To Whom It May Concern

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Dt: December 15, 2021

Re: Review of two modeling reports prepared to analyze effects of Trail Ridge mining on the Okefenokee Swamp as well as aspects of the surface mining and groundwater withdrawal applications:

"MODELING THE GROUNDWATER FLOW SYSTEM AT THE PROPOSED TWIN PINES MINE ON TRAIL RIDGE" a report prepared by GSI Environmental for Twin Pines Minerals LLC, 7/20/2021, and

"IMPACT OF THE PROPOSED TWIN PINES MINE ON THE TRAIL RIDGE HYDROLOGIC SYSTEM" prepared by Robert Holt, 1/14/2020

Issue #1. The way the hydrogeologic model boundaries are defined precludes the model(s) from finding any effects of the mining operations on Okefenokee water levels.

A groundwater model uses a computer to break time and space into little pieces and solve the 4-dimensional differential equation that describes groundwater flow. This equation is called Richards equation, and it basically says that water will move from high energy to low energy in any of the three spatial dimensions (and time) as a function of the hydraulic properties of the soil/rock and the moisture content of the soil/rock (the model allows any cell to be either saturated or unsaturated). Such a model requires that boundary conditions are defined at all boundaries of the model area (top, bottom, and sides). These boundary conditions can be either defined hydraulic head, defined inputs or outputs (hydrologists call these fluxes), or locations where the boundary conditions can go back and forth between these cases. Without defined boundary conditions, groundwater models are "ill-posed", meaning there is an infinite family of possible solutions to the differential equation.

The GSI model is currently set up so that the western boundary of the model is largely a defined-head boundary in the swamp (Figure 23 in the GSI report). The boundary cells that are not defined head are called "drain package" boundaries that set a minimum head at the boundary but allow outflow to occur when heads inside the domain become higher than the boundary head. In neither case do these boundary conditions allow water levels to fall below the defined head. Similarly, the Holt model uses a defined head boundary for both the eastern and western boundaries. Consequently, the mining operation could pump an entire river of water from Trail Ridge, and the model would not show an effect on water levels at the western model boundary within the edge of the swamp. Consequently, **if the applicants state that the models predict no effects of the operation on swamp water levels, I believe them, because the model boundary conditions preclude any such predictions**.

If the model were set up to allow changes to the hydrology of the swamp, the model domain would have to extend to the watershed boundaries of the swamp and the St Marys River. By doing so, the boundary conditions (except for the rivers themselves) would become no-flow boundary conditions. However, this would make the model much larger and far more difficult to develop and calibrate. It would still be subject to a lot of uncertainty in geologic properties and the fluxes moving through the

Hawthorne formation that constitutes the lower boundary condition. Furthermore, **the effects of the mine operations on swamp hydrology won't be static – they will vary by season and by year. It is well known that the swamp is prone to drought episodes, and fires that start during droughts. A long time-varying simulation (with better boundary conditions), would be necessary to assess the effects of the mine operations on swamp hydrology**. The point is that it will be difficult for anyone to accurately model the groundwater in this surficial aquifer at this scale and to account for the temporal variations in operational effects on the swamp.

Issue #2. The most recent version of the mining land use plan references the need to pump the 50ft deep mine pits while they are active, which would require an enormous amount of groundwater pumping not included in the groundwater withdrawal permit application.

On page 7 of the mining land use plan, it states: "WHEN THE MINE IS INACTIVE, THE WATER LEVEL IS EXPECTED TO RISE TO APPROXIMATELY 45 FEET ABOVE THE MINE BOTTOM. IN ORDER FOR THE MINING OPERATION TO START AGAIN, THE ACCUMULATED WATER WILL NEED TO BE REMOVED DOWN TO 1.5 FEET ABOVE THE MINE BOTTOM." This implies that the pits will have to be dewatered during mining, which essentially requires drawing down the water table by 50 feet in a "well" that is 100 feet wide and 500 feet long. This would require an enormous amount of continuous water withdrawal, and this is not modeled or included in the groundwater withdrawal permit.

Issue #3. The objectives and scenarios assessed by the new modeling effort are not clear, nor is the connection of this modeling effort to the previous modeling effort by Dr. Holt.

Is the GSI model supposed to merely assess the post-closure effect of the backfill on the flow field? Are the readers/reviewers supposed to rely on the previous modeling to assess the effect of groundwater pumping on the flow field? Furthermore, the presentation of results for both models lacks certain graphics that are highly relevant to the inference made in the text. Specifically, if this is a Tothian flow field as proposed by the authors of both reports, where is the cross-section of hydraulic head contours from west to east? How do the different pumping and backfill scenarios affect this horizontal flow field through Trail Ridge? Which scenario is analyzing the effect of dewatering the pit? Why are all the groundwater-affecting operations not evaluated in a single model run?

Specifically, the GSI report leaves the reader to wonder what specific operational questions are being addressed with this modeling effort and what scenarios are analyzed. This effort does not seem to address any effects of the groundwater pumping required for the keeping the mining pits dry.

Why was a new model constructed? How do these models differ? Furthermore, the Holt model appears to model only the effects of pumping the process water, not the water for dewatering the pits. In summary, the organization and content of the modeling reports does not allow the reader to figure out what specific questions were asked of the models and whether the inference is appropriate.

Issue #4. The argument that pumping process water won't affect swamp water levels is based on large-scale regional hydrologic studies that are 1) not meant for this type of detailed analysis, and 2) have been shown to be wrong in places (e.g. in the town of St Marys, Georgia).

The field of hydrology is based on the fundamental idea that water must be conserved in watersheds. I.e. what water goes in must equal the sum of what comes out plus any changes in storage within the watershed. Another way to put this is: if you take some water out, it has to come from somewhere. This has repercussions for thinking about the mining activities. We know the mine will extract groundwater for processing the sands and, apparently, for dewatering the pits, and this water will be taken from the confined Floridan aquifer below Trail Ridge. This will lower pressures in the Floridan aquifer, drawing in water from all-around, and potentially from the surficial aquifer above which is directly connected to the swamp. The modelers argue that the Hawthorne confining layer over the Floridan in the vicinity of the mining operation is too thick to allow leakage from the surficial aquifer above. This is based on USGS regional groundwater studies, specifically and recently by Williams and Kuniansky (2015), which indicates that the coastal semi-confining unit is approximately 300 feet thick and unbreached. However, the report says the same thing about the area beneath the town of St Marys, Georgia, and it is well known that past pumping of the Floridan by the defunct pulp and paper mill in St Marys affected water levels in the unconfined aquifer above. Without conducting long-duration pump tests in the Floridan aquifer with observation wells in the unconfined aquifer, it is impossible to know how this pumping will affect the swamp. It is because of these complications that the USACE recommended that an EIS be conducted for this project during the permitting process.

Issue #5. Mixing clays into the sand mix returned to the pits is a well-intentioned large-scale experiment to reduce the hydraulic conductivity of the mixture with difficult-to-predict effectiveness.

Taking layered geologic materials and mixing them inherently increases the bulk hydraulic conductivity of the system, with the effect that Trail Ridge will transmit water faster after mining unless low conductivity clays are mixed into the sand mixture returned to the pits. The second iteration of the mining plan includes such amendment of the sands with clays. How thoroughly the clay can be mixed, and how well it will work to lower the conductivity of Trail Ridge, are both impossible to predict. **Essentially, the mine proposes to conduct a large-scale construction experiment the outcome of which will affect how the mine alters the hydrology the swamp**.

Issue #6. The swamp ecosystem is sensitive to changes in the depth and duration of saturation, particularly during drought periods.

Even removing a relatively small amount of water from the system could adversely affect water levels in the swamp's SE corner and flow to the upper St Marys River. The swamp doesn't have a very big contributing area, and, because the swamp features a lot of open water and groundwater levels near the ground surface, evaporation and transpiration from the swamp are very high, almost equal to the evaporative demand of the climate. Thus, flows down the St Marys and Suwanee Rivers are quite low for basins of their size. As it leaves the swamp, the St Marys frequently doesn't flow at all (USGS Gage 02228500, North prong St Marys at Moniac). Average PET in this region actually exceeds average precipitation, so most of the water entering the swamp as rainfall or streamflow leaves the swamp as evaporation or transpiration. Because of the complexity of the hydrogeology of the situation, and the relatively small amount of past hydrologic characterization of the swamp and its surrounding

environment, it will be difficult to accurately estimate the water level effects on the swamp, with or without a model.

In summary, the current construction of the groundwater models will not find any effect of the mine's operations on swamp water levels because the design of the model boundary conditions precludes this possibility**. It is certain by hydrogeologic theory that the mining operation will reduce water levels in the SE corner of the swamp by some amount, and it is unlikely we can predict this amount accurately.**

Issue #7. The track record of reclaiming the land surface after Trail Ridge sand mining is poor.

There is no reason to believe that post-mining surface reclamation at this site will be done any better than it has been done in the Florida Trail Ridge mining operations, and a quick glance at Google Earth images of those areas shows clear problems with forest regeneration.

Issue #8. Land Use Incompatibility

The Georgia surface mining law requires that "The Mining Land Use Plan shall be consistent with land use in the area of the mine." The law also requires that the mining land use plan include "protection of contiguous natural and other resources." My overall view is that mining Trail Ridge from the St Marys River to Hickox, Georgia is incompatible with the surrounding land use, namely the Okefenokee swamp and its surrounding commercial forests.

The Okefenokee Swamp is unique to the world in terms of its geology and ecology. It is the largest blackwater swamp in North America. It is a National Wildlife Refuge, a biodiversity hotspot, and a major tourist destination. It was designated a National Natural Landmark in 1974. It creates one of the two largest dark sky sites east of the Mississippi in the U.S. The Okefenokee Swamp is one of the natural wonders of Georgia along with Cumberland Island and the southern Blue Ridge Mountains. The swamp is of great value to the state's culture, tourism, and biodiversity. It is part of the Georgia brand. Currently, the swamp is surrounded by commercial forest lands extending several miles from the boundaries of the wildlife refuge. These forest lands act as habitat buffers for the swamp, providing connected habitat outside the swamp boundaries and keeping light and constant noise of human activities from altering insect and animal behavior in the swamp.

The mine's operations will bring loud, constant noise and bright lights to the swamp's perimeter. It will eliminate wetland and forest habitat in the mining area and destroy potential habitat for several threatened and endangered species including the gopher tortoise, indigo snake, and flatwoods salamander. The lights will bring light pollution and eliminate the dark skies for which the area is famous, reducing the tourist value of the swamp. Finally, the groundwater pumping necessary to operate the mine will affect the hydrology of the SE corner of the swamp, with unknown ecological effects. None of these effects are compatible with the swamp.

Qualifications of the Author of this Critique

I write this critique as a hydrologist with 36 years of experience including two years monitoring groundwater around landfills in Los Angeles, four years in doctorate studies at the University of Washington during which I constructed and ran groundwater models of shallow subsurface flows in hillslopes, 2.5 years running hydrologic models and reviewing stormwater plans for large developments for King County Surface Water Management in Seattle, three years working as an environmental consultant helping developers, municipalities, timber companies, and quarries with various hydrologic and water quality issues, including permitting of projects affecting wetlands, and 24 years as an academic hydrologist at the University of Georgia. I have authored and co-authored over 100 peer-reviewed journal articles and book chapters on hydrology, stormwater management, pollutant transport, and stream ecology, and these publications have garnered over 6600 scientific citations. I have worked with the timber industry and the Georgia Forestry Commission to revise and update the Forestry Best Management Practices for Georgia. My graduate students have gone on to work for USGS, USEPA, USFS, state agencies, consulting firms, and NGOs.