THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

Office of the General Manager

December 21, 2016

Ms. Diana Blake
Grants Management Specialist
Bureau of Reclamation
P.O. Box 61470
Boulder City, Nevada 89006-1470

Dear Ms. Blake:

Final Performance and Financial Reports for
Agreement No. R14AP00073 "California Friendly Turf Replacement Incentive Program" Phase 2

The Metropolitan Water District of Southern California (Metropolitan) is pleased to submit the enclosed final performance and financial reports for the California Friendly Turf Replacement Incentive Program Phase 2 for the period ending September 30, 2016. Incentives were provided to replace 1.07 million square feet of thirsty turf landscapes. This transformation will provide an estimated lifetime water savings of 1,400 acre-feet.

We appreciate Reclamation's continued support for landscape water use efficiency and look forward to working with you in the future. If you have any questions, please contact Diane Harrelson at (213) 217-6568 or via email at dharrelson@mwdh2o.com.

Sincerely,

William P. McDonnell

William P. McDonnell
Team Manager, Water Efficiency

Enclosures (3) – Final Performance Report
SF425 – Federal Financial Report
Release of Claims

cc: Ms. Debra Whitney
Bureau of Reclamation Grants Officer Technical Representative
27708 Jefferson Avenue, Suite 202
Temecula, CA 92590
dwhitney@usbr.gov / LCFA@usbr.gov

FEDERAL FINANCIAL REPORT

(Follow form instructions)

1. Federal Agency and Organizational Element to Which Report is Submitted **Bureau of Reclamation**	2. Federal Grant or Other Identifying Number Assigned by Federal Agency (To report multiple grants, use FFR Attachment) **R14AP00073**	Page 1 of 1 pages

3. Recipient Organization (Name and complete address including Zip code)

Metropolitan Water District of Southern California 700 N. Alameda Street, Los Angeles, CA 90012

4a. DUNS Number	4b. EIN	5. Recipient Account Number or Identifying Number (To report multiple grants, use FFR Attachment)	6. Report Type	7. Basis of Accounting
06-384-2975	**95-6002071**	**1462**	☐ Quarterly ☐ Semi-Annual ☐ Annual ☑ Final	☑ Cash ☐ Accrual

8. Project/Grant Period (Month, Day, Year)		9. Reporting Period End Date (Month, Day, Year)
From: **09/11/2014**	To: **09/30/2016**	**09/30/2016**

10. **Transactions**	Cumulative
(Use lines a-c for single or combined multiple grant reporting)	
Federal Cash (To report multiple grants separately, also use FFR Attachment):	
a. Cash Receipts	**$299,000.00**
b. Cash Disbursements	**$299,000.00**
c. Cash on Hand (line a minus b)	**$0.00**
(Use lines d-o for single grant reporting)	
Federal Expenditures and Unobligated Balance:	
d. Total Federal funds authorized	**$299,000.00**
e. Federal share of expenditures	**$299,000.00**
f. Federal share of unliquidated obligations	**$0.00**
g. Total Federal share (sum of lines e and f)	**$299,000.00**
h. Unobligated balance of Federal funds (line d minus g)	**$0.00**
Recipient Share:	
i. Total recipient share required	**1,000,000.00**
j. Recipient share of expenditures	**1,806,957.10**
k. Remaining recipient share to be provided (line i minus j)	**0.00**
Program Income:	
l. Total Federal share of program income earned	**$0.00**
m. Program income expended in accordance with the deduction alternative	**$0.00**
n. Program income expended in accordance with the addition alternative	**$0.00**
o. Unexpended program income (line l minus line m or line n)	**$0.00**

11. Indirect Expense	a. Type	b. Rate	c. Period From	Period To	d. Base	e. Amount Charged	f. Federal Share
				g. Totals:	**0**	**0**	**0**

12. Remarks: Attach any explanations deemed necessary or information required by Federal sponsoring agency in compliance with governing legislation:

13. Certification: By signing this report, I certify to the best of my knowledge and belief that the report is true, complete, and accurate, and the expenditures, disbursements and cash receipts are for the purposes and intent set forth in the award documents. I am aware that any false, fictitious, or fraudulent information may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 18, Section 1001)

a. Typed or Printed Name and Title of Authorized Certifying Official **Deven N. Upadhyay, Manager, Water Resource Management**	c. Telephone (Area code, number, and extension) **213-217-6686** d. Email Address dupadhyay@mwdh2o.com
b. Signature of Authorized Certifying Official	e. Date Report Submitted (Month, Day, Year) **12/28/2016** 14. Agency use only:

Standard Form 425 - Revised 10/11/2011
OMB Approval Number: 0348-0061
Expiration Date: 2/28/2015

UNITED STATES DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION Southern California Area Office	Agreement Number **R14SP00073**
RELEASE OF CLAIMS	Agreement Date **9/14/14 – 9/30/16**

WHEREAS, by the terms of the above-identified agreement for

California Friendly Turf Replacement Incentive Program-Phase 2

entered into by the United States of America, hereinafter also referred to as the United States, and the grant recipient whose name appears on the agreement as

Metropolitan Water District of Southern California

it is provided that after completion of all work, the grant recipient will furnish the United States with a release of all claims;

NOW, THEREFORE, in consideration of the above premises and the payment by the United States to the recipient the total amount of

$299,000.00

the grant recipient hereby remises, releases, and forever discharges the United States, its officers, agents, and employees, of and from all manner of debts, dues, liabilities, obligations, accounts, claims, and demands whatsoever, in law and equity, under or by virtue of the said agreement except:

IN WITNESS WHEREOF, the agreement recipient has executed this release this 21st day of December, 2016.

By ______________________
(Signature)

Deven Upadhyay
(Name -- Type or Print)

Manager, Water Resource Managment
(Title)

Metropolitan Water District of Southern California
(Agreement Recipient)

California Friendly® Turf Replacement Incentive Program – Phase 2 Southern California

Final Project Report

Agreement # R14AP00073
The Metropolitan Water District of Southern California
700 N. Alameda Street
Los Angeles, CA 90012-3352
September 30, 2013

1. Recipient Information:	
Recipient Name: (Name, contact person, address and phone number)	The Metropolitan Water District of Southern California Mr. Bill McDonnell 700 North Alameda Street, Los Angeles 90012-3352 Phone: 213-217-7693; email: bmcdonnell@mwdh2o.com
Project Name:	California Friendly Turf Replacement Incentive Program – Phase 2
Assistance Agreement	R14AP00073
Date of Award: (Month, Year)	September 11, 2014
Estimated Completion Date	September 30, 2016
Actual Completion Date: (Month, Year)	September 30, 2017

2. Final Funding Information	**Funding Amount**
Non-Federal Entities	
1. Metropolitan Water District of Southern California	$1,806,957.10
2.	
3.	
Non-Federal Subtotal:	$1,806,957.10
Other Federal Entities	
1.	
2.	
3.	
Other Federal Subtotal:	
Requested Reclamation Funding:	$299,000.00
Total Project Funding:	$2,105,957.10

3. One Paragraph Project Summary:

The California Friendly® Turf Replacement Incentive Program – Phase 2 (Program) transformed 1.07 million square feet of thirsty turf landscapes to California Friendly landscapes with climate-appropriate plants, efficient irrigation, permeable surfaces to allow rainwater infiltration, and mulch to preserve soil moisture. These 1.07 million square feet have included residential and commercial projects throughout Metropolitan's 5,200 square mile service area. The program provided 1,400 acre-feet in lifetime water savings, increased acceptance of non-turf lawns, and continued market transformation. Because a significant portion of Metropolitan's water supplies are imported from the Colorado River and Bay-Delta, this program also provided benefits for energy efficiency, critical habitat for threatened and endangered species, and water markets.

4. **Final Project Description:** *Briefly describe components of the project and the work completed, including each element of the scope of work and the work completed at each stage of the project. Please include maps, sketches, and/or drawing of the features of the completed project, as appropriate. In addition, please describe any changes in the project scope.*

This Program's scope of work included three elements: engaging member agencies, administering the program, and evaluating progress. Each element was successfully completed.

Engaging member agencies began at the monthly Water Use Efficiency meetings held for conservation coordinators from all of Metropolitan's member agencies. These meetings allow member agencies to learn about new conservation programs and were the perfect avenue for promoting the Program. Over several meetings, Metropolitan provided Program information and requirements, administrative assistance, landscaping educational materials, and technical assistance to encourage member agency participation.

The second element of this Program was administering the grant and distributing grant funds. Metropolitan first created addendums with participating member agencies to incorporate grant funds. Metropolitan issued a task order to its vendor for region wide rebates to include grant funds. Payments to the vendor and grant expenditures were tracked per invoice.

Evaluation, the third element of this Program, has been ongoing with semi-annual performance reports and invoices to USBR. Metropolitan has also welcomed ongoing program feedback from member agencies through roundtables and one-on-one discussions. Water savings for turf removal through the Program were calculated from previous studies, Metropolitan is currently working on updated water savings analysis.

5. **Accomplishment of Project Goals:** *Describe the goals and objectives of the project and whether each of these was met. Where appropriate, state the reasons why goals and objectives were not met, and describe any problems or delays encountered in completing the project. Please include whether or not the project was completed within cost.*

There were seven goals and objectives for this project focused on programmatic benchmarks, collaboration, and environmental health. All of these goals and objectives were met. The project was completed within cost.

The two programmatic benchmark goals were to transform 1,300,000 square feet of irrigated turf to a California friendly landscape and to conserve approximately 1,800 AF of water over turf removal's ten year lifespan. The three goals focused on collaboration were to continue the partnership with USBR to promote the evolution of landscape norms from high-water use to water efficient landscapes, provide water agencies with the opportunity to augment the base incentive to create greater incentives for their customers, and assist retail agencies in complying with 20x2020 and fulfilling requirements of the California Urban Water Conservation Council Memorandum of Understanding Regarding Urban Water Conservation in California. The last three goals involved promoting environmental health. These goals were to contribute to the state's goal of achieving a 20 percent reduction in per capita potable water use by 2020 and to provide benefits for energy efficiency, critical habitat for threatened and endangered species, and the Colorado River and Bay-Delta systems.

Transform 1.3 million square feet of irrigated turf to a California Friendly landscape and conserve approximately 1,800 acre feet of water over 10 year lifespan

At the close of this project 1.07 million square feet of turf had been transformed to a California Friendly Landscape utilizing the USBR Grant.

The goal of was to save 1,800 acre feet of water over a 10 year lifespan. The savings of 1,400 of quantifiable water savings was from areas receiving incentives. Potentially an additional 1,800 acre feet of non-quantifiable savings may have occurred due to landscape changes as a result of program influence. Metropolitan estimates that for every 1,000 square feet of turf replaced with California Friendly landscape; another 1,000 square feet would be changed without the need for program incentives. For example, some customers might be motivated to transform their lawn without applying for an incentive after seeing drought tolerant landscapes, hearing marketing, receiving a high bill, or experiencing the general trend toward accepting drought tolerant yards.

The total quantifiable water savings of the 1.07 million square feet of turf removed with an incentive from this program was 1,400 AF over a 10 year life. Assuming another 1.07 million square feet of turf was removed without an incentive, the total AF saved over 10 years is 2,800. This savings meets the approximate program goal of saving 1,800 AF.

Continue collaborating with Reclamation to promote California Friendly landscape and encourage the evolution of landscape norms from high-water use to water efficient landscape norms

The California Friendly Turf Replacement Incentive Program has successfully continued the collaboration between Metropolitan and USBR to promote California Friendly landscapes. Currently, Metropolitan is also collaborating with USBR on the evaluation of water savings, additional benefits and cost-effectiveness of turf removal.

In addition to incentives, Metropolitan also utilizes education as a strategy to change landscape norms. The California Friendly Landscape Training (CFLT) program was implemented in 2013 to provide California friendly landscaping workshops to residential customers throughout Metropolitan's service area. The CFLT program teaches residential property owners about water efficient landscape practices, design and construction, irrigation systems, plant selection, and runoff minimization.

Provide water agencies with the opportunity to augment the base incentive with additional funding to create a greater incentive for their customers to participate

Metropolitan successfully provided water agencies with the opportunity to augment the $1.00 per square foot base incentive. Through yearly agreements, water agencies could designate the amount of augmentation added to the base incentive in their service area.

There are multiple factors that affect program participation ranging from the nation's economic health, to the regional housing market, to local water rates. In addition to these factors outside of the program's control, there are also factors directly associated with the Program. Examples of these are the tendency for successful conservation programs to gain momentum over the years, program specific marketing efforts, and an overall cultural trend away from turf lawns. Within this mix of factors, the impact of increased turf removal incentive amounts is difficult to determine.

Contribute to the state's goal of achieving a 20 percent reduction in per capita potable water use by 2020 (SBX7-7, Water Conservation Act of 2009 known as "20x2020)

This Program has successfully contributed to the State's goal of achieving a 20 percent reduction in per capita potable water use by 2020 by saving an estimated total of 2,800 acre feet over a 10-year period.

In October 2010, Metropolitan adopted the Integrated Water Resources Plan 2010 Update (IRP) that provides a long-range plan for water supply reliability within the region. The IRP identifies the need for 580,000 AF of new annual water savings by 2020 to meet dry year demands. These savings can be achieved through a combination of increased conservation and recycled water use that offsets potable demand. The 580,000 AF of savings would reduce the per capita portable water use 20 percent from the historic average of 177 gallons per capita per day (GPCD) to 141 GPCD within ten years.

The water savings from this Program will contribute to the overall IRP water savings goal. In addition, the program pioneers an important transition in water conservation from indoor savings to outdoor savings. Southern California has seen considerable progress on indoor water conservation with high efficiency toilets, urinals, clothes washers, faucet aerators, and other devices. Over the past two decades, Metropolitan has invested $352 million in conservation activities and has begun to maximize the water savings available indoors. Moving forward, it is becoming increasingly important to address outdoor water conservation. According to the California Department of Water Resources, landscape irrigation comprised approximately 27 percent of urban water use within the South Coast Hydrologic Region in 2001.[1] (Metropolitan's service area encompasses a majority of this hydrologic region.) A 1999 national study on residential uses indicates that approximately 60 percent of residential water use is for irrigation. [2] Within Metropolitan's service area, landscapes are dominated by irrigated turf. With average annual precipitation of 17.6 inches in this region, turf requires nearly three times the amount of water provided through natural rainfall. In addition, this region receives the majority of annual precipitation from November through February with little or no rainfall during the remainder of the year. Therefore, 100 percent of turf water needs must be provided through irrigation during warmer months when resources are constrained and reservoir levels are lower.

Transforming landscape norms, through the California Friendly Turf Replacement Incentive Program – Phase 2 and similar programs, are essential in contributing to the state's goal of achieving a 20 percent reduction in per capita potable water use by 2020. Transforming 1.07 million square feet of turf to a California Friendly Landscape not only contributes to 20 x 2020 by saving water; it has also laid the foundation for future savings by transforming landscape norms.

Assist retail agencies in complying with 20x2020 and fulfilling requirements of the California Urban Water Conservation Council Memorandum of Understanding Regarding Urban Water Conservation in California

This Program has successfully assisted retail agencies in complying with 20x2020 and fulfilling the requirements of the California Urban Water Conservation Council

[1] California Department of Water Resources, 2005 California Water Plan Update.

[2] American Waterworks Association Research Foundation. Residential End Uses of Water. 1999.

Memorandum of Understanding regarding urban water conservation in California. Turf removal addresses the state's long-term water issues because of its potential to provide long-term, sustained water savings through changing social and landscape norms. The funding provided through this program allowed many retail agencies, which otherwise would not have the funds, to start turf removal programs. Communities are looking for turf alternatives and other means to lower water demand. Residents and businesses want to replace turf to lower water bills and/or publically demonstrate their conservation ethic. However, cost is still a barrier. Providing funding for local programs has successfully increased the number of projects that demonstrate the transition from turf to California Friendly landscapes; thereby assisting in reaching the 20x2020 requirements.

Provide benefits for energy efficiency, critical habitat for threatened and endangered species, and water markets by reducing demands on the Colorado River and Bay-Delta systems.

The California Friendly Turf Replacement Incentive Program – Phase 2 has reached its goal of benefiting energy efficiency, critical habitat for threatened and endangered species, and improved water markets by reducing demands on the Colorado River and Bay-Delta systems.

Contribute to Energy efficiency

The California Friendly Turf Replacement Incentive Program – Phase 2 reduced an estimated 1,400 acre feet of imported water, which is pumped from the Colorado River through the Colorado River Aqueduct and from the Bay-Delta through the State Water Project. According to recent statewide studies prepared for the California Public Utilities Commission, the average energy intensity of water delivered by Metropolitan to its member agencies is 2,473 kWh/AF[3]. In addition, the range of energy intensity to distribute supplies to end users is 45-1,574 kWh per million gallons, or 138-4,830 kWh per acre foot.[4] Based on the energy intensity data in the Commission's studies, the program resulted in the following energy savings due to reduced demand for water imported from the Colorado River and State Water Project:

Water Savings	Energy Intensity Range kWh/AF	Estimated Energy Savings Range
2,800 AF/year	2,611 – 7,303	7,310,800 – 20,448,400

The benefit of this energy savings is further enhanced by timing. Irrigation demands within Metropolitan's service area are highest during the warmer months. Historic reference evapotranspiration during July is nearly three times higher than the low in January. The project's estimated water and energy savings will primarily occur during

[3] California Public Utilities Commission. Embedded Energy in Water Studies Study 1: Statewide and Regional Water-Energy Relationship. Prepared by GEI Consultants/Navigant Consulting, Inc. August 31, 2010.

[4] California Public Utilities Commission. Embedded Energy in Water Studies Study 2: Water Agency and Function Component Study and Embedded Energy – Water Load Profiles. Prepared by GEI Consultants/Navigant Consulting Inc. August 31, 2010.

the warmer months when demands are high, resources are constrained, and reservoirs are lower.

Benefit critical habitat for threatened and endangered species

This program has reduced an estimated 280 acre feet per year of imported water from the Colorado River and Bay-Delta. Both water sources provide critical habitat for federally listed endangered species, which are affected by water diversions. Endangered fish species within the Lower Colorado River include: Moapa Dace (*Moapa coriacea),* Woundfin *(Plagopterus argentissimus*), Virgin River Chub (*Gila robusta seminude*), Bonytail (*Gila Elegans*), Humpback Chub (*Gila Cypha*), Razerback Sucker (*Xyrauchen texanus*), and Colorado Pike Minnow (*Ptychocheilus Lucius*). Within the Bay-Delta, threatened species include: Central Valley Steelhead (*Oncorhynchus mykiss*), Central Valley Spring-run Chinook Salmon (*Oncorhynchus tshawytscha*), Delta Smelt (*Hypomesus transpacificus*), and North American Green Sturgeon (*Acipenser medirostris*). The Sacramento River supports the endangered Winter-run Chinook Salmon (*Oncorhynchus tschawtscha*). There are also listed mammal, bird, plant, and amphibian species that are dependent on the water quality and water quantity of these riparian water systems.

Benefit the Colorado River and Bay-Delta along with associated water markets

The reduced demand for water from the Colorado River and Bay-Delta reduces the need to divert water from these systems; reduced diversion improves flexibility for water management and contributes to improved status for these water systems. Maximizing these benefits is the timing of water reductions caused by turf removal which is primarily in the spring and summer. These months are also when the Colorado River and Bay-Delta systems are most impacted by water withdrawals.

The water conserved through this program supports existing water markets for Colorado River, State Water Project, and Central Valley contractors. This region is dependent on imported water to meet municipal and industrial demand. Reducing Metropolitan's demand through the CA Friendly Turf Replacement Incentive Program – Phase 2 provides more flexibility for participating in water markets when transfer and storage opportunities are advantageous to the region and improve the management of water across the state. In addition, greater water supply in the Colorado River, State Water Project, and Central Valley Project systems will provide Indian tribes with more access to water markets.

6. **Discussion of Amount of Water Conserved, Marketed or Better Managed: In responding to the questions set forth below, Recipients should rely on the best data or information available. Actual field measurements should be used whenever possible** (e.g., baseline data or post-project data derived from measuring devices, diversion records, seepage tests, etc.) Where actual field measurements are not available, water savings (or amounts marketed or better managed) may be estimated based on studies, other similar improvement projects, or anecdotal evidence.

A Recipient's total water supply (average, annual, available water supply in acre-feet per year):

Metropolitan has two sources of water supply: Colorado River, delivered through the Colorado River Aqueduct, and the Bay-Delta, delivered through the State

Water Project. Deliveries from each source for the 2006-2010 are shown below. Supply numbers for 2010-2013 are not yet available.

Year	Colorado River Aqueduct (AF)	State Water Project (AF)	Total (AF)
2010	1,150,000	1,500,000	2,650,000
2009	1,043,000	908,000	1,951,000
2008	896,000	1,037,000	1,933,000
2007	696,000	1,648,000	2,344,000
2006	535,000	1,695,000	2,230,000
Total	4,320,000	6,788,000	11,108,000
Average Annual Supply (total / 5 years)			2,221,600

B. Amount of water conserved, marketed or better managed as a result of the project

Two hundred and eight acre feet conserved for the first program year. Additional research is needed to estimate savings persistence over time. A water use reduction of 42 gallons per day was used to calculate water savings. Total water savings over the expected 10 year life of the program are estimated to be 2,800 acre-feet.

C. Describe how the amounts stated in response to 6.B were calculated or estimated: In responding to this question, please address (1) – (3) below.

1. Describe the information/data being relied on to calculate/estimate the project benefits. State how that data/information was obtained, if appropriate. Provide any other information necessary to explain how the final calculation/estimate of project benefits was made.

Water savings were calculated at 42 gallons per day over a 10 year life.

Functional Form

Water use billing data are often strongly skewed in a positive direction, violating a key assumption of the standard linear regression model.[5] Accordingly, the natural log of water use was used as the dependent variable in the models to be developed. A direct result of this log-linear model specification is that the coefficient on the program participation variable can be interpreted as the approximate average percentage change in water use due to the turf replacement program.[6]

Independent Variables

The measures available for "explaining" variations in water use other than program participation are limited to a set of weather and climate variables. Future research would do well to expand on this limited set of explanatory variables, although the measurement of variables like income, attitudes and behavior is often difficult in practice.

[5] This is the assumption that the model errors are normally, or at least symmetrically, distributed.

[6] This contrast with the *amount of change* interpretation that would be made if the dependent variable was kept in its original form.

A Fourier series was used to capture the cyclical effects of climate on outdoor water use. Temperature is represented using a moving average of daily maximum temperature matched to the associated monthly or bimonthly cycle. Rainfall, measured as total daily precipitation is similarly expressed. Temperature and rainfall are made orthogonal, or independent of each other, by statistical construction.[7] This provides a more sensitive measure of these two otherwise highly correlated effects. A set of interactions between rainfall and maximum temperature are also used to represent the cyclic influence of weather.

Choice of an Estimator

The underlying structure of the data—consisting of both variation between sites and variation over time within a given site—suggests that a panel model, rather than ordinary least squares (OLS), is appropriate[8]. The particular structure of panel data involves a collection of independent observations, each measured over time. This is precisely the character of the water savings data where repeated measures on use were obtained for a set of independent sites. A second major advantage of the panel model is its ability to capture and represent the effect of site-specific variables not explicitly represented in the model.

Intuitively, it would not be surprising to find that differences in water use between sites result from factors other than climate and weather.[9] To the extent that collective effect of these types of unaccounted for factors differ between sites but remain constant within sites, OLS can yield statistically inconsistent estimates.[10] By accounting for the time-invariant influence of these systematic but unmeasured site-specific effects, panel model estimators can avoid this problem.[11]

The choice of a panel model estimator usually involves selection between the so-called "fixed" and "random" effect models. A principal consideration in selecting between these two estimators involves the assumed correlation between the time-invariant site-specific effect and the model error term. If a correlation is assumed to exist, the fixed effect model is appropriate. If not, the random effects model has some relative advantages, including a relative gain in efficiency.[12]

Because it seems likely that the error term, which includes time-invariant effects, is correlated with the program participation, weather and climate variables comprising the water use model, the fixed-effects estimator will be used in the following analysis.[13,14,15] Also, since the observations are

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[7] The precipitation and temperature values were obtained using NOAA station recordings closest to each agency.

[8] An F-test rejected the null hypothesis of a single common intercept per meter at the $p>0.001$ level.

[9] The proportionate effect of the turf replacement program is assumed to be the same across sites.

[10] Inconsistent estimates tend to be "wrong" on average and do not improve as the sample size increases.

[11] Technically speaking, OLS is inconsistent if the unobserved variables are correlated with the set of predictors included in the model. This is sometimes referred to as the "omitted variable" problem.

[12] An efficient estimator has the smallest possible error variance.

[13] This choice is not without consequence since the estimated effects of the random effects model are inconsistent if

clustered within sites, the estimated standard errors were adjusted to explicitly account for this fact.

At the individual level, the fixed-effects model for site *i* and time *t*, can be written as

$$y_{ij} = \alpha_j + x'_{it}\beta + \varepsilon_{ij}$$

Where
y_{ij} measures water use at site i and time j,
α_j is the unobserved but estimatable site-specific effect influencing water practices at site j, x'_{it} is a px1 vector of measurements on the p observed explanatory variables, β is a 1 x p column of regression coefficients, and ε_{ij} is the associated error term assumed to be identically and independently distributed. The presence of the site-specific effect α_j is what distinguishes the fixed-effect panel model from the standard regression model.

2. As appropriate, please include an explanation of any concerns or factors affecting the reliability of the data/information relied on.

The water conservation community is still in the early stages of understanding how best to quantify the water savings of landscape efficiency measures. There are many challenges facing accurate calculation of outdoor water conservation. For this Program, data analysis challenges focused around participant behavior, water usage data, control groups, and the time-frame and nature of landscape savings.

Participant behavior can factor greatly into water use at a property; however it is very difficult to predict or track. For example, during the two year Program period, a turf removal participant may have added additional people to the household thus increasing water usage. They could also have added a vegetable garden, an addition to the home, or other upgrade that would increase water usage. On the converse side, participants might install high efficiency toilets or clothes washers that would save water. Or they might fix an ongoing leak or have a decrease in household members that would lead to reduced water usage.

Related to participant behavior is the accuracy of water usage data. Many residential properties do not have separate outdoor and indoor water meters. Instead, water is metered as it enters the property. Therefore it is very difficult to tell where water is being used or saved on the premise. In addition, water usage data can be difficult to collect from water agencies.

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the fixed effects model is appropriate.

[14] The standard Hausman test, a statistical test often used to decide between the fixed and random effect models, failed in both cases. The fixed-effect model will therefore be used since it is consistent even if the random-effect estimator is technically the correct one. This decision may result in some loss of efficiency.

[15] A notable limitation of the fixed-effect model is its inability to estimate time-invariant variables. This precludes including the amount of turf replaced as an explanatory variable.

Many water agencies do not have the billing system, staff time, or ability to report on customer's water consumption data.

The lack of a control group is also in part related to participant behavior. To have a solid control group for a turf removal participant Metropolitan would need two properties with identical yard square footage, indoor water using fixtures, full time residents, and similar conservation habits. This type of match is extremely difficult to identify and to maintain over the two year Program period.

The last challenge with water savings analysis is the nature of landscape based water savings. This Program encouraged the installation of California Friendly Landscapes. These landscapes often take up to three years to fully establish and gain resilience to drought. Until the plants are fully established, participants will still need to water their landscapes. It is possible that the true water savings of California Friendly yard transformations will not be seen until the fourth year after installation. The fact that this Program is only two years and the full benefit of California Friendly landscapes may not be seen for three or four years makes it very likely that the water savings calculations in this report underestimate true savings.

It is also possible that water savings could be over-estimated due to the process customers use to remove their lawns. For example, if a customer uses an herbicide to kill their grass they will need to water the grass liberally during the "killing" period to assist the grass in absorbing the herbicide. This could increase their water usage right before the transformation takes place thus skewing the analysis results.

The different types of California Friendly landscapes can also affect water savings. California Friendly landscapes range from a majority of permeable decomposed granite to succulents to chaparral plants. Each of these yard "pallets" has a different water savings profile.

With respect to the empirical analysis, it is important to emphasize that the data available may not be representative of the full set of retail agencies participating in the program. This would be the case if, for example, agencies who suspected good results were more likely to provide the requested data. Second, the program participants may not be a representative sample of all customers served by a given agency. This would be true if participants were selected based on the expectation that their particular sites would especially benefit from the program. It would also happen if participants themselves joined the program for this reason, or because of a higher than average sensitivity to the importance of water use efficiency. In other words, if participants differed systematically from "typical" customers, the results developed in this analysis may not apply to the full customer population. This could limit the generalizability of the results.

A second issue affecting generalizability is that the analysis is conducted for all retail agencies as a group, not separately for individual agencies. The reason is that most of the individual agencies did not provide enough information for enough sites to justify separate analysis. Accordingly, model estimates are best viewed as applying to the average program participant and not to savings achieved by any given agency.

While generalizability of findings is a concern, so is internal validity. In the present context, internal validity depends largely on the a priori belief that an effect of interest—i.e., water savings—are due to the turf replacement program. This is more than a question of the statistical significance of the estimate.

Internal validity tends to be maximized in controlled experiments in which participants are randomly assigned to treatment and control groups. The main feature of this data generation model is that factors other than program participation systematically effecting outcomes are averaged out between groups, allowing a pure estimate of program effects. In practice, and especially when it comes to social programs, it is very difficult to conduct controlled experiments in field settings[16]. As a result, analytic methods attempting to approximate the idealized conditions of the controlled experiment have been developed. One of these, the so-called interrupted time-series design, will be used here.

The interrupted time series design uses each program participant, or site, as its own control group. Data are collected for both the pre- and post-program periods. Changes in the outcome variable of interest are measured in terms of pre-post differences. The key assumption is that all other factors contributing to the outcome are adequately controlled statistically. A standard linear regression model is often use for this purpose.[17]

The regression approach assumes that factors other than program participation systematically influencing measured outcomes are accurately, fully and explicitly included in the regression model. To the extent this is not achieved, estimates of program effects will tend to be wrong. The limitations of the usual regression approach in meeting these requirements are immediate in light of the available data. In particular, the only variables available for explaining variations in water use other than the program variable are a set of weather and climate measures. While variations in water use over the time considered may include program participation, they certainly also include the influence of income, personal preferences and behavior, the perceived importance of water conservation and other site-specific factors. Fortunately, the panel model estimators

[16] This can be especially true were social programs are involved since it may unethical or illegal to deny program services.

[17] The t-test or simple analysis of variance (ANOVA) is sometimes used as a less desirable alternative since it does not control for additional confounding factors.

used in the analysis provide a possible remedy for the limiting assumptions of the regular regression model.

3. Attach any relevant data, reports or other support relied on in the calculation/estimate of project benefits, if available. Please briefly describe the data/information attached, if any.

Please see the accompany report titled "Water Savings from Turf Replacement" in Appendix A.

D. Use of Conserved Water: *Please explain where the water saved, better managed, or marketed as a result of the project is going (e.g. used by the recipient, in stream flows, available to junior water users, etc.*

The water conserved through this Project could support existing water markets for Colorado River, State Water Project, and Central Valley Project contractors. This region is dependent on imported water to meet their municipal and industrial demand. In addition, reduced demand will provide flexibility for participating in water markets when transfer and storage opportunities are advantageous to the region and improve the management of water across the state.

E. Future tracking of project benefits: *Please state whether and how the recipient plans to track the benefits of the project (water saved, marketed or better managed) in the future.*

Metropolitan is currently conducting an updated analysis of water savings of turf removal.

7. **Discussion of Amount of Renewable Energy Added:** *If your project included the installation of a renewable component, please describe the amount of energy the system is generating annually. Please provide any data/reports in support of this calculation.*

This Program did not include the installation of a renewable component.

8. **Describe how the project demonstrates collaboration, stakeholder involvement or the formation of partnerships, if applicable:** *Please describe the collaboration involved in the project, and the role of any cost-share or other types of partners. If there were any additional entities that provide support*

Collaboration and stakeholder involvement

The California Friendly Turf Replacement Incentive Program successfully encouraged collaboration and involvement among Metropolitan's twenty-six member agencies, associated retail agencies, and other stakeholders. Through monthly meetings convened by Metropolitan, water agencies regularly shared information to increase the programmatic and technical capacity surrounding turf removal and outdoor water conservation within the region. In addition to impromptu discussions, Metropolitan also held "round-table" discussions for member and retail agencies on turf removal program successes, difficulties, and lessons learned.

The collaboration on programmatic and technical issues surrounding turf removal has also spread to educational efforts. The California Friendly Landscape Training (CFLT) program educates residential customers on California Friendly landscapes. Although not specifically aimed at turf removal, the course contains all the information customers need to begin a turf removal project and transform their landscape. CFLT is a uniform course that is available to residents throughout the Metropolitan service area. The creation of the CFLT curriculum is an example of collaboration between member agencies, Metropolitan, and the contractor. Launched in 2013, CFLT continues to be a collaborative effort with Metropolitan receiving feedback from member agencies and incorporating them into the program.

9. **Describe any other pertinent issues regarding the project:**

Grant funding has contributed to turf removal programs spreading throughout Metropolitan's service area. Since the beginning of this Program in 2011, turf removal has gained momentum throughout Metropolitan's service area.

Due to the popularity of turf removal, Metropolitan's board approved an unprecedented amount of $450 million for conservation programs in fiscal year 2015/2016.

10. **Feedback to Reclamation regarding the WaterSMART Program:** *Please let us know if there is anything we can do to improve the WaterSMART program in general, including the process for applying for or completing a WaterSMART project. Your feedback is important to us.*

Metropolitan does not have any recommendations regarding the WaterSMART Program at this time.

11. Attachments: *Please attach the following*

    a. Any available data or information relied on in responding to paragraph 7, above;

    Not Applicable

    b. A map or illustration showing the location of the recipient's facilities (see paragraph 4, above);

c. Maps, sketches, and/or drawings of the features of the completed project, as appropriate (see paragraph 5, above);

Not applicable

d. Representative before and after photographs, if available

Not applicable

e. A table showing the total expenditures for the completed project (please see Sample Final Project Costs Table, below).

Deliverable per Agreement	Due Date	% Complete	Funds Expended to Date Federal Grant	Local Share	Total
Task 1 Issue addendum to member agency agreements to incorporate grant requirements	September 2016	100%			
Task 2 Provide agencies with information to acknowledge Reclamation funding on program materials	September 2016	100%			
Task 3 Administer program	September 2016	100%	$299,000.00	$1,806,957.10	$2,105,957.10
Task 4 Collect and analyze data	Ongoing	100%			
Task 5 Project assessment and evaluation, Final Report	September 2016	100%			
TOTAL			$299,000.00	$1,806,957.10	$1,299,000.00
Cost Share %			14%	86%	100%
Min. Cost Share %			50%	50%	100%

End of Report

Appendix A:
Water Savings from Turf Replacement

Harrelson,Diane L
Metropolitan Water District of Southern California

Executive Summary

Between 2011 and 2013 the United States Bureau of Reclamation and the Metropolitan Water District of Southern California jointly funded the replacement of more than 2.4 million square feet of turf with "California friendly" landscapes. Subject to qualifications discussed in this report, the turf replacement program resulted in water use reductions of 23.9% at commercial sites and 18.2% at residential sites.

Background and Objectives

The *California Friendly Turf Replacement Incentive Program* provided financial incentives to encourage customers to replace traditional turf with "California friendly" landscapes. Jointly funded by the Metropolitan Water District of Southern California (MWD) and the United States Bureau of Reclamation (USBR), the new landscapes combine climate appropriate plants, permeable surfaces and more efficient irrigation systems in an effort to save water.[18] Because a large share of MWD's water supplies originates with the Colorado River and the Bay-Delta, the program may also provide secondary benefits in the form of reduced energy use and more water for endangered species.[19]

Under the jointly-funded turf replacement program more than 2.4 million acres of commercial and residential irrigated turf were replaced with water efficient landscapes.[20] The objective of this paper is to develop an estimate of water savings attributable to the program. The methods of doing so, and the resulting savings estimates, are discussed in the following sections.

Data

A total of 43 retail agencies participated in the turf replacement program. Of these, 13 provided usable customer billing data for purposes of the water savings analysis. Collectively, these agencies were responsible for more than 659,000 square feet of turf replacement, or 27% of the total accomplished under MWD-USBR funding. Forty-four percent of all acreage replaced involved commercial sites; 56% were residential.[21] Thirty sites and 1734 billing-period observations are available for the commercial analysis. The residential analysis involves 287 sites and 10,632 observations.

It is important to emphasize that the available data may not be representative of the full set of retail agencies participating in the turf replacement program. This would be the case if, for example, agencies who suspected good results were more likely to provide the requested data. Second, the program participants may not be a representative sample of all customers served by a given agency. This would be true if participants were selected based on the expectation that their particular sites would especially benefit from the program. It would also happen if participants themselves joined the program for this reason, or because of higher than average sensitivity to the importance of water use efficiency. In other words, if participants differed systematically from "typical" customers, the results developed in the following analysis may not apply to a utility's full customer population.

A second issue affecting generalizability is that the analysis is conducted for all retail agencies as a group, not separately for individual agencies. The reason is that most of the individual agencies did not provide enough site information to support separate analysis. Accordingly, model estimates are best viewed as applying to the average program participant and not to savings achieved by any given agency.

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[18] The program has helped promote customer acceptance of non-turf lawns and begun a market transformation towards more water-efficient landscapes.

[19] See Metropolitan's *California Friendly Turf Replacement Incentive Program: Final Project*, Agreement No. R11AP35314, December 30, 2013, for additional information about program design and implementation.

[20] This does not include 0.3 million square-feet of additional landscaping paid for by customers. Additional turf replacement financed by the California Department of Water Resources is likewise not included.

[21] The commercial property total includes the common area of homeowner associations.

While generalizability of findings is a concern, so is internal validity. In the present context, internal validity depends largely on the *a priori* belief that an effect of interest—i.e., water savings—is due to the turf replacement program. This is more than a question of statistical significance.

Internal validity tends to be maximized in controlled experiments where participants are randomly assigned to treatment and control groups. The main feature of this data generation model is that factors other than program participation systematically effecting outcomes are averaged out between groups, allowing a pure estimate of program effects. In practice, and especially when it comes to social programs, it is very difficult to conduct controlled experiments in field settings.[22] As a result, analytic methods attempting to approximate the idealized conditions of the controlled experiment have been developed. One of these, the so-called interrupted time-series design, will be used here.

The interrupted time series design uses each program participant, or site, as its own control group. Data are collected for both the pre- and post-program periods. Changes in the outcome variable are measured in terms of pre-post differences. The key assumption is that all other factors contributing to the outcome are adequately controlled statistically. A standard linear regression model is often use for this purpose.[23]

The regression approach assumes that factors other than program participation systematically influencing measured outcomes are accurately, fully and explicitly included in the regression model. To the extent this is not achieved, estimates of program effects will tend to be wrong. The limitations of the usual regression approach in meeting these requirements are apparent in light of the available data. In particular, the only variables available for explaining variations in water use other than the program variable are a set of weather and climate measures. While variations in water use over the time considered may include program participation, they certainly also include the influence of income, personal preferences and behavior, the perceived importance of water conservation and other site-specific factors. Fortunately, the panel model estimators, discussed in the next section, provide a possible remedy for the limiting assumptions of the regular regression model.

Aside from issues involving the data generation process and the estimator used in the analysis, several other data limitations need to be recognized. First, some of the turf replacement sites had very limited pre- or post-program billing histories. These sites could have been dropped from the analysis on that basis. But the belief is that the panel estimator will be robust in the presence of this type of imbalance, and that it is useful to retain as many observations as possible. This assumption will be tested in a later section.

Second, the monthly and bimonthly character of the available meter read consumption data creates a problem in matching consumption to weather. Water meters tend to be read on a rolling basis throughout the month. Discrete calendar months of weather measures are not well suited to explaining the continuous effects of these variables within billing periods. To address this limitation, a method for matching weather measures to rolling meter-read consumption will be used.[24]

[22] This can be especially true where social programs are involved since it may be unethical or illegal to deny program services.

[23] The t-test or simple analysis of variance (ANOVA) is sometimes used as a less desirable alternative since it does not control for additional confounding factors.

[24] See A&N Technical Services, *Continuous-Time Error Components Models of Residential Water Demand: A Report*

As a final matter, some of the residential sites show unusually high levels of use. Checks were made with agencies to make sure these high-use sites were truly residential. Based on the assurances received, there is no basis for reclassifying these sites as commercial. They will therefore be retained during the preliminary estimation stage. The possibility of their disproportionate influence will be addressed during the model diagnostics phase.

Model Specification

Functional Form

Water use billing data are often strongly skewed in a positive direction, violating a key assumption of the standard linear regression model.[25] This is apparent in the density plots shown in the upper part of Figures 1 and 2 on the following page. Fortunately, as shown in the lower part of these figures, a simple logarithmic transformation of water use produces symmetric distributions much more in keeping with standard assumptions. Accordingly, the natural log of water use will be used as the dependent variable in the models to be developed. A direct result of this log-linear model specification is that the coefficient on the program participation variable can be interpreted as the approximate average percentage change in water use due to the turf replacement program.[26]

Independent Variables

As discussed earlier, the measures available for "explaining" variations in water use other than program participation are limited to a set of weather and climate variables. Future research would do well to expand on this limited set of explanatory variables, although the measurement of variables like income, attitudes and behavior is often difficult in practice.

Table 1 lists the name and definition of variables used in estimating the panel models. To briefly elaborate, the geometric terms sin1 through cos6 represent a Fourier series designed to capture the cyclical (seasonal) effects of climate on outdoor water use. Temperature is represented using a moving average of daily maximum temperature matched to the associated monthly or bimonthly cycle. Rainfall, measured as total daily precipitation, is similarly expressed. Temperature and rainfall are made orthogonal, or independent of each other, by statistical construction.[27] This provides a more sensitive measure of these two otherwise highly correlated effects. A set of interactions between rainfall and maximum temperature are also used to represent the cyclic influence of weather.

Figure 1: Commercial Site Daily Water Use Before and After Logarithmic Transformation

Submitted to The Metropolitan Water District of Southern California, June 1992, for an early discussion of this method. For recent extensions see Thomas W. Chesnutt and Hossein Parandvash, *Applications of a High Resolution Continuous-Time Aggregate Water Demand Model: Recession and Weather-Induced Variation in the Northwest*, Conference Proceedings of the 7th IWA Conference on Efficient Use and Measurement of Water, October 2013.

[25] This is the assumption that the model errors are normally, or at least symmetrically, distributed.

[26] This contrast with the *amount of change* interpretation that would be made if the dependent variable was kept in its original form.

[27] The precipitation and temperature values were obtained using NOAA station recordings closest to each agency.

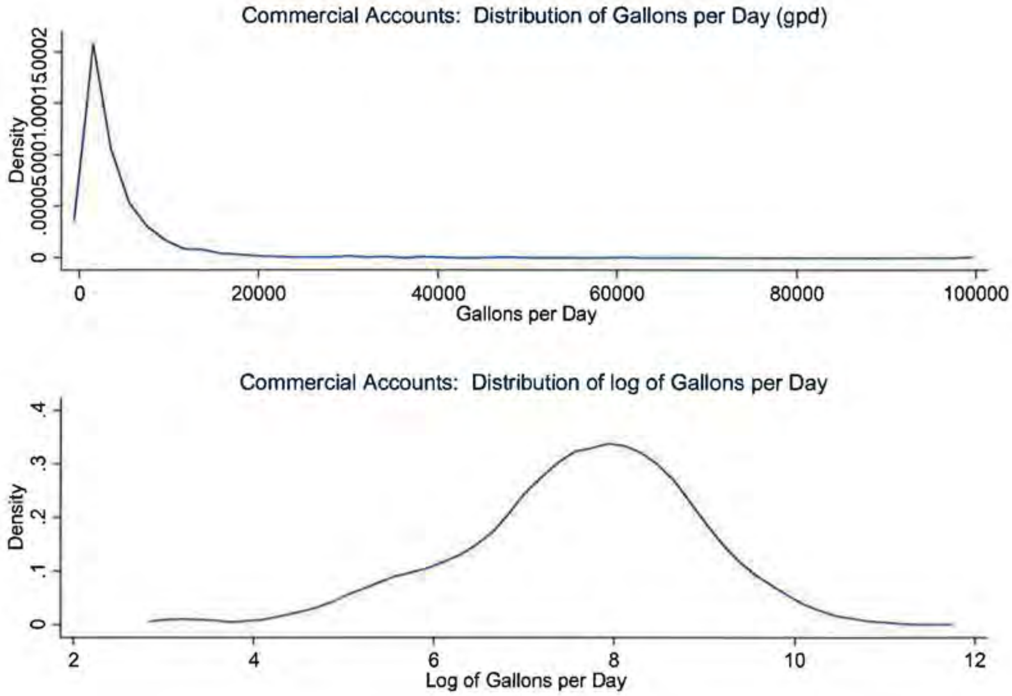

Figure 2: Residential Site Daily Water Use Before and After Logarithmic Transformation

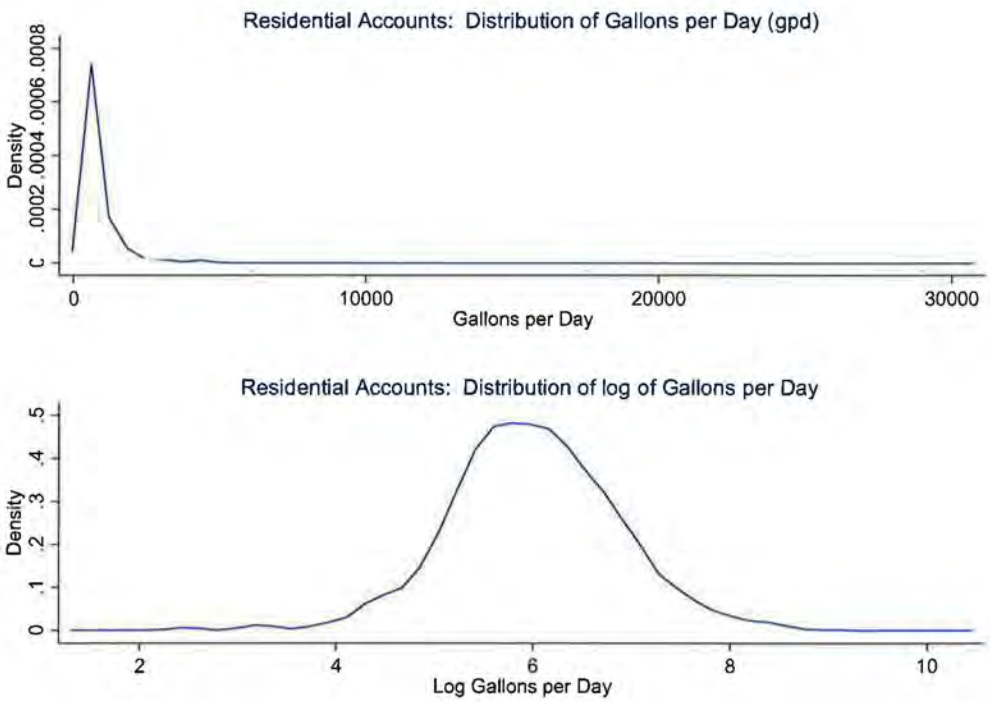

Table 1: Variable Names and Definitions

Mnemonic	Definition
lngpd	Log of gallons per day (gpd).
z1	Program effect.
sin1	First sine.
sin2	Second sine.
sin3	Third sine.
sin4	Fourth sine.
sin5	Fifth sine.
sin6	Sixth sine.
cos1	First cosine.
cos2	Second cosine.
cos3	Third cosine.
cos4	Fourth cosine.
cos5	Fifth cosine.
dlr_mean	Log of the mean difference of total daily rainfall.
dlr_1	Log of the mean difference of total daily rainfall lagged one billing period.
dlr_sin1	Interaction for the log of mean difference of total daily rainfall and the first sine.
dlr_cos1	Interaction for the log of mean difference of total daily rainfall and the first cosine.
dlt_mean	Log of the mean difference of maximum daily temperature.
dlt_sin1	Interaction for the log of mean difference of maximum daily temperature and the first sine.
dlt_cos1	Interaction for the log of mean difference of maximum daily temperature and the first cosine.

Choice of an Estimator

The underlying structure of the data—consisting of both variation between sites and variation over time within a given site—suggests that a panel model, rather than ordinary least squares (OLS), is appropriate.[28] The particular structure of panel data involves a collection of independent observations, each measured over time. This is precisely the character of the water savings data where repeated measures on use were obtained for a set of independent sites. A second major advantage of the panel model is its ability to capture and represent the effect of site-specific variables not explicitly represented in the model.

Intuitively, it would not be surprising to find that differences in water use between sites result from factors other than climate and weather.[29] To the extent that the collective effect of these types of unaccounted for factors differ between sites but remain constant within sites, OLS can yield statistically inconsistent estimates.[30] By accounting for the time-invariant influence of these systematic but unmeasured site-specific effects, panel model estimators can avoid this problem.[31]

The choice of a specific panel model estimator usually involves selecting between the so-called "fixed" and "random" effect models. A principal consideration in this choice involves the assumed correlation between the time-invariant site-specific effect and the model error term. If a correlation is assumed to

[28] An F-test rejected the null hypothesis of a single common intercept per meter at the $p<0.001$ level.

[29] The proportionate effect of the turf replacement program is assumed to be the same across sites.

[30] Inconsistent estimates tend to be "wrong" on average and do not improve as the sample size increases.

[31] Technically speaking, OLS is inconsistent if the unobserved variables are correlated with the set of predictors included in the model. This is sometimes referred to as the "omitted variable" problem.

exist, the fixed effect model is appropriate. If not, the random effects model has some advantages, including a relative gain in efficiency.[32]

Because it seems likely that the error term, which includes time-invariant effects, is correlated with the program participation, weather and climate variables comprising the water use model, the fixed-effects estimator will be used.[33,34,35] Also, since the observations are clustered within sites, the estimated standard errors will be adjusted to explicitly account for this fact.

At the individual level, the fixed-effects model for site *i* and time *j*, can be written as[36]

$$y_{ij} = \alpha_i + x'_{ij}\beta + \varepsilon_{ij}$$

where y_{ij} measures water use at site i during time j, α_i is the unobserved but estimatable site-specific effect influencing water practices at site i, x'_{ij} is a px1 vector of measurements on the p observed explanatory variables, β is a 1 x p column of regression coefficients, and ε_{ij} is the associated error term assumed to be identically and independently distributed. The presence of the site-specific effect α_i is what distinguishes the fixed-effect panel model from the standard regression model.

Estimation Results

Commercial Accounts

Table 2 contains the panel model estimates for commercial accounts. As can be seen, the estimated program effect (z1) is statistically significant at the 5% level. The estimated climate effect (the sine and cosine terms) and the main effect of rainfall and temperature are also significant. Combined, this set of variables account for 52% of the within-group variance, although the R^2 statistic is not particularly relevant in the current application.

Based on the coefficient on "Program effect," the turf replacement program for commercial accounts is estimated to have reduced water use by an average 23.9% for all commercial sites considered in the analysis[37]

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[32] An efficient estimator has the smallest possible error variance.

[33] This choice is not without consequence since the estimated effects of the random effects model are inconsistent if the fixed effects model is appropriate.

[34] The standard Hausman test, a statistical test often used to decide between the fixed and random effect models, failed in both cases. The fixed-effect model will therefore be used since it is consistent even if the random-effect estimator is technically the correct one. This decision may result in some loss of efficiency.

[35] A notable limitation of the fixed-effect model is its inability to estimate time-invariant variables. This precludes including the amount of turf replaced as an explanatory variable.

[36] This expression can be skipped with no loss of continuity.

[37] If b is the estimated coefficient on a binary variable and the dependent variable is expressed in log terms, the exact percentage can be calculated as exp(b)/exp(0.5*V(b))-1, where b is the coefficient and V(b) is its variance.

Table 2: Commercial Site Program Effect Estimates

```
Fixed-effects (within) regression               Number of obs      =      1734
Group variable: id2                             Number of groups   =        30

R-sq:  within  = 0.5193                         Obs per group: min =        11
       between = 0.1258                                        avg =      57.8
       overall = 0.2360                                        max =       170

                                                F(19,29)           =     46.43
corr(u_i, Xb)  = -0.0580                        Prob > F           =    0.0000

                                   (Std. Err. adjusted for 30 clusters in id2)
```

lngpd	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
z1	-.2436551	.101238	-2.41	0.023	-.4507101	-.0366001
sin1	-.3868226	.0349554	-11.07	0.000	-.4583144	-.3153307
sin2	-.1134642	.0263188	-4.31	0.000	-.1672921	-.0596363
sin3	.0054785	.0195651	0.28	0.781	-.0345365	.0454936
sin4	.0335528	.0232417	1.44	0.160	-.0139819	.0810875
sin5	.0557576	.0264394	2.11	0.044	.0016831	.1098322
sin6	.0195205	.0296438	0.66	0.515	-.0411078	.0801487
cos1	-.805546	.0673384	-11.96	0.000	-.9432685	-.6678236
cos2	-.0466816	.026494	-1.76	0.089	-.1008678	.0075047
cos3	.0508139	.0232268	2.19	0.037	.0033097	.0983181
cos4	.0126151	.0192299	0.66	0.517	-.0267145	.0519448
cos5	-.0402567	.0238525	-1.69	0.102	-.0890405	.0085272
dlr_mean	-.37268	.0541854	-6.88	0.000	-.4835016	-.2618583
dlr_1	-.2587398	.0456929	-5.66	0.000	-.3521922	-.1652874
dlr_sin1	-.2562041	.0653559	-3.92	0.000	-.389872	-.1225363
dlr_cos1	-.0786511	.0806115	-0.98	0.337	-.2435201	.0862178
dlt_mean	1.97099	.4393209	4.49	0.000	1.072478	2.869502
dlt_sin1	-.5193696	.5778853	-0.90	0.376	-1.701278	.6625385
dlt_cos1	.3029952	.9403137	0.32	0.750	-1.620162	2.226153
_cons	7.585388	.0336182	225.63	0.000	7.516631	7.654145
sigma_u	1.2102016					
sigma_e	.64091493					
rho	.78096367	(fraction of variance due to u_i)				

Residential Accounts

Table 3 shows the panel model effects for residential accounts. Based on these estimates the turf replacement program for residential sites reduced water use by an average of 18.2%.

Table 3: Residential Site Program Effect Estimates

Fixed-effects (within) regression		Number of obs =	10632
Group variable: id2		Number of groups =	287
R-sq: within = 0.3582		Obs per group: min =	4
between = 0.0265		avg =	37.0
overall = 0.1569		max =	176
		F(19,286) =	38.96
corr(u_i, Xb) = -0.0053		Prob > F =	0.0000

(Std. Err. adjusted for 287 clusters in id2)

lngpd	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
z1	-.1843285	.0303423	-6.07	0.000	-.244051	-.1246061
sin1	-.203574	.011596	-17.56	0.000	-.2263984	-.1807496
sin2	-.0226013	.008847	-2.55	0.011	-.0400149	-.0051878
sin3	.0061786	.0064807	0.95	0.341	-.0065772	.0189344
sin4	.0016722	.0059927	0.28	0.780	-.0101232	.0134677
sin5	.0287724	.0070544	4.08	0.000	.0148873	.0426576
sin6	.0037207	.00893	0.42	0.677	-.0138561	.0212976
cos1	-.4209534	.0188565	-22.32	0.000	-.4580684	-.3838383
cos2	-.0242631	.0075704	-3.20	0.002	-.039164	-.0093623
cos3	.0222163	.0061338	3.62	0.000	.0101431	.0342895
cos4	.008693	.0060342	1.44	0.151	-.0031841	.0205701
cos5	-.0176192	.0063902	-2.76	0.006	-.030197	-.0050415
dlr_mean	-.1777565	.0201238	-8.83	0.000	-.217366	-.138147
dlr_1	-.1245676	.012495	-9.97	0.000	-.1491614	-.0999739
dlr_sin1	-.0416406	.0181534	-2.29	0.023	-.0773719	-.0059094
dlr_cos1	.0168526	.0298889	0.56	0.573	-.0419775	.0756827
dlt_mean	1.154087	.1554353	7.42	0.000	.8481447	1.460029
dlt_sin1	.545113	.2044209	2.67	0.008	.1427527	.9474734
dlt_cos1	.6394431	.2673314	2.39	0.017	.1132565	1.16563
_cons	6.028086	.0066468	906.91	0.000	6.015003	6.041169
sigma_u	.75673958					
sigma_e	.45949412					
rho	.73062307	(fraction of variance due to u_i)				

Diagnostics

It is good practice to perform model diagnostics when applying standard regression methods. While the same sentiment applies in the case of panel models, many of the usual diagnostic measures are not directly applicable to panel data.[38] Consequently, the diagnostic measures available from the software's standard OLS regression procedure will be used to identify potential model fit issues. Since the statistical basis of the tests used may be compromised by the use of OLS, it is the relative size rather

[38] The STATA statistical software was used for the analysis. See www.stata.com.

than the statistical significance of the diagnostic measures that will guide the diagnostic analyses.[39, 40] Robust regression will also be used for this purpose.[41]

Three diagnostic measures are used to evaluate the fit of the regression models. Leverage identifies observations with values on the set of predictor variables that are extreme relative to the group means. The larger the leverage value, the larger the influence of a given observation and the greater its influence on the estimated regression coefficients. This means the estimated model estimates are likely to be sensitive to the inclusion or exclusion of the influential observation. This is highly undesirable.

The externally standardized residual measures the relative size of model residuals—the difference between the actual and the estimated values of the dependent variable. The larger the value, the greater the influence of an individual observation.[42] Values larger than 3.5 indicate potentially high influence observations.

The individual weights calculated from robust regression will serve as the third diagnostic criterion. The smaller this value, the greater the influence of individual observations. While exact thresholds are not available in the literature, experience suggests that values smaller than 0.20 indicates potentially extreme observations.

Commercial Accounts

Table 4 summarizes the testing for commercial accounts. The first column repeats the values shown earlier in Table 1.[43] Columns 2 through 4 contain statistics to be used in identifying and assessing

Table 4: Commercial Accounts: Regression Diagnostics

Statistic	Base model	r=3.5 w=0.15	Change	r=3.0 w=0.20	Change	r=2.5 w=0.25	Change
Program Effect	-0.2437*	-0.2471*	1.40%	-0.2529*	3.78%	-0.2417*	-0.82%
Standard Error	0.1012	0.0987	-2.47%	0.098	-3.16%	0.0986	-2.57%
Sample Size	1,734	1,650	-3.98%	1,646	-5.07%	1,640	-5.42%

*p<0.05 **p<0.01 ***p<0.001 r=studentized threshold w=robust weight threshold

Note: change is measured relative to the base model.

the importance of potentially influential observations. The thresholds used are shown in the column labels with "r" representing the value of the standardized Student statistic and "w" indicating the threshold for the robust weight.[44] The matter of interest here is how sensitive the estimated program effect and its standard error are to excluding potentially influential observations under successively

[39] Fizmaurice, Garrent M., Laird, Nan M. and Ware, James H. *Applied Longitudinal Analysis*, 2nd edition, p. 266. Hoboken, New Jersey, John Wiley and Sons, 2011, describe a residuals transformation that may restore the statistical foundations of these tests. The time available, however, did not permit programming and evaluating their procedure.

[40] An influential observation is one that has a disproportionate influence on model fit.

[41] Robust regression employs an estimated weight matrix and generalized least squares to correct for heteroskedasticity and autocorrelation in the residuals.

[42] Conventionally, values larger than $2 * p/n$ are considered influential, where p is the number of predictors (independent variables) and n is the size of the sample.

[43] Because of their incidental importance to the matter at hand, the estimated coefficients for the weather and climate variables are not reported in these tables.[43]

[44] The value of the leverage statistics is kept at 2*p/n throughout.

more stringent thresholds. The relative number of cases deleted at each step and the sensitivity of model estimates are shown in the "Change" columns of the table.

As can be seen in Table 4, the value of the program effect changes only slightly when filtering the data by the three sets of thresholds. This would seem to suggest that the estimate is stable in the face of potentially influential observations, the difference between the base case and that with the most stringent exclusion conditions (r=2.5 w=0.25) being relatively small.

The results of the diagnostic analysis indicate that the program effect estimate in Table 2 (and Table 4) is robust and *good* in the statistical sense of the word.[45] The major decision, then, is which estimate to use to represent water savings attributable to the turf replacement program. Because it remained so stable during diagnostic testing, and because it is based on the largest number of observations, the base model estimate is proposed for this purpose.

Residential Accounts

Table 5 shows the results of diagnostic testing for the residential model. These results are very similar

Table 5: Residential Accounts: Regression Diagnostics

Statistic	Base model	r=3.5 w=0.15	Change	r=3.0 w=0.20	Change	r=2.5 w=0.25	Change
Program Effect	-0.1843***	-0.1851***	0.43%	-0.1850***	0.38%	-0.1850***	0.38%
Standard Error	0.0303	0.0304	0.33%	0.0305	0.66%	0.0305	0.66%
Sample Size	10,632	10,609	-0.22%	10,596	-0.34%	10,596	-0.34%

*p<0.05 **p<0.01 ***p<0.001 r=studentized threshold w=robust weight threshold

Note: change is measured relative to the base model.

to those obtained for the commercial model, again suggesting that the estimated results in Table 3 (and Table 5) for the program variable are both robust and good.

Summary and Qualifications

Generalizing the savings estimates discussed above to the full set of sites funded by the program, the turf replacement program is expected to save a total of 2,745 acre-feet of new water over the assumed 10-year life of the program. These and other program statistics are summarized in Table 6.

[45] These results do not address questions about the generalizable of these estimates. Additional data, not currently available, are needed to make that assessment.

Table 6: Summary Program Statistics

Item	Units	Commercial Sites	Residential Sites	All Sites
Estimated Savings for Sample Participants				
Pre-Intervention Use per sampled site (gpd/site)	gpd/site	4071	631	
Estimated percentage reduction in use due to program participation	%	23.9%	18.2%	
Water savings per site per day (gpd)	gpd/site	973.8	115.0	
Water savings per site per year (AFY)	AFY/site	1.09	0.13	
Number of sites in sample	sites	30	287	
Program life (years)	years	10	10	
Lifetime savings per sampled site (AF)	AF/site	10.9	1.3	
Total lifetime savings (AF), all sampled sites	AF	327	370	697
Estimated Savings for All Participants				
Total turf removed (square feet), all sampled sites	sq. ft.	221,399	437,733	659,132
Total turf removed (squre feet), all participants	sq. ft.	1,081,031	1,357,994	2,439,025
Turf of sampled sites as percent of total turf removed	%	20.5%	32.2%	27.0%
Total lifetime savings (AF), all participants (10 years)	AF	1,598	1,147	2,745

It is important to restate several caveats about the generalizability of the results obtained here. Not all participating sites provided data for the analysis and customers participating in the program may have been different from the typical customer. In either case, caution is needed in extrapolating the results discussed here to the more general population of water utility customer.

Similar caution is necessary when attempting to extrapolate to program participates for whom no data was available. If average water savings for this later group were markedly different, the estimated program totals in Table 6 could be incorrect.

During the course of the analysis it was noted that water use actually increased at some sites after the installation of water efficient landscapes. It is not clear if this reflects increased inefficiency or the need to use greater water in the short-run as new plants establish themselves. Unfortunately, the post-installation billing data for the sites involved was usually too short to explore this issue in any depth. It is an important question, though, and one that could be addressed as additional post-program billing data becomes available.

Several other questions could be useful explored with more post-installation data. First and foremost, additional work should be done to confirm and extend the estimates discussed in this paper. Second, the persistence of water savings is an important question that can only be addressed with additional data. The issue of savings persistence matters because total water conserved and program cost-effectiveness directly depends on the actual life of program savings.

As a final matter, the cost-effectiveness of the program cannot be assessed at this time due to a lack of necessary program cost information. Collecting these data in an appropriate form should be emphasized as a part of future grant funding so that the relative effectiveness of the program can be compared with other water use efficiency measures.