SUMMARY REPORT

Dead Pike Lake and Powell Marsh Planning Considerations

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Applied Ecological Services, Inc.™

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EXECUTIVE SUMMARY

In June 2017, Applied Ecological Services led a working team of professionals, government officials, and concerned stakeholders in a discussion of options to address impaired water quality in Dead Pike Lake (DPL), with an initial focus on the regulatory (NR 103) exceedance of phosphorus recorded within DPL waters. The team also wished to better understand sources and paths of iron (Fe) and manganese (Mn) entering the lake, lake tributaries and the Powell Marsh State Wildlife Area (PMSWA). Using discussions to create shared understandings, principles were developed to guide both ongoing discussions as well as develop a prioritized list of potential management recommendations and solutions to address water quality concerns in DPL and PMSWA.

Team members reviewed existing data from the DPL Management Plan (Barr Engineering 2011) and the conditionally approved PMSWA Master Plan (WDNR 2016). The team also considered as well as existing landscape data, bog ecology information, unpublished water quality and ecotoxicology data from ongoing studies.

The group indentified seven (7) technical challenges: (1) Excess iron and manganese in surface waters and groundwater, (2) Water balance and hydraulic dynamics in Dead Pike Lake, (3) Water quality nutrification effects on PMSWA and expanded threats downstream, including DPL, (4) Ecotoxicity issues, (5) Lack of year-round and long-term representative data on hydrology conditions in PMSWA and DPL, (6) Misunderstanding bog history, dynamics and alterations, and (7) Alteration of bog ecology.

The issue of excess iron and manganese in DPL and PMSWA is complex. Sources and pathways include the iron-rich underlying glacial substrate, dikes built of that same substrate, and seasonal fluctuations in water levels (and hence, hydrologic pressure) that facilitates an exchange of surface and groundwater with a resultant increased load of iron and manganese that is exported from PMSWA to DPL. During the analysis of likely sources and pathways, weaknesses in existing studies were identified and data needs outlined. The physical and chemical pathways that result in the formation of iron/managanese flocculant (floc) that creates a potential biological issue and an aesthetic nuisance in DPL were detailed as part of the search for management strategies.

Solution strategies focused on four issues: (1) water quality of DPL, (2) water supply to DPL, (3) integrated solutions to identified problems, and (4) formulation of a new DPL Management Plan that incorporates new data and proposed solutions. The team identified 3 solution strategies and associated management recommendations for DPL, and 7 solution strategies and recommendations for PMSWA. The two paired solutions/recommendations with the greatest potential for meeting articulated water quality goals are: (1) Restore historic levels of DPL based on accurate modeling that incorporates historical data and (2) Introduce limestone ditch backfill and wetland biofilters into the ditch system of PMSWA to address both excess iron as well as nitrification concerns. A third recommendation involves creating a surface water diversion within PMSWA to influence seasonal flows. This would require additional study on both its expense and potential efficacy.

INTRODUCTION

On June 13-15, 2017, members of the Dead Pike Lake Association, staff from the Wisconsin Department of Natural Resources (WDNR), and staff from Applied Ecological Services (AES) met to consider and discuss options for addressing impaired water quality in Dead Pike Lake (DPL). The focus was the regulatory (NR 103) exceedance of phosphorus, measured within Dead Pike Lake waters. In addition, we sought to understand sources and paths of iron (Fe) and manganese (Mn) entering the lake, lake tributaries and the Powell Marsh State Wildlife Area (PMSWA). The latter is managed by the WDNR to meet an aesthetic standard for waters released from PMSWA. Currently, there are no quantitative numeric standards to regulate water quality constituents in surface or groundwater resources in Wisconsin unless they are also used for human consumption.

Meeting participants followed a detailed agenda (Appendix 1) that guided the sharing of data and other useful information about key issues. Using discussions to create shared understandings, principles were developed to guide both ongoing discussions as well as develop potential management recommendations and solutions to address the water quality concerns (Appendix 2). These principles also provided a sounding board for potential solutions identified during the meeting.

Solution and strategies for addressing the water quality problems in DPL and in PMSWA were outlined and defined with expository bullet points. Each articulated strategy was given a preliminary evaluation based on meeting discussions about potential estimated capital costs, estimated operation and maintenance costs, and strategies to meet regulatory challenges and obtain approvals prior to implementation. During the meeting, potential solutions were prioritized based on qualitative understandings of each opportunity. Participants also considered phasing or sequencing of individual solutions in ways that represent the greatest potential usefulness in an adaptive management strategy. For example, it made little sense to the group to implement an iron management program in the waters of DPL before a management plan was implemented to address iron originating from PMSWA and its tributaries to DPL. Thus, sequencing of solutions, and decoupling the solution strategies from one another, were necessary to ensure that each could be considered as part of a larger solution package and so that each could be phased as needed in an adaptive management plan. This approach was chosen so that we could learn from the benefits from each implemented solution and refine each potential next solution if additional actions were deemed necessary to further improve the water quality in PMSWA and DPL.

SUMMARY OF MEETING OUTCOMES

The June meeting, and its several months of preparation, were focused on ensuring that data sharing was reasonably complete, and that each attendee's review and preliminary analytical inquiry about the data were focused on addressing the important goals articulated in the DPL Management Plan (Barr 2011) as well as the PMSWA Master Plan (WDNR 2016) that had conditional approval by the Wisconsin Natural Resource Board. Operationally, the meeting opened with a focus on listening and confirming mutual understandings of attendees and presenters. This was followed by a concise summarization of what was shared and learned. Participants then translated their understandings into operating principles, goals, performance metrics (standards) as well as potential strategies and solutions.

Goals were discussed and reaffirmed by each attendee so that it was clear that a common understanding of the intent of the goals was held by all participants. This conversation was used to develop principles (Appendix 2). The goals were also used to create draft solutions and performance metrics and standards for the team to use in later when testing each solution. Preliminary proposed standards included aesthetic (qualitative) standards and also numeric (quantitative) standards. It was the intent of the participants that some final version of these standards would be incorporated in a new or amended DPL Management Plan and PMSWA Master Plan. The draft goals and performance standards are summarized in Appendix 3**.**

TECHNICAL CHALLENGES

In this section, we summarize existing data on the landscape, water quality data from the DPL/PMSWA complex as well as common scientific understandings about the issues of iron and manganese in surface and groundwater on a landscape such as this. This information is presented within the following topical technical challenge categories.

Challenge 1: Excess iron and manganese in surface waters and groundwater

Iron occurs as an adsorbed cation on both dissolved and particulate organic carbon. On this DPL/PMSWA landscape, as iron is oxidized upon emergence on ditch side slopes, ditch bottoms and the subgrade of the dikes, levees and roads, it transforms to a suspended flocculant (floc), which settles as an orange to reddish solid in PMSWA ditches, tributaries and DPL.

This occurs through the following pathways. Interactions between the chemical valence state of the iron and water management practices in PMSWA affect the aesthetic appearance of the water in both PMSWA and DPL. Beginning with the ionic form of the element, iron changes forms as it passes from the glacial till substrates beneath PMSWA and enters the deeply dug ditch systems intersecting these same glacial till substrates. Transformed into a flocculant, it is then exported via the surface water flows passing through iron-rich subgrade substrates of the dike/levee road system in PMSWA. Inspection of this gravel subgrade by AES team members confirmed composition with a substantial component of taconite ore (a low-grade iron ore). This acts as another likely source of iron and manganese in the waters of PMSWA and DPL. Thus, water moving through the subgrade of the road combined with groundwater entering side slopes and ditch bottom substrates from underlying glacial till, have been documented (and observed during this study) as the main sources of iron in the DPL/PMSWA system. This water likely also transports manganese and other heavy metals associated with the iron but not currently the focus of quantitative studies in PMSWA and DPL.

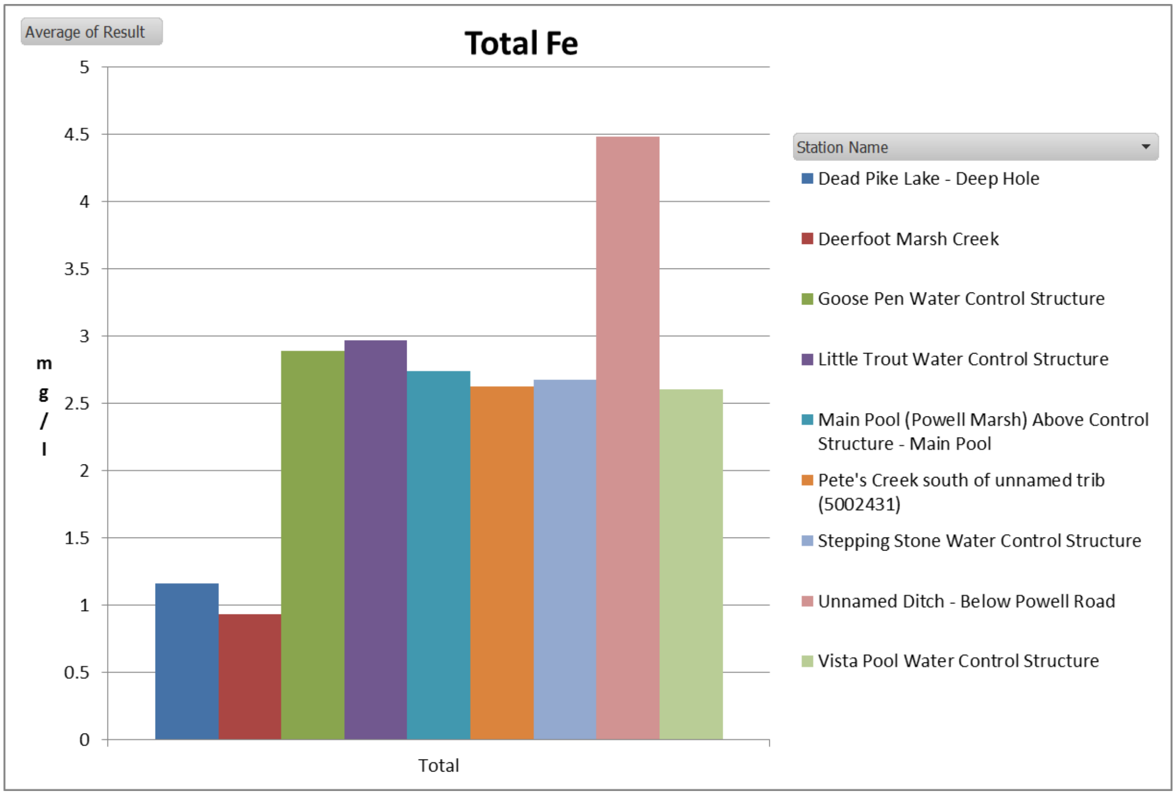
In actively running water, such as occurs in ditches during high water periods, iron remains as an adsorbed cation on dissolved and/or particulate organic carbon. In this form, it is swept from the wetland and removed from glacial till-derived groundwater sources and the gravels used to construct the roads that border primary ditches in PMSWA. It then exits through drop structures and begins an oxygenation process. It is further aerated during its movement through culverts under Powell Road, the inlet stream of DPL, and eventually by wave action on DPL waters. This aeration movement acts to further oxidize adsorbed iron, causing it to precipitate as floc.

This precipitation is particularly noticeable on the downwind side of DPL, suggesting that there is a relationship to groundwater discharges occurring along the north shorelines of the lake. This process may be further accelerated by wave action, apparent on the north side of the lake, and may be partially responsible, in combination with re-suspension and redistribution of the iron floc materials by wind and waves, for the heavy iron floc levels that are seasonally present on DPL along the shoreline. By contrast, in calm areas near the inlet stream to DPL, lake currents and winds move floc materials into deeper zones of the lake, where, once collected, they are often not re-suspended.

It is a significant challenge to manage sources of iron from PMSWA's roads, road subgrades, and the intersected glacial till substrates below the peat substrates within the marsh. Management of iron in all its forms (dissolved organic carbon, cations bound to both dissolved and particulate organic carbon, and precipitated flocculant or floc) is needed to reduce the overall quantity of iron entering DPL. Some pinpointing of sources has been accomplished through iron sampling from the ditch system of PMSWA. Initial results suggest that the greatest quantities of iron are coming from the primary ditches (Figure 1).

Specifically, Figure 1 depicts measured levels of total iron in all forms expressed as milligrams/liter (mg/l). Water assessed from a main un-named ditch of PMSWA downstream of Powell Road had measured levels of iron greater than or equal to 3 parts per million (ppm). This ditch, and some of its key tributaries, coincide with the main roads built on dikes that appear to be composed mainly of taconite gravels and cobbles. By contrast, secondary shallower ditches (e.g., Deerfoot Marsh Creek), originating from wetlands that have remained relatively undisturbed, exhibit iron levels of approximately 1 ppm.

Figure 1. Average iron concentrations (mg/l) from surface water sampling from various locations in DPL and PMSWA. (Data are from grab samples collected by WDNR in 2017.)



Challenge 2: Water balance and hydraulic dynamics in Dead Pike Lake

Another technical challenge for the management of PMSWA and DPL is maintaining a water supply in the marsh adequate to achieve the habitat goals (WDNR 2016) as well as the hydraulic performance of DPL (i.e., lake water levels and dynamics). The 2016 WDNR study was commissioned to determine the amount of water existing within the total system and recommend a minimal flow level to achieve the outcome required by statute whenever a navigable stream, as defined in wetland law, is blocked.

The primary WDNR study question was: "How much water can we *afford* to release and still not jeopardize functioning of the flowages?" Dam integrity was considered with respect to whether a rain surge would collapse the main dike and wash out Powell Road. The study concluded that a rain surge would not wash out the dam—that the westward flow immediately above the culvert would absorb any surge. A release rate of water from PMSWA was chosen at 1.2 cubic feet per second (cfs) to downstream water bodies, including DPL. This required water management protocol positions the PMSWA to supply baseflow water needs of downstream water bodies.

Even with the targeted existing release of 1.2 cfs, lake water levels in DPL appear to be substantially (perhaps 18-24 inches or more) below the apparent historic average levels as determined by ice scarring, high water marks, and the growth of long-lived tree species and flood intolerant perennial vegetation on the shoreline. This decrease in water levels appears to be relatively recent within the past few decades(Little and Mason 1983). Evidence of a very recent decline is levels is suggested by data (collected since 1936) from Anvil Lake in Vilas County that show a noticeable drop in lake levels beginning around 2000 (Anvil Lake Association 2017).The WDNR is slated to confirm this water level decrease of DPL via GPS survey. This confirmation is anticipated to lead to formulation of suggested practices to manage the outlet control structure to modulate the release rates as needed to maintain acceptable water levels in DPL. Having accurate water level measurements will be an important technical component in any revisions of the management plan for DPL and the resolution of water release rates for PMSWA.

During the study we learned that PMSWA managers typically remove beaver dams in the DPL outlet stream to reduce the lake elevation of the lake and thus maintain a head and drop between PMSWA and the lake, as per the directive in the PMSWA Master Plan (WDNR 2016). This positive gradient between the outlet and surface water offers a direct means of control of water released from PMSWA. Further study is needed to determine the significance of the head difference and increased pressure effects between DPL and PMSWA during spring runoff and the influence this has on driving surface water into underlying iron-rich glacial till substrates.

It is strongly suspected is that during spring high water levels the naturally enhanced head resulting from the water level differential between marsh and lake drives acidic water into the underlying glacial till substrates. Once there, these waters dissolve iron, manganese, and other chemical constituents. As surface water levels in the marsh and lake drop in late summer and fall, the groundwater recharge head is reduced. Subsequently, the recharged groundwater (now with an expanded load of dissolved chemical constituents) moves from the shallow groundwater back into the ditch system and from there is flushed from the ditch into DPL. This accordion-like movement into and out of the groundwater occurs annually.

Further study is needed to quantify the significance of the head differences and increased pressure effects between DPL and PMSWA during spring runoff and the resulting influence on driving surface water into underlying iron-rich glacial till substrates. With such information, surface water elevations of DPL and flowages could be more accurately manipulated to facilitate dropping the hydrologic pressure resulting from elevational differentials. A constant push toward groundwater recharge, for example, is estimated to occur with a differential of about eight (8) feet between the Vista Flowage and the main ditch. The scheduled GPS surveys by the WDNR will be used to examine the accuracy of this prediction. Without manipulation of water levels, what is the effect of such continuous increased head pressure on groundwater entry into the ditches in PMSWA and eventual release into DPL?

Historically, beaver dams historically were commonplace downstream in the DPL outlet stream. A analytical review of 2015 aerial photographs and topographic maps (Appendix 5, Figures 5-1 to 5-6) and LiDAR suggests that in the outlet stream before the first road crossing (from outlet to the invert level of the road culvert) there is a current estimated gradient drop of about 2.5 to 3 feet. The aerial photographs also allow review of numerous remnant beaver dams that have been breached in the past. Questions about their historic control on DPL water levels, and how to reconcile future and historic water levels, are likely important to planning efforts.

Challenge 3: Water quality nutrification effects on PMSWA and expanded threats downstream, including DPL

Water quality data provided by WDNR documented elevated levels of nitrogen and phosphorus in some ditches of PMSWA. The highest and elevated levels are found in the deepest excavated ditches (including the main ditch), several secondary ditches, and the Little Trout Lake ditch. Within both PMSWA and DPL, this nutrification presents a significant threat to the perpetuation of their high quality native vegetation systems and wildlife habitat. In general, nitrification represents a threat to a healthy biodiversity. This is currently manifested in PMSWA most clearly by colonization by the non-native reed canary grass (*Phalaris arundinacea*) and giant reed grass (*Phragmites communis*). This occurs primarily along ditch margins adjacent to the degraded water source but it is currently expanding outward. For example, along the Little Trout Lake ditch, reed canary grass is now colonizing an area of historic highly acidic bog vegetation by rooting shallowly in the acidic sphagnum and sedge peat substrates, spreading rapidly by paralleling the ditch, and moving laterally away from the ditch into other areas of PMSWA. In addition, this invasive species has moved through the outlet structure and now is bordering the inlet stream and colonizing along margins of the stream course entering DPL.

In summary, high nutrient loads appear to foster significant deleterious effects on rare plant and animal communities and habitats in PMSWA and DPL. Most of the area possesses high quality native vegetation communities, identified by WDNR plant studies and other investigations of the area. Invasive non-native plants represent a serious very costly risk to the future health and stability of shorelines and vegetation systems in both PMSWA and DPL.

Challenge 4: Ecotoxicity issues

Manganese has been documented to have ecotoxicological effects on reproduction, growth and health of species and populations of aquatic macroinvertebrates (e.g., insects, crustaceans and other arthropods; mollusks; worms, etc.) and certain fish species (Howe et al., 2004; Pinsino et al. 2012, and others). Young of the year fishes are particularly vulnerable. Manganese uptake in aquatic invertebrates significantly increases with temperature increase and salinity and with pH decrease (Baden et al., 1995). Documented effects of excessive manganese on plants include reductions in growth rates, biomass, and photosynthetic abilities (Millaleo et al. 2010). This, in turn, translates on the ground to a reduction in native sedge, wet prairie and bog communities—the prevailing plant communities present in PMSWA—and changes in species compositions of the shoreline and adjoining wetlands of DPL. Iron also has been documented to affect these same organism groups (Vuori 1995).

We have reviewed results of the June 2017 ambient whole effluent toxicity (WET) ecotoxicological testing of inflow and lake waters in DPL by the WDNR (Kari Fleming, Environmental Toxicologist, WDNR Bureau of Water Quality, pers. comm.). These findings documented minor water-column ecotoxicity in one of the samples, with other tests documenting no toxicity to the test organisms. Additional testing of the ecotoxicity of the sediments and flocculant materials is being conducted with final results pending. Like water column WET testing, upon review, we found the assessment of sediments and flocculant materials (Barr Engineering 2011) to underrepresent potential ecotoxicological sensitivity.

We advocate for a reduction in the levels of manganese because of its known and documented ecotoxicity from other studies. As previously mentioned, no numeric standards exist in Wisconsin for released surface or groundwater not used for human consumption. In spite of this, given the high quality natural habitat and the corresponding preparation of a management plan for DPL, we suggest that numeric standards for surface and groundwater be set based on the known ecotoxicology impacts of these chemical constituents on these aquatic organism groups. Specific effects of increased loads of manganese and iron on rare plant and animal communities might be determined by additional ecotoxicological testing of PMSWA and DPL ecological communities.

Challenge 5: Lack of year-round and long-term representative data on hydrology conditions in PMSWA and DPL

Two studies of the hydrology and surface and groundwater levels of DPL were conducted by U.S. Geological Survey (USGS) (Krohelski et al. 2001), and by Barr (Barr Engineering 2011). These reports present very different conclusions about ground and surface water percentages that contribute to the water budget of DPL. Our review of these analyses suggests that both studies have opted to not consider historic conditions as a basis for comparison to the existing hydrologic and water budget. In addition, both studies have used a series of assumptions to create models and calculations that appear to have errors relative to the conditions currently present at PMSWA and DPL. The identified problems in the modeling are as follows:

1. Modeling and calibration of the Barr water budget is not congruent with data on documented lake stage measurements.
2. Modeling of the water budget by USGS used annual averages of lake stages. These data are also inadequate for the task since they do not correlate with current lake stage measurements or with measured inflow and outfall water quantities by season.
3. Neither study adequately considered the history of the ecological systems present in PMSWA and DPL to form conclusions about present conditions and the dynamics that have contributed to these conditions.

In short, in both studies, the lack of historical analysis seems to be a critical deficiency. For this reason, during the meeting, AES presented a review of the history of bog formation, and applied this to the PMSWA and DPL as follows:

1. USGS models have failed to consider that the groundwater flows are not steady state. Rather, they vary during the year according to the relationships between lake stage and groundwater inflows.

2. Barr studies have failed to create a water budget that correlates with measured lake water levels. In addition, the modeling used inflow data and outflow data from different years which adds unnecessary variability and makes it difficult to calculate an accurate balancing of the water budget.

Challenge 6: Misunderstanding bog history, dynamics and alterations

We propose to use historic and current bog ecology conditions and principles of bog formation to structure an alternative paradigm that informs management of PMSWA and its relationship with DPL. On the larger landscape, Vilas County is one of the globally recognized locations where rapid glacial recession occurred. Today, many wetlands and lakes are found in depressions once occupied by huge chunks of glacial ice. PMSWA, once a very large undisturbed bog complex, is one such area. Initially filled with ice blocks and water, as glaciers retreated the area ice was replaced by a lake whose bottom substrate was continually filled with deposits of fine sediments and glacial till. Over time, erosion from adjacent uplands, not yet sufficiently stabilized by vegetation, continued to fill the lake and wetland. Deposits of fines included ash from wildfires and organic plant material which began to seal the bottom of the lake ecosystem. As the process continued, the lake system developed vegetation, growing from the margins inward. In a feedback loop, the continuously accumulating sediment generated new opportunities for establishment and growth of vegetation including submerged rooted aquatics and emergent species. These all fostered the transition from open water to vegetated wetlands. Eventually the entire lake system was covered by vegetation. In the case of PMSWA, peat deposits that reach 20 to 30 feet deep, or deeper, reflect this long ecological history.

Given appropriate conditions of temperature and moisture, the sequential peat layers overlying the glacial till substrate began supporting development of *Sphagnum* moss. *Sphagnum* comprises a very unique suite of congeneric species because, unlike other green plants, *Sphagnum* liberates hydrogen ions (rather than hydroxyl anions) as a product of photosynthesis. This contributes to increasing concentrations of hydrogen ions and a concomitant lowering of the pH (increased acidity) of the water. As pH decreases below a neutral value of 7, the incipient bog is considered to be acidic in nature. (The measure of pH is a logarithmic function. Thus, a decrease in value from a neutral pH of 7 to a pH of 6 represents a tenfold increase in acidity along with a tenfold increase in hydrogen ions. Likewise, a shift from pH7 to pH5 represents a one hundred-fold increase in hydrogen ions and acidity.)

Glaciers transported iron-rich rocks and sediment materials south and southwest from the Mesabi iron range in northern Minnesota and Michigan's Upper Peninsula iron range and deposited them in the area now occupied by PMSWA and DPL in Vilas County, Wisconsin. This substrate material and tributary waters are lacking in significant quantities of calcium, magnesium, and/or carbonates that typically act to buffer trends toward acidification. For example, in areas with abundant limestone in the substrate, *Sphagnum* moss liberates hydrogen ions, but the pH does not drop significantly because the available carbonate or carboxyl anions continually neutralize the hydrogen ions. (Rain water, typically nutrient-depleted, is usually considered to be neutral pH but nowadays, because of ongoing release of industrial air pollutants, it is often acidic.) Thus, in a setting such as PMSWA, acidic conditions conducive for *Sphagnum* moss growth are commonplace. As a consequence of all these interacting factors, large areas of PMSWA are dominated by *Sphagnum*-generated peat.

Challenge 7: Alteration of bog ecology

Bog ecology (e.g., plant and animal communities, natural processes) is altered when tributaries are nutrified with nitrogen and phosphorus. It is altered when erosion, especially with nutrient rich soils such as from agriculture, enters the bog system. It is also altered by ditching or attempts to dewater and fill shallower areas and convert them for agricultural or forestry production.

Excavated ditches in bogs are typified by highly variable water chemistry, dependant in part on their depth. When surface ditches are dug into the surface dome of *Sphagnum* moss developed on top of the peat bog, the resulting ditch waters are highly acidic. If the ditch system goes deeper, into the underlying sedge peats and algal peats, the emerging waters are typically moderately to highly acidic, have very low nutrient levels, and are depleted in calcium or magnesium carbonates (i.e.,"soft water"). When a ditch is dug down into glacial till, acidic water from the *Sphagnum* enters the iron-rich, carbonate-poor glacial till layers and liberates iron, manganese and other metals into the water column. As previously mentioned in this report, during spring snow melt a hydraulic head resulting from high water levels drives acidic water into the glacial till. As ditch water is released congruent with lowered ditch water levels, water re-emerges into the ditch from the till carrying with it an enhanced load of dissolved iron, manganese, and other metals.

Upon contact with oxygen, and aided by "iron bacteria" (including the locally identified *Leptothrix* spp., and *Ferrobacillus* spp.), iron and other metals begin to precipitate as flocculant. These materials then flush into the ditches and eventually reach downstream receiving waters such as DPL. This cycle of ditching, the seasonal influx of acidic waters into the till substrate, and re-emergence of iron-rich water into the ditches continues at PMSWA and contributes to the ongoing water quality impairment of PMSWA and DPL.

In addition, in the past, the WDNR quarried local iron-bearing glacial till gravels and cobbles from moraine ridges within the marsh and used them to make dikes and levees and surface roads. This increased the amount of iron-rich substrate continuously exposed to acidic surface water from the ditches and thus increased potential release of additional iron and other cations into ditch water. During low flow periods, the release of iron from road subgrades and underlying glacial tills is revealed by staining of side slopes and ditch bottoms. When iron emerges during low water periods it is in an anaerobic state, typically adsorbed to dissolved organic carbon or particulate carbon. It is not conspicuous until it oxidizes, as it does in wave action and warm temperatures. When it oxidizes, the resulting orange to red iron flocculant is highly visible and becomes an aesthetic nuisance, particularly on DPL beaches and shorelines. During higher flow conditions, iron typically remains in solution and is quickly moved through the PMSWA outlet structure into DPL. In this case, it only becomes conspicuous if residence time in DPL allows for oxidation and precipitation of the highly visible flocculant.

Increasing the flow of water through the ditches to reduce the development of iron flocculants within PMSWA does little to ensure the flocculation doesn't subsequently occur in DPL. In fact, an increased flow through the ditches may result in higher net accumulations of iron in DPL and resultant higher rates of flocculation. The calculation of minimum inflows will be particularly crucial to determining whether the source of flocculant is primarily from PMSWA.

SOLUTIONS and STRATEGIES FOR ADDRESSING CONCERNS

The AES technical team, the WNDR, and DPL Association members examined the PMSWA and DPL management plans before the meeting and during the project. The team also reviewed the recommended alternatives considered in the PMSWA master plan (WDNR 2016). Discussions regarding previous alternatives A and B and a subsequent final recommended alternative in the PMSWA master plan were discussed during the meeting. Bullet points were created to summarize each alternative. In Figures 6-6 through 6-15 (Appendix 6) alternatives solution strategies considered for DPL and PMSWA have been graphically illustrated and summarized.

Participants also discussed the challenges resulting from details of DPL not being considered in depth during the PMSWA master planning process. The principles developed during the meeting were relevant to both PMSWA and DPL (Appendix 2, 4, and 6**).** This was confirmed by stakeholders attending the meeting in their roles representing concerns about DPL and PMSWA, as well as larger township.

In response to reviews of the DPL Management Plan, PMSWA Master Plan, information from site visits and other data, the potential alternative or additive solutions were discussed during PMSWA and DPL site visits and by attendees at the meeting (Appendix 4,6). Preliminary discussions with the PMSWA wildlife manager and lake management specialists from the WDNR also occurred during the meeting. Potential solutions were developed and given a preliminary evaluation of capital costs, operation/maintenance costs, and regulatory requirements associated with each of the strategies. This evaluation assigned a high, medium and low score to each solution in terms of costs.

Subsequent to the meeting, the potential solutions were graphically developed, and each was tested with scenario modeling using STELLA software (ISEE systems). STELLA software comprises modeling and simulation platforms that provide great flexibility in evaluating hydrology and water quality integrated with human management decisions, proposals and impacts. It allows the researcher to combine the costs of each solution first considered singly, in isolation, and subsequently as phased or sequenced additive solutions.

In this project, the STELLA evaluation process sequentially inserted each of the alternatives and sub-alternatives into a base model framed by using input data from the USGS report, Barr models, calibration data from WDNR, and resident daily stage measurements on DPL.

After the individual solutions were tested in isolation, evaluation moved to logical sequencing and combining of solutions. An initial solution evaluated the preferred alternative from the PMSWA Master Plan (WDNR 2016). The procedure then sequenced additional solutions to the preferred alternative and added solutions to alternative approaches needed to address management challenges of DPL, achieve the performance criteria and meet the principles set by the working group during the meeting, and achieve desired outcomes.

SUMMARY of APPROACH and FINDINGS

Through an analytical process using STELLA modeling and an evaluation matrix that ranks (high, medium, low) relative effort of monetary costs, regulatory requirements, technical design challenges and constructability (buildability) requirements, the team evaluated and ranked potential solution strategies. This report refines the scoring for each solution. We have further elaborated on the likely costs and regulatory procedures and time requirements needed to implement any of the solution strategies. If any solution strategies were deemed not to be viable, a justification was entered into the matrix (Table 1).

Solution strategies focused on four issues:

1. **Water quality in the lake.**
   Solutions addressed excessive iron, manganese, phosphorus in Dead Pike Lake as well as sources of these materials.
2. **Water supply to the lake**.
   Solutions sought a clearer understanding of release rates from PMSWA and DPL with respect to water level dynamics.
3. **Integrated solutions.**
   Solutions assessed the possibility of integrating solutions for DPL and PMSWA.
4. **Creation of a new Dead Pike Lake Management Plan.**
   Finally, solutions focused on integrating strategies for issues 1-3, above.

The solution strategy matrix constructed by the working team (June 2017) included 3 strategies for DPL, and 7 strategies for PMSWA (Appendix 4, Tables 4-A and 4-B). Two of these solutions, including one for DPL and one for PMSWA, seem to have the greatest potential for accomplishing program goals. A third proposed solution requires further study. We describe these three solutions in more depth immediately below. In addition, we have captured in this report some of the other thoughts and communications shared during the discussions between team members (Appendix 7).

Solution 1: Restoring historic levels of DPL

Estimated total cost: $200,000.00 to $300,000.00.

Restoring lake levels to an estimated elevation of approximately 1596.5 ft. msl (still water level) or greater could eliminate the influx of iron rich groundwater into the lake, although a better understanding of the effect of spring first flush discharge on iron, phosphorus and manganese levels is needed to fine-tune the prediction and resulting prescription.

This strategy of actively restoring the normal water level of the lake back to historic levels has been projected to reduce or eliminate the excessive iron, manganese and phosphorus influx into DPL from surrounding groundwater sources. When the normal lake water elevation is increased approximately 18 inches (1595 ft. to 1596.5 ft.) the hydrological head created on the groundwater reduces or eliminates the entire seasonal influx of iron and other constituents into the lake from groundwater. At this time, it appears this can be accomplished through a restriction on the outflow that better matches inflows, coupled with a slight raising of the elevation of the lake bank. This work would entail about 1000 to 1500 feet of fill to raise the north side of the lake bank to prevent overflow combined with modifications to the outlet.

Solution 2: Introducing ditch backfill and wetland biofilters in PMSWA

Estimated total cost: $300,000.00 to $700,000.00.

Introducing wetland biofilters into backfilled ditch systems of PMSWA would disconnect the surface-to-groundwater interaction created by the original excavation of deep ditches. It also would assist in the clean-up of excessive iron, manganese and phosphorus prior to discharge of surface water to DPL. The first step of this solution is backfilling approximately the lower two-thirds of each ditch with limestone screenings, or limestone rock, topped with a filter fabric followed by installation of soil that is subsequently planted with wetland vegetation. This backfilling approach is intended to seal the bottom of the ditches and thus disconnect the pathways acidic surface waters follow to enter the groundwater where they flush out iron, manganese and phosphorus. These undesirable chemical constituents are subsequently released via surface water to DPL.

Because the ditch will not be completely backfilled, stopping flow, flowing surface water will still carry water from PMSWA to DPL, transporting unwanted chemical constituents. The planted wetland vegetation and low-flow, meandering, shallow channels will be designed with a long flow path length and lengthened residence time so that any remaining iron, manganese and phosphorus will be biofiltered by the wetland before the water is discharged into DPL. Consideration will also be given to the need for a final polishing wetland biofilter at the end of the ditch system to accomplish further reduction in these chemical constituents. As an alternative to Solution 2, we suggest that a treatment wetland of about 25 to 40 acres involving about 2 feet of excavation, added soil amendments, and possible construction of an outlet control structure be considered. This might cost $300,000.00 rather than $700,000.00.

Solution 3: Creating a surface water diversion

Estimated total cost: $60,000.00

Solution 3 will need further exploration before proposing it as a primary solution. The proposed idea is to create a surface water diversion from Stepping Stone Reservoir to Pete's Creek using gravity-fed piping. This will reduce the pool over Powell Marsh, reduce the groundwater head near Stepping Stone Pool, and result in the release of clean surface waters to DPL without interaction with iron-rich groundwater.

At this time, we recommend that the working group proceed with further analytical testing of these three solution strategies in both PMSWA and DPL, including consideration of costs and constructability. Over the course of the next six months, this analysis and process of engagement and collaboration between the PMSWA wildlife manager, the lake management group at the WDNR, stakeholders of Dead Pike Lake Association, staff of AES, and other participants should continue to collect additional information and refine the STELLA modeling of the water quality benefits to the DPL and PMSWA.

RECOMMENDATIONS

In this section, we present the outlined scope proposed for a management plan aimed at restoring historic water levels in DPL. Subsequent to the June 2017 meeting, evaluations of the draft solution strategies were updated to reflect the primary findings resulting from testing solutions with the STELLA model (Table 1)**.** A series of technical questions and data needs were identified through the modeling process.

At this time, we recommend that WDNR, Dead Pike Lake Association and/or Manitowish Waters Township secure funding to fund studies that address the identified technical questions and data needs. Addressing these data needs will create a foundational understanding needed to formulate details needed for a final design process (plans, budgets, regulatory permits) for each solution and facilitate the refinement of management plans. The following recommendations and associated scopes are recommended to address the questions and data needs necessary to implement Tasks 1, 2, and 3. The total estimated budget for conducting Tasks 1 -3 is ~$26,000.00

Task 1. Restoring historic levels of DPL.

Restoring levels of DPL to an estimated elevation of about 1,596 ft. msl or greater could eliminate the influx of iron rich groundwater into the lake. We also need to understand effects of the spring first flush on water discharge and iron, phosphorus, and manganese levels. In order to create the plan for restoration of the historic DPL water levels, the following scope are proposed under this task.

Task 1A. Refined elevation surveys of historic shoreline and ice ridge.

An existing ice-thrust ridge is present around the perimeter of the lake and mature trees are growing in association with its upper margins. During winter and spring 2018, historic lake water levels will be surveyed with TKS survey instrumentation to establish the historic footprint of DPL.

Task 1B. Model calibration with historic surveyed shoreline.

STELLA modeling will be refined via calibration using the new lake shoreline survey.

Task 1C. Development of lake level dynamic statistics for existing and historic normal lake water levels.

A 30-year continuous precipitation record will be used to refine the normal water level (average annual) estimate. First, the STELLA-calibrated water budget will be applied to existing water levels measured in 2017. Secondly, the 30-year continuous precipitation record will be applied using the surveyed historic normal lake water levels as the base.

Task 1D. Testing new normal water level and lake level dynamic.

STELLA will be used to re-run water balance and iron, phosphorus, and manganese mass balances. Relationships will be created using the new water level and annual predicted variances. We will set a new water level fluctuation, aligned with historical lake elevations.

Task 1E. Measurements of PMSWA spring flush of iron, phosphorus, manganese, and discharge of water.

Using existing WDNR datasondes and WDNR chemistry laboratory analyses, we propose to extend existing WDNR chemistry and water discharge sampling from PMSWA until fall 2017 freeze-up, and again to redeploy the monitoring equipment prior to the first flush of spring snowmelt. To capture this first flush, equipment will be reinstalled in mid to late February 2018. The new data from monitoring will be added to the existing databases used in development and calibration of STELLA. The effect will be to extend the sampling period of the data used to calibrate STELLA and thus capture more of the inherent variability.

Task 2. Introducing wetland biofilters in backfilled ditch systems in PMSWA.

This solution is proposed to disconnect the surface-to-groundwater interaction created by the deep ditches. It also is proposed to further clean up remaining excess iron, manganese, and phosphorus prior to the release of surface water to DPL. The following tasks are proposed to create conceptual plans for these biofilters.

Task 2A. Measurement of ditch volumes to determine backfill material volumes.

The goal of this task is to determine the potential opportunity to partially backfill ditches that represent sources of iron, manganese, and phosphorus. The main ditch (Little Trout Lake Ditch) and Stepping Stone Ditch along the railroad tracks will be surveyed. Surveys of representative cross sections will create bathymetric and above-water cross sections. Following surveys, computations to backfill selected ditches will determine potential types of material and volumes as well as costs to deliver and install backfill materials. The actual nature of the material to be used in the backfill will be determined in Task 2B.

Task 2B. Application of existing STELLA modeling to determine water quality benefits with various wetland biofilter conceptual sizing and locations.

Wetland biofilter conceptual designs will be applied to existing upland areas, where the potential for lined wetland cells will be explored. Restoration in backfilled ditches will revegetate newly created wetland biofilters with dense native vegetation that will act to filter surface runoff. Selected locations will be tested for sizing, costs, and water cleansing effectiveness. Concepts will be integrated with the overall STELLA water balance and water quality modeling. We will summarize the water quality improvements under various sizing and location options.

Task 2C. Wetland biofilter optimization.

Using lime, gypsum, or other precipitant-inducers, the wetland biofilters evaluated under Task 2B will be optimized for water quality improvements. We will explore conceptual alkaline wetland treatment designs using lime treatments. This is likely to be passive lime treatment using some percentage of limestone and bentonite materials as a part of the backfilled ditches.

Task 3. Creating a surface water diversion in the vicinity of Stepping Stone Reservoir to Pete's Creek

This solution would reduce the pool over Powell Marsh that is creating a head over the groundwater near Stepping Stone Pool. This would facilitate the release of clean surface waters to the lake without interaction with iron- rich groundwater.

Task 3A. Groundwater concentrations and flow direction using piezometers.

During frozen conditions of winter, an ATV-mounted Gidding hydraulic soil sampling unit will extract 15-20 foot long 2-inch diameter core samples through the peat substrates of Powell Marsh. Multiple soil core samples will be collected from locations starting by the outlet structure to the vicinity of Pete's Creek. Samples in clear plastic tubes will be bar-code labeled and delivered to a soils laboratory for peat hydraulics analysis. Two-inch diameter ABS water sampling wells will be installed into up to 5 holes that were used for core sampling. The core samples will be analyzed for water levels and water chemistry (phosphorus, iron, manganese, etc) and will be sampled once a month during winter 2018 through early summer 2018. This subtask is focused on understanding in greater detail the groundwater movement toward the southeast shoreline of Dead Pike Lake.

Task 3B. Evaluation and conceptual design of Stepping Stone Pool water quality for diversion source.

WDNR G-Flow modeling of the groundwater concentration areas suggests the southeastern and north shorelines of the pool have some of the heaviest groundwater discharges entering Dead Pike Lake. Task 3B is focused on collecting data on the hydraulics and water budget for a potential Pete's Creek water diversion. Methods will include use of a fluorescent dye placed into the piezometer water wells to determine the groundwater movement. This dye study, used to calibrate WDNR G-flow modeling, will help determine the efficacy of diverting surface pooled waters from the Stepping Stone Pool through a pipe that could be installed to discharge pool waters directly into Pete's Creek. Such a concept would bypass interaction with groundwater, thus reducing potential for accumulation and transport of iron, phosphorus, and manganese from PMSWA to DPL.

Table 1 (A and B). Alternative or additive solutions discussed during June 2017, working team meeting.

Priority solutions suggested by STELLA modeling, highlighted with green. (Focus of planning grant to gather supporting data.)
Solutions dropped from further consideration at this time highlighted with red.
Solutions that need further evaluation highlighted with yellow.

A. POTENTIAL SOLUTIONS POWELL MARSH (PMSWA). Two major component considerations: 1) remedial, 2) preventative

OPTION	DESCRIPTION	DATA NEEDS	O/M RANK L,M,H*	REGULATORY RANK L,M,H*	COST RANK L,M,H*	NOTES
0. Do nothing: Maintain allexisting infrastructure						Not considered further because goals are not achieved.
	Maintain O and M					
1. Rewilding: return to pre-disturbance condition		Map remnants Map glacial uplands Map disturbances Invasive species Property bounds LiDAR				Not considered further at this time because it appears to not be entirely consistent with PMSWA master plan goals.
	Remove ditching					
	Remove WCSs					
	Remove RR grades					
2. West culvert diversion		Revise water budget Floodway analysis Dam regulatory				Not considered further because this strategy would result in reduced surface water entering DPL being replaced by iron-rich groundwater, increasing levels of lake iron.
	Spillway at DPL inlet					
	New channel to Lost Creek Inlet or some other mechanism					
3. Modified Master Plan Alternative		Wetland and plant species inventory (T&E) Soil samples Topo survey + LiDAR West Channel H20 quality Material volume (cut fill/proximity)				Shortest term to align withDNR approved plan--- rather than a general modification to the master plan. The solution suggests very specific refinements of the master plan.
	Treatment wetland Except w/ ditch enhancement and sealing					

4. P and N Little Trout Treatment Wetland (included in Solution #2)		Better understand access from east Better understand cranberry farm operations and interests in collaboration	H- Need for pump L-Grantee H, cranberry L-DNR	M	M- Pump is needed L- if gravity fed	We now lump treatment of water from Little Trout lake ditch with Solution #2 below.
	Nitrogen					
	Phosphorous – Add to Vista Pond Treatment Wetland					
SOLUTION #2. Backfill ditches and create wetland biofilters		Similar to #1	L	L-M	H	
	8,000 ft of ditch/5,450 ft of dike			Backfilling is already approved per the PMSWA master plan. Federal permits likely necessary. But, because state has already approved and the goal is restoration based, these permits should not be challenging to obtain.	Assume 3.7 cy /foot -length (20 ft wide by 5 foot depth) x 8000 lf = 30,000 cy @20/delivered/placed rock/ soil= $600,000.00 Plus filter fabric 8000 lf x 25 ft width X.20/sf= $40,000. Estimated with engineering and permitting **TOTAL COST: $700,000.00**	
	Selected, sequential abandonment					
	Selected, sequential lining/biofilter of other ditches					Ditch modification different than #1
SOLUTION 3. Pete's Creek Piped Diversion		L	L	L-M	L-M	
	With control structure at main inlet	DPC Fe measurements of "Clear water Areas" Flow (channel) and storage H2O Volume			Design, engineering, permitting estimated at $30,000.00 + 6"-10" heavy wall ABS pipe installed on wetland surface & pushed into surface substrates by driving over it with track vehicle. 3000 lf @ $10/ft- $30,000 for pipe. **Total cost of $60,000.00**	Pete's Creek not a mapped stream Method to supplement water to the lake

***L=Low, M=Medium, H=High**

B.POTENTIAL SOLUTIONS DEAD PIKE LAKE

OPTION	DATA NEEDS	O/M Rank L,M,H*	Regulatory Rank L,M,H*	Cost Rank L,M,H*	Notes
Lime (Lake) Introduce as far away from outlet as possible, temporary outlet control	H2O- Calcium, Mn, Dissolved Organics Lake volume Data sonde infor Old data: Lake profile Sedimentation rates	L	L-M	L	At this time liming of DPL will be considered further after a more complete understanding of the benefits of SOLUTIONS 1, 2 and 3 are available and only if a single lime treatment of DPL once it has a controlled outlet, can be documented to actually result in a cleaning eposode that might be important to change the trajectory of the water quality in the lake. Currently, the thinking is that is if solutions 1, and 2, and perhaps with the inclusion of Solution #3 are as effective as suggested by STELLA modeling, then normal lake flushing plus the benefits of Solutions 1,2, and 3, may provide the benefits to rapidly change the trajectory of the lake water quality.
SOLUTION 1. Establish (maintain) higher lake stage, construct outlet structure	Floodway Wetland Delineation Flood Easements Flood Elevation + modeling GFLOW0 model w/ H2O Level change	L	H—state and federal permits for NR104, NR 151, Section 404/401 clean water act; Hydraulic and flood no-rise analysis and documentation that infrastrcture up on the lake or downstream will not be effected. 18-24 month timeline	H—Design, engineering, regulatory, materials/build estimated at **total cost of $200-$300,000.00** **Total COST $150k for dam (worse case)** **$50-150k for regulatory requirements**	Can be restored with formal dam, or by raising bottom elevation of outlet stream with cobbles, or by reducing the width of the outlet stream with cobbles.
Allow beavers to build dams at outlets					Beaver dams fluctuate in their effectiveness and are not reliable or enforceable.For these reasons, goals of maintaining prescribed water levels and containing iron influx would not be ensured.

***L=Low, M=Medium, H=High**

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APPENDIX 1: Detailed Agenda to Guide the Planning Meeting.

AGENDA

TUESDAY, June 13, 2017

DAY 1. MORNING, 8:30AM: Aberdeen Cabin

1. **INTRODUCTIONS** - ***(Group Round)*** *15 minutes*

Discussion and Overview of Project and Workshop Goals- *(AES to Lead, Group Interaction)*

1. **Overview of History *(Part I.)*** of Powell Marsh, Dead Pike Lake watershed(s) and watershed modifications.
   a. Lake residents overview of existing, DPL conditions, *including 14 minute video.* ***(Gale to Lead)*** *30 minutes*

2. **Overview of Findings** from previous studies of PM, DPK.
   a. Lake Management Plan ***(Dan and Gale to Lead)*** *10 minutes*
   b. USGS report *(**Dan to Lead**,* 5 minutes
   c. Trout Heavy Metal ***(Dan to Lead)*** *10 minutes*
   d. Aquatic plant community ***(Dan to Lead)*** *5 minutes*
   e. Water clarity (secchi) ***(Dan to Lead)*** *5 minutes*
   f. Water chemistries at Marsh and DPL ***(Dan to Lead)*** *10 minutes*
   g. Garrison's loading reports and paleology sediment chemistry **(Dan to Lead)** *(10 minutes)*

3. **DOC references and recent data** (April 2017) ***(Dan to Lead)*** *10 minutes*

4. **Site tour of DPL and PMSWA** . ***(Dan, Gale, John to Lead****) 2-3 hours*
   a. Tour of Lake (***Pete)*** (to see inlet, outlet, tributary stream, lake margins, vegetation, etc)
   b. Tour of Watershed including Sugar Bush
   c. Tour of Marsh (***Dan)*** (WM) (to see outlets, dikes, ditches, pools, etc.

DAY 1. AFTERNOON, 12:00PM: Aberdeen Cabin

5. **Introduction to Bog Ecology and Hydrology *(Jim and Steve A. to Lead****)* *30 minutes*

6. **Overview of Similar Projects** results where similar watershed/bog/lake modifications have been addressed. ***(Jim and Steve A. to Lead)*** *1 hour*

7. **Introduction to the use of STELLA** to integrate history, existing condition, disparate and conflicting findings from previous studies, and to establish a process of testing solution strategies and sensitivity analysis to address differences in findings from previous studies. Discuss how conflicting findings from previous studies is to be addressed with STELLA, and how uncertainty is to be addressed with STELLA. ***(Doug to Lead)*** *2 hours*

8. **Facilitated Work Session** - to brainstorm solutions ***(Steve D. and Steve A to Lead)*** *30 minutes*

   a. Team Work Session (Break into Groups)
      i. STELLA development, refinement *(Doug and Fugui to Lead)* *3 hours*

      ii. ***La*nd use change and hydrology, hydraulics, i**ncluding watershed modifications; create a graphic chronology and supporting bullet points that simply and graphically explains changes in watershed, PM and DPL ***(Jason, Steve A, Steve D, Gale, John, Pete, Kathryn, Others)*** *1 hour*

      iii. ***Eco*logical changes**--- create a graphic chronology and supporting bullet pints that simply and graphically explains fundamental changes in watershed, PM, DPL ecological system changes —***(Ludwig, Steve A, Dan to Lead)*** *1 hour*

      iv. ***Ch*emistry dynamics** definition under historic and existing conditions in Powell marsh (within intact peats, in disrupted peats, in ditches, in the inlet to DPL, and in water column of DPL, and at outlet of DPL ***(Jim, Dan, etc. to Lead)*** *1 hour*

   b. **Future Scenarios** - Preliminary brainstorming session to define potential future scenarios as a solution matrix. This team's goal is to create a graphics and bullet point summary that explains the changes necessary to convert watershed, PM and DPK from the existing conditions to each potential future solution scenario. ***(Steve D to Lead)*** *2 hours*

DAY 1. EVENING - Aberdeen Cabin

Summary, Presentation, Discussions on Day 1. Achievements. *1-2 hours*

7:30PM - Frank B. Koller Memorial Library

2 US-51, Manitowish Waters, WI 54545 - (715) 543-2700

Steve A. Presentation -*"Natures Second Chance"* to include follow-up discussion with Team and other participants.

TEAM DINNER – ***Location to be determined***

WEDNESDAY, June 14, 2017

DAY 2. MORNING, 8:30AM: Aberdeen Cabin ***(AES and Work Group Members)***

9. **Overview of History** ***(Part II.)*** of Powell Marsh, Dead Pike Lake watershed(s) and watershed modifications.
   a. Department overview of proposed PM management actions ***(Chuck to Lead)*** *15 minutes)*
   b. Department overview of partial restoration actions ***(Chuck to Lead)*** *15 minutes*

10. **Measures of Success** –Preliminary definition of measurements of success, and evaluation of the pro's and con's of each solution strategy. ***(Dan and Gale with Steve D to Lead)*** *1 hour*

11. **STELLA Solution Definition** of each future Scenario ***(Doug to Lead)*** *1 hour*

12. **Solution Ranking** –Projected benefits of each solution, and development of bullet point listing of underlying assumptions, for use of each solution strategy, into short(1-5 yrs) and long term (25 yrs+) timelines ***(Steve D and Jim L to Lead)*** *1.5 hours*

TEAM LUNCH at Aberdeen Cabin

DAY 2. AFTERNOON – Aberdeen Cabin

13. **Cost estimation for each solution strategy** – Cost estimation template creation and preliminary estimation of one or more solution strategies ***(Steve A, Steve D and Jason to Lead)*** *4 hours*

14. **STELLA modeling first runs of** highest priority solutions or bracketing of a chosen subset of solution strategies to begin to understand probability and cost of what success is believed to be achievable. ***(Doug and Fugui to Lead)*** *4 hours*

15. **Team Work session —** This session will focus on taking one or more of the highest priority solution strategies and working as a large group to build more details into the STELLA modeling. The same teams are asked to ensure the areas of focus from day 1 is addressed. ***(Team Group)***

Day 2. EVENING – Aberdeen Cabin

Summary, Presentation, Discussions on what was achieved during Day 2, and Next Steps. Team Discussion ***(Team Group)*** 1.5 *Hours*

TEAM DINNER - Location to be determined

THURSDAY, June 15, 2017

DAY 3. MORNING, 8:30AM: Aberdeen Cabin (AES and Work Group)

Team Work Session – Refine, revise, rerun, graphically and expository document findings. *2 hours*
Share an updated presentation to WDNR representative, ***(HOA representative)*** *1 hour*

TEAM LUNCH at Aberdeen Cabin

ADJOURNMENT and Depart for ***Home***

APPENDIX 2. Potential Management Principles, Recommendations and Solutions to Address Water Quality Concerns.

SUBCATEGORES	PRINCIPLES	PMSWA	DPL
H2O Quality			
	Reduce P below NR103 levels	x (Prevention)	x (Remediation)
	Reduce Fe (Mn) Floc to SW	x	x
	Stabilize existing Fe floc (remediation)		x
	Create disconnect between Surface and Ground Water	x	
Hydrology			
	Maintain water levels	x	x
	7Q10 base flow (25% of low flow, dam failure analysis)	x	
Property Rights			
	Address property owner/shoreline rights	x	x
	Address existing agreements	x	
	Address LDF Tribal rights*	x	
Ecological			
	Support diverse game/non-game wildlife objective	x	x
	Address fisheries objectives **		x
	Address species and species of concerns	x	x
	Maintain high quality native vegetation***	x	x
	Use project as learning to apply to other projects		x

APPENDIX 3. Goals and Performance Standards for PMSWA and DPL

PMSWA Goals	Performance Matrix	Standard
Provide Open Wetland Habitat		
	Acres of open wetland habitat; Meet master plan goal	Acres of: sedge meadow, wet prairie, shallow emergent, shrub car. Report ~ 5yrs
	Invasive plant management/monitoring	*Phlaris, Phragmites*
	Waterfowl and bird use	Monitor and set improvement goals
	Management Plan-Annual Report	
Maintain/Enhance Use		
	Visitor use survey by WDNR user survey program	
	Promotion of passive use	
	Consider improved access without impacting H2O quality	
Meet Discharge Water Quality Standards		
	Discharge rates	
	Phosphorus levels	
	Nitrogen levels (?)	
	Aesthetics/Fe and flocculant	
	Monitor water quality	
DPL Goals	**Performance Matrix**	**Standard**
Inflow Lake H2O Quality		
	Secchi disk reading	>5 m
	Phosphorus levels	<0.015
	Flocculant deposition on shoreline	<5mm/yr
	Iron and manganese levels	<1 / 0.1 mg/l
Lake Water Level		
	Staff gauge and pressure transducer (calibrate annually to address ice impacts)	Confirm ordinary/set to historic high
	Avoid flooding and maximize for water quality	Reset annual/permanent BM near gauge
	Test setting ordinary high	
High Quality Fishery		
	Creel surveys documenting improved fishery (life cycle): walleye, SMB, Muskie- spawning habitat	Fish survey every 5-yrs compare to other healthy lakes
	Rainbow smelt	
	Measure/monitor macroinvertebrates	Compare to other healthy lakes
Maintain/Protect Shoreline		
	Conservation plan for all private shorelines –address fertilizer use	CP adoption by DPL Association
	Invasive species monitoring (annual)	EDD process in place
	3-day plant survey	

APPENDIX 4. Alternative or Additive Solutions Discussed During Site Visits.

Table 4-A. Potential Solutions for PMSWA.

Two major component considerations: 1) remedial, 2) preventative

OPTION	DESCRIPTION	DATA/ACTION NEEDS	O/M RANK L,M,H*	REGULATORY RANK L,M,H*	COST RANK L,M,H*	NOTES
5. Do nothing: Maintain all existing infrastructure						
	Maintain O and M					
6. Rewilding: return to pre-disturbance condition		Map remnants, glacial uplands, disturbances Invasive species property bounds, LiDAR	L	H (>5 yrs)	M	Long-term solution
	Remove ditching					
	Remove WCS's					
	Remove RR grades					
7. West culvert Diversion		Revise water budget Floodway Analysis Dam regulatory	H	H	H	Lose water source to lake
	Spillway at DPL inlet					
	New channel to Lost Creek Inlet or some other mechanism					
8. Modified Master Plan Alternative		Wetland and Plant species inventory (T&E) Soil samples Topo survey + LiDAR West Channel H20 quality Material volume (cut fill/proximity)	L	M	H	Shortest term to align w/ DNR approved plan
	Treatment wetland Except w/ ditch enhancement and sealing					
9. P and N Little Trout Treatment Wetland		Continue to create an open exchange of ideas with all stakeholders. Better understand access from east Better understand cranberry farm operations and interests in collaboration	High- Need for pump Low- Grantee H- cranberry/L-DNR	M	M, if pump needed L- if gravity fed	Plunge pool needed
	Nitrogen					

	Phosphorous – Add to Vista Pond Treatment Wetland					
10. Abandon Ditching on Old Alt A		Similar to #1	Low	High	Mediu m	
	8,000 ft of ditch/5,450 ft of dike					
	Selected, sequential abandonment					
	Selected, sequential lining/biofilter of other ditches					Ditch mod different than #1
11. Pete's Creek Piped Diversion		L	L	H		
	W/ Control Structure at Main Inlet	DPC Fe measurements of "Clear water Areas" Flow (channel) and storage H2O Volume				Pete's Creek not a mapped stream Method to supplement water to the lake

***L=Low, M=Medium, H=High**

Table 4-B. Potential Solutions for DPL

OPTION	DATA NEEDS	O/M RANK L,M,H	REGULATORY RANK L,M,H	COST RANK L,M,H	NOTES
Lime (Lake) Introduce as far away from outlet as possible, temporary outlet control	H2O- Calcium, Mn, Dissolved Organics Lake volume Data sonde infor Old data: Lake profile Sedimentation rates	Low	Low-M	Low	
Establish (maintain) higher lake stage, construct outlet structure	Floodway Wetland Delineation Flood Easements Flood Elevation + modeling GFLOW0 model w/ H2O Level change	Low	High	High Cost Estimates per "in"/"out"	
Allow beavers to do build dams at the outlet		Low	Low	Low	Not reliable or enforceable

***L=Low, M=Medium, H=High**

APPENDIX 5. Supporting Figures

Figure 5-1. Field notes and discussions

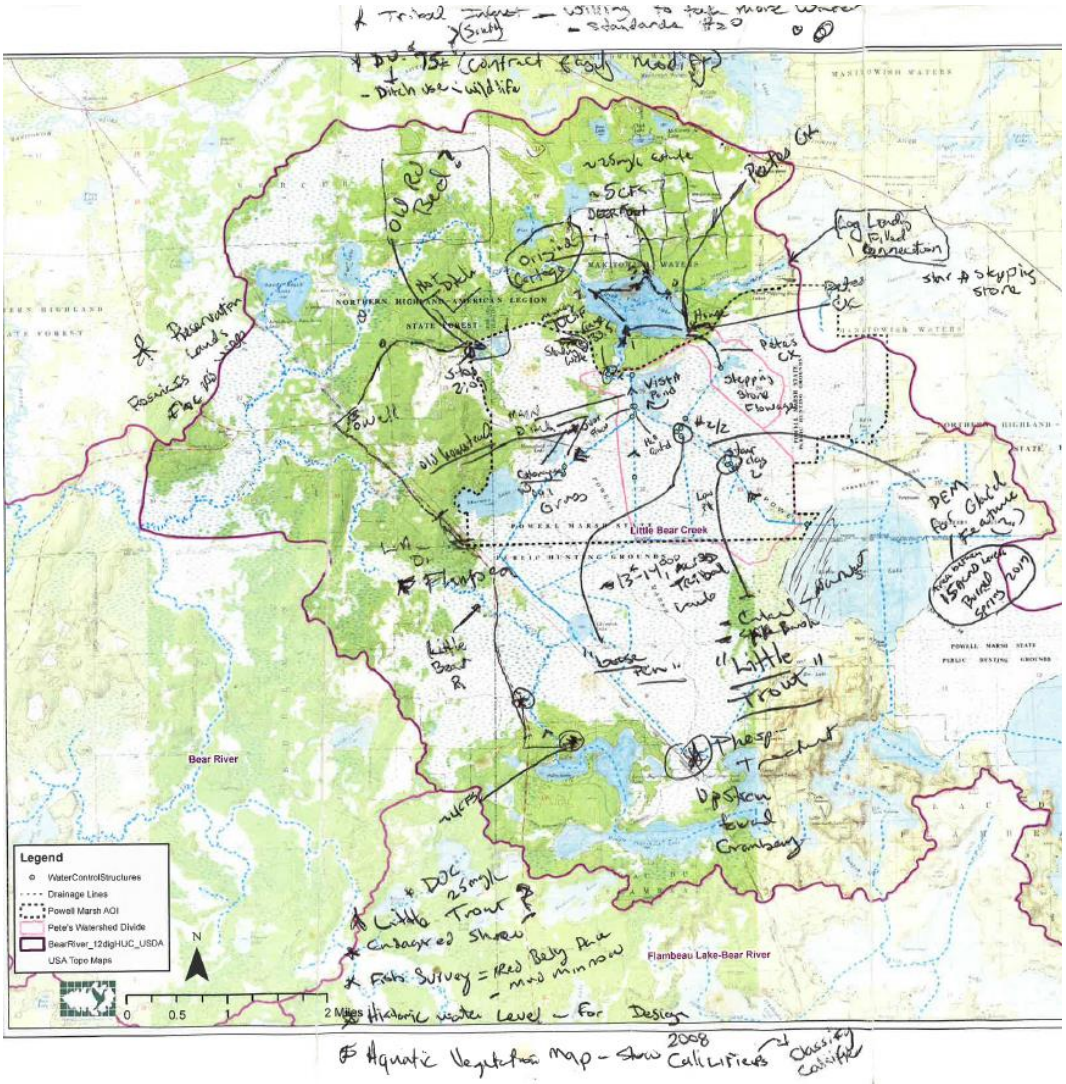


Figure 5-2. Photo log and inspection points

Figure 5-3. 1937 Composite aerial photo of Powell Marsh State Wildlife Area and Dead Pike Lake

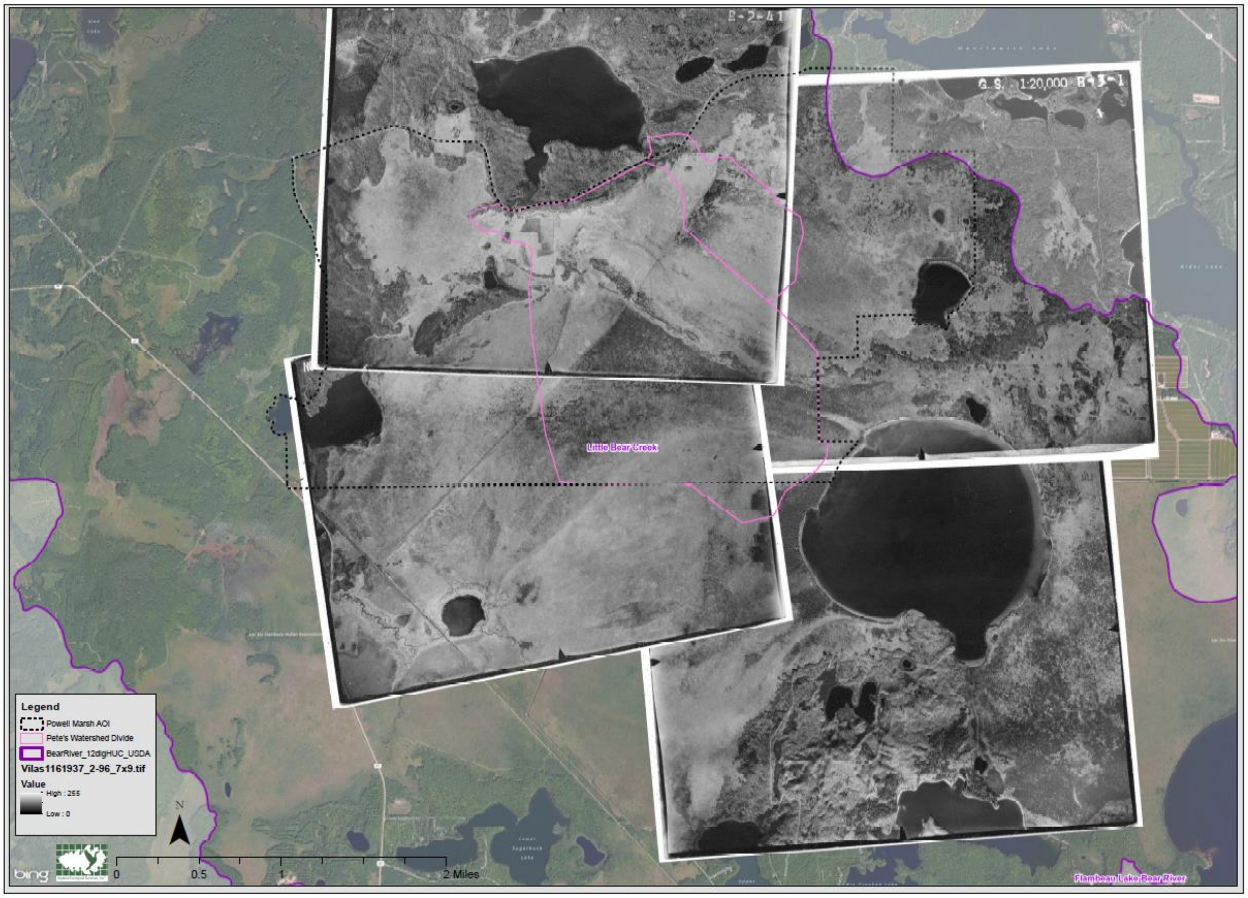


Figure 5-4. Aerial photo of Powell Marsh and Dead Pike Lake

Figure 5-5. Aerial photo of Powell Marsh and Dead Pike Lake – Little Bear Watershed

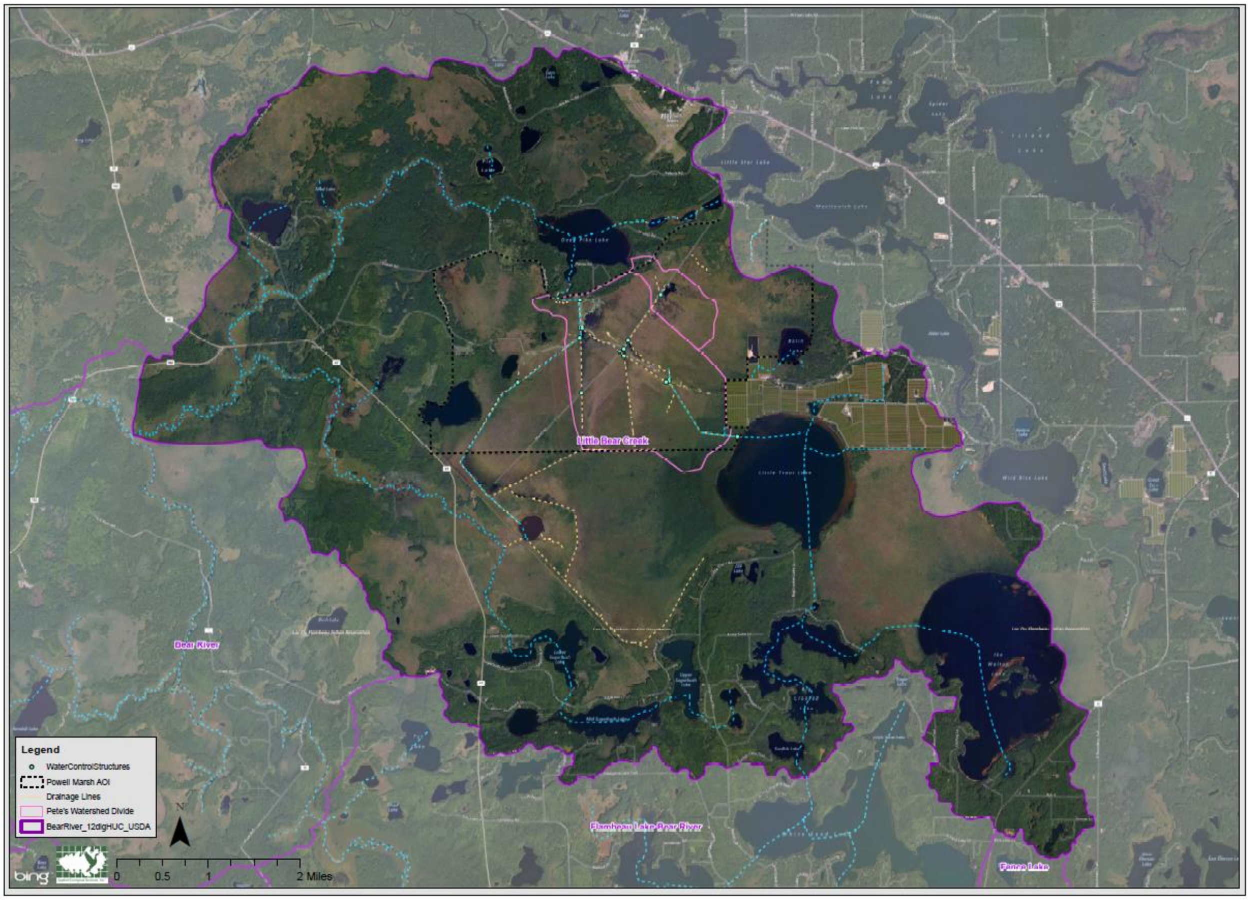
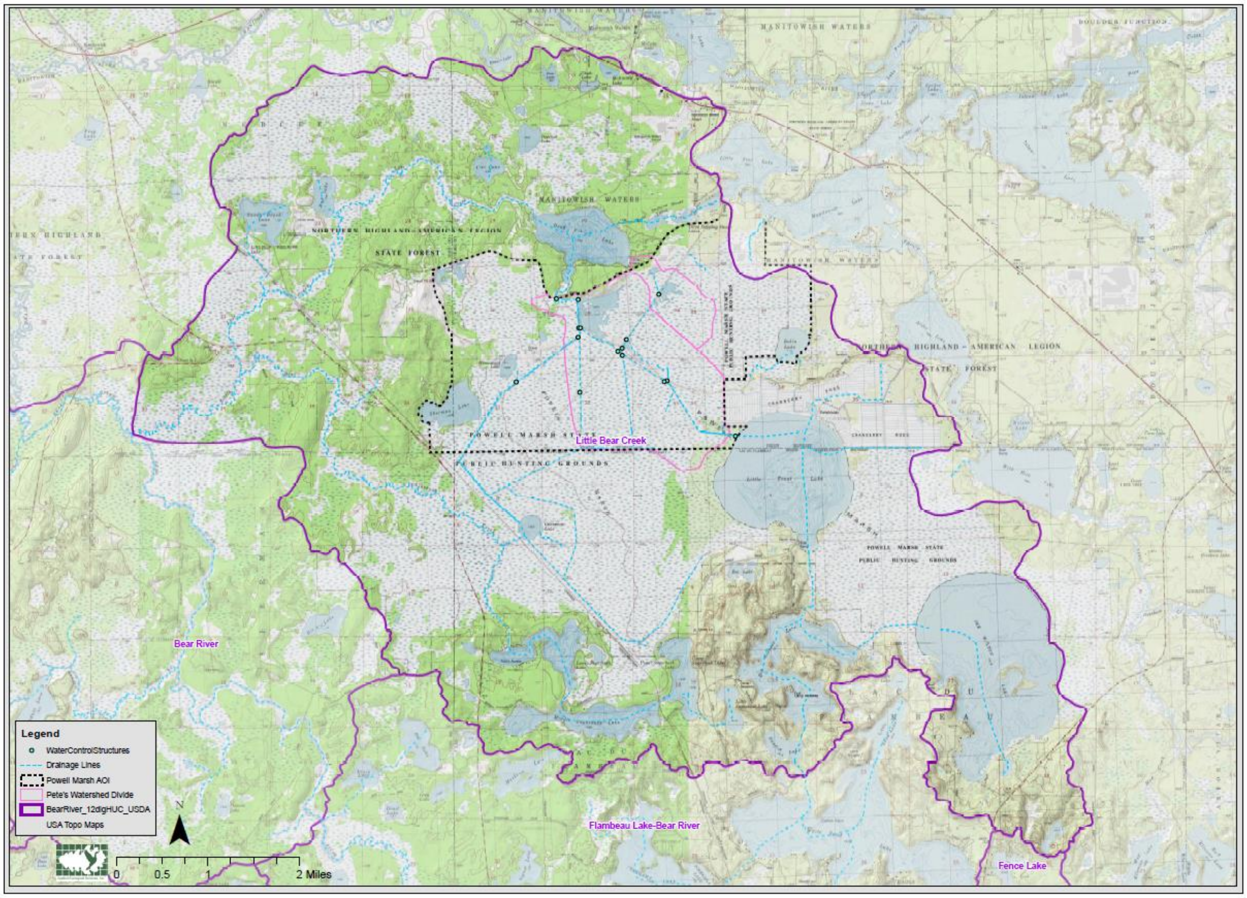


Figure 5-6. USGS 24k Topographic map of Powell Marsh and Dead Pike Lake – Little Bear Creek Watershed



APPENDIX 6. Solution Strategies Catalogue

Figure 6-7. Lime DPL

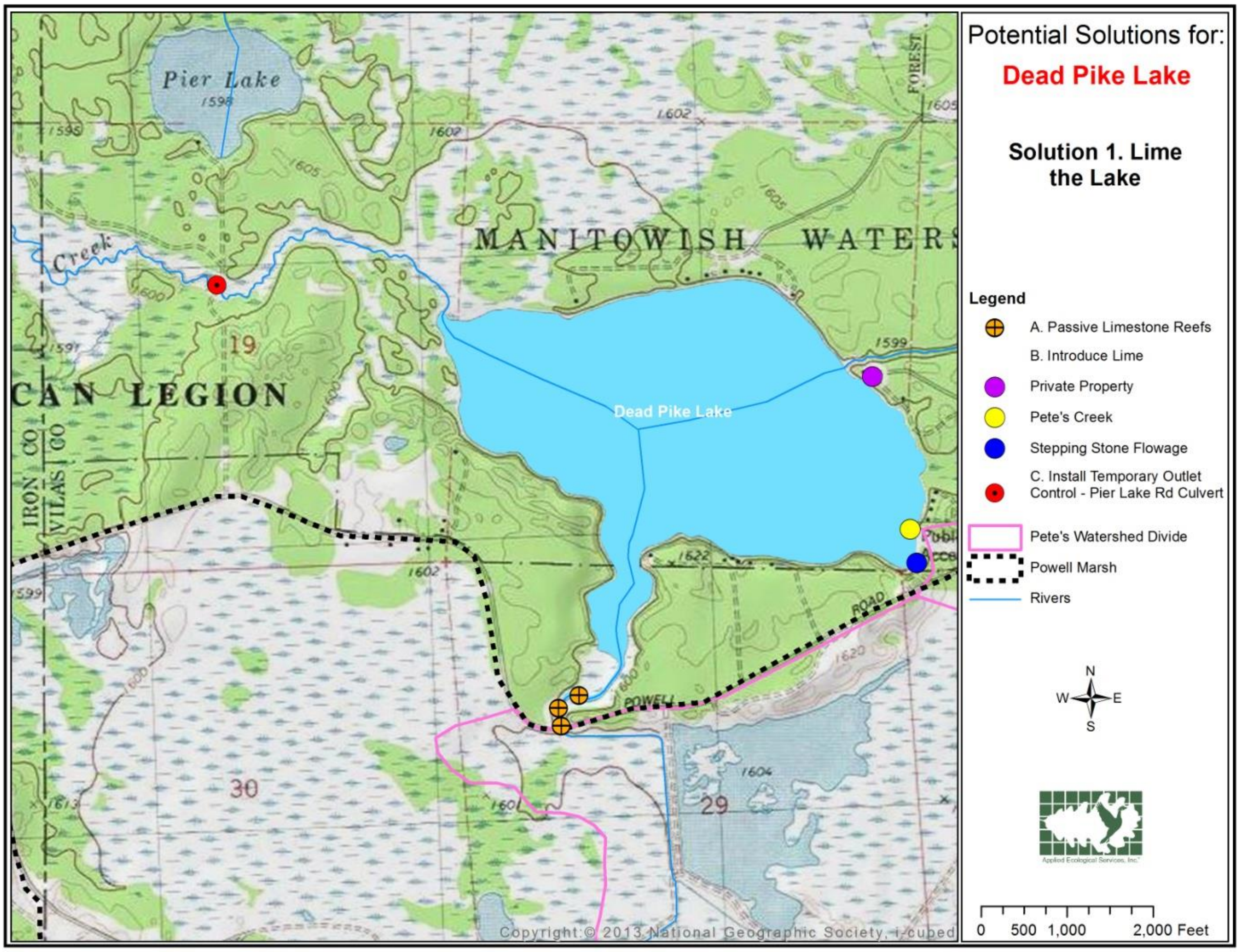


Figure 6-8. Establish higher NWL for DPL

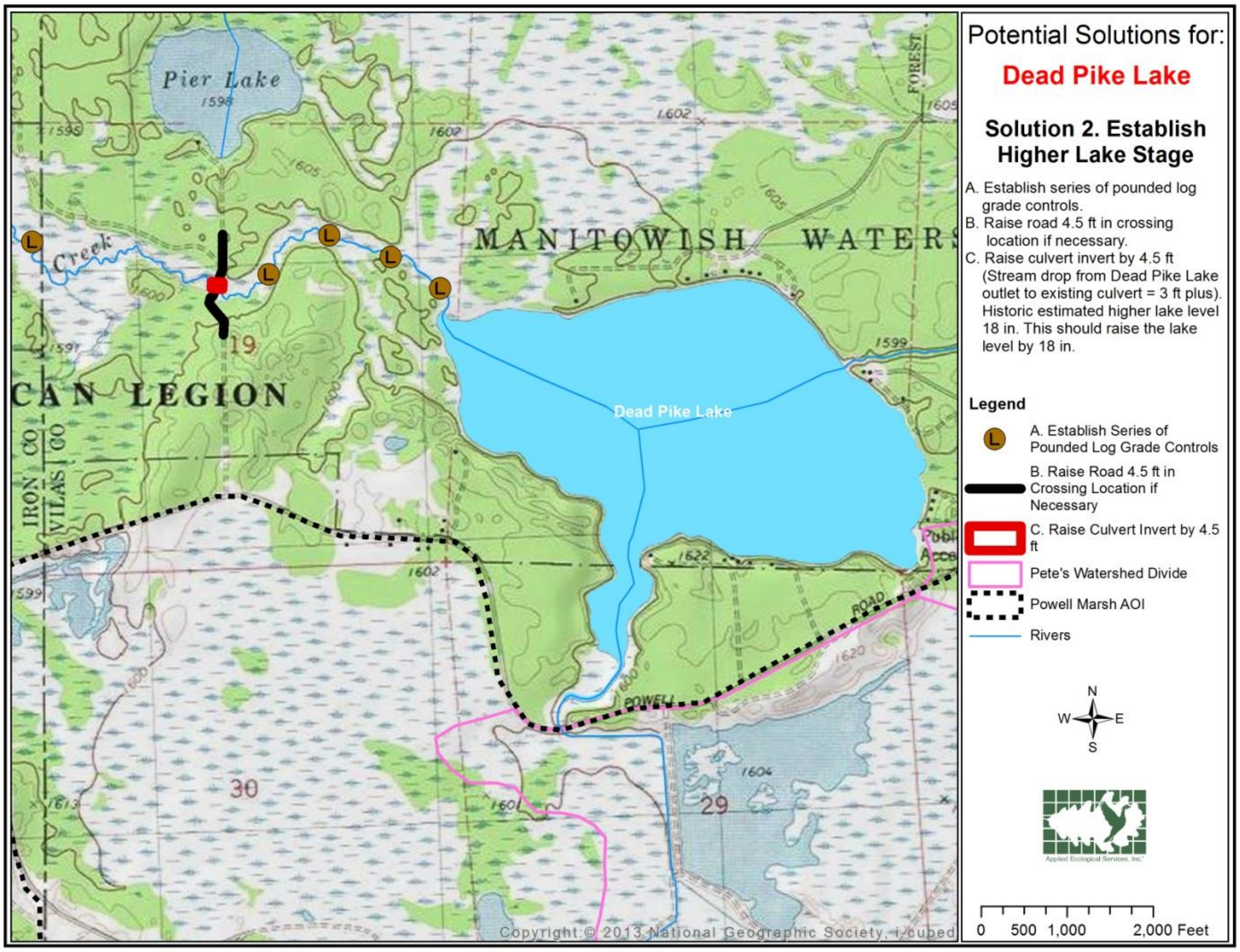


Figure 6-9. Encourage Beaver to Raise DPL outlet Invert elevation

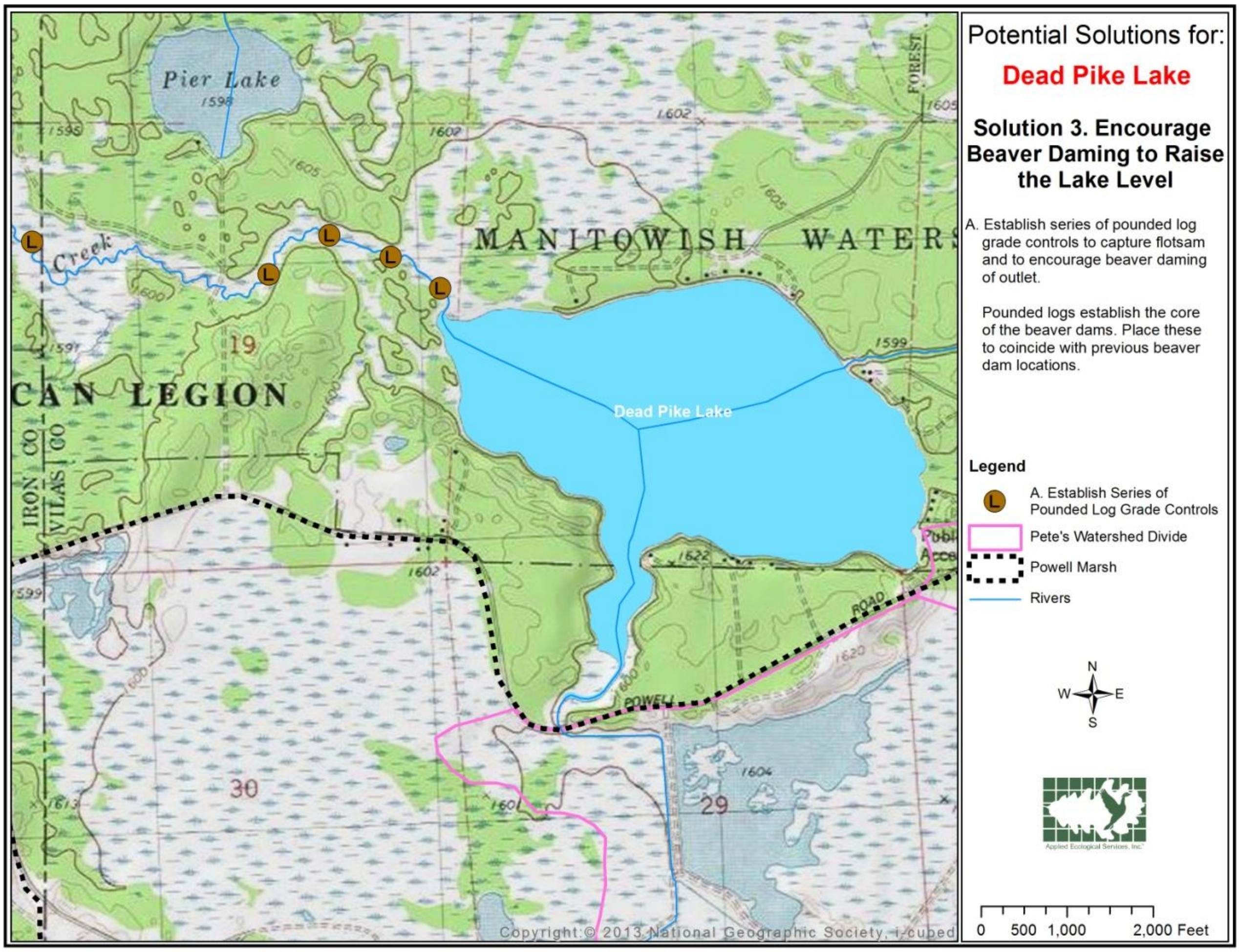


Figure 6-10. Re-wilding---Backfill ditches and restore surface and ground water of bog system.

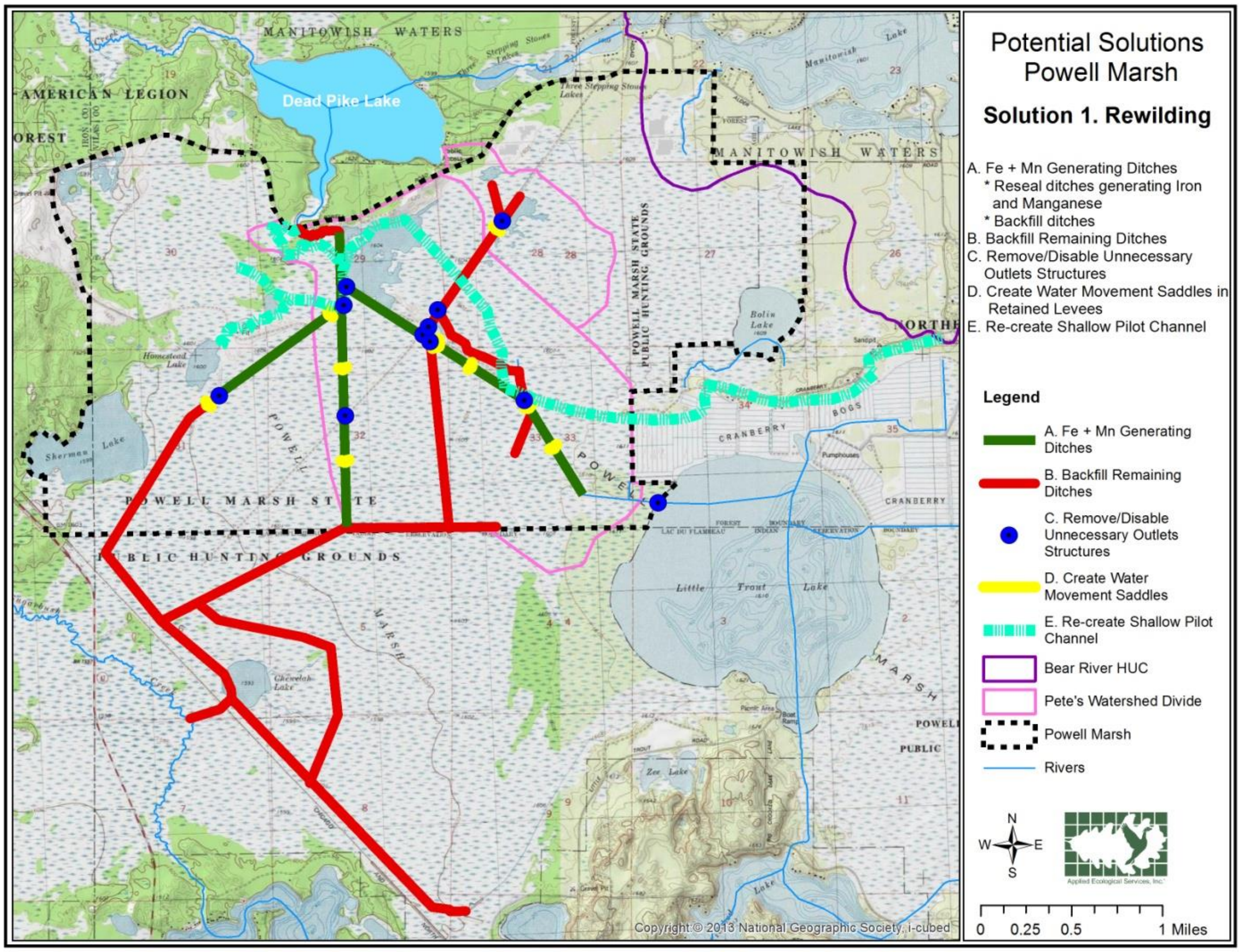


Figure 6-11. West Culvert diversion to move PMWMA water around DPL

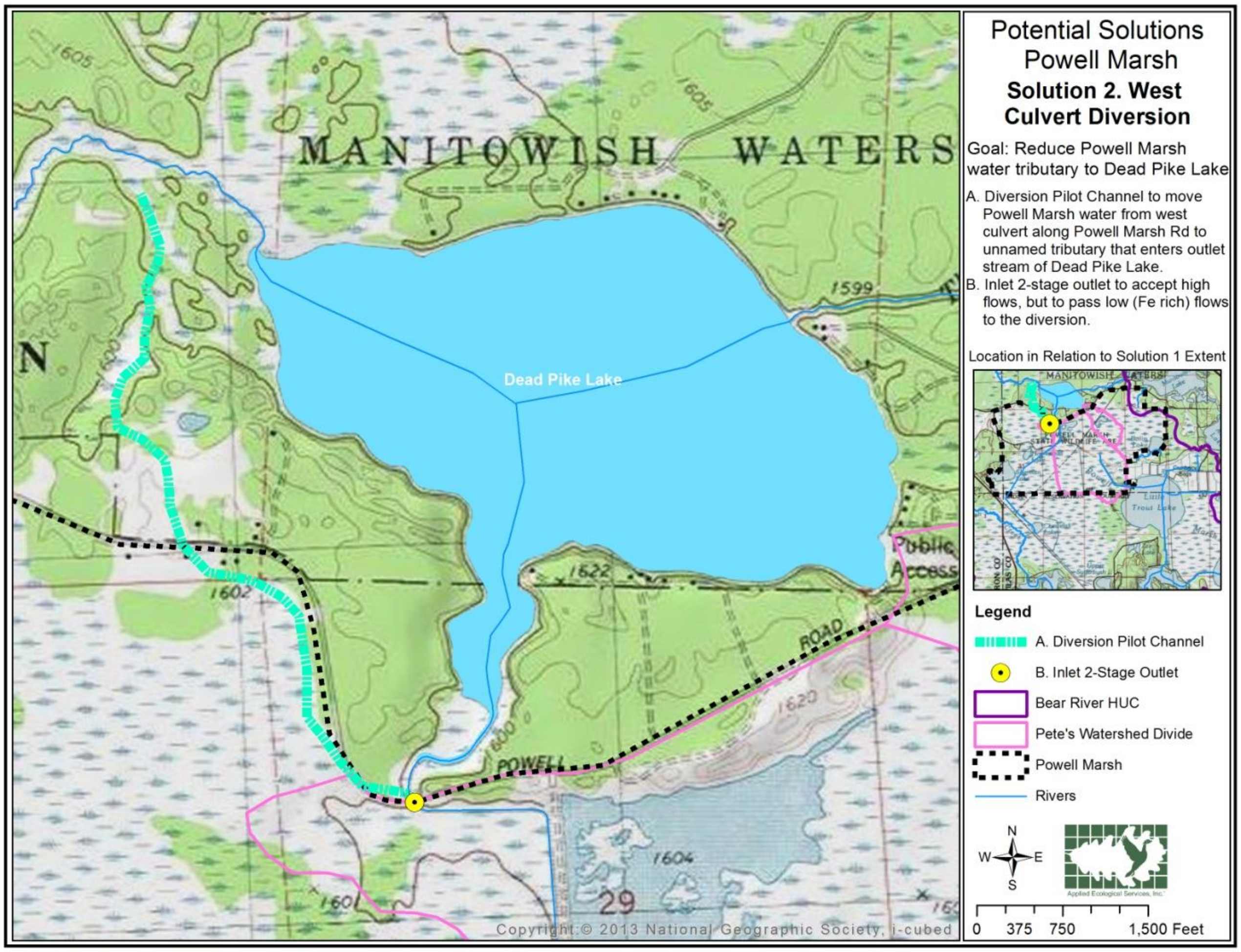


Figure 6-12. Modified PMWMA Master Plan Alternative to include wetland biofilters, modified ditches

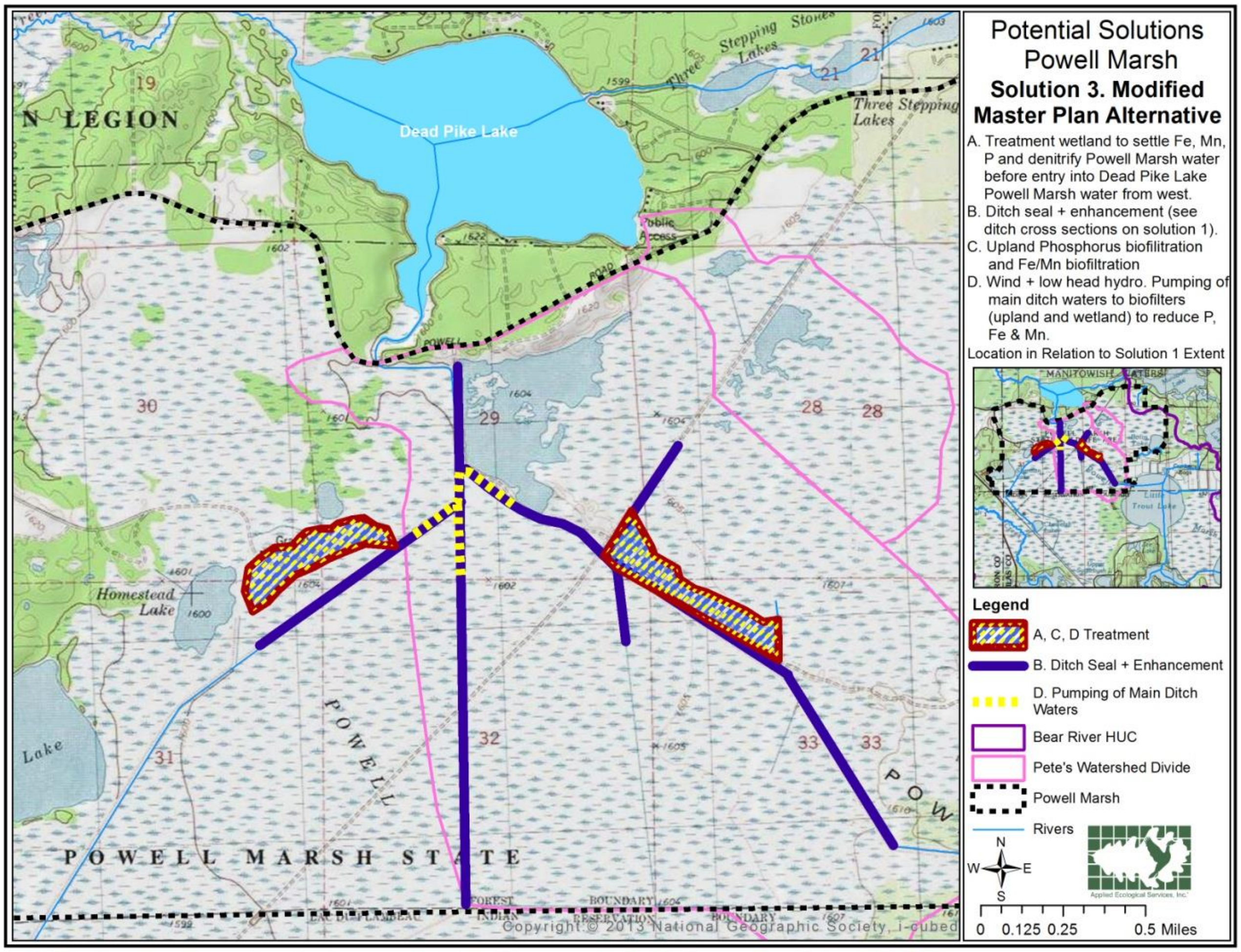


Figure 6-13. Little trout lake ditch phosphorus and nitrogen biofilter wetlands

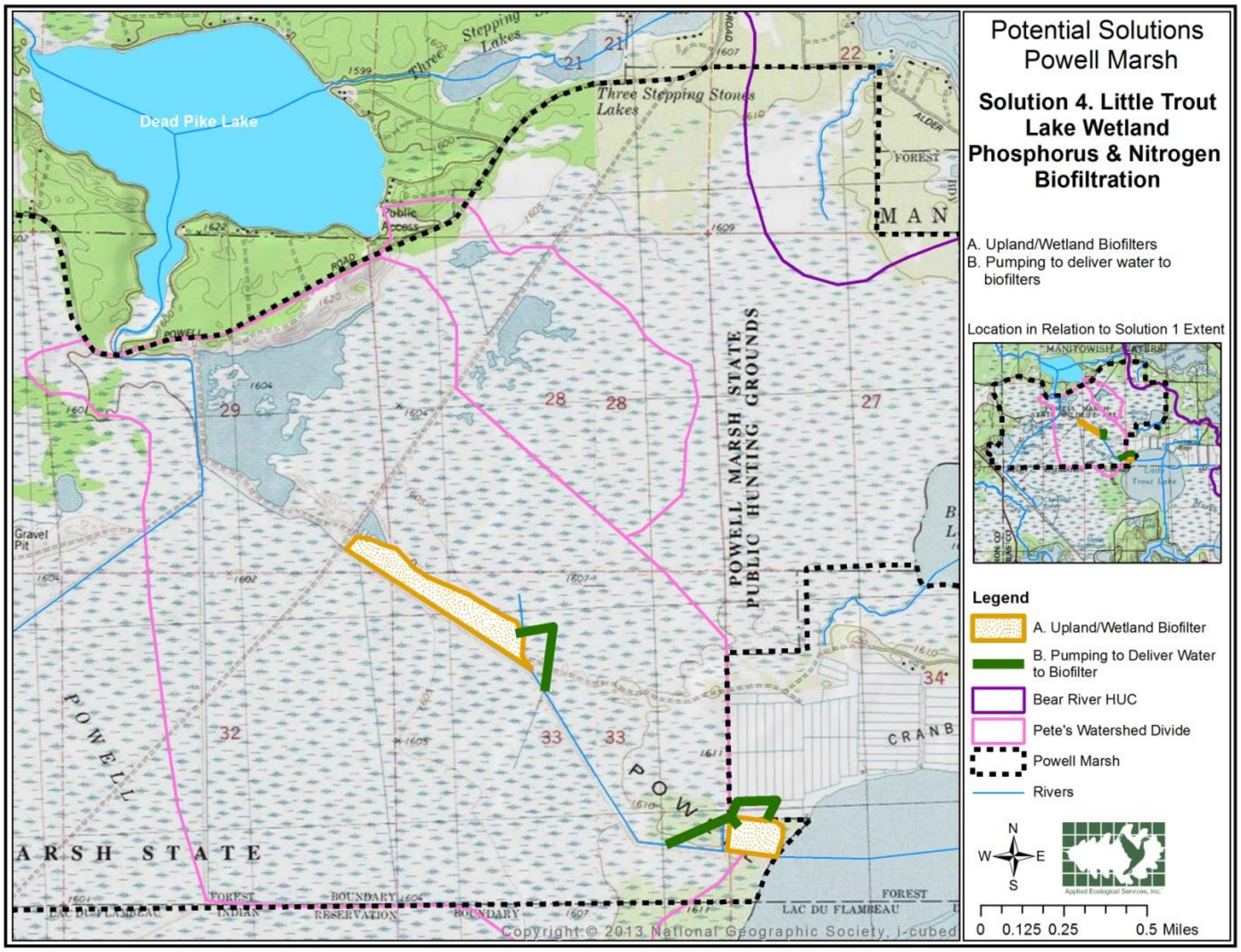


Figure 6-14. Ditch abandonment in Powell Marsh Alternative A in master plan

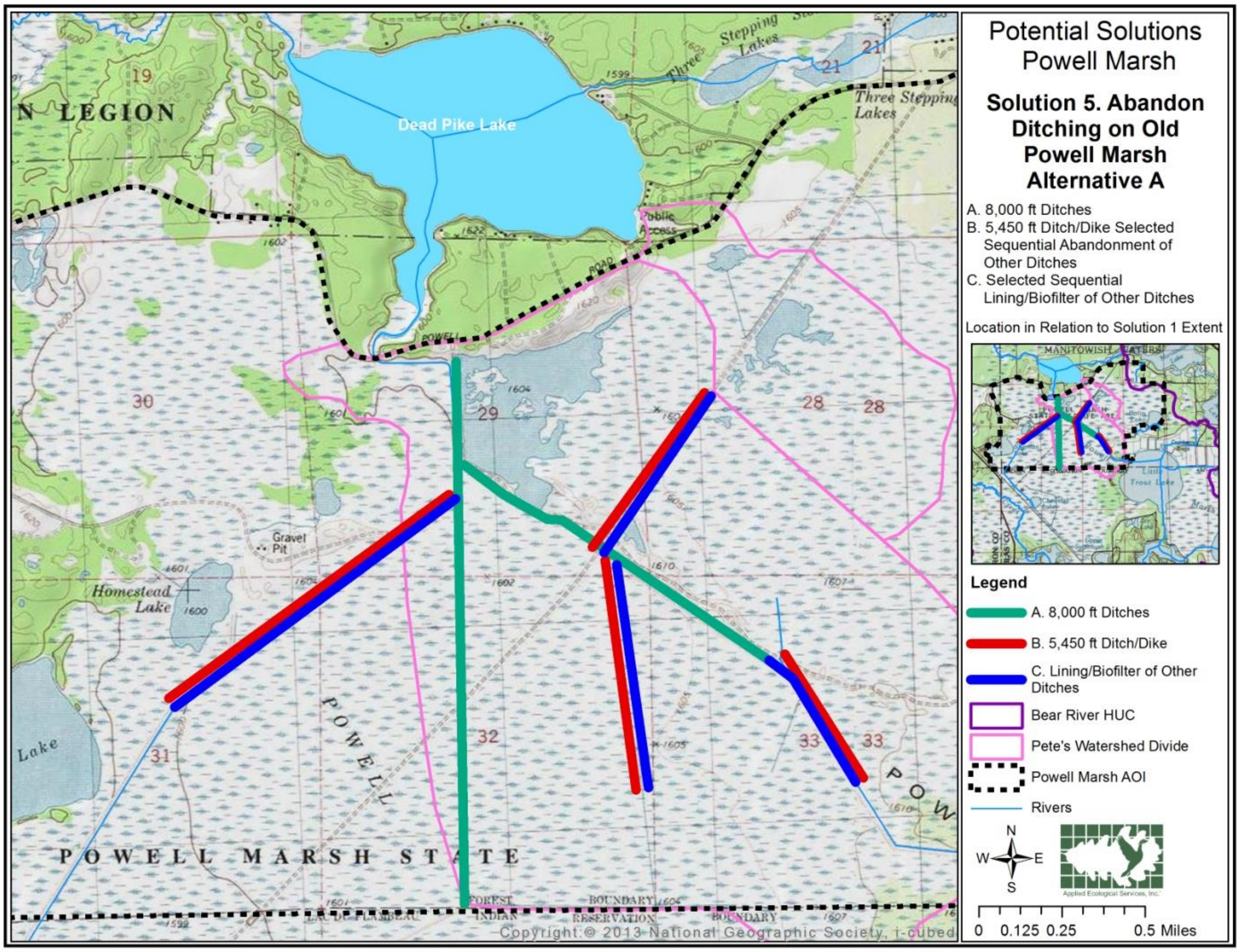
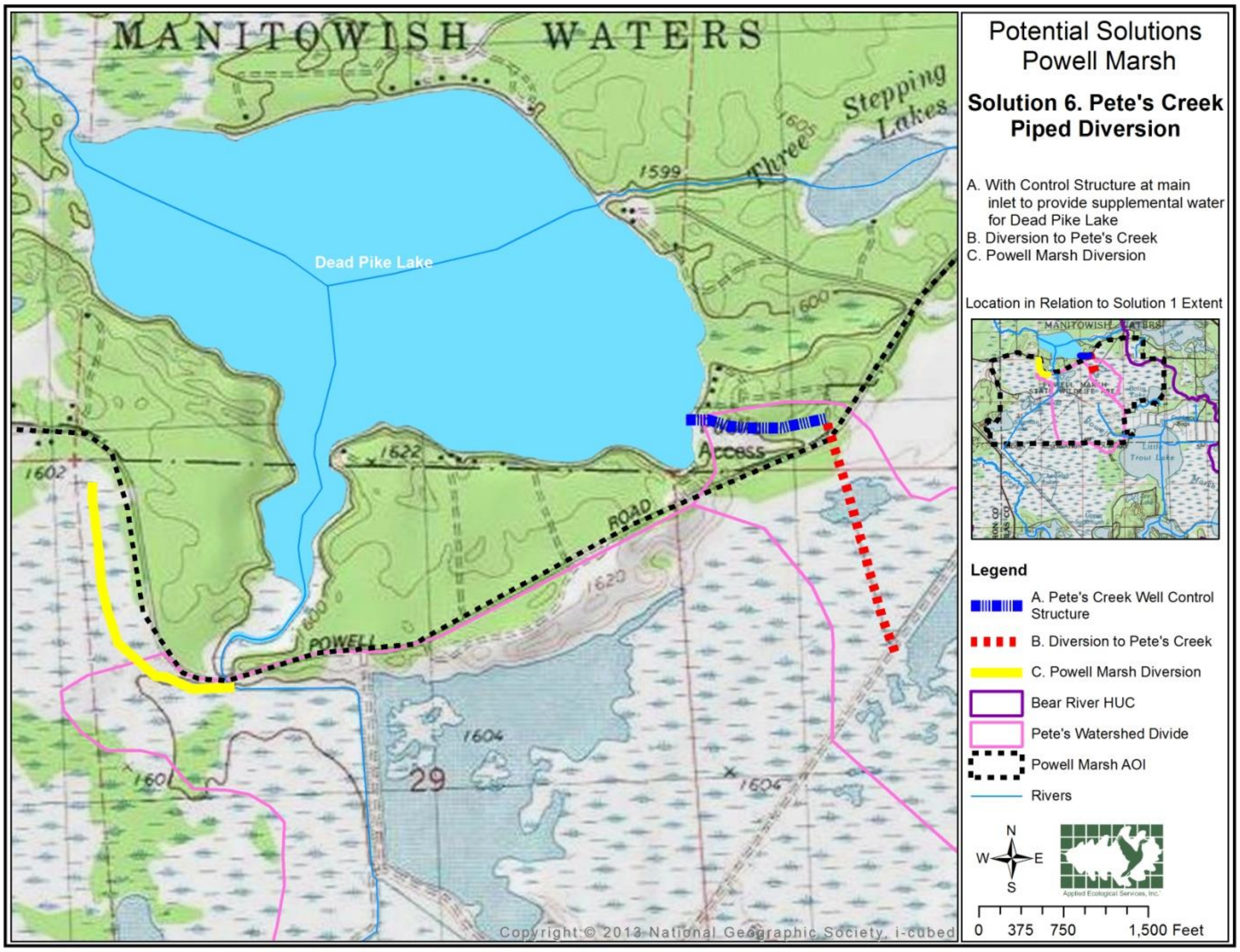


Figure 6-15. Pete's Creek piped diversion



APPENDIX 7. Notes and Communications

Miscellaneous Notes and Thoughts --Dead Pike Lake/Powell Marsh, July 18, 2017

1. **Apply lime and polyacrimiad resin (formulation with very low aquatic organism toxicities) to roadway/dike surfaces and side slopes.** This strategy would be used to tie up Fe and Mn emerging from the glacial till stone/gravel/sand bed of the dikes and roadways. Establish Fe/Mn monitoring stations in piezometers installed in the dikes.
2. ***Phalaris* and *Phragmites* control**. Both invasive species have gained a foothold in the marsh along the Little Trout Lake ditch, and in a few other minor locations along other dikes. Treat these plants with up to three fall/spring carefully selected herbicide spraying (over monoculture areas) and/or herbicide wick applications (over locations with retained native plant diversity worthy of protection).
3. **Raise the outlet elevation of DPL by 18-24 inches.** This can be done with de-minimus impacts on wetlands and waters of USA and WI by installing hand-pounded wood post arrays across the outlet stream in 3-4 locations downstream of the DPL outlet. The goal of this installation is to capture flotsam and attract beavers to raise the elevation for he outlet stream and lake. It appears that historically, beaver may have been the primary control over the outlet elevation of the lake. Stated WDNR removal of dams and beavers has resulted in reduced DPL levels by what appears to be 18-24 inches. If replacement of the culvert on the DPL roadway was lowered compared to historic elevations, this also could be partly responsible for this lake level decline.
4. **Install beaver-proof weep tube in beaver dams that are built to control maximum lake stage.** Beaver-proof weep culverts that create no flowing water sound are left alone by the beaver who do not perceive any damage to their dams that requires attention.
5. **Create small sacrificial Fe/Mn precipitation cell in Powell Marsh.** In the main ditch and Little Trout Lake ditches (where elevated levels of Fe/Mn have been by documented by WDNR) install stilling basins for precipitating and biofiltering iron/manganese before it enters DPL.
6. **Create small sacrificial Fe/Mn precipitation cell in DPL.** In the main inlet(s) to DPL (where elevated levels of Fe/Mn have been documented by WDNR) install stilling basins for precipitating and biofiltering iron/manganese before it enters the larger DPL.
7. **Reverse major ditch and Little Trout Lake Ditch and move water with pumping into upland wetland/grassland/sand biofilters on the morainal features in PMSWA**. Biofilter phosphorus, iron and manganese in upland (morainal) biofilter cells and release cleansed water to pool to NE then back into ditches
8. **Is it possible to perform electrical charge (cathode/anode) collection of Fe/Mn** in locations with highest concentrations perhaps by using solar pumping of groundwater from north shore glaicial tills, and then passing the water into holding tanks for electroplating/eletroprecipition removal?
9. **Can we introduce *Leptothrix* and *Ferrobacillus* into upland and settling cell biofilters to remove Fe/Mn from the waters in ditches?**
10. **Can we magnetize? Fe by place magnets in culverts and collect it on electro magnets?**
11. **Dredge sediment deposits on inflow stream of DPL to reduce re-suspension of materials into DLP during major storm/flood events?**

Ditch Waste to Liming Solution Explanation

DITCH WASTE → Strong Oxidation Cell → Electro Magnetic Collection → Biofilter with lime / Po/H20

Here is what to expect with liming. First, the chemical form of the lime source is important. The oxide forms (the sort of stuff that come from lime kilns) as CaO + MgO is the most concentrated form that will give the largest pH change per gram applied to the water. However, without very heavy agitation, it is harder to dissolve the oxides than agricultural lime (ag-lime) which is typically $CaCO_3$ + $MgCO_3$ with some waters of hydration. I actually think ag-lime is both the best and cheapest form to use because you will get the cations (Ca + Mg) and both carbonate and bicarbonate into the lake waters when it dissolves. Given that the lake is already subacid (~pH 6), the carbonate form should dissolve readily, especially if highly agitated with either the lake water or inlet water from the marsh. The anions (CO_3 + HCO_3) become important because those will complex with the floc to generate much larger molecules than the floc that is now present and that should settle much faster and probably penetrate the thermocline to get to the bottom sediments. These anions also will help complex the dissolved organics, but without very detailed knowledge of exactly what the dissolved organic are, I cannot give you any feel for how much of those will also fall out of solution or their rates of settlement, just that some will, especially the tannins that colour the water brown.

We can expect a significant uptick in the lake pH. The lake waters there are pretty low conductivity (~60 umohs as I recall) with the inlet waters from the marsh at about 35 umohs with pHs in the fives. The total dissolved existing ionic load at DPL is very low relative to most surface waters (e.g., Lake Superior is about 150 umohs, Lake Michigan about 225 and Lake Erie about 285 for reference. Typical inland lakes will range from 80 - 500 umohs depending on their watersheds and human inputs). This means that relatively small additions of dissolved ionic species, especially those bivalent cations, will increase pH and conductivity quickly at DPL, whereas liming a lake with high conductivity will have far less effect. I have played around with the numbers and a crude estimate of the DPL lake volume and suspect that the addition of about 200 metric tons of well-agitated calcitic lime (80% $CaCO_3$, 20% $MgCO_3$) should increase Ca levels to about 10 mg/l and Mg to about 1.4 mg/l with a pH shift of about 0.6 - 0,8 units upwards. This sort of calculation is what I refer to as an 'informed WAG' (translated as an informed wild-assed guess based on experience) as I cannot defend this on a base of strong peer-reviewed published research.

It is a lot harder to project changes in the concentrations of CO_3 and HCO_3 anions in a treated lake because metabolism of lake organisms and bacteria plus atmospheric sources and rates of dissolving/equilibration of CO_2 with the air are involved too, as well as the pH. Generally, higher pH favours more HCO_3, but the rate constants are 'muddy' to say the least as people have not (as far as I can tell from the literature) worked out those interactions in natural lake systems. What is clear is that dissolved alkalinity will rise appreciably and that will have the effect of tipping everything in the system towards the heavier complexed molecules that should settle out much faster. We should also expect to see some beneficial effects on the phosphorus content of the water in the lake as the iron floc complexes should also incorporate some of the dissolved ortho-P and bring that down too.

Another benefit should be a reduction of the mercury flux into fish in this system. In the Michigan example I have sent this pictures for, we had just about a 50% reduction in the Hg in the fillets of the walleyes after five years in that Michigan lake. In the Michigan example, we had about a four-fold increase in total alkalinity after the liming with the calcitic ag-lime.

In summary, provided the lime source is very well agitated when applied in order to force as much of the lime source into solution as possible, I would expect to see major improvements in transparency, floc settling rates into the deeper parts of the lake's basin, improved rooted submerged aquatic plant growth with greater and deeper light penetration. less coloured water and some substantial benefits to the health of the fish there. There are a number of fish species (especially trout) very sensitive to the iron and manganese concentrations that are common to DPL and especially the marsh. Liming should have the effect of changing the suitability of the lake for a number of species benefitting most species substantially.

You might also consider suggesting several other things to the audience. For example, if the inlet ditches and natural streams to the lake were lined with limestone crushed to 1 - 2 inches (a lot of road contractors use this stuff for road base), then you get the acidic waters passing over a lime source; remember that this entire watershed is exceptionally calcium and magnesium poor so that those important cations are in very short supply in Vilas County and especially at DPL. This would provide a passive source of liming and require no effort or cost beyond an initial modification of the ditched inlet and could use the existing road infrastructure. The other places like Pete's Creek where there is a continuous inflow could be modified too. As this limestone is consumed by the acidic waters from the marsh, it can be replaced readily.

Finally, I should think that the crux of this matter is the loading rate and flux of the ionic iron and manganese. I know that the legalities of lake level regulation are a real regulatory hurdle here, but think that a major contributor to the mess there is the reduced lake levels at DPL. If we could raise the lake level back to where it was historically - and those levels are inscribed on the shorelines - then we reduce both surface and groundwater inflows substantially and the loadings decline abruptly at the same time. Liming as a massive one-time intervention should be regarded as an experiment and emergency treatment for an acute problem simply because there is a lot more water (more loadings) now moving through the system and far more I suspect that did flow through historically. Altering the watershed is the ultimate answer. So, let's see if we can do the passive liming in the ditches and inlet streams and recruit some beavers to finesse the legalities of a man-made outlet control structure as the ultimate answer and depend on the one-time liming as only an emergency measure we use to learn the effects. With the presently existing flows through the DPL system, such a large liming treatment can be -at best - a temporary solution.

Toxicity test results discussion –August 2017—email communications from JPLudwig

Thanks for the results of the toxicity tests. The Stepping Stone numbers do not surprise me as the actual bioavailability of both iron and manganese goes up logarithmically as the pH drops; remember that pH is on a log scale to the base 10. In this case, a pH of 5.59 would be roughly three times less on a linear scale than pH 6 and about 30 times less than pH 7; the toxicity of iron and manganese should follow the inverse of pH roughly, but not necessarily in an identical logarithmic manner. As pH goes down, toxic effects will go up and there may be a particular toxic threshold that the lower pH shift causes the iron and manganese to cross. Another way to look at these data would be in terms of hydrogen ion availability and that is what pH measures. When I looked at pH effects on brook trout in Michigan's Iron River in the UP back in the late 1970s, that sort of threshold of real damage to the wild trout population in that trout stream impacted by acidic mine drainage from old iron mine workings was between pH 5.7 and 5.9 and these data look a lot like that.

Now, there is another important variable in play here as well (that was largely not in play in the Iron River case that was pretty much a groundwater-fed system only) and that is the dissolved and suspended organics that tend to chelate metallic ions and quite literally buffer the toxic effects of these metals. The chelation 'protective' effect is also somewhat pH-related. As hydrogen ion concentration rises, the metals tend to dissociate with chelating organic molecules and again the toxic effects are then greater. These changes also probably are another threshold phenomenon: when the pH drops (= hydrogen ion concentration increases) to a critical level (and for most aquatic systems that is in the pH 5.5 - 5.8 range), these dissociations of metals from the organics increase rapidly. It is reasonable to suspect both the concentrations of dissolved organics and pH are at work here in the DPL system and its tributaries.

The short version is that we do not have all of the information needed to interpret these data with precision in the absence of detailed information on the dissolved organics including what sorts of compounds are in play there – e.g., Are these tannins or saponins, or both, and in what ratio?. Those sorts of data would require a lot of analytical work that your lab is not likely to have the capacity to generate. So, the best I can do is give you generalizations at this point. However, note how the dissolved manganese in particular has dropped markedly when the pH in the Lake is in the 7s. The one exception is at the outlet where strong currents will produce lots of turbulence and that turbulence may also release some of the manganese into the dissolved state. The lake also has the benefit of the daytime diurnal pH shift phenomenon from photosynthesis that will shift pH upwards markedly at the very time of day you are sampling.

It could be edifying to do a 4 AM set of readings on pHs at these various stations as the pH numbers could be quite different when photosynthesis is at a minimal or non-existent level in the lake. A large diurnal shift is especially likely with the relatively 'soft' waters of the DPL system since there is more than adequate P available to drive productivity. Also, the absence of data on calcium, magnesium, carbonate/bicarbonate levels and total alkalinity could help me interpret these data, but the lab is not doing those tests. About the best I can say is that there is little dissolved chemical buffering capacity in the DPL lake system and a substantial diurnal pH shift is very likely. Most of the actual buffering will be related to the dissolved and suspended organics in DPL.

I also think your speculation about the effects of the iron floc on the sediments is a most interesting and important question, especially for fish reproduction as most species reproduce over rocky bottoms, often on reefs. The behaviour of the iron and manganese in the microhabitat of the sediments where oxygen dynamics come into play and floc settlement over eggs is another large unknown here. We all know that as oxygen levels drop, iron and manganese have a valence shift to the reduced more toxic forms of those ions. Fish embryos are probably about a half-order to an order of magnitude (i.e., power of ten) more sensitive to these metals than the adult minnows used in the toxicity tests and any valence shift driven by sediment oxygen demand will not be helpful to survival and development of those species. All that could be going on in a very thin layer of the surface of the sediments that settle on the sensitive fish eggs. The performance of macroinvertebrates colonizing (or failing to colonize) on substrates set into these sedimentation areas could tell us a good deal about how the iron/manganese floc actually impacts the fisheries in the lake.

Finally, let me suggest that we think about doing a crude index of the state of the fish populations in DPL. Some shallow water seining at a standardized group of stations should give an index of many small prey species (e.g., *Notropis* and *Pimephales* species). Several experimental mesh gill nets (from 1" square mesh to 2-3/4 square mesh nets) set at three or four stations in the epilimnion would give us a crude index of the status of game fish numbers in DPL. If we are going to be modifying this system hydrologically and/or chemically, we need a measurable baseline of the state of fisheries in the before case in order to document success or failure of our strategies and whether these could (or should) be used elsewhere in Wisconsin. As far as I can tell, we do not have those data on fish at present (If I am mistaken on this, let me know). Early September is a good time to do those kinds of field tests.

Feel free to share my speculations/interpretations of these data with anyone on the team. I should be available most of the time from now up to September 24, but am off to Ireland on the 25th until October 12. Later today or tomorrow after I get my wife off to Ireland via the Toronto airport I will look at the rest of the data you sent me and send on any comments I have.