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Memorandum

To: File, Anna Truszczynski, Feng Jiang, Bill Frechette, John Ariail, Christine Voudy, Edward Rooks, Jamie Lancaster, and William Cook

From: Wei Zeng

Date: November 16, 2023

Re: Summary of hydrologic analyses on Twin Pines Mineral's (TP's) Charlton County project

Introduction

On November 13, 2020, TP submitted an application to Georgia Environmental Protection Division (EPD) for a Surface Mining Permit, which would allow TP to conduct mining activities along the Trail Ridge in Charlton County, Georgia. On June 12, 2020, TP submitted an application to EPD for a Groundwater Withdrawal Permit, which would allow TP to withdraw up to 1,000 gallons per minute (gpm) or 1.44 million gallons per day (mgd) from the Floridan Aquifer as part of the mining operation.

Geologists, modelers, and managers of the Water Supply Program have two roles in EPD's review of TP's applications. In the first role, the Water Supply Program needs to determine the availability of water from the Floridan Aquifer to support the intended withdrawal and the impact of such a withdrawal. This is part of the Water Supply Program's regulatory review conducted as part of the water withdrawal permitting process. In the second one, the Water Supply Program functions as an internal technical consultant to EPD's Land Protection Branch (Surface Mining Unit) in its review of the surface mining permit application and supporting materials, especially on different aspects of geology and hydrology relating to TP's proposed mining operations.

As part of TP's mining operation, activities that may have an impact on groundwater or surface water include:

(1) Disturbing a black sand layer serving as a confining feature along the Trail Ridge and replacing it with a layer of bentonite to mimic the original hydraulic properties,

(2) Pumping up to 1,000 gpm (or 1.44 mgd) of water from the Floridan Aquifer to fill/refill TP's Water Management Pond System and provide process water for the operation,

(3) Managing the Water Management Pond System to provide industrial process water in the mining operation and to provide storage space for high inflows to avoid discharges,

(4) Dewatering a mining pit (500 feet long by 100 feet wide by 50 feet deep) at the rate of 783 gpm utilizing storage space in the Water Management Pond System, and

(5) Evaporating up to 1,000 gpm of water from the Water Management Pond System using eight EcoVAP 120 Gen2 Series modular units.

In this memorandum, I summarize the Water Supply Program's assessments of the hydrologic implications (on the Okefenokee Swamp and on the St. Mary's River) from these mining-related activities. These assessments and conclusions are based on the latest technical information submitted by TP in its applications or responses to EPD's request for additional information.

On April 19 and 20, 2023, EPD associates visited the St. Mary's River and the Okefenokee National Wildlife Refuge (ONWR) and received guided tours of the river and the swamp. Interactions among EPD associates, Emily Floore, representative of the St. Mary's Riverkeeper, and Michael Lusk and other ONWR staff revealed additional questions that need to be answered in EPD's review process. I will use a section of this memorandum to summarize the interactions and action items that resulted from such.

<u>Disturbance of Sediment Structure and TP's Groundwater Modeling of Impacts</u>

One of the central questions associated with TP's mining project is whether near surface groundwater hydrology along Trail Ridge, especially in the area east of the Okefenokee Swamp and west of the Trail Ridge, will be altered as a result of the mining operation, i.e. disturbing the original layered sediment structure, removing the original black sand layer, homogenizing soil particles, and potentially changing hydraulic properties. See Figure 1 for a map of the Okefenokee Swamp and its various hydrologic compartments. The proposed mining site is roughly 3 miles southeast of the southeastern corner of the swamp. See Figure 2 for the domain of TP's groundwater model relative to the Okefenokee Swamp and the Trail Ridge.

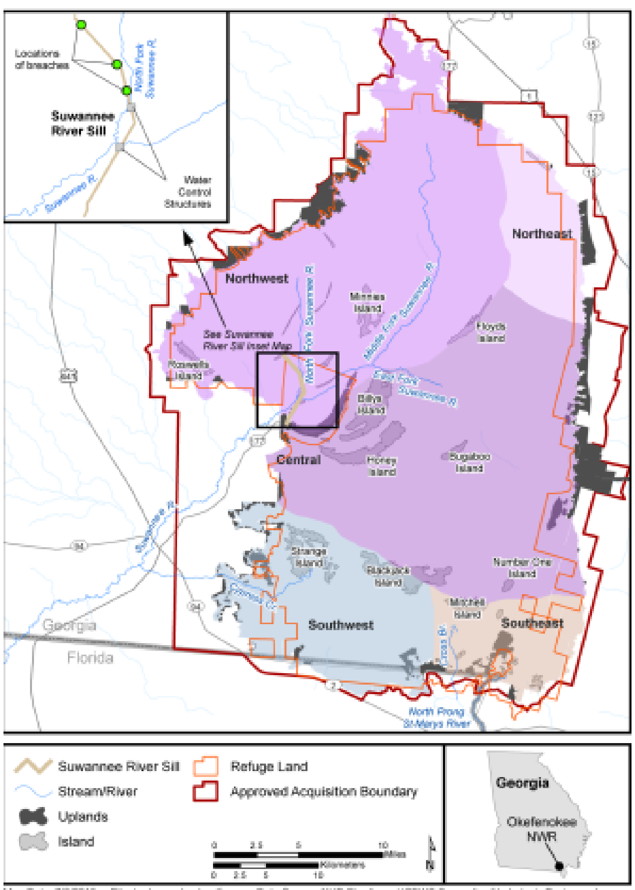


Figure 1. Drainage areas in Okefenokee Swamp (from Water Resource Inventory and Assessment: Okefenokee Wildlife Refuge by USFWS (August 2015))

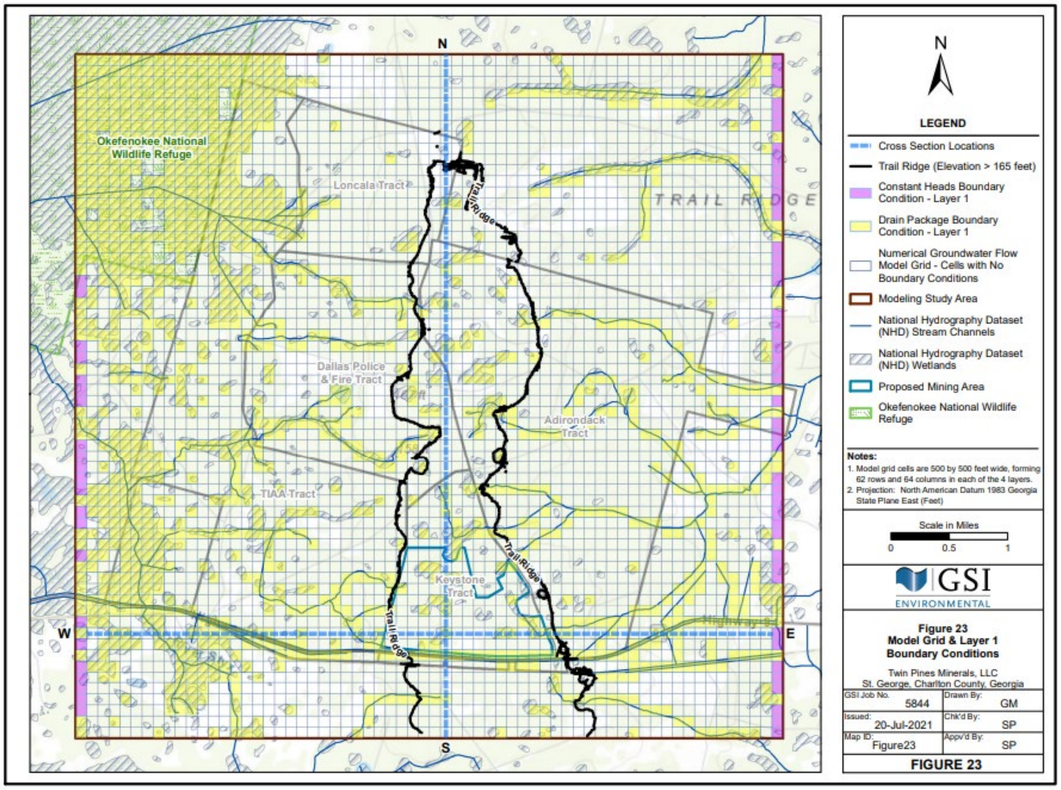


Figure 2. Domain of groundwater model and location of proposed mining area (from Modeling the groundwater flow system at the proposed Twin Pines Mine on Trail Ridge (Twin Pines Minerals, LLC, September 14, 2021))

TP's groundwater model has been developed to address this issue. Using information collected at the potential mining site, TP was able to map out general lithology of the area, including the presence, depth, and thickness of the confining black sand layer. This information was then incorporated by TP into the baseline model scenario (Baseline).

TP's mining operation includes returning homogenized post-processing soil particles back to the back end of the moving mining pit. Critically, it also includes putting a bentonite treated layer back at the depth where the original black sand layer was encountered pre-mining. The bentonite treated layer will be a replacement confining layer and functions in similar fashions to the original black sand layer. TP's intended consequence is to restore hydraulic properties of the post-mining soil to that of the pre-mining soil layers, or as close to that as possible. This post-mining information is included in the post-mining model scenario (Post-mining).

What the groundwater model does is, given the same hydrologic input and boundary conditions, to compare groundwater levels and flows within the two scenarios (Baseline and Post-mining) to see if mitigation measures that will be taken by TP will keep Post-mining hydraulic properties and therefore near-surface groundwater hydrology similar to Baseline conditions.

The central aspects of EPD's review of the TP groundwater model include the following: (a) Has the groundwater model been developed with the best available tool? (b) Has the model incorporated parameter values that are consistent with field measurements or otherwise reasonable? (c) Has the model been assigned proper boundary conditions? (d) Have the model's input hydrologic conditions been developed in a reasonable manner? (e) Has the model been calibrated properly? (f) What level of uncertainty is there associated with the model, and has this uncertainty been addressed with proper sensitivity analyses?

After program staff's review of material submitted by TP and program staff's discussions with TP's hydrogeologist, EPD came to the following understanding. TP's groundwater model has been developed with the state-of-the-art tool – MODFLOW. The MODFLOW model software is a widely used and acceptable software to model groundwater flow. The MODFLOW-NWT software, which was used for the simulations of Baseline and Post-mining scenarios at the TP site, is commonly used to simulate unconfined aquifers (in this case the Surficial Aquifer). The parameters of the model reflect either physical conditions acquired through field investigations or through the calibration process. The model's boundary conditions have been set in a reasonable manner. The most important boundary conditions of the model to note are the north and south boundary conditions which are no flow conditions, and this is due to the natural groundwater flow of the area being predominantly east-west, with Trail Ridge acting as a hydrogeologic divide in the area. Further, the bottom of the model, which is the confining layer overlying the Floridan Aquifer system is represented as a no flow boundary in the model. This is a common and acceptable practice because the permeability of the confining layer is very low, so movement of groundwater through that layer is almost non-existent. The model's input conditions have been developed to represent current (Baseline) groundwater flow conditions of the Trail Ridge area of southern Georgia.

The TP model has been properly calibrated against field measurements made by TP (or TP's contractors) in 2019. The calibration process included assessing Goodness-of-Fit between simulated water levels and measured water levels and provided 11 statistics, indicating reasonable match between simulated and observed results. Program staff questioned TP's hydrogeologist (Dr. Sorab Panday), on the level of uncertainty and sensitivity runs to cover the uncertainty. Dr. Panday categorized the types of uncertainty into 4 classes:

- Type I sensitivity is defined for parameters that cause insignificant changes to the calibration residuals as well as to model conclusions/predictions of interest.
- Type II sensitivity is defined for parameters that cause significant changes to the calibration residuals but insignificant changes to model conclusions/predictions of interest.
- Type III sensitivity is defined for parameters that cause significant changes to the calibration residuals as well as to the model conclusions/predictions.
- Type IV sensitivity is defined for parameters that cause insignificant changes to model calibration residuals but significant changes to the model predictions.

Of all parameters involved in the TP model, recharge and hydraulic conductivity of the consolidated black sands have a Type I sensitivity, while hydraulic conductivity of the unconsolidated and semi consolidated sand units (hydrogeologic units 1 and 3) have a Type III sensitivity. None belong to Type IV. This means either that slight change of parameter values tested in sensitivity analysis will not substantially alter the model results and conclusions or that the range of possible parameter values is substantially narrowed through the calibration process limiting the amount of uncertainty involved. In other words, successful calibration of the model ensures that model predictions are reasonable, appropriate, and realistic.

There were critical comments (*Independent Technical Review of the Twin Pines Permit Application Hydrologic Modeling, Kiren Bahm and Rajendra Paudel, South Florida Natural Resources Center, National Park Service, February 2023*) on the model's being a steady-state one rather than a transient one. It is important to understand that the purpose of the model is to assess whether Post-mining sediment structure would cause a change in hydrology when compared to the Baseline condition. When input conditions on hydrologic extremes have been applied to the Baseline and the Post-mining scenarios, very little difference in potentiometric surface (and groundwater hydrology) between the scenarios can be seen, indicating a lack of difference. This lack of difference captured at hydrologic extremes is a strong indication that the change in the sediment structure does not cause significant changes in groundwater flow. In other words, it is very hard to contemplate substantial differences between the Baseline and Post-mining scenarios under a transient modeling framework given the lack of a difference between the scenarios under a steady-state model.

Comparison of the Baseline and the Post-mining scenarios shows a lack of difference between the potentiometric surfaces, indicating similarity between the Baseline hydrology and the Post-mining hydrology for the model domain. Sensitivity analyses have also been conducted on recharge rate, hydraulic conductivity of consolidated black sand layers, hydraulic conductivity of unconsolidated and semi-consolidated sand and the silty and clayey sand. EPD Program staff asked Dr. Panday to perform one additional set of sensitivity analysis to alter the western constant head boundary to reflect gage height of a USGS gage to the west of the model domain. This additional sensitivity analysis was performed by Dr. Panday, which showed little difference in near-surface groundwater hydrology between the Baseline scenario and the Post-mining scenario.

In a letter (dated March 23, 2020) to Mr. Stephen Wiedl, Manager of EPD's Wetlands Unit, Dr. James Kennedy, then State Geologist, expressed his support of the steady-state modeling approach (Pages 1-2). Dr. Kennedy's March 23, 2020 letter is incorporated as Appendix 1 of this memorandum.

There were comments (*Independent Technical Review of the Twin Pines Permit Application Hydrologic Modeling, Kiren Bahm and Rajendra Paudel, South Florida Natural Resources Center, National Park Service, February 2023*) questioning whether it was appropriate to have a constant head boundary condition at the edge of the model domain. Given the fact that changes to lithology would take place at the middle of the model domain, EPD staff believes it is appropriate to assess the impact of such changes with a reasonable constant head at the boundary of the model domain, or some distance away from the location of alteration. This opinion is strengthened by two additional facts: First, Dr. Panday's additional sensitivity runs confirmed that altering the boundary conditions to reflect gage height changes at a USGS gage west of the model domain would not change findings of no significant difference in hydrology within the model domain. Second, EPD program staff ran surface water reservoir models to assess potential impacts to the Okefenokee Swamp (and the southeastern compartment of it) and found very small differences in water levels, i.e. indicating that a constant head boundary condition is reasonable. See Sections Groundwater Pumping from the Floridan Aquifer and Hydrologic Impact to the Southeast Compartment of the Okefenokee Swamp for details.

There were comments (*Independent Technical Review of the Twin Pines Permit Application Hydrologic Modeling, Kiren Bahm and Rajendra Paudel, South Florida Natural Resources Center, National Park Service, February 2023*) questioning whether the model domain is not far enough on the western side, i.e. whether the rest of the Okefenokee Swamp should be included in the model domain. This question can be considered with the perspective of the range of a potential impact. Typically, an impact is felt at the location of alteration and its vicinity. The farther away it is from the location of alteration, the less impact there is. The current model domain contains a substantial portion of the swamp, and it is showing the lack of a difference in hydrology between Baseline scenario and Post-mining scenario in areas including portions of the swamp. It is unlikely that a larger model domain itself would cause any larger differences in near surface groundwater hydrology.

Pumping Groundwater from the Floridan Aquifer

TP applied for a groundwater withdrawal permit up to 1,000 gpm (or 1.44 mgd) as needed, sourced in the Floridan Aquifer. A typical review of an application like this involves three major elements: the applicant's need for water, the source's capability to provide the needed amount, and identification of negative impacts and associated mitigation measures. While the first two elements have been addressed by the regulatory review conducted by the Water Supply Program's Groundwater Withdrawal Permitting Unit, I will address the Program's assessment of the third in this memorandum.

Major concerns have been raised by many stakeholders regarding whether the groundwater withdrawal from the Floridan Aquifer in the amount requested would cause impacts to the Okefenokee Swamp, including the Okefenokee National Wildlife Refuge, or ONWR (*Independent Technical Review of the Twin Pines Permit Application Hydrologic Modeling, Kiren Bahm and Rajendra Paudel, South Florida Natural Resources Center, National Park Service, February 2023; Comments on TPM LLC Draft Mining Land Use Plan (and supporting documents), C. Rhett Jackson, University of Georgia, February 26, 2023; Letter from William H. Schlesinger, Duke University, February 11, 2023; Letter from Emily Floore, St. Mary's Riverkeeper, March 15, 2023*). The intended groundwater withdrawal would likely take place through a well (or wells) drilled into the Floridan Aquifer at an approximate depth of 450 feet below ground surface or deeper. Any hydrologic impact on the Okefenokee Swamp from pumping through this well (or these wells) will need to propagate through the various units in the Hawthorn formation (Miocene) which is considered an aquitard and approximately 350 feet thick in this area. See Figure 3 showing the area's general lithology. Figure 3 shows a typical hydrogeologic cross-section near the proposed mining area (*Revised hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina, Professional Paper 1807, Lester J. Williams and Eve L. Kuniansky, April 2015*). The surficial aquifer, which is connected to the ONWR, can only be affected after the impact goes through the aquitard. Complicated and indirect methods have been contemplated, and yet there exists a simple and conservative way of assessing this impact.

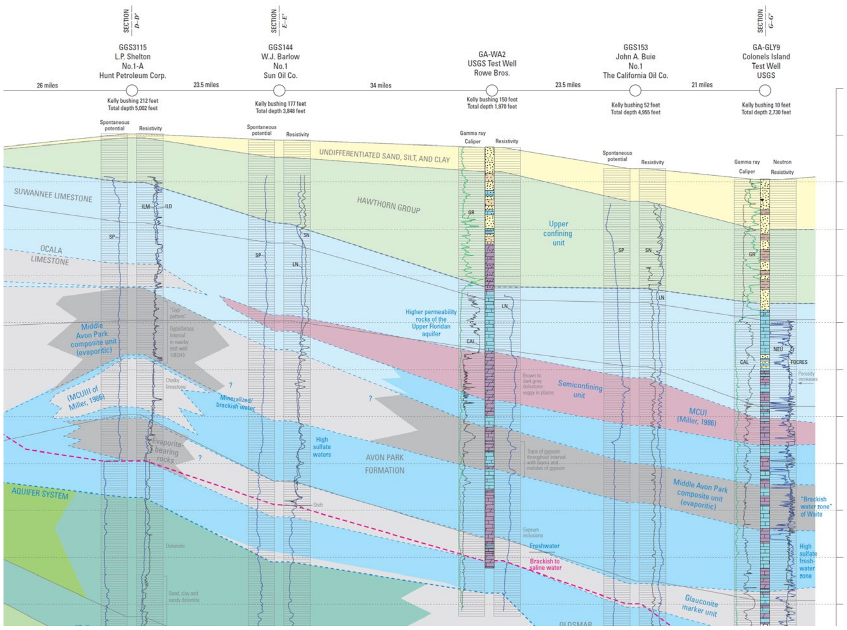


Figure 3. Cross-sectional profile near the mining site showing hydrogeologic features

Assuming that the Okefenokee Swamp is a wide (at 438,000 acres in surface area), shallow (with an average depth of 2 feet), and well-connected surface water reservoir, we analyzed how water level in the reservoir would respond to a direct surface water withdrawal of 1.44 mgd. We assumed that the historical precipitation is the only source of inflow to the reservoir, ignoring additional flows that may come from tributaries further upstream. This is another layer of our conservative approach. Available data enables us to run our simulation from 1948 to 2021. This period incorporates all the recent record-breaking multi-year droughts. We assumed corresponding historical evaporation as the major way of water being lost from the swamp. We also assumed overflow when the reservoir's storage capacity is reached (i.e. it being full).

This analysis shows that even if 100% of the 1.44 mgd withdrawn by TP comes not from the Floridan Aquifer, but directly from the Okefenokee Swamp, the withdrawal's impact on water level within the swamp will be limited to 0.2 inches (or 5 mm). As stated earlier, the hydrologic impact on surficial aquifer would need to go through an aquitard with a thickness of hundreds of feet, and the real impact on the surficial aquifer is likely a small fraction of what is indicated here.

We did not stop our analysis here. Instead, we analyzed the impact of removing 1.44 mgd from the St. Mary's River, as if the Floridan Aquifer withdrawal would have a 100% impact on the river. Again, this is a very conservative approach for the reason stated above. We showed a small amount of reduction in stream flow when using the St. Mary's River at MacClenny gage. For further information, see Appendix 2 (December 7, 2022 technical memorandum from Wei Zeng to Jamie Lancaster and William Cook summarizing EPD's assessment of impact to the St. Mary's River). We chose this gage because of its continuous and long record, as well as its high quality of data, especially during years of severe drought.

Dr. Rhett Jackson of the University of Georgia commented on our choice of this gage in a number of communications to EPD. He argued that the choice is wrong and that the more upstream Moniac gage presents a better representation of hydrologic impact on the Okefenokee Swamp. Dr. Jackson and I had a conversation on March 7th, 2023, in which I explained how EPD's modelers used a more direct and conservative approach in assessing the impact on the Okefenokee Swamp and consequently how we did not need to use either gage for the purpose of assessing an impact on the swamp. The gage analysis was entirely used to assess any potential impact on the St. Mary River itself. Dr. Jackson agreed during that call that EPD's choice of the MacClenny gage is appropriate for assessing the impact on the St. Mary's River. So, there is not a substantive dispute between Dr. Jackson and EPD on choosing the right gage in assessing the impact on the St. Mary's River. On March 8, 2023, Dr. Jackson sent me a summary of our conversation. On March 9, 2023, I sent a marked-up version of the summary back to Dr. Jackson. Both documents confirm the appropriateness of EPD's use of the MacClenny gage for assessing the St. Mary's River. See Appendix 3 of this memorandum for the March 8, 2023 summary from Dr. Jackson and Appendix 4 of this memorandum for the March 9, 2023 marked-up summary from me to Dr. Jackson.

In our conversation about EPD's assessment of impact on the swamp (i.e. surface water reservoir modeling approach), Dr. Jackson further commented that while it is appropriate to assume well-connectedness within the Okefenokee Swamp under wet or normal hydrologic conditions, it may not be so when there is a severe drought causing the different compartments within the swamp to be disconnected. Dr. Jackson suggested that using water level data collected by USFWS and flow data from the Moniac gage would be helpful in assessing this isolated impact. I expressed EPD's willingness to conduct further analyses to address that concern. The Section below titled Hydrologic Impact to the Southeastern Compartment of the Okefenokee Swamp has additional information on this matter.

Coastal Sound Science Initiative Model

Program staff ran the Coastal Sound Science Initiative (CSSI) model to assess the potential impact of the proposed groundwater withdrawal on saltwater encroachment in coastal Georgia. Results from the CSSI model show that the 1.44 mgd of groundwater withdrawal at the mining site from the Floridan Aquifer would not have an appreciable impact on saltwater encroachment.

Seepage into the Mining Pit and Associated Dewatering

As part of TP's mining operation, a 500-feet long, 100-feet wide, and 50-feet deep mining pit will exist and move within the footprint of the operation. TP has estimated that a seepage of 783 gpm (or 1.13 mgd) may take place into the mining pit. Since the mining pit will need to be maintained relatively dry, there is the need to dewater the mining pit and put the water into TP's Water Management Pond System.

Removing water from the mining pit is similar to pumping water from a well that is placed into the surficial aquifer, with its impact in the form of a cone of depression and the corresponding potentiometric surface in the form of a set of concentric circles. Dr. Jackson has placed the western half of the impact (estimated to be 0.56 mgd or 0.87 cfs) on the Okefenokee Swamp. The Program does not believe that the entirety of the 0.87 cfs will be placed on the swamp but choose to conservatively assess the impact using the full magnitude of it.

Following the surface water reservoir modeling approach, we assessed the impact of this 0.87 cfs of direct withdrawal on the reservoir (i.e. the Okefenokee Swamp) elevation to be 0.08 inches (or 2 mm). Note that the potential effect of mining pit dewatering and the potential effect of pumping from the Floridan Aquifer do not take place simultaneously. As long as the dewatering process yields more than 300 gallons per minute of flow, there is enough water to offset the loss of 300 gallons per minute in the industrial process and therefore no need for water withdrawal from the Floridan Aquifer. See Section Pumping Groundwater from the Floridan Aquifer above and Section Water Management at the Mining Facility below for additional information.

Hydrologic Impact to the Southeast Compartment of the Okefenokee Swamp

Following suggestions by Dr. Jackson, EPD conducted an additional technical analysis on hydrologic impact on the southeastern compartment of the Okefenokee Swamp, as if it is disconnected from the rest of the swamp during drought times. See Figure 1 for the location of the southeastern compartment of the Okefenokee Swamp relative to the rest of it. With this approach, we would need to assume that (a) the mining pit is hydraulically connected to the southeastern compartment of the swamp and that compartment is not connected to the rest of the swamp, and (b) the rest of the swamp (roughly 94% of the swamp's area) is disconnected and therefore not impacted.

Water elevation data collected by the US Fish and Wildlife Service (1982 to 1993) have been made available to EPD. Using this information and corresponding flow data from the Moniac gage, we synthesized inflow time series to the compartment and limited the impact from mining pit dewatering to just the compartment.

Then we established the pre-impact scenario as the "reservoir" having its baseline inflow and modeled the post-impact scenario as it receives an inflow time series that is reduced because of the hydrologic impact. The nature of this analysis is the same as the ones discussed earlier, where we treat the swamp (in this case the southeastern compartment of the swamp) as if it is a shallow reservoir and where we place the entire amount of impact (in this case 0.87 cfs) on the reservoir as if it is a direct surface water withdrawal.

Results of this modeling analysis indicate that the maximum change in water elevation in the southeastern compartment of the swamp would be 0.58 inches (or 14.7 mm). Note that part of the assumption in this modeling approach is that the rest of the swamp (94% in area) is disconnected from the southeastern compartment and therefore not affected. The number of days with zero flow at the Moniac gage would be changed from 77 days (out of a 12-year period of simulation) in the Baseline scenario to 85 days in the Post-mining scenario.

Water Management at the Mining Facility

TP has a water management pond system with four ponds having a total capacity of 111.9 million gallons. This system is used to manage water used for industrial process, wastewater after the industrial process, and stormwater generated by precipitation events (the Water Management Pond System). The Program's objectives in assessing the Water Management Pond System included determining whether there is enough water to compensate for the assumed water loss in the industrial mining process, whether there is enough storage space to handle water pumped from the mining pit, whether there is enough storage space to deal with high inflow associated with heavy precipitation events, and whether there is the risk of unintended discharge.

Total storage of the Water Management Pond System is divided into two sections, one handling the need for water and the other left empty to store high inflows. This configuration is quite similar to that of a typical reservoir where conservation water use and flood control are two major functions of the project. Assessing how the Water Management Pond System works is likewise similar to assessing how a typical reservoir works under various hydrologic conditions.

A reservoir operation model has been developed to reflect potential operation of the Water Management Pond System for both conservation and flood control purposes. Because of the limited amount of drainage area associated with the Water Management Pond System, the only inflow to the system is precipitation falling directly onto free water surface associated with the System. A precipitation time series going from 1948 to 2021 has been identified as representing the inflow. TP has provided its estimated seepage (783 gallons per minute) into the mining pit and presumed the need to dewater the mining pit for normal mining operations to proceed. The amount of mining pit dewatering becomes the second inflow to the Water Management Pond System.

There are two ways water leaves the Water Management Pond System. The first is natural evaporation taking place over open water surface. The second is artificial evaporation through TP's evaporators. Estimated evaporation rates have been compiled for this modeling effort. TP provided information indicating that eight EcoVAP 120 GEN2 Series modular evaporation units will be installed to provide a general evaporation capacity at 1,000 gallons per minute.

Given the above information, program modelers were able to conduct a sequential simulation of water management utilizing the Water Management Pond System. Modeling results indicate that (a) there is enough water to support the assumed loss of about 300 gallons per minute in the industrial process; (b) the capacity of storage space in the system can handle the 783 gallons per minute of mining pit dewatering; (c) the capacity of storage space in the system can handle historical precipitation events without the risk of discharging; and (d) given the assumption of the seepage rate and the associated mining pit dewatering, the long-term need for pumping from the Floridan Aquifer to refill the Water Management Pond System is minimal.

Recommendations to the Land Protection Branch

This section does not contain hydrologic analyses done by the Water Supply Program. Instead, it contains recommendations made by the program, which has served as internal consultants on anything hydrology-related, to the Land Protection Branch based on hydrologic assessments done by program staff. The Water Supply Program recommends to the Land Protection Branch that the following conditions be included in the Surface Mining Permit to ensure that TP's stated environmental objectives are met in the course of the mining operation.

TP's groundwater modeling indicated the lack of difference between Baseline and Post-mining hydrology over the mining area between Trail Ridge and the Okefenokee Swamp. Reliability of the modeling results rests partially on TP's faithful and successful implementation of the Soil Amendment Plan. For this reason, the Water Supply Program recommends to the Land Protection Branch that implementation of the Soil Amendment Plan be regularly (e.g. quarterly) checked and certified by an independent Georgia-registered Professional Geologist or Professional Engineer.

TP's intended installation of eight EcoVAP 120 GEN2 series modular units to provide the anticipated evaporative capacity of 1,000 gallons per minute. In order for the artificial evaporation part of the operation to function properly, the Water Supply Program recommends to the Land Protection Branch that the installation of the evaporators be certified by an independent Georgia-registered Professional Engineer. It is further recommended that the evaporators be regularly (e.g. annually) examined for proper functioning and that such examinations be certified by an independent Georgia-registered Professional Engineer. This is in addition to the manufacturer's installation, maintenance, and operational requirements.

Visit to the Okefenokee National Wildlife Refuge and the St. Mary's River

On the 19th and 20th of April 2023, EPD associates Anna Truszczynski, Feng Jiang, William Cook, Mike Coughlan, and Wei Zeng visited the St. Mary's River and the Okefenokee National Wildlife Refuge (ONWR). On April 19th, EPD associates attended a guided tour of the St. Mary's River organized by Emily Floore of the St. Mary's Riverkeeper. The tour included visits to the Moniac USGS gage along the North Prong St. Mary's River, the MacClenny USGS gage along the St. Mary's River, St. George boat ramp for a boat tour of the river, and Boone Creek overpass.

On April 20th, EPD associates met with ONWR staff led by Mr. Michael Lusk, manager of the facility. Mr. Lusk provided an overview of ONWR's history and its unique geology and hydrology. He and his staff provided a boat tour of portions of the ONWR.

On both days, EPD associates had casual conversations with ONWR (US Fish and Wildlife Service) staff and associates of the St. Mary's Riverkeeper on the process of EPD's regulatory review. Discussions also included technical review of information submitted by the applicant and what additional information may help with EPD's work. It was in this process that some additional questions arose.

First, there was a question on whether water users sourced in the surficial aquifer in the vicinity of the mining site have been identified and potential impacts on them assessed. It is suggested that the applicant may hire a third party (e.g. the county) to investigate what private residential wells may exist within a certain distance of the mining site and their configurations. Then a technical assessment can be done to see if these wells may be impacted.

Second, it was brought to our attention that there is documented evidence of Atlantic Sturgeon in the St. Mary's River. I have reached out to Dr. Elizabeth Booth of EPD's Watershed Planning and Monitoring Program, Georgia Department of Natural Resources' Wildlife Resources Division, the University of Georgia, and National Oceanic and Atmospheric Administration, National Marine Fishery Service (NMFS) on whether the presence of Atlantic sturgeon would trigger any heightened review from a water quality or fishery perspective. On May 25, 2023, NMFS provided a letter to EPD commenting on the project. Among other parameters, NMFS identified dissolved oxygen and temperature as key factors affecting the sturgeon species. Dr. Booth and I attended a virtual meeting hosted by the St. Mary's Riverkeeper and listened to a presentation by Dr. Adam Fox of the University of Georgia on the sturgeon species in the river. Experts from the NMFS were present in the meeting, and the provided a map illustrating the portion of the river identified as critical habitat. Dr. Booth's Program has planned to survey the bathymetry of the section of the St. Mary's River identified as critical habitat for the sturgeon species. After the survey data becomes available, an open channel hydraulic model will be developed to assess potential impacts. After this work is completed, I will provide a supplemental memorandum summarizing the results of this assessment.

Third, the St. Mary's Riverkeeper would like to see our assessment of the impact on the St. Mary's River east of Trail Ridge from the mining pit dewatering. As stated earlier in this memorandum, the mining pit dewatering is similar to having a groundwater withdrawal at the rate of the average seepage, determined by TP as 783 gallons per minute, which translates to 1.13 mgd or 1.74 cfs. It is worth noting that there is no direct withdrawal of water from the St. Mary's River. What impact the mining pit dewatering has on the St. Mary's River is very indirect and attenuated. Following the assumption that half of the impact is on the eastern side of the Trail Ridge, we place 0.87 cfs on the eastern side of the St. Mary's River as if the impact is a direct withdrawal from the river. As stated earlier in this memorandum, this is a rather conservative approach.

Two USGS gages can be used for this purpose, St. Mary's River at Ferry Landing near Folkston, GA (02231175) and St. Mary's River at I-95, near Kingsland, GA (02231254). The Folkston gage provides gage height reading but not flow rate on a regular basis. However, going back to 2017, USGS recorded 9 field measurements with flow information. These field measurements took place in September 2017, June 2020, and July 2021. The flow rates range from 2,310 cfs to 21,800 cfs. The Kingsland gage appears to be tidally influenced with very obvious change in flow direction twice a day. The magnitude of flow at this gage is roughly between 20,000 cfs and -20,000 cfs (with the negative sign indicating a reversed flow direction). In either case, the impact of 0.87 cfs appear to be minimal.

Fourth, the St. Mary's Riverkeeper would like to see our assessment of mining pit dewatering on the St. Mary's River with greater levels of details. As stated earlier in this memorandum, we assessed the days of zero flow out of the southeastern compartment of the swamp and found that there would be an addition of 8 days in the Post-mining scenario beyond the 77 days in the Baseline scenario. We further assessed the lower half of the flow spectrum to provide the following statistics. The 5th percentile flow under the Baseline scenario is 0.68 cfs, while the 5th percentile flow under the Post-mining scenario is 0.61 cfs. The 10th percentile flow under the baseline scenario is 1.71 cfs, while the 10th percentile flow under the Post-mining scenario is 1.64 cfs. The 20th percentile flow under the baseline scenario is 8.07 cfs, while the 20th percentile flow under the mining scenario is 7.62 cfs. The median flow under the baseline scenario is 33.52 cfs, while median flow under the mining scenario is 32.90 cfs.

<u>Conclusions</u>

In summary, program staff has had extensive interactions with the Land Protection Branch and the applicant's technical experts on key hydrologic elements of the TP applications. Program staff asked questions directed at, sought additional information from, and received such information from TP's technical experts. When all information is available to the Water Supply Program, staff was able to complete various hydrologic assessments leading to the following conclusions.

1. The groundwater model submitted by TP answers the critical question of whether the change in sediment structure would cause significant differences in the near surface groundwater hydrology in the Trail Ridge – Okefenokee Swamp area. The model was developed with the best available tool, with appropriately assigned parameter values, with reasonable boundary conditions, and was the right tool for the question asked. The answer from the groundwater model is that there would not be a significant change in groundwater hydrology, if TP faithfully implements its Soil Amendment Plan.

2. As part of the Water Supply Program's regulatory review, there is very little impact from the proposed groundwater withdrawal of 1.44 mgd from the Floridan Aquifer. The Floridan Aquifer in the area sustains withdrawals of this magnitude in the area without impacts to other users or the resource itself. The withdrawal would not have appreciable impact on coastal saltwater encroachment either.

3. The potential impact of the 1.44 mgd withdrawal from the Floridan Aquifer would have a very low impact on the Okefenokee Swamp, even if we make very conservative assumptions such as placing the entire amount of the withdrawal onto the swamp's surface water. Our reservoir mass balance model

shows a maximum impact in water level to be 0.2 inches (or 5 mm), if we assume well connectedness within the swamp and treat it as a large and shallow reservoir.

4. The potential impact from this Floridan Aquifer withdrawal on the St. Mary's River has also been assessed. Even if we place the entire amount of the 1.44 mgd on the St. Mary's River, the impact is relatively low. Dr. Rhett Jackson of the University of Georgia agreed with me on the appropriateness of using the MacClenny gage for this this purpose.

5. A seepage of 783 gallons per minute into the mining pit and the associated need to dewater this amount into the Water Management Pond System would behave as if it is a groundwater withdrawal from the surficial aquifer, which probably has a hydraulic connection to the swamp. A similar mass balance modeling was done to account for half of the impact (0.87 cfs) onto the swamp. Here again, we used the conservative assumption of placing the entire 0.87 cfs onto the swamp, even though we believe only a portion of it would in fact has an impact on the swamp. This modeling assessment indicates that the maximum amount of water level impact is 0.08 inches (or 2 mm).

6. Following my conversation with Dr. Rhett Jackson of the University of Georgia, program staff adopted an approach suggested by him in an additional assessment in which we isolated the impact to the southeastern compartment of the swamp. This assessment is on be premises that during drought times only the southeastern compartment of the swamp is impacted by TP's mining operation and that it is not hydraulically connected to the rest of the swamp. Modeling indicates that the water level impact would be 0.58 inches (or 14.7 mm). It also shows that the number of days with zero flow into the North Prong St. Mary's River (near the Moniac gage) would change from 77 days (out of a 12-year simulation period) in the Baseline scenario to 85 days in the Post-mining scenario.

Appendix 1. March 23, 2020 Letter from Dr. James Kennedy to Mr. Stephen Wiedl

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

Chuck Mueller, Chief

EPD Land Protection Branch
2 Martin Luther King, Jr. Drive
Suite 1052, East Tower
Atlanta, Georgia 30334
404-463-8509

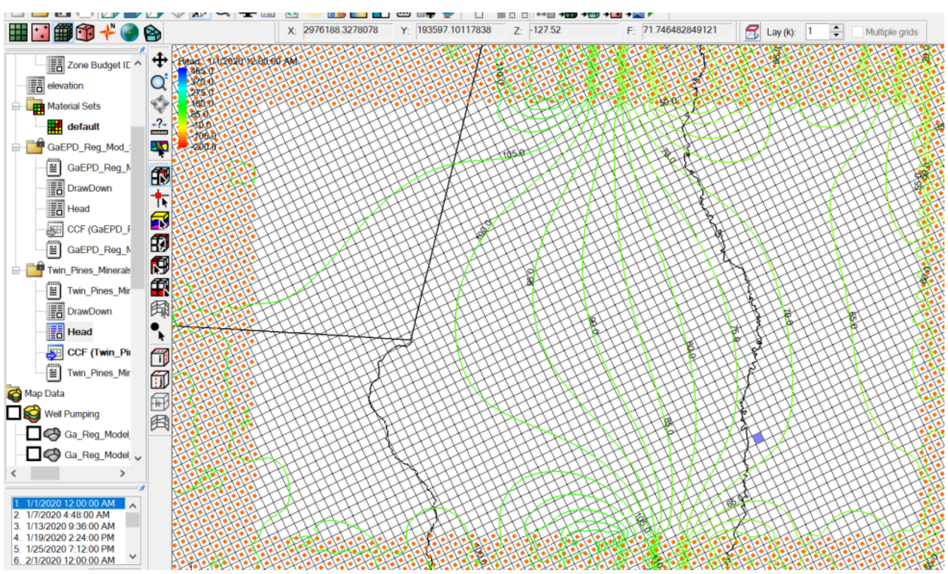
23 March 2020

Mr. Stephen C. Wiedl, PWS
Manager – Wetlands Unit
Georgia Environmental Protection Division
7 Martin Luther King, Jr. Drive, Suite 450
Atlanta, Georgia 30334

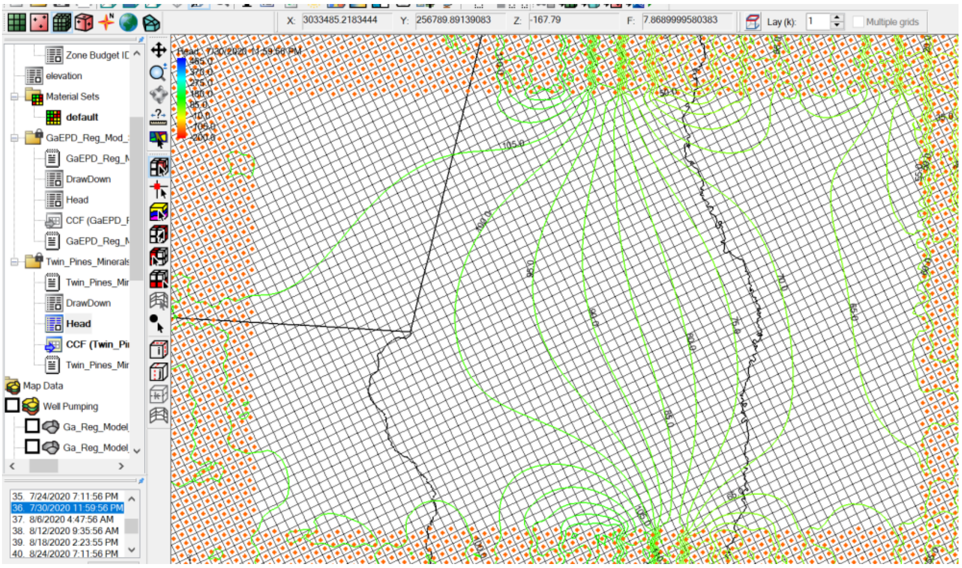
Dear Mr. Wiedl:

With this letter I am presenting review comments of the report Impact of the Proposed Twin Pines Mine on the Trail Ridge Hydrologic System. The report was prepared by TTL of Tuscaloosa, Alabama, for Twin Pines Minerals, LLC. Several of the documents cited in the review were available from the wetlands/401/unit electronic files made available for the review. Each of the following comments is numbered and refers to a page in Impact of the Proposed Twin Pines Mine on the Trail Ridge Hydrologic System report.

Comment 1 P. 3: It is stated in the report that MODFLOW-2005 was used to simulate steady-state groundwater flow in the model domain. Attached are figures from the State Water Plan revised transient model with Layer 1 in the vicinity of the proposed mine set to a variable head boundary.



Hydraulic Head Layer 1 January



Hydraulic Head Layer 1 July

The January hydraulic heads (period of high recharge and little agricultural pumping) looks the same as the July hydraulic heads (period of low recharge and much agricultural pumping). The lack of change in hydraulic heads between January and July indicates that a steady state model could be used to simulate conditions at the mine.

<u>Comment 2 P. 4</u>: It is stated in the report that the model includes 15 layers. There is no table or figure in the report giving the depths and elevations of the 15 layers. The layers are shown on Fig. 11 & 12 of the report but there is no depth or elevation data given on the figures. There are no dimensions of any kind given on the figures.

Geologic cross-sections through the mine site show layers of black sand and clayey sand that should be continuous across the site (see comment 9). It is not known what layers in the pre-mining model were used to depict theses layers of black sand and clayey sand (if they were depicted). The report must tabulate the depths and elevations of the 15 model layers and say and show which layers were used to depict the layers of black sand and clayey sand (if any).

<u>Comment 3 P.5</u>: Reference is made to Table 1 in the report which presents hydraulic conductivity (k) values for each soil type at the site to ensure that the vertical and horizontal hydraulic conductivity in grid blocks far from soil borings locations were consistent with those calculated from aquifer (pumping) tests and slug tests. The hydraulic conductivity units in Table 1 are centimeters per second (cm/s):

Soil Type	Hydraulic Conductivity (cm/s)
Unconsolidated Sand	1.00×10^{-2}
Semi-consolidated Sand	1.00×10^{-3}
Consolidated Sand	5.00×10^{-5}
Silty-Clayey Sand	1.00×10^{-4}
Clayey Sand	1.00×10^{-4}
Clay	5.00×10^{-5}

The consolidated sand described in the 11 December 2019 report titled Subsurface Lithology of the Surficial Aquifer at Twin Pines Mine is described as consolidated black sand that includes sands that are cohesive due to significant amounts of humate. Page 5 then says e.g., a horizontal hydraulic conductivity of 6.36 x 10^{-3} (E-03) cm/s (18 feet per day [ft/d]) and a vertical hydraulic conductivity of 2.6 x 10^{-4} cm/s (0.74 ft//d). It is unclear what this e.g. refers to. The numbers cannot be found in the 31 October 2019 report on the Hydrogeologic Field Characterization at Twin Pines Mines which presents results of aquifer tests and slug and bail tests.

Page 5 says that initial model hydraulic conductivity values for each model layer are shown in Figures 15 – 29. The units of hydraulic conductivity in Figures 15 – 29 are in feet per second (ft/s), not cm/s or ft/d. There are nine zones of hydraulic conductivity shown (they are designated as zones for future discussion). The conversions for the hydraulic conductivity units were 1 ft/s x 30.48 cm/ft = 30.48 cm/s, 1 ft/s x 86,400 s/d = 86,400 ft/d:

Zone	k (ft/s)	k (cm/s)	k (ft/day)
1	0.010	0.3048	864
2	0.009	0.2743	778
3	0.008	0.2438	691
4	0.007	0.2134	605
5	0.006	0.1829	518
6	0.005	0.1524	432
7	0.004	0.1219	346
8	0.003	0.0914	259
9	0.002	0.0610	173

All the hydraulic conductivities values on Figures 15 – 29 are at least an order of magnitude higher than the Page 5 e.g. value horizontal hydraulic conductivity of 6.36 x 10^{-3} cm/s (18 ft/d). Figures 15 – 29 show most of the initial model hydraulic conductivities to be the color blue (Zone 4, 0.007 ft/s = 0.2134 cm/s/= 605 ft/d). This is inconsistent with Page 5 e.g. value horizontal hydraulic conductivity of 6.36 x 10^{-3} cm/s (18 ft/d). These inconsistencies in the model hydraulic conductivities need to be addressed in a revision of the report.

Comment 4 P. 6: Calibrated model horizontal hydraulic conductivities are shown on Figures 32 through 46 for layers 1 to 15. The hydraulic conductivity zones on Figures 32 through 46 have hydraulic conductivity in units of feet per second (ft/s). It is unclear if "<10e-1" means 10 x 10^{-1} = 1 or if it means 10^{-1} = 0.1. For the following discussion it will be assumed 10e-1 = 0.1.

The conversion of unit hydraulic conductivity from ft/s to cm/s is 1 ft/s x 30.48 cm/ft = 30.48 cm/s. The hydraulic conductivity zones on Figures 32 through 46 would therefore have the following units:

Zone	Hydraulic Conductivity (ft/s)	Hydraulic Conductivity (cm/s)
1	10e1	304.8
2	10e0	30.48
3	10e-1	3.048
4	10e-2	0.3048
5	10e-3	0.03048

6	10e-4	0.003048

The highest hydraulic conductivity unit given in Table 1 of the report was unconsolidated sand with a hydraulic conductivity of 1.00 x 10^{-2} cm/s. This corresponded to hydraulic conductivity zone 5 in the report of Subsurface Lithology of the Surficial Aquifer at Twin Pines Mine (0.03048 cm/s).

Figures 15 – 29 show most of the initial model hydraulic conductivities to be the color blue (Zone 4, 0.007 ft/s = 0.2134 cm/s/= 605 ft/d). This is equivalent to Zone 4 (10e-2 ft/s/= 0.3048 cm/s) in the calibrated model horizontal hydraulic conductivities shown on Figures 32 through 46. Zone 4 in the calibrated model horizontal hydraulic conductivities is much smaller than Zone 4 in the initial model hydraulic conductivities. If the assumption that 10e-1 = 0.1 is incorrect and 10e-1 = 1 that would be equivalent to Zone 3 (10e-1 ft/s/= 3.048 cm/s) in the calibrated model which is also much smaller than Zone 4 in the initial model hydraulic conductivities. The report must explain why the calibrated model horizontal hydraulic conductivities are so different from the initial model hydraulic conductivities.

Only small portions of Figures 32 through 46 are designated as zone 5 or the less permeable zone 6. Most of Figures 32 through 46 are designated as zones 4 or higher with permeabilities of 10e-2 ft/s or 0.3048 cm/s (3.048 x 10-1 cm/s) or higher. None of the geologic units cited in Table 1 of the report had permeabilities this high. This discrepancy in the data must be addressed by revision to the report. A lower hydraulic conductivity in the modeled area would result in a higher water table in modeled results.

The post-mining horizontal conductivities of the layers are given in Fig 49 through 63 of the report but from the figures one cannot tell which of the post-mining layers represent the pre-mining horizontally continuous of black sand and clayey sand which may have to be reconstructed to maintain the shallow water table need to support the wetlands along Trail Ridge. This should be clarified in a revision to the report.

<u>Comment 5 P. 6</u>: It is stated that the trial and error calibration approach led to a reduction of the initial recharge rate. A recharge rate of 4.54 inches per year (in/yr) led to unreasonably high modeled hydraulic head values. A recharge rate of 4.54 inches per year is equivalent to 4.54 in/yr x 1 foot/12 in x 1 yr/365 day = 0.00103653 foot per day (ft/day), the units used in the Georgia State Water plan groundwater flow model of the Coastal Plain. Applying a recharge rate of 2.8 in/yr (0.00063927) was found to produce hydraulic head values consistent with those found along Trail Ridge.

The State Water Plan model is a calibrated transient model with grid size of 1,760 feet over 708 rows and 984 columns and seven layers representing major aquifers in the Coastal Plain. The recharge rate in the area of the proposed mine ranged from 0.00000476 ft/day (0.02 in/yr) to 0.000143 ft/day (0.06 in/yr) with an average value (such as would be used in a steady state model) of 0.0000095204 ft/day (0.04 in/yr).

The value for recharge used in proposed Twin Pines Mine was much larger than the recharge used in the calibrated State Water Plan model. A higher recharge in the modeled area would result in a higher water table in modeled results. Perhaps a lower recharge rate would offset the higher water table caused by using the lower hydraulic conductivity values in Comment 4. The model must be recalibrated using lower values for hydraulic conductivity and recharge before the pre-mining water table configuration is acceptable.

Such a higher recharge rate in the proposed Twin Pines Mine model would allow for a quick re-establishment of the shallow water. If the recharge rate from the calibrated State Water Plan model was used in the proposed Twin Pines Mine model the water table would not re-establish as quickly if at all. The difference between the recharge rate in the proposed Twin Pines Mine model and the State Water Plan model must be addressed.

Comment 6 P. 6: The report says that after mining is completed, the mined volume will be filled with homogenized sand spoil. The report also says that experiments conducted on homogenized sands from the Twin Pines Mine study area reveal that the horizontal hydraulic conductivity of the pit filling will be approximately 1×10^{-3} cm/s. This is opposed to a pre-mining horizontal hydraulic conductivity of 6.36 10^{-3} cm/s (18 ft/d) given on page 5 of the report calculated from aquifer tests and slug tests, a reduction of about 84 percent from the pre-mining condition.

The report gives no details of the experiments used to determine the horizontal hydraulic conductivity of the homogenized sands from the Twin Pines Mine citing the reference Holt et al. 2019f which is the 26 November 2019 report Laboratory Testing Data at Twin Pines Mine. Page 7 of this report describes the blending of bentonite with processed material from the proposed mine site and concludes that bench-scale studies indicated that a mixture of approximately 10 to 12.5 percent bentonite would be required to achieve a relative permeability similar to the results calculated for the black humate-cemented sand samples tested on which the shallow water table supporting the on-site wetland may be perched. It would be helpful if these details were included on page 6 of the report on the Impact of the Proposed Twin Pines Mine on the Trail Ridge Hydrologic System.

Comment 7 P. 6: The report says that the calibrated hydraulic conductivity values in all grid blocks above 119 ft within the mine footprint were replaced with a horizontal and vertical hydraulic conductivity of 1.0×10^{-3} for the groundwater flow model for post-mining conditions. It is unclear if this vertical hydraulic conductivity includes the blending of bentonite with processed material from the proposed mine site with a mixture of approximately 10 to 12.5 percent bentonite that is described in the report Laboratory Testing Data at Twin Pines Mine.

Appendix E of the laboratory testing data report includes results of vertical hydraulic conductivity report for bench-scale testing of three samples with 10 to 12.5 percent blending of bentonite. The vertical hydraulic conductivity of the three samples ranged from 6.8×10^{-7} to 1.0×10^{-8} cm/sec and was not near the vertical hydraulic conductivity of 1.0×10^{-3} cited in the report on the report of Impact of the Proposed Twin Pines Mine on the Trail Ridge Hydrologic System. The groundwater flow model of post-mining conditions therefore is inadequate and must be re-done.

The remodeling of the post-mining conditions must include a sensitivity analysis of what the post-mining water table may look like if the mine area is not reclaimed as planned. At a minimum the sensitivity analysis must include simulations and analyses of higher and lower horizontal and vertical hydraulic conductivities of the reclaimed mine spoil, analyses of higher and lower rates on post-mining aquifer recharge, and analyses of higher and lower topography of the reclaimed mine. The ranges of higher and lower must be the range of the possible values for each of the model input parameters.

Comment 8 P. 7: The assessment of the impact of a moving mine is completely inadequate. On page 1 the report says the average time a portion of the mine will be open is approximately five days. On page 9 of the report it is calculated that the volumetric discharge from the pit (Q) will be 150,000 cubic feet per day (ft^3/d) assuming a pit size of 100 ft x 100 ft x 50 ft depth. The number 150,000 is based on excavation of a pit 100 ft x 100 ft x 50 ft = 500,000 ft^3 x 0.3 porosity = 150,000 ft^3. The calculation does not account for any groundwater flow to the open pit which will occur over the approximately five days it is expected to be open. It will be a lot more than the calculated 150,000 ft^3/d.

The impacts of a moving mine pit must be recalculated using equations from the textbook Foundation Engineering (G. A. Leonards, McGraw Hill, 1962) and Groundwater Control (Army TM 5-818-5, Navy NAVFAC P-418, Air Force AFM 88-5, Chap 6), or an equivalent source of information. The groundwater flow to the open moving pit must be estimated and the resulting water table drawdown resulting from the groundwater flow must be calculated. The impacts of a moving mine pit are analyzed in the report are analyzed analytically. The revised report could also analyze the impacts of a moving mine pit using a numerical MODFLOW or an analytic element model.

Comment 9 Fig. 7 & 8: Several of the black sand and clayey sand units are shown to be laterally discontinuous. On p. 1 the report says that Trail Ridge represent the crest of a former beach complex and was formed as inland sand dunes. Page 10 of the 12 September 2019 Geo-Hydro, Inc. report to the Southern Environmental Law Center says that Trail Ridge is composed of Pliocene-age bodies of aeolian sands that form the Trail Ridge orebody and is generally 1 to 2 kilometers wide (i.e., laterally continuous for 1 to 2 kilometers) and about 11 meters thick. Such an environment of deposition (EOD) would allow horizontal continuity of units unlike a fluvial or deltaic EOD which would allow horizontally discontinuous units. The EOD would allow deposition of vertically discontinuous units.

Fig. 7 & 8 should be redrawn with laterally continuous units of black sand and clayey sand as was done in slide 16 of the USFWS Power Point presentation to the USACE in July 2019 and as was done in the TTL Figure 4 Generalized Hydrogeologic Cross-Section D-D' included with the 12 September 2019 letter from Geo-Hydro, Inc. to the Southern Environmental Law Center. These pre-mining laterally continuous low permeability layers must be included in the models of the mine site to determine if they are needed to maintain a shallow water table along Trail Ridge that maintains the wetlands along the ridge.

Comment 10: There is no discussion in the report on what the chemical impact of the homogenized mine spoil may be. The units of consolidated sand, silty-clayey sand, and clayey sand will be mixed with the unconsolidated sand throughout the reclaimed mine. Groundwater flowing through the homogenized mine spoil will interact with clay minerals and humate that is currently exposed to little or no groundwater flow. The interaction of groundwater with clay minerals and humate may result in a chemistry of groundwater discharging to wetlands and stream base flow that is significantly different than the geochemistry present in the 31 October 2019 report on Water Quality at Twin Pines Mine.

As a minimum the report on the Impact of the Proposed Twin Pines Mine must include information on the clay mineralogy of the silty-clayey sand and clayey sand units, analyses of the cation exchange capacities of the clay minerals, chemical analyses of the inorganic and organic materials adsorbed to the clay minerals, and leaching analyses of the humate associated with the black consolidated sand. As a minimum the report must include an analysis of the potential release of inorganic and organic materials from clay minerals and humate on the chemistry of surface water and groundwater in the reclaimed mine site.

That concludes my comments. I hope they are helpful. Please contact me if you have questions on the comments or need additional information on the basis for a comment.

Sincerely,

James L. Kennedy, Ph.D., P.G.
Georgia Environmental Protection Division
State Geologist

Appendix 2. December 7, 2022 Wei Zeng (EPD Water Supply Program) Memorandum to Jamie Lancaster and William Cook (EPD Land Protection Branch)

Memorandum

From: Wei Zeng (Water Supply Program)

To: Jamie Lancaster, William Cook (Land Protection Branch)

Feng Jiang (Hydrology Unit)

Date: December 7, 2022

Re: Additional hydrologic analysis in response to Dr. Rhett Jackson's 11/22/2022 comment

The purpose of this technical memorandum is to supplement my prior draft memorandum dated September 29, 2022 on potential impacts from Twin Pines Minerals (TP) mining project in Charlton County. It also serves as a response to one of the comments received from Dr. Rhett Jackson of the University of Georgia on November 22, 2022.

In Dr. Rhett Jackson's November 22, 2022 comment letter, he used USGS gage 02228500 (North Prong St. Marys River at Moniac, GA) in assessing the potential impact from the mining pit seepage and associated dewatering. This gage controls 160 square miles of drainage area, has 28,351 days of daily record, and has a more or less continuous record since the early 1950's (with a gap of about two years from October 2004 to October 2006). Dr. Jackson concludes that the occurrence of extreme events at the very low end of the flow spectrum would be tripled had the St. Marys River been impacted by TP's dewatering of the mine pit.

Before presenting the Water Supply Program's assessment on this issue, I will provide a brief description of relevant hydrologic analysis that has been documented in the September 29, 2022 draft memorandum. In that draft memorandum, the hydrologic impact of a 1.44 mgd of water withdrawal from the Floridan Aquifer has been analyzed in a rather conservative way, i.e. our unrealistically placing the entire amount directly on the Okefenokee Swamp as if this was a direct surface water withdrawal from the swamp itself. We have modeled the impact of this loss of water and concluded that water level in the swamp will have an impact of roughly 5 mm at the worst time.

We also conducted a study on the potential impact of this withdrawal on the receiving St. Marys River using USGS Gage 02231000 (St. Marys River near MacClenny, FL). The magnitude of this unrealistic withdrawal (1.44 mgd or 2.23 cfs) is very low in comparison to the median flow of 212 cfs or the average flow of 629.4 cfs. When compared to the absolute minimum flow historically recorded, the quantity of the whole withdrawal is significant at 23.26%. However, this is certainly the result of the overly conservative approach. In reality, the effect of 1.44 mgd of withdrawal from the Floridan Aquifer on either the swamp or the St. Marys River would be greatly attenuated through the aquitard (with a thickness of several hundred feet).

TP has since provided more updated information on seepage rate from its mining pit, at 783 gallons per minute. This indicates the need for dewatering from the mining pit when the mining operation is underway. Since the industrial process will be associated with a water loss of 300 gallons per minute, what will be pumped into the Water Management Pond System is around 483 gallons per minute.

Even though these quantities are less than the 1.44 mgd withdrawn from the Floridan Aquifer, dewatering from the mining pit may have a higher level of connection with the surficial aquifer or the swamp than the Floridan Aquifer withdrawal. It is worth noting that mining pit dewatering and pumping from the Floridan Aquifer will not likely take place simultaneously because the seepage already provides more water than water lost in the industrial process (or make up water).

We updated our hydrologic analysis to reflect this new information and as a way of responding to Dr. Jackson's point on hydrologic impact to the St. Marys River. As we did in the prior study, we choose USGS 02231000 (St. Marys River near MacClenny, FL). This gage controls a drainage area of 700 square miles, has 35,129 days of daily record, and has a continuous record since October 1, 1926. We chose this gage because of its long and continuous record (a better basis for developing an exceedance curve and statistics), as well as the quality of field measurements in prolonged drought periods, which tend to be associated with low flows.

In order to make our point and maintain conservative, we continue to use the 1.44 mgd (2.23 cfs) as if it is entirely removed from the St. Marys River. Flow exceedance curves have been developed for the original gage record and an altered flow sequence as if 2.23 cfs has been removed from the original flow sequence. The two curves are very close for the upper 80% of the flow spectrum (Figure 1). We developed Figure 2 to zoom in to the lowest 30% of the flow exceedance. Here, we see the separation of the two curves, but the difference remains small. At the very low end of the flow exceedance curves, there may be an increase in the occurrence of such low flows (e.g. around 10 cfs). However, that is true when analyzing any magnitude of a flow reduction and on any stream.

Other than the longer record of USGS 02231000 and its record being continuous, we also have reasons to believe that its data during multi-year droughts are of higher quality when compared with USGS 02228500 (the gage used by Dr. Jackson). This is based on the USGS field measurement record during the historical multi-year droughts when flows tend to be at or near the lower end of the flow spectrum. USGS routinely sends its field crew to conduct field measurements to update its gage rating curves and to make sure the gages work properly. These field measurements are documented as part of the gage records. When these measurements are done, there is an assessment of the quality of such measurements. The assessment classifies each field measurement as Excellent, Good, Fair, Poor, or Not specified. Per USGS Code Description, an Excellent rating means that the data is within 2% of the actual flow; a Good rating means that the data is within 5% of the actual flow; a Fair rating means that the data is within 8% of the actual flow; and a Poor rating means that the data is beyond 8% of the actual flow.

We developed Figures 3 through 7 to show the comparison of field measurement quality between the two gages. Figure 3 shows the comparison for the drought period of 1954-1955. Bars in the chart show the percentage of field measurement in each classification. The blue bars represent USGS 02231000, and the orange bars represent USGS 02228500. The percentage values associated with the bars of the same color add up to 100%. The higher the bars toward the left of the chart, the better the field measurement quality. The higher the bars toward the right of the chart, the poorer the quality of the field measurements. For example, during the 1954-1955 drought, USGS 02231000 has 82% of the field measurements classified as Good, while USGS 02228500 has 36% of its measurements classified as such. At the right side of the chart, USGS 02231000 has only 6% of the field measurements classified as Poor, while USGS 02228500 has 27% of the field measurements in that category.

Figure 4 shows a similar comparison for the drought period of 1986-1988. Figures 5, 6, and 7 are for the drought periods of 1999-2002, 2006-2008, and 2011-2012, respectively. It is almost universally true that USGS 02231000 provides higher bars on the left side of the charts, meaning higher quality field measurements, than USGS 02228500 does. The only exception in these figures is probably in Figure 7 showing the 2011-2012 drought, where USGS 02228500 has 12.5% of the field measurements assessed to be Excellent and USGS 02231000 does not have field measurements assessed in that category. But even for this multi-year drought, USGS 02231000 still has a lower percentage of Poor rating (at roughly 6%) than USGS 02228500 does (at 25%).

When the focus of a hydrologic analysis is on the lower end of the flow spectrum, especially when it is mostly about the extremely low flows, it is important to rely on gage data of better quality. We believe USGS 02231000 provides a longer period of record, a more complete record, and a record of higher quality in the historically critical drought years. We believe the use of this USGS gage is appropriate. Based on this data set and with very conservative assumptions, we believe the hydrologic impact on the St. Marys River from dewatering of the mining pit would be very low.

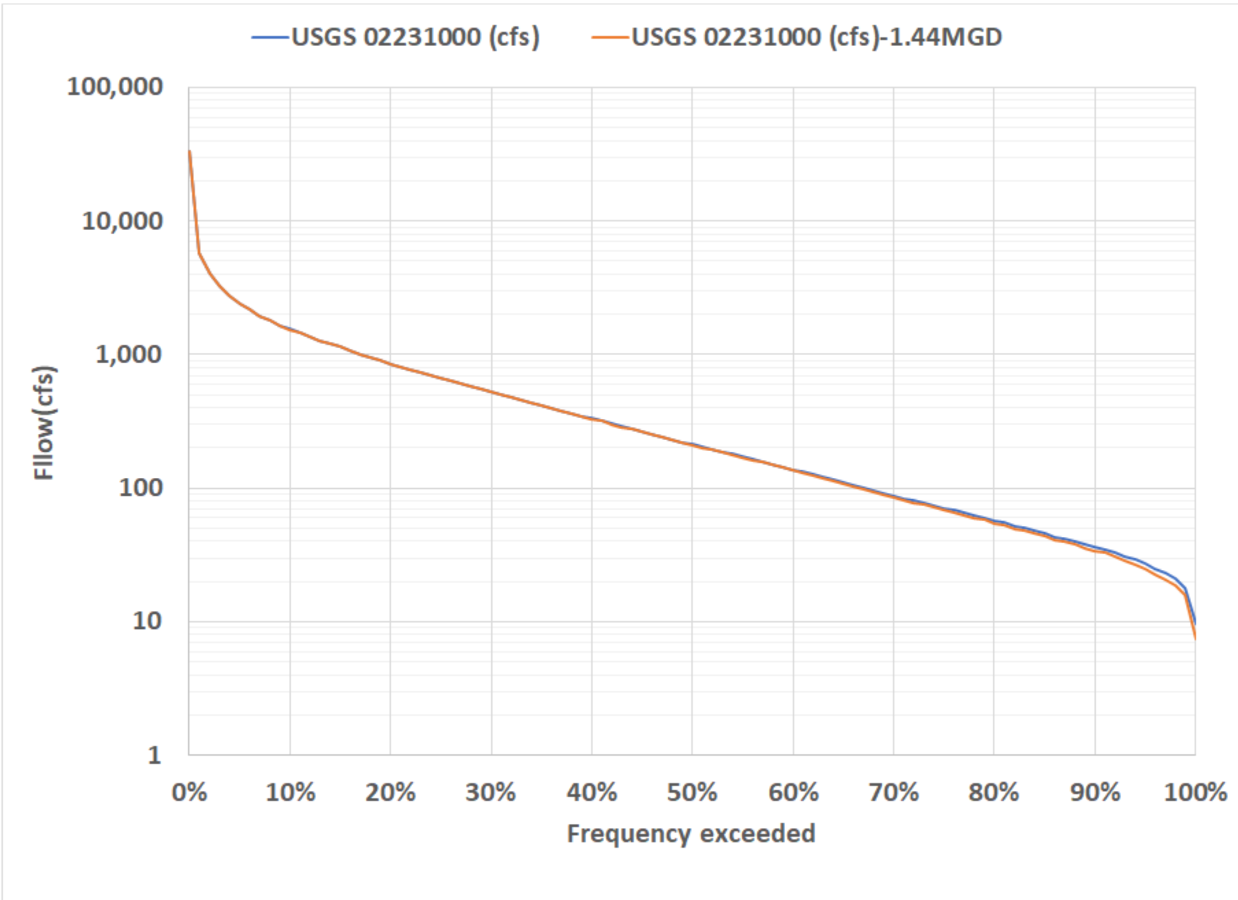


Figure 1. Flow exceedance at USGS 02231000

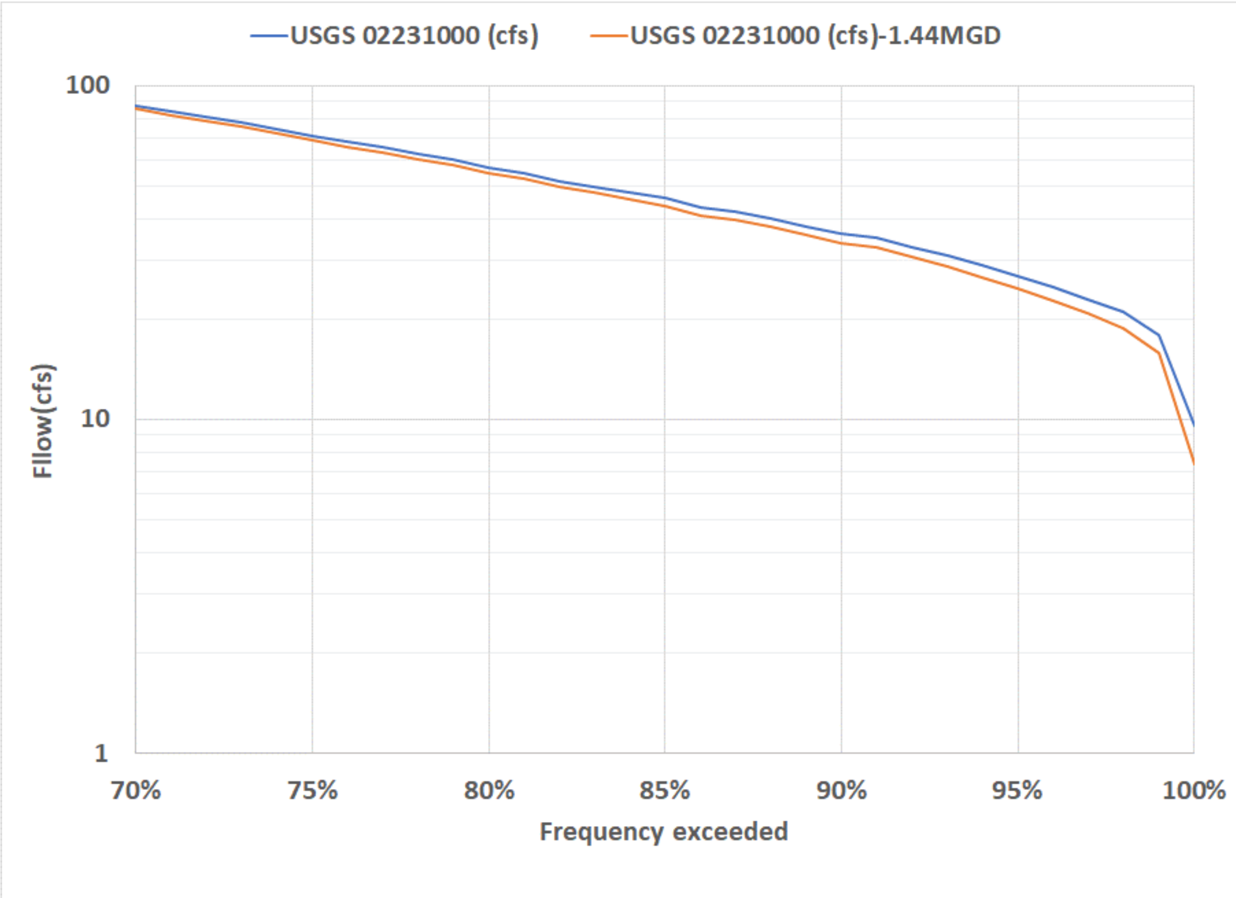


Figure 2. Flow exceedance at USGS 02231000 (lower 30% of the flow spectrum)

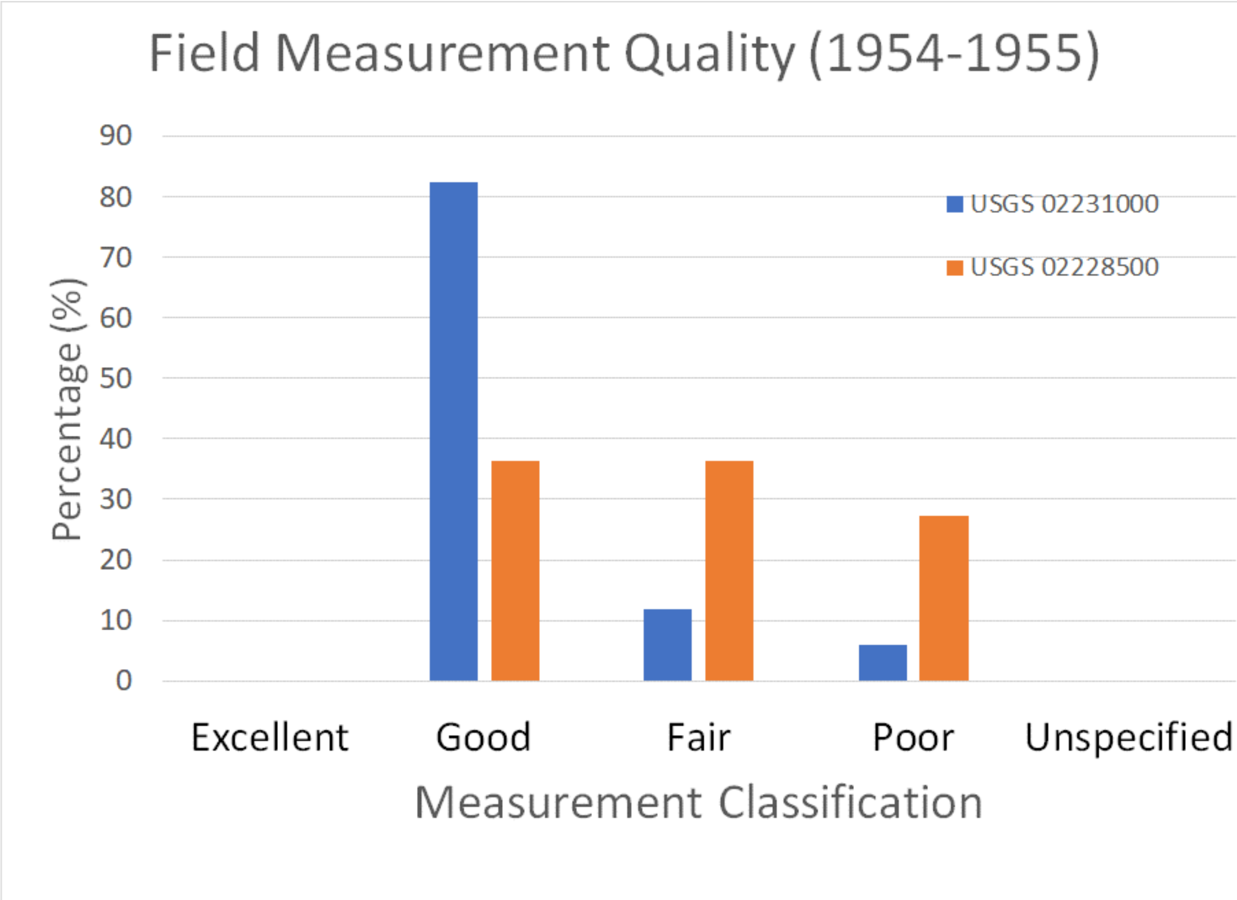


Figure 3. Comparison of quality of USGS field measurements, 1954-1955

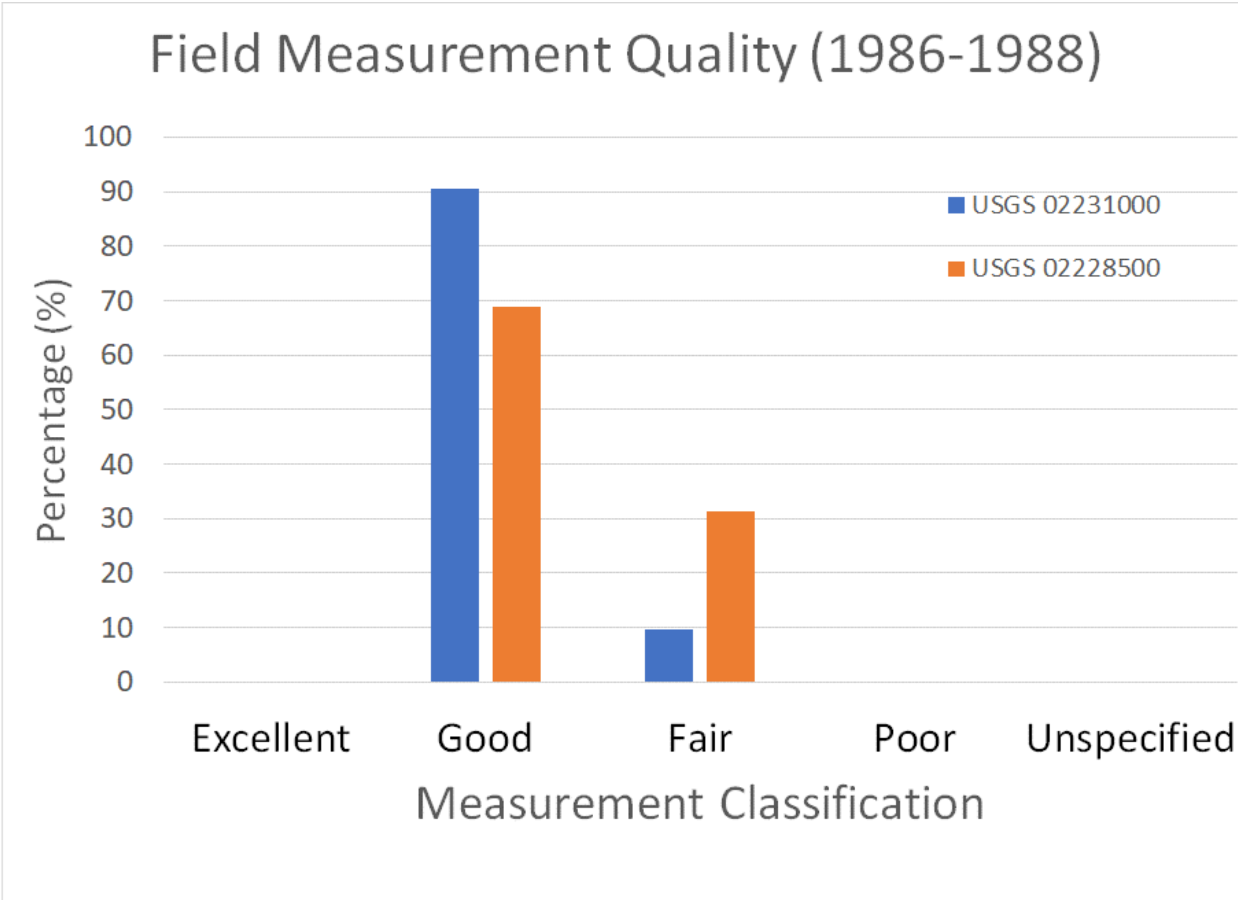


Figure 4. Comparison of quality of USGS field measurements, 1986-1988

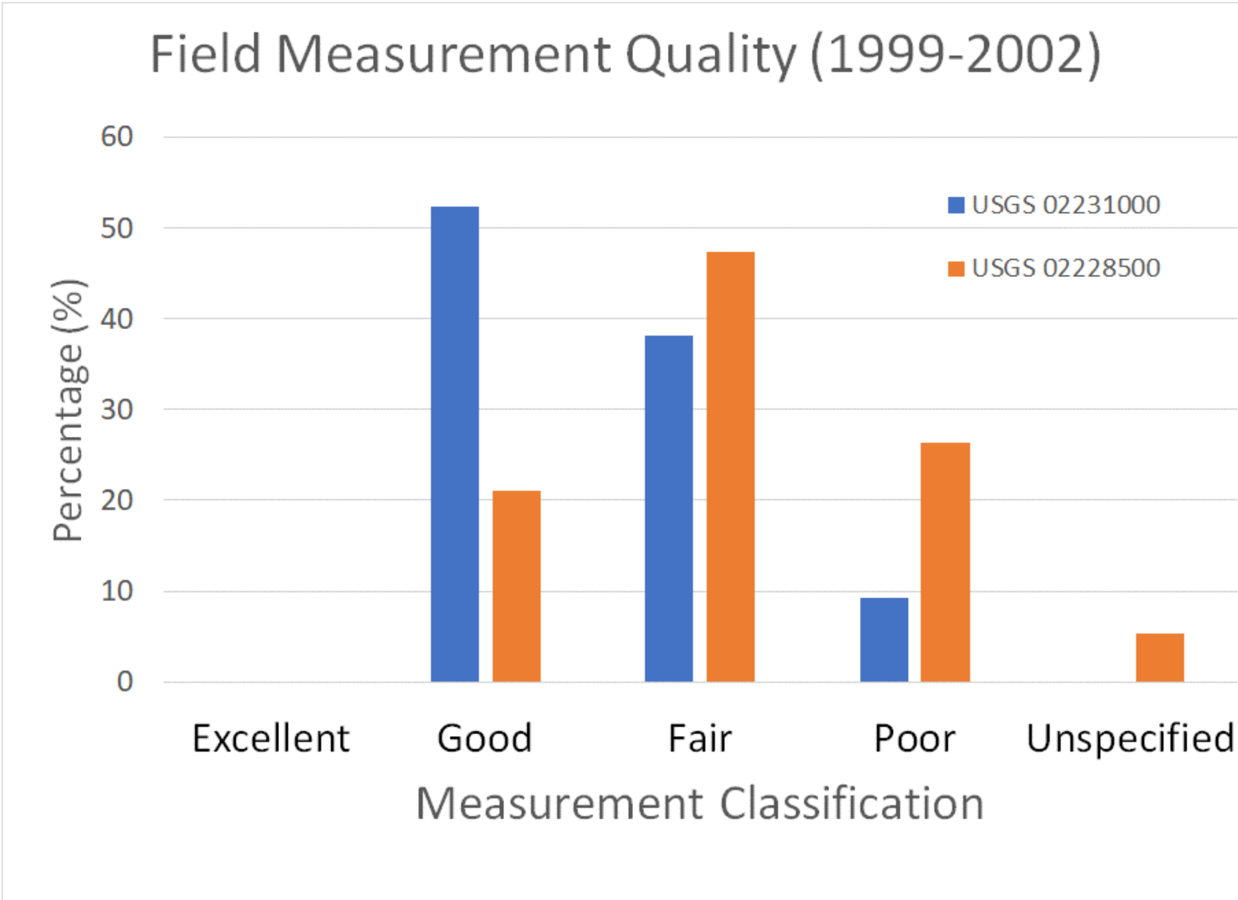


Figure 5. Comparison of quality of USGS field measurements, 1999-2002

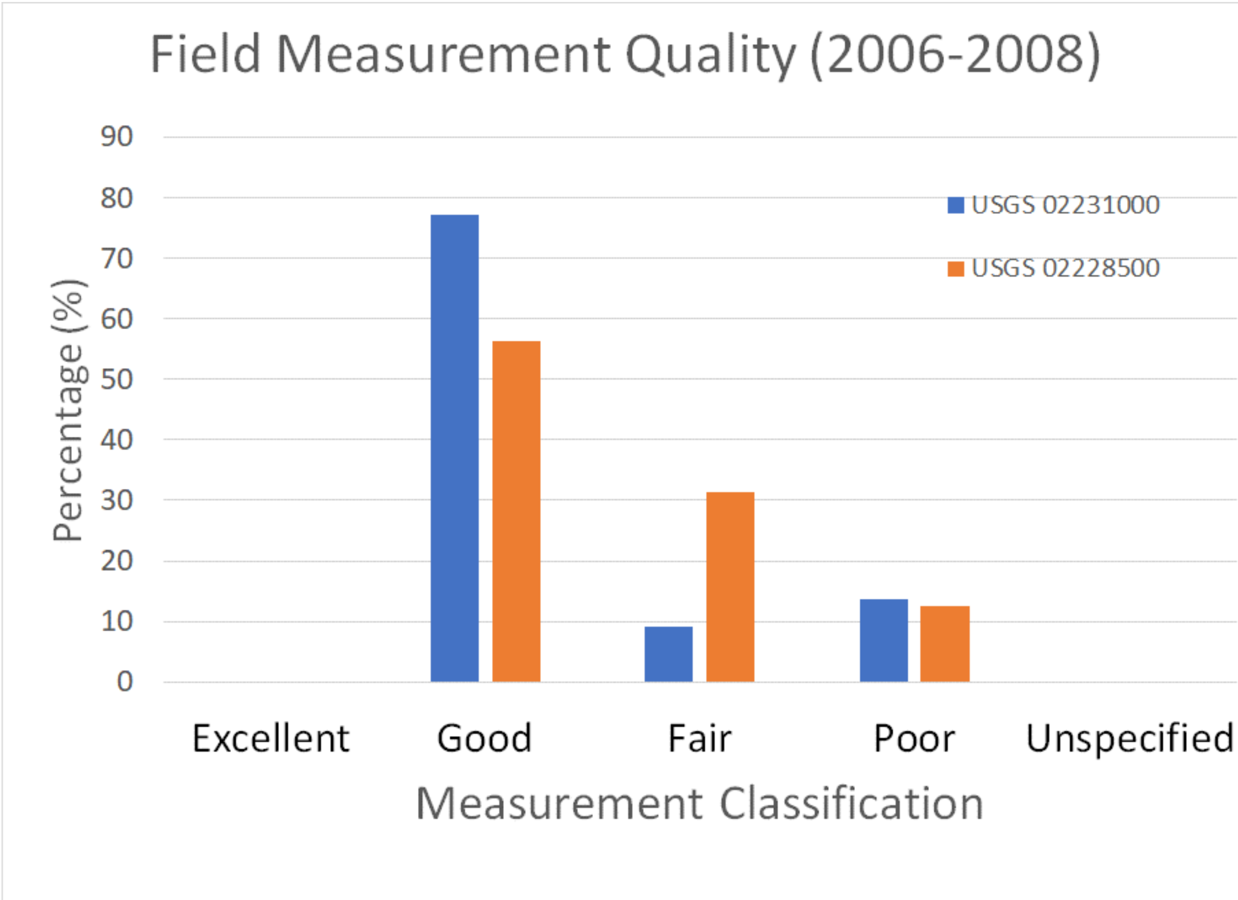


Figure 6. Comparison of quality of USGS field measurements, 2006-2008

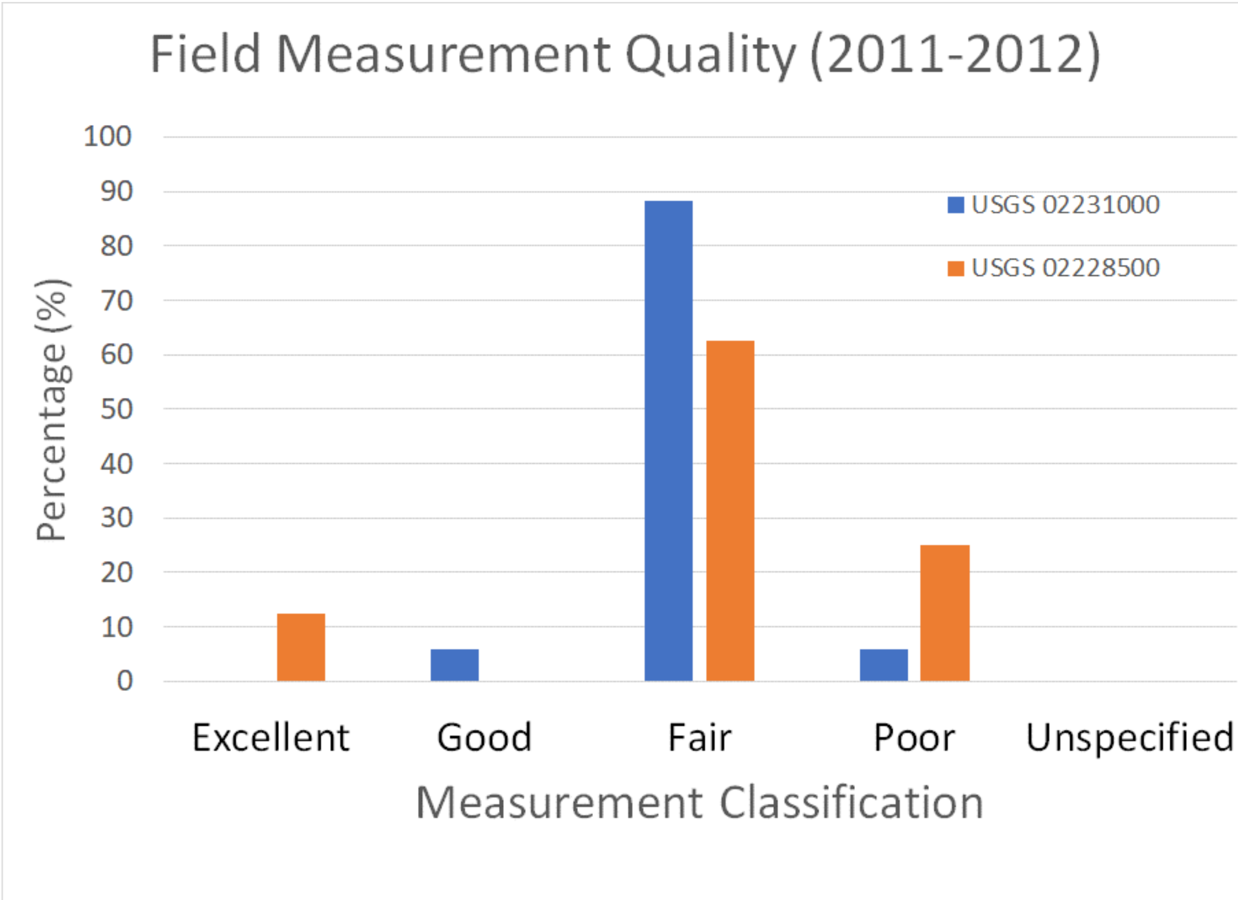


Figure 7. Comparison of quality of USGS field measurements, 2011-2012

Appendix 3. March 8, 2023 Notes from Dr. Rhett Jackson Summarizing a March 7, 2023 Conversation between him and Wei Zeng of EPD's Water Supply Program

Summary of EPD's hydrologic analyses conducted to assess potential effects of the proposed TPM LLC mineral sands mine on regional hydrologic and water quality issues

This summary is based on a phone conversation with Wei Zeng on March 7, 2023

Summarized by C. Rhett Jackson, March 8, 2023

EPD staff have conducted three separate modeling and data analysis exercises to examine potential effects of the TPM LLC mine on regional hydrologic issues: 1) effects of the 1.44 MGD withdrawal from the Floridan on salt water intrusion; 2) effects of the 1.44 MGD withdrawal on assimilative capacity of the mainstem St Marys River; and 3) potential effects of the 1.44 MGD withdrawal on dynamic swamp water levels. Below I will elaborate on each analysis and then comment on the analysis.

Salt Water Intrusion

EPD used the Coastal Sound Science Initiative groundwater model to evaluate how withdrawing 1.44 MDG from the Floridan would affect salt water intrusion problems on the coast – specifically the salt water intrusion problem at Hilton Head Island, SC.

<u>Response</u>: This is the right model for the question, and the analysis would be useful if there were salt water intrusion problems nearby in St Marys or Fernandina Beach, but Hilton Head is too far too worry about. I assume this was done because of the political issues around the Hilton Head saltwater intrusion problem.

Assimilative Capacity of the St Marys River

The 2022 Georgia 303(d) list cites the St Marys River for dissolved oxygen problems. These DO issues limit the assimilative capacity of the river and preclude new effluent discharges. Lowering river flows can exacerbate assimilative capacity issues. Therefore, EPD assumed that all of the 1.44 MGD Floridan aquifer withdrawals would reduce mainstem flows by the same amount, and they analyzed this loss at the Macclenny, FL gage, the only non-tidal gage on the mainstem St Marys River.

<u>Response</u>: This is an appropriate analysis for the problem. The withdrawals are negligible at the Macclenny gage.

Swamp Water Levels

Swamp water levels are important for ecological, social, and fire-risk issues. To evaluate the potential effect of a 1.44 MGD loss from swamp inputs, EPD modeled the entire swamp as a level-pool reservoir. They routed long-term rainfall data through a level pool with a uniform bottom and the surface area of the entire swamp, used a simplification for ET, and assessed the effects of the withdrawal on water levels over time. They found only a 5mm reduction in water levels during the worst droughts.

<u>Response</u>: The swamp presents a very difficult hydrologic modeling challenge. First of all, the internal hydrologic divides within the swamp are dynamic. At very high water levels, the swamp becomes a well-connected reservoir, but at lower water levels the swamp is divided into approximately five compartments identified by Cynthia Loftin and the USFWS, with minimal interaction between compartments. In other words, hydrologic routing within the swamp depends on water levels. At very low water levels, the swamp likely becomes a patchwork of mostly disconnected small basins. Even at high water levels, the swamp has two outlets: the Suwannee River and the St Marys River, but there are

multiple drains connecting the swamp to each major outlet. The hydrologic divide between the two river systems in the swamp can move based on differences in precipitation and tributary inputs on different sides of the swamp. The swamp covers enough area that there can be significant precipitation differences between one side and another.

All hydrologic models are hopefully useful simplifications of reality. The swamp's hydrodynamics do not fit any of the simplifications used to model either rivers, groundwater, or reservoirs. To capture the stage-storage-discharge relationships used in hydrologic routing, a minimum necessity would be high-resolution high-quality LiDAR data shot at an extreme low water level, but this does not presently exist. Even if this did exist, much of the topography of the swamp is not created by soil but rather by buoyant mats of organic matter. The moisture holding and release characteristics of such peat mats are not understood. To accurately model evapotranspiration from the swamp, it would be helpful to have eddy covariance tower data spanning wet and dry periods, but this also does not exist.

Satellite imagery of the swamp clearly illustrates that the swamp does not behave as a level-pool reservoir, and prior hydrologic investigations indicate that the southeastern compartment adjacent to the mine site is isolated during low water periods.

During rainy periods, the swamp gets a lot of water, and during normal and wet periods, the effects of TPM's withdrawals are inconsequential in terms of swamp water levels or outflows. It is only during drought periods that the 0.87+ cfs loss due to the mine's consumptive groundwater use becomes an issue for swamp hydrology. Any analysis of the mine's potential effects on the swamp needs to focus on drought conditions, and it needs to focus only on the southeastern compartment of the swamp. The swamp is too large and disconnected for the mine to affect swamp areas draining to the Suwannee River. Because of the above complications, it is difficult to assess swamp water level issues. For that reason, I focused on the flows measured at the North Prong of the St Marys River at Moniac, GA. Using this data, we see that a 0.87 cfs loss of water from the system has a substantial effect on flows (and presumably water levels, according to the correlation reported by Hyatt 1984) for the lowest 15% of recorded flows.

In order to accurately model the effects of the withdrawals on swamp water levels, it would be necessary to have either a good stage-storage-discharge relationship for the North Prong of the St Marys River basin (we don't) or to have a good empirical relationship between swamp water levels and flows at Moniac (we don't, but this would be easier to develop). Then we could develop a water level deceedance curve with and without various withdrawals. At this point, the best available surrogate assessment of the effects of the mine on swamp water levels are the flow duration curve analyses using the Moniac data.

Appendix 4. March 9, 2023 Memorandum from Wei Zeng of EPD Water Supply Program to Dr. Rhett Jackson with Supplemental Summary and Clarification on Their March 7, 2023 Conversation

Summary of EPD's hydrologic analyses conducted to assess potential effects of the proposed TPM LLC mineral sands mine on regional hydrologic and water quality issues

This summary is based on a phone conversation with Wei Zeng on March 7, 2023 (Wei Zeng provides additional summary/comments below in [square brackets] to reflect our conversation or to provide further clarifications.)

Summarized by C. Rhett Jackson, March 8, 2023

EPD staff have conducted three separate modeling and data analysis exercises to examine potential effects of the TPM LLC mine on regional hydrologic issues: 1) effects of the 1.44 MGD withdrawal from the Floridan on salt water intrusion; 2) effects of the 1.44 MGD withdrawal on assimilative capacity of the mainstem St Marys River; and 3) potential effects of the 1.44 MGD withdrawal on dynamic swamp water levels. Below I will elaborate on each analysis and then comment on the analysis. [On (2), the water quantity analysis using the MacClenny gage covers assimilative capacity and beyond, i.e. issues having to do with the level of flow in the St. Mary's River. I would also add the following point to the summary: (4) EPD conducted modeling of on-site water management before and after receiving seepage information provided by Twin Pines. This work determines that the project would not need to discharge given all of the updated operational parameters, including the seepage rate and the 55 evaporators at 40 gallons per minute capacity.]

Salt Water Intrusion

EPD used the Coastal Sound Science Initiative (CSSI) groundwater model to evaluate how withdrawing 1.44 MDG from the Floridan would affect salt water intrusion problems on the coast – specifically the salt water intrusion problem at Hilton Head Island, SC.

Response: This is the right model for the question, and the analysis would be useful if there were salt water intrusion problems nearby in St Marys or Fernandina Beach, but Hilton Head is too far too worry about. I assume this was done because of the political issues around the Hilton Head saltwater intrusion problem. [EPD has a general approach in using the CSSI model for significant groundwater withdrawals from the Floridan Aquifer within the coastal region (24 counties). This is consistent with the agency's Coastal Permitting Strategy and reflects the agency's prudence in assessing water resources in the area.]

Assimilative Capacity of the St Marys River

The 2022 Georgia 303(d) list cites the St Marys River for dissolved oxygen problems. These DO issues limit the assimilative capacity of the river and preclude new effluent discharges. Lowering river flows can exacerbate assimilative capacity issues. Therefore, EPD assumed that all of the 1.44 MGD Floridan aquifer withdrawals would reduce mainstem flows by the same amount, and they analyzed this loss at the Macclenny, FL gage, the only non-tidal gage on the mainstem St Marys River. [As stated earlier, the water quantity analysis was for a general assessment of the impact on flows in the St. Mary's River. This certainly covers assimilative capacity, but also goes beyond. I should also note that imposition of the entire 1.44 mgd on the St. Mary's River is a rather conservative approach, given that there is not a direct hydraulic connection between the Floridan Aquifer and the St. Mary's River.]

Response: This is an appropriate analysis for the problem. The withdrawals are negligible at the Macclenny gage.[I am happy to see your assessment of our work in the above paragraph and the fact that we do not have a substantive dispute on the use of the MacClenny gage.]

Swamp Water Levels

Swamp water levels are important for ecological, social, and fire-risk issues. To evaluate the potential effect of a 1.44 MGD loss from swamp inputs, EPD modeled the entire swamp as a level-pool reservoir. They routed long-term rainfall data through a level pool with a uniform bottom and the surface area of the entire swamp, used a simplification for ET, and assessed the effects of the withdrawal on water levels over time. They found only a 5mm reduction in water levels during the worst droughts. [A few things I would like to add to the summary. First, again we are being very conservative in our approach, assuming that the entire amount of the 1.44 mgd would be placed on the swamp as if it is a direct surface water withdrawal. In reality, there is an aquitard with a depth of several hundred feet separating the Floridan Aquifer and the surficial aquifer. Any effect on the swamp from pumping in the Floridan Aquifer would be substantially attenuated. So, the true impact from the Floridan pumping is likely to be a fraction of 5 mm. Second, a similar modeling task has been conducted to account for half of the mining pit dewatering, i.e. 0.87 cfs. Using a similar approach to the above, we found the water level impact to be less than 2 mm. Third, the modeling approach has been with the conservative approach of assuming total hydraulic connection between the mining pit and the swamp. Fourth, it has been with the assumption that the swamp is one and well connected water body, which has to do with your critique below.]

Response: The swamp presents a very difficult hydrologic modeling challenge. First of all, the internal hydrologic divides within the swamp are dynamic. At very high water levels, the swamp becomes a well-connected reservoir, but at lower water levels the swamp is divided into approximately five compartments identified by Cynthia Loftin and the USFWS, with minimal interaction between compartments. In other words, hydrologic routing within the swamp depends on water levels. At very low water levels, the swamp likely becomes a patchwork of mostly disconnected small basins. Even at high water levels, the swamp has two outlets: the Suwannee River and the St Marys River, but there are multiple drains connecting the swamp to each major outlet. The hydrologic divide between the two river systems in the swamp can move based on differences in precipitation and tributary inputs on different sides of the swamp. The swamp covers enough area that there can be significant precipitation differences between one side and another.

All hydrologic models are hopefully useful simplifications of reality. The swamp's hydrodynamics do not fit any of the simplifications used to model either rivers, groundwater, or reservoirs. To capture the stage-storage-discharge relationships used in hydrologic routing, a minimum necessity would be high-resolution high-quality LiDAR data shot at an extreme low water level, but this does not presently exist. Even if this did exist, much of the topography of the swamp is not created by soil but rather by buoyant mats of organic matter. The moisture holding and release characteristics of such peat mats are not understood. To accurately model evapotranspiration from the swamp, it would be helpful to have eddy covariance tower data spanning wet and dry periods, but this also does not exist.

Satellite imagery of the swamp clearly illustrates that the swamp does not behave as a level-pool reservoir, and prior hydrologic investigations indicate that the southeastern compartment adjacent to the mine site is isolated during low water periods.

During rainy periods, the swamp gets a lot of water, and during normal and wet periods, the effects of TPM's withdrawals are inconsequential in terms of swamp water levels or outflows. It is only during drought periods that the 0.87+ cfs loss due to the mine's consumptive groundwater use becomes an issue for swamp hydrology. Any analysis of the mine's potential effects on the swamp needs to focus on drought conditions, and it needs to focus only on the southeastern compartment of the swamp. The swamp is too large and disconnected for the mine to affect swamp areas draining to the Suwannee River. Because of the above complications, it is difficult to assess swamp water level issues. For that reason, I focused on the flows measured at the North Prong of the St Marys River at Moniac, GA. Using this data, we see that a 0.87 cfs loss of water from the system has a substantial effect on flows (and presumably water levels, according to the correlation reported by Hyatt 1984) for the lowest 15% of recorded flows.

In order to accurately model the effects of the withdrawals on swamp water levels, it would be necessary to have either a good stage-storage-discharge relationship for the North Prong of the St Marys River basin (we don't) or to have a good empirical relationship between swamp water levels and flows at Moniac (we don't, but this would be easier to develop). Then we could develop a water level deceedance curve with and without various withdrawals. At this point, the best available surrogate assessment of the effects of the mine on swamp water levels are the flow duration curve analyses using the Moniac data.

[Before getting into what additional technical work may be done to address concerns expressed above, I would like to offer a couple of observations from your comments on our analysis of swamp water levels. First, I believe it is fair to say that our analysis would cover the wetter and normal times when plenty of water enters the swamp through precipitation. Your concerns are more related to drought times when the swamp may not be well connected among the different hydrologic compartments. Second, if we believed that the different hydrologic compartments are less than well connected during drought times, then an additional impact analysis isolating the southeast portion of the swamp would in fact be with the assumption that the rest of the swamp is not affected by the mining pit dewatering at all.

In terms of the detailed approach in additional modeling, we propose something similar to (but not exactly the same as) your second idea expressed in the last paragraph of your summary. We propose the reconstruction of a drought time inflow time series to the southeast portion of the swamp. This can be done by having (1) the water level time series from the US Fish and Wildlife Service, and (2) flow data at the Moniac gage for the same time periods. These data will serve as the basis of developing inflow time series to the southeast portion of the swamp. (The process is quite similar to developing reservoir inflow data from measured releases and water levels.) Once we have the inflow time series, we can then deduct the flow impact of 0.87 cfs from it to see the effect of such on both the swamp level (southeastern portion) and the release or resulting flow at Moniac gage.

To the extent that people question the assumption of good hydraulic connection between the mining pit and the lack of it within different hydrologic compartments of the swamp, I would like to say that this approach is a refinement of our earlier work and that we continue to make conservative assumptions in assessing any potential impacts to the swamp.]

[On-site Water Management

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EPD conducted modeling analysis of water management at Twin Pines' mining site utilizing its Water Management Pond System. Given the latest parameters of seepage into the mining pit, the subsequent need to dewater it, the storage within the Water Management Pond System, the demarcation of storage between the portion supporting the industrial process and the portion that handles high inflows, and the intended evaporation of wastewater at 1,000 gallons per minute (with 55 evaporators each at 40 gallons per minute capacity), we concluded that the water management as described is feasible and is without the need to discharge.]