TPM LLC's Proposed Trail Ridge Mine: Hydrologic Effects on the Okefenokee Swamp

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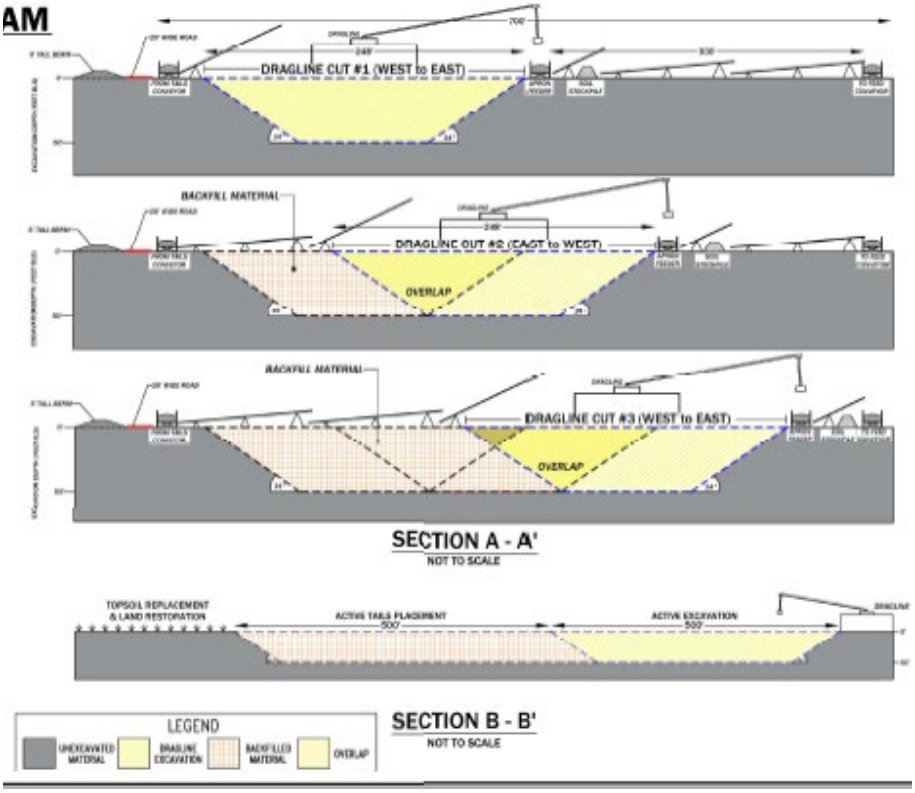
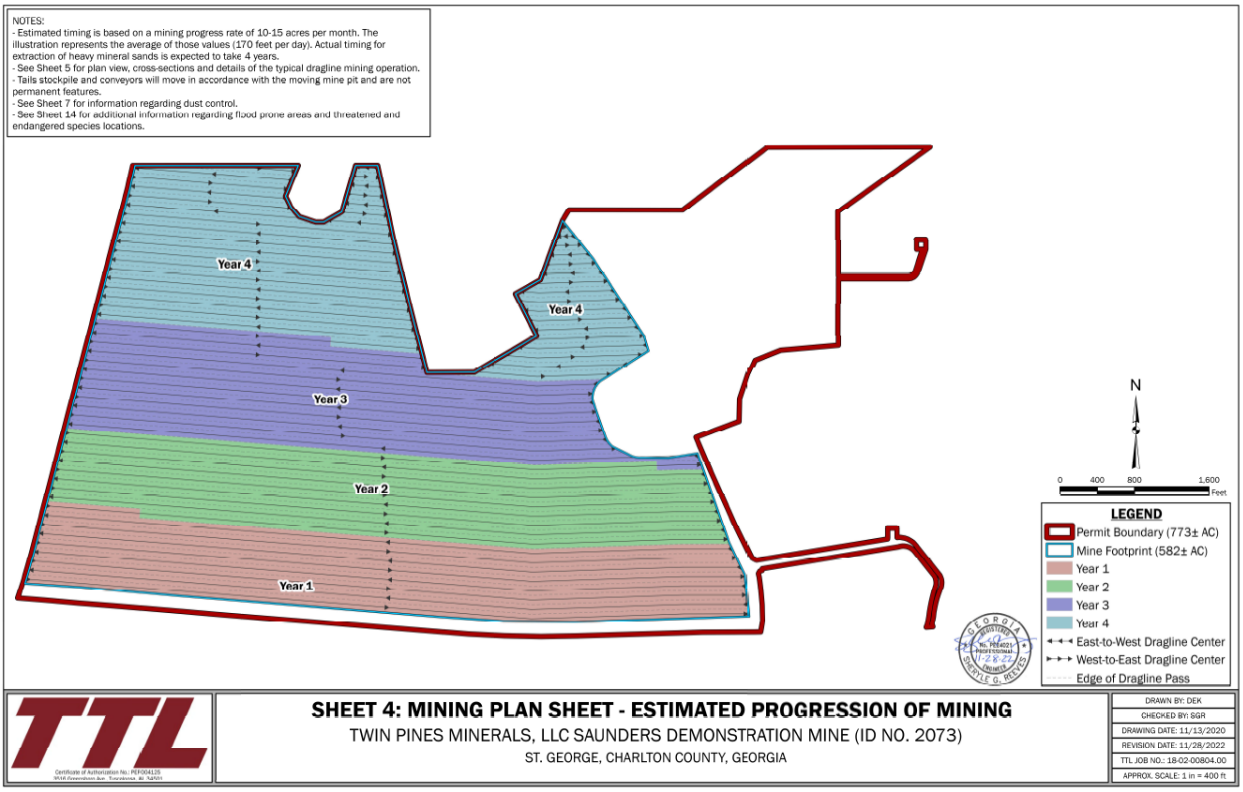
University of Georgia, 1/28/2023

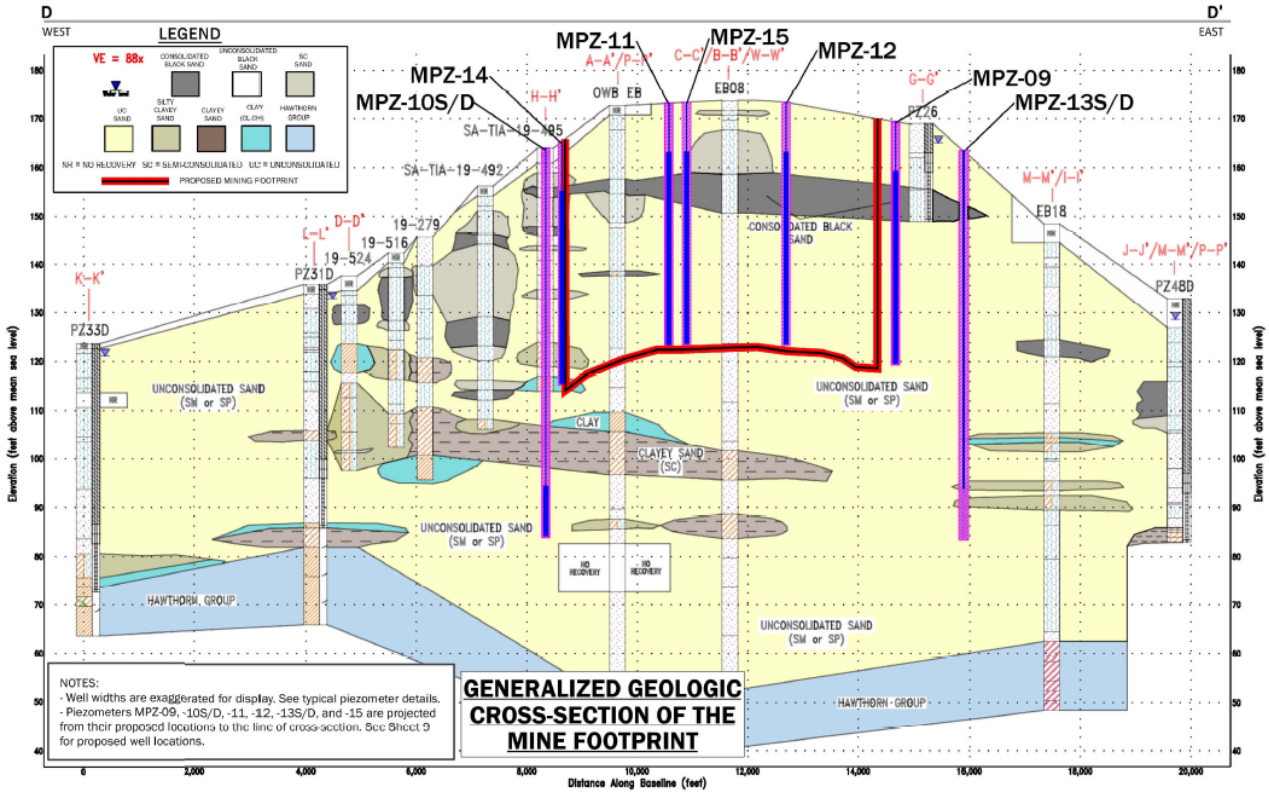
How would the mine basically work?

To understand the hydrologic effects of the proposed mine, it is necessary to have a basic understanding of how the proposed mine would work. The mine operations are detailed in the documents available at the Georgia EPD TPM LLC permitting website: Twins Pines docs for comment | Environmental Protection Division (georgia.gov) However, the documents are voluminous and not easy to follow. Some of the documents are large and will bind up in Acrobat. Below, in a little more than a page of text, supported by figures from the permit documents, I summarize the proposed mine operations.

TPM LLC proposes to mine mineral sands from Trail Ridge using a moving 500ft x 100ft x 50ft deep (bottom dimensions, surface dimensions larger) open pit that will move back and forth across the ridge (below). All of the land in the mining area, upland and wetland, will be excavated and mined (below). Groundwater seepage into the pit will be continuously pumped and evaporated using mechanical evaporators to keep the pit dry. Sands withdrawn from the ore beds will be processed similarly to gold panning, except using machines to pass water and sands down long helical sluices to separate the sands by density. Additional process water will be drawn from wells drilled into the confined Floridan aquifer several hundred feet down. Within the old barrier islands of the Coastal Plain, there are lenses of dark sands known as mineral sands (see generalized geologic cross section below), and these mineral sands are good for a number of things, but currently their biggest economic value is as a source of titanium dioxide used as a whitening pigment. These mineral sands may comprise 5-10% of the ore beds, but will be largely absent from the lighter sands above and below the ore beds. After the mineral sands are removed, the remaining sands will be returned to the pit, and the process just keeps moving.

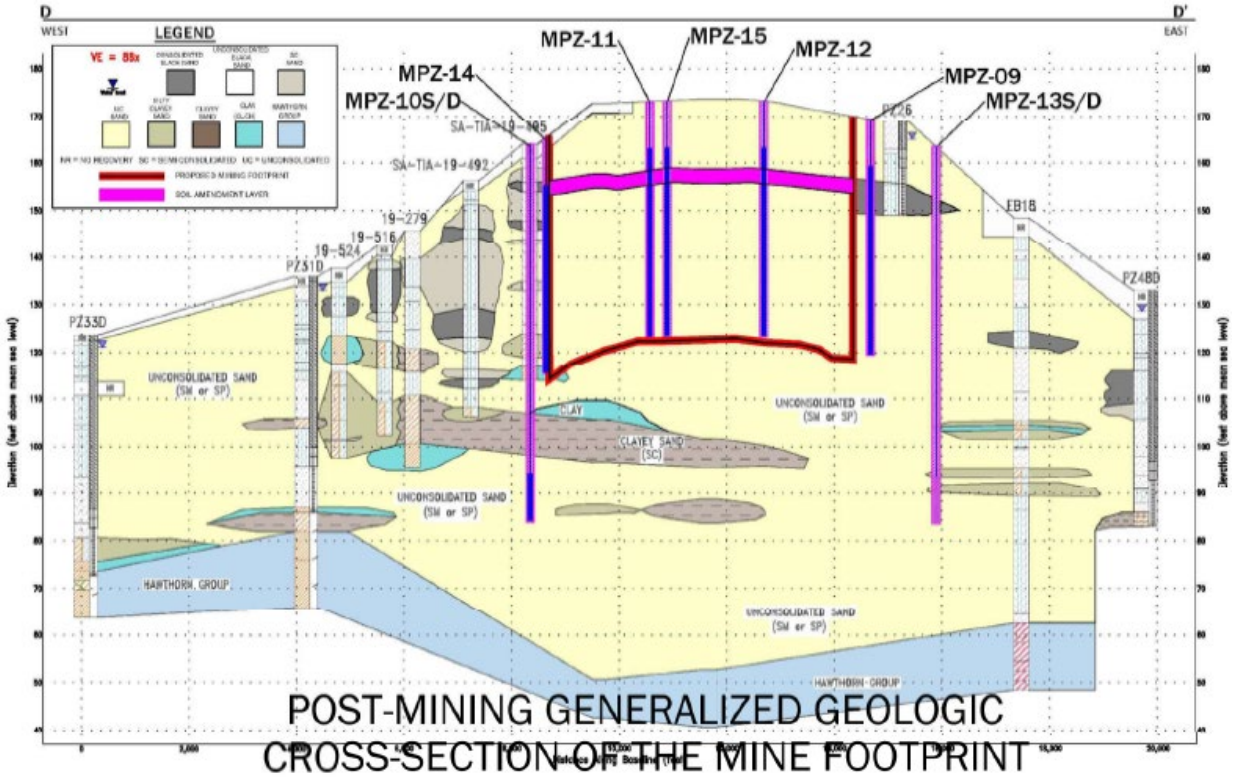



NOTES:
- Estimated timing is based on a mining progress rate of 10-15 acres per month. The illustration represents the average of those values (170 feet per day). Actual timing for extraction of heavy mineral sands is expected to take 4 years.
- See Sheet 5 for plan view, cross-sections and details of the typical dragline mining operation.
- Tails stockpile and conveyors will move in accordance with the moving mine pit and are not permanent features.
- See Sheet 7 for information regarding dust control.
- See Sheet 14 for additional information regarding flood prone areas and threatened and endangered species locations.
Year 4
Year 4
Year 3
Year 2
Year 1
N
0 400 800 1,600
Feet
LEGEND
Permit Boundary (773± AC)
Mine Footprint (582± AC)
Year 1
Year 2
Year 3
Year 4
East-to-West Dragline Center
West-to-East Dragline Center
Edge of Dragline Pass
TTL
SHEET 4: MINING PLAN SHEET - ESTIMATED PROGRESSION OF MINING
TWIN PINES MINERALS, LLC SAUNDERS DEMONSTRATION MINE (ID NO. 2073)
ST. GEORGE, CHARLTON COUNTY, GEORGIA
DRAWN BY: DEK
CHECKED BY: SGR
DRAWING DATE: 11/13/2020
REVISION DATE: 11/28/2022
TTL JOB NO.: 18-02-00804.00
APPROX. SCALE: 1 in = 400 ft


D
WEST
D'
EAST
LEGEND
VE = 88x
CONSOLIDATED BLACK SAND
UNCONSOLIDATED BLACK SAND
SC SAND
UC SAND
SILTY CLAYEY SAND
CLAYEY SAND
CLAY (CL-CH)
HAWTHORN GROUP
NR = NO RECOVERY SC = SEMI-CONSOLIDATED UC = UNCONSOLIDATED
PROPOSED MINING FOOTPRINT
MPZ-14
MPZ-10S/D
MPZ-11
A-A'/P-P'
MPZ-15
C-C'/B-B'/W-W'
MPZ-12
MPZ-09
MPZ-13S/D
H-H'
OWB EB
EB08
G-G'
PZ26
SA-TIA-19-495
SA-TIA-19-492
M-M'/I-I'
EB18
CONSOLIDATED BLACK SAND
J-J'/M-M'/P-P'
PZ48D
L-L'
D-D'
19-279
19-516
19-524
PZ31D
K-K'
PZ33D
UNCONSOLIDATED SAND (SM or SP)
CLAY
CLAYEY SAND (SC)
UNCONSOLIDATED SAND (SM or SP)
NO RECOVERY
NO RECOVERY
UNCONSOLIDATED SAND (SM or SP)
HAWTHORN GROUP
UNCONSOLIDATED SAND (SM or SP)
HAWTHORN GROUP
Elevation (feet above mean sea level)
Distance Along Baseline (feet)
NOTES:
- Well widths are exaggerated for display. See typical piezometer details.
- Piezometers MPZ-09, -10S/D, -11, -12, -13S/D, and -15 are projected from their proposed locations to the line of cross-section. See Sheet 9 for proposed well locations.
GENERALIZED GEOLOGIC CROSS-SECTION OF THE MINE FOOTPRINT

Prior to excavation, TPM LLC will stockpile mixed topsoils from the wetlands and uplands so they can be spread over the surface after sands are returned to the excavation areas. Because less sand is returned to the pit then excavated, there will be sand deficits, and there will consequently be lakes left behind on Trail Ridge (the sand deficit is not discussed in the reclamation plan). Furthermore, because the sands returned to the pit will be loose and unconsolidated, there will be settling of the land surface over time.

The generalized geologic cross section above shows that the proposed mining pit (outlined in the crimson polygon) contains layers and lenses of unconsolidated sands, partly consolidated sands, consolidated black sands, and clays. Each of these layers has different hydraulic properties that affect groundwater flow and the position of the surficial water table under Trail Ridge. The effect of replacing this layered system with a uniform mixture of disturbed materials is to increase the rate at which groundwater can flow through the ridge. To mitigate the effect of this mixing on the hydrology of the ridge, TPM LLC proposes to place a layer of bentonite clay (the fuschia band in the figure below) at the approximate location of the current consolidated black sands lens during the process of returning the sands to the pits. In order for this to create the desired impediment to flow, this layer will have to placed and compacted so that it is a continuous layer with inconsequential gaps and irregularities.

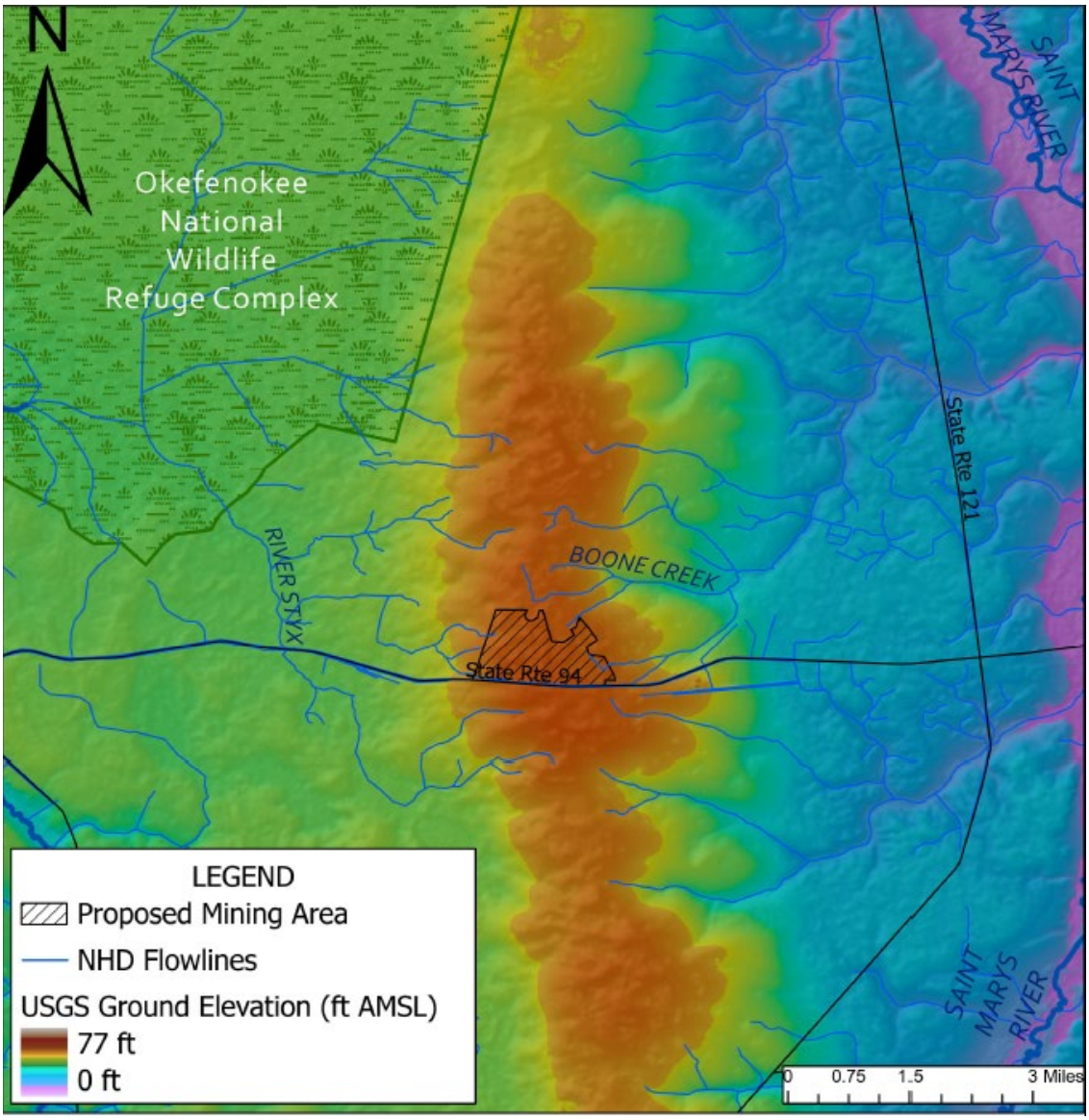


POST-MINING GENERALIZED GEOLOGIC CROSS-SECTION OF THE MINE FOOTPRINT

The St Marys River is classified as impaired due to several water quality conditions including sediment, turbidity, and dissolved oxygen, all of which could be affected by discharges of mine process water. To avoid the need for treatment of mine water, TPM LLC proposes to use mechanical evaporators to evaporate the water pumped from the mine pit and the Floridan aquifer wells.

TPM LLC needs a surface mining permit to operate the mine and a groundwater withdrawal permit to withdraw operations water from the Floridan aquifer. Due to peculiarities of Georgia law, pumping of surficial groundwater from the mine pit is not considered a groundwater withdrawal needing a permit, regardless of the hydrologic or ecological effects of such withdrawal. Georgia's surface mining law

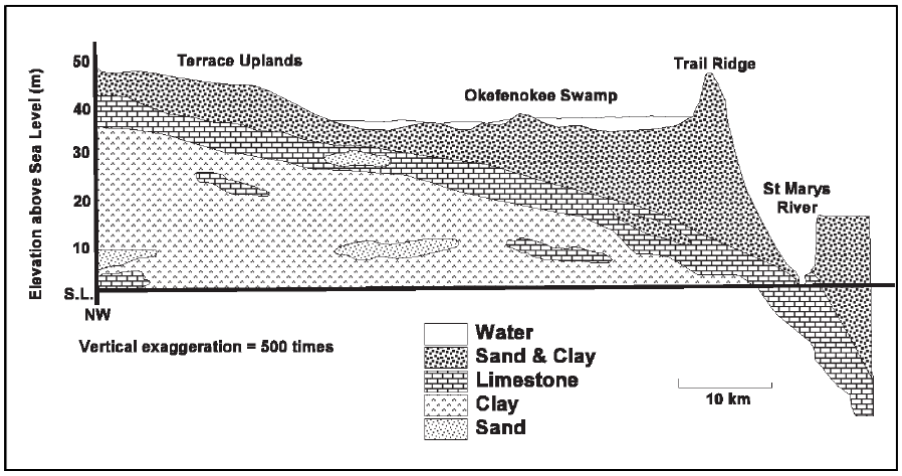
requires that the mine operations protect the environment and resources of the State and shall be consistent with land uses in the area of the mine. As can be seen from the map below, half of the mine site drains to the southeastern portion of the swamp and its tributaries.



The mine site, southeast of the swamp, north of SR 94, and west of St. George.

Effects of the TPM LLC mine on swamp hydrology

The Okefenokee Swamp is mostly rain-fed (70-80%) and highly sensitive to intra- and inter-annual variability in rainfall due to meager storage within the swamp and the low amount of groundwater inputs to the swamp. The average depth of the swamp is only about 0.5 meters, and the turnover time of water in the swamp is only 3-4 months. The swamp has very little contributing area other than the swamp itself. Seventy to eighty percent of the water reaching the swamp comes from rainfall incident upon the swamp. The remainder of hydrologic inputs are from small tributary watersheds on the west and northwest edge of the swamp as well as from surficial aquifer drainage from Trail Ridge on the eastern and southeastern boundary. Trail Ridge itself is an ancient barrier island that acts as a long, tall, earthen dam that created conditions for the swamp to form (see below). Groundwater inputs from tributary watersheds and Trail Ridge provide small amounts of flow to the swamp during droughts. Water leaves the swamp by evapotranspiration, flow into the Suwanee and Upper St Marys Rivers, and leakage through the Hawthorn Formation into the underlying Floridan aquifer. *The Okefenokee swamp is very sensitive to drought*.

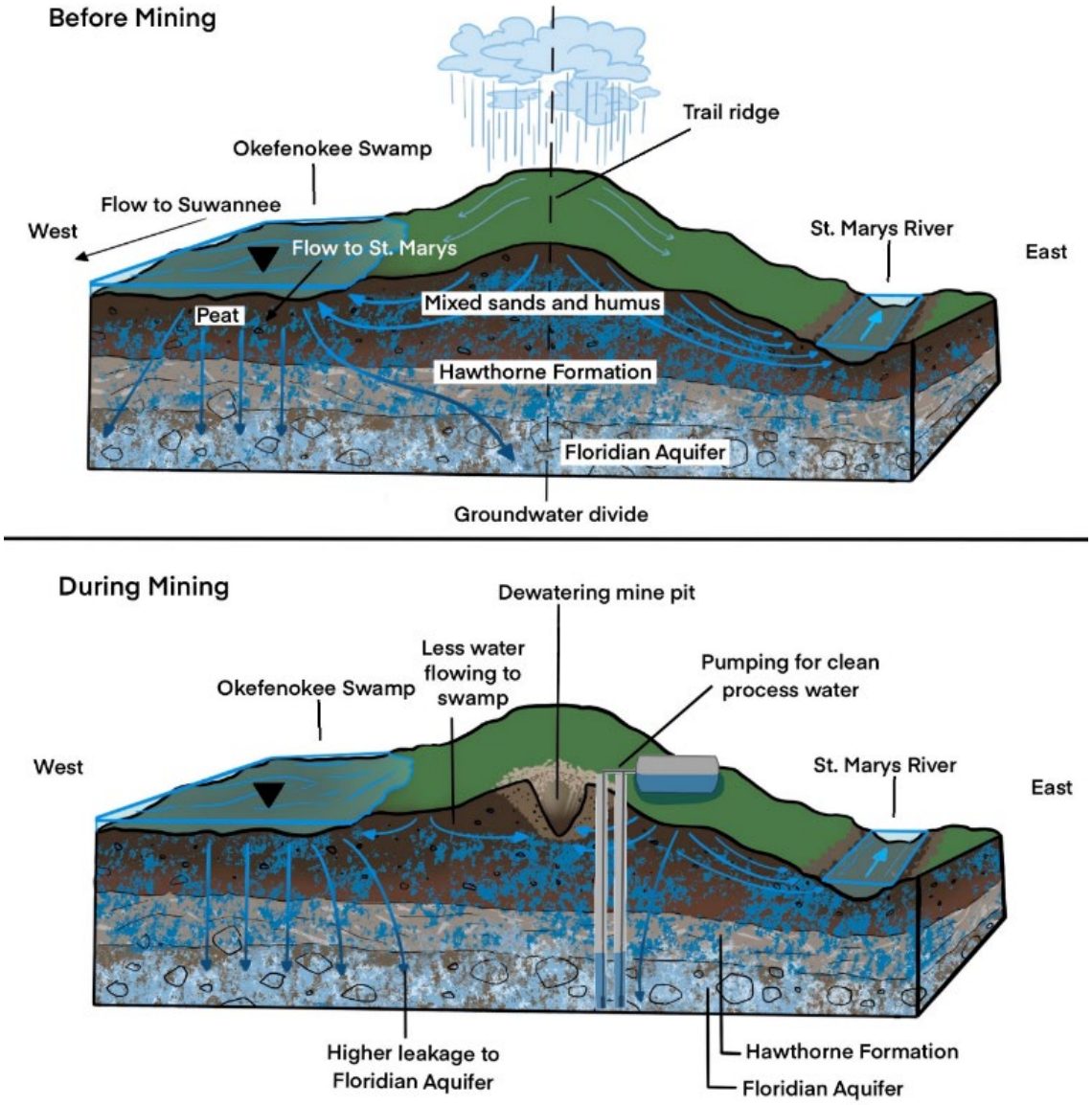


The proposed TPM LLC mine will remove groundwater from Trail Ridge and the Floridan aquifer and consequently increase the frequency and severity of drought. The current version of the TPM water management plan for the mine predicts that 500 ft x 100 ft x 50-foot-deep mining pit will need to be continuously pumped to remove groundwater seeping into the hole from the surrounding surficial aquifer. The plan states that this seepage will average 783 gallons per minute (gpm), equivalent to 1.128 million gallons per day (MGD) or 1.75 cubic feet per second (cfs). This estimate agrees with that predicted by well equations calculated by other experts.

Surficial groundwater will keep flowing into the pit as long as it is pumped. The resulting water level in the pit will be lower than the Trail Ridge water table in all directions. Lowering the water table by approximately 50 feet at the point of the mining pit will bring the water level in the pit down to the same elevation as the typical swamp water level.

We can assume that half of this 1.128 MGD (1.745 cfs) of seepage water to the mine pit will come from the west side of Trail Ridge, and the other half will come from the east. This is because the cones of depression of groundwater levels around pumped wells are generally symmetrical. According to the hydrogeologic studies and models conducted by the applicant and in accordance with groundwater flownet theory developed by Tóth (1963), the proposed mine straddles what currently acts as a groundwater divide beneath Trail Ridge. Groundwater to the west of Trail Ridge crest flows west to the swamp, and groundwater to the east of Trail Ridge crest flows east to the Lower St Marys as it flows north toward Folkston.

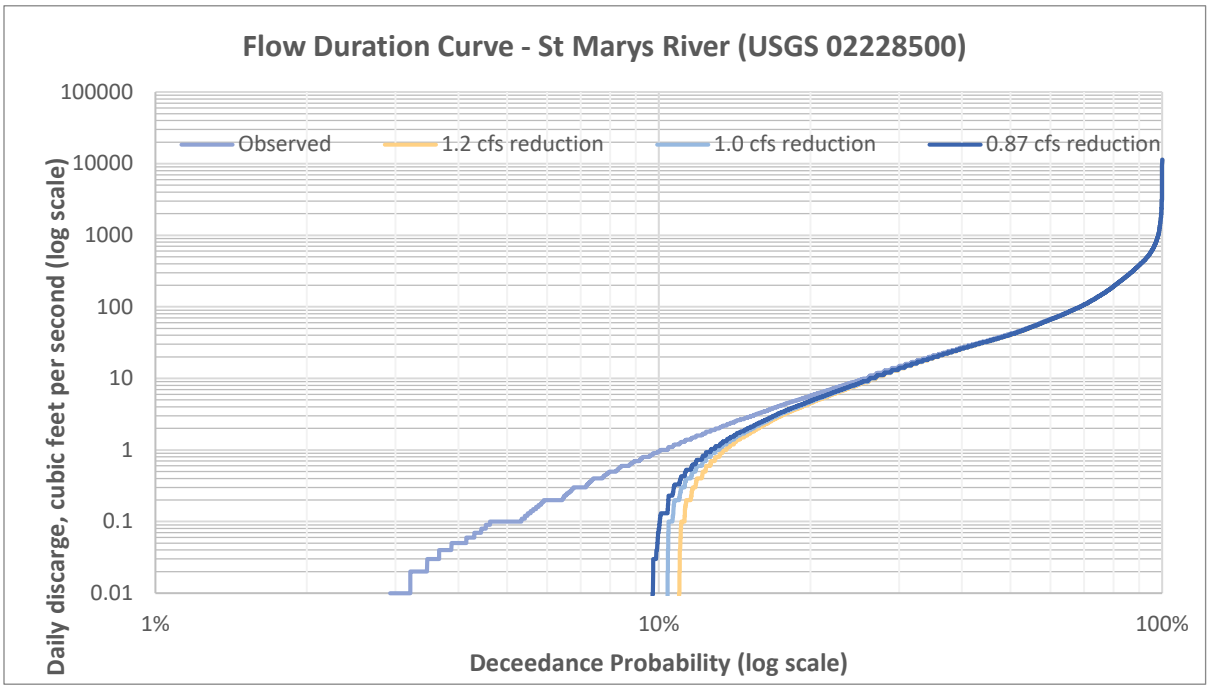
Therefore, *half of the water pumped from the mining pit will come from groundwater that would otherwise flow into the Okefenokee Swamp, reducing flows to the swamp by at least 0.87 cfs. Removing water from the west side of the surficial aquifer under Trail Ridge necessarily means removing that water from the water budget of the swamp. This loss will be most noticeable during drought conditions, as it is this surficial groundwater seepage that helps sustain the swamp during droughts*.



This loss of surficial groundwater to the swamp will be exacerbated by additional leakage through the Hawthorn Formation into the underlying Floridan Aquifer. This is because the mine will also episodically withdraw up to 1.44 MGD (2.23 cfs) of clean process water from the Floridan Aquifer. Lowering hydraulic pressures in the Floridan Aquifer will increase downward leakage through the Hawthorn Formation from the overlying swamp. While an accurate estimate of the resulting loss of swamp water due to leakage is uncertain, this loss will add to the loss caused by pit dewatering.

A standard hydrologic method for estimating the effects of water withdrawals from a watershed is to evaluate the river hydrograph characteristics or statistics before and after withdrawals. Here we assess

how the mining withdrawals will change the river flow-duration curve, a curve that shows the fraction of time that flows are less than or equal to flows of a specified magnitude (flow deceedance probability, as shown below).



The flow-duration curve shown here is created using USGS-measured streamflow record for the Upper St Marys River as it leaves the swamp (USGS gage 02228500). The figure shows that the undisturbed river has no measurable flow during just over 3% of the gage record, indicating the sensitivity of the swamp to drought. Previous analysis has shown that flows at this gage are highly correlated with US FWS-measured water levels in the swamp (Hyatt, PhD dissertation, Univ. of Georgia, 1984).

We also plot flow duration curves for a range of possible withdrawals; 0.87, 1.0, and 1.2 cfs. The 0.87 cfs loss equals half of the necessary pumping for mine pit dewatering, and this is the minimum potential effect of the mine. The larger withdrawal cases reflect additional 0.13 and 0.33 cfs losses due to increased leakage from the swamp due to Floridan Aquifer pumping by the mine. Water loss from the swamp due to pit dewatering and groundwater pumping is likely to be within this range. As stated above, Floridan pumping will be episodic, so that it is difficult to estimate how much swamp water will be lost due to higher leakage.

Removing the mine pit dewatering water (0.87 cfs) from the swamp water budget increases the no-flow fraction from 3% of the time to 9.5% of the time. *Groundwater withdrawals from the mining pit will triple the frequency of severe drought in the SE portion of the swamp and the Upper St Marys River*. Such an increase in drought frequency will have substantial effects on swamp ecology, wildfire frequency, and boating access for tourism, management, and scientific purposes. *Additional losses from the swamp water budget due to Floridan aquifer pumping could quadruple the frequency of severe drought conditions.*

EPD has skewed their analysis of the effects of the proposed water withdrawals by analyzing their effects on flows far downstream on the St Marys, where the watershed and average discharge are over 4.4X larger than where the river exits the swamp. This is equivalent to analyzing a Mississippi River flooding problem in Minneapolis, MN using gage data from Grafton, Illinois just north of St. Louis, MO.

Why do increasing drought frequency and severity matter?

Increasing the frequency and severity of drought will commensurately increase the risk of wildfire in the swamp and surrounding region, with effects on the surrounding timberlands, swamp ecology, and local residents. It is well known that very large wildfires periodically initiate within and burn on the swamp margins, most recently in 2007, 2011, and 2017 (see graphics below showing the extent and ownership of lands burned in the 2017 fire). "The 2007 fire in the swamp had perhaps the biggest impact, with a total cost of about $130 million, including $65 million in lost timber and $44 million in firefighting costs…Over 6000 people had to evacuate their homes" (Okefenokee Swamp Fire: Why Swamps Burn, AJC, Mary Caldwell, 5/19/2017). Such fires are ignited during drought conditions, so increasing drought in the swamp necessarily increases wildfire risk.

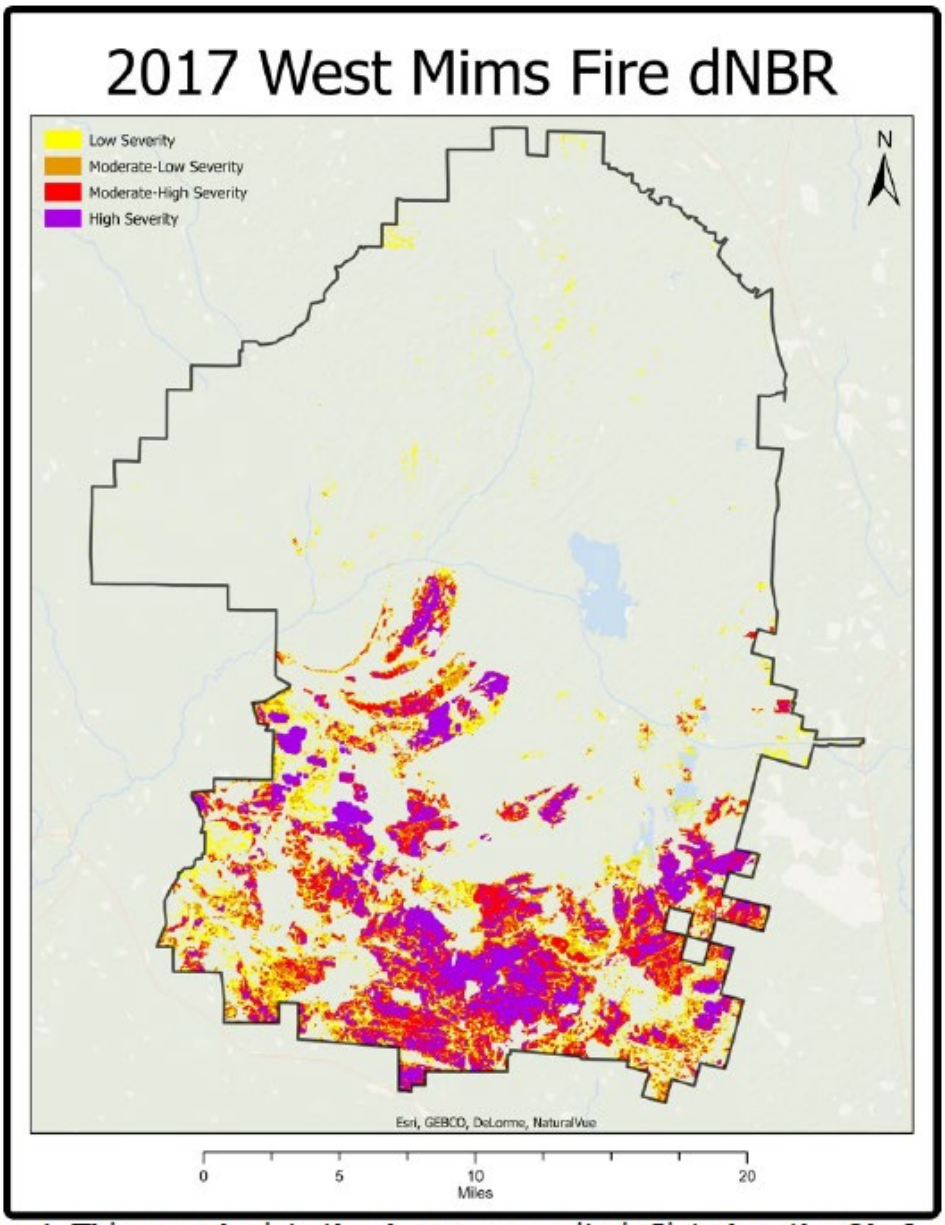
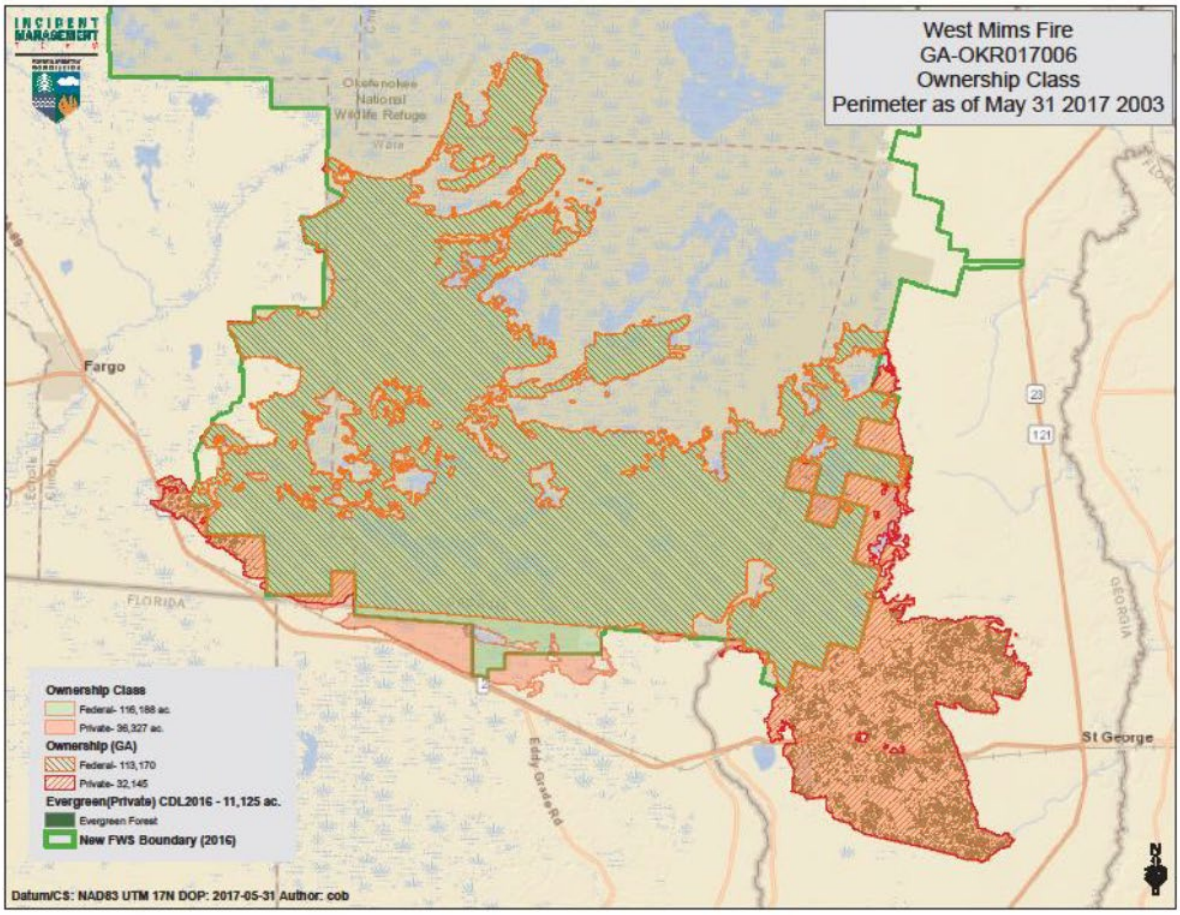


Figure 1. This map depicts the damage severity inflicted on the Okefenokee Swamp by the West Mims Fire.

From NASA report. Kendall, B., Steen, K., Schmidt, H. and Plott, L., 2022. Okefenokee Water Resources: Using Earth Observations to Assess Hydrologic Changes and Wildfire Risk in the Okefenokee Swamp.



GFC. Wildfire Damage Assessment for the West Mims Fire, Chip Bates, Forest Health Coordinator, Georgia Forestry Commission. [Wildfire Damage Assessment for the West Mims Fire (gatrees.org)]

Increasing the frequency and severity of drought and fires will have effects on the competitive balance of plant species, resulting in a cascade of changes to plant succession that will alter the ecology of the swamp. Plants are the base of all ecosystems and food chains. The swamp supports a mosaic of habitat types, differing in their relative wetness, and the high habitat diversity helps support 850 different plant species. Drought and fire are two critical abiotic factors that control the relative competitiveness of plants, and thus increasing their frequency will change plant communities with effects on all aspects of swamp ecology.

As the average depth of the swamp is only 0.5 meters, boating anywhere but the lakes and canals in the swamp isn't possible during drought. "The fires of 2007 and 2011 burned so close to the park, that it was closed weeks at a time. Also, persistent droughts left water in the canals so low, the park couldn't conduct its popular boat tours" (The Florida Times Union, Terry Dickson, 9/29/2012). *Increased drought frequency and severity will similarly triple the number of days in which kayaking the water trails isn't possible*.

Both the mine operations and the resulting negative press will deter out-of-state tourists from visiting the swamp. What do non-Georgians think of when they think about Georgia? Atlanta, Hartsfield airport, a rich music history, Martin Luther King Jr., the southern Appalachians, peaches, pecans, and peanuts, Georgia Bulldog football, and … the Okefenokee Swamp. These are our geographic and cultural jewels. They give people a warm and fuzzy feeling about Georgia and make them want to come visit. Why on Earth would we permit an environmentally-damaging, ugly, and brand-destroying mineral sand mine next to one of our crown jewels? When the mine starts, national papers like the NYT, WSJ, and the Washington Post will run stories with aerial pictures of the mine with the swamp in the background and question why a prosperous state like ours would permit such a monstrosity next the Okefenokee Swamp. Every time there is a drought and/or wildfire in the swamp, newspapers will run stories about the science that predicted that the mine would exacerbate drought. Then they will run stories about the poverty of Charlton County, and how the mine didn't raise living conditions there. The mineral sands mining industry in Florida is known to have a poor track record in mine reclamation, and other stories are likely to show poor pine regeneration and bare sands in the mined areas. We won't be framing a crown jewel with diamonds, but with costume jewelry.

A better alternative for the region would be to invest in the gateway communities of the Okefenokee Swamp and empower them as economic engines for a sustainable and multi-generational pathway to prosperity, focused on educational and recreational opportunities in southeast Georgia. The secondary benefits to Charlton County – groceries sold, restaurant meals purchased, increased opportunity, additional workforce housing, and the authentic employment of local residents – will only be realized through an innovative strategy that capitalizes on the untapped outdoor recreation value of the swamp.

Proposed evaporation of withdrawn groundwater will cause salt deposition downwind

TPM is planning to use evaporator devices in an attempt to eliminate the enormous amounts of wastewater generated and stored onsite. This is being proposed in order to avoid discharging the wastewater to the St Marys River basin. The wastewater naturally contains high concentrations of humates and dissolved solids (see picture below), commonly referred to as salts, and the mist created by the evaporators will generate aerosols, or saline clouds, as a natural result of evaporation. Consequently, there will be "salt rain" downwind of the evaporation system. It is also uncertain what effect the humates (large organic molecules) will have on the operation of the mechanical evaporators.

Using an evaporation rate of 1000 gpm and a solute concentration of 200 mg/L (typical concentration in mineral sands waters), the total salt load to the surrounding landscape will be about 1090 kg/day, equivalent to 2400 lb/day, or 1.2 US tons/day. This salt load will substantially reduce long-term soil productivity in the downwind areas. Given that winds in the area are often from the east, significant salt deposition into the swamp is inevitable, with substantial negative consequences for the integrity of the freshwater ecosystem and the nearby forests.

In its assessment of TPM's plan for evaporating the wastewater, EPD did not address the threat posed by these saline clouds. This oversight should be remedied by conducting an updated analysis of the evaporation process and whether evaporation can be allowed at all.

*Process Water in Mineral Sands Mining***.** Note that the water is very turbid (dark) due to dissolved and suspended matter. Spraying this water into the atmosphere will result in evaporation of the water, but not the dissolved and suspended sediments. These will form aerosols (dust, salt) that will drift with the wind, which is mostly toward Okefenokee Swamp.

If this evaporation process doesn't work, *there is no plan for monitoring or addressing discharges of process water to the tributaries of the St Marys River*. The EPA already lists the St Marys River as impaired for sediments, turbidity, and dissolved oxygen, all issues that would be exacerbated by discharges from the mine. When the evaporation system fails, it will be during extended wet weather when creeks are high. It is necessary to have some plan for the likelihood of dishcarges in such periods. Right now there is none.

Reclamation Plan Deficiencies

Without delving into the details of the problems with the proposed mitigation plan, suffice it to say that the mitigation plan is pro forma and minimalist. It basically says the mine will destroy all existing soil structure, mix wetland and upland topsoils, regrade the pre-mining surface topography (minus the 1.5% of the soils removed from the site), push the mixed topsoils back in place, and plant some trees. The only nod to the special characteristics of the site is the placement of a deep bentonite (a type of clay) layer to mimic the hydrologic effects of the existing black sands layer. This bentonite layer is novel, and it will be difficult to place as a continuous layer. There is no track record of such placement achieving its hydrologic goals. Civil Engineers I have spoken with scoff at the idea that a functional bentonite layer can be placed at he speed with which the operation will move.

Employing this style of mitigation at the Trail Ridge mining sites and at nearby phosphate mines in Florida has resulted in very poor soil conditions and very poor vegetative regrowth (see example photo below). It is likely this mitigation plan will result in poor soil conditions, a low-productivity scrubby forest, and few, if any, wetland areas on the ridge top. Before mining, the TPM LLC site is over 50% wetlands.

Reclaimed mine lands on Trail Ridge NE of Starke, FL. Google Earth image. This image taken 20 years after reclamation began. There are lots of examples of poor regeneration on mineral sands and phosphate mines in Florida in terrain similar to the TPM LLC site.

Conclusions

Mineral sands mining on Trail Ridge will make drought in the eastern portion of the swamp more frequent and more severe, and this will affect the competitive balance of plants in the swamp with cascading effects on the ecosystem. It will increase the probability of wildfires on the swamp margin, which periodically cause major problems for the region including large-scale loss of commercial timber, and it will increase the number of days on which recreational boating is not possible in parts of the swamp. Furthermore, mining on Trail Ridge will damage the tourism potential of the Okefenokee Swamp, to the detriment of the state and the region.

The mining plan fails to address key environmental issues, specifically the effects of salt deposition downwind of the evaporation system, the necessity of a contingency plan for unplanned discharges to the local tributaries to the St Marys River, and the need for a reclamation plan better than has been used on most mineral sands mines in Florida.

References

Hyatt, Robert Allen. 1984. *Hydrology and Geochemistry of the Okefenokee Swamp Basin*. PhD Dissertation, University of Georgia.

- Hyatt modeled the St Marys River at Moniac (USGS gage 02228500) using water levels in Sapp Prairie within the Okefenokee Swamp (measured by the USFWS).
- Water levels in Sapp Prairie explained 81 percent of the variation in streamflows, indicating the high correlation between river flows and swamp water levels.

Tóth, Jozsef. 1963. A theoretical analysis of groundwater flow in small drainage basins, *Journal of Geophysical Research*, 68(16):4795-4812, doi:10.1029/JZ068i016p04795.

Note about the Author:

I have received no compensation, monetary or otherwise, for my analyses of the TPM LLC proposal to mine mineral sands on Trail Ridge. Furthermore, I have worked at the behest of no one but myself. All of the work I have done, reviewing permit documents, reading scientific papers on the hydrogeology of the swamp, preparing spatial analysis of wetlands on the mine site, analyzing hydrologic data, reading the Georgia surface mining law, visiting the swamp and the Mission Mine, writing a journal article, writing memoranda to Georgia EPD permitting staff, and answering questions from the public – has been performed out of professional interest in this resource management and policy question and out of a sense of duty to the citizens of Georgia who pay my salary at the University of Georgia.