Questions on Beals and Thomas Stormwater Report Peer Review dated 11/25/2024
Montrose School Campus Site Improvements
(John Woodhull, Conservation Commission, questions as discussed during meeting on 1/23/2025)

Beals and Thomas (B&T) provided a peer review of the Stormwater Report submitted by the Montrose Foundation, Inc. (the Applicant) dated July 31, 2024, in a letter to the Board of Health dated November 6, 2024. The Applicant issued an updated version of the Stormwater Report dated November 15, 2024, in response to B&T comments. B&T issued a second letter dated November 25, 2024, containing their initial comments, the Applicant responses, and additional B&T comments. Review of the November6th and 25th letters resulted in questions for B&T from a member of the Conservation Commission (John Woodhull) that are listed below:

1. The Massachusetts Stormwater Handbook states that loss of annual recharge to groundwater shall be eliminated or minimized. The Massachusetts Hydrology Handbook for Conservation Commissioners explains that the flow of streams and rivers, and wetland hydrology in general, can be altered by a reduction in groundwater recharge, significantly altering local ecosystems. Additionally, groundwater tables may be lowered, affecting the available water supply (the project is located within Zone II protection area). In the Stormwater Report for this project, as revised November 15, 2024, the Applicant states that:

   "Due to the decrease in impervious area onsite, by definition there will be an overall increase in stormwater recharge into the ground. Structural stormwater recharge is not viable onsite due to high groundwater."

   The first part of this statement is only true if all pervious areas have the same percentage infiltration. A large fraction of the site redevelopment is two new synthetic turf fields. As the fields are underlaid by drainage laterals set on compacted soil, the percentage infiltration for these areas will be less than that from areas of high-quality grass. Whether there is a net decrease in infiltration for the total site on an average annual basis depends on the actual infiltration rate for the synthetic turf field for the typical mix of precipitation received annually and how much of the area to be replaced by synthetic turf is currently impervious. Have Beals and Thomas (B&T) been able to confirm that the infiltration rate from the planned synthetic turf field will be high enough that there will not be a net decrease in groundwater recharge for the site? Fully answering this question is much more involved than the text from the Applicant suggests. Resolution of the issues raised by B&T's comment 10 is needed as a first step (see below).

2. Comment 10 from B&T's 11-6-2024 letter relative to the Applicant's stormwater submittal dated 7-31-24 states:

   "The post-development stormwater modeling utilizes a curve number (CN) value for the turf field of 39, which is identical to the CN used for the existing grass field in the existing condition. ***The turf surface and subsurface material will more closely mimic an impervious service as the water will quickly enter the underdrain system*** *and continue to the discharge location. A typical impervious CN is 98. The increased rate of runoff with the CN revision will also impact the flow to the water quality structures and potentially impact the sizing of the structures. We request that the Applicant revise the analysis accordingly and confirm the sizing of the water quality structures."*

This comment from B&T clearly states that they expect infiltration from the synthetic turf field to be much less than infiltration from the existing grass field (runoff from the synthetic turf field is expected to be higher than runoff from the existing grass field).

Infiltration to the subsurface beneath the turf field is not modeled using SCS curve numbers. It has been modeled as a "pond" using the Darcy Equation. Runoff rates do not "closely mimic an impervious surface" – runoff from the 1-in-100-year design case as modeled amounts to only 19% of incident rainfall. Runoff from an impervious service for a storm with the same recurrence interval is calculated as 97% using SCS with CN=98.

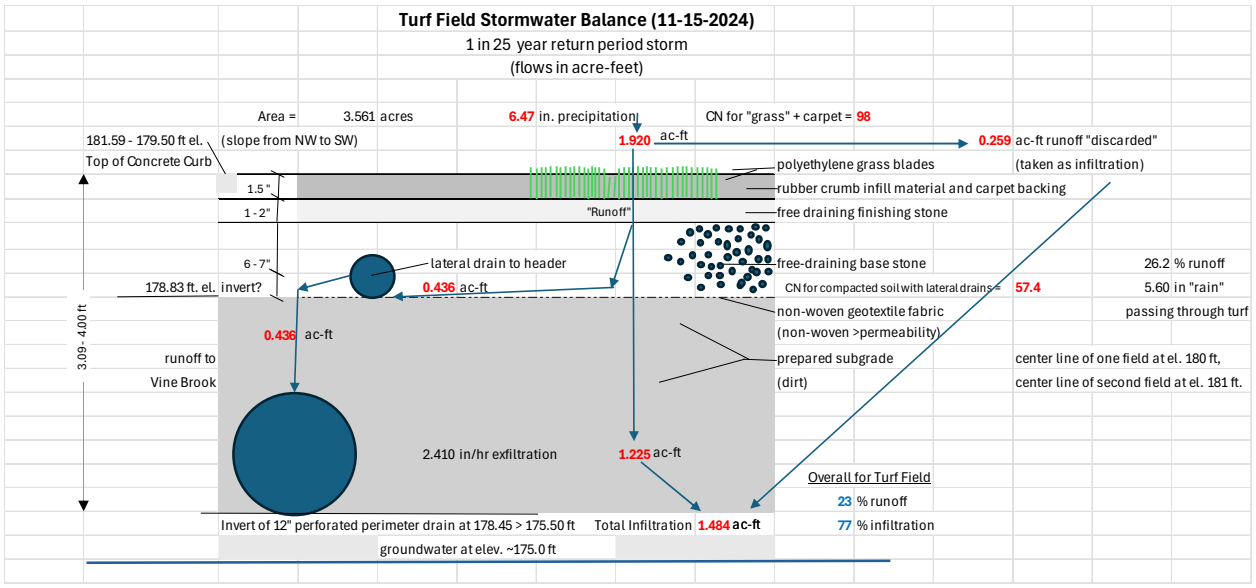
The Applicant responded to the comment from B&T, saying that they disagree with use of a CN of 98, and provided text from Activas (the synthetic turf vendor) supporting use of a CN value for the synthetic turf field of 39 based on the concept that essentially all the rain falling on the synthetic turf field will flow rapidly through the infill, carpet backing and stone layers, reaching the subgrade where it will infiltrate in much the same way that rain infiltrates the soil of a natural grass field.

To examine the model in more detail, in the updated calculations dated 11-15-2024, prepared in response to B&T's comments, the Applicant has estimated runoff volume and rate from the synthetic turf field using an updated version of the HydroCAD model they prepared for the site. The synthetic turf field is modeled using two separate calculation blocks, sub-catchment P2E and Pond PS3:

1. sub-catchment P2E, which consists of the surface of the synthetic turf field (3.375 acres) plus adjacent grass and paved surfaces (0.186 acres) and
2. "Pond" PS3, the area beneath the synthetic turf field (3.331-acres, 8 inches deep) containing base stone and perforated lateral drains sloped to perforated drainage headers. Base stone beneath the synthetic turf fields is underlain by a layer of non-woven fabric over compacted soil.

Sub-catchment P2E separates the incident rainfall into two streams: "runoff" and "discarded", with the distribution between the two determined by the rainfall depth and the specified curve number using the SCS runoff correlation equation. The HydroCAD model components are configured so that calculated "runoff" from P2E is not routed directly to one of the three reaches of Vine Brook (R1, R2, R3), but to Pond PS3 (the 8-inch-deep volume beneath the turf field). The "discarded" stream (which would correspond primarily to infiltration through the crumb rubber and carpet backing) is not used further in the model (it is "discarded").

For calculation of the total volumetric flows or runoff and infiltration, the Turf Field Pond PS3 calculation block receives the "runoff" flow from sub-catchment P2E as an input and splits it between "primary" (runoff flow directed to Vine Brook reach R2 via the lateral drains and collection header) and "discarded", exfiltration from the storage volume (infiltration to the soil beneath "Pond" PS3) which is "discarded" from the model. As an illustration, the overall balance for the 1 in 25-year return period 24-hour storm using values from the calculations in the 11-15-2024 submittal from the Applicant is shown in the figure below:



To calculate what fraction of the "runoff" stream flows through the lateral drains to the drain header and ultimately to Vine Brook, the curve number calculation method is not used; instead, the geotextile fabric/soil surface has been modeled using the Darcy equation and a saturated hydraulic conductivity (K_{sat}) of 2.410 inches per hour. The Darcy equation calculates infiltration flux as the product of the hydraulic conductivity and the hydraulic gradient. The assumptions that have been used to define the hydraulic gradient are very important to the result, but are not clear from the HydroCAD output. For the 1-in-25-year 24-hour storm event and the 11-15-2024 version of the HydroCAD model, the result is a runoff volume equivalent to what would be obtained using a CN of about 52 – much lower than the runoff volume B&T anticipated when commenting that the CN value for the synthetic turf field should be set at 98.

The response from Beals and Thomas to the updated stormwater calculations described above is: "**This comment has been addressed by the applicant.**"

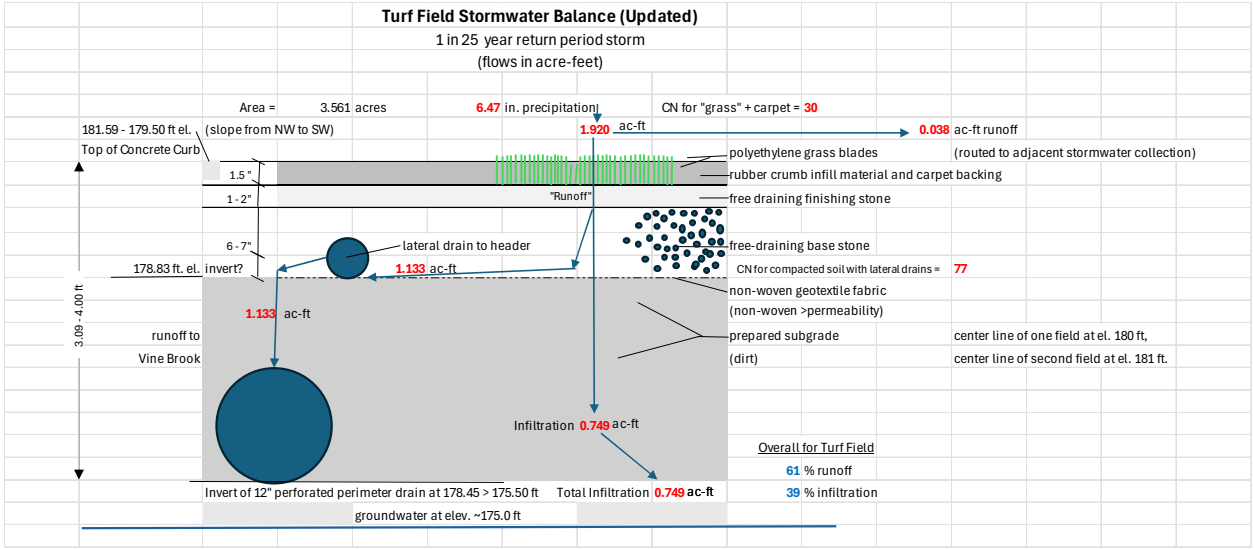
Several of the elements which enter into calculation of runoff from the synthetic turf field deserve additional consideration and have not been fully addressed by the Applicant. Specifically:

- If (as was done in the 11-15-2024 submission from the Applicant) sub-catchment P2E is modeled using the SCS runoff model with a high CN of 98 consistent with an impervious surface, logically the "runoff" stream from P2E must flow to the R2 reach of Vine Brook (via the P2B and P2A sub-catchments) with the "discarded" stream routed to "Pond" PS3 (the base stone filled volume beneath the synthetic turf field). Treating the calculated runoff volumetric flow as infiltration is clearly inconsistent with the SCS runoff model and is confusing to reviewers. The SCS curve number of 98 is used in this way to force the model to allow nearly all the rainfall incident on the synthetic turf field to pass through the crumb rubber infill and permeable carpet backing into the base stone volume beneath (into PS3) using the SCS CN value calculation block. The remaining incident rainfall that is not assigned as "runoff" is "discarded". Manipulating the HydroCAD model in this way is confusing and incorrectly discards from the model

the portion of the flow that the SCS CN model does not identify as runoff, reducing the calculated runoff as a result.

- If a lower CN (e.g. 39) is used with the two-calculation block model (as was done for the earlier submission by the Applicant dated 7-31-24) it is still true that for logical consistency with the SCS runoff model the runoff stream cannot be routed to "Pond" PS3 but must flow to R2 (Vine Brook via the P2B and P2A sub-catchments) with the "discarded" stream routed to "Pond" PS3. The model instead is configured with only the runoff stream (a very small fraction of the total incident rainfall) routed to "Pond" PS3 and the bulk of the flow "discarded" from the model. This approach to modeling runoff from the synthetic turf field is so clearly incorrect that it is surprising that it was ever seriously proposed by the Applicant. The initial turf field model submitted by Hancock Associates (dated 7-31-24) resulted in a calculation where, for the 1-in-100-year, 24-hour storm, only 1% of the rainfall incident on the turf field became runoff.
- The Activas text discussing synthetic turf field runoff does not appear to be addressing a model where two-calculation blocks are used for the turf field, with the second on modeled using the Darcy equation. The Activas text implies a single calculation block model based on an SCS Curve Number calculation. For a calculation configured in this way the appropriate curve number for a synthetic turf field would not be the same as for a grass field in good condition as is proposed by Activas. There are two reasons for this. These are that the subsoil (beneath the base stone in the area excavated for the synthetic turf field) will not be covered by grass and that the subsoil will have been graded and compacted. Tables in TR-55, Urban Hydrology for Small Watersheds, show curve numbers for compacted bare soil ranging from 77 to 100. Removal of grass and compaction make the surface smoother, reducing resistance to horizontal flow (toward the drain laterals). Bare soil has a higher curve number than vegetated soil. The ***minimum*** estimate of CN for newly graded, Type A soil would be 77, as shown in Table 2-2a in TR-55.
- For the Pond PS3 calculation block, the saturated hydraulic conductivity value of 2.410 inches/hour used for the soil under the synthetic turf field and beneath the base stone is consistent with the Rawls saturated hydraulic conductivity for Loamy Sand (group A), included in the Massachusetts Stormwater Handbook for use in the design of stormwater recharge areas. As is the case for an infiltration rate calculated using the SCS curve number equation, hydraulic conductivity is reduced by a lack of vegetation and soil compaction. Many sources recommend a more conservative design infiltration rate for group A soils than the one used by the Applicant. For example, in design of infiltration basins the Minnesota Stormwater Manual provides a saturated hydraulic conductivity range for group A soils of from 0.8 – 1.63 inches per hour (based on review of 30 guidance manuals including Rawls). Field infiltration tests can be carried out if a more precise value is needed. It is also evident that perforated drain laterals placed at 20-foot intervals greatly increase runoff and decrease potential infiltration from Pond PS3. The saturated hydraulic conductivity value of 2.410 inches/hour does not in any way account for the presence of drain laterals. A reduction in hydraulic conductivity would be one way in which they could be accounted for.

- The HydroCAD model proposed by the Applicant estimates flow into the soil beneath the base stone of the synthetic turf field using the Darcy equation which calculates infiltration as the product of the saturated hydraulic conductivity and the hydraulic gradient. Using values from the calculation sheet, the base elevations of the laterals draining the synthetic turf fields range from 178.83 ft to 175.50 ft. In May 2024, groundwater levels in the area of the synthetic turf field were measured at an elevation of about 175 ft, only 0.5 - 3.8 ft below the soil at the base of the synthetic turf field. In the discussion of compliance with Standard 3, high groundwater levels are noted in the Stormwater Report as a reason for not being able to make use of stormwater infiltration for groundwater recharge. The small difference between the base of the infiltration area and groundwater levels reduces the hydraulic gradient, which is the driving force for infiltration from the synthetic turf field. Has B&T been able to obtain the details of the values used for this calculation and confirm their reasonableness? The calculated infiltration rates for the synthetic turf field appear higher than would be expected for a site with such a small distance to groundwater and laterals at 20-foot intervals lying directly on the fabric covering the soil beneath the field. What hydraulic gradient has been used and why?
- The synthetic turf field could be modeled using the SCS CN method for both P2E and PS3, with the infiltration ("discarded" in HydroCAD) from P2E directed to PS3. Using a very low CN value (e.g. 30) for P2E, and a higher value consistent with graded, compacted, vegetation-free soil for PS3 (e.g. 77) results in runoff rates greater than those proposed by the Applicant in either their 7-31-2024 or their 11-15-24 submission, but much less than what would result from the use of SCS correlations with a CN equal to 98 as initially recommended by B&T. Is this type of approach B&T was anticipating when they made their comment about the need to greatly increase calculated runoff from the synthetic turf field?
- The result of a calculation using CN values of 30 and 77 for the 1 in 25-year return period storm (the "Updated" version) is shown in the figure below:



Using this technique (or something similar) results in estimated stormwater runoff volumes for proposed conditions that are higher than stormwater runoff volumes for existing conditions for both the 2-year and 25-year return period:

Volume of Runoff (As Updated)				
Return		(acre-feet)		
Period ->	2 -year		25-year	
Discharge	Existing	Proposed	Existing	Proposed
R1 >	0.331	0.096	1.085	0.408
R2	0.459	0.694	1.786	2.306
R3	0.013	0.000	0.067	0.007
Total	0.472	0.694	1.853	2.313

Standard 3 from the Massachusetts Stormwater Handbook calls for annual recharge from the post-development site to equal or exceed annual recharge from predevelopment conditions. After reviewing this analysis, is B&T satisfied that Standard 3 is met by the proposed development? It seems likely that with the addition of the synthetic turf field as currently configured, runoff volumetric flow from the post development case will be higher than runoff for the predevelopment (existing) case.

3. The HydroCAD Model is configured using a time span for calculation of 0 – 20.00 hours for a 24-hour event. Although calculating in this way captures the peak flow, which occurs at about 12 hours, it misses flow from the "tail" of the event. As a result, values for the total flow of runoff calculated by the HydroCAD Model using the SCS curve number method are low by about 10%. For example, area E1 is 4.143 acres, with 2.296 acres impervious, so the CN weighted by area and rounded to the nearest whole number is 72. The 1 in 2-year return period 24-hour precipitation is 3.4 inches. The runoff volume shown in the calculations from the HydroCAD model in the report dated 11-15-2024 is 0.331 acre-feet; it is 0.365 acre-feet (10%higher) if the SCS Correlation is used without breaking up the calculation into time steps or limiting the time span to 20 hours.

   For the data set discussed above and the 1 in 2-year return period, changing the calculation to use two individual CNs for each sub-catchment area instead of the weighted-average CN equal to 72 increases the calculated runoff from 0.365 acre-feet to 0.607 acre-feet. This results from the form of the equations used in the SCS runoff correlation. For total rainfall of 3.4 inches, runoff calculated using the SCS correlation with CN=98 is 3.1668 inches; runoff with CN=39 is 0.0046 inches and runoff with CN=72 is 1.056 inches. The area-weighted runoff using the runoff values for the two individual CNs is 1.757 inches. This is 66% more than the hand-calculated runoff value from the SCS equation calculated using a single area-weighted-average CN of 72 which results in 1.056 inches of rainfall as runoff. The magnitude of the difference between runoff volumes calculated using the weighted average CN and those calculated using individual CNs for impervious and pervious areas is less for longer return period (higher precipitation volume) storms as illustrated by the table below comparing calculation of runoff using the average CN with calculation of runoff using individual CNs:

Volume of Runoff 11/15/24								
Return	(acre-feet)							
Period ->	2 -year				25-year			
Discharge	Existing		Proposed		Existing		Proposed	
	avg. CN	ind. CN	avg CN	ind. CN	avg. CN	ind. CN	avg. CN	ind. CN
R1 >	0.331	0.607	0.096	0.227	1.085	1.283	0.408	0.508
R2	0.459	1.009	0.594	1.038	1.786	2.228	1.571	1.944
R3	0.013	0.036	0.000	0.001	0.067	0.086	0.007	0.009
R2 + R3	0.472	1.045	0.594	1.039	1.853	2.314	1.578	1.953

Total runoff volumes would be increased for both existing and planned future conditions by running the HydroCAD model with a longer time span and using separate CN values for the pervious and impervious areas. Has B&T considered the impact that using the average CN instead of individual CN values for pervious and impervious areas has on both average and peak runoff flowrates? Would use of individual CN values instead of an average CN impact either water quality structure sizing or the need for increased groundwater recharge?

4. In comment 17, B&T notes that new regulations are likely to be promulgated requiring 65% phosphorus removal for existing sites with at least 1-acre of impervious area in the Charles River basin. Based on the likely technologies that could be used for phosphorus removal, are there any adjustments to the proposed layout that B&T would recommend in order to facilitate future addition of a phosphorus removal system?

5. The synthetic turf fields are drained by a series of perforated pipe laterals set at 20-foot intervals. Did the B&T review consider the possibility of increasing the space between laterals as a way of increasing infiltration? Alternatively, infiltration would be greatly increased if the depth of the base stone layer were increased by 3 or 4 inches beneath the elevation of the drainage laterals to increase stormwater residence time in the system. Were either of these modifications, or others with the same objective, considered? Does B&T feel that modifications such as these would have *any* negative impact on the design, and if so, what would that negative impact be?

6. Some researchers have expressed concern about runoff from synthetic turf fields potentially containing microplastic particles, various organics including 6PPD-q, and metals including zinc at concentrations high enough to be toxic to some aquatic organisms (or humans). For water that infiltrates into the soil, a fraction of the zinc ions will be removed by adsorption onto negatively charged sites on the soil particles. High soil pH in particular increases zinc adsorption. Soil can also act as an effective filter for microplastics. 6PPD-q is readily adsorbed by soils. For example, the contaminant removal benefits of stormwater infiltration are mentioned in the EPA's Best Management Practices for design of stormwater infiltration systems. It is likely that design modifications that decrease runoff and increase infiltration at the synthetic turf field will reduce the mass of contaminants flowing off-site. Has B&T considered the need to minimize offsite flow of any contaminants that may be present in runoff from a synthetic turf field as a reason for implementation of a design that maximizes synthetic turf field infiltration? Are there any soil amendments that could be considered to decrease the mobility of potential contaminants (for example limestone to increase the alkalinity or activated

carbon/biochar to increase adsorption of organics in the soil under the stone beneath the synthetic turf field)?