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Peer Review Panel Report

TAMPA PIPELINE PROJECT

Prepared for
Southwest Florida Water Management District
and
City of Tampa

September 11, 2008

1.0 INTRODUCTION

In 2007, the Southwest Florida Water Management District (District) approved a minimum flow and level (MFL) (Rule 40D-8.041(1), FAC) that established a seasonally dependent minimum flow for the lower Hillsborough River of 20 to 24 cubic feet per second (cfs) at the base of the Hillsborough River dam in Tampa. Also, the District approved a recovery strategy to achieve the MFL for the lower Hillsborough River (Rule 40D-80.073, FAC).

In order to help meet the MFL for the lower Hillsborough River, the District and the City of Tampa (City) have agreed to jointly fund and implement a number of projects. One of the potential projects currently being considered in the recovery strategy is the construction of a pipeline to transport water from the middle pool of the Tampa Bypass Canal (TBC) to the base of the Hillsborough River Dam (see Figure 1).

A panel consisting of Phillip R. Davis (SDI Environmental Services, Inc.), Mark A. Ross, Ph.D., (University of South Florida), and Louis H. Motz, (Ph.D., University of Florida) was contracted by the District and the City to conduct a peer review and render an opinion relative to the potential water savings resulting from the proposed pipeline project. Panel members reviewed documents relative to the proposed water savings that were submitted by the District and City, reviewed other documents and materials supporting the concepts and information presented, and participated in meetings at the District's Tampa service office with District and City staff regarding the purpose of the peer review and the information submitted to the panel.

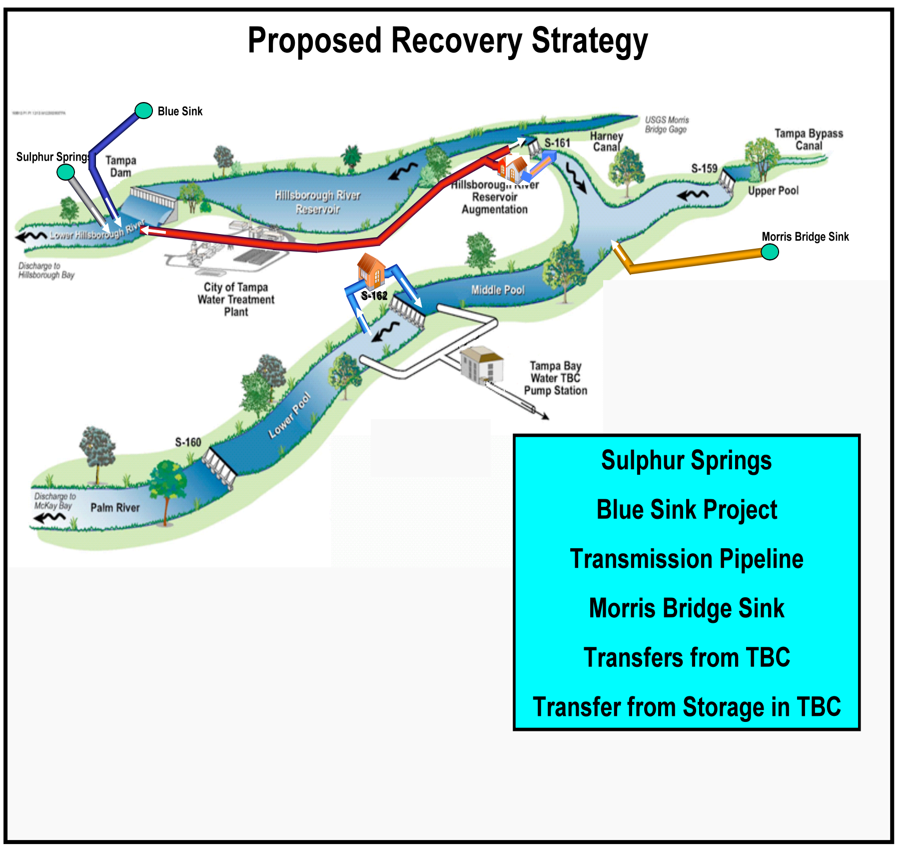

Figure 1. Proposed Recovery Strategy (Source: Southwest Florida Water Management District 2008)

The following material in this letter report represents the collective views of the peer review panel concerning our evaluation of the data, analyses, models, and methodologies used in determining the potential water savings that would be expected as a result of the pipeline project.

1.1 Documents And Reports Reviewed

During this investigation, members of the panel reviewed materials consisting of the joint funding agreement between the District and the City of Tampa (2007), rules of the District for recovery and prevention strategies for MFLs (Southwest Florida Water Management District, 2007), the Harney efficiency spreadsheet analysis prepared by Hazen and Sawyer (2007), the District's comments concerning the Harney efficiency analysis (Chen, 2007), and Hazen and Sawyer's response to the District's comments (Clayton, 2008).

Consulting reports by Environmental Science and Engineering, Inc. (1987), Geraghty & Miller, Inc. (1982 and 1986), and SDI Environmental Services, Inc. (1997 and 2001) were reviewed, as well as reports by the U.S. Geological Survey (USGS) (Goetz, *et al.*, 1978; Knutilla and Corral, 1984; Wolansky and Thompson, 1987; and Woodham, 1991), the U.S. Army Corps of Engineers (1970), and the Florida Bureau of Geology (Motz, 1975). Also, a memorandum by Flannery (1997) and a letter report by Motz (1997) were reviewed. Two additional USGS reports (Ryder *et al.*, 1980, and Stewart and Mills, 1984), which were referenced in the ESE (1987) report, also are included in the list of references.

2. CONCEPTUAL MODEL

2.1 Hillsborough River Reservoir Characteristics

The Hillsborough River Reservoir (Reservoir) is a long, linear reservoir on the Hillsborough River with a watershed area of 624 square miles. The Reservoir stretches from the Hillsborough River dam 12.5 miles northwestward to Fletcher Avenue and varies in width from 100 to 1,000 ft. The average depth of the Reservoir is approximately 15 ft (Goetz, *et al.*, 1976). The water surface area of the Reservoir is approximately 500 acres, and the estimated maximum capacity of the Reservoir is approximately 1.7 billion gallons.

Inflow into the Reservoir comes from a number of sources, including surface water, groundwater and direct rainfall. The primary surface water inflows are from the Hillsborough River (HR), Trout Creek, Cypress Creek, and the ungaged watersheds between the three upstream gaging stations and the Hillsborough River dam. Ungaged groundwater inflow can occur between the upstream gaging stations and the Hillsborough River dam.

Surface water outflow from the Reservoir occurs through the Hillsborough River dam to the lower HR. Under flooding conditions, outflow can also occur through Structure S-161 on the Harney Canal to the middle pool of the TBC. Evaporation occurs directly from the water surface of the Reservoir. Most of the groundwater outflow (leakage) from the Reservoir flows toward the TBC middle pool, which means that, during periods when the TBC is pumped for augmentation, this water is not 'lost' to the system. It is merely re-circulated, reducing the effective augmentation rate.

In addition to the natural inflows and outflows to the Reservoir, anthropogenic inflows and outflows occur because the City has used the Reservoir as a water supply reservoir since the 1940's. The City withdraws water at its treatment plant near the Hillsborough River dam. Intermittently since the 1960's and the 1970's, the Reservoir has been augmented during dry seasons by pumping water from Sulphur Springs or from below Structure S-161 on the Harney Canal. The Harney Canal pump station replaced temporary pumps initially used to augment the Reservoir.

The TBC and its system of structures are designed to bypass floodwaters from the HR to alleviate flooding both upstream and downstream of the Reservoir. The TBC excavation breached the upper Floridan aquifer system, and the TBC acts as a hydraulic sink (drain) to the groundwater system, with the water being held in check by the TBC structures. Because of this groundwater connection and the fact that water levels in the TBC middle pool are at a lower elevation than the Reservoir water levels, some leakage (groundwater outflow) occurs from the Reservoir into the TBC middle pool.

2.2 Reservoir Water Budget

In simple terms, the water budget for the Hillsborough River Reservoir is:

Inflow = Outflow +/- Change in Storage.

A water budget can be developed for any common period of time. Each of the potential inflows and outflows were identified and discussed in Section 2.1. Some water budget components can be measured directly, and others can be estimated using the results or relationships defined by previous studies. There is some level of error involved in measuring or estimating each and every component of the Reservoir water budget.

Hydrologic data have been collected on selected components of inflow and outflow to the Reservoir for many years. Data from late October 2005 to late October 2006 were selected for analysis in developing a water budget. This period follows the reconstruction of gates in the Hillsborough River dam, which significantly improved the measurement of discharges from that structure. This period represents a below normal period of rainfall (45.91 in/yr) during which augmentation occurred on 149 days, nearly 41 percent of the time.

Table 1 presents an average daily water budget for the Reservoir for the October 24, 2005 to October 23, 2006 period. Flows are given in both million gallons per day (mgd) and cubic feet per second (cfs) units. Stream flow accounted for 90 percent of the inflow to the Reservoir. The unmeasured component of ungaged stream flow was estimated from a relationship determined by SDI (1997) using gaged flows at the Trout Creek and Cypress Creek gaging stations. No reported estimate of groundwater inflow to the Reservoir could be found, but it would be expected to be small in relation to surface water inflows. Augmentation from the TBC represented the second largest inflow during the 1-year period.

Public supply water use during the 1-year period represented approximately 60 percent of the total Reservoir outflow. Estimates of evaporation and groundwater leakage by SDI (1997 and 2001) total 10.3 mgd. The difference between total inflow and total outflow for the water budget is 1.9 mgd, which is an error of less than a 2 percent and considered very acceptable.

A review of the daily augmentation rates from January 2003 through October 2006 showed that the City's daily withdrawal rates exceeded the daily augmentation rates every day but one, typically by a factor of two to three. This means that augmentation does not increase the water levels in the Reservoir, but it does diminish the rate of water level decline in the Reservoir by a small amount daily. In other words, the additional augmentation to the Reservoir has essentially no effect on the magnitude of evaporation from the Reservoir or groundwater outflow (leakage) to the groundwater system.

The only water lost to the system is that quantity of water evaporating from the Reservoir. Because augmentation does not significantly affect the surface area of the Reservoir, the quantity of evaporation is essentially unaffected by augmentation.

Table 1. 1-Year Hillsborough River Reservoir Average Daily Water Budget (10/24/2005 – 10/23/2006)

Inflows	CFS		MGD	
Morris Bridge Gaged	147.45		95.30	
Trout Creek Gaged	12.36		7.99	
Cypress Creek Gaged	14.87		9.61	
Ungaged Inflow (SDI 1997)	7.65		4.94	
Total Stream Flow		182.33		117.84
Rainfall	2.64		1.71	
Decrease in Storage (22.16 ft to 21.42 ft stage)	0.65		0.42	
Augmentation	17.03		11.01	
Total Inflow		202.65		130.98
Outflows	**CFS**		**MGD**	
Hillsborough River Dam	47.16		30.48	
S-161 to Harney Canal	15.70		10.15	
Total Stream Outflow		62.86		40.63
City of Tampa (Public Water Supply)	120.89		78.13	
Evaporation (SDI 2001) (average stage = 21.37 ft)	3.60		2.33	
Groundwater Outflow (SDI 2001)	12.38		8.00	
Total Outflow		199.73		129.09

2.3 Regional Impacts of Pumping TBC on Hillsborough Reservoir

The groundwater and surface-water systems in the Reservoir area are hydraulically connected (ESE 1987). Sinkholes, which occur throughout the area, have been mapped in the riverbed of the Reservoir upstream from the dam (Stewart and Mills 1984 and Goetz et al. 1978). When water levels in the Reservoir are higher than the potentiometric surface of the upper Floridan aquifer and water levels in the TBC, leakage can occur from the Reservoir to the upper Floridan aquifer. Some flow may occur to the TBC and the Harney Flats areas, where discharge from the groundwater system into the canal system takes place (Motz 1975). Figure 2 shows the May 2006 potentiometric contour map of the upper Floridan aquifer in the study area.

The amount of groundwater flow from the Reservoir to the TBC is a function of the transmissivity of the upper Floridan aquifer and leakance of the overlying confining unit, the distance between the river and the canal, the leakance and area of the streambed affected by drawdown due to the canal, and the difference in

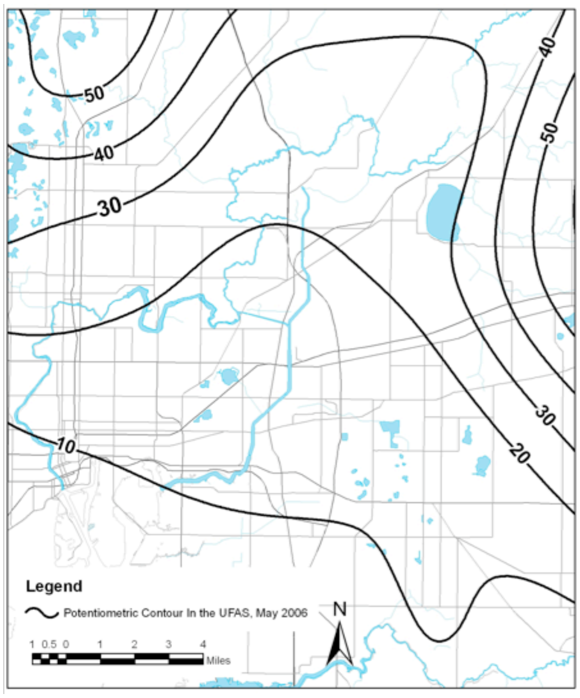

Figure 2. Upper Floridan Potentiometric Contours, May 2006.

water-surface elevation between the river and canal (ESE 1987). Historical water level records for the TBC middle pool indicate that prolonged pumping from the middle pool lowers water levels in the middle pool by approximately two feet (Geraghty & Miller, Inc., 1986).

Computer model scenarios indicated that approximately 10 to 15 percent of the base flow of the TBC might be derived from the Reservoir. Assuming that 15 percent of the water pumped from the TBC into the Reservoir flows back into the TBC, it was indicated that the flow rate from the Reservoir to the TBC was approximately 700,000 gpd per foot of head difference between the water-surface elevation of the Reservoir and the TBC middle pool. Assuming an increased water level difference of 2 ft is caused by augmentation, the estimated re-circulation due to augmentation would be approximately 1.4 mgd. Again, this water is not 'lost' to the system, merely re-circulated.

2.4 Leakage at Structure S-161

Leakage occurs from the HR to the Harney Canal across Structure 161 and through the permeable earthen embankment because of the head differential across the structure. Unfortunately, no measured data exist as to the magnitude of this leakage. However, the upper limit for this value would be significantly less than the combined leakage plus evaporation losses previously estimated by water budget considerations for the Reservoir. Under drought conditions, leakage and evaporation were conservatively estimated to be approximately 10.3 mgd (SDI, 2001). Therefore, an upper limit, believed to be very conservative, for leakage at S-161 would be 15% of 8 mgd, or 1.2 mgd.

This upper limit of 1.2 mgd would be associated with the highest water level differentials across Structure S-161. The Army Corps set an upper operational limit for water level differences across S-161 at 10 ft (ref original Corps operational manual). However, the District manages the structure under a much lower operational head differential of 5 ft or less. During extremely low Reservoir levels, the typical water level differentials are 2 to 4 ft maximum.

It is believed that leakage at S-161 would be around and below the concrete and steel structures and through the earthen embankment, and presumably not over the structure. Thus, leakage could be treated as orifice flow in which case it would be proportional to the square root of head. Alternatively, assuming groundwater seepage dominates, it would be proportional to head to a power of 1. A conservative estimate, and believed to be the most likely scenario, is to consider leakage at S-161 as mostly groundwater seepage, which would yield roughly a linear relationship to changes in head differentials. Thus, assuming 1.2 mgd leakage at 4 ft head differential, the rate of increase in leakage associated with water level changes due to augmentation would be approximately 0.3 mgd/ft.

Assuming a 0.25 ft maximum water level increase from augmentation with <u>no</u> simultaneous withdrawals, the increased leakage across S-161 would be less than 0.1 mgd. Again, this is believed to be a worst case upper limit. Lastly, it should be pointed out that this quantity of water is not a 'loss', merely recirculation, which lowers the effective augmentation rate slightly. In summary, the leakage at Structure S-161 is believed to be insignificant. It is not considered an issue in the consideration of a pipeline.

3. REVIEW OF HAZEN AND SAWYER'S AUGMENTATION EFFICIENCY ANALYSIS

In work conducted for Tampa Bay Water, Hazen and Sawyer (H&S) (2007) utilized a spreadsheet to analyze a methodology to estimate the efficiency of pumping augmentation water from the TBC directly into the Reservoir. No written documentation of the work conducted by H&S was included with the spreadsheet.

Based on a review of the spreadsheet, it appears that H&S used a daily water balance approach to calculate efficiency for those periods (segments) of time when daily augmentation occurred, and rainfall on those days was considered insignificant. The water balance methodology relied on measured data that were readily available, such as gaged stream flow and production data. H&S analyzed data for the period from January 1, 2003 to October 23, 2006.

H&S assembled a daily water balance using measured quantities of inflows and outflows. The resultant cumulative change in Reservoir volume since the day preceding the augmentation period of interest was calculated using differences in Reservoir stage and a calculated stage-volume curve. H&S adjusted this cumulative volume change by the difference between selected inflows (the three stream flows) and selected outflows (two stream outflows and the City of Tampa withdrawals). This net cumulative adjusted volume change would, conceptually, be equal to the quantity of augmentation from the TBC minus any augmentation losses.

The ratio of the net cumulative adjusted Reservoir volume change to the cumulative measured augmentation volume was reported as a calculated "efficiency". This calculation was performed for each day of a selected augmentation period (or segment), with the ending value on the last day of a period being the "efficiency" value assigned to that period.

Using this rationale, H&S identified 12 periods for which they calculated efficiency, with values ranging from -14 percent to 109 percent. Results for four of these periods were disregarded by H&S because of large, unaccounted for inflows and/or possible runoff interference. The remaining 8 "efficiency" values ranged from 71 to 96 percent, implying that between 4 and 29 percent of the augmentation water is 'lost'. The range of results using the H&S methodology indicates that the approach used is technically flawed. Of the 155 days represented in the H&S summary table, 33 days have implausible values, *i.e.*, efficiencies either greater than 100 percent or less than 0 percent. The implausible values and the large range in efficiency occur because the H&S methodology disregards inflow and outflow components that are present but not measured.

Several factors were not taken into consideration using this methodology to calculate efficiency. Runoff from the gaged portions of the watershed was accounted for by using measured stream flow data. However, the three gaging stations only represent approximately 89 percent of the HR watershed, with a large portion of the ungaged area being urban and located adjacent to the Reservoir. Although H&S selected days of no or insignificant rainfall, by their own account they disregarded 4 of the 12 periods they evaluated due to large, unaccounted for inflows.

The H&S methodology also disregarded estimates of direct rainfall inflow to the Reservoir and several outflow components, such as evaporation and groundwater leakage. The disregarded outflow components occur whether or not the Reservoir is being augmented.

By not including these other Reservoir inflows and outflows, the H&S methodology incorrectly calculates the total difference between Reservoir inflow and outflow, thus always producing an unreliable estimate of the "efficiency" of the augmentation process.

3.1 Chen's Review of Hazen and Sawyer's Spreadsheet

Dr. XinJian Chen (2007) of the District conducted a review of the H&S augmentation efficiency analysis. Dr. Chen analyzed the Reservoir inflows and outflows and water use data for the same period used by H&S: January 1, 2003 to October 23, 2006. His analysis indicated potential problems with the H&S methodology and findings, and suggested a much higher efficiency for HR augmentation from the TBC.

For his approach, Dr. Chen carried out a water balance analysis seeking to account for evaporation, leakage at Structure S-161, groundwater seepage, and ungaged runoff into the Reservoir on a daily time step. Dr. Chen's analysis sought to quantify the changes in those fluxes from augmentation through resultant changes in water level in the Reservoir using what was referred to as a *"scale analysis"*. Dr. Chen defined an efficiency factor (e),

$$e = 1 - (E + L + S - Q_r) / Q_a,$$

where E is evaporation,
L is leakage at Structure S-161,
S is groundwater seepage,
Q_r is ungaged runoff,
Q_a is the augmentation rate, and
all terms are at daily time step.

To calculate the daily water balance differences, Dr. Chen first found a daily maximum water level increase. Considering the background stage/volume/ area relationships for the Reservoir, which appears reasonable and generally accepted, and neglecting simultaneous withdraws, Dr. Chen calculated a potential daily maximum water level increase of 0.25 ft.

Based on this scale analysis and using lake evaporation estimates for Florida, evaporation was assumed to increase proportionally as surface area increased due to the 0.25 ft rise in water levels. It should be noted that this assumption is conservative because evaporation from the additional area inundated is neglected. In reality, increased evaporation would just be the increased surface area assumed to be at the open water evaporation rate minus the near shore, vegetated surface ET rate. This littoral or barren moist adjacent soil region may exhibit very similar magnitude combined ET to the open water value. Consequently, Chen derived a small evaporation increase for the Reservoir associated with the calculated water level increase.

Lastly, Dr. Chen attempted to quantify groundwater seepage using several approaches, including increases from augmentation, by attempting to regress total net loss, N ($E + L + S - Q_r$) to stage. However the resultant regression was statistically invalid (R^2 of 0.02) and no reasonable relationship was found. After making several assumptions, Chen estimated a groundwater seepage rate. Combining estimates for increased leakage, seepage and evaporation, Dr. Chen derived an overall efficiency estimate of 99.575% for augmentation water from the TBC.

Overall, a thorough consideration of Dr. Chen's analysis was made by the peer review panel and, while some of his assumed background losses could be arguably different, the methodology appears sound and within reasonable professional limits and approach. His augmentation loss estimates are probably low for reasons cited, but are offset somewhat because Chen considered a maximum water level increase. It should be noted that, considering simultaneous withdraw of augmentation volumes on a daily basis by the water treatment plant or for downstream augmentation, water level rises would not occur.

3.2 Hazen and Sawyer's Response to District's Comments

The peer review panel was provided with a H&S review of Dr. Chen's analysis (Clayton, 2007) in which it was concluded that Chen's analysis was *"absolutely correct for his interpretation of the analysis goals of the original work"*. While, it is not totally clear what was meant by this statement, H&S states that the original intent of the H&S analysis was to look at different augmentation schedules and *"delayed recovery of reservoir volume"*. H&S defined efficiency in a different way than defined by Dr. Chen (*i.e.*, using total losses over incremental losses from augmentation volumes). H&S further stated that Dr. Chen's incremental efficiency estimate would somehow need to be added. Again, noting that if withdrawals are coincident with the recommended augmentation schedule, there would be, at most, only negligible water level changes in the Reservoir.

4. DISCUSSION, CONCLUSIONS AND ALTERNATIVE ANALYSIS CONSIDERATION

The primary objective of this peer review was to determine the projected water saving that might be expected to result from the construction of a pipeline to convey augmentation water pumped from the TBC to the Reservoir based on available studies. Basically, the studies completed in the area are either based on a water budget analysis or a groundwater flow model simulation. The peer review panel developed a conceptual hydrologic model of the Reservoir and a 1-year water budget for the Reservoir using recent data. That 1-year budget relied upon estimates and assumptions of several previous studies.

Hazen & Sawyer (2007) recently conducted an augmentation efficiency analysis for Tampa Bay Water. That study, using data from January 2003 through October 2006, utilized a daily water budget approach only for the periods of augmentation to estimate the potential efficiency of transferring water through the Reservoir. Several components of Reservoir inflow and outflow were disregarded in the H&S analysis. Because the methodology developed by H&S resulted in a significant number of implausible values, the peer review panel determined this study produces unreliable estimates of augmentation efficiency.

The District (Chen, 2007) also reviewed the H&S analysis, modifying and redefining the H&S methodology to estimate augmentation efficiency. While incorporating more of the neglected water budget components, the District analysis was performed on a theoretical basis for a time period of one (1) day, with augmentation but no corresponding withdrawals. The peer review panel determined that while the District's methodology may be more technically sound, its estimate of augmentation efficiency might be too high in part because the methodology used to estimate groundwater leakage was statistically invalid.

Several previous groundwater modeling studies evaluated the flow system in the vicinity of the Reservoir under various pumping conditions. In addition, TBC tests have been conducted assessing the impacts of withdrawing water from the TBC middle pool for augmentation to the Reservoir. From these studies, estimates were made of the quantity of groundwater 're-circulated' between the Reservoir and the TBC as a function of head differentials.

Using previous groundwater modeling results, it is possible to estimate increased groundwater re-circulation due to augmentation pumping. However, none of the studies reviewed tried to quantify the increased evaporation losses due to augmentation.

4.1 Conclusions

The peer review panel felt that the two recent studies to estimate augmentation efficiency failed to recognize one basis premise. In the calculation of augmentation 'efficiency', no distinction was made between water 'lost' to evaporation and water 're-circulated' in the groundwater system between the Reservoir and the TBC. The peer review panel strongly believes that the only water truly lost to the system is that going to evaporation. With regard to augmentation, the only water that can be lost to evaporation is that quantity of **increased** evaporation due to the addition of water pumped for augmentation.

The peer review panel believes that, if both authors of the recent studies were asked to differentiate between **increased** evaporation losses and **increased** groundwater re-circulation, they would agree that the increased evaporation losses would be minor.

Based on best available information, the peer review panel believes that the increased evaporation losses are less than a few tens of thousands to a few hundred thousand gallons per day. Therefore, the projected water savings by transporting the augmentation water in a pipeline rather that through the Reservoir is relatively small.

4.2 Alternative Analysis Consideration

Because of the limitations and deficiencies of all of the previous studies, the peer review panel believes the only approach that might have merit in better quantifying the potential increase in evaporation losses due to augmentation would be to utilize an existing integrated hydrologic model already developed for the area, provided that adequate calibration of that model in the area of the Reservoir and TBC can be demonstrated. However, given that the peer review panel believes the projected water savings realized by a pipeline is relatively small, the panel does not recommend that such an analysis be undertaken. Even if the estimate of increased evaporation losses were underestimated by a factor of two or three, the projected water savings would still be small.

Respectfully submitted,

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