

# Fort Huachuca and the San Pedro River:

## *Improving Water Deficit Liability Calculations Through Economic Modeling*

by

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## 1.0: Background and Regulatory Framework

The San Pedro River is one of the nation's hotspots of native biological diversity. The river enters Arizona from Sonora, Mexico and flows north to join the Gila River 100 miles north near Winkelman. Because the San Pedro maintains surface flows year round, it has developed an extensive riparian zone that provides critical habitat for over 350 species of birds, 80 mammals, two native and several introduced species of fish, and more than 40 species of amphibians and reptiles.<sup>1</sup>

The San Pedro River is heavily dependent on groundwater. The regional groundwater aquifer is the key source of the river's perennial flows and the health of its riparian ecosystem. It is particularly critical during the dry times of the year. The aquifer, however, is the sole source of water for the region's population and economy. Currently, groundwater is being pumped well in excess of aquifer recharge rates, leading to a water deficit in the upper basin of between 5,144 and 7,000 acre feet (af) per year, although more recent estimates place that deficit as high as 10,800 acre feet per year.<sup>2</sup> The groundwater deficit, in turn, has deleterious effects on the San Pedro River riparian ecosystem. Unsustainable water pumping has caused base flows to decline by 67% since the 1940s, and conservation groups fear that the San Pedro will eventually resemble the lower reaches of the Santa Cruz, Gila, Salt, and Colorado Rivers: "dry, treeless, and devoid of the diversity of life which once graced its waters and shores."<sup>3</sup>

Of particular concern are impacts on species listed as threatened or endangered under the federal Endangered Species Act. These include the Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*) and southwestern willow flycatcher (*Empidonax traillii extimus*). Groundwater depletion is recognized as one of the primary factors adversely affecting these species along the San Pedro River (USFWS, 2002).

Agriculture, urban development, the Cananea copper mine in Sonora, and Fort Huachuca are the most important direct and indirect sources of groundwater demand in the San Pedro watershed (Sprouse, 2005). Because Fort Huachuca is a federal facility its operations are subject to the National Environmental Quality Act (NEPA) and Endangered Species Act (ESA) and their implementing regulations. Importantly, both NEPA and ESA require Fort Huachuca to disclose and mitigate the effects of its activities on the groundwater deficit. Council of Environmental Quality (CEQ) regulations implementing NEPA require disclosure and mitigation of three types of environmental effects arising from Fort Huachuca's operations or actions:

- Direct effects, which are caused by agency actions or operations and which occur at the same time and place.
- Indirect effects, which are caused by agency actions or operations and that are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may

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<sup>1</sup> See [www.blm.gov/az/nca/spnca/resources.htm](http://www.blm.gov/az/nca/spnca/resources.htm) (accessed 5/7/07).

<sup>2</sup> The lower estimate (5,144) is from Fort Huachuca (2002). The higher estimate (7,000) is from CEC (1999). The 10,800 figure was reported in the Sierra Vista Herald on 5/10/07 ("USPP water deficit higher than projected") and is attributable to the U.S. Geological Survey.

<sup>3</sup> See <http://www.biologicaldiversity.org/swcbd/programs/watersheds/spr/index.html> (accessed 5/8/07).

include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems.<sup>4</sup>

- Cumulative effects, which are the impacts on the environment which result from the incremental impact of agency actions or operations when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions.<sup>5</sup>

With respect to groundwater, Fort Huachuca considers direct and indirect groundwater effects to be those associated with water used on-post in base operations, water used by “people who live in the Sierra Vista sub-watershed due to the presence of Fort Huachuca,” and water use associated with “off-post induced economic development” that would not occur but for the presence of the Fort (Fort Huachuca, 2002; 2004).

Section 7 of the Endangered Species Act (ESA) and its implementing regulations contain similar requirements. The ESA requires formal consultation with the U.S. Fish and Wildlife Service (USFWS) for any federal actions that may affect listed species and implementation of conservation measures to significantly reduce or eliminate effects.<sup>6</sup> As set forth in ESA regulations, effects of any federal action refer to the “direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action.”<sup>7</sup> Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

To mitigate direct and indirect effects of Fort Huachuca’s actions and operations to fulfill obligations under both NEPA and the ESA, the Fort has pledged to eliminate its contribution to the groundwater deficit by 2011 by implementing its Army Water Resource Management Plan (AWRMP) and by adhering to Fort Huachuca Policy 119 which requires that “any organization increasing its overall personnel strength in the Fort Huachuca area must mitigate the water use associated with these additional personnel and their family members.”

To determine its liability for the groundwater deficit and thereby the requisite level of mitigation, Fort Huachuca’s 2002 biological assessment employed a simple model that divides the population in the Sierra Vista sub-watershed attributable to the Fort’s operations and activities by the total population, multiplies that fraction by the 5,144 acre foot water deficit figure, and adds a minor amount (109 af) to account for future personnel growth (Fort Huachuca, 2002). In its 2002 biological opinion, the USFWS adopted this approach (USFWS, 2002). The results suggest

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<sup>4</sup> Court decisions construing NEPA have consistently recognized that federal agencies must evaluate the effect of their actions and operations on urban growth and development. See e.g., *City of Davis v. Coleman*, 521 F.2d 661 (9th Cir. 1995) (highway construction); *Carmel-by-the-Sea v. U.S. Dept. of Transportation*, 123 F.3d 1142 (9th Cir. 1997) (highway construction); *Morongo Band of Mission Indians v. FAA*, 161 F.3d 569 (9th Cir. 1998) (airport expansion).

<sup>5</sup> 40 CFR § 1508.7; § 1508.8.

<sup>6</sup> 16 U.S.C. § 1531-1544.

<sup>7</sup> 50 CFR § 402.02.

that Fort Huachuca is liable for 2,784 af of the groundwater deficit, 5,725 af if the new deficit figure of 10,800 af is used. In 2006, the Center for Economic Research (CER) revisited Fort Huachuca's 2002 analysis to remedy what the Center viewed as errors in double counting and inappropriate use of economic multipliers to estimate induced population attributable to Fort Huachuca's activities. The new CER analysis will likely serve as the basis for a revised biological opinion necessitated by the Fort's decision to re-initiate consultation with USFWS to account for "increased missions for intelligence training stemming from the Iraq war and the war on terrorism."<sup>8</sup> If the CER numbers are adopted, it would imply a liability of only 1,379 af, a reduction from the USFWS estimate of over 50% if the 2002 deficit figure is used. If the new deficit figure of 10,800 af is used, the implied liability would be 2,744 af.

As we discuss below, the population based models used by Fort Huachuca, USFWS, and CER are problematic, and likely to significantly underestimate Fort Huachuca's liability. This is because the models fail to tally all water use associated with indirect, induced, interrelated, and interdependent economic activity throughout the Sierra Vista sub-watershed on both sides of the border that would not occur but for the presence of the Fort and its annual expenditures on salaries, goods and services, and the recycling of these funds through the local economy. While the original 2002 analysis by Fort Huachuca attempted to address these induced effects – albeit in a roundabout way – the CER analysis entirely neglects this important factor in regional water demand.

An alternative approach is to replace or supplement Fort Huachuca's population-based methods by utilizing tools of regional economic analysis, water intensity studies, and econometrics to capture all of the direct, indirect, induced, interrelated, and interdependent effects of Fort Huachuca's expenditures on the groundwater deficit as required by both the ESA and NEPA. The purpose of this report is to first critique the population based method adopted by Fort Huachuca, USFWS, and CER and then suggest three alternative economic approaches for estimating the Fort's water use and associated groundwater deficit liability.

The remainder of the report is organized in three Sections. In Section 2, we present the original Fort Huachuca analysis and CER's modification, identify shortcomings with these population based models and discuss the advantages of economic-based approaches in meeting Fort Huachuca's legal obligations under NEPA, the ESA, and Policy 119. In Section 3 we present three alternative economic based models and discuss the implications for Fort Huachuca's liability. Conclusions are presented in Section 4.

## **2.0 Population and Economic Based Approaches for Modeling Water Deficit Liability**

The original biological opinion prepared by the U.S. Fish and Wildlife Service in 2002 and the new approach proposed by CER in 2006 both rely on what can be described as a "population based" approach for modeling Fort Huachuca's water deficit liability. In this section, we review the basic steps in this approach, identify shortcomings, and discuss an alternative framework based on economic modeling.

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<sup>8</sup> From Tucson Citizen, Thursday, March 2<sup>nd</sup>, 2006 "Fort wants review of impact on endangered species," The Associated Press.

## 2.1 Population model prepared for the 2002 biological opinion

The 2002 USFWS biological opinion found Fort Huachuca's liability for the water deficit in the Sierra Vista subwatershed to be 54.12% or 2,784 af, 5,725 af if the new deficit figure of 10,800 af is used. This estimate was generated by multiplying the fraction of population in the Sierra Vista subwatershed attributable to Fort Huachuca by the annual water deficit and then adding an amount to reflect water use attributable to future personnel growth. In particular, the 2,784 af was calculated as such:

$$[1] \quad FH_t = \left[ \left( \frac{FH_{pop}}{SV_{pop}} \right) \times (R_t - W_t) \right] + \left[ \left( \frac{FH_{grw}}{SV_{pop}} \right) \times (R_t - W_t) \right]$$

In equation [1]  $FH_t$  is Fort Huachuca's water deficit liability (2,784 af),  $FH_{pop}$  is the population attributable to Fort Huachuca in the Sierra Vista subwatershed (34,993),  $SV_{pop}$  is the total population in the Sierra Vista subwatershed (64,655),  $R_t$  is annual aquifer recharge (9,209 af),  $W_t$  is annual aquifer withdrawals (19,072), and  $FH_{grw}$  is projected personnel growth (1,369). Numbers in parentheses are the figures used in the 2002 biological opinion. The calculation of  $FH_{pop}$ , in turn, is the sum of (a) assigned personnel on and off post, civilian and government contractors, retirees, survivors and family members (26,531) and; (b) "an interrelated and interdependent population of induced employees and family members" (7,093).<sup>9</sup> The population of "a" was corrected for double counting<sup>10</sup> and for those non living in the Sierra Vista subwatershed (3%). The population of "b" was determined as such:

$$[2] \quad IIP = [[(EN \times MIL \times .968) + (CC \times CIV \times .968)] \times (1 - FAM)] \times PEO$$

In equation [2]  $IIP$  (7,093) is the interrelated and interdependent population,  $EN$  is enlisted personnel (4,199),  $MIL$  is the assumed employment multiplier for enlisted military personnel (.332288),  $CC$  is the number of contractors and government civilians supported by Fort Huachuca (5,879),  $CIV$  is the assumed multiplier for contractors and civilians (.383932),  $FAM$  is the assumed proportion of family members holding induced jobs (.2675), and  $PEO$  is the ratio of jobs to population in the Sierra Vista subwatershed (2.74). The constant (.968) is a discount factor to account for those not living in the Sierra Vista subwatershed.

## 2.2 Population model used by Center for Economic Research

In December of 2006 the Center for Economic Research (CER) at Cochise College reanalyzed the population attributable to Fort Huachuca ( $FH_{pop}$  from equation [1]) by applying an alternative method to remedy some of the alleged shortcomings from the 2002 analysis. CER estimates  $FH_{pop}$  to be 18,543 rather than 33,345. Primary changes to the calculation approach were (a) elimination of interrelated and interdependent population of induced employees and family

<sup>9</sup> See USFWS (2002) including Appendices I and J for more detail.

<sup>10</sup> The issue of double-counting population attributable to Fort Huachuca is a major issue that arises from the nature of how the Fort's annual economic impact statements (AEIS) are prepared. According to USFWS (2002), AEIS statements draw from several independent databases that classify personnel in different ways. Since these categories often overlap, a procedure to address double counting is necessary.

members (*IIP*) as a population category and (b) a new approach to correct for double-counting.<sup>11</sup> CER offers several reasons for eliminating *IIP*, however, the overarching justification is that “the use of economic multipliers in an attempt to forecast population growth is inappropriate” (Carreira, 2006 at 11). The new CER methodology also arrives at a new estimate of 75,140 for the total population on the U.S. side of the Sierra Vista subwatershed ( $SV_{pop}$  from equation [1]) by correcting from some alleged distortions in Arizona Department of Economic Security data. As a result, and by substituting these figures into equation [1], the CER study implies that Fort Huachuca is liable for no more than 26.8% or 1,378 af of the groundwater deficit, 2,744 af if the 10,800 af deficit figure is adopted.

### 2.3 Shortcomings of the population-based approach

Both the USFWS and CER approaches are atypical for modeling water demand and are likely to understate groundwater pumping and associated groundwater deficit attributable to Fort Huachuca’s operations and overall presence in the Sierra Vista subwatershed or otherwise present an inaccurate assessment. There are several reasons why this is the case:

#### 2.3.1 Failure to adequately capture water use associated with off-post economic development.

First, neither approach adequately tallies groundwater pumping and associated deficit liability associated with “off-post induced economic development” that would not occur but for the presence of the Fort – a factor acknowledged by Fort Huachuca as key to fulfilling its obligations under NEPA and the ESA with respect to indirect, induced, interrelated, and interdependent effects of its operations.<sup>12</sup> Off post induced economic development is best modeled by carefully tracking the economic effect, associated with the flow of funds from Fort Huachuca through the local economy and considering water use at each stage. Off-post induced economic development is also triggered by the mere presence of the Fort, independent of any actual expenditure. There are many economic development pathways and associated water use links to consider.

One pathway is the money Fort Huachuca spends on salaries for assigned military personnel and both civilian and military contractors. In 2005, the Fort estimated this amount to be \$491 million, supporting 13,379 jobs (Fort Huachuca, 2006). On-duty, such personnel engage in various water using activities both on and off base. Off duty, such personnel use water in managing their households (cooking, cleaning, watering gardens, etc.) but also induce water use in the local economy by spending money on goods and services from local businesses that use water as a factor of production needed to provide such goods and services. So, for example, when off base military personnel play golf, buy food, landscape their homes, wash their cars, or eat out they induce water use at golf courses, supermarkets, nurseries, carwashes, and restaurants. These businesses, in turn, purchase at least some of their goods and services locally, inducing further use of water by suppliers.

Another pathway is direct procurement of goods and services by Fort Huachuca, estimated by the most recent (2005) Annual Economic Report to be of \$339.4 million in Sierra Vista alone. Again, businesses that provide the Fort with laundry, hospitality, or maintenance services or

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<sup>11</sup> Appendix C to Carreira (2006) provides the detailed methodology.

<sup>12</sup> See USFWS (2002) at 111 – 112.

food, medicines, equipment, technology, or other goods all use water themselves as a factor of production and also induce further water use by purchasing at least some of their goods and services locally. Another pathway is water use by households that benefit from all this economic activity. Households that subsist wholly or in part on economic activity generated by Fort Huachuca both on and off base use water themselves but also recycle a portion of their earnings through the local economy and thus contribute to additional water use by area businesses.

Yet another pathway is associated with the economic activity generated by the Fort just because of its presence. An example is economic activity generated by visits by out of area family members, by those on business with the Fort, or by those touring the Fort's museums or historical sites. Expenditures on hotels, motels, hospitality and recreational services, restaurants, gift shops, and fuel by these visitors generate additional water demands in the Sierra Vista subwatershed. Another example is the retiree population located in Sierra Vista due to the presence of Fort Huachuca. A 2002 study found that roughly 25% of military retirees in the state would move if military bases in Arizona closed, so CER attributes 25% of the retiree population in the Sierra Vista subwatershed to the presence of Fort Huachuca (Maguire, 2002). Regardless of the exact number, retiree households, as any other household in the area, use water themselves but also induce water use in the local economy through their purchases of goods and services.

Regional economic models used by government agencies including the Department of Army generally group economic effects arising from various economic development pathways into three main categories<sup>13</sup>:

- Direct effects, which represent the immediate changes in employment or income resulting from an increase or decrease in final demand for a good or service or menu of goods and services. A relevant example is additional employees hired at laundering facilities needed to cope with an increase in base personnel.
- Indirect effects, which represent the changes in employment or income caused by the iteration of industries purchasing from industries resulting from direct final demand changes. A relevant example is food stores having to purchase more local produce from area suppliers to respond to an increase in food demand caused by an increase in base personnel and civilian contractors.
- Induced effects, which represent the changes in employment or income in all local industries caused by the expenditures of new household income generated by the direct and indirect effects of direct final demand changes. A relevant example is a local mechanic taking a raise due to an increase in business not only from the base but from companies that do business with the base and then purchasing more consumer goods and services

A reasonably accurate model of water use and water deficit liability for Fort Huachuca would take into account water use associated with all direct, indirect, and induced economic effects caused by Fort Huachuca's expenditures or mere presence in the area. The population based approaches used by USFWS and CER fail to do this. At best, these approaches merely address water use associated with a portion of Fort Huachuca's direct economic effects because they are based on a simple head count of population attributable to Fort Huachuca including employees

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<sup>13</sup> The definitions of direct, indirect, and induced effects are taken from MIG (2004).

and their families. However, the USFWS (2002) analysis at least attempted to be more comprehensive by supplementing the simple head count with an estimate of an interrelated and interdependent population of induced employees and their families (*IIP*), albeit in a roundabout and incomplete way that did not fully take into account expenditures of those employees or procurement of goods and services by the Fort in the local economy. This can be seen by revisiting the formula for calculating *IIR* from equation [2] – *IIR* is simply a multiple of assigned personnel and contractors working directly with the Fort, it is not based on a analysis of Fort expenditures independent of that population (i.e. the \$339.4 million spent in 2005). The CER analysis excluded consideration of indirect or induced effects at all and, thus, is facially inadequate as a basis for estimating water use and associated groundwater deficit liability associated with off-post induced economic development.

### 2.3.2 Exclusion of possible spillover effects on the Mexican side of the subwatershed.

The San Pedro River originates near the mining town of Cananea in Mexico and flows north roughly 25 miles to the border. The upper watershed encompasses an area of approximately 7,600 square kilometers – 5,800 in Arizona and 1,800 in Sonora, Mexico (Kepner et al., 2004). In the Mexican portion of the basin, population growth, mining and agriculture have been identified as factors contributing to the groundwater deficit and or surface flows though the magnitude of impact is uncertain. Significant groundwater pumping supports the copper mine at Cananea. Groundwater pumping also supports agriculture and domestic uses. According to the USFWS:

Groundwater pumping and land use upstream of the (San Pedro National Conservation Area) in Mexico affect flows as well. The best information available indicates that about 3,200 acres of farmland are irrigated in the Mexican portion of the San Pedro River basin (Watts et al. 1998). An estimated 9,600 AF of water is used per year to irrigate these crop lands. If this pumping were eliminated, median flows at Palominas would increase roughly by five cfs (3,500 AF per year [San Pedro Expert Study Team 1999]). An increase of 3,500 AF would represent about an eighteen percent increase in annual groundwater supplies in the Sierra Vista subwatershed. An estimated 2,300 AF per year is pumped for domestic uses in Cananea, Naco, and other smaller settlements.<sup>14</sup>

Ever since NAFTA, the economies of southern Arizona and Sonora have become more and more integrated (Koch, 2006). Minerals (including ore concentrate from the copper mine at Cananea), livestock, produce, maquilador goods, automobiles are among goods that flow from Sonora to Arizona (*Id.*). Because Fort Huachuca is the primary driver of economic activity on the Arizona side, it is reasonable to expect that Fort Huachuca's economic impact on the Sierra Vista subwatershed extends across the border generating at least some of the demand for these imports and the water needed to produce them as well as some of the income needed to support households and their water consumption.

There is also the issue of migrant workers, who may repatriate funds earned in southern Arizona to Sonora to support households on the Mexican side of the border, including households located in the upper San Pedro watershed. Given the large contribution of Fort Huachuca to the Cochise

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<sup>14</sup> USFWS (2002) at 84.

County economy, significant support industries can be expected to employ migrant workers from the nearby pool of labor just across the border. Indeed, the City of Naco has approximately 5,300 residents; however, this population can grow to 7,000 counting transient workers waiting to cross into the United States (Browning-Aiken, 2003).

Both the USFWS and CER models fail to acknowledge any liability for groundwater pumping that may occur in Mexico as a result of this cross border economic activity generated by Fort Huachuca. While cross border links in economic activity and the relationship between that activity and groundwater pumping in Mexico has yet to be studied, there are many potential pathways and it is erroneous to assume that the effect on the San Pedro watershed's groundwater deficit is zero.

### 2.3.3 Invariance with respect to Fort Huachuca's expenditures

The USFWS and CER models fail to capture changes in water use and associated groundwater deficit liability as Fort Huachuca's local expenditures change. As set forth above, the core of the population based approaches used by USFWS and CER is the Fort's direct workforce, which includes assigned personnel, military students, and civilian and contractor employees. The correlation between changes in this population and changes in Fort expenditures is weak. Between 2002 and 2005, the direct workforce increased from 12,022 to 13,379, an increase of 11.3%. During this same period, however, direct expenditures in Cochise County increased from \$569.7 million to \$830.6 million, an increase of 45.8%.

This increase in expenditures can be expected to result in a similar increase in induced economic activity in the Sierra Vista subwatershed, which, in turn, may result in a similar increase in water demand. Thus, by limiting the Fort's liability for the groundwater deficit to a multiple of the direct workforce alone, the USFWS and CER population based models fail to capture changes in that liability that may result from changes in the Fort's expenditures and overall influence on the economy in the Sierra Vista subwatershed.

### 2.3.4 Exclusion of relevant population subgroups

Both the USFWS and CER analyses exclude water-using subgroups. Both analyses exclude 3.2% of the population attributable to Fort Huachuca because they are assumed to live outside the Sierra Vista subwatershed. However, while on-post or visiting Sierra Vista on business or for pleasure they still use water, so it is unclear why this subgroup was entirely excluded. Both the USFWS and CER analyses also exclude visitors. A significant component of visits to Sierra Vista and other parts of the subwatershed may indeed be due to the presence of Fort Huachuca. Clearly, those on business with the Fort or in town visiting friends and family ought to be counted. So should those who visit Sierra Vista and other parts of the watershed to view the Fort's tourist and natural attractions. A 2006 CER report found that "[t]he museums on the post draw approximately 80,000 visitors annually," so the visitors subgroup is clearly significant (CER, 2007 at 48).

Also significant are migrant workers who work in sectors that benefit from expenditures of Fort Huachuca and its attributable population. As previously discussed, it is reasonable to expect that

migrant workers make up a significant component of the workforce in Sierra Vista and Cochise County. Indeed, the Cochise County Sheriff reports that 37 percent of his operating budget is allocated for issues related to migrant workers and illegal aliens. Miller (2002) reports that between 500,000 and 1.5 million illegal migrants may enter Cochise County annually. But because migrant workers are undocumented, they are not counted.

As discussed previously, the CER analysis entirely excludes interrelated and interdependent population of induced employees and family members. The USFWS at least attempted to include this population, but, as discussed above, likely underestimated its extent. The CER analysis also excludes 75% of military retirees on the assumption that just 25% of this population is attributable to the presence of Fort Huachuca. The USFWS study retained this group in its entirety. Since military retirees are beneficiaries of a federal program and since the intent of mitigation under both NEPA and the ESA is to mitigate the effects of all federal actions (and not just one particular agency or program) it seems prudent to retain the entire military retiree population rather than exclude 75%.

### 2.3.5 Unsubstantiated or arbitrary assumptions

The population based approaches used by USFWS and CER rely on a number of unsubstantiated or arbitrary assumptions that are critical to the overall conclusions of the report and results of the analyses. Below, we focus on six.

#### **Assumption 1:** *Population growth necessary to account for groundwater deficit*

CER maintains that “an increase in the groundwater deficit, if it were solely the result of residential and commercial development, would necessitate an increase in the population of the Sierra Vista sub-watershed between 18,167 and 38,533 people between 2002 and 2005” (Carreira, 2006 at 3). This estimate is based on the change in the groundwater deficit between 2002 and 2005 and the USGS estimate of an average per capita usage of 160 gallons of water per day. However, while the deficit accrued over a three-year period, CER finds the resultant population based on a *single* year. This grossly over-estimates the required population that would be necessary for to account for the increase in the deficit.

CER relied on the Center for Biological Diversity and the Maricopa Audubon Society’s report indicating that the 2002 groundwater deficit of 5,144 acre-feet has risen to between 8,400 and 12,050 af in 2005. Thus, in the three-year period (2002 – 2005) the deficit has increased between 3,256 to 6,906 af. Converting af to gallons (where 1 acre foot = 325,851 gallons) yields an increase in the deficit of between 1.061 billion and 2.250 billion gallons (consistent with CER). This deficit accrued over a three-year period, or 1095 days. Thus, the *average* daily deficit is between 968,923 gallons and 2.1 million gallons. Assuming a per capita per day use of 160 gallons, this equates to a required change in the population of between 6,506 and 12,844. Thus, CER overstates the required increase by 12, 112 to 25,689 people. The population change provided by CER is consistent with a per capita use of 53 gallons per person per day, not 160.

Furthermore, the USGS number of 160 gallons per person per day is based on all usage except *mining* and *irrigation*. However, economic activity associated with Fort Huachuca can be

expected to generate demand in each of these sectors. Without taking the deficits accrued to these two activities, the estimated increase in population is biased and over-estimates the required increase.

**Assumption 2:** *Water use intensity is constant across all population groups*

The USFWS and CER models contain an implicit assumption that the water use profile of the population attributable to Fort Huachuca is no different than that of the general population in the Sierra Vista subwatershed. This is because the first term in equation [1] assigns equal per capita liability for the water deficit to both groups. However, both people and businesses have very different water use habits and needs. Failure to acknowledge these differences may significantly distort the results of the USFWS and CER analyses.

**Assumption 3:** *Validity of DES population data*

The CER report provides a lengthy discussion about the validity of the data produced by the Arizona Department of Economic Security (DES) and questions the methodology of the DES. The CER report suggests the U.S. Census data has greater accuracy and should be used. However, the CER estimations rely heavily in the DES data for period analysis not covered by the Census. There is no discussion or caveat as to the impact of using the DES data has on the CER estimates.

**Assumption 4:** *All same-sized Arizona communities are identical*

The CER provides a comparison of population trends for Arizona communities of comparable size to Sierra Vista. The communities include Avondale, Lake Havasu City, Prescott, and Bullhead City. While the cities may compare in size, geographically they are diverse and so the comparison in growth may be erroneous. For example, Avondale has seen an increase of 84% in population. Avondale is a suburb of the greater Phoenix Metro area consequently it can be expected to see growth relative to economic conditions in the Phoenix area, not necessarily Avondale itself. Sierra Vista is not a suburb of a large metropolitan area and growth will be determined by the local conditions, not “Phoenix-like” conditions. Lake Havasu City is a recreation destination on the shores of Lake Havasu. The recreational opportunities in Sierra Vista, a city in the middle of the desert, may not be comparable to Lake Havasu City, thus the comparison is problematic.

The assumption made is that since most Arizona communities are growing, the growth in Sierra Vista cannot be attributed to the Fort. By parallel argument, we would assume that the proximity of Avondale to Phoenix is not responsible for growth in Avondale. If local factors do not have some impact on population growth, then what is the driving force? This assumption is made, but there is no support provided this argument.

A complete comparison to Sierra Vista would include statistically controlling for forces suspected of causing population changes (job growth, urban development, etc.). An effort clearly not attempted in the CER study. Fort Huachuca is suspected of causing a significant portion of Sierra Vista’s population change. For a complete analysis of the change, Sierra Vista would need

to be evaluated in two states of the world; a state with and with out Fort Huachuca's existence. This is not undertaken nor even attempted in the CER report.

**Assumption 5:** *All new jobs are filled locally*

CER assumes that an increase in jobs automatically correlates to a reduction in unemployment. Assuming this is to assume that the new jobs created are filled by the existing population and that there exist people in the unemployment pool who are qualified to fill the newly created jobs. This is an oversimplification. Moreover, CER assumes that if new jobs are created then family members of active military fill the newly created jobs. This assumption fits with the CER method of "population accounting" but is unfounded in economic literature.

For example, Acemoglu (1999) has found that for an increase in jobs to reduce unemployment, the skill set of workers is important. Particularly, they find that if a firm creates new jobs and the productivity gap between skilled and unskilled is small then an increase in jobs may reduce unemployment. This result occurs if the economy is in a pooling equilibrium. However, if the gap between skilled worker demand and unskilled worker supply is significant the economy switches to a separating equilibrium wherein wages and employment for the skilled rise while at the same time unemployment among the unskilled rise. CER's assumption of an increase in jobs correlating to reduced unemployment clearly negates the effect of worker skill on the interaction, an unfounded oversimplification.

A second comment must be made concerning the argument about unemployment. Assume for a moment that the argument of jobs being filled locally is true. Couple this with the statement that Sierra Vista had the lowest unemployment rate in Cochise County with an unemployment rate of 4.1%. Given a natural rate of unemployment of between 3 and 4%, this leaves a job pool of between 0.1 and 1.1 percent of the workforce. With this small of an employment pool, any economic activity that results in new jobs will be filled from external sources. The CER argument is circular and cannot hold.

**Assumption 6:** *Economic multipliers are not appropriate to estimate population growth*

The CER report states:

In summary, it is the opinion of the CER that the use of economic multipliers in an attempt to forecast population growth is inappropriate. Accounting for threats to the validity of this approach, which was used in the 2002 biological opinion, mitigates estimates of increased population. This indicates the increased population resulting from the economic activity of Fort Huachuca, beyond the military, government, and non-governmental employees and their family members already accounted for, is negligible. The CER offers an alternative approach to estimating the share of the population of the U.S. side of the Sierra Vista sub-watershed (Carreira, 2006 at 11).

The implied assumption is that the simple population accounting method is appropriate and superior to an economic based approach. There are two main problems with this assumption. First, dating back to the 1950s researchers have used multipliers based on sectoral interaction to

determine impacts to the structure of the economy given a change in one of the sectors (Sonis et al., 2000). Rasmussen (1956) and Hirschman (1958) developed a framework wherein the economic landscape could be analyzed in light of the synergetic interdependencies that exist between economic activities. From that time a more formalized approach was adopted by Leontief (1966) and later in Leontief (1970). In his 1970 work, Leontief evaluated the effects of pollution on society through the interdependences of sectors in the economy.

In the past three and a half decades urban and regional analysis has come to depend heavily on the use of sectoral interdependencies to evaluate the economic landscape. Technical innovation via computer programming have allowed for complicated models of general equilibrium analysis to evaluate sector connectedness. Software, e.g. IMPLAN PRO, allows researchers to model a shock then its ripple through the economy. Given a shock to one sector of the economy, primary impacts are captured. The entire effect of the shock, however, is not realized in simply the direct impact. Secondary and tertiary impacts are part of the economic shock. Sectoral analysis, particularly input – output analysis, allows for the entire magnitude of the shock to be measured. For CER to criticize the use of multipliers to estimate population changes regionally is to negate the standard economic method used in urban and regional planning analysis.

Secondly, and as previously discussed, the CER estimate can only be considered a direct impact, which is that it is an estimate of people who are directly connected to the Fort. This implied assumption is that secondary effects and tertiary effects (indirect and induced) are inconsequential. Assuming the CER estimate of 18,543 directly connected people is accurate, the CER analysis implies there are no strategic interactions through the regional economy. The fallacy of this approach and this assumption is that these people are part of the greater regional economy of which Fort Huachuca is a part. Their expenditures and interaction in the economy is not measured in the CER method of estimation. A regional analysis using input – output models and models of general equilibrium are thought to be a better measure of capturing the complete impact of Fort Huachuca.

#### *2.4 An economic framework for modeling water deficit liability*

Given the inherent problems with population-based models for modeling Fort Huachuca's water deficit liability an economic based model may be a far better approach. In an economic modeling framework, water is seen as an input into the production processes of public institutions and agencies like Fort Huachuca, businesses, and households. In the business sector, water use is determined by the nature of the business, level of demand, technology, the number of employees, work habits, hours of operation, etc. Household use of water use is related to family size, size of dwellings, amount and type of appliances, etc. An economic based model would relate Fort Huachuca's expenditures in the local economy on salaries, goods, and services as well as its overall presence to factors affecting water use across all economic sectors in Sierra Vista.

There are many advantages to estimating Fort Huachuca's water deficit liability using an economic based approach. First, economic based models can capture far more of the water use associated with Fort Huachuca's operations in the Sierra Vista subwatershed because they not only consider use by Fort Huachuca's assigned personnel, military students, civilian and contractor employees but the indirect and induced water use associated with their expenditures in

the local economy as well as the direct, indirect, and induced water use associated with the Fort's procurement of goods and services. An economic based approach would also capture water use by visitors. As such, an economic based approach is a much better fit for satisfying the Fort's legal obligations under both the ESA and NEPA, which require comprehensive accounting of all interrelated, interdependent, induced and indirect effects that would not occur but for the Fort's presence in the subwatershed.

Secondly, an economic based approach is capable of capturing differences in water use intensity in the various sectors affected by the Fort's presence and thus providing a more accurate estimate of the Fort's water deficit liability than the population based models, which assume constant per capita use. Third, an economic based model could track increases or decreases in water use associated with increases or decreases in the Fort's expenditures. As explained in subsection 2.3.3, the current population models fail to adequately do this. Another advantage is that economic models of military base expenditures including site specific local multipliers have already been developed and peer-reviewed, are widely endorsed, and can be extended to predict water use liability in a relatively straightforward manner. Thus, they may be far less controversial than population based approaches (such as that proposed by CER) that require a variety of untested assumptions.

### 3.0 Potential Economic Based Approaches Applicable to Fort Huachuca

In this section, we suggest three alternative approaches to modeling Fort Huachuca's water deficit liability based on its overall economic impact. In each case, we discuss the general model and data sources, and indicate the likely direction of water deficit liability change that would result relative to the USFWS and CER population models.

#### 3.1 Gross regional product approach

One simple approach would be to assign water deficit liability based on the share of regional economic activity attributable to Fort Huachuca in the Sierra Vista subwatershed. Gross regional product is one way to measure this. Gross regional product is the value of all goods and services transacted in the subwatershed. Under this approach, the Fort's share would be calculated by using a standard input-output model to estimate direct, indirect, and induced income generated by the Fort's expenditures on salaries, contractor fees, goods, and services and divide that by the total income received by factors of production engaged in the process of production (including labor) in the subwatershed. Under this approach equation [1] would be rewritten as such:

$$[3] \quad FH_l = \left[ \left( \frac{FH_{inc}}{SV_{inc}} \right) \times (R_t - W_t) \right] + \left[ \left( \frac{FH_{incgrw}}{SV_{inc}} \right) \times (R_t - W_t) \right]$$

Where  $FH_{inc}$  is the direct, indirect, and induced income associated with Fort Huachuca's expenditures,  $SV_{inc}$  is income earned by all factors of production in the Sierra Vista subwatershed, and  $FH_{incgrw}$  is income growth associated with anticipated future increases in Fort Huachuca's expenditures. As before,  $R_t$  and  $W_t$  are terms representing aquifer recharge and withdrawals and  $FH_l$  is Fort Huachuca's water deficit liability. While this type of model has yet to be constructed, from what we know about Fort Huachuca's influence on the economy of the

Sierra Vista subwatershed it would likely yield a much higher estimate of Fort Huachuca's water deficit liability than either the USFWS or CER approaches.

For example, according to the Fort's 2005 Annual Economic report, the Fort spent \$830.4 million on salaries, goods, and services in Cochise County, the majority in the Sierra Vista subwatershed (Fort Huachuca, 2005). Using a range for economic multipliers published by CER (1.3323) and the Army Environmental Policy Institute (1.684) this implies a total impact of between \$1.11 and \$1.40 billion in income generated.<sup>15</sup> In 2005, CER estimated per capita income for Sierra Vista to be \$23,278 (CER, 2007). Multiplying this by CER's estimate of the total population in the U.S. side of the Sierra Vista subwatershed (75,140) yields a total personal income figure of \$1.75 billion. If total personal income is a proxy for total factor income, this implies that Fort Huachuca's share of economic activity and, consequently, share of the water deficit in the subwatershed to be in the range of 63% to 80%, not counting future growth.

Another indication is the size of the workforce attributable to Fort Huachuca. CER estimates the employed civilian workforce in Sierra Vista to be roughly 17,544 in 2006 (CER, 2007). Adding active military personnel (and students) brings this total to 23,224. Fort Huachuca provides 13,379 jobs directly, or 58% of the total. Using the multiplier range from above implies that the Fort's total contribution to the workforce counting both direct and indirect impacts is in the range of 17,824 to 22,530, or between 77% and 97%, with the lower end of this range being more plausible due to some double counting of employees by the Fort (CER, 2007).

Or consider taxable sales. Direct purchases by the Fort in Sierra Vista totaled \$339.4 million in 2005. Using the multiplier range from above, this implies a total of \$451 to \$570 direct and indirect purchases. In 2006, CER (2007) reports a total of \$828.5 million in taxable sales in Sierra Vista, implying that the Fort's direct and indirect purchases may account for 54% – 69% of the activity. However, this does not include purchases by both on and off post personnel, visitors, or any other element of the population attributable to Fort Huachuca so the total share of taxable sales is actually much higher. These percentages, of course, are just ballpark estimates of what may be found once rigorous models are built – none the less, they indicate that models based on the Fort's share of economic activity rather than share of population may result in significantly higher estimates of water deficit liability.

### 3.2 Water intensity – labor market approach

A second approach to modeling Fort Huachuca's water deficit is to consider the labor associated with the Fort's impact via the number of employees attributable to the Fort in primary, indirect and induced activities and the average water use per employee. To this would be added associated population. Unlike the average daily water per person or the gross regional product approach, both of which assume homogeneity across use, the intensity of use model recognizes

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<sup>15</sup> The use of multipliers to analyze income and employment effects is not disputed. According to CER: "the use of multipliers is appropriate for calculating the economic impact of spending by military bases" (CER, 2006 at 8). The 1.3323 multiplier was estimated by CER as the appropriate multiplier for military personnel. A higher multiplier (1.3839) was estimated for civilians and contractors. Here, we used the military multiplier to set the lower bound on the liability ranges discussed above.

heterogeneity of intensity of labor and intensity of water use in different industries. The model captures the nuances of water use across industries.

Under this approach, the Fort's share would be calculated by employing an IMPLAN model to estimate to total number of employees (primary, indirect, and induced) in all activities attributable to the Fort. This allows for heterogeneity across activities in labor. Secondly, we address the water use across activities. Ideally, a primary study for each economic activity would be undertaken in order to estimate the production for each activity. This is not only cost prohibitive, but unrealistic given the shear volume of data necessary and, most likely, unavailable. Instead, a benefit transfer approach could be employed, where primary study results from other areas are transferred into the study area. Primary studies that are applicable include, for example, Gleick et al. (2003) or Cook at al (2001). These studies consider that labor and water are both inputs into any given production process. In the short run (which assumes a constant technology and scale of production), the ratio of water use to employee is fairly constant. Thus water use in an industry can be estimated from the total number of employees in the industry times the gallons of water used per employee per day (GED). For example, Gleick et al. estimate the GED for a governmental office is 136, for primary metal industries is 1,318, while for food and kindred products it is 1,967.

Total water use attributable to the Fort and associated activities in a given year would be estimated by

$$[4] \quad FH_w = \left[ \sum_{i=1}^I (GED_i * E_i) + \sum_{j=1}^J (GED_j * E_j) + \sum_{m=1}^M (GED_m * E_m) \right] \left[ \frac{365}{325,851} \right]$$

Where  $FH_i$  is total af of water attributable to Fort Huachuca activities, where there are  $i=1, \dots, I$  primary activities,  $j=1, \dots, J$  indirect activities and  $m=1, \dots, M$  induced activities.  $E_p$  is employees attributable to Fort Huachuca activities ( $p=i, j, m$ ), 365 are the number of days per year, and 325,851 is the conversion for gallons to af. This estimate, added to the total number of gallons consumed by households ( $FH_{HH}$ ) associated with Fort Huachuca activities, provides an estimate of the total number of gallons consumed by fort activities. That is  $FH_{TOTAL} = FH_w + FH_{HH}$ . The percentage of water consumed by Fort activities is then simply:

$$[5] \quad FH\% = \frac{FH_{TOTAL}}{W},$$

where  $FH\%$  is the percentage of water consumed by Fort activities and  $W$  is the total water consumed in the sub-watershed. Assuming that the Fort's deficit share is proportional to its consumption, equation [5] provides an estimate of the Fort's deficit share.

This modeling approach also requires that the Fort's effect on population in Cochise County (the region) be determined. Using a method of dynamic simulation the region can be modeled in two states of the world; with and without Fort Huachuca's presence in order to assess the impact. The approach is described in the following paragraphs.

A regional economy can be thought of as interaction between industry and population. Interaction is the exchange of dollars for goods and services. Industry is firms who produce in the region. Primarily this constitutes Fort Huachuca and firms in Cochise County. The population provides labor services to industry in return for wages. Industry provides goods and services to the population in return for dollars. Given this, the regional economy can be modeled as the interaction (flow of services) between three stocks; population, workers, and industry.

Population stock can be described in the following way. It is distributed throughout the region in terms of where people live. More will be said about geographic location at a later point. Population can additionally be characterized by the relative age distribution; youth, working age, and retired people. Moreover the population can be described by educational attainment, which correlates to skill level description of the population. This characterization allows the model to say who lives in the region, how old they are, and *if* they work what jobs they are qualified for.

Industry in the region organizes labor and other resources to create product, goods and services for consumption. Regional industry can be characterized using the US Census system of NAIC classification of twenty primary economic sectors. At each point in time, industry demands labor to fill the jobs in each of the 20 economic sectors. As population increases, industry grows consequently demanding more labor to fill newly created jobs. Each sector has specific skill requirements for jobs performed therein, e.g. each sector demands labor according to skill ability. Labor is provided by the workforce.

Population stock creates the workforce stock. People of working age and skill level constitute the workforce and supply labor to meet industry labor demand. Labor demand looks to the workforce to fill necessary jobs according the skill level of workers. If workers of specified skill are not available the model increases population through migration to fill industry labor demand. If the workforce provides more labor than industry demands then there is unemployment. Corresponding to each job type in economic sectors are estimates of water use per person per day.

The model's purpose is to isolate the Fort's impact in the region. As such the region is divided into three spatial geographic places; Fort Huachuca, Sierra Vista sub watershed not including the Fort, and Cochise County not including the watershed. The model uses these places as Fort, watershed, and county. Each of the previously listed stocks is described in terms of these three places. That is, there is a population, workforce, and an industry that exists in the Fort, watershed, and county. Industry in each place can demand labor from the workforce where workers can live in any of the three places. Model data needs are obtained from both Census and Labor Statistics Bureaus.

The model described here allows for simulation with the Fort in the region and with its absence. Interaction will show anticipated population and water use in both states of the world. Evaluating population and water use differences produced from two scenarios will isolate Fort Huachuca's impact to population, which then can be tied to published GED estimates.

This model is conceptual at this stage and so it cannot be used to ascertain a new estimate of Fort Huachuca's liability. However, we can hypothesize that the deficit share attributable to the Fort

would be considerable larger than the CER approach which captures only primary activities simply due to the inclusion of the indirect and induced population attributed to the Fort. In addition, allowing for variation in the intensity of use of water across activities will most likely result in additional increases in the Fort's liabilities due to relatively high water use activities associated with military bases.

### 3.3 Econometric approach.

The third approach to modeling the Fort Huachuca water deficit liability is to use econometrics. This approach provides the ability to ascertain the statistical significance of factors affecting the water deficit. The technique may provide superior results to either of the aforementioned models, but it also requires a significant amount of data in order to obtain usable results. In this method, the water deficit is modeled as a function of factors that are hypothesized to impact the deficit. That is;

$$[6] D = f(\mathbf{X})$$

where  $D$  is the deficit in a given period and  $\mathbf{X}$  is a vector of factors hypothesized to impact  $D$ . These right hand side variables (RHS) are the independent variables and the left hand side variable (LHS) is the dependent variable. Using OLS,<sup>16</sup> the best-fit equation is determined. For example, two of the factors hypothesized to impact the water deficit could be economic activity associated with the Fort ( $FH$ ) and the economic activity in the sub-watershed not associated with the Fort ( $SV$ ). Assuming a linear relationship between the variables we would estimate;

$$[7] D = \beta_{FH} FH + \beta_{SV} SV + \varepsilon$$

where  $\beta_{FH}$  and  $\beta_{SV}$  are the parameter estimates associated with Fort Huachuca's activity and the rest of the sub-watershed, respectively,  $\varepsilon$  is the error term, assumed to have a normal distribution with a mean of zero, and the intercept term is assumed zero, as there would be no measured deficit without human activity.

The share of the deficit directly attributable to the Fort is then ;

$$[8] D_{FH} = \beta_{FH} FH .$$

In addition, a measure of responsiveness of  $D_{FH}$  to changes in the level of the Fort's economic activity can be estimated from [7]. Let  $r$  be responsiveness. Measure  $r$  by:

$$[9] r = \frac{\partial D}{\partial FH} \frac{FH}{D} .$$

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<sup>16</sup> OLS is ordinary least squares, an estimation technique that finds the best fit equation based on the criteria of the minimum sum of errors squared. That is, take the difference between the actual  $D$  and the estimated  $D$  (from the equation) for each observation, square the difference and then add the squared difference together. The equation that provides the smallest value is the best fit line.

For a given level of *FW* and *SV* there is a corresponding level of *D*. The term *r* can then be interpreted as the percentage change in *D* given a 1% change in *FH*, all else constant. This provides information concerning changes in the level of activity at the Fort, as measured by *FH* and captures aggregate changes in the water deficit as the scale of activity at the Fort changes.

While the above example is given as a linear estimation, meaning the impact of the RHS variables is additively separable, the functional form would depend on the hypothesized interactions between the RHS variables.

It is most difficult to hypothesize as to the changes in the estimated share of the deficit attributable to the Fort, because the final estimate would depend on, among other things, the data available and the appropriate functional form. However, given that this modeling approach allows for changes across activities and captures changes within an activity, we can surmise that the CER estimates is again a lower bound on the activity because it ignores anything but primary impacts and does not allow for variation across and within activities.

#### **4.0 Conclusions**

Given Fort Huachuca's obligations under both NEPA and the ESA to mitigate the effects of its operations and activities on the Sierra Vista subwatershed groundwater deficit, it is critical for the Fort and the U.S. Fish and Wildlife Service (USFWS) to utilize models capable of capturing all of the direct, indirect, induced, interrelated, and interdependent effects that would not occur but for the Fort's presence in a rigorous fashion. The population based methods that appeared in the 2002 biological opinion and in the Center for Economic Research (CER) 2006 reanalysis are facially inadequate for this task because they fail to account for water use associated with the vast majority of off post induced economic development on both sides of the border associated with the Fort's presence, fail to capture significant variations in water use intensity, are largely invariant with respect to Fort Huachuca's expenditures, exclude relevant population subgroups, and rely on too many unsubstantiated or arbitrary assumptions.

An economic based method may be far more accurate. Economic based methods tie water deficit liability to the share of economic activity in the region that would not occur without Fort Huachuca's expenditures and overall presence in the subwatershed, and are far more likely to capture all of the direct, indirect, induced, interrelated, and interdependent effects. Three variations include a model based on Fort Huachuca's share of gross regional product, a water intensity model that emphasizes water use by labor market sector, and an econometric model that links Fort Huachuca's expenditures to groundwater pumping activities throughout the subwatershed. All of these models are likely to find a water deficit liability greater than the 54.3% found by Fort Huachuca's 2002 biological assessment. In fact, preliminary data suggest that a model based on share of economic activity may find the Fort's water deficit liability to be as high as 80%.

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