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June 6, 2022

Dan Hill, Esq.
Hill Law
6 Beacon Street
Boston, MA 02108

Subject: Vernal Pools Water Budget Analysis for "The Sanctuary"
Assessors Map 43, Lot 18, School Street, Manchester-By-The-Sea, MA

Dear Dan:

As you know, I have been retained by Manchester Essex Conservation Trust, Inc. ("MECT") to review "The Sanctuary" project (the "Project") located off School Street (the "Property") in Manchester-By-The-Sea.[1] Specifically, I have been asked to assess whether the Project as submitted to the Town protects both the northerly Vernal Pool ("VP") and the southerly Vernal Pools (see Figure 1 on page 2).[2] My assessment is based on Project plans by Allen & Major Associates, Inc. ("A&M"), dated through May 5, 2022, as well as a related drainage report by the same firm dated through May 8, 2022.

I find the Project plans *incomplete* as A&M has not provided a water budget for the VPs. A water budget is a comparison of pre- and post-development conditions regarding changes to watershed areas, impervious areas, and water velocity and volume changes entering the vernal pool. A water budget is critical to any design analysis to ensure that the Project does not alter[3] these protected resources. Consequently, MECT requested that I perform a surface water budget analysis and review potential wildlife habitat impacts for the VPs shown in Figure 1. *From my analysis I conclude that the proposed Project will substantially alter the VPs studied.*

Of note, multiple Massachusetts OADR adjudicatory decisions address the issue of a water budget. In The Matter of Bosworth (2016), the court stated,

> It is well known that vernal pool habitat is particularly susceptible to impacts from certain work in the buffer zone because of the habitat's relative fragility. Vernal pool habitat is sensitive to changes in water, light, and chemical influences. *Generally, in order for vernal pool habitat to continue to function and co-exist with nearby development its water budget must be sustained post-development.* If surface runoff is redirected or groundwater recharge in proximity to the vernal pool is reduced by impervious surfaces, then the vernal pool water budget could be adversely impacted, potentially resulting in adverse impacts to the vernal pool habitat. Land use changes,

[1] See my Qualifications in the Addendum on page 13.

[2] An off-site VP is located west of the Project beside Old School Street and is not part of this analysis.

[3] "Alter" is defined in 310 CMR 10.04.

such as clearing, increases in impervious surfaces, and changes in the watershed can increase or decrease water runoff, which could alter the amount of water received by a vernal pool, destroying the water budget that is necessary to sustain the habitat of that pool. Vernal pools with a significantly disturbed watershed generally have a higher pH, more mineral substrate, and more algae, which negatively impacts the habitat... *This susceptibility to changes in light, chemicals, or water is why in similar cases project applicants have performed detailed assessments to determine how work in the buffer zone will impact the vernal pool habitat, particularly its water budget.*[4]

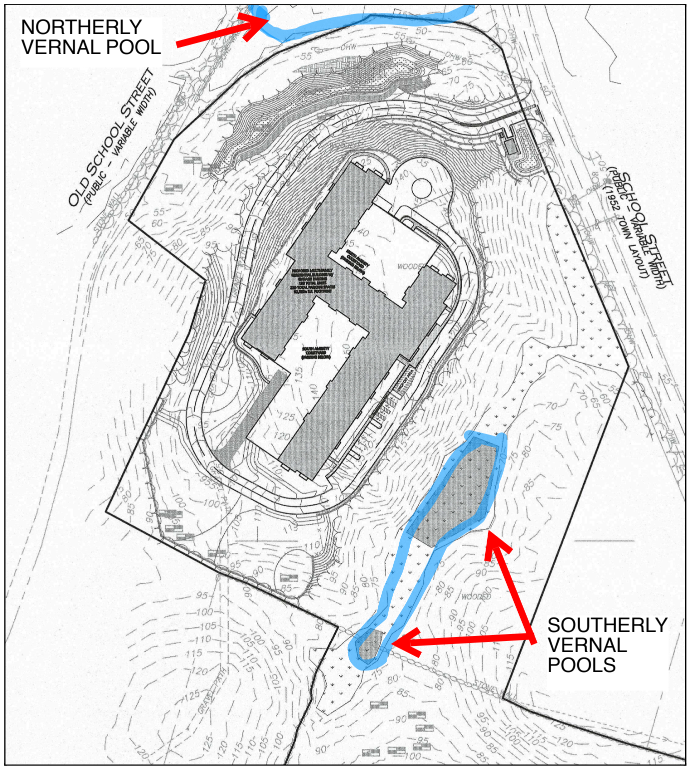


Figure 1. Locus for vernal pools.

REVIEW OF PROPOSED PROJECT

In late 2020, I was asked to review the Project. I walked the perimeter of the Property on January 11, 2021, took photographs and made observations regarding protected wetland resource areas, topography, vegetative conditions and cover. I observed areas of Bordering Vegetated Wetlands ("BVW") along Sawmill Brook as well as within the Property.

As part of my investigation, I viewed MassGIS/MassMapper data layers, including aerial photography. I have also reviewed USGS mapping, USDA soils data, and wetland resource data layers for the Property, as well as the Project engineering plans, drainage calculations and

[4] Matter of Bosworth, OADR Docket No. WET-2015-015, Recommended Final Decision (February 17, 2016) adopted by Final Decision (March 14, 2016) (emphasis added); see also Matter of Scott Nielsen and The Levi-Nielsen Company, Inc. (April 12, 2010) (improperly-designed stormwater system that deprives a vernal pool of its water budget would fail to meet the Act's performance standard for BVW under 310 CMR 10.55(4)).

supporting documents. Finally, I have confirmed through MassGIS data[5] that VPs lie to the north, west and south of the Property.[6]

VP Impacts

VP health is determined by: **Water Budget, Water Quality and associated Wildlife Habitat**.[7] For this Property I have quantified the proposed development impacts by:

- Calculating surface water budgets for both the northerly and southerly VPs (see Sections 1 - 3 below);
- Analyzing potential water quality impacts; and
- Analyzing potential impacts to Wildlife Habitat associated with the VPs.

Water Budget

Section 1 - Surface Water

A surface water budget analysis for a potentially impacted VP is necessary to ensure that the Project complies with the Wetland Protection Act ("WPA"). In accord with recent OADR adjudicatory decisions, my VP annual water budget analyses examine the following elements:

- pre- and post-development *velocity* changes;
- pre- and post-development *watershed areas*;
- pre- and post-development *change in impervious area*;
- and pre- and post-development *volume* changes.

To calculate potential VP water budget changes, I first determined the *pre-development* project-related watershed area for both the northerly and southerly VPs (shown in Figures 2 and 4). I then calculated the *post*-development watershed area for each of the VPs (shown in Figures 3 and 5), and compared the two.

[5] See Natural Heritage Endangered Species Program layers

[6] Certified VPs ("CVP") are classified as Outstanding Resource Waters ("ORW"). Pursuant to 314 CMR 4.06(2), a CVP is designated as a Class B ORW.

[7] In addition to surface flows from precipitation, a VP typically receives groundwater, which is the case for the VPs on or near this site. A separate analysis of *groundwater* impacts is being conducted by Scott Horsley.

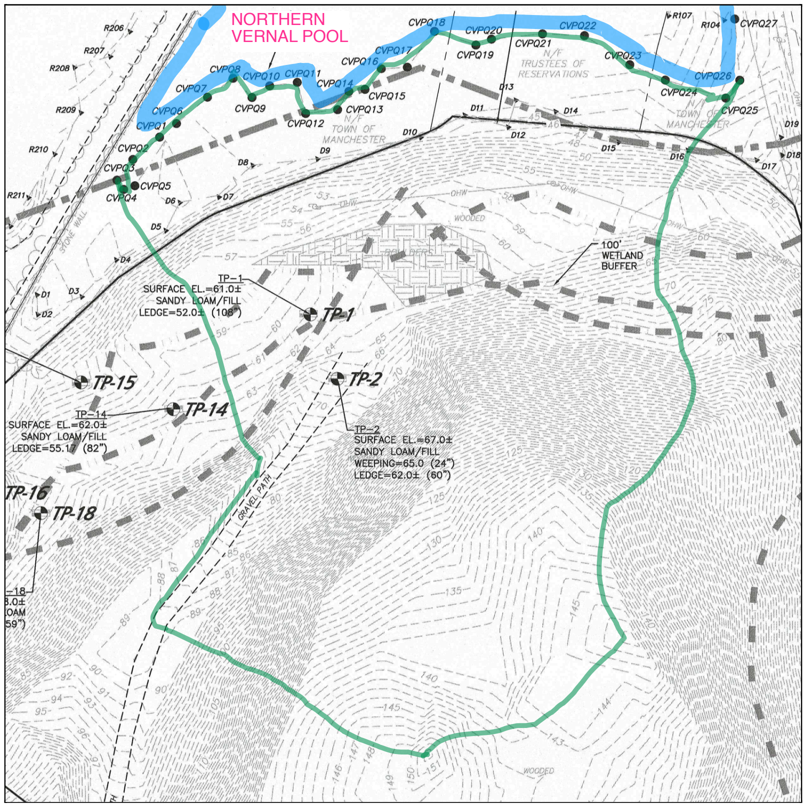


Figure 2. Pre-development watershed for northerly VP.

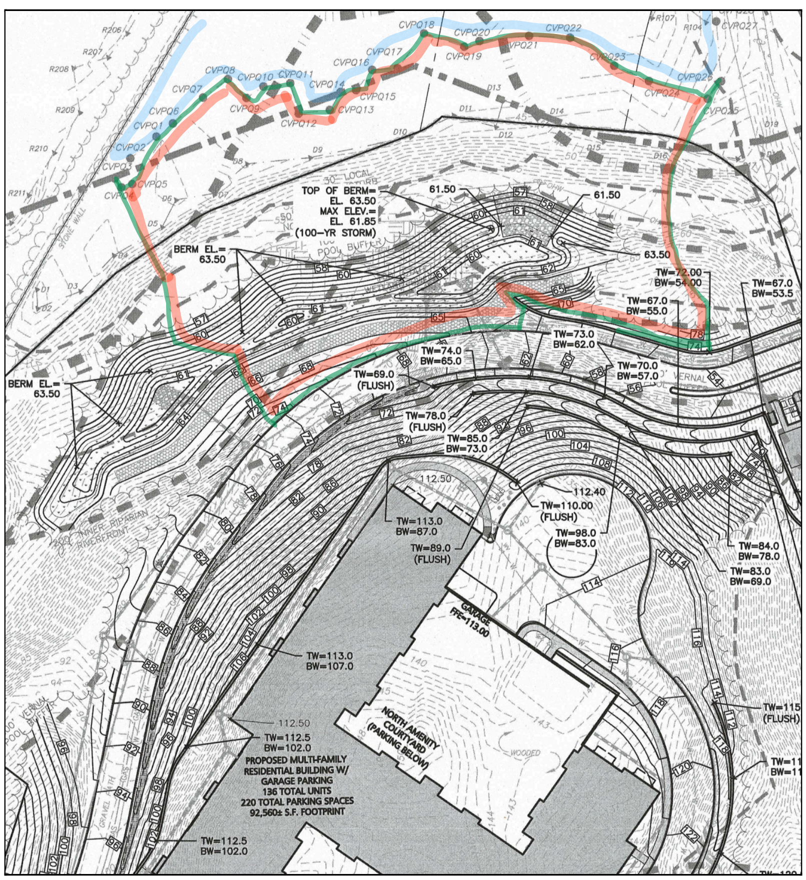


Figure 3. Post-development northerly VP watershed.

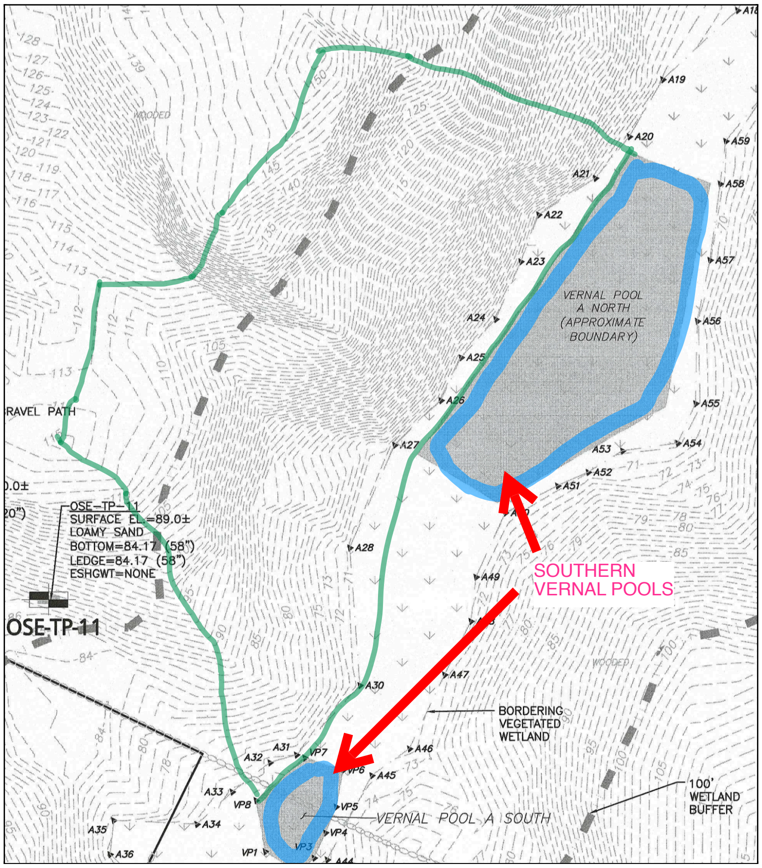


Figure 4. Pre-development watershed for southerly VPs.

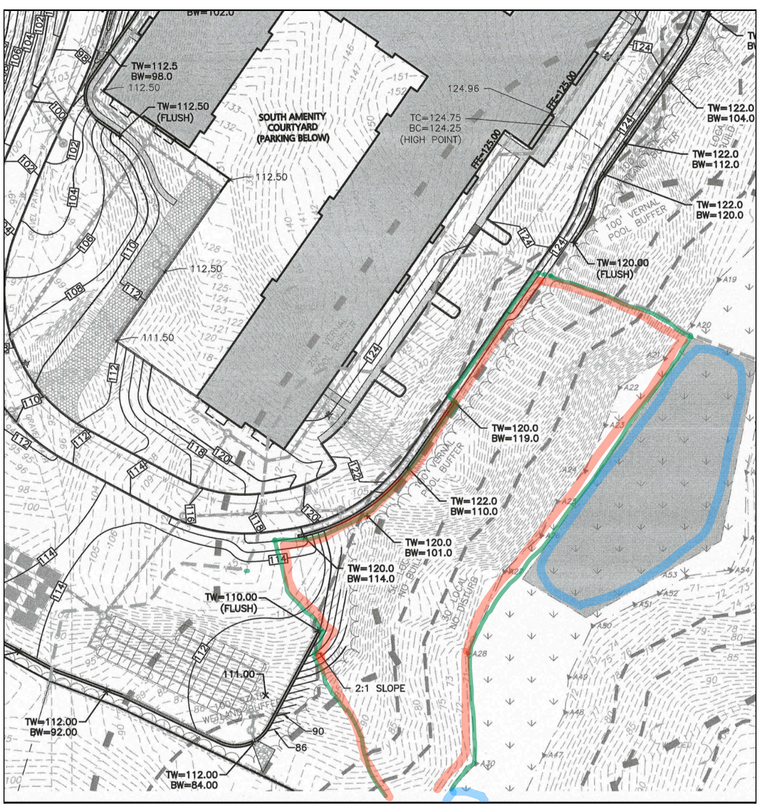


Figure 5. Post-development southerly VP watershed.

Other components of my analysis included determining the Hydrologic Soil Group of the existing soils; slope; time of concentration (Tc); and the curve number of the soil (designated as Cn — a measure of imperviousness). I used federal Soil Conservation Service (now NRCS) data for that purpose.

After developing base data for the VP watersheds, I ran calculations in HydroCAD,[8] which is a commercial iteration of the SCS Technical Release-55 (note that TR-55 was developed specifically to calculate runoff and discharges in small watersheds). HydroCAD is the most widely used program in New England (and in much of the United States) to calculate runoff data. The use of the TR-55 method is recommended by the Massachusetts Department of Environmental Protection ("MassDEP") in its publication, *Hydrology Handbook for Conservation Commissions* (March 2002, pages 4 - 6).[9] Consequently, VP water budget analysis typically uses HydroCAD for analysis.

Precipitation for an annual water budget is based on a 24-hour 1-year storm event. My source for that data is the Extreme Precipitation Tables, Northeast Regional Climate Center ("NRCC"). For the Project, the 24-hour 1-year storm event is 2.72-inches. The NRCC data reflects the most current precipitation data for this region.

Extreme Precipitation Tables

Northeast Regional Climate Center

Data represents point estimates calculated from partial duration series. All precipitation amounts are displayed in inches.

Smoothing	Yes
State	Massachusetts
Location	
Longitude	70.768 degrees West
Latitude	42.578 degrees North
Elevation	0 feet
Date/Time	Tue, 24 May 2022 10:32:50 -0400

Extreme Precipitation Estimates

	5min	10min	15min	30min	60min	120min		1hr	2hr	3hr	6hr	12hr	24hr
1yr	0.27	0.41	0.51	0.67	0.84	1.06	**1yr**	0.72	0.98	1.24	1.60	2.08	2.72

Figure 6. Precipitation data.

Section 2 - Water Sources

A VP water budget may be derived from two sources: groundwater and surface water flow. To quote from the *Field Guide to the Animals of Vernal Pools*,[10] VPs "are ephemeral wetlands which fill annually from *precipitation*, *runoff* and rising *groundwater*." Groundwater within a VP fluctuates daily, weekly and seasonally. As the *Field Guide* notes, VPs lose or gain water through changes in groundwater, evaporation and transpiration.

[8] See Addendum: VP Watershed Impacts Analysis (HydroCAD), page 16.

[9] TR-55 is also referenced for use in the WPA regulations, and in the MassDEP *Stormwater Management Policy Handbook* (1997).

[10] Kenney & Burne, 2001

In addition to rising and falling vertically, groundwater moves horizontally. Directional flow can be determined by using specialized monitoring wells (often referred to as piezometers). Many wetland experts will set a small network of these wells in the vicinity of VPs to determine directional movement.

To my knowledge, directional groundwater analysis has not been done by A&M, and consequently, precise information about groundwater movement is missing from the project data.

Regardless, groundwater flow is typically disrupted or redirected by site "improvements" such as roads, drainage infrastructure, subsurface infiltration, retaining walls and foundations. All of these disruptions occur on the Project site. In fact, up to 63% of the Project VP watersheds are substantially altered after development (see Figures 3 and 5, as well Tables 1 and 2 on pages 6 and 7).

Section 3 - Findings

My calculations indicate that the VPs would be *substantially* altered[11] by the Project. Alterations to all VP components occur — that is, watershed area, impervious area, runoff velocity (in cu. ft/sec, or cfs), and volume (in acre feet, or af) are altered. These changes are illustrated in Tables 1 and 2 below.

Table 1. Comparison of Changes to *northerly* VP Water Budget, Pre- & Post-Development

	Area (ac)	Cn	Velocity (cfs)	Volume (af)	Tc
PRE-DEV	2.84	83	3.85	0.29	7.0
POST-DEV	1.04	79	1.33	0.092	3.8

Percentages of Change to *northerly* VP, Pre- and Post-Development

	Area (ac)	Cn	Velocity (cfs)	Volume (af)	Tc
POST-DEV	-63%	-5%	-65%	-68%	-46%

Table 2. Comparison of Changes to *southerly* VP Water Budget, Pre- & Post-Development

	Area (ac)	Cn	Velocity (cfs)	Volume (af)	Tc
PRE-DEV	1.35	77	1.31	0.099	5.9
POST-DEV	0.98	77	1.00	0.072	4.5

Percentages of Change to *southerly* VP, Pre- and Post-Development

	Area (ac)	Cn	Velocity (cfs)	Volume (af)	Tc
POST-DEV	-27%	0%	-24%	-27%	-24%

[11] "Alter" under 310 CMR 10.04 is defined as, "Alter means to change the condition of any Area Subject to Protection under M.G.L. c. 131, § 40. Examples of alterations include, but are not limited to, the following: (a) the changing of pre-existing drainage characteristics, flushing characteristics, salinity distribution, sedimentation patterns, flow patterns and flood retention areas; (b) the lowering of the water level or water table; (c) the destruction of vegetation; (d) the changing of water temperature, biochemical oxygen demand (BOD), and other physical, biological or chemical characteristics of the receiving water."

Projected watershed changes to all VPs are significant. Alterations of as much as 65% occur. For instance,

- the watershed area for the northerly pool decreases by 63%;
- the watershed area for the southerly pool decreases by 27%.

- the velocity of stormwater entering the northerly pool decreases by 65%;
- the velocity of stormwater entering the southerly pool decreases by 24%;

- the volume of stormwater entering the northerly VP decreases by 63%;
- the volume of stormwater entering the southerly VP decreases by 27%;

- the times of concentration (Tc)[12] for the northerly pool decreases by 46%; and
- the times of concentration (Tc) for the southerly pool decreases by 24%.

Volumetric changes alter the VP water elevation, and consequently, alter the Wildlife Habitat conditions for the VP. In addition, volumetric alterations may appreciably change the hydroperiod (i.e., the duration of flooding) of the pool. These changes threaten the species which inhabit the VPs on and near this site. (Although the Applicant has indicated that they will submit a Wildlife Habitat Assessment, the extent of their analysis is unknown, and nothing has been provided to the Board to date on this issue.

Of particular note, times of concentration (Tc) of stormwater flow will be markedly decreased by the Project. With a decrease, frequent, low-intensity storm events are far more likely to flow into the VPs than under existing conditions.

Compounding the impacts, the flow length (that is, the total distance stormwater flows from one end to another through a watershed) is reduced both north and south after development. For instance, the existing flow length for the northerly VP is 450 feet; under proposed conditions that length is decreased to 140 feet. This 69% *decrease* in length is a significant change that would, when combined with a shortened Tc, potentially increase the impact of frequent, low-intensity storm events. Similarly, the existing flow length for the southerly VP is 190 feet; under proposed conditions that length is decreased to 145 feet, which represents a 24% *decrease* in length.

Therefore, stormwater entering the pools would become “flashier,” with flows and fluctuations becoming more abrupt and more frequent. Why does this matter? More volatile storm flows negatively impact fauna life cycles. In *Vernal Pools,*[13] Elizabeth A. Colburn notes that such changes result in "shifts in predator-prey dynamics and community composition.” Further, “changes in the hydroperiod alter the fauna of vernal pools and affect the ability of amphibians and other species to reproduce successfully in the pools.”

To maintain the fragile habitat characteristic of a vernal pool, a site designer normally strives to ensure that the annual water budget post-development, including proposed runoff characteristics, is in balance with pre-development conditions. In the case of this Project, there appears to be no attempt to mimic pre-development hydrologic characteristics for the VPs on or near the site.

[12] Tc = the time it takes water to travel from the highest point in a watershed to the lowest.

[13] See *Vernal Pools,* Colburn, 2008*,* p. 245.

Water Quality

I also analyzed changes in water quality that would occur from a Project of this intensity. My multi-year monitoring of other area vernal pools — which now cumulatively includes hundreds of monthly water quality measurements — indicates that post-development changes, unless carefully designed, affect water quality, which in turn affects breeding potential. Typical changes include higher saline measurements, lower Biological Oxygen Demand (BOD) and higher pH values, which are all detrimental to the fauna of vernal pools.

Corroborating my observations, Colburn states,[14] "Water quality also changes with development ... Significantly disturbed watersheds have a higher pH, more mineral substrate, and more algae, on average, than do pools whose watersheds are not developed. The fauna of pools may change dramatically in response to development…"[15] She notes, as I consistently observe during my own monitoring of VPs across Massachusetts, that development leads to an increase in VPs in "turbidity, nutrient levels and dissolved contaminants."

Further, changes to stormwater temperature also affect pool fauna. Short-circuited flows off lawns and unshaded areas are hotter than stormwater from wooded areas. Colburn states, "… the amount of oxygen that can be dissolved in water decreases with increasing temperature. Some marine invertebrates can maintain a constant metabolic rate over the range of temperatures typical of their habitat, but this has not been demonstrated for invertebrates that are found in vernal pools…." Therefore, decreasing stormwater travel time, as well as changing the vegetative conditions from undisturbed woods to lawns and roads will inevitably create warmer stormwater discharges into the VPs on the Property.

I also reviewed whether the proposed Project complies with the MassDEP recommendation to "Design the development using environmentally sensitive site design and low impact development techniques to preserve natural vegetation, minimize impervious surfaces, slow down times of concentration, and reduce runoff."[16] My conclusion is that the Project design is not "environmentally sensitive," as it does not "preserve natural vegetation," and does not "minimize impervious surfaces."

Habitat would be affected by the multiple hydrologic changes to the VPs, as described above.[17] Potential impacts from herbicides, pesticides, fertilizers and road runoff into the VPs should be evaluated. To my knowledge, A&M has not conducted such an evaluation.

[14] Ibid, p. 249

[15] In addition, this conclusion is affirmed in Matter of Bosworth, OADR Docket No. WET-2015-015.

[16] MassDEP Stormwater Handbook, Volume 2, Chapter 1

[17] In a 1998 California study that recommended methods to preserve VPs, "Management Considerations for Small Vernal Pool Preserves," (Clark, Roscoe, van Ess & Wyler), the authors note under a section entitled, *Changes in Hydrology*, "Summer water runoff is a substantial problem facing vernal pool preserves adjacent to developed or irrigated lands… Runoff from residential lawns and playing fields may also contain significant amounts of fertilizer. Since the quality and quantity of water received could substantially influence the flora and fauna of the pool (Holland and Jain, 1973; Ferren and Gervitz, 1990), it is important to consider potential impacts to vernal pools from modifications to their watershed (Stromberg and Hecht, 1991)."

Therefore, it is my professional opinion that the numerous alterations proposed in the watersheds of the VPs would impair the functions of the pools, and negatively impact the ORW, wildlife habitat and introduce pollution in violation of 310 CMR 10.01(2).

Wildlife Habitat

Evidence of human disturbance within the proposed Project area is minimal; the site is almost entirely wooded. A large percentage of the woods appear to have been unlogged for decades. This condition is ideal habitat for the fauna identified as breeding in the VPs.

As Kenney and Burne note in *Field Guide*, salamanders "live underground in the forest up to one-half mile [more than 2,500 feet] from their breeding pool." Similarly, wood frogs are found "in moist woodlands." Both species are highly dependent on contiguous undisturbed woods.

In *Habitat Values of New England Wetlands*,[18] the authors state, "salamanders of the genus *Ambystoma* (spotted, blue-spotted, Jeffersons), as well as the wood frog, breed exclusively in vernal pools. These salamanders travel in mass migrations along traditional routes to return to the pools where they were born to breed." The key phrase in this quote is that the "salamanders travel in mass migrations along traditional routes to return to the pools…" Loss of these routes disrupts "traditional" travel ways to the pools. *To my knowledge, the Applicant has not identified the travel ways used by obligate species, and therefore cannot project impacts.*

DeGraaf and Rudis[19] note that habitat includes "undisturbed damp, shady deciduous or mixed woods, bottomlands, swamps, ravines …" The project site mirrors that description and can be accurately described as being composed of "undisturbed damp, shady deciduous or mixed woods, bottomlands, [and] swamps."

310 CMR 10.04 states:

> Vernal pool habitat means confined basin depressions which, at least in most years, hold water for a minimum of two continuous months during the spring and/or summer, and which are free of adult fish populations, as well as the area within 100 feet of the mean annual boundaries of such depressions, to the extent that such habitat is within an Area Subject to Protection Under M.G.L. c. 131, § 40 as specified in 310 CMR 10.02(1). These areas are essential breeding habitat, and provide other extremely important wildlife habitat functions during non-breeding season as well, for a variety of amphibian species such as wood frog (*Rana sylvatica*) and the spotted salamander (*Ambystoma macultum*), and are important habitat for other wildlife species.

This same section of the WPA (10.04) specifically notes that an area up to 100 feet outside of the "mean annual boundaries" of VPs is essential breeding habitat for many species, including the Wood frog. Yet as noted directly above, academic studies consistently indicate that 100 feet is inadequate to protect habitat for either salamanders (commonly ranging up a one-half mile from breeding pools) or the Wood frog (ranging between 200 and 1,320 feet).

As discussed above, the Project through its road system, drainage and buildings disregards and uniformly severs potential interconnections between the northerly and southerly VP habitats.

[18] US Army Corps of Engineers, 1995
[19] *Amphibians and Reptiles of New England* (1983)

In March 2006, MassDEP issued a definitive manual entitled, *Massachusetts Wildlife Habitat Protection Guidance*. In section F (page 7), the guidance states:

> IMPACTS TO CERTIFIED OR DOCUMENTED VERNAL POOL HABITAT IN ALL RESOURCE AREAS
> In all resource areas, **any direct alteration** associated with certified or documented vernal pool habitat requires a detailed wildlife habitat evaluation (Appendix B). A finding that impacts to vernal pool habitat will not result in an adverse effect will only occur under rare and unusual circumstances. A finding of no adverse effect must include consideration of the restoration and/or replication proposed after two growing seasons. However, replication and restoration of vernal pool habitat is difficult to successfully accomplish. Therefore, avoidance of impacts to vernal pool habitat is almost always necessary to meet performance standards. [emphasis added]

Although — as my calculations clearly indicate —the VP water budgets would be significantly impacted, no Appendix B has been filed for this Project. Further, no "replication and restoration of vernal pool habitat" is proposed for the Project. As I have detailed elsewhere in this report, significant alteration of the hydrology and water quality for the VPs constitutes, in my professional opinion, a direct alteration of the resource.

Section C.3 of the same guidance goes on to state,

> Vernal Pool Habitat: Mitigation for direct alterations to vernal pool habitat in resource areas may involve restoration or replication of that habitat. Careful design of restored or replicated vernal pool habitat must closely replicate the hydrology of the existing condition, and must be in close proximity to the existing vernal pool. The substrate of the pool (i.e. dead leaves, organic or mineral soil) and the vegetation in and around the pool must also mimic existing conditions. However, there are other indirect and potentially important alterations that must be identified and mitigated if they cannot be avoided. Projects altering resource areas can inadvertently disrupt existing migration routes between vernal pool systems, or between vernal pool habitat and other wetlands or upland nesting areas. In some cases, effective mitigation can involve a field survey to identify the migration patterns of obligate and facultative species and design features that maintain connections between vernal pool/wetland/upland habitats used. Some strategies may include wildlife tunnels, oversized stream culverts or arch culverts combined with fencing to direct wildlife movement to crossing structures. In addition, design features may include restrictions on construction during breeding, egg-laying or dispersal periods for the identified species, creation of nesting areas and monitoring and adjustment of erosion controls as necessary to prevent obstruction of animal movement. Some vernal pool hydrology depends on overland surface water drainage that should not be diverted...

The Project as currently designed would "disrupt existing migration routes between vernal pool systems" and "between vernal pool habitat." To my knowledge, no field survey has been conducted to "identify the migration patterns of obligate and facultative species. No "design features that maintain connections between vernal pool/wetland/upland habitats" have been proposed. This MassDEP guidance applies to instances of "direct alterations" within resource areas, which I conclude will occur to the VPs if the Project is permitted as designed.

Indeed, from my own years of monitoring vernal pools, I have documented pools wherein all identified vernal pool species became extirpated within a single breeding season, even when undisturbed buffer zones were greater than 50 feet.

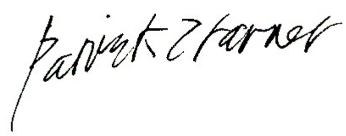
The *MACC Environmental Handbook*[20] emphasizes that proposed activities should "not impair wildlife habitat functions (feeding, breeding, nesting, over-wintering and migration)." As I have emphasized, the proposed Project does not adequately protect the interest of wildlife habitat on the Property. Further, the proposed project would impair the wildlife habitat functions of the VPs in violation of 310 CMR 10.01(2) by altering the water cycles, and by destroying travel ways, as well as essential breeding and overwintering habitat.

SUMMARY

The water budget analysis described above indicates that the hydroperiod and water quality of the vernal pools would be negatively impacted by the proposed Project, and that pre- and post-development conditions are not balanced for each of the vernal pools, as is required. This will cause a loss of species habitat, and will impair the capacity of the Vernal Pool Habitat on the Site to function as Wildlife Habitat, in violation of the performance standards in the Wetlands Protection Act, including the requirements under 310 CMR 10.53(1) for the protection of Wildlife Habitat — an "interest" under 310 CMR 10.01(2) — and the protection of Vernal Pool Habitat, as defined under 310 CMR 10.04 and 310 CMR 10.60(2)(c).

The A&M Project analysis also has not yet provided any evaluation of impacts to wildlife, or any determination of migratory travel ways, and it is unknown at this time if such information will be sufficiently forthcoming or comprehensive. In addition, the Applicant has omitted any mitigation for the proposed alterations that might, depending on design, reduce impacts to the vernal pools. My professional opinion is that the current design violates the provisions in the WPA and its accompanying regulations, and that absent a significant re-design of the proposal, the project cannot be approved under the Massachusetts Wetlands Protection Act.

Very truly yours,



Patrick C. Garner
wetland Scientist, hydrologist

ADDENDUM

[20] Massachusetts Association of Conservation Commissions, page 292 (9th ed.)

ADDENDUM

Professional Qualifications

I am the Principal of Patrick C. Garner Co., Inc., an environmental consulting firm. I am a wetland scientist and hydrologist with more than thirty years of experience, and have performed hundreds of wetland studies and delineations. I frequently appear before Conservation Commissions in Massachusetts, and regularly represent clients before MassDEP. In that capacity, I review medium and large scale proposals and advise Conservation Commissions about regulatory compliance.

I have taught numerous workshops and seminars for the Association of Massachusetts Wetland Scientists and for MACC, and have been president of both organizations. I have 20 online continuing education courses for professional education firms in the areas of wetland science, hydrology and land surveying.

I have been a member of five MassDEP Technical Advisory Committees, including the Intermittent/Perennial River Committee, the Mean Annual High Water/Bankfull Committee, the Ecological Restoration Committee, the Wetlands Advisory Subcommittee and the Stormwater Advisory Group. As a hydrologist, I have offered expert witness testimony in water-related cases in Massachusetts Superior Court on issues related to stormwater, rivers, vernal pools and groundwater. I have also testified as a wetlands and hydrology expert in MassDEP adjudicatory (OADR) appeals for over twenty years.

I have trained with the Natural Resources Conservation Service in procedures to calculate storm runoff, including use of TR-55, and have taken advanced courses from HydroCAD Software Solutions. I have also advised MassDEP regarding use of extreme precipitation data and stormwater technology. I am a current peer reviewer for the federal Hydrometeological Design Studies Center (HDSC) regarding extreme precipitation.

For the last 20 years, I have certified VPs and regularly monitor multiple pools. That monitoring includes water quality testing for pH, dissolved oxygen, temperature, saline levels and turbidity, as well as fluctuations in water levels to track pool hydroperiods (i.e., the duration of flooding). Additionally, I have analyzed the annual water budget of VPs for both private and public clients. Doing so entails determining and comparing existing and post-development conditions, and analyzing whether proposed development may impact the function of the VP.

Technical Notes

VP Watershed Analysis

This VP watershed analysis examines the potential impacts from *any intrusion into any portion of a VP watershed*. For example, a proposed project may overlap into portions of the net VP watershed with roads, walls or grading, However, the most accurate way to examine potential impacts is to analyze that *portion* of the watershed altered by the development project, not the entire net watershed.

In all cases for this Project, the overall watershed for each VP is larger than the watershed impacted by the Project. The portion impacted by the Project is, in effect, a subcatchment. That subcatchment is then analyzed.

Examining the entire VP watershed, rather than just that portion impacted by development, *dilutes* the VP alterations from a given development, and creates a distinct bias — that is, a disproportionate weight — toward minimization of impacts.

Evaluating *incremental* watershed changes is critical, particularly as cumulative effects multiply negative alterations. An analogy is a theoretical floodplain that is incrementally filled (prior to a series of federal and state regulations that became law in the 1970s and 1980s, incremental floodplain filling was common.) In such a theoretical case, each alteration may appear to have a de minimus effect on floodwater storage. Yet cumulatively, incremental filling decreases the overall storage capacity, eventually leading to increased downstream flooding during major storm events. Similarly, incremental alterations to a VP watershed may — as is the case for this Project — be immediately significant, or said alterations may slowly exhaust the pool's reproductive functions over a longer period of time.

As Colburn notes in *Vernal Pools,* "Watershed alteration by residential and commercial development … changes the hydrology, water quality and energetics of vernal pools." *Any* "changes in the hydroperiod alter the fauna of vernal pools and affect the ability of amphibians and other species to reproduce successfully in the pools."

This was confirmed in the MassDEP Office of Appeals and Dispute Resolution ("OADR") adjudicatory decision in Matter of Bosworth, OADR Docket No. WET-2015-015, Recommended Final Decision (February 17, 2016) adopted by Final Decision (March 14, 2016), which found that:

"… in order for vernal pool habitat to continue to function and co-exist with nearby development its water budget must be sustained post-development. If surface runoff is redirected or groundwater recharge in proximity to the vernal pool is reduced by impervious surfaces, then the vernal pool water budget could be adversely impacted, potentially resulting in adverse impacts to the vernal pool habitat. Land use changes, such as clearing, increases in impervious surfaces, and changes in the watershed can increase or decrease water runoff, which could alter the amount of water received by a vernal pool, destroying the water budget that is necessary to sustain the habitat of that pool. Vernal pools with a significantly disturbed watershed generally have a higher pH, more mineral substrate, and more algae, which negatively impacts the habitat.... This susceptibility to changes in light, chemicals, or water is why in similar cases project applicants have performed detailed assessments to determine how work in the buffer zone will impact the vernal pool habitat, particularly its water budget."

Soils Data

As I noted in the main body of this report, I used NRCS data to determine Project soils. My findings correlate with those of A&M, and I have used the same underlying data as that firm.[21]

[21] See the A&M Drainage Report.

Upland soils on site are predominately Chatfield-Hollis Rock Outcrop (with 15 - 35% slopes), and Udorthents (with 3 - 25% slopes). Wetland soils are classified as Swansea muck. Soils throughout the Project are Hydrologic Soil Group D, which is the most impervious of ranked soils.

Essex County, Massachusetts, Southern Part (MA606)

Essex County, Massachusetts, Southern Part (MA606)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
32A	Wareham loamy sand, 0 to 3 percent slopes	0.2	0.3%
51A	Swansea muck, 0 to 1 percent slopes	14.9	29.7%
102E	Chatfield-Hollis-Rock outcrop complex, 15 to 35 percent slopes	28.0	55.8%
105D	Rock outcrop-Hollis complex, 3 to 25 percent slopes	1.1	2.1%
651	Udorthents, smoothed	6.1	12.1%
Totals for Area of Interest		**50.1**	**100.0%**

Figure 7. Essex County Project soils.

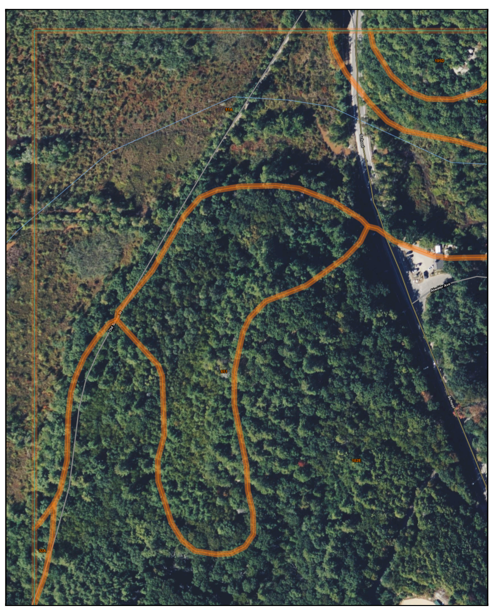
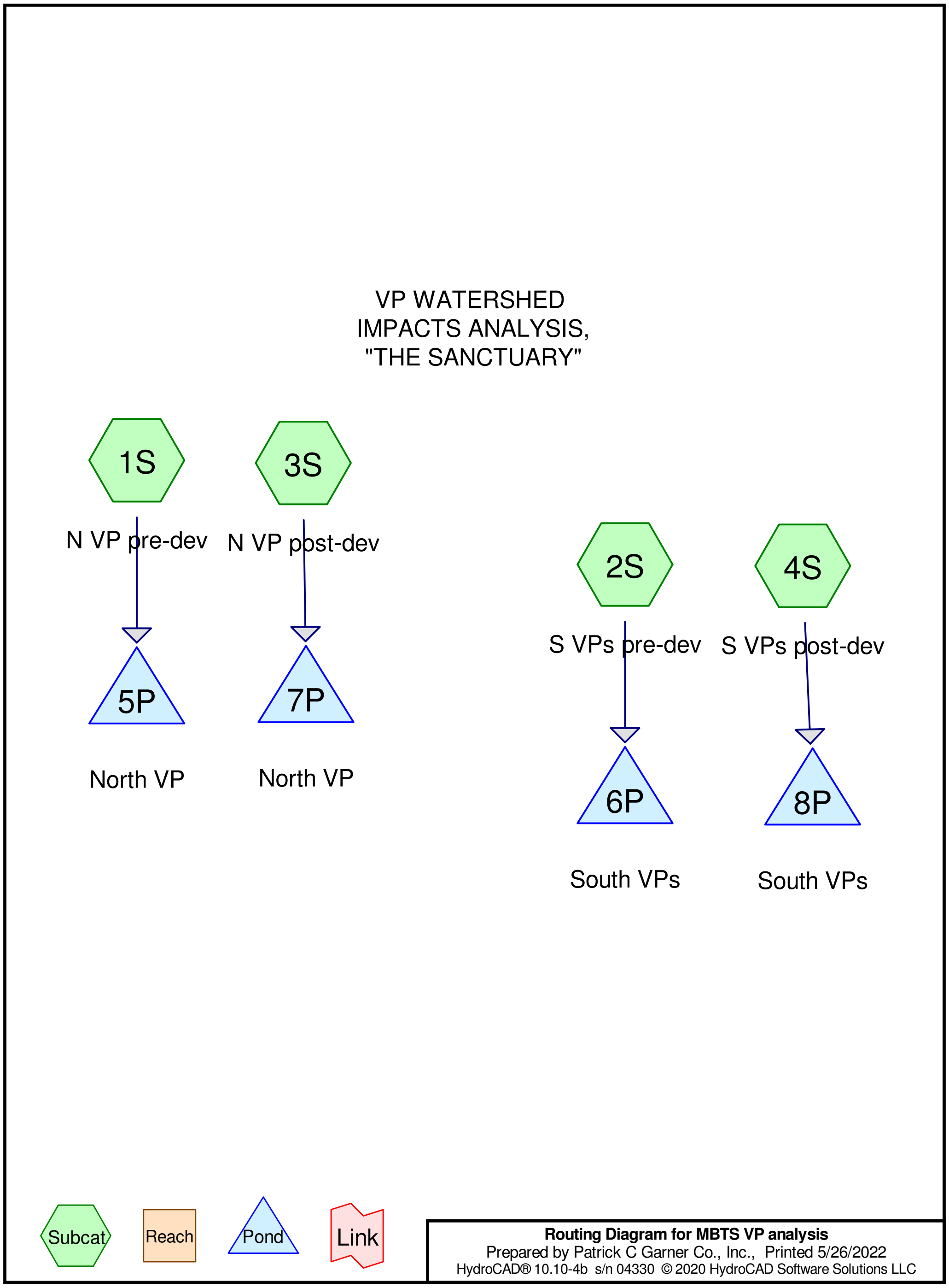


Figure 8. Soil location plan from USDA Web Soil.


VP WATERSHED
IMPACTS ANALYSIS,
"THE SANCTUARY"
1S
N VP pre-dev
3S
N VP post-dev
5P
North VP
7P
North VP
2S
S VPs pre-dev
4S
S VPs post-dev
6P
South VPs
8P
South VPs
Subcat
Reach
Pond
Link
Routing Diagram for MBTS VP analysis
Prepared by Patrick C Garner Co., Inc., Printed 5/26/2022
HydroCAD® 10.10-4b s/n 04330 © 2020 HydroCAD Software Solutions LLC

Rainfall Events Listing (selected events)

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	1-year	Type III 24-hr		Default	24.00	1	2.72	2

Area Listing (all nodes)

Area (acres)	CN	Description (subcatchment-numbers)
0.148	80	basin side slopes grassed (3S)
0.890	95	boulders (1S, 3S)
0.034	80	grass (4S)
0.100	91	gravel road (1S)
1.024	78	wetlands (1S, 2S, 3S, 4S)
4.094	77	woods, good (1S, 2S, 3S, 4S)
6.290	**80**	**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (acres)	HSG-B (acres)	HSG-C (acres)	HSG-D (acres)	Other (acres)	Total (acres)	Ground Cover	Subcatchment Numbers
0.000	0.000	0.000	0.000	0.148	0.148	basin side slopes grassed	3S
0.000	0.000	0.000	0.000	0.890	0.890	boulders	1S, 3S
0.000	0.000	0.000	0.000	0.034	0.034	grass	4S
0.000	0.000	0.000	0.000	0.100	0.100	gravel road	1S
0.000	0.000	0.000	0.000	1.024	1.024	wetlands	1S, 2S, 3S, 4S
0.000	0.000	0.000	0.000	4.094	4.094	woods, good	1S, 2S, 3S, 4S
0.000	**0.000**	**0.000**	**0.000**	**6.290**	**6.290**	**TOTAL AREA**	

Summary for Subcatchment 1S: N VP pre-dev

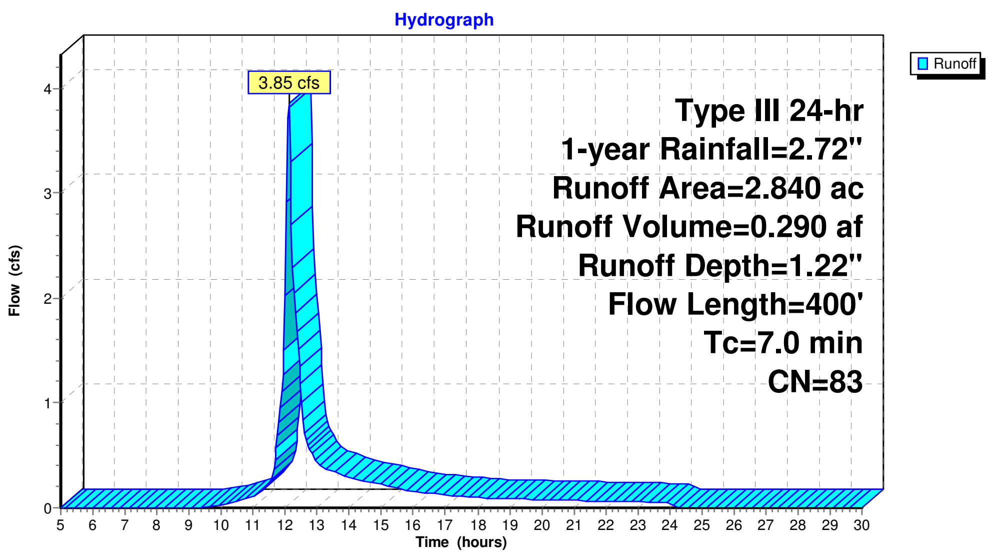
Runoff = 3.85 cfs @ 12.11 hrs, Volume= 0.290 af, Depth= 1.22"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-30.00 hrs, dt= 0.04 hrs
Type III 24-hr 1-year Rainfall=2.72"

	Area (ac)	CN	Description
*	0.417	78	wetlands
*	0.810	95	boulders
*	0.100	91	gravel road
*	1.513	77	woods, good
	2.840	83	Weighted Average
	2.840		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.5	50	0.2400	0.18		**Sheet Flow, Sheet flow** Woods: Light underbrush n= 0.400 P2= 3.24"
2.5	350	0.2200	2.35		**Shallow Concentrated Flow, Shallow concentrated** Woodland Kv= 5.0 fps
7.0	400	Total			

Subcatchment 1S: N VP pre-dev



Summary for Subcatchment 2S: S VPs pre-dev

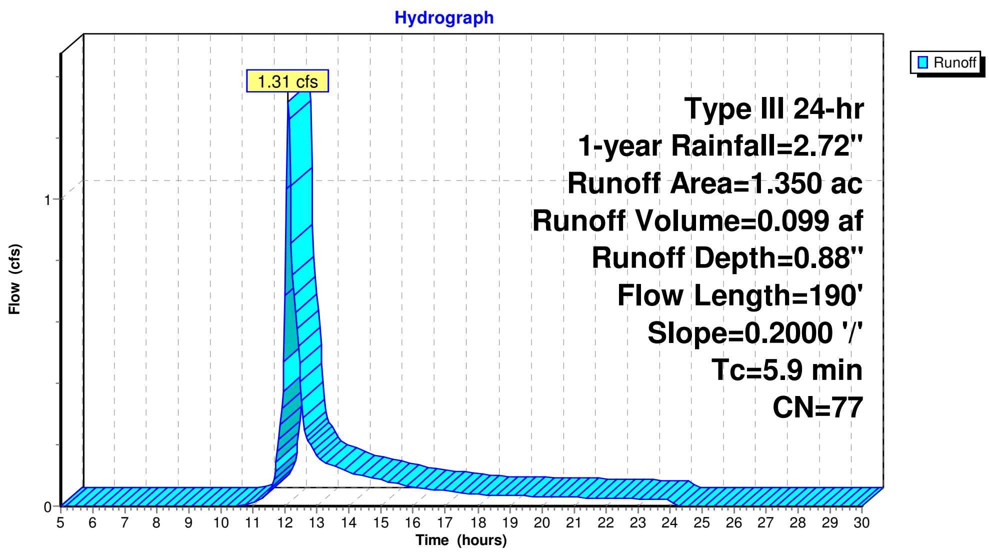
Runoff = 1.31 cfs @ 12.10 hrs, Volume= 0.099 af, Depth= 0.88"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-30.00 hrs, dt= 0.04 hrs
Type III 24-hr 1-year Rainfall=2.72"

	Area (ac)	CN	Description
*	0.095	78	wetlands
*	1.255	77	woods, good
	1.350	77	Weighted Average
	1.350		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.9	50	0.2000	0.17		**Sheet Flow, Sheet flow** Woods: Light underbrush n= 0.400 P2= 3.24"
1.0	140	0.2000	2.24		**Shallow Concentrated Flow, Shallow conc** Woodland Kv= 5.0 fps
5.9	190	Total			

Subcatchment 2S: S VPs pre-dev



Summary for Subcatchment 3S: N VP post-dev

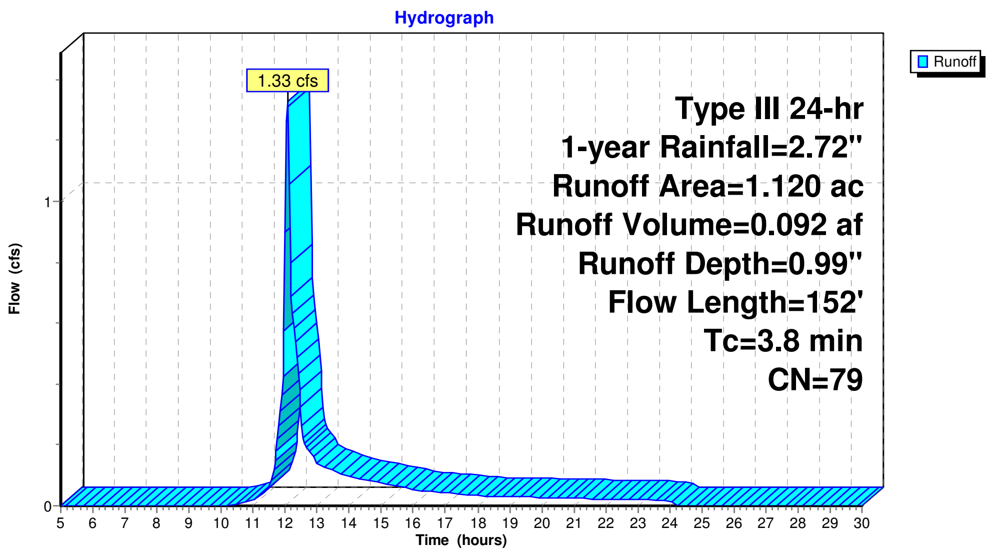
Runoff = 1.33 cfs @ 12.07 hrs, Volume= 0.092 af, Depth= 0.99"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-30.00 hrs, dt= 0.04 hrs
Type III 24-hr 1-year Rainfall=2.72"

	Area (ac)	CN	Description
*	0.417	78	wetlands
*	0.080	95	boulders
*	0.148	80	basin side slopes grassed
*	0.475	77	woods, good
	1.120	79	Weighted Average
	1.120		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
2.7	50	0.3300	0.31		**Sheet Flow, Sheet flow** Grass: Dense n= 0.240 P2= 3.24"
1.1	102	0.1000	1.58		**Shallow Concentrated Flow, Shallow conc** Woodland Kv= 5.0 fps
3.8	152	Total			

Subcatchment 3S: N VP post-dev



Summary for Subcatchment 4S: S VPs post-dev

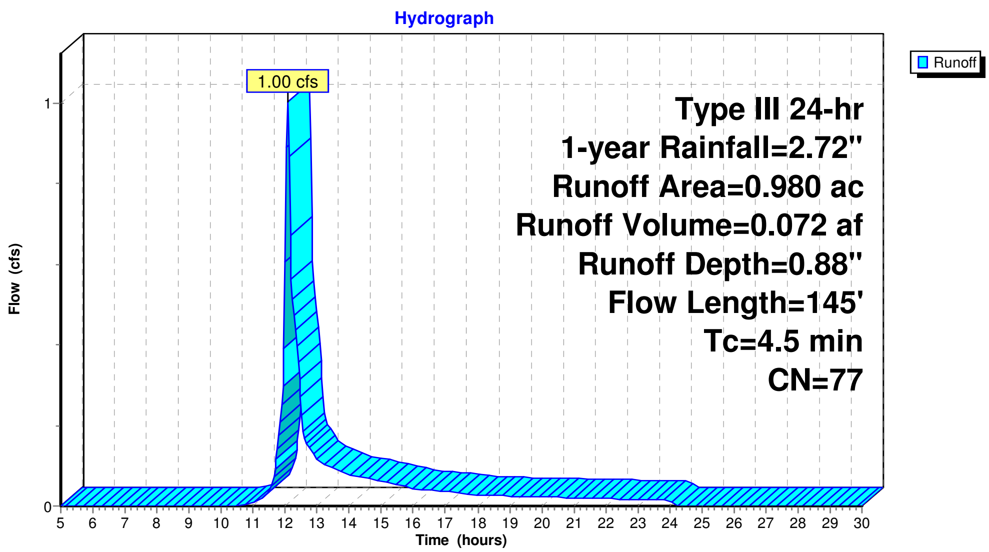
Runoff = 1.00 cfs @ 12.08 hrs, Volume= 0.072 af, Depth= 0.88"

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 5.00-30.00 hrs, dt= 0.04 hrs
Type III 24-hr 1-year Rainfall=2.72"

	Area (ac)	CN	Description
*	0.034	80	grass
*	0.851	77	woods, good
*	0.095	78	wetlands
	0.980	77	Weighted Average
	0.980		100.00% Pervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
4.0	50	0.3300	0.21		**Sheet Flow, Sheet flow** Woods: Light underbrush n= 0.400 P2= 3.24"
0.5	95	0.4200	3.24		**Shallow Concentrated Flow, Shallow conc** Woodland Kv= 5.0 fps
4.5	145	Total			

Subcatchment 4S: S VPs post-dev



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