H2H ASSOCIATES, LLC
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WATER RESOURCES IMPACT ASSESSMENT REVIEW
PROPOSED WASHINGTON LOOP FILL PIT
PUNTA GORDA, FLORIDA

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EXECUTIVE SUMMARY

The H2H Associates, LLC Specialized Geological Modeling Group (H2H) was contracted by Charlotte County to review a permit application submitted by the Triple D Investment Group L.L.C. for the proposed Washington Loop Fill Pit (Pit) that included a water budget analysis prepared by Johnson Engineering (JE); comment on the completeness of their assessment of potential impacts on groundwater and nearby water bodies; and recommend a consistent methodology for the development of groundwater resource impact assessments from which Charlotte County can review this and similar proposals in the future.

In order to achieve these objectives H2H reviewed documents concerning the proposed Washington Loop Fill Pit provided to H2H by Charlotte County; identified, obtained, and reviewed publicly available documents and reports relevant to the hydrogeology and hydrology of the region surrounding the Pit; and developed a water budget analysis and a cursory steady-state numerical groundwater flow model that we used to qualitatively evaluate the sensitivity of model-predicted impacts on water table elevations associated with the proposed Pit construction to variations in the most relevant modeling parameters.

The assumptions underpinning the analyses and recommendations presented in this report are based on the following hydraulic conceptualization, which we derived from the existing reports and data. The proposed Pit will be entirely constructed in the surficial aquifer, which is hydraulically separated from the underlying Intermediate and Floridan aquifer systems by a layer of clay. The proposed Pit will be hydraulically connected to the adjacent Myrtle Slough and Shell Creek. Groundwater flow between the Pit and the water bodies is governed by water table elevations. Finally, under natural conditions both runoff and recharge from the Pit and surrounding areas flows to either Myrtle Slough or Shell Creek via overland flow or groundwater flow through the surficial aquifer.

The purpose of the hydrologic component of the County’s environmental impact assessment should be to assess potential reductions in water flow to Myrtle Slough and Shell Creek, potential reductions in groundwater level elevations that could negatively impact the nearby wetlands, and potential contamination to the surficial aquifer that could arise from proposed activities.

The water budget analysis submitted by JE does not adequately assess any of these potential impacts. Their calculations fail to account for the fact that both runoff and recharge from the Pit area will likely flow to either Myrtle Slough or Shell Creek and therefore it is the net change in the sum of runoff and recharge that needs to be estimated. Also, their analysis focused only on average conditions whereas predictions under drought conditions could reveal substantially different conclusions and therefore provide a more realistic bracket on potential impacts that could occur in any given year. Finally, there is insufficient data to evaluate the impacts to local water levels and stream flows due to estimated changes in recharge or runoff associated with the development and operation of the Pit.

By performing the same type of water budget analyses but focusing on a drought condition scenario and the associated reduction in flow to Myrtle Slough and Shell Creek, we conclude that construction of the Pit could result in a net change in recharge in the Pit area of as much as -24.68 in/yr under, which equates to a net reduction in flow to the adjacent water bodies of as much as 37.0 in/yr or approximately 175,000 gallons per day. Furthermore, evaporation from the Pit during dry periods could drain water from Myrtle Slough and/or Shell Creek if the water table elevation in the pit falls below the slough and creek channel bottoms.

Additional data and a more detailed analysis is needed in order to evaluate the potential changes to groundwater levels or stream flows that could occur as a result of Pit construction and operation. Both onsite and offsite monitoring wells are needed to determine groundwater levels in the Pit area and hydraulic gradients toward the adjacent creeks. Flow measurements from the creeks will also be required in order to compare estimated flow losses to natural levels and thereby assess potential relative impacts. Once this data is collected, more detailed analyses should be performed in order to estimate groundwater level and stream flow impacts associated with Pit operation during drought periods. Groundwater modeling is the most suitable approach to perform these analyses because both groundwater levels and stream flows can be predicted under both natural and post Pit development conditions in both normal and drought periods.

INTRODUCTION

The H2H Associates, LLC Specialized Geological Modeling Group (H2H) was contracted by Charlotte County to review a permit application submitted by the Triple D Investment Group L.L.C. for the proposed Washington Loop Fill Pit (Pit) that included a water budget analysis prepared by Johnson Engineering (JE); comment on the completeness of their assessment of potential impacts on groundwater and nearby water bodies; and recommend a consistent methodology for the development of groundwater resource impact assessments from which Charlotte County can review this and similar proposals in the future. In order to achieve these objectives H2H performed the following tasks.

- Reviewed documents concerning the proposed Washington Loop Fill Pit provided to H2H by Charlotte County, which included the following.
    - Ardaman & Associates, Inc. - Subsurface Soil and Water Table Exploration for "Washington Loop Fill Pit" Charlotte County, FL, 2006.
    - Excavation Construction Activity Narrative Washington Loop Fill Pit Triple D Investment Group, L.L.C., 2008.
    - Engineering diagrams prepared by Johnson Engineering for Triple D Investment Group: sheets 3-9.
    - Washington Loop Fill Pit Water Budget Analysis prepared by Johnson Engineering for Triple D Investment Group L.L.C., 2008.

- Identified, obtained, and reviewed publicly available documents and reports relevant to the hydrogeology and hydrology of the region surrounding the Pit. The most significant of those documents included the following.
    - Southwest Florida Water Management District (SWFWMD) - Integrated Northern Tampa Bay Hydrologic Model: Overview of Conceptual Basis, Power Point presentation with reference to ET maps.
    - SWFWMD - Peace River Comprehensive Watershed Management Plan - 2001
    - US Geological Survey (USGS) - Generalized Thickness and Configuration of the Top of the Intermediate Aquifer, West-Central Florida, WRIR 84-4018, 1984.
    - USGS - Hydrogeology of the Surficial and Intermediate Aquifer Systems in Sarasota and Adjacent Counties, Florida, WRIR 96-4063, 1996.
    - US Department of Agriculture, National Resources Conservation Service - Soil Survey Geographic (SSURGO) database for Florida, 1990
    - Florida Department of Environmental Protection (FDEP) – Drainage Basins GIS Coverage for Charlotte County, 1998.
    - Florida Geological Survey (FGS) – Lithologic Database, 2008.

- Developed a water budget analysis and a cursory steady-state numerical groundwater flow model that we used to qualitatively evaluate the sensitivity of model-predicted impacts on water table elevations associated with the proposed Pit construction to variations in the most relevant modeling parameters including: boundary conditions, hydraulic conductivity, rainfall, and evapotranspiration.

- Developed this report discussing our assessment of JE's water budget analysis and our recommendations for a modeling-based approach that would provide a more effective tool for evaluating and mitigating potential groundwater impacts from this and future proposed developments.

FOCUS OF STUDY

It is our contention that the purpose of the hydrologic component of the County's environmental impact assessment should be to assess:

1. potential reductions in water flow to Myrtle Slough and Shell Creek;
2. potential reductions in groundwater level elevations that could negatively impact the nearby wetlands; and
3. potential contamination to the surficial aquifer that could arise from proposed activities.

The proposed configuration of the Pit indicates that it will be developed in the surficial aquifer. The focus of our analysis was to determine if JE's assessment adequately evaluated potential impacts of the proposed Pit construction on flows into Myrtle Slough and the Shell Creek from the Pit area, and groundwater levels in the vicinity of the Pit, as a consequence of the proposed development. Our analysis was based on the following conceptualization about the hydraulic connection between surficial aquifer and the water bodies.

- Both Myrtle Slough and Shell Creek are hydraulically connected to the surficial aquifer, which is the aquifer that will be impacted by the Pit according to the engineering diagrams provided by JE.
- Water flow between the water bodies and the surficial aquifer is governed by water table elevations.
- Under natural conditions, all runoff and recharge from the proposed Pit area and the surrounding area will flow to either Myrtle Slough or Shell Creek via overland flow or groundwater flow through the surficial aquifer.

WATER BUDGET ANALYSIS

Johnson Engineering's Analysis

JE's assessment of potential groundwater impacts due to the development of the Pit stemmed primarily from water budget calculations using published data for pre- and post-Pit development scenarios. Their calculations are based on the equation:

Recharge = P – E – T – R

where: P = precipitation,
E = evaporation,
T = transpiration, and
R = runoff; and the following data:

- average annual precipitation = 52 in/yr, source USGS;
- average evaporation and transpiration combined (ET) = 39.4 in/yr, source JE;
- average lake evaporation = 52 in/yr, source FLDEP;
- average natural runoff = 12 in/yr, source USGS; and
- average post-development runoff in the Pit area = 2.76 in/yr into the Pit, source JE.

Their calculations were as follows.

- Pre-development: recharge = 52 – 39.4 – 12 = 0.6 in/yr.
- Post-development: recharge = 52 – 52 – (-2.76) = 2.76 in/yr.

From these calculations, JE concluded that recharge to the surficial aquifer in the Pit area will increase as a result of the development of the Pit due to runoff directed into the Pit from the surrounding area created by developments on the west side of the Pit.

H2H Analysis

The data used for the water budget analyses are consistent with accepted ranges for the respective data in Southwest Florida and the water budget equation used to predict recharge is standard in hydrogeological investigations. In this case, the application of the water budget equation does not adequately address the purpose of the assessment as it fails to estimate potential impacts on flow in Myrtle Slough or Shell Creek or the magnitude of potential changes in groundwater elevations that could adversely impact local wetlands. This is because local groundwater recharge and runoff flow to the water bodies. A reduction in either recharge or runoff will therefore diminish those flows.

From the perspective of impact on flows, the only relevant component of the water budget analysis is the difference between evapotranspiration over land (39.4 in/yr) and lake evaporation (52 in/yr), which is a loss of 12.6 in/yr. Changes to runoff are misleading because that water will flow to the water bodies whether it travels as overland flow (i.e. natural conditions) or groundwater flow after induced recharge through the Pit as calculated for the post-development scenario. Thus JE's calculated 2.76 in/yr of recharge to the Pit does not represent an increase in flow to the streams from natural conditions because it is derived from runoff beyond the Pit that would have flowed to the streams regardless of the Pit construction. The calculations are as follows:

- Pre-development: flow to water bodies = 12 (runoff) + 0.6 (recharge) = 12.6 in/yr.
- Post-development: flow to water bodies = -2.76 (runoff) + 2.76 (recharge) = 0.0 in/yr.
- Net loss in flow due to development = 12.6 – 0 = 12.6 in/yr

Given the proposed area of the Pit (63.73 acres), the increased evaporation will result in an approximate reduction of flow to the water bodies of:

> 63.73 acres x 43,560 ft^2/acre x (12.6/12 ft/yr) / 365 days/yr / 86,400 sec/day = 0.09 cfs.
> 0.09 cfs x 7.48 gallons/cubic foot x 60 sec/min x 60 min/hr x 24 hr/day = 58,165 gallons/day.

The focus on average conditions in the water budget analysis is a second deficiency in the assessment because the most significant impacts on the environment are likely to occur during drought conditions. Recharge tends to increase during droughts because water table elevations fall below the root zone thus reducing or eliminating transpiration. To illustrate this point, a water budget analysis using the 2006-2007 drought conditions provides the following prediction of impacts on recharge and flows.

- P = 43.68 in/yr for the southern part of the SWFWMD, source SWFWMD.
- ET = 15 in/yr when water table elevations drop below the root zone, source SWFWMD.
- R = 10.08 in/yr which was calculated by H2H by reducing runoff by the same percentage as the reduction in precipitation.
- R in the Pit area after development = 2.24 in/yr which was calculated by H2H by reducing runoff by the same percentage as the reduction in precipitation.

- Pre-development: recharge = 43.68 – 15 – 10.08 = 18.6 in/yr.
- Post-development: recharge = 43.68 – 52 – (-2.24) = -6.08 in/yr.

- Pre-development: flow to water bodies = 10.08 (runoff) + 18.6 (recharge) = 28.68 in/yr.
- Post-development: flow to water bodies = -2.24 (runoff) – 6.08 (recharge) = -8.32 in/yr.
- Net loss in flow due to development = 28.68 – -8.32 = 37.0 in/yr.

During drought conditions, these calculations indicate that the increased evaporation will result in an approximate reduction of flow to the water bodies of:

> 63.73 acres x 43,560 ft^2/acre x (37.0/12 ft/yr) / 365 days/yr / 86,400 sec/day = 0.27 cfs.
> 0.27 cfs x 7.48 gallons/cubic foot x 60 sec/min x 60 min/hr x 24 hr/day = 174,493 gallons/day.

Focusing on drought conditions therefore indicates a greater than three-fold larger impact on flows into the water bodies than was estimated for the average conditions. Moreover, the Pit can become a groundwater sink during drought conditions if water table elevations fall below the elevations of Myrtle Slough and/or the channel of Shell Creek. This is because the proposed elevation of the bottom of the Pit (~ -31.52 ft) is well below those elevations. The Pit will therefore remain flooded and subject to evaporation even when water table elevations fall below Myrtle Slough and Shell Creek. Under these conditions, the water bodies will lose water to the surficial aquifer and local flow will be directed to the Pit due to extractions by evaporation.

Hypothetical water table configurations associated with average and drought conditions are shown in Figure 1. The best way to constrain probable water table configurations due to variations in rainfall, evaporation, and the Pit configuration, and the resulting potential impacts on flows in the water bodies and groundwater levels beneath the wetlands is through the development and use of a groundwater flow model. Benefits of and requirements for such a model will be discussed later in this report.

Of lesser importance but worth considering, JE's water budget analysis did not address the impacts of changing land-use in the Pit area. The Pit will be placed on land that is currently used for agriculture wherein roughly half of the land is reportedly used for silviculture and the other half for row crops. The main issue that should be addressed is irrigation. If irrigation is used and derived from the surficial aquifer, the post-development change in recharge will likely be higher than estimated because evaporation from irrigated lands is typically higher than average. If, on the other hand, irrigation is derived from the intermediate or Floridan aquifers, additional reductions in recharge to the surficial aquifer can be expected due to the lack of irrigation-recharge derived from the lower aquifers.

Finally, the potential impact on water quality in the nearby water bodies was not addressed in JE's analysis. Because it will be flooded during its operational life, the surficial aquifer will be more vulnerable to contamination in the Pit area than it is under natural conditions.

MODELING-BASED ANALYSIS

The main limitations of a water budget analysis stem from the simplicity of the tool. Such analyses tend to rely on published data for broad regions and as such are most useful for cursory evaluations designed to bracket potential future conditions across broad regions such as sub-watersheds or river basins. The method is not well suited for site-scale predictions because the calculations are rarely based on site-scale data. In the Washington Loop case, the most probable long-term change in recharge due to construction of the Pit will likely fall somewhere between the values predicted by the water budget calculations for average and drought conditions (+2.06 in/yr - -6.08 in/yr). From these calculations, it is apparent that the Pit could create a groundwater mound under average or high rainfall conditions and a sink under drought or less than average rainfall conditions.

In order to make more reliable predictions of impacts on groundwater levels and stream flows in the Pit area, a more refined method of analysis that is based on site-specific data is needed. Numerical groundwater modeling is one such method and is well suited for this type of analysis because a properly constructed groundwater model can be used to quantify potential water table declines and reductions in flow to the surrounding water bodies due to Pit construction and operation under any set of environmental conditions. Additionally, a groundwater flow model can be used to evaluate potential water quality impacts as well as water quantity impacts.

Mathematical Basis for Groundwater Models

A numerical groundwater flow model is a tool used to simulate 2-D or 3-D groundwater flow through a conceptualized hydrogeologic environment and then make predictions about how the simulated flow might change as a consequence of natural or anthropogenic changes to the conceptualized environment. The simulated flow system is created by solving numerical approximations to one or more mathematical equations describing flow through the conceptualized environment between neighboring points on a grid or mesh of nodes covering the modeled region. In every case, the mathematical component of the model is based on some form of a simple mass-balance equation:

flux of water out of any region = flux of water into that region

where flux out can include:

- natural groundwater discharge,
- anthropogenic extractions (i.e. from a well or dewatered quarry),
- evaporation,
- transpiration, and/or
- groundwater flow out of the modeled region into an adjacent region;

and flux in can include:

- recharge from rainfall,
- recharge from irrigation,
- anthropocentric injections (i.e. from an aquifer storage and recovery operation),
- leakage into the aquifer from surface water bodies,
- leakage into the aquifer from vertically adjacent aquifers, and/or
- groundwater flow into the modeled region from an adjacent region;

and, in most cases, some form of the Darcy equation for flow through a porous media:

$q = (K) \times (dh/ds)$

where:

- q = discharge of water through a unit area of aquifer,
- K = permeability of the media through which the flow occurs for water,
- dh = change in hydraulic head across the region of flow, and
- ds = distance across which the water flows.

The Darcy equation has proven to be a sound model for groundwater flow through any media in which the distribution of porosity and permeability is such that the resulting flow is diffuse, such as sand and gravel, and in some cases limestone. The equation is not appropriate however for any environment in which the porosity and permeability is organized into channels such as karst limestone or fractured rocks of low permeability. In those types of environments, multiple equations are necessary to represent flow through the channels and into and out of the channels from or into the surrounding rock matrix. The accuracy of the model predictions is therefore primarily dependant on the degree to which the conceptualized model framework honors the real-world environment, and the accuracy of the explicit and implicit assumptions underlying the modeling approach.

Components and Characteristics of a Well-Constructed Groundwater Model

The key components of a well-constructed groundwater flow model include:

- an appropriate delineation of a region to include in the model;
- appropriate boundary conditions describing the magnitude of flow into and out of the modeled region;
- the thickness of the aquifer(s) addressed by the model;
- a characterization of the lithology of the aquifer(s) across the modeled region;
- measured or acceptable ranges for rainfall, evaporation, transpiration, groundwater elevations, stream stage and flows, and hydraulic conductivity for the lithologic units in the modeled region; and
- acceptable calibration to groundwater levels and stream stage and flows in the modeled region, as well as clearly defined criteria for “acceptable” calibrations.

An appropriate delineation of a region to include in the model must be significantly broader than the proposed Pit area and should ideally extend out to measurable hydrologic divides. In the Washington Loop area, those divides include:

- Shell Creek to the north;
- Myrtle Slough to the east; and
- a watershed divide to the south that separates flow to Shell Creek from flow to the Gulf of Mexico.

Boundary conditions define how groundwater flows across the physical external boundaries of the model. Generally speaking, there are six boundaries to any roughly block-shaped 3D model: top, bottom, and four sides. There are three basic types of conditions that describe groundwater flow across any section of each of those boundaries. A “no-flow” boundary does not allow flow to cross. This condition describes natural divides between adjacent groundwater basins, impermeable barriers, and boundaries parallel to groundwater flow. This condition is an appropriate descriptor for the watershed divide to the south of the Pit that separates flow to Shell Creek from flow to the Gulf of Mexico; for the clay layer separating the surficial aquifer from the underlying Intermediate and Floridan aquifer systems; and for a roughly north-south line west of the proposed Pit where groundwater flow is directed toward Shell Creek.

“Constant head” boundaries allow groundwater to cross at a rate dependent on the hydraulic gradient defined by model-derived heads internal to model region and head values prescribed for the specified part of the boundaries. This type of condition is most effectively used when there is sufficient data to describe groundwater elevations and it is possible to estimate the flux across the boundary. Appropriate assignments for the Washington Loop area would be the trends of Myrtle Slough and Shell Creek where stage and flow can be directly measured, and possibly for an east-west line south of the Pit area which would have to be defined by groundwater levels measured in wells.

“Constant flux” boundaries are similar to constant head boundaries except that they are used when the flux across the boundary can be more readily defined than hydraulic head at the boundary. The most common such boundary is the upper surface across which the flux is defined by recharge. Both constant flux and constant head boundaries can be defined as actual constant values (i.e. 18.6 in/yr recharge) or by functions that describe the change in head or recharge along or across the boundary through time.

Aquifer thickness is an important variable because it significantly impacts the magnitude of predicted water level declines and groundwater velocities. In the case of the proposed Pit area, the critical value is the thickness of the sediments between the land surface and the clay layer separating the surficial aquifer from the underlying Intermediate and Floridan aquifer systems.

Characterizing lithologic variation within the modeled aquifers is critical to an accurate prediction of groundwater flow paths and therefore the localization of potential impacts on groundwater levels associated with spatially constrained events or developments. This is most often done through the evaluation of boring logs, geophysical surveys, and/or geologic and soil maps. The results are used to support the choice of mathematical formulations of the groundwater flow equations that form the basis of the model, i.e. homogeneous or heterogeneous, and/or isotropic or anisotropic.

Finally, model calibration is the act of varying input parameters that are poorly constrained by data until the simulated groundwater levels and fluxes compare favorably to observations of real-world conditions. Hydraulic Conductivity (K) (Transmissivity (T) for 2D models) and recharge are the most commonly varied parameters used in the calibration process because these values are rarely, if ever, well constrained across the entire modeled region. The final model values for these parameters should fall within accepted ranges for the values defined by site-specific or regional data. Groundwater levels and fluxes are the calibration targets because these values are relatively easily constrained by data and a model that matches observed values for these conditions can be reasonably assumed to provide accurate predictions of groundwater levels, flow paths, and velocities resulting from changes made to the configuration of parameters in the calibrated model.

It is critical that groundwater models be calibrated to both groundwater levels and fluxes to reduce the non-uniqueness of the model results. For example, numerous configurations of recharge and K can produce nearly the same simulation of groundwater levels but each one of those simulations will likely yield different fluxes across the model boundaries. But, by matching both levels and fluxes, the number of parameter configurations that produce the same or similar results is greatly reduced.

Recommended Characteristics and Data Requirements for a Washington Loop Area Groundwater Model

The hydrogeology of the Washington Loop area relevant to the proposed Pit consists of:

- a surficial aquifer composed of sand and silty sand probably greater than 130 feet thick,
- a layer of clay underlying the surficial aquifer that separates it from the Intermediate and the Floridan aquifer systems below,
- flowing streams to north (Shell Creek) and east (Myrtle Slough) of the proposed Pit,
- a watershed divide to the south but distant from the proposed Pit that separates the Shell Creek and Gulf of Mexico watersheds, and
- apparent northward linear flow toward Shell Creek on the west side of the proposed Pit.

Based on this conceptualization, the Darcy equation is an appropriate predictor of groundwater flow and either a 2-D or 3-D model could be constructed to adequately simulate flow in the surficial aquifer through the Pit to Myrtle Slough and Shell Creek. The resulting model could then be used to predict the impacts on groundwater elevations in the vicinity of the Pit and groundwater discharge to Myrtle Slough and Shell Creek as a consequence of the Pit construction and operation.

The model boundaries should include the natural hydrologic divides created by Shell Creek to the north and Myrtle Slough to the east, an arbitrary east-west line well to the south of the proposed Pit, and a north-south line well to the west of the proposed Pit roughly perpendicular to Shell Creek. Constant head boundary conditions should be assigned to both creeks and the arbitrary southern boundary. No-flow conditions should be assigned to the north-south line to the west. Figure 2 shows a box surrounding the general area that should be addressed in a well-constructed groundwater model.

The following data will be needed to adequately define the boundary conditions:

- stream stage data for Shell Creek and Myrtle Slough;
- minimum of three wells along the southern model boundary from which groundwater levels can be measured; and
- minimum of two additional wells along the western model boundary from which groundwater levels can be measured.

We could not find any publically available data defining the thickness of the surficial aquifer in the Pit area. The borings installed by Ardaman & Associates are not situated along the required boundaries nor are they deep enough to constrain the thickness of the surficial aquifer. Ardaman & Associates installed eight borings in the Pit area that were terminated in sand and ranged in depth between 30 and 50 feet below land surface. They installed three deeper borings near the on-site wetlands to depths of between 120 and 130 feet below land surface. None of the borings intersected the clay presumed to underlie the surficial and separate it from the underlying Intermediate and Floridan aquifer systems. Available boring data from outside the Pit area but in the general vicinity indicates that the clay layer should be encountered at around 110 feet below land surface.

Lithologic variation in the Pit area can be sufficiently delineated from the boring data provided by Ardaman & Associates and regional data collected and maintained by the Florida Geological Survey.

A survey of topographic and aerial maps for the region reveals that there are other open water bodies near the proposed Pit that should be included in a modeling analysis. The size and depths of these features should be measured.

Sufficient data is available from the USGS and SWFWMD for ranges in rainfall, lake evaporation, evapotranspiration, and runoff. Site-scale data for these parameters would however increase the confidence in the model simulations and predictions.

Finally, there is not sufficient data available for stream flows or groundwater levels to develop an acceptably calibrated groundwater model. Three wells should be completed in the proposed Pit area to constrain groundwater levels beneath the site and gradients between the proposed Pit and Myrtle Slough and Shell Creek. Six additional wells (including the five boundary wells described above) should be installed to constrain groundwater levels along the southern and western model boundaries and the gradient between the Pit area and Shell Creek. Three to four of the nine total wells should be completed from borings that penetrate to the lower clay layer thereby defining the thickness of the surficial aquifer in the Pit area.

Stream stage and flow measurements should be obtained for the Slough and Creek from two locations in Myrtle Slough and three locations in Shell Creek allowing for a quantification of flow gains or losses in each creek across the modeled region. Data collections from the wells and stream stage/flow stations should be performed over as short a time period as possible to ensure that all measured values are reflective of the same hydrologic condition. The combined dataset should be obtained at least twice, once during average/high water level conditions, and once during low water level conditions. Figure 2 depicts a distribution of boundaries and site wells, and stage and flow measurements that would fulfill the data requirements.

CONCLUSIONS

- Reductions in groundwater levels in the vicinity of Myrtle Slough and Shell Creek, and reductions in flow from the surficial aquifer to those water bodies are the two most critical potential environmental impacts that should be addressed for the proposed Pit.
- The water budget analysis submitted by JE does not adequately assess either of these potential impacts. Their calculations fail to account for the fact that both runoff and recharge from the Pit area will likely flow to either Myrtle Slough or Shell Creek and therefore it is the net change in the sum of runoff and recharge that needs to be estimated.
- Any water budget analysis should address drought level conditions in addition to average conditions in order to bracket the potential impacts on the water bodies that occur in any given year.
- Water budget analyses performed for average and drought condition estimates of rainfall, lake evaporation, evapotranspiration, and runoff indicate that construction of the Pit could result in a net change in recharge in the Pit area of between +2.16 in/yr under average conditions and -24.68 in/yr under drought conditions; and a net reduction in flow to the water bodies of between 12.6 and 37.0 in/yr or approximately 58,000 and 175,000 gallons per day.
- Additional data is required to adequately predict potential changes to groundwater levels and stream flows that could occur as a result of Pit construction and operation, particularly surficial aquifer water levels from onsite and offsite groundwater monitoring wells and stream flows from the adjacent Myrtle Slough and Shell Creek.
- A groundwater modeling approach is better suited than a water budget analysis for an evaluation of potential impacts on groundwater levels and discharge to the water bodies associated with the construction and operation of the proposed Pit.

RECOMMENDATIONS

- Install between three and nine surficial aquifer monitoring wells positioned to define the hydraulic gradients between the proposed Pit area and the adjacent Myrtle Slough and Shell Creek.
- Collect water levels measurements from those wells and define the hydraulic gradients between the Pit area and the adjacent creeks during both normal and drought or dry periods.
- Measure stream flows in Myrtle Slough and Shell Creek during both a normal and dry period to establish pre-development flows from which predicted impacts can be assessed.
- The County should consider requiring groundwater modeling aimed at predicting groundwater level declines associated with Pit development and operation and the impact of those predicted declines on flows to adjacent streams.
- The County should consider developing an independent groundwater model at a scale sufficient to address this and probable future developments in the Washington Loop area. Such a model would provide an independent and consistent means by which the current and future development proposals can be evaluated.

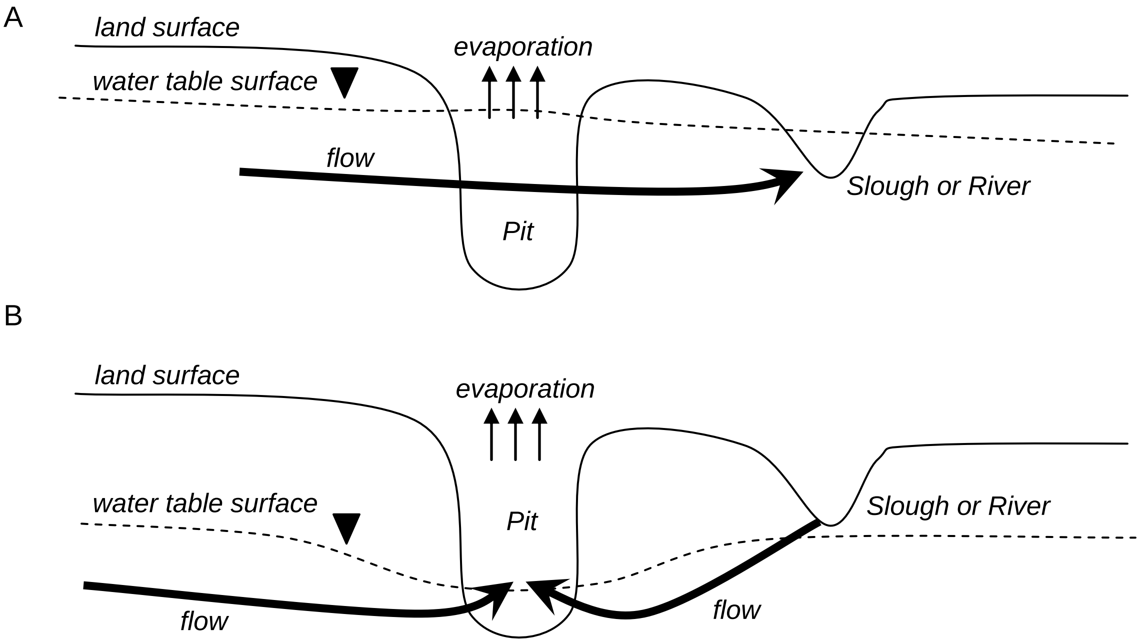

Figure 1. Hypothetical water table configurations between the proposed Pit and the nearby Myrtle Slough and Shell Creek during (A) average conditions and (B) drought conditions where water table elevations fall below the slough and river. During average conditions any potential depression in the water table around the Pit is not likely to result in loss from the slough or river, however during drought conditions, evaporation from the Pit could result in loss because the Pit will remain saturated after water table elevations fall below the slough and river.

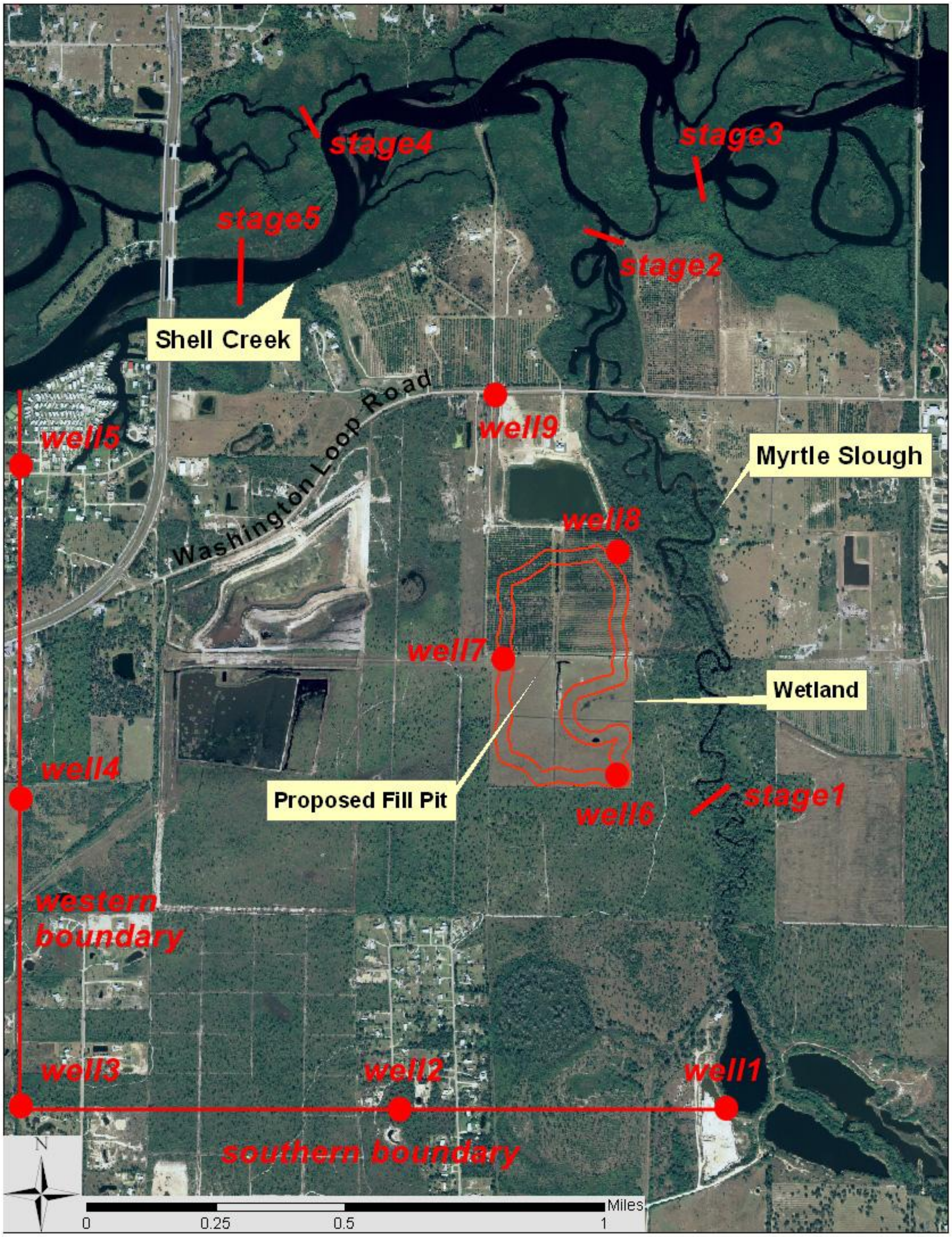

Figure 2. Aerial map showing the location of the proposed Pit relative to the recommended locations of groundwater model boundaries and required data points.