? _X_Yes ___No
(**Note:** 120 days after award notification AwwaRF may cancel the award--see TC proposal guidelines for details.)

Are there any conditions of the AwwaRF Co-Funding Agreement that would prevent you from signing it as it is currently worded? _____Yes __X__No
If yes, please explain: (attach additional pages if required)

The person signing below acknowledges they are authorized to commit their organization to the proposed work.

Signature  Print Name Steven N. Arakawa

Title Manager, Water Resource Management Group_____Organization MWD of Southern Cal

Date 3/26/2007 5/22/07 Phone 213.217.6052

Mailing Address PO Box 54153, Los Angeles, CA 90054-0153

TC CO-FUNDING SUPPORT FORM

Note: Each co-funding organization (including the sponsoring utility) must complete a separate Co-Funding Support Form and include it in the proposal.

Co-Funding Organization: Tualatin Valley Water District

Type of Organization: ✓ water utility ____ consulting firm ____ manufacturer ____ other (describe)

Is your organization eligible to participate in one of AwwaRF's subscription programs? ✓ Yes ____ No

Is your organization requesting that AwwaRF match its funds? ✓ Yes ____ No

Is your organization eligible for AwwaRF matching funds? ✓ Yes ____ No

Cash co-funding amount being provided by your organization (in USD) $ 50,000

Person responsible for contract matters for your organization:
Name: Greg DiLoreto, General Manager

Address at which FedEx packages can be received: 1850 SW 170th Avenue
Beaverton, OR 97006

Phone/Fax/e-mail: (503) 642-1511 (503) 649-2733 fax greg@tvwd.org

Person responsible for accounting matters for your organization:

Name: Debbie Jarrett - Accounts Payable
Bernice Bagnal - CFO

Address at which FedEx packages can be received: above

Phone/Fax/e-mail: above debbiej@tvwd.org bernice@tvwd.org

What approvals will be required in order for your funds to be released to AwwaRF? (e.g., City Council, Board of Commissioners)
General Manager approval

Have these approvals been obtained? ✓ Yes ____ No

Can approvals be obtained and co-funding agreements be signed within 120 days of award? ✓ Yes ____ No
(**Note:** 120 days after award notification AwwaRF may cancel the award--see TC proposal guidelines for details.)

Are there any conditions of the AwwaRF Co-Funding Agreement that would prevent you from signing it as it is currently worded? ____ Yes ✓ No
If yes, please explain: (attach additional pages if required)

The person signing below acknowledges they are authorized to commit their organization to the proposed work.

Signature _____ Print Name Greg DiLoreto

Title General Manager Organization Tualatin Valley Water Dist.

Date 2/21/07 Phone (503) 848-3032

Mailing Address P.O. Box 745 Beaverton, OR 97075

TC CO-FUNDING SUPPORT FORM

Note: Each co-funding organization (including the sponsoring utility) must complete a separate Co-Funding Support Form and include it in the proposal.

Co-Funding Organization: Portland Water Bureau

Type of Organization: ✓water utility ____consulting firm ____ manufacturer ____other (describe)

Is your organization eligible to participate in one of AwwaRF's subscription programs? ✓Yes ____ No

Is your organization requesting that AwwaRF match its funds? ✓ Yes ____No

Is your organization eligible for AwwaRF matching funds? ✓ Yes ____No

Cash co-funding amount being provided by your organization (in USD) $50,000

Person responsible for contract matters for your organization:

Name: Annette Dabashinsky, Contract ReviewAdmin

Address at which FedEx packages can be received: 1120 SW 5th Ave, Room 600, Portland, OR 97204

Phone/Fax/e-mail: (503) 823-7921 / (503)823-4500 / adabashinsky@water.ci.portland.or.us

Person responsible for accounting matters for your organization:

Name: Tom Fitzgerald, Accounting Manager

Address at which FedEx packages can be received: 1120 SW 5th Ave, Room 600, Portland, OR 97204

Phone/Fax/e-mail: (503) 823-6142 / (503)823-6133 / tfitzgerald@water.ci.portland.or.us

What approvals will be required in order for your funds to be released to AwwaRF? (e.g., City Council, Board of Commissioners)
None

Have these approvals been obtained? ✓Yes ____ No

Can approvals be obtained and co-funding agreements be signed within 120 days of award? ✓Yes __No (**Note:** 120 days after award notification AwwaRF may cancel the award--see TC proposal guidelines for details.)
The funding for PWB cash contribution has been approved and is in the FY06-07 budget. The fiscal year ends June 30, 2007. After that date we need to get funding approval.

Are there any conditions of the AwwaRF Co-Funding Agreement that would prevent you from signing it as it is currently worded? ____Yes ✓No
If yes, please explain: (attach additional pages if required)

The person signing below acknowledges they are authorized to commit their organization to the proposed work.

Signature _____ Print Name EDWARD A. CAMPBELL

Title RESOURCE PROTECTION & PLANNING DIRECTOR Organization PWB

Date 1/20/07 Phone (503) 823-2787

Mailing Address _____

CASH AND IN-KIND SUPPORT FORM

Cash and In-Kind Support from Participating Utilities and Other Participating Organizations				
Name of Organization	**Name of Contact**	**Cash* Commitment (US $)**	**In-Kind* Commitment (US $)**	**Total* Commitment (US $)**
Metropolitan Water District of Southern California	Warren Hagstrom whagstrom@mwdh2o.com	$50,000	$25,000	$75,000
The Municipal Water District of Orange County	Richard Bell rbell@mwdoc.com		$10,000	$10,000
The City of Portland Bureau of Water Works	Hossein Parandvash hparandvash@ water.ci.portland.or.us	$50,000	$45,000	$95,000
Tualatin Valley Water District	Greg DiLoreto greg@tvwd.org	$50,000	$10,000	$60,000
Contractor in-kind contribution	Tom Chesnutt tom@antechserv.com		$31,680	$31,680
TOTAL		**$150,000**	**$121,680**	**$271,680**

*Please note: Letters of commitment that specify dollar amount must be included with proposal for all in-kind included on this worksheet.

MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Executive Office

June 5, 2007

Mr. Roy Martinez
TC Proposal Desk
Awwa Research Foundation
6666 West Quincy Avenue
Denver, CO 80235

Dear Mr. Martinez

Participation in AwwaRF Tailored Collaboration Proposal:
Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

The Metropolitan Water District of Southern California (Metropolitan) is pleased to participate as a member of the research team that is submitting a tailored collaboration proposal to the American Water Works Association Research Foundation entitled "Empirical Demand Analysis of AMR Data for Distribution and Systems Planning." This project will assist in providing critical information concerning optimizing the use of automatic meter reading technology to meet future demands and to project future infrastructure needs. Metropolitan will assist in the research project by providing $25,000 of in-kind contributions of staff time in support of this vital project.

Very truly yours,

Stephen N. Arakawa
Manager, Water Resource Management

WPH:tw
o:\a\s\c\2007\WPH_AwwaRF Tailored Collaboration Proposal-AMR Data.doc

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

10500 Ellis Avenue
P.O. Box 20895
Fountain Valley, California 92728
(714) 963-3058
Fax: (714) 964-9389
www.mwdoc.com

June 18, 2007

Mr. Roy Martinez
TC Proposal Desk
Awwa Research Foundation
6666 West Quincy Avenue
Denver, CO 80235-3098

Subject: Participation in AwwaRF Tailored Collaboration Proposal: *Empirical Demand Analysis of AMR Data for Distribution and System Planning*

Dear Mr. Martinez,

The Municipal Water District of Orange County (MWDOC) is pleased to participate as a member of the research team that is submitting a tailored collaboration proposal to the American Water Works Association Research Foundation entitled *"Empirical Demand Analysis of AMR Data for Distribution and System Planning"*.

This project will assist in providing critical information concerning optimizing the use of automatic meter reading technology to better evaluate demand patterns and will greatly help in meeting future demands and to project future infrastructure needs.

MWDOC will assist in the research project by providing $10,000 of in-kind contributions of staff time in support of this important project.

Very truly yours,

Karl W. Seckel, PE
Assistant General Manager/Chief Engineer

cc: Steven N. Arakawa/Warren Hagstrom

CITY OF
PORTLAND, OREGON
BUREAU OF WATER WORKS

Randy Leonard, Commissioner
David G. Shaff, Interim Administrator
1120 SW 5th Avenue
Portland, Oregon 97204
Information (503) 823-7404
Fax (503) 823-6133
TDD (503) 823-6868

June 1, 2006

Mr. Roy Martinez
TC Proposal Desk
Awwa Research Foundation
6666 West Quiney Avenue
Denver, CO 80235

Dear Mr. Martinez:

Participation in AWWARF Tailored Collaboration Proposal:
Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

The Portland Water Bureau (PWB) is pleased to participate as a member of the research team that is submitting a tailored collaboration proposal to the American Water Works Association Research Foundation entitled "*Empirical Demand Analysis of AMR Data for Distribution and Systems Planning.*" This project will assist in providing critical information concerning optimizing the use of automatic meter reading technology to meet future demands and to project future infrastructure needs. PWB will assist in the research project by providing a cash co-funding contribution of $50,000 in addition to in-kind contributions of staff time in support of this vital project. Our ability to participate in this project cash contribution, however, depends on being able to make the first payment prior to June 30, 2006. If this is an issue please contact us as soon as possible.

Sincerely,

Edward Campbell
Group Director Resource Protection

Cc: G. Hossein Parandvash
Michael Stuhr

Tualatin Valley Water District

1850 SW 170th Ave. • P.O. Box 745 • Beaverton, Oregon 97075 • 503/642-1511 • FAX: 503/649-2733

ory E. DiLoreto
ral Manager

ice Bagnall
Financial Officer

Heidgerken
ager, Community
ergovernmental
ions

Fishback
ager, Operations
eld Services

da Lennox
ager, Customer &
ort Services

Pippin
ager, Engineering
ces

a Enckson
an Resources
dinator

June 6, 2007

Mr. Roy Martinez
TC Proposal Desk
AWWA Research Foundation
6666 West Quincy Avenue
Denver, CO 80235

Dear Mr. Martinez;

Participation in AwwaRF Tailored Collaboration Proposal: Empirical Demand Analysis of AMR Data for Distribution and Systems Planning

The Tualatin Valley Water District (TVWD) is pleased to participate as a member of the research team that is submitting a tailored collaboration proposal to the American Water Works Association Research Foundation entitled "Empirical Demand Analysis of AMR Data for Distribution and Systems Planning." This project will assist in providing critical information concerning optimizing the use of automatic meter reading technology to meet future demands and to project future infrastructure needs. MWD will assist in the research project by providing $10,000 of in-kind contributions of staff time in support of this vital project.

Respectfully,

Gregory E. DiLoreto
General Manager

A&N Technical Services, Inc.

June 5, 2007

Dear Warren Hagstrom,

Ref: AwwaRF Tailored Collaboration - "Empirical Demand Analysis of AMR Data for Distribution and Systems Planning."

I am pleased to be a participant with Metropolitan Water District of Southern California (MWD) team that is submitting the above Tailored Collaboration. This proposal is being offered to the American Water Works Research Foundation (AwwaRF). This project will assist in providing critical information concerning optimizing the use of automatic meter reading technology to meet future demands and to project future infrastructure needs. As a participant, I will be providing in-kind services with a monetary value of $31,680 non-cash contribution.

Sincerely yours,

Dr. Thomas W. Chesnutt

839 2nd Street Suite 5 • Encinitas, CA 92024-4452 • Tel: 760.942.5149 • Fax: 760.942.6853
11808 Stanwood Drive • Los Angeles, CA 90066 • Tel: 310.439.1883 • Fax: 310.439.1884

APPENDIX A

Résumés of Project Team

THOMAS W. CHESNUTT

EDUCATION

1987	Ph.D., RAND Graduate School, Public Policy Analysis, Distinction in Economics
1985	M.Phil., RAND Graduate School, Public Policy Analysis
1983	M.S., Georgia Institute of Technology, Technology and Science Policy
1980	B.A., Kenyon College, Ohio, High Honors in Economics

EXPERIENCE

3/86-Present — A & N Technical Services, Inc., Santa Monica, California

Cofounded the organization to provide state-of-the-art expertise in the fields of resource economics, program evaluation, market and cost analysis, rate design, and empirical policy analysis. Design and implementation of microcomputer-based applications of policy analysis--including econometric time-series analysis, stochastic simulation, forecasting, and decision support software. These applications are in the areas of water policy analysis, environmental policy, health statistics, and regulatory analysis.

12/85 —The A & N Group, Santa Monica, California

Cofounded this nonprofit organization dedicated to international technology assistance. Composed primarily of returned Peace Corps volunteers, the A & N Group focuses on improving public and private management in Sub-Saharan Africa through the applications of microcomputer technology.

9/83-9/87 — RAND, Santa Monica, California

Worked four years as a graduate fellow performing applied policy analysis under time constraints, primarily in the area of environmental policy. Conceived and estimated an econometric time series model of chlorinated solvent markets for the Environmental Protection Agency to use in analysis of regulatory alternatives. Developed, estimated, and forecast chlorofluorocarbon production to assess its effect as a potential ozone depleter. Emphasis on empirical applications using methods from statistics, operations research, and economics. Specific applications include simultaneous equations, nonlinear regression, James-Stein Pre-test estimators, Bayesian inference, time series analysis, and panel data methods.

6/82-6/83 — Georgia Institute of Technology, Atlanta, Georgia

Master's Thesis: A Risk Assessment of the Earthquake Hazard in the Southeastern United States. Estimated the physical risk from regression analysis of previous seismic events in five southeastern

cities. Devised a questionnaire to elicit the perception of earthquake risk in the five cities. Evaluated the derived and elicited estimates of seismic hazard for policy implications.

6/81-9/81 — Peace Corps

Peace Corps Trainer, Cameroon, West Africa. Trained new education volunteers in an intensive program of education methodology.

6/80-9/81 — Peace Corps

Peace Corps Education Volunteer in Cameroon, West Africa. Taught differential calculus at the Cameroon College of Art, Science and Technology (20 hrs./wk. to 300 students). Developed a curriculum based upon the British GCE Advanced level syllabus.

ORGANIZATIONS

Member of the California Bay Delta Authority Water Management-Science Board
The American Statistical Association
The American Water Works Association
  Member of the Planning and Evaluation Committee, Conservation Division
  Member of the Rates and Charges Subcommittee, Management Division
The Econometric Society
The Institute for Operations Research and the Management Sciences
The National Peace Corps Association
The Internation Water Association
The Šejek Society

PUBLICATIONS

Mayer P., W. DeOreo, T.W. Chesnutt, D.M. Pekelney et al. *Water Budgets and Water Rates,* Awwa Research Foundation, forthcoming.

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, *Water Efficiency Programs for Integrated Water Management"* Awwa Research Foundation, January 2007. Contains planning models for estimating Water Utility Direct Avoided Costs from WUE programs and WUE Benefit Cost Planning.

Chesnutt, T.W. and D.M. Pekelney, *A Review of Planning Methods and Tools Potentially Applicable for Advanced Treatment Technology In the Net New Water Supply Study (NEWAS),* A report for the U.S. Bureau of Reclamation, February 2006.

Chesnutt, T.W., D.M. Pekelney, and J. Berg, "*Evaluation of the Landscape Performance Certification Program*," AWWA Water Sources 2006 Conference Proceedings, February 2006.

Chesnutt, T.W., C.N. McSpadden, and J. Economedes, "The Water Demand Shaping Effects Of New Irrigation Technology: Evapotranspiration Irrigation Controllers In Southern California," *International Water Association International Conference On Water Economics, Statistics, and*

Finance, Rethymno Crete, Greece, July 2005.

Chesnutt, T.W., C.N. McSpadden, and J. Economedes, "Allocating Transportation Costs in a Water Network," *International Water Association International Conference On Water Economics, Statistics, and Finance*, Rethymno Crete, Greece, July 2005.

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, "Water Efficiency Programs for Integrated Water Management," in *Proceedings of the International Water Association Conference, Efficient 2005*, Santiago, Chile, March 2005.

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, "Avoided Cost Analysis in Integrated Planning for Water Efficiency: Concepts, Controversies, and Guidelines," in *Proceedings of the International Water Association Conference*, Efficient 2005, Santiago, Chile, March 2005.

Chesnutt, T.W., D.M. Pekelney, *Urban Water Conservation Implementation Challenges and Opportunities* prepared for, A report for the California Urban Water Agencies, September 2004.

Chesnutt, T.W., D.M. Pekelney, *CUWA Urban Water Conservation Potential—2003 Technical Update* , A report for the California Urban Water Agencies, July 2004.

Chesnutt, T.W. and J.A. Beecher, "The Tragedy of Common Benefits: Implementing Regional Conservation Anyway", *Proceedings of the American Water Works Association Water Sources Conference 2004 in Austin*, January 2004.

Chesnutt, T.W. and P. Mayer, "Water Budget-Based Rate Structures: A New Look at an Old Idea", *Proceedings of the American Water Works Association Water Sources Conference 2004 in Austin*, January 2004.

Chesnutt, T.W., D.M. Pekelney, and M. Erbeznik, *Evaluation of the Landscape Performance Certification Program*, A report for the Municipal Water District of Orange County and the Metropolitan Water District of Southern California, December 2003.

Chesnutt, T.W. and S. Gaur, *Residential Runoff Reduction Study—Statistical Analysis of Water Savings and Runoff Reduction*, A report for the Municipal Water District of Orange County, December 2003.

Chesnutt, T.W., *Economics of Water Recycling*, Workshop S4-Reclaimed Water, American Water Works Association Water Quality Technology Conference 2003 in Philadelphia, November 2003.

Chesnutt, T.W., *Spatial Demand Allocation for Distribution System Design*, Report No. 1P-4C-9093402/03-CM, Awwa Research Foundation, 2003.

Chesnutt, T.W. and T. Gould, "Recent Applications of Marginal/Incremental Cost Pricing in American Water Utilities", *Proceedings of the International Water Association Conference, Efficient Use and Management of Urban Water Supply*, Tenerife, Spain, April 2003.

Chesnutt, T.W. and J.A. Beecher, *Revenue Effects of Conservation Programs: The Case of Lost Revenue*, A White Paper prepared for the California Urban Water Conservation Council, March 2003.

Chesnutt, T.W., "Spatial Demand Allocation for Distribution System Design", *Proceedings of the American Water Works Association Conference 2002 in New Orleans*, June 2002.

Beecher, J.A. and T.W. Chesnutt, "Avoided Cost for Comparing Water Sources and Resources: Concepts, Controversies, and Guidelines", *Proceedings of the American Water Works Association Water Sources Conference 2002 in Las Vegas*, January 2002.

Chesnutt, T.W. and D.M. Pekelney, "A Primer on Individualized Water Rates: Designing and Implementing Water Budget-based Rates", *Proceedings of the American Water Works Association Water Sources Conference 2002 in Las Vegas*, January 2002.

Chesnutt, T.W., D.M. Pekelney, and D. Mitchell, "Valuing Desalination as a Water Resource Alternative: Five Risk Related Issues", *Proceedings of the American Water Works Association Water Sources Conference 2002 in Las Vegas*, January 2002.

Chesnutt, T.W. and S. Gaur, *Continuous-Time Short-Term Models of Daily Water Demand in San Diego County*, A report for the San Diego County Water District, February 2001.

Chesnutt, T.W. and S. Gaur, *Statistical Analysis of ULF Toilet Replacement on the Monterey Peninsula*, A report for the Monterey Peninsula Water Management District, February 2001.

Beecher, J.A., T.W. Chesnutt, and D.M. Pekelney, *Socioeconomic Impacts of Water Conservation*, Report No. 1P-5C-90817-3/01-CM, Awwa Research Foundation, 2001.

Pekelney, D., T. Chesnutt, and S. Gaur, *Orange County Water Futures Conservation Plan: Economic Methods and Models Overview*, prepared for the Municipal Water District of Orange County, August 2000.

Chesnutt, T.W., "Rates and Charges for the Twenty First Century", *Journal of the American Water Works Association*, Vol. 92, No. 1, pp. 64-65, January 2000.

Pekelney, D. and T. Chesnutt, *A Guide to Data and Methods for Cost-Effectiveness Analyses of Urban Water Conservation Best Management Practices*, A report for the California Urban Water Conservation Council, March 1999

Chesnutt, T.W., D.M. Pekelney, and G. Raftelis, *Water Rate Study*, for the Victor Valley Water District, December 1998.

Pekelney, D., W. Illingworth, and T. Chesnutt, "Economic Analysis of Regional Water Recycling Solutions in the San Francisco Bay Area," *WateReuse Association Symposium XIII Proceedings*, September 1998.

Chesnutt, T.W., et al., "Botching Storage: Ten Avoidable Ways to Wrongly Value Storage Capacity", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

McSpadden, C.N. and T.W. Chesnutt, "Valuing Water Transfers in an Integrated Resources Plan", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Mitchell, D.L. and T.W. Chesnutt, "Wheeling-ness to Pay: Guidelines for Establishing System Wheeling Charges", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Chesnutt, T.W. and J. A Beecher, "Designing, Evaluating, and Implementing Conservation Rates", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Beecher J. A. and T.W. Chesnutt, "Implementing Water Conservation Rates", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Beecher J. A., T.W. Chesnutt and P.C. Mann, "Efficiency and Profitability: Conservation Incentives for Investor-Owned Utilities", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Pekelney D.M. and T.W. Chesnutt, "Landscape Water Conservation Programs: Evaluation of Water Budget Based Rate Structures", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Chesnutt, T.W., D.M. Pekelney and M. Hollis, "Why do you always tell me it depends when I ask you how big a sample I need: A primer on sample size calculations", *Proceedings of the American Water Works Association Conference in Dallas*, June 1998.

Chesnutt, T.W. and J. A. Beecher, "Conservation Rates in the Real World", *Journal of the American Water Works Association*, Vol. 90, No. 2, pp. 60-70, February 1998.

Chesnutt, T.W., et al., *Designing, Evaluating, and Implementing Conservation Rate Structures*, A handbook for the California Urban Water Conservation Council, Sacramento, California, July 1997.

Pekelney, D.M. and T.W. Chesnutt, *Landscape Water Conservation Programs*, A report for the Metropolitan Water District of Southern California, July 1997.

Chesnutt, T.W., D.M. Pekelney, and D.L. Mitchell, "Valuing Conservation", *Proceedings of the American Water Works Association Conference in Toronto*, June 1997.

Chesnutt, T.W., "Performance Standards for Demonstrating Urban Water Conservation", *A briefing book prepared for the California Urban Water Agencies*, Sacramento, California, June 1997.

Chesnutt, T.W., C.N. McSpadden, and D.M. Pekelney, *An Impact Evaluation of Home Water Surveys in Los Angeles*, A report for the Metropolitan Water District of Southern California October 1996.

Pekelney, D.M., T.W., Chesnutt, and W. M. Hanemann, *Guidelines For Preparing Cost-Effectiveness Analyses of Urban Water Conservation BMPs*, A report for the California Urban Water Conservation Council, Sacramento, California, September 1996.

Chesnutt, T.W., and C. N. McSpadden, "Five Ways to Botch An Integrated Resource Planning Analysis," *Water Resources Update*, Issue No. 104, pp. 55-56, Summer 1996.

Chesnutt, T.W., C. N. McSpadden, and J. A. Beecher, "Putting the Pieces Together: Integrating Water Resources in IRP", *Proceedings of the American Water Works Association Conference in Toronto*, June 1996.

Pekelney, D.M., T.W., Chesnutt, and D.L. Mitchell, "Cost-Effective Cost-Effectiveness: Quantifying Conservation on the Cheap", *Proceedings of the American Water Works Association Conference in Toronto*, June 1996.

Pekelney, D.M., and T.W., Chesnutt, *Reference Document: Program Design Tool and Savings Estimates*, A report for the Metropolitan Water District of Southern California, May 1996.

Chesnutt, T.W., C.N. McSpadden, and J. Christianson, "Revenue Instability Induced by Conservation Rate Structures", *Journal of the American Water Works Association*, January 1996, pp. 52-63.

Chesnutt, T.W., A. Bamezai, C.N. McSpadden, J. Christianson, and W. M. Hanemann, *Revenue Instability and Conservation Rate Structures*, A report for American Water Works Association Research Foundation and the United States Bureau of Reclamation, 1995.

Chesnutt, T.W., C.N. McSpadden, and A. Bamezai, *Ultra Low Flush Toilet Programs: Evaluation of Program Outcomes and Water Savings*, A report for the Metropolitan Water District of Southern California, July 1995.

Chesnutt, T.W., C. N. McSpadden, and D. M. Pekelney, "What is the Reliable Yield from Residential Home Water Survey Programs? The Experience of the Los Angeles Department of Water and Power", *Proceedings of the American Water Works Association Conference in Anaheim*, June 1995.

Chesnutt, T.W. and C.N. McSpadden, *Determinants of Phoenix Water Demand*, A report for the City of Phoenix, February, 1995.

Bamezai, A. and T.W. Chesnutt, *Residential Water Audit Program: Evaluation of Program Outcomes and Water Savings*, A report for the Metropolitan Water District of Southern California, December 1994.

Bamezai, A. and T.W. Chesnutt, *Public Facilities Toilet Retrofits: Evaluation of Program Outcomes and Water Savings*, A report for the Metropolitan Water District of Southern California, December 1994.

Chesnutt, T.W., A. Bamezai, C. N. McSpadden, J. Christianson, and W. M. Hanemann, "Revenue Instability Induced by Conservation Rate Structures: An Empirical Investigation of Coping Strategies", *Proceedings of the American Water Works Association Conference in New York*, June 1994.

Chesnutt, T.W. and C. N. McSpadden, *A Systems Model of Local Supply and Demand for Water in Southern California*, A report for the Metropolitan Water District of Southern California, April 1994.

Chesnutt, T.W. and C. N. McSpadden, *Putting the Pieces Together: Decision Support for Integrated Resources Planning Using IRPSIM*, A report for the Metropolitan Water District of Southern California, April 1994.

Chesnutt, T.W., W. L. Corpening, C. A. Tagler, A. Bamezai, *Ultra Low Flush Toilets in Commercial Installations*, A report for California Urban Water Agencies and California Urban Water Conservation Council, February 1994.

Chesnutt, T.W., C. N. McSpadden, *Is Demand Side Management Observable?*, Paper presented to the Western Economic Association International Conference, Lake Tahoe, Nevada, June 1993.

Chesnutt, T.W., "Marketing Uncertainty in Policy Analysis: Why it Does not Sell and How to Repackage it into Something that Does", *Proceedings of the Association for Policy Analysis and Management Conference*, Denver Colorado, October 1992.

Chesnutt, T.W., C. N. McSpadden, S. A. Adnan, and A. Bamezai, *A Model-Based Evaluation of Irvine Ranch Water District Residential Retrofit and Survey Water Conservation Projects*, A report for the Metropolitan Water District of Southern California, August 1992.

Chesnutt, T.W., Moynahan, M., and A. Bamezai, "Ultra-Low-Flush Toilet Rebate Programs in Southern California: Lessons For Water Managers and Planners", *Proceedings of the American Water Works Association Conference in Vancouver*, Canada, June 1992.

Chesnutt, T.W., Bamezai, A., and C.N. McSpadden, *The Conserving Effect of Ultra Low Flush Toilet Rebate Programs*, A report for the Metropolitan Water District of Southern California, June 1992.

Chesnutt, T.W., Bamezai, A., and C.N. McSpadden, *Continuous-Time Error Components Models of Residential Water Demand*, A report for the Metropolitan Water District of Southern California, June 1992.

Chesnutt, T.W., Bamezai, A., and C.N. McSpadden, *Mapping the Conserving Effect of Ultra Low Flush Toilets: Implications For Planning*, A report for the Metropolitan Water District of Southern California, June 1992.

Chesnutt, T.W. and C.N. McSpadden, *A Model-Based Evaluation of the Westchester Water Conservation Programs*, A report for the Metropolitan Water District of Southern California, Jan. 1991.

Chesnutt, T.W. and C.N. McSpadden, *The Evaluation of Water Conservation Programs: What is Wrong with the Industry Standard Approach?*, A report for the Metropolitan Water District of Southern California, January 1991.

Chesnutt, T.W. and C.N. McSpadden, *Improving the Evaluation of Water Conservation Programs*, A report for the Metropolitan Water District of Southern California, January 1991

Chesnutt, T.W. and S.A. Adnan, *Quantifying Water Forecast Uncertainty: Simulating Monthly Climate Measures*, A report for the Metropolitan Water District of Southern California, May 1990.

Chesnutt, T.W. and C.N. McSpadden, *Quantifying Water Forecast Uncertainty: A Stochastic Simulation of Water Demand in Southern California*, A report for the Metropolitan Water District of Southern California, December 1989.

Chesnutt, T.W. and C.N. McSpadden, *Leveraged Demand for Metropolitan Water: A Simultaneous Equations Model of Aggregate Demand and Local Supply*, A report for the Metropolitan Water District of Southern California, November 1989.

Chesnutt, T.W. and C.N. McSpadden, *Statistical Analysis of Water Demands During the Current Drought*, A report for the Metropolitan Water District of Southern California, January 1989.

Chesnutt, T.W., *The Market Response to the Government Regulation of Chlorinated Solvents: A Policy Analysis*, P-7548-RGS, The Rand Corporation, October 1988.

Chesnutt, T.W., *Market Responses to the Government Regulation of Toxic Substances: The Case of Chlorinated Solvents*, N-2636-EPA, The Rand Corporation, March 1988.

Dertouzos J.N., J.M. Polich, A. Bamezai, and T.W. Chesnutt, *Recruiting Effects of Army Advertising*, R-3577-FMP, The Rand Corporation, June 1987.

Quinn T.H., K.A. Wolf, W.E. Mooz, J.K. Hammitt, T.W. Chesnutt, and S. Sarma, *Projected Use, Emissions, and Banks of Potential Ozone-Depleting Substances*, N-2282-EPA, The Rand Corporation, January 1986.

DAVID M. PEKELNEY

EDUCATION

Ph.D., RAND Graduate School of Policy Studies, Public Policy Analysis, January 1991. RAND Graduate School Fellowship, 1986-1991. *Dissertation:* "Analyzing Environmental Policies for Chlorinated Solvents with a Model of Markets and Regulations." *Committee:* Drs. Frank Camm (chair), Kathleen Wolf, and Bart Bennett. *Sponsor:* National Science Foundation.

M.P.P., Graduate School of Public Policy, U.C. Berkeley, May 1986. *Thesis:* "The Use of Taxes and Fees to Fund California's Hazardous Waste Management Programs: Who Pays?"

B.A., University of Colorado, Boulder, Distributed Major: Political Science, Astrogeophysics, and Physics, May 1980.

EXPERIENCE

Director of Policy Analysis, A & N Technical Services, Santa Monica, California (April 1996-present; Policy Analyst: November 1993-March 1996, April 1990-July 1991). Conduct economic evaluations and planning studies concerning environmental and natural resource policies. Develop economic and statistical models, forecasts, and data bases. Write proposals and manage research projects.

Air Quality Policy: Analyzed emissions trading credit allocation options under consideration for a regional haze control program in the Western U.S. Analyzed air quality cost data used to compare regulatory alternatives. Prepared issue analysis paper regarding a multi-state emissions trading program designed to control tropospheric ozone.

Water Resources Policy: Developed economic methods and calculation tools to evaluate water recycling investments that have been used by utilities and government agencies both in the San Francisco Bay Area and in Southern California. Developed cost-benefit analysis guidelines that have since been adopted to assess urban water conservation measures in California. Developed a software planning tool used by 28 Southern California water agencies to calculate conservation program savings and cost-effectiveness. Evaluated the effectiveness of a variety of water conservation programs in California and the Southwest.

Visiting Assistant Professor, University of Michigan School of Public Health, Ann Arbor, Michigan (September 1994-May 1995). Taught courses covering health and environmental policy applications of policy analysis, cost-benefit analysis, microeconomics, and program evaluation to students in the Master of Public Health degree program.

Adjunct Assistant Professor, UCLA School of Public Health, Los Angeles, California (1992-1997). Conducted seminars on microeconomic policy analysis and economic incentives regulation to students in the Master of Environmental Health Science and Doctor of Environmental Science and Engineering degree programs.

839 Second Street, Suite 5 • Encinitas, CA 92024-4452 • Voice: 760.942.5149 • Fax: 760.942.6853
11808 Stanwood Dr. • Los Angeles, CA 90066 • Voice: 310.439.1883 • Fax: 310.439.1884

Policy Analyst (Air Quality Specialist), South Coast Air Quality Management District, Office of Planning and Rules, Los Angeles, California (July 1991-November 1993). Developed air quality programs and regulations. Conducted analyses of economic and air quality impacts of proposed air quality regulations.

Market Incentives Regulation: Designed components of RECLAIM, an emissions trading program for the South Coast Air Basin to regulate photochemical smog. Developed a linear programming model of the markets for RECLAIM pollutants used to evaluate the economic and environmental impacts of the program. Key staff to the advisory and steering committees composed of representatives of government, environmental, labor, and industry groups that guided program development.

Stratospheric Ozone Depletion: Designed regulatory proposals to phase out ozone depleting compounds. Estimated the increase in demand for substitute pollutants in industries such as aerospace, electronics, foam production, and wood products.

Research Fellow and Consulting Research Analyst, The RAND Corporation, Department of Economics and Statistics (September 1986-July 1991), Social Policy Department (Consulting Status, July 1991-July 1995), Santa Monica, California. Analyzed public policies with quantitative and qualitative research methods (e.g., microeconomics, statistics, linear/nonlinear programming, technology assessment, and regulatory analysis). Presented formal briefings, prepared research proposals, wrote documents for publication.

Environmental Policy: Conducted research project sponsored by the National Science Foundation on chemicals regulation. Developed an economic model that compares changes in technology and markets induced by alternative environmental regulations.

Regulatory and Market Incentives: Conducted a study of the incentive structure of regulations that restrict land disposal of hazardous wastes. Analyzed data on hazardous waste generation in California using a materials balance approach to determine the effects of state and federal programs.

Medical Malpractice: Assessed the ability to target deterrence policies at negligence-prone physicians based on malpractice histories. Responsibilities included data analysis and statistical modeling of claims records and physician characteristics.

Guest Instructor, UCLA Program in Toxic and Hazardous Materials Control and Management, Los Angeles, California (February 1990-February 1993). Taught introductory classes in cost-benefit analysis and market incentives regulation to mid-career professionals.

Policy Analyst Intern, California Senate Office of Research, Sacramento, California (January-May 1986). Analyzed the use of fees and taxes to fund California's hazardous waste management programs. The final report includes consideration of tax design, alternative revenue sources, regulatory incentives, and legislative proposals.

Policy Analyst Intern, World Resources Institute, Washington, D.C. (June-August 1985). Analyzed energy pricing and tax policies of developing countries and the United States. Research conducted as part of a study for the United Nations World Commission on Environment and Development.

Graduate Student Instructor, U.C. Berkeley, (September 1985-May 1986). Teaching assistant in *Microeconomic Policy Analysis* and *The Politics of Energy and Environmental Policy*.

Policy Analyst Intern, United States Environmental Protection Agency, Region IX, San Francisco, California (March-May 1985). Designed environmental mediation proposal for air pollution control rule-making. Report included dispute settlement process for the EPA Region IX "Reasonable Efforts

Program."

Mountaineering Instructor, National Outdoor Leadership School, Alaska, British Columbia, and Washington (1986-1998). Organized and led expeditions to remote mountain areas (e.g., Mt. McKinley, Mt. Rainier, and the Waddington Range); taught technical climbing skills, natural history, and leadership.

PROFESSIONAL ACTIVITIES

American Water Works Association
Association for Public Policy Analysis and Management
Association of Environmental and Resource Economists
Air and Waste Management Association
South Coast Air Quality Management District, Socioeconomic Technical Review Committee
California Urban Water Conservation Council, Measurement and Evaluation Committee
Journal of Policy Analysis and Management, Reviewer

PUBLICATIONS AND REPORTS

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, "Water Efficiency Programs for Integrated Water Management," AWWA Research Foundation, forthcoming. Contains planning models for estimating Water Utility Direct Avoided Costs from WUE programs and WUE Planning. Forthcoming.

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, "Water Efficiency Programs for Integrated Water Management," in Proceedings of the International Water Association Conference, Efficient 2005, Santiago, Chile, March 2005.

Chesnutt, T.W., G. Fiske, J.A. Beecher, D.M. Pekelney, "Avoided Cost Analysis in Integrated Planning for Water Efficiency: Concepts, Controversies, and Guidelines," in Proceedings of the International Water Association Conference, Efficient 2005, Santiago, Chile, March 2005.

U.S. EPA Region IX, "An Evaluation of the South Coast Air Quality Management District's Regional Clean Air Incentives Market – Lessons in Environmental Markets and Innovation," November 2002 (research team member with Industrial Economics, Inc. and EPA staff.)

Pekelney, D.M., "Economic Value of Reliable Water and Wastewater Services in the Big Bear Valley," A&N Technical Services, Inc., October 2002, Executive Summary and Technical Report, (prepared for the Big Bear Area Regional Wastewater Agency).

Harrison, D., D.H. Pickrell, D.M. Pekelney, and J. Patchett, "Assessing the Potential Indirect Effects of Electricity Infrastructure on Regional Growth Patterns," National Economic Research Associates, October 2002 (prepared for Southern California Edison), Draft Final.

Pekelney, D.M. and W. Illingworth, "CUWA Recycled Water Evaluation Decision Model," Economic Insights and A&N Technical Services, Inc., November 2000 (prepared for California Urban Water Agencies).

Beecher, J.A., T.W. Chesnutt, and D.M. Pekelney, "Socioeconomic Impacts of Water Conservation," American Water Works Association Research Foundation, September 2000.

Pekelney, D., T. Chesnutt, and S. Gaur, "Orange County Water Futures Conservation Plan: Economic Methods and Models Overview," August 2000 (prepared for the Municipal Water District of Orange County).

Pekelney, D. and T. Chesnutt, "A Guide to the Data and Methods for Cost-Effectiveness Analysis of Urban Water Conservation Best Management Practices," California Urban Water Conservation Council, July 2000.

Beecher, J.A., D.M. Pekelney, and T.W. Chesnutt, "Socioeconomic Impacts of Water Conservation," *American Water Works Association 2000 Annual Research Conference,* June 2000.

Pekelney, D.M., T.W. Chesnutt, and J.A. Beecher, "Quantifying the Costs and Benefits of Water Reclamation and Reuse: Economic and Financial Issues," *American Water Works Association 2000 Annual Research Conference Paper, June 2000.*

Chesnutt, T., and D. Pekelney, "Market Assessment: Potable Water Markets in Southern California" A&N Technical Services, Inc., February 2000.

Southern California Comprehensive Water Reclamation and Reuse Study: Phase II (Coauthor), "Short Term Implementation Plan," January 2000 (prepared for the U.S. Bureau of Reclamation, California Department of Water Resources, Central Basin and West Basin Municipal Water Districts, City of Los Angeles, Metropolitan Water District of Southern California, City of San Diego, San Diego County Water Authority, Santa Anna Watershed Project Authority, and the South Orange County Reclamation Authority).

San Diego County Water Authority (Coauthored with T.W. Chesnutt, S. Gaur, and SDCWA), "Rate and Revenue Study: Analysis of Options for Revenue Restructuring," January 2000.

Illingworth, W., T. Chesnutt, and D. Pekelney, "Recycled Water Master Plan," Chapter 4 with Appendices, San Francisco Bay Area Regional Water Recycling Program, December 1999.

Pekelney, D.M. "Initial Cost Analysis," A&N Technical Services, Inc., September 1999 (prepared for the Western Governors' Association, Market Trading Forum).

Illingworth, W., et al., "Regional Urban Water Management Plan," Draft, Foster Associates Inc., July 1999 (prepared for the Metropolitan Water District of Southern California).

Pekelney, D.M., J.A. Beecher, and T.W. Chesnutt, "Methods To Evaluate Socioeconomic Impacts Of Conservation Rate Structures," *Proceedings of the American Water Works Association Annual Research Conference*, June 1999.

Pekelney, D.M., W. Illingworth, and T.W. Chesnutt, "Economic Evaluation of Regional Approaches to Water Recycling Investment," *Proceedings of the American Water Works Association Annual Research Conference*, June 1999.

Pekelney, D.M., T.W. Chesnutt, and J.A. Beecher, "Evaluating Conservation Rate Structures," *Proceedings of the American Society of Civil Engineers Annual Research Conference*, June 1999.

Pekelney, D.M., and J. Gross, "Analysis of Emissions Trading Allocation Options," A&N Technical Services, Inc., March 1999 (prepared for the Western Governors' Association, Market Trading Forum).

Chesnutt, T.W., D.M. Pekelney, and G. Raftelis, "Water Rate Study," A & N Technical Services, Inc. and Raftelis Environmental Consulting Group, December 1998 (prepared for the Victor Valley Water District).

Pekelney, D., W. Illingworth, and T. Chesnutt, "Economic Analysis of Regional Water Recycling Solutions in the San Francisco Bay Area," WateReuse Association Symposium XIII Proceedings,

September 1998.

Chesnutt, T.W., D.M. Pekelney and M. Hollis, "Why do you always tell me it depends when I ask you how big a sample I need: A primer on sample size calculations," Proceedings of the *American Water Works Association Annual Research Conference*, June 1998.

Pekelney D.M. and T.W. Chesnutt, "Landscape Water Conservation Programs: Evaluation of Water Budget Based Rate Structures," *Proceedings of the American Water Works Association Annual Research Conference,* June 1998.

Pieroni, C.C., W. Jacoby, and D.M. Pekelney, "The Program Design Tool: A Regional Approach to Conservation Reporting," *Proceedings of the American Water Works Association Annual Research Conference,* June 1998.

Hollis, M.E., A. Bamezai, and D.M. Pekelney, "The Reliability and Validity of Conservation Measures," *Proceedings of the American Water Works Association Annual Research Conference,* June 1998.

Pekelney, D., W. Illingworth, and T. Chesnutt, "BARWRP Decision Model to Evaluate Water Recycling Investments: A Handbook," A&N Technical Services, Inc. and Foster Associates, Inc., April 1998 (prepared for the Bay Area Regional Water Recycling Program).

Pekelney, D., and T. Chesnutt, "Landscape Water Conservation Programs: Evaluation of Water Budget Based Rate Structures," A&N Technical Services, Inc., September 1997 (prepared for the Metropolitan Water District of Southern California).

Chesnutt, T., and D. Pekelney, "Valuing Water Conservation," *Proceedings of the American Water Works Association Annual Research Conference*, June 1997.

Pekelney, D., and T. Chesnutt, "Cost-Effectiveness of Urban Water Conservation Best Management Practices," *Proceedings of the American Water Works Association Annual Research Conference*, June 1997.

Chesnutt, T., et al., "Handbook for Designing, Evaluating, and Implementing Conservation Rates Structures," A&N Technical Services, Inc., October 1996 (prepared for the California Urban Water Conservation Council).

Pekelney, D., T. Chesnutt, and W.M. Hanemann, "Guidelines to Conduct Cost-Effectiveness Analysis of BMPs for Urban Water Conservation," A&N Technical Services, Inc., September 1996 (prepared for the California Urban Water Conservation Council).

Chesnutt, T., C. McSpadden, and D. Pekelney, "An Impact Evaluation of Home Water Surveys in Los Angeles," A&N Technical Services, Inc., October 1996 (prepared for the Metropolitan Water District of Southern California).

Johnson, S.L., and D. Pekelney, "Economic Assessment of the Regional Clean Air Incentives Market: A New Emissions Trading Program for Los Angeles," *Land Economics*, Vol. 72, No. 3, August 1996.

Pekelney, D., T. Chesnutt, and D.L. Mitchell, "Cost-Effective Cost-Effectiveness: Quantifying Conservation on the Cheap," A&N Technical Services, Inc., June 1996 (presented at the American Water Works Association national conference in Toronto, Canada).

Chesnutt, T. and D. Pekelney, "Economic Valuation of Water Conservation Measures," A&N Technical Services, Inc., May 1996 (prepared for the Metropolitan Water District of Southern California).

Pekelney, D., and T. Chesnutt, "Reference Document: Program Design Tool and Savings Estimates," A&N Technical Services, Inc., May 1996 (prepared for the Metropolitan Water District of Southern California).

Chesnutt, T., C. McSpadden, and D. Pekelney, "What is the Reliable Yield from Residential Home Water Survey Programs?" A&N Technical Services, Inc., July 1995 (prepared for the Los Angeles Department of Water and Power and the Metropolitan Water District of Southern California).

Pekelney, D., "Assessment of the RECLAIM Emissions Trading Market: Identification and Description of Public Data Sources," A&N Technical Services, Inc., August 1994.

Pekelney, D., "A Model of Chemical Solvent Use: Do Regulations Reduce or Merely Substitute Environmental Hazards?" February 1994 (working paper).

Office of Stationary Source Compliance (coauthored), "The Regional Clean Air Incentives Market: Rules and Staff Report: Vols. I-V" South Coast Air Quality Management District, October 1993.

Pekelney, D., "Emissions Trading: Applications to Water and Air Quality," *Pollution Prevention Review*, Vol. 3, No. 2, Spring 1993.

Rolph, J., D. Pekelney, and K. McGuigan, "Amending the National Practitioner Data Bank Reporting Requirements: Are Small Claims Predictive of Large Claims?," *Inquiry*, Vol. 30, No. 4, Winter 1993.

Office of Stationary Source Compliance (coauthored), "The Regional Clean Air Incentives Market," South Coast Air Quality Management District, *Conference Proceedings of the Air and Waste Management Association*, February 1993.

Office of Planning and Rules (coauthored), "The Regional Clean Air Incentives Market: Summary Recommendations," South Coast Air Quality Management District, March 1992.

Office of Planning and Rules (coauthored), "Marketable Permits Program Working Paper #5: Air Quality Assessment and Socioeconomic Impacts - Implications for the Basin," South Coast Air Quality Management District, December 1991.

Office of Planning and Rules (coauthored), "Marketable Permits Program Working Paper #4: Trading - The Centerpiece," South Coast Air Quality Management District, October 1991.

Office of Planning and Rules (coauthored), "Marketable Permits Program Working Paper #3: Compliance - The Critical Element," South Coast Air Quality Management District, August 1991.

Chesnutt, T., and D. Pekelney, "Model-Based Imputation for Missing Daily Climate Data," A&N Technical Services, Inc., July 1991 (prepared for the Metropolitan Water District of Southern California).

Pekelney, D., "Analyzing Environmental Policies for Chlorinated Solvents with a Model of Markets and Regulations," The RAND Corporation, N-3267-RGSD, May 1991.

Pekelney, D., J. Rolph, and K. McGuigan, "Targeting Negligence-Prone Physicians: Exploratory Data Analysis of Variables for Surgical and Ancillary Specialties," The RAND Corporation, WD-5275-AHCPR, January 1991.

Pekelney, D., J. Rolph, and K. McGuigan, "Exploratory Data Analysis of Variables for the Targeting Negligence-Prone Physicians Project," The RAND Corporation, WD-5227-AHCPR, November 1990.

Pekelney, D., J. Rolph, and K. McGuigan, “Physicians Who Change Malpractice Insurers and their Claims Records,” The RAND Corporation, WD-5135-AHCPR, September 1990.

Pekelney, D., “Hazardous Waste Generation, Transportation, Reclamation, and Disposal: California's Manifest System and the Case of Halogenated Solvents,” *Journal of Hazardous Materials*, Vol. 23, July 1990.

Pekelney, D., “The Use of Taxes and Fees to Fund California's Hazardous Waste Management Programs: Who Pays?” May 1986 (prepared for the California Senate Office of Research).

Tuma, J., D. Pekelney, J. Kruger, and N. Bonnelycke, “United States Environmental Protection Agency, Region IX: Reasonable Efforts Program Conflict Management Procedure,” May 1985 (prepared for EPA Region IX).

Pekelney, D., “San Francisco Bay Chapter Sierra Club Conservation Committee: An Organizational Analysis,” December 1984 (prepared for the San Francisco Bay Chapter Sierra Club).

Dana Holt

EDUCATION

1991 M.S. Computer Information Science, Coleman College, San Diego CA
1987 B.S. Computer Science, Coleman College, San Diego CA

EXPERIENCE

Over 17 years experience in software and hardware project lifecycle development, software implementation, project management, technical writing, and training. Have worked in diverse environments in small, medium, and large teams.

A & N Technical Services, August 2003 to Present

Sr. Analyst

Responsible for database, programming, web development, and financial analyses under tight time and budget constraints. No job too small, no problem too difficult.

AutoCare America Encinitas, CA July 2002 to November 2002

Office Manager/VP Administration

AS the Office Manager and Vp of Administration I was responsible for daily management of all office activities. Periodically I scheduled tasks for subordinates, and developed team building strategies. I also provided Human Resources management as well as managed customer relations through e-mails, voice, and on-sites.

Convera (formerly Excalibur Technologies) Carlsbad, CA Oct. 1996 to Oct. 2001

Professional Services Consultant/Integration Engineer

As a Professional Services Consultant and Project Manager I was responsible for implementing solutions based on Convera's Screening Room and RetrevalWare products. This involved gathering customer requirements, documenting current system, and preparation of an implementation plan. I would also be frequently involved in customizing code modules as part of the integration effort, analyzing hardware requirements, as well as managing the entire project. Post implementation tasks included documentation development and training.
As an example, I recently implemented a major Screening Room system at a large television broadcast facility in Los Angeles. This involved extensive site planning and coordination with the broadcast staff due to the critical real-time nature of the operation. I both managed and assisted

with all phases of this implementation, which involved software code modifications and hardware integration with broadcast equipment. After installation was complete, I prepared and delivered technical training to the customer.
My integration services responsibilities included installation and implementation of product evaluation units, traveling to customer sites to perform needs evaluation and analysis, and installation & implementation of digital content management software (both RetrievalWare and Screening Room). I assisted customers in training and development of custom interfaces using Product SDK's and API's. This would often involve product customization using low-level API's, using Visual Basic and C/C++ languages.
I also served as a manager, coordinator and developer of digital content management training courses. Management responsibilities included scheduling customer training either on-site or at corporate training facilities, revenue tracking and reporting, quarterly forecasting, team building, and scheduling tasks for subordinate.
My development responsibilities included using Microsoft Visual Studio (Visual Basic and C++) to create and maintain API applications for course curriculum, and to create custom applications using product APIs. Product APIs included image management (Visual RetievalWare), text management (RetrievalWare), and video management (Screening Room).

Reynolds & Reynolds Healthcare San Diego, CA July 1993 to Oct. 1996

Programmer Analyst III.

I created and maintained healthcare software programs, using RPG on the AS/400 and C on multiple Unix platforms. My duties involved customer problem analysis, and development of resolutions. I developed scripts for handing telecom functionality in the UNIX environment. For large-scale projects, which required cross-functional teams, my duties included analyzing, developing, and documenting functional and design specifications utilizing the Reynolds methodology, PSD3.

Coleman College San Marcos, CA 1987 to 1993

Computer Information Science Instructor

I developed and delivered technical training in computer science. Courses taught covered all seven classes in core curriculum, including upper-division courses in Turbo C++, RPG/400, and CICS. Other courses taught include COBOL, PL/1, BASIC, General Accounting, Systems Analysis and Design, Tele-processing, and Database design concepts. Assisted in design, development, and programming of new course curriculum used for teaching concepts in programming and related topics.

Brodart Automation San Diego, CA 1986 to 1987

Programmer Analyst

I designed, developed, and maintained programs for Library Automation division, J.K. Gill division and Stacys division. Languages included CICS COBOL, Micro focus COBOL, and Mantis. Responded to and resolved customers problems and complaints. I debugged retail-processing problems during weekend updates. I generated and maintained MVS Job Control for night processing.

Programming Languages
C, Visual Basic, HTML/XML, Tcl/Tk, RPG, COBOL

Operating Systems
Windows XP, Windows 2000, Windows NT 4.0, OS/400, UNIX, and MVS

Databases
Microsoft SQL Server, Oracle, Access

Applications
MS DevStudio, MS Office, Visio, SourceSafe, Convera RetrievalWare, Convera Screening Room, Pivitol, Crystal Reports, QuickBooks

G. HOSSEIN PARANDVASH
CURRICULUM VITAE

AREAS OF SPECIALTY AND INTEREST

Econometrics, Statistics, Economics of Utilities, Financial and Cost-Benefit Analysis, Production Economics, Resource Economics, Welfare Economics, Modeling and Simulation, data collection and maintenance.

WORK EXPERIENCE

PRINCIPAL ECONOMIST, Resource Protection and Planning, Portland Bureau of Water Works, Portland, Oregon. *July 1996 to present*. Responsibilities include:

- Developing and updating a daily demand model for water consumption used for forecasting and structural analysis.
- Regional water demand forecasting for 26 regional water providers.
- Forecasting long-term water demand based on climate, demographic, and economic factors.
- Evaluating and estimating the effects and cost-effectiveness of various water conservation programs.
- Providing statistical and financial analysis for Bureau's Habitat Conservation Plan for the protection of endangered species in the Bull Run watershed.
- Providing financial and statistical analysis for setting water rates.
- Managing the Customer Demand Monitoring Project. This project involves real time monitoring of water consumption of a random sample of 700 single-family residential households. The meters are read on 15-minute intervals and reported to a host computer via a proprietary Automatic Meter Reading system. The collected data will be used for micro-level demand analysis, which relates water use with household demographic and economic characteristics, price of water, age of the property, presence or lack of water efficient fixtures, and weather. The result of the analysis will be used for demand forecasting, planning, and rate structure. My responsibilities from the inception have been designing the statistically valid sample, coordinating installation, and data collection and data analysis.
- Collecting and maintaining daily water demand data for 26 regional water providers.
- Collecting and maintaining Water Bureau's billing data for demand and conservation program evaluation analysis.
- Reviewing the statistical and economic analysis part of the Long-term 2 Enhanced Surface Water Treatment Rule and proposing a course of action in analysis to the Bureau.
- Participating in the Water Bureau's Infrastructure Master Plan.
- Participating in the Distribution System Master Plan. This is a multi year project involving consultants and bureau staff, studying the current and future conditions and needs for the water delivery distribution system. I am responsible for demand forecasting for different water delivery nodes and conducting analysis for estimating the probability of pipe breakdowns using advance limited dependent regression models.
- Participating in the planning process for the enhancement of the Bureau's production, storage, and transmission capabilities in the face of growing demand for water.
- Training the staff of the different water providers in the region for data collection and basic statistical analysis.

6320 SW Tillamook Pl. • Beaverton, Oregon 97007 • Phone: Work (503) 823-5350, Home (503) 649-2098
E-mail: hparandvash@comcast.net

ECONOMICS FACULTY, Department of Economics, Western Oregon University, Monmouth, Oregon. *October 1989 to June 1996*. Taught undergraduate and graduate courses in Principles of Economics, Microeconomics, Managerial Economics, International Economics (International Trade and Finance), and Industrial Relations.

AGRICULTURAL ECONOMIST, (GS 12) Economic Research Service, United States Department of Agriculture, Washington DC. *September 1988 to October 1989*. Responsibilities included:

- Planning and conducting empirical research and analysis relating to farm finance and income, including analysis of business performance by size and type of farm.
- Selecting methods, techniques and procedures including statistical data collection and processing, and organizing the data into a project to produce satisfactory information on the factors affecting problem area.
- Collecting and evaluating large quantities of economic data and determining their implications and the significance of research findings.

RESEARCH ASSISTANT AND ASSOCIATE, Department of Agricultural and Resource
Economics, Oregon State University. *August 1983 to January 1988*. Conducted research in areas related to water management pertaining to irrigation and hydropower generation. Also, developed a new class of econometric estimators.

EDUCATION

Ph.D., AGRICULTURAL AND RESOURCE ECONOMICS, Oregon State University. Corvallis, Oregon. *December 1987*.
Thesis title: "On the Incorporation of Nonnumeric Information into Estimation of Economic Relationships in the Presence of Multicollinearity." Thesis was recognized by the department as the outstanding dissertation and submitted to the American Agricultural Economic Association for 1987-88 national competitions.

M.S., APPLIED ECONOMICS, Portland State University. Portland, Oregon. *August 1982*.
Specialty fields: Cost-Benefit Analysis, Project Evaluation, and Economic Planning.
Outside fields: Quantitative Management, Modeling and Simulation, and Statistics.

B.S. ECONOMICS, Portland State University. *August 1979*.

B.A., BUSINESS ADMINISTRATION, Iranzamin College. Tehran, Iran. *August 1977*.

CONSULTING AND ACADEMIC ACTIVITIES

Commissioned by Northwest Power and Conservation Council to develop a demand model for electricity for short-term forecasting. *December 2006*.

Adjunct Faculty of Economics at the University of Phoenix, Portland Campus, teaching graduate level courses in economics, business, and quantitative methods.

Participated in a study by the Climate Group of the University of Washington, Seattle, about

the long-term effects of climate change on the Pacific Northwest. My contribution was the measurement of long-term climate effect on the future water demand in the Portland Water Bureau service area. Published by National Assessment Synthesis Team, "**Climate Change Impact on the United States: the Potential Consequences of Climate Variability and Change**," *August 2000*.

Conducted research in cooperation with University of Kerman, Kerman, Iran, sponsored by the **United Nations Development Program (UNDP)**, *June 20-August 20, 1992*. Designed questionnaires for collecting data. Conducted econometric analysis and estimation of production function and demand function for dates.

COMPUTER SKILLS

Statistical, Analytical, Modeling, Database, and MS Office Packages: EVIEWS, STATA, GAUSS, SAS, CRYSTAL BALL, STELLA, IWR-MAIN, EXCEL, ACCESS, FOX PRO, and SQL Server 2000.

FOREIGN LANGUAGES

Fluent in Farsi (Persian), Some Japanese.

AWARDS AND INTERESTS

Recipient of the Robert Johnson Fellowship awards for *1984-85*.
Reading, Foreign Languages, Cooking, Billiard, Ping Pong and Golf.

PUBLICATIONS

Parandvash, G. H., "**EFFECT OF LONG-TERM CLIMATE CHANGE ON DEMAND FOR WATER**," forthcoming.

Jourabchi, M. E. and Parandvash, G. H., "**FORACASTING DEMAND FOR ELECTRICITY UNDER DIFFERENT WEATHER CONDITIONS**," forthcoming.

Parandvash, G. H., "**DEMAND AND REVENUE VOLATILITY OF A WATER UTILITY DUE TO WEATHER EFFECT AND RATE STRUCTURE**," presented at the PNREC, May 11-12, 2006, Portland Oregon.

Parandvash, G. H., "**WHITE PAPER ON DEMAND AND REVENUE VOLATILITY**," Portland Bureau of Water Works, August 2005.

Parandvash, G. H., "**PEAK SEASON WATER DEMAND FORECASTING,**" presented at the PNREC, May 19-21, 2004, Tacoma, Washington.

Hanson, D. G., Parandvash, G. H., and Ryan, J., "**LOAN REPAYMENT PROBLEMS OF FARMS IN THE MID-1980'S**," Agricultural Economic Report, USDA-ERS, No. 649, September 1991.

Parandvash, G. H., "**MANY SPECIALIZED CROP FARMS CAN NOW CASH-FLOW LAND PURCHASES**," Agricultural Income and Finance, Situation and Outlook Report, USDA-ERS, AFO-33, May 1989.

Hanson, D. G. and Parandvash, G. H., "**HOGS: A SOFT SPOT IN THE RECOVERY**," Agricultural Outlook, April 1989, P.28.

6320 SW Tillamook Pl. • Beaverton, Oregon 97007 • Phone: Work (503) 823-5350, Home (503) 649-2098
E-mail: hparandvash@comcast.net

Parandvash, G. H. and Brown, W. G., "**INCORPORATION OF NONNUMERIC INFORMATION INTO THE ESTIMATION OF ECONOMIC MODELS: A NEW APPROACH FOR DEALING WITH MULTICOLLINEARITY**," Paper, MS #H13, presented in the August 1988 AAEA annual meeting in Knoxville, Tennessee.

McCarl, B. A. and Parandvash, G. H., "**IRRIGATION DEVELOPMENT VS HYDROELECTRIC GENERATION: CAN INTERRUPTIBLE IRRIGATION PLAY A ROLE**," Western Journal of Agricultural Economics, 1988, 13(2):267-276.

Nelson, A. G., McCarl, B. A., and Parandvash, G. H., "**ISSUES IN VALUING AND ALLOCATING WATER**," presented in Agricultural Conference Days, February 27-28, 1985, at Oregon State University.

Parandvash, G. H. and Brown, W. G., "**NONNUMERIC INFORMATION MIXED ESTIMATION (NIME) AS AN ALTERNATIVE TO RIDGE REGRESSION**," Unpublished.

6320 SW Tillamook Pl. • Beaverton, Oregon 97007 • Phone: Work (503) 823-5350, Home (503) 649-2098
E-mail: hparandvash@comcast.net

MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

WARREN HAGSTROM

Education

Rutgers University – BS Civil Engineering
University of Southern California – MS Construction Engineering

Summary

Civil engineer with specialization in the planning and design of water resource public improvement projects, with over 30 years experience in managing activities of engineers and planners in the public and private sectors. Experience in governmental coordination, and public interaction activities. Technical background includes flood control, water supply, wastewater treatment, coastal engineering, contract administration, and engineering consulting.

Experience

Designed portions of sewage treatment plants, pump stations, and interceptors on a $300 million wastewater treatment project (Cape May, New Jersey).

Senior project Manager of the $1.4 billion Santa Ana River Flood Control project:
- Coordinated activities of 70 member design team.
- Interfaced Federal goals and objectives with local concerns.

Directed design and construction of numerous small projects ($5-$15 million) with an annual budget of up to $18 million in design fees.
- Coordinated and directed the efforts of engineers, technical experts, construction mangers, city managers, mayors, and representatives of other Federal, state and local agencies to assure construction.
- All projects progressed either on or ahead of schedule.
- Two projects critical for local flood protection were completed nearly one year ahead of schedule.

Developed the first escrow agreement to be used by the Los Angeles District Corps of Engineers to make flood control projects more affordable for small communities. This agreement is now used routinely for all new construction projects.

Administered public involvement program during the design of the Santa Ana River project. Broadly interviewed by news media.

700 North Alameda Street – Los Angeles, CA 90012 – Voice: 213.217.6963 – Fax: 213.217.6949

Developed and administered consulting services contracts valued at $350 thousand per year including: geotechnical investigations, environmental studies, real estate mapping/appraisals, topographic surveys, petroleum abandonment and civil design.

Provided technical expertise, wrote legal position papers, reviewed design drawings for completeness and accuracy, prepared expert testimony, and analyzed contracts in managing the negotiation and defense for the cities of Los Angeles and Oxnard against the multi-million dollar construction claims associated with the Terminal Island, and City of Oxnard, sewage treatment plants.

Developed and ran sophisticated computer models using supply, demand, and distribution system models to help keep Metropolitan one step ahead of any potential supply or distribution shortfall. Since possible solutions can take many years to implement, I spent much of my time working with projections of what southern California might be like 10 to 50 years in the future.

I have 15 years experience in planning studies for large municipal water systems. I have coordinated the technical efforts behind three EIRs (Inland Feeder Pipeline, Semitropic Groundwater Storage Program, and Union Station Headquarters Building); and have accomplished numerous smaller studies concentrating on areas of particular concern such as:
Skinner Area study – where I accomplished an analysis of future flows and treatment needs that resulted in the determination that a new module was needed as soon as it could be put on-line.
Pipeline 6 – where I determined the projected facility needed on-line date.
Orange County Water Reliability Study – where I acted as liaison between the MWDOC and Water Resources and coordinated the many information needs that the study group required of MWD.
Ozone facilities – where I provided projections of future flows for all treatment facilities required to properly plan facility on-line dates.
Central valley water exchange study – where I provided reconnaissance level construction costs for various canal and pipeline configurations.
Numerous requests for new service connections – where I analyzed historical flow data, future needs, and hydraulic capacity constraints to determine the feasibility of providing new service.
Peak Factor analysis - where I developed a tool to quickly mine the huge database of historical Automatic Meter Reading flow data and provide peak factors for any facility, Member Agency, master meter, or service connection.
Long-term planning – where I analyzed historical flow data and sales projections, and provided flow projections for all member agencies and facilities on an as-needed basis.

The types of studies included Reconnaissance, Feasibility, Area study, Survey, Overview, and Environmental Impact Reports.

Methods of analysis included computer modeling (EPANet, spreadsheet model, IRPDSM, CRSSez) and database analysis (Research WINS wherehouse for historical flow data, Peak Factor tool).

Employment History

1991 – Present
Metropolitan Water District of Southern California
Engineer

1983 – 1991
U.S. Army Corps of Engineers
Project Manager
Chief, Emergency Management Branch

1981 – 1983
O'Brian-Kreitzberg & Associates
Construction Claims
Construction Management

1977 – 1981
U.S. Army Corps of Engineers
Project Manager

1975 – 1977
Pandullo-Quirk & Associates
Assistant Project Manager
Assistant Design Engineer