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Groundwater

Groundwater in the several main aquifers beneath FMNF will almost certainly be a tempting target for pumping and use elsewhere as the Charleston metropolitan area and other nearby developed areas grow and water resources (both surface waters and groundwater) come into more demand and competition in use. Legitimate arguments will be made that the footprint of even a large wellfield can be small and minimally obtrusive (small fenced enclosures at the actual sites of the scattered wells) and with pipelines, and even electrical powerlines, buried unobtrusively along existing forest roads. Where there will be much more risk to the forest environment will be in easily made misunderstandings and inaccurate assumptions in hydrologic arguments and assessments. While it is possible and even probable that the deepest major aquifers beneath FMNF are sufficiently isolated hydraulically from the surface environment so that they might be pumped safely and even heavily without harm to the surface environment, it is the shallower aquifers that will be more coveted due to their lesser salt content (and possible other constituents, e.g., dissolved boron that can harm lawn and golf course grasses). FMNF is dominated almost exclusively by high-watertable forests and wetlands and thus is especially vulnerable ecologically (and in fire susceptibility, at least so far as the peaty wetlands are concerned: e.g., Wambaw Swamp, Hell Hole Swamp) to even very minor lowering of the watertable. A somewhat similar high-watertable forest mosaic at Green Swamp in west-central Florida decades ago showed the ecological effects of watertable lowering above heavy pumping of the principal limestone aquifer, it being closely related to the limestone and aquifer situation just beneath FMNF (studies at South Pasco well field by the USGS and SW Florida Water Management District). Reduced spring flow and stream flow is also to be expected from heavy pumping of a shallower aquifer (more directly affecting a spring) and from a decline in watertable (more directly affecting a stream). Groundwater extraction proposals will need to be examined extremely carefully and professionally and from an ecological as well as hydraulic and land-use "footprint" perspective.

There are also less-obvious risks or threats associated with any future proposal for groundwater extraction, revealed by similar situations occurring in the past elsewhere. There is much room for misinterpretation of the vulnerability of the surface ecosystem and hydrologic system to heavy and prolonged groundwater pumping. The simplest common misinterpretation is misconstrual of the conceptual model of the aquifer stratigraphy. Another common misinterpretation involves pumping-based hydraulic tests for vertical interconnection. Persons responsible for FMNF should at least know of the ways that hydrologic assessments may be faulty or biased. Extremely brief descriptions follow.

A geologic formation beneath the uppermost principal aquifer may have a different lithology (e.g. here, sand vs. limestone) and a different geologic formation name (e.g. here again, Black Mingo Fm. vs. Santee Limestone) and then be assumed to be a different aquifer, that is a different hydrologic or hydraulic unit (a hydraulic unit implying direct interconnection). This taxonomic "splitting" has been done intentionally by proponents of new pumping in other areas. A single aquifer or hydraulic unit, however, may consist of several stacked layers of geologic units of different names and lithologies, as has been shown for the Tertiary limestone (mainly Santee Fm. here) and the underlying Tertiary sand aquifer (mainly Black Mingo Fm. here) in other nearby areas of this combined system to the northwest of FMNF. It is a mistake to assume or propose that pumping from the deeper stratum does not involve extraction from that (or those) shallower one above it, and especially a mistake to conclude that the surface wetland or shallow-watertable environment will be unaffected. Hydraulics, not nomenclature or lithology, are the direct factors.

Technical evaluation of the interconnection of the water table, or else the uppermost principal aquifer, with deeper aquifers from which heavy pumping is proposed is notoriously difficult and chronically misinterpreted even with a hydraulic perspective. Estimation of permeability of intervening potential confining units (strata) has sampling difficulties for obtaining representative average samples (plus effective localized breaching can be missed). More typically, pumping-test data are misinterpreted. Even where heavy long-term pumping of an aquifer would in fact acutely affect (lower) the water table and greatly affect forest ecosystems, the interconnection of a deeper aquifer with the shallow watertable aquifer can be missed or misinterpreted despite the use of pumping tests thought (or purported) to be specifically designed to evidence such an interconnection. The key difficulty is often failure to differentiate the concepts of "evidence" and "test" (both used here as a verbs). Lack of evidence (noun) for interconnection in a pumping test is often misconstrued as direct evidence for some opposite condition, i.e., for a lack of effective interconnection, when in fact it is lack of evidence and does not indicate strongly one way or the other regarding interconnection.

The most common and dangerous error is in test pumping from the deeper aquifer and seeing no drawdown in observation wells in the water-table aquifer (or indeed, any shallower aquifer) and concluding a lack of effective interconnection. If one does see a concurrent drawdown, that then is very strong evidence for an effective interconnection. But when one does not detect any drawdown in the shallower aquifer that typically does not indicate or strongly suggest that there is no effective interconnection that could prove troublesome (up to disastrous) under future widespread, prolonged heavy pumping of the deeper aquifer. Judged by pumping test and wellfield experience worldwide those wellfield conditions (wide, pronounced, prolonged pumping) are the ones that eventually exhibit the clear interconnections where they exist. You may not see any effects in a medium-length pumping test (say, 72 hours) and far less likely in a short one (say 12-24 hours) but that does not mean that interconnection may not be ecologically substantial after a few years of heavy pumping. And wellfields are usually permanent. One main reason that such pumping tests are insensitive to actual interconnection and effective downward leakage and drainage of the surface environment is because shallow aquifers can readily replace leaked water by lateral flow under small hydraulic gradients. The critical item is long-term effect. The USFS should have expert technical advice in evaluating the acceptability of any proposed heavy prolonged pumping (short-term heavy pumping, say for temporary excavation dewatering in construction, may be perfectly acceptable and there one would be concerned more with where the pumped water was discharged, especially if muddy).

Another factor in any future groundwater use involves water chemistry (quality). If deep aquifers are demonstrated to be safely pumped for use by distant users, any salts-reduction treatments (e.g., reverse osmosis) should be done nearer the distant users (even if this is less efficient in terms of pumping) to avoid discharge of locally atypical saltier wastewater in FMNF itself.

The likely tight interconnection between biotic communities or ecosystems and the prevailing water-table regime (e.g., depth to water table or depth of water, and typical variation, both seasonal and among years) makes it very likely that small hydrologic changes, if persistent, will have appreciable ecological effects. A lowering of average watertable elevation may be more visually apparent by, say, pines colonizing into cypress forests than by any other observation save detailed water-level measurements and data analysis. Subtle changes in hydrology have the ready potential for significant to substantial changes in local biology in an ecosystem where the water table lies close to the surface, whether above or below, and small shifts in water levels can have large shifts in ecological forces, say especially from flooding.

There has been some concern among groundwater hydrologists and others that South Carolina may be susceptible to pumping-induced aquifer compression and ground-surface subsidence. In such a case, oddly, heavy pumping of a deep aquifer could cause the surface environment to become wetter by becoming physically lower. Thick major sand aquifers with appreciable clay content, say as interlayers, are most susceptible to this problem, and then only if heavily pumped to produce a large (broad and deep) drawdown. Careful attention should be paid to any targeted studies of these same aquifers where pumped heavily in other areas of southeastern United States (e.g., Grand Strand). Precise re-leveling of old monuments can sometimes detect a lowering of ground level. Any major wellfield planning or development of hydraulically low-risk deep aquifers should include rigorous assessment of this wide-acting factor as well, because this forest (vs., say, Sumter NF) would be so much more vulnerable to the effects.

Environmental history

FMNF has several types of sites that can have special, up to unique, value as localized concentrated repositories of archeological and environmental-history (paleoecological and paleontological) evidence. Sinkholes (solution holes), substantial springs, peat- or muck-filled wetlands, and stream corridors are of obvious potential value here. Isolated drier sites that were former high-water-times focuses of animal and human (including historical) activity are also important in wetland environments. While streams are found throughout the state, the other mentioned features are not common elsewhere in the state but are found in important occurrences in FMNF.

Sedimentary charcoal evidencing past fire regimes and their possible shifting; pollen, spores, and other plant remains evidencing past flora directly and thus past ecology and climate and their shifts and changes; paleontological remains (bones, teeth, scales, and other remains) similarly evidencing past fauna and environments; and undoubtedly archaeological remains in or focused adjacent to these types of sites are invaluable scientifically and increasingly are valuable in assessing modern forest management practices (perhaps especially fire regime) and others under possible future shifts in rainfall and water table.

Sinkholes (solution holes) are unique repositories of remains from the sinkhole itself and surrounding former environments. Where peat or muck filled, as some (many?) are in FMNF, and thus with a stratigraphic sequence, the past changes or shifts can be shown and the stages or boundaries more easily dated (by 14C, 210Pb, optical luminescence). Wet sites in an unflooded general environment also attract animal and human activity and thus are still more important because they concentrate remains: they are focuses of activity. FMNF recognizes the special importance of sinks by official recognition of the Honey Hill Lime Sinks area of significant concentration. There are other elsewhere in FMNF, however, also deserving of recognition of their existence and importance. Not all are as conspicuous as at Honey Hill, where high-slope uppermost walls can protrude conspicuously above the level sediment and where surface water may be conspicuous most of the year. Limesinks just as valuable elsewhere can have infilled peaty sediment nearly to the level of the surrounding forest and thus appear similar to the common shallow sand-bottomed cypress "ponds" of far-lesser paleoenvironmental significance. One infilled sink, now for all appearances simply a shallow cypress "pond," was cored decades ago to almost 7-meter depth and 14C dated about half way down to ~11,000 BP (14C years "before present"): an infilled sinkhole of some sort. Sand/muck interlayering found at depth might evidence severe storms, severe fires, or conceivably even repeated earthquake shaking. There is much paleoenvironmental evidence, including paleoclimatic information, stored in infilled sinkholes and their importance should be recognized. Initial investigation of a representative few could help reinforce recognition of their importance.

Shallower but much larger depressions in the mineral (sand/limestone) general ground surface (and of yet unclear geologic origin) similarly can contain at least some organic sediment (peat or muck) of wetland origin, also having considerable usefulness in paleoecologic (e.g., paleohydrologic) reconstructions. Wambaw Swamp and Hell Hole Swamp are obvious examples. There are undoubtedly smaller less familiar ones.

Organic sediments (peat, muck, peaty or mucky clays or sands) deserve some special attention not only because of their ecological value (as specialized habitat) and paleoecological-research value, but also because they have special threats. They are combustible and can be lost in severe fires, especially when overdrained, and they can be economically valuable as a mined or extracted product, perhaps especially when misrepresented as a "renewable" material or a "mineral" material. The organic matter is not mineral (it has no regular crystalline structure, nor any set chemical composition). Renewal (replacement) times, if inferred from original emplacement (accretion) times, would be minimally a few thousand years for thicknesses worth the effort of mining. This is not truly renewable in the generally accepted sense. Special caution must be given to evidence for any supposed rapid accretion based on dating of shallow layers. For notable example, shallow samples (say, <0.5 m) of peat may give very young 14C dates by the effect of root intrusion, implying incorrectly that peat deposits can renew relatively quickly. Worse, mined deposits revert to ponds too deep to form peat. The original deposit formed over a long period of rising water table and was never deep. The textbook pond-filling sequence for peat-bog development is incorrect for most southeastern United States situations (it applies mostly to glaciated terrain of the upper Midwest) and should not be allowed to direct decisions here. The argument that organic-sediment deposits are "renewable" (say, as a timber crop is) is inaccurate but its use has been attempted in the state for Carolina Bays. There have even been more extreme preliminary proposals and true-expert advice should be available to FMNF to evaluate any in the future (flooding a Carolina Bay peat deposit with a lye solution to extract valuable humic acids while supposedly "leaving" the peat after the leaching and collection was one such proposal).

Substantial springs have special ecological functions of fairly wide recognition, but they also possibly existed and functioned as focuses of animal and human activity in the drier era before the widespread development of wetlands and perhaps streams (in southeastern United States generally before 5000-7000 BP, when the pineland also arrived). Ill-advised development (e.g., clearing, leveling, etc.) could readily destroy important deposits adjacent to (or even in) larger springs. Ill-advised groundwater pumping could eliminate springs of all sizes. Blue Spring on Echaw Creek is well known. Others likely exist (Tabor, 1939, mentioned their apparently common existence in the related limestone terrain of the nearby Santee-Cooper project). Blue Springs' likely high vulnerability to water-table lowering (i.e., by its not discharging from a separate and appreciably deeper aquifer) is suggested by its young groundwater age (apparent post-WWII recharging, based on 14C in dissolved inorganic carbon).

Streams and immediate stream corridors probably have similar values and vulnerabilities as the springs, and for similar hydrologic reasons.

The same Santee Limestone near the town of Santee (to the NW of FMNF) has small caves in it. These are known because parts lie above the water table and were noticed and explored. Underwater caves may exist in FMNF (Amataya n.d.)(springs and sinkholes also hint at this). Carbonate cave flowstone formed in former times of lower sea level and lower water table can possess important isotopic evidence of climate in these previous times. Underwater caves can possess endemic fauna as well.

Geologic Materials

Subsurface materials in addition to groundwater at FMNF are likely to have continued and perhaps increasing pressure for extraction, especially given the continued urban and industrial growth in the wider Charleston metropolitan area and especially if private entities hold any "mineral rights." Additionally, any low-elevation urban or urbanizing coast is going to have enormous eventual demands for fill or raised-pad material under conditions of rising sea level (which also defines freshwater drainage base level). Geological resources definitely include abundant limestone, sands, and some peat or muck deposits (and perhaps some geologically young marine shell deposits), even while common conceptions of "mineral resources" would be for more valuable and localized deposits (e.g., ores) and while peat and muck are not technically made of minerals dominantly. Florida successfully fought attempts to consider and mine the limestone bedrock of Everglades conservation areas as "minerals," which at the very least shows that such attempts will likely come eventually to similar FMNF and should be planned for. Additional South Florida wetland areas once slated for conservation have been extensively mined in recent decades (see NW of Miami on Google Maps or similar photographs). South Carolina has previously faced the threat of mining of peat and muck deposits (in Carolina Bays) on the pretext that these plant-origin geological materials were "renewable" and would "naturally grow or accrete back" in the deeper depressions the mining left behind. As noted above, FMNF officials should be aware (1) that such deposits took a few millennia to accrete, or to "renew," while true renewable are restored on time scales of a growing season up to a few decades. No higher-value (per mass) geologic material is known to be available in commercial abundance or concentration (e.g., phosphate, or titanium minerals in heavy sands).

Some Useful Initial Research

Research goals in the realm of geology include some that can be directly useful in the short terms, and those that need attention now mainly in terms of protecting their potential now for their future exploration.
It might be useful to have a survey sampling of basal organic sediments 14C dated to document about how long it would take to "renew" an organic sediment deposit under FMNF conditions, if it could be renewed at all.

It might also be useful to examine a few of the probable "data caches" of paleoecological information, including archaeological information, to (1) demonstrate their value in several sciences, and (2) obtain initial information of more-nearterm use to forest managers themselves, especially apparent fire-frequency (but including such items as mercury deposition) in the pre-modern and pre-historic past, plus other aspects of natural-era (or at least pre-European) forest ecology.

Documenting the relationship of the principal or notably important or present natural communities to the watertable regime (USDA, Forest Service, 2012) would go a long way toward being able to predict any negative impacts of proposed future modifications or activities, including ones that might be naively thought of as minor. It is assumed that an ecosystem above a high water table (i.e., shallow, to above-ground) is highly attuned to it, and that small changes in the annual procession of level will have a profound effect (even though a forest above a deep water table may not "feel" or respond at all to a similar or larger change). A tight interconnection would, of course, be far stronger evidence in future decision making regarding water resources if it is documented rather than inferred or assumed.

Ultimately, confident planning predictions and management decisions are also highly dependent upon a good understanding of the surface and shallow-zone physical (and to an extent, geochemical including pollutant) hydrology of the FMNF ecosystem. Continuing, and appropriately focusing and integrating, the growing body of information on the overall water budget of FMNF is essential here.

Summary for Hydrologic/Ecological Aspects

The FMNF ecosystem is almost undoubtedly very sensitive to even minor shifts in the water-table regime, including shallow surface flooding, and several obvious sources of such minor (or greater) shifting are apparent for this large and valuable area (e.g., wellfield development, climate change). Understanding and confident prediction are clearly needed for effective planning and management.

One can hardly overestimate the importance of understanding the controls on, and ecological functions of, the water table (i.e., the water-table aquifer and its upward extension into surface flooding) for a high-watertable and wetland ecosystem. In addition, the water-table system feeds most or nearly all of the streamflow (but with some deeper-origin springs at least possible) and all or nearly all of the innumerable wetland depressions.

Understanding both the hydrology and ecological effects of the water table are critically important for at least several main reasons. In a high-watertable ecosystem the near-surface position (whether below or above the ground) of the top of saturation exerts both favorable conditions (mainly water availability, but also dispersion route and aquatic habitat if flooded) and also stresses (including, anoxic soil conditions and outright drowning). It is obvious that an ecosystem with the water table near the ground surface is much more sensitive to small fluctuations in level than, say, ecosystems with the water table two meters above (a lake) or below the surface (e.g., a mesic forest). Small to moderate changes in surface hydrology can easily arise from human activities (e.g., wellfields, adjacent development drainage, mining dewatering) and of course any future climate changes in SE United States are as likely to be expressed in rainfall changes as in temperature. Understanding hydrology allows far better predictions of future ecosystem conditions under changes in hydrological factors. To that last point, it would be worthwhile to make some initial estimates as to how sensitive FMNF's surface hydrology is to rising drainage baselevel, that is, sea level. And of course, the critical other side of the 'impact" equation is the biological or ecological linkages between watertable regime (position and short term, say seasonal to decadal return-frequency shifting).

No attempt is made here to review what is known at present about water-table hydrology at FMNF or the related ecology. Extensive studies for the former (hydrology) are listed and briefly reviewed in Amatya et al. (2015). USDA Forest Service and local university hydrology and hydrogeology researchers have been extensively involved. These and other existing studies should be closely evaluated for the significance of their hydrologic findings in application to a high-water table resident ecosystem, particularly its management and its vulnerabilities to future hydrologic changes that may be proposed or imposed. An understanding of the "ecohydrology" is the needed ultimate goal (Amatya et al., 2015), though very basic hydrologic information is required as part (e.g., Callahan et al., 2012, on estimating recharge rates).

The water table itself and controls on its position (depth below or height above ground, seasonal fluctuations, extremes at different timescales, etc.). For technical reasons, a water-table aquifer often is mathematically more complex than a deeper confined aquifer (the saturated thickness of the tater-table aquifer often changes through short times) and less hydrogeologic emphasis seemingly has been paid to these types. Considerable attention has come instead from agronomy and forestry hydrologist researchers. Expertise and findings from both main disciplines (hydrogeology and agricultural/forestry hydrology) will be necessary to understand the main controls on water-table behavior (position and fluctuations) at FMNF. Amatya et al. (and references)(2015) show examples of the types of relevant research that can yield the needed hydrologic-regime understanding and how they can be built upon. Research often leads to answers that would not have been assumed without it. A potential example lies with the sinkholes. Are we sure that shallow ground water generally flows down in them, as we might be tempted to assume from many sinks elsewhere? It need not though, especially seasonally, and this would be straightforward to answer regarding these unique patchy wetlands.

On the ecosystem level and emphasizing now the biota, the effects of a high-watertable regime (mainly acting directly, presumably, on the autecology of individual taxa, but with a cumulative ecosystem influence), a critical overall question is "How sensitive, and in what ways, is the FMNF ecosystem susceptible to small to moderate changes in water-table hydrology?" This resolves itself into many individual questions, of course. The ecologies (for main examples, flooding or drying tolerances) of principal taxa are obvious examples, while shifts in habitat or prey taxa have repercussions farther in the ecosystem. USDA, Forest Service (2012) explores and shows ways to proceed with these basic and critical assessments.

"Forensic ecology" via a host of historical records to determine vegetational-landscape and surface-water conditions in early historical times, times unimpacted by modern technology, can yield important and unanticipated information and is an effort well worth considering (for outstanding example, McVoy et al., 2011).

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