BEC Berkeley Economic Consulting

Memorandum

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To: CUWA

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RE: Technical Memorandum on Recommended Methodology for Estimating Employment Impacts of Water Related Infrastructure Projects

Executive Summary

At CUWA's request, we have: 1) reviewed economic models capable of estimating employment impacts associated with large scale infrastructure projects and recommended the IMPLAN model for use in such efforts; and 2) produced employment multipliers[1] for eight California regions corresponding primarily to the ten hydrologic regions in California as defined by the U.S Geological Survey[2] and U.S. Census consolidated statistical area (CSA) boundaries. These multipliers may be used to prepare preliminary employment impact estimates for proposed water projects.

We recommend the IMPLAN model for several reasons: 1) it is flexible and can be used to model impacts at the county, regional, or state level; 2) it is relatively inexpensive – the state model including all counties costs about $2,265; and 3) it is widely accepted and frequently used by many federal and California state agencies. The model was originally developed for the U.S. Forest Service.

Using IMPLAN, we calculated employment multipliers for the eight regions. These rates are summarized in the following table:

Region	**Employment Impact per $1B in Water-related Infrastructure Investment**	
	Local (in project region)	**Statewide (including project region)**
Central Coast	10,007	12,205
Lake Lahontan	8,547	10,361
LA South Coast	12,979	13,208
North Coast	10,499	12,548
Sacramento River	11,816	13,132
San Joaquin River	10,640	13,140
SF Bay Area	10,231	11,128
Tulare Lake	8,992	11,681

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[1] Each multiplier gives the number of jobs created per $1 billion in infrastructure investment. A single job may be full or part time. Estimates of full time equivalents (FTEs) can be made based on conversion tables available from IMPLAN.

[2] See http://water.usgs.gov/GIS/huc.html.

These multipliers can be used to estimate projected project-related employment impacts. For example, for a $5 billion water infrastructure project in the Central Coast region, the corresponding estimate of job creation would be 5*10,007 = 50,035 jobs in the Central Coast region and 5*12,205 = 61,025 jobs in the entire state of California. These jobs are a combination of full and part time positions.

Note that these ratios provide an initial estimate of the jobs created by the infrastructure investment in each region. They represent jobs created during construction. As such, they are not permanent. Values vary because of the degree of economic self-sufficiency in each region, which is determined by level of development, region size, and proximity to state borders. Further, while using these values provides a first estimate of employment impacts, they are no substitute for detailed impact analysis for specific projects.

Finally, there are three limitations that should be recognized. First, the ratios presented here provide estimates of jobs at the local and state level – not at the national level. Some jobs will undoubtedly be created outside California, but the number can not be estimated reliably using the state level IMPLAN model. Access to all 50 state models would be required to make this estimate. Second, these ratios will change over time as the buying power of the dollar varies and as productivity changes. Consequently, the ratios should be updated periodically. IMPLAN data files are updated every year, but annual updates may not be necessary if inflation and productivity trends are relatively flat. Third, the ratios are not adjusted to account for increased taxes that may be required to finance the projects under study. Increased taxes will reduce consumer spending and will to a degree offset construction job increases.

I. Introduction and Overview

Employment impacts of major government sponsored capital investments are generally of great interest to policy makers. This is especially the case when unemployment rates are high or projects are expensive. Consequently, economists have developed several methodologies to estimate these employment impacts. They fall into three categories – input-output models (IO), integrated input-output econometric models (IOE), and computable general equilibrium models (CGE). Each has its advantages and disadvantages. No model has been endorsed as the most appropriate. Rather, model choice is determined by a number of factors, including the degree of geographic complexity (city v. county, v. state, v. country), nature of the project (i.e., whether it involves capital spending or taxation), data availability, time availability, and cost. After careful consideration of these factors, we recommend that an input-output model be used to estimate employment impacts of water-related infrastructure projects. More specifically, we recommend the IMPLAN model, a commercially available input-output model. This is explained further below.

The remainder of this memo is organized as follows. Section II reviews the available methodologies. Section III reviews several recent national and state-level studies presenting employment impacts from government-funded capital projects. Section IV presents the basis for our recommendation. Section V provides an example of estimating employment impacts from a hypothetical dam project applying the IMPLAN model. Section VI presents regional employment multipliers based on IMPLAN estimates for eight regions covering the state of California and demonstrates how CUWA member agencies can use these multipliers to estimate job creation associated with water-related infrastructure programs in their region. Section VII provides brief biographies of the memo authors. Section VIII provides references.

II. Review of Available Methodologies

Economists have developed several modeling approaches to measure employment and other economic impacts of capital projects and government policies and regulations. There are three primary models – the input-output model, the input-output econometric model, and the computable general equilibrium model. A fourth approach referred to as an ad hoc approach has been used at the national level. Each is discussed below.

a. Input-Output Models

The input-output model was first specified in 1941 by Leontief for which he won the Nobel Prize in economics.[3] The core of this model is a matrix of average input (purchase) coefficients that describe the mix of goods, services and labor that are required to produce a unit of output. These coefficients represent what economists refer to as production functions. The dimensions of the matrix are determined by how many industry sectors are accounted for and whether government and household sectors are included. The basic model can be expressed in a straightforward equation: $X= (I-A)^{-1} *dY$ where (I-A) is the inverse of the Leontief matrix, dY is a change in final demand and X is output.

So-called employment and output multipliers can be derived from this equation. These multipliers describe the change in employment or output for a given change in final demand. Models are referred to as Type I and Type II depending on whether they include a household sector. Type II models, which incorporate the household sector provide multipliers that capture direct, indirect, and induced impacts. Direct impacts refer to the direct purchases of goods, services, energy, and labor to meet a final demand. Indirect impacts refer to the purchases of goods, services, energy, and labor required to produce the directly demanded

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[3] In 1941 Leontief published his first book on input-output economics under the title *The Structure of the American Economy, 1919-1929*.

factors. Induced impacts refer to the purchases of goods, services, energy, and labor to meet the demands of households who see increased income as a consequence of additional employment. IMPLAN is the most widely used model based on this IO structure. IMPLAN has been used by many California government agencies.[4] IO based multipliers are also available from the U.S. Department of Commerce RIMS (regional impact multiplier system) at the county and state level.

The IMPLAN model has several advantages and several disadvantages. First consider the advantages. This model is widely recognized and accepted in the academic literature and by government agencies. The input-model is a relatively simple model and as a result is transparent. Modification of the model is straightforward. Purchase coefficients are frequently updated. Second, consider the disadvantages. The model is static with respect to production functions, price changes, and inter-county/inter-state trade. Thus, no changes occur in the mix of goods and services that are required to produce output even if demand and prices would actually lead to changes in the way products are produced. Additionally, although these models can account for inter-county and inter-state trade, the trade patterns are fixed. Thus, shifts in competitive advantage are not captured. However, as discussed below, some of these limitations have been overcome by combining input-output with econometric models.[5]

As previously mentioned, many analysts rely on multipliers extracted from the Bureau of Economic Analysis' (BEA's) RIMS II IO model rather than purchasing an entire software package with embedded multipliers such as IMPLAN. There are, however, several advantages to using IMPLAN over RIMS II, the foremost being user-friendliness. IMPLAN and REMI are computer software packages whereas RIMS II is a spreadsheet-based model where the user is responsible for setting up the multiplier worksheet. This means that each time a new variable is added, the worksheet must physically be changed. In addition, users of the RIMS II methodology can purchase either Type I or Type II multipliers from the BEA, but no mechanism for breaking up impacts into direct, indirect and induced effects is readily available. Another disadvantage of the RIMS II model is its lack of flexibility. In contrast to IMPLAN, RIMS II does not allow for the creation of custom multipliers based on specific features of a given economy. Also, while users of the RIMS II methodology can order multipliers for any region consisting of one or more contiguous counties, multipliers for each county or state within the region are not provided. Thus, if a user wants to analyze more than one region or different combinations from the same set of counties, then he or she must either buy the multipliers for each different region separately, or purchase all the component county multipliers he or she is interested in and aggregate the data to larger geographical units manually. The IMPLAN software package, on the other

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[4] IMPLAN's client list includes the California Department of Finance, the California Department of Transportation, the California Department of Water Resources and the California State Water Resources Control Board. At the federal level, IMPLAN has been used by the US Army Corps of Engineers, the Bureau of Economic Analysis, the Bureau of Land Management and the Bureau of Reclamation.

[5] William H. Miernyk (1965), *The Elements of Input-Output Analysis,* New York: Random House.

hand, allows for the easy aggregation and disaggregation of geographic units (provided that the user has purchased the full set). A final disadvantage of the RIMS II methodology is its lack of regional purchase coefficients (RPCs). In order to regionalize national technical coefficients, the BEA employs the location quotient (LQ) technique, which assumes that local demand is satisfied first and that the remainder of an industry's output is exports. In contrast to IMPLAN's RPC technique, the LQ method does not allow for cross-hauling, i.e. the simultaneous importation and exportation of a particular good. Rather, a good must either be exclusively exported or exclusively imported. If cross-hauling exists, then the LQ method produces overstated multipliers, all other things equal.

b. Input-Output Econometric Models

Economists have attempted to address the deficiencies of input-output models by using econometric models to add dynamic responses to price and technology changes. The most well known and widely used model of this type is called REMI.

The REMI model is a dynamic forecasting and impact analysis tool that incorporates aspects of several modeling approaches, including econometric, input-output, and computable general equilibrium modeling. It contains detailed industries and the complete inter-industry relationships found in IO models while allowing firms and individuals to change their behavior in response to changing economic conditions over time. It also captures the spatial dimension of the economy by incorporating the benefits to productivity and competitiveness arising from the concentration of economic activity and the clustering of industries. The model consists of a system of equations and response estimations with a structure defined by five major blocks: (1) Output, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Wages, Prices, and Costs, and (5) Market Shares. REMI models have been used to study a wide range of topics such as economic development, the environment, energy, transportation, and taxation, forecasting and planning by clients such as the City of San Francisco and the Los Angeles County Metropolitan Transportation Authority.

REMI's main attraction is that it attempts to incorporate all of the strongest elements of a variety of methodologies: it is, at its core, an IO model, with some econometric-based adjustments. It is also a dynamic model, that is, it can demonstrate economic changes over time, an option not readily available in IMPLAN. Despite its widespread use and acceptance, REMI also has some serious disadvantages. For one, it is what economists and engineers refer to as a "black box" – it consists of thousands of simultaneous equations that make it difficult to discern what the model is actually doing. It is far less transparent than IMPLAN. In addition, it has limited user access and is costlier than other software packages.

c. Computable General Equilibrium Models

The CGE model is a general equilibrium optimization model that implements the neoclassical framework of an economy. It is a 'general equilibrium' model in that it depicts an economy-wide circular flow of supplies, demands, prices and incomes all of which are determined simultaneously within the model subject to the constraint that for each sector, supply equals demand at market-clearing prices; 'computable' in that it solves empirically for all internally-derived variables; an 'optimization' model in that it provides the optimal solution mix of internally-derived variables in response to an external shock. Embedded in the model are utility-maximizing consumers, profit-maximizing producers, international trade, and a government that sets taxes and exchange rates in addition to providing services and subsidies. CGE models also often stratify household types according to occupation or income level, and model a two-step distribution of income – first to institutions, then to households – to allow for the inclusion of policy instruments and enterprise decisions about retained earnings.[6] The wide scope and internal complexity of the model make it especially well-suited for evaluating large investment projects that are expected to have broad effects across many sectors.

A prominent example of a CGE model is the Environmental Dynamic Revenue Assessment Model (E-DRAM), which was recently employed in the economic evaluation of California's Climate Change Draft Scoping Plan Pursuant to AB32. Developed by a University of California, Berkeley professor, E-DRAM is a static computable general equilibrium model of the California economy. It draws from data provided by the BEA, the California Employment Development Department, the California Energy Balances database, the Consumer Expenditure Survey for the Western US, and state records. Model parameters such as elasticities of substitution are adapted mostly from the published literature. E-DRAM constructs a future-year reference case from existing forecasts of income, population, and energy use. The model solves for the market-clearing commodity and factor prices and levels of industry activity and household income, given aggregate factor endowments, households' consumption technologies and industries' transformation technologies. It derives a price for the output of each of 120 industrial sectors, the wage and the rental rate. With respect to the Climate Change Scoping Plan, E-DRAM was used to analyze changes in statewide output, income, and employment, changes in income for different socioeconomic groups and the effects of redistributing allowance revenue.

CGE models have the advantage of being able to accommodate a wide range of specifications such as short-term capacity constraints. The CGE model has the foundations of an IO model but can be either comparative-static or dynamic with respect to price and time. A main benefit of the model is that it explicitly determines full price response on the supply side as well as the demand side. This is because unlike the IO model, it contains explicit supply constraints, and therefore achieves equilibrium through quantities *and* prices rather than just accommodating demand-driven shocks through changes in supply and demand quantities, holding prices fixed. However, such models can be very expensive and offer limited user access. Implementation of the CGE model requires specification of a large number of parameters generally not available to the user, hence forcing the user to employ best guess estimates. The model is at times overwhelmingly complex, particularly for the larger-scale types of projects it is best-suited for: CGE models are generally highly non-linear, necessitating the use of complex solution algorithms or numerical solution techniques when solving for all internally-derived variables in the system of simultaneous equations.

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[6] Peter Berck, Sherman Robinson and George Goldman (July 1990), "The Use of Computable General Equilibrium Models to Assess Water Policies," Working Paper No. 545, UC Berkeley Department of Agricultural and Resource Economics, pp. 2-3.

d. Ad Hoc Approach

Some economists have followed an ad hoc approach in estimating the labor impact of new policies and investments. This entails combining off-the-shelf multipliers and elasticities (measures of changes in demand output resulting from changes in product or input prices) with historical data to establish average multipliers and ‘rules of thumb’ that dictate how investments will translate into employment and output, and injecting fresh funding amounts into this rather simplistic picture of the economy. This approach is perhaps more straightforward than modeling all the cost and price structures and interdependencies in an economy. One advantage of this approach is that it relieves the user of having to purchase any of the expensive software packages mentioned above. However, this approach cannot be readily applied at the state or county level. It is not able to account for interactions between counties, regions, and states. It also does not account for differences in industry production functions across these geographic areas.

Table 1: Summary of Approaches to Employment Impact Estimation

Model Name	Model Type	Advantages	Disadvantages
IMPLAN	Input-Output	• Transparent structure • User-friendly • Frequently updated • Extreme flexibility • Easy regional aggregation/disaggregation • Relatively inexpensive	• Static model • Fixed trade patterns
RIMS II	Input-Output	• Inexpensive	• Static model • Lack of flexibility • Not user-friendly • Does not allow for cross-hauling of goods
REMI	Input-Output Econometric	• Dynamic model • Spatial dimension	• Not transparent • Not as user-friendly • Expensive
Computable General Equilibrium	Computable General Equilibrium	• Extreme flexibility • Supply-side as well as demand-side response • Dynamic or Static	• Expensive • Not transparent • Not user-friendly • Large implementation requirements
Ad-hoc	Ad-hoc	• Inexpensive • Straight-forward	• Difficult to construct multi-regional models • Difficult regional aggregation/disaggregation

III. Review of Recent Studies

Four recent studies regarding the impact of large scale government infrastructure spending on the U.S. economy in general and employment in particular produced frequently cited rates of employment creation per billion dollars of investment. The methodologies relied on each of these studies is described below.

a. Milken Institute

The Milken Institute's January 2010 paper entitled "Jobs for America: Investments and policies for economic growth and competitiveness" analyzes proposed investments totaling $425.6 billion across 10 projects over three years. The selected projects are high-impact investments in both high-growth and traditional industries that provide high-paying jobs. All 10 projects fall under the broad themes of public safety, competitive transportation, and energy security.[7] These projects are projected to generate $1.4 trillion in total output (including ripple effects), creating 3.4 million jobs directly and 10.7 million jobs in total (including ripple effects). This translates to, a direct employment impact of about 7,989 jobs and a total employment impact of about 25,141 jobs, per $1 billion in infrastructure investment. The jobs created are mostly construction and R&D related. Since the impacts will likely be spread across a three-year period, it is important to note that the average annual increase would be 3.5 million jobs and $468 billion in output.[8]

The authors use the BEA's RIMS II employment and earnings final demand multipliers to compute the economic and employment impact of proposed investments. In determining which industry multipliers to use, they examine program descriptions provided by the federal government and trade groups for the 10 projects to determine the primary industry a given project relies on. For example, because highway expansion mainly involves construction, the BEA final demand multiplier for construction is used to estimate the employment and earnings effects of investment in that project. They then determine proposed investment funding amounts for each project based on recent funding allocation and industry knowledge.[9] A key assumption is that any new funding will follow the same allocation priorities as recently passed legislation.[10] These proposed investment funding amounts are then inputted into RIMS II as the 'initial change in final demand' required in generating estimates of direct and indirect employment and earnings effects when using the final demand multipliers.

b. Political Economy Research Institute (UMass Amherst)

In a January 2009 study entitled "How Infrastructure Investments Support the U.S. Economy: Employment, Productivity, Growth," published by the University of Massachusetts Amherst's Political Economy Research Institute (PERI), the authors estimate the labor impact of two hypothetical infrastructure investment scenarios for the year 2007. In the *Baseline scenario*, $87 billion per year in new infrastructure investment is injected into the US economy over the next 5 years. $54 billion would come from the public sector and $33 billion would be private

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[7] Ross DeVol and Perry Wong (January 2010), *Jobs for America: Investments and policies for economic growth and competitiveness*, Milken Institute, http://www.milkeninstitute.org/jobsforamerica/, p. 5.

[8] *Ibid.,* p. 6.

[9] Sources include congressional reports, industry analysts, academia, the National Association of Manufacturers (NAM), and the Milken Institute. (*Ibid.*, p. 40)

[10] *Ibid.,* p. 42.

investment. In the *High-end scenario*, there would be $148 billion in new infrastructure investment per year, with $93 billion coming from the public sector and $55 billion coming from the private sector.[11] The categories of infrastructure investment considered in this paper break down into four broad categories: transportation, public school buildings, water infrastructure, and energy. Use of the input-output model requires assigning each category of infrastructure investment to a particular industrial category specified in IMPLAN. In cases where the authors model investment in newer industries, such as solar and wind energy, that are not accurately described by any of IMPLAN's pre-existing industrial categories, the authors construct synthetic 'industries' by combining components of industries that are already included in the government accounts. Within each synthetic industry, the authors assign relative weights to each of the component industries in terms of their contributions based on profiles drawn from industry sources.[12] In general, the authors estimate that annually, each $1 billion in infrastructure investment will generate 12,988 jobs in the baseline scenario and 12,729 jobs in the high-end scenario if only direct and indirect effects are considered and 18,104 jobs in the baseline scenario and 17,791 jobs in the high end scenario if induced effects are accounted for.[13]

The authors use a straight-forward employment model based on US input-output accounts in order to estimate direct and indirect job creation. The input-output tables are compiled by the BEA and updated between the quinquennial census years. The total requirements table (or Leontief inverse matrix) gives the output multiplier, which shows how an increase in final demand for a particular industry's product will lead to increased output in that industry and all related industries. Obtaining the employment multiplier from the output multiplier requires multiplying the former by the employment/output ratio. The authors assume that employment/output ratios remain fixed in the short-run, so they can presumably obtain this data from the BEA IO tables. They use IMPLAN Pro (Version 2.0), which is calibrated to the BEA IO tables, to calculate the employment multipliers in the manner described above at the 500 sector level of disaggregation. Their input-output model is calibrated using 2006 data.[14]

The IO model can also be used to calculate induced employment effects. It assumes that there exists a fixed consumption function; hence when total compensation goes up, it is accompanied by a proportionate increase in household consumption (a category of final demand). The authors maintain that the IO model, which endogenizes the household sector, tends to create implausibly large multiplier effects.[15] They accordingly elect to calculate the induced labor impacts separately from direct and indirect employment effects.

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[11] James Heintz, Robert Pollin, and Heidi Garrett-Peltier (January 2009), *How Infrastructure Investments Support the U.S. Economy: Employment, Productivity and Growth,* Political Economy Research Institute, http://www.peri.umass.edu/236/hash/efc9f7456a/publication/333/, p. 2.

[12] *Ibid.,* p. 23.

[13] *Ibid.,* pp. 30-31.

[14] *Ibid.,* p. 49.

[15] This is partly because the propensity to consume out of employee compensation (or value-added) implicit in the endogenous household input-output model is large. (*Ibid.,* p. 52)

The authors proceed with the calculation of induced employment effects by first estimating the consumption function. Rather than relying on the consumption function implicit in the IO accounts, the authors estimate the relationship between real gross employee compensation and real personal income expenditures econometrically using a dynamic empirical model. They then estimate the feedback effects, or the impact of the increase in household consumption on employee compensation,[16] using their IMPLAN calibrated IO model and restricting their estimates to direct and indirect effects only. The authors then integrate their estimates of the consumption function and feedback effects into their basic IO model to calculate induced effects. First, they calculate the total impact on household consumption of a $1 increase in employee compensation. They find this to be $0.8232 in induced household consumption for each additional dollar in employee compensation. Multiplying this by the 11.2 additional jobs per $1 million increase in final household consumption estimate generated from the basic IO model yields a total dynamic induced effect of 9.2 jobs for each $1 million in employment income generated through direct and indirect effects.

c. California Infrastructure Coalition (CIC)

In the wake of the release of the Schwarzenegger Administration's May budget revisions for fiscal year 2004-2005, which would have overturned the January budget proposal by restoring California's transportation funding rather than diverting more than $4 billion from transportation projects, the California Infrastructure Coalition commissioned the April 2004 study, "Economic Impact of Funding California's Transportation Infrastructure." Through the CIC's relationship with the SAER Group, the Sacramento Regional Research Institute (SRRI) was commissioned to estimate the positive impacts resulting from the restoration of transportation funding in California, or more specifically, the provision of $383 million to the Traffic Congestion Relief Fund (TCRP), which would then pass on $184 million to the State Highway Account and $36 million to the Public Transportation Account. Using IMPLAN 2.0 with the 2001 data set and coefficients based on Legislative Analyst's Office (LAO), SAER Group, and TCRP information, SSRI finds that every $1 billion of transportation spending in California creates approximately 18,000 new jobs in the state.[17]

SSRI's analysis is based on the assumption that of the transportation dollars approved in the budget, 50.3 percent will be spent on roadway construction projects, 47.8 percent will be spent on transit construction projects, and 1.8 percent will be spent on procurement activities. Right of Way costs were removed prior to the IO analysis. Hence, at the $1 billion dollar level, only $864 million would actually go towards transportation projects: $16 million to

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[16] Additional household consumption increases the vector of final demand in the I-O model and, through direct and indirect employment effects, raises employee compensation. (*Ibid.*, p. 53)

[17] *Economic Impact of Funding California's Transportation Infrastructure* (2004), California Infrastructure Coalition, http://www.cbrt.org/other_documents/cic_transportation_study.pdf, pp. 1-2.

procurement activities, $435 to roadway construction, and $413 to transit construction.[18] Spending on roadway construction and transit construction is associated with IMPLAN's Highway, Street, Bridge, and Tunnel Construction sector and Other New Construction sector, respectively.[19] SSRI chooses to place procurement funds in IMPLAN's Wholesale Trade Sector based on a review of the statewide economic relationships of the State and local government passenger transit sector and industry classification descriptions. In this manner, the $1 billion transportation infrastructure investment scenario yields a $1.7 billion increase in output and an employment impact of 12,793 jobs if only direct and indirect effects are taken into account and 17,866 jobs when induced effects are included.[20]

d. Romer and Bernstein

In their January 2009 study entitled "The Job Impact of the American Recovery and Reinvestment Plan," Christina Romer and Jared Bernstein undertake a preliminary analysis of the jobs effects of some of the prototypical recovery packages that were under discussion at the time.[21] They assume a package just slightly over $775 billion, of which about $44.4 billion[22] would go towards infrastructure investment. Key provisions of the package include substantial investments in infrastructure, education, health, and energy, expansion of social welfare programs, state fiscal relief, business investment incentives, and a middle class tax cut. Their finding is that the recovery package as a whole will generate about 3,675,000 jobs by the end of 2010.

Romer and Bernstein employ an ad-hoc approach to estimating the economic impacts of the above stimulus plan. In estimating the output effects of the package, they average the multipliers for increases in government spending and tax cuts from Macroeconomic Advisors, a leading private forecasting firm, and the Federal Reserve's FRB/US model. They then translate the effect on GDP into job creation using the rule of thumb that a 1 percent increase in GDP corresponds to an increase in employment of approximately 1 million jobs, or about three-quarters of a percent. They maintain that this rule of thumb is fairly conservative and has been the rough correspondence over history. For core

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[18] *Ibid.*, pp. 3-4.

[19] Note that these IMPLAN sectors no longer exist in the most current version of IMPLAN. In IMPLAN version 3, these two construction sectors now both fall under IMPLAN sector code 36, or Construction of other new nonresidential structures.

[20] *Ibid.*, p. 5.

[21] Christina Romer and Jared Bernstein (January 9, 2009), *The Job Impact of the American Recovery and Reinvestment Plan*, http://www.illinoisworknet.com/NR/rdonlyres/6A8FF039-BEA1-47DC-A509-A781D1215B65/0/2BidenReportARRAJobImpact.pdf.

[22] For core spending programs, Romer and Bernstein assume the direct output effects move one-for-one with the spending increase. (*Ibid.*, p. 5) Using their rule of thumb, (377,700 jobs)*[(.01*$11,770 billion change in GDP)/1 million jobs]*($1 in infrastructure investment/$1 change in GDP) = 377,000*117.7 = $44.37 billion in infrastructure investment. Note that we multiply $11,770 billion (real GDP without the stimulus) by .01 to obtain a dollar value for 1% of real GDP, which by Romer and Bernstein's rule of thumb corresponds to 1 million new jobs.

spending programs, the assumption is that the direct output effects move one-for-one with the spending increase. Their results indicate that the employment impact of the infrastructure investment component of the recovery package in 2010Q4 will amount to a direct effect of 236,000 jobs and an indirect effect of 142,000 jobs, for a total job creation of 377,000. They define the indirect effects as "those coming from the fact that the newly employed workers spend more and this stimulates other industries."[23] Hence it is safe to conclude that their categorization of 'indirect effects' includes induced effects.

Table 2 presents the results of these various studies in terms of methodology and job creation per billion dollars in infrastructure spending. When considering the latter ratio, it is important to consider the effects of price inflation and place the results in constant dollar terms. The Milken Institute study uses RIMS II multipliers that are based on the 1997 national IO table. The PERI and CIC studies both utilize IMPLAN 2.0 that is based on 2001 data. The IMPLAN 3.0 model uses input-output data from 2008. Thus, we choose 2008 as the comparison year, and use the GDP Implicit Price Deflator for Nonresidential Fixed Investment – Structures to put infrastructure spending into constant 2008 dollars.

Table 2: Summary of Literature Review

Study	Model/Methodology	Job Creation (per $1B infrastructure spending – various years)	Job Creation (per $1B infrastructure spending – 2008 dollars)
Milken Institute	RIMS II	25,141	12,952
Political Economy Research Institute	IMPLAN (version 2.0)	17,791 – 18,104	10,813 – 11,103
California Infrastructure Coalition	IMPLAN (version 2.0)	17,866	10,860
Romer and Bernstein	Ad-hoc approach	8,500[24]	8,500
CUWA	IMPLAN (version 3.0)	10,361 – 13,208	10,361 – 13,208

IV. Methodology Recommendation

Based on our review of the available models and recent studies we recommend that IMPLAN be used to estimate the employment impact of water related infrastructure projects. As discussed above, IMPLAN is a widely recognized and applied input-output model. Several of the recent studies of infrastructure investment reviewed above have relied on it in whole or in part. Consequently, relying on IMPLAN makes comparisons to other studies more feasible by

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[23] *Ibid.*

[24] The $44.37 billion infrastructure component of the stimulus package considered in the study is estimated to create about 377,000 jobs.

eliminating a potential central difference. In addition it provides a reasonably transparent structure making it easier to understand the reasons behind resulting estimates. Its structure also provides the opportunity to overcome its static limitation, at least in part by incorporating econometric based adjustments.

IMPLAN can also be aggregated at county, multiple county and state level aggregation levels. It has a detailed industry structure and has been recently updated. Finally, it can be obtained and run at relatively low cost. Prices range from $265 each for individual county data files to $2,265 for the California state data package to $35,265 for the national package. Although IMPLAN has been developed to be user-friendly and can be implemented without extensive training in economics, some level of training is necessary in order to understand the workings of the model and to interpret results. IMPLAN offers tutorials and workshops to help users apply the model appropriately. In addition, IMPLAN data files are updated annually. Regardless of which model an agency chooses to rely on, updates will be necessary as economic conditions in California will change over time. Finally, while it is possible to use two or models in order to test for some congruence of findings, such an effort would be very time consuming and costly. Since IMPLAN is widely recognized and used, the results are not likely to be questioned with respect to the underlying model and data. Comments are more likely to address assumption regarding model inputs and project descriptions.

V. Example Application

To better understand how IMPLAN can be used to estimate employment impacts of a water related project, we have prepared the following example using a prototype project. This example illustrates both the different levels of regionalization that IMPLAN is capable of modeling and the different types of output the program is capable of producing.

The example project considered here is a multi-purpose[25] reservoir formed by an earth-and-rock fill dam, as the vast majority of dams that have been constructed in California over the past 30 years have either been earth, rock, or earth-and-rock fill.[26] For simplicity we will assume that the dam serves as both a surface water storage and flood control mechanism, but that it does not generate electricity. The project entails the construction of an earth-and-rock fill dam, sediment basins (to capture storm runoff during construction), and water supply structures (which include raw water intake structure and transmission lines and spillway). We do not consider land acquisition or public recreational facilities. The capacity of the completed reservoir is 150,000 acre-feet, with a probable maximum flood peak inflow of about 180,000 cubic feet per second. For illustrative purposes, we will assume that the project takes place in San Diego County. The results would vary if we assumed the project takes place elsewhere in the state.

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[25] The State water package contains provisions for both surface water storage and flood control projects.

[26] http://www.water.ca.gov/damsafety/damlisting/index.cfm

Using the Seven Oaks Dam as a reference point, for purposes of this example we assume that a project of this capacity would cost about $300 million to construct in 2008 dollars.[27] This construction capital outlay is further broken down into $162 million for dam and sediment basin construction and $138 million for the construction of water supply structures. We use IMPLAN sector code 36 (which corresponds to "Construction of other new nonresidential structures") when modeling both types of construction.[28] In addition, these facilities will incur an incremental $2.335 million in operations and maintenance costs on an annual basis over the life of the facility: $660,000 for the continuous maintenance needs of the dam and sediment basins (including mowing and brush control as well as repair of pipes and structures) and $1,675,000 for the maintenance needs that accrue over the life span of the raw water intake structure and transmission lines.[29] We model all operations and maintenance costs using IMPLAN sector code 39 for "Maintenance and repair construction of nonresidential structures." All project costs are presented in the Table 3.

It is important to note that the employment impacts we present are sensitive to the construction pattern of the project. For example, if the construction phase of the project only lasts one year, then the entire $3 million construction expenditure would occur within the first year of the project, with project spending dropping to the level of the annual O&M costs in all subsequent years. The employment impacts would follow a similar pattern. If we assume that construction spending occurs over the course of three years with a linear rate of spending, then the total employment creation attributable to construction spending would be divided evenly over this three year period. Note that the rate of construction expenditure need not be linear. Finally, note that the results for San Diego County are not representative of the impacts that would be observed in other counties or regions. We address county and regional differences in Section VI below.

Table 3: Example Water Project Cost Breakdown

Cost Category	Impact	Value	IMPLAN Sector Code
Construction Cost	Dam & Sediment Basins Construction	$162,000,000	36
	Water Supply Structures Construction	$138,000,000	36
Operations and Maintenance Cost (O&M)	Dam & Sediment Basins O&M	$660,000	39
	Water Supply Structures O&M	$1,675,000	39

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[27] The Seven Oaks Dam, completed in 1999, has a capacity of 145,000 acre-feet and cost $250 million to construct. (http://www.co.san-bernardino.ca.us/flood/dampage.htm)

[28] According to the breakdown of IMPLAN Construction codes available on the IMPLAN website, the Census categories "Dam & reservoir construction", "Sewers, water mains, & related facilities" and "Water storage facilities" all fall under IMPLAN sector 36, or "Construction of other new nonresidential structures". (Construction codes spreadsheet accessible here: http://implan.com/v3/index.php?option=com_kb&task=article&article=108)

[29] We use roughly the same ratios of construction to operations and maintenance costs as presented in Alan Lauver (July 2006), "Regional Economic Impact Assessment of the West Tarkio Creek Multipurpose Reservoir."

A Note on Construction Inputs. To date, few studies of this type explicitly account for the final demand impact of infrastructure projects on construction input sectors.[30] This is likely because by definition, the construction sectors buy items that are integral to the structure being built, that is, final demand changes in sectors manufacturing the raw materials utilized in construction are already effected indirectly when money is injected into an IMPLAN construction sector. Land acquisition and contracted architectural/engineering expertise can be modeled separately, but for the purposes of this example we choose to ignore these final demand impacts.

As previously mentioned, one advantage of IMPLAN is the facility with which the user can aggregate and disaggregate multi-county regions. In modeling our example project, we can show the local impacts (that is, the impacts that take place in San Diego County only), the statewide impacts (that is, the impacts that take place in the economy encompassing all California counties including San Diego) and the impacts in any other combination of counties specified by the user. Accordingly, in addition to local and statewide results, we present the employment and output impacts for a multi-county region that we have termed "LA South Coast", comprised of Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego and Ventura counties. This region was constructed based on the geographic boundaries delineated by consolidated statistical areas and the California hydrologic regions. For a more detailed description of how this and other regions considered in this memo are constructed, please refer to pages 22-23.

Once the model has been run, IMPLAN offers several different types of results reports for interpretation by the user. There is the Impact Summary report, which shows the direct, indirect, induced and total effects in terms of output, employment, labor income or value added. In Table 4 we present the Impact Summary report for San Diego County, the L.A. South Coast region and the entire state of California for employment and output. IMPLAN can also produce an Impact Detail, which shows each industry's individual contribution to the direct, indirect and induced effects shown in the Impact Summary table. This Impact Detail also comes with an aggregation option, which aggregates the individual industries together into broader industrial categories. We've shown an example of this in Table 5 for employment in San Diego County and the remainder of California counties. Finally, the user can also generate a Top Ten report to show the top ten industries affected by the project in terms of employment, output, labor income or value added. An example of the Top Ten industries report for employment in San Diego County and the rest of California is presented in Table 6.

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[30] An exception to this is Heintz, Pollin and Garrett-Peltier (2009), which models the solar and wind industries to include manufacturing in addition to construction and design industries. (Heintz, Pollin and Garrett-Peltier (2009), p. 51)

Please note that estimates of this nature will clearly vary by county or region and in particular, (1) whether a county or region borders a different state, (2) the degree of economic development within the county or region, and (3) the size of the county or region. In addition, estimates using later datasets are also likely to differ, as multipliers are likely to change over time as technologies, labor mix, relative prices and comparative advantage patterns change. As a consequence, it is important that multipliers be updated on a frequent basis.

A Note on Purchasing Power and Productivity. Employment multipliers are sensitive to inflation and productivity changes. Generally, these changes are gradual and will be captured sufficiently by updating the IMPLAN tables periodically. Annual updates are available, but updates can under most circumstances be made less frequently. The recent recession, for example, has slowed the rate of inflation. In fact, the costs of certain goods and services have fallen because of reduced demand. This would tend to increase employment impacts especially if it allowed for additional project spending. At the same time, however, the recession also led to increased productivity as firms began doing more with fewer employees. Firms eliminated redundancy and increased hours.

Table 4: Local, Regional and Statewide Impact of Water Project in San Diego County (Using IMPLAN 2008 Data Set)[31]

Region	Impact Type	Employment (jobs)	Output (2010 dollars)
San Diego County	Direct Effect	1,808	$302,335,008
	Indirect Effect	605	$101,611,872
	Induced Effect	913	$126,981,352
	Total Effect	*3,326*	*$530,928,224*
LA South Coast Region	Direct Effect	1,808	$302,335,008
	Indirect Effect	860	$172,592,560
	Induced Effect	1,099	$159,388,230
	Total Effect	*3,766*	*$634,315,792*
California State Total	Direct Effect	1,808	$302,335,008
	Indirect Effect	883	$181,644,360
	Induced Effect	1,116	$163,610,624
	Total Effect	*3,807*	*$647,589,984*

Table 5: Impact detail for employment, aggregated industries

Sector Description	San Diego County				Rest of California			
	Direct	**Indirect**	**Induced**	**Total**	**Direct**	**Indirect**	**Induced**	**Total**
Agriculture	0	4	4	8	0	4	3	7
Mining	0	3	0	4	0	4	0	4
Construction	1,808	4	8	1,819	0	3	2	5
Manufacturing	0	46	9	55	0	83	14	97
TIPU[32]	0	28	26	54	0	34	18	52
Trade	0	101	222	324	0	22	35	57
Service	0	412	632	1,044	0	125	128	253
Government	0	6	13	19	0	3	3	6
Total	*1,808*	*605*	*913*	*3,326*	*0*	*278*	*203*	*481*

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[31] Note that Direct, Indirect and Induced Effects may not sum up to Total Effect due to rounding error in the IMPLAN software.

[32] TIPU stands for transportation, information and public utilities.

Table 6: Top Ten IMPLAN Industrial Sectors by Employment Creation

San Diego County			Rest of California		
Description	**Total Employment**	**Total Output**	**Description**	**Total Employment**	**Total Output**
Construction of other new nonresidential structures	1,791	$300,000,000	Architectural, engineering, & related services	30	$4,505,763
Architectural, engineering, & related services	159	$23,597,318	Food services & drinking places	24	$1,575,263
Food services and drinking places	123	$8,039,474	Wholesale trade businesses	22	$4,477,709
Real estate establishments	79	$14,067,470	Transport by truck	19	$2,631,171
Wholesale trade businesses	66	$13,720,277	Employment services	16	$695,336
Employment services	54	$2,784,333	Real estate establishments	15	$2,831,308
Offices of physicians, dentists, & other health practitioners	53	$7,297,708	Accounting, tax preparation, bookkeeping, & payroll services	14	$1,726,185
Retail Stores - Food & beverage	40	$3,180,685	Comm./indust. machinery & equipment repair & maintenance	9	$1,759,849
Retail Stores - General merchandise	40	$2,520,203	Services to buildings and dwellings	9	$592,368
Retail Stores - Motor vehicle & parts	33	$2,943,973	Ornamental & architectural metal products manufacturing	8	$1,801,388
Total	*2,438*	*$378,151,441*	*Total*	*166*	*$22,596,340*

As depicted in Table 4, we estimate that a project of this capacity, cost specifications and location would generate about 2,691 new jobs statewide if only direct and indirect employment effects are taken into account and about 3,807 jobs if induced effects are included. For the L.A. South Coast Region, the total job estimate amounts to 3,766, implying that the vast majority of the employment creation in the state would actually be confined to this region. Broadly speaking, the biggest employment impacts at the county-level would occur in the construction and services sectors, with total employment creation estimates of approximately 1,819 jobs and 1,044 jobs, respectively. For the rest of state, manufacturing and service industries would receive the biggest employment boost.

A Note on Full-Time Equivalence. An important distinction that most studies of this type (including those put forth by PERI and the Milken Institute) fail to make is that between full-time and part-time employment. The job creation estimates produced by the IMPLAN model count the total number of positions created in the regional economy as a result of the initial investment. This includes both full-time and part-time positions. Converting the employment estimates to their full-time equivalent (FTE)[33] values requires additional calculation. One can obtain an Excel spreadsheet with ratios to translate IMPLAN jobs to FTE on the IMPLAN website. These FTE values are based on national average ratios from the National Institute of Pension Administrators (NIPA) accounts. For illustrative purposes, we perform the FTE calculation for the employment estimates generated in our example and present the results in Table 7 below.

Table 7: Local, Regional and Statewide Impact of Water Project in San Diego County in Terms of Full-Time Equivalent (FTE) Employment[34]

Region	Impact Type	Employment (FTE jobs)	Employment (jobs)
San Diego County	Direct Effect	1,748	1,808
	Indirect Effect	559	605
	Induced Effect	808	913
	Total Effect	*3,115*	*3,326*
LA South Coast Region	Direct Effect	1,748	1,808
	Indirect Effect	799	860
	Induced Effect	976	1,099
	Total Effect	*3,523*	*3,766*
California State Total	Direct Effect	1,748	1,808
	Indirect Effect	820	883
	Induced Effect	989	1,116
	Total Effect	*3,560*	*3,807*

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[33] FTE is defined as the number of total hours worked divided by the maximum number of compensable hours in a work year as defined by law. For example, an FTE of 1.0 means that the person is equivalent to a full-time worker, while an FTE of 0.5 signals that the worker is only half-time.

[34] Note that Direct, Indirect and Induced Effects may not sum up to Total Effect due to rounding error in the IMPLAN software.

A Note on Fiscal Constraints. An important criticism of analyses of this type is that the cost of funding the project under study is ignored.[35] While capital projects will increase demand for goods and services and increase income (assuming that full employment has not been reached), government-financing of the project may result in higher taxes or, in cases of extremely large expenditures such as the stimulus plan, interest rates (due to increased government indebtedness). Increased taxes or interest rates reduce the income effect and thereby, the overall employment impact. We have made no adjustments to account for the opportunity cost of government project spending, but may find it necessary in any actual analysis. The studies described above generally make no such adjustment arguing that because of the recession there will be no interest impact or any immediate tax increase.

To facilitate comparison between our example and other studies, our estimate of total job creation translates to about 12,600 jobs per $1 billion in investment. This estimate falls short of the numbers put forth in the PERI and CIC studies, specifically, the often-cited figure of 18,000 jobs per $1 billion in infrastructure investment.[36] Note that our estimate is also lower than the estimate cited in the Milken study; this is likely due to differences between the IMPLAN and RIMS II methodologies. There are a number of reasons that could explain why our labor impact estimate is substantially lower than the numbers found in the other studies that use IMPLAN: (1) geographical scope; (2) the estimation of induced effects; (3) IMPLAN model version updates; (4) macroeconomic trends. First, consider geographical scope. Our prototype project takes place in a single county in California, whereas the PERI study analyzes nation-wide infrastructure investments and the CIC study uses the state as its geographical designation. Our estimate accounts for the leakage of employment benefits to regions outside of the state of California, while all domestic leakages are self-contained in the economic study area examined by PERI. It is unclear what measures were taken in the CIC study in order to account for leakages. Another explanation could be differences in the methodologies employed in the estimation of induced effects between our study and PERI's. PERI chose to estimate their consumption function empirically, whereas we chose to run the IMPLAN model closed with respect to households, thus generating induced employment effects with what is referred to as an endogenized household sector. This means that households are effectively considered to be another source of production like the industrial sectors. Consequently, the proportion of induced to direct and indirect effects in the PERI study is greater than in our example, in spite of the fact that PERI claims to utilize its own methodology so as not to overestimate induced effects.

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[35] See for example, Edwin S. Mills (1993), "The Misuse of Regional Economic Models," *Cato Journal*, Vol. 13, No. 1, 29-39. Mills criticizes the REMI model in particular, for evaluating government projects as though the capital were free.

[36] For example, see: http://articles.latimes.com/2008/sep/22/business/fi-roadjobs22/2; http://cbs13.com/local/schwarzenegger.stimulus.job.2.697982.html.

Table 8: Comparison of Impacts Breakdown in BEC Study and PERI Study

Study	**BEC Study**		**PERI Study**	
Measure	**# of Jobs**	**Fraction of total**	**# of Jobs**	**Fraction of total**
Direct and Indirect Effects	2,411.9	0.725	1,130,244	0.717
Induced Effect	912.6	0.275	445,254	0.283
Total Effect	3,324.6	1	1,575,498	1

Perhaps the most likely cause of discrepancy between our results and those presented in the PERI and CIC studies is the time elapsed between them and the accompanying alterations to the IMPLAN model and macroeconomic trends. CIC and PERI both use IMPLAN Professional version 2.0 while we use IMPLAN version 3.0, which was only just released in November 2009. For version 3.0, the sectorization was altered to conform to the newly released BEA 2002 benchmark IO tables, which had placed three previously distinct IO industries -- 'Highway, street, bridge, and tunnel construction', 'Water, sewer, and pipeline construction', and 'Other new construction' – under one IO industry code for 'Other nonresidential structures.' Accordingly, the previously separate IMPLAN sectors 'Highway, street, bridge, and tunnel construction', 'Water, sewer, and pipeline construction', and 'New nonresidential construction - Other new construction', were all combined under IMPLAN sector code 36, or 'Construction of other new nonresidential structures.' Combining three separate production functions into one could easily produce different multipliers. In terms of macroeconomic changes, worker productivity increases over time, meaning lower payroll and smaller induced effects, while an increasingly globalized economy means a higher level of imports and thereby smaller employment multipliers.

VI. Application of IMPLAN Multipliers

While the application of the IMPLAN model can provide substantial detail with respect to geographic area and industry, it also provides the means to generate a set of regional multipliers, enabling analysts to prepare initial "ball park" estimates using a back of the envelope calculation.

No single multiplier can accurately describe every county or region. As discussed in the previous section, the impacts in San Diego County of a major capital project will not necessarily be representative of the impacts of a project that takes place elsewhere in the state. A county or region with a large diverse economy will generate more local jobs than a county or region with a smaller, less diverse economy. Location matters as well. A county or region sharing a border with another state, for example, is more likely to experience some job leakage to the neighboring state.

To allow water agency analysts to account for this regional variation, we present a full set of regional multipliers in Table 9. The table presents employment impacts per $1 billion for eight regions. These regions are defined as follows: (1) counties within the same combined statistical area (CSA) as defined by the U.S. Census are grouped together by default; (2) if a county has no affiliation with a CSA, then it is assigned to a region based on the hydrologic region encompassing the majority of its geographic area. The regions are shown in Figure 1. Table 9 presents the counties in each geographic area.

These values should be used as a first approximation of employment impacts in these regions. Actual impacts will vary depending on the type of project undertaken. Dams, for example, may have different employment impacts than conveyance systems.

Table 9: Regional Employment Impacts for a $1 billion Infrastructure Project

Region	Employment Impact per $1B in Infrastructure Investment	
	Local (in project region)	Statewide (including project region)
Central Coast	10,007	12,205
Lake Lahontan	8,547	10,361
LA South Coast	12,979	13,208
North Coast	10,499	12,548
Sacramento River	11,816	13,132
San Joaquin River	10,640	13,140
SF Bay Area	10,231	11,128
Tulare Lake	8,992	11,681

For cases where a more detailed and accurate analysis is neither necessary nor possible, we present an example of how the values in this table might be applied in the evaluation of a major infrastructure program:

Say an analyst at a CUWA member agency wants a ball park of estimate of the regional economic impact (in terms of employment) to be expected from a proposed construction project. Say the proposed construction project is a $5 billion water conveyance facility to be built in Alameda County. Then the ball park job creation estimate would be 5*10,231 = 51,155 jobs in the SF Bay Area. What if the analyst was interested in the statewide employment impact of this project? Then the job creation estimate would be 5*11,128 = 55,640 jobs in the state of California. What if the proposed construction project only cost $5 million instead of $5 billion? Then the regional job creation estimate would be .001*5*10,231 = 51 jobs in the SF Bay Area, since .001*$1 billion = $1 million.

Table 10: List of Counties in Each Region Presented in Table 8

Region	Component Counties
Central Coast	Monterey, San Luis Obispo, Santa Barbara
LA South Coast	Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, Ventura
Lake Lahontan	Alpine, Inyo, Lassen, Mono
North Coast	Del Norte, Humboldt, Mendocino, Siskiyou, Trinity
Sacramento River	Butte, Colusa, El Dorado, Glenn, Lake, Modoc, Nevada, Placer, Plumas, Sacramento, Shasta, Sierra, Sutter, Tehama, Yolo, Yuba
San Joaquin River	Amador, Calaveras, Fresno, Madera, Mariposa, Merced, San Joaquin, Stanislaus, Tuolumne
SF Bay Area	Alameda, Contra Costa, Marin, Napa, San Benito, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, Sonoma
Tulare Lake	Kern, Kings, Tulare

Figure 1: Map of Regions Presented in Table 8

VII. Biographies

Dr. Mark Berkman is a director and cofounder of Berkeley Economic Consulting (BEC). He has over 25 years of experience as an economic consultant. Prior to BEC, Dr. Berkman was a vice president of Charles River Associates and NERA Economic Consulting. He also served as a budget and policy analyst at the Congressional Budget Office and was a research fellow at the University of Pennsylvania. Dr. Berkman has frequently conducted economic impact and employment impact studies throughout his career. He has, for example, estimated the economic and employment impacts of water shortages, water flow restrictions, power plant construction, industrial plant closures, electricity rate increases and environmental regulations. His dissertation, funded by an award from the Regional Science Association and the U.S. Economic Development Administration, addressed the economic impact of proposed acid rain regulations using econometric and input-output models. Dr. Berkman earned his B.A. in economics and urban affairs from George Washington University, a master’s degree in planning and policy analysis from Harvard University and a PhD from the University of Pennsylvania’s Wharton School program in public policy, managerial science and applied economics.

Dr. David Sunding is a director and cofounder of Berkeley Economic Consulting (BEC). In addition, he is the Thomas Graff Professor of Natural Resource Economics at the University of California, Berkeley where he also serves as co-director of the Berkeley Water Center. Dr. Sunding has written widely on water related issues in California and across the United States. He has advised numerous state, regional, and local water agencies regarding water demand, storage capacity, water rights and water pricing issues. He has also addressed environmental concerns regarding water supply management and discharge disposal. Dr. Sunding earned his B.A. in economics from Claremont McKenna College and his PhD in natural resource economics from the University of California, Berkeley.

Ms. Michelle Tran is a research analyst at Berkeley Economic Consulting (BEC). Ms. Tran has participated in numerous economic modeling and forecasting projects. Prior to joining BEC she was an intern at Beacon Economics, an economic forecasting firm. At the University of California, Berkeley, she served as a research assistant on an economic assessment of the Western Climate Initiative and contributed to a November 2008 paper commissioned by Next 10 entitled, “California Climate Risk and Response.” Ms. Tran earned her B.A in political economy from the University of California, Berkeley and a master’s degree in finance from the University of Cambridge.

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