Memo

TO: **Project File**

FROM: **Atwell, LLC**

DATE: **August 2, 2024**

RE: **Sapling Solar Stormwater Runoff – Alcona County / Gustin Township**

This memorandum summarizes the effects on stormwater runoff due to the resulting change in land use for the proposed solar photovoltaic (PV) project ("Project"). The Project will primarily convert areas of agricultural crop development into solar energy development PV arrays with grassy ground cover, elevated solar panels and gravel driveways to site equipment. Due to land availability, there will also be areas of undeveloped woods and pasture/meadow land cover that will be utilized for PV arrays. The PV arrays and electrical equipment will be contained within a perimeter security fence to prevent unauthorized access.

Typical preparation for installation of PV arrays consists of clearing vegetation with minor grading as needed to allow driving panel support posts into the ground. Generally, site grading is avoided or minimized but may be necessary due to topographical constraints (i.e., steep slopes and/or ridges/valleys within the tracker rows) to comply with tracker vendor requirements. These grading areas are localized and will not alter the existing drainage patterns to divert large areas away from their existing downstream areas.

After the Project is built and proper ground cover established, the resulting land use will consist of a grassy field best categorized as "meadow" classification per *Michigan Department of Environment, Great Lakes and Energy* ("EGLE"), with gravel driveways. The panels are elevated above ground and do not diminish the ability of the ground cover below to accept and treat rainfall. During a rain event, rainfall will either land directly on the ground or flow off the panels and onto the ground below where it will be filtered, absorbed, infiltrated, or run off. The amount of gravel cover for the project is typically very small relative to the overall array area, consisting primarily of narrow driveways distributed throughout the arrays – the only area where higher gravel concentration is needed is at a potential Project substation, which is at times permitted separately. The amount of land cover displaced by support posts is negligible over the array area. In larger rain events, runoff will flow offsite from the array, following the same existing runoff routes as from the existing agricultural crop development. A comparison of existing and proposed conditions is necessary to determine how the change in land use will affect runoff, and if mitigation measures are warranted for areas where runoff is expected to increase from existing conditions.

To compare existing and proposed runoff from the site, the EGLE "*Calculations for Storm Water Runoff Volume Control*" (EQP9278) spreadsheet was used for the existing and proposed land uses. The EGLE calculations reference "pre-settlement" conditions (i.e., before farming or other development) but are also applicable for currently existing and proposed conditions using the proper input parameters – Drainage Area, Rainfall Depth and Land Cover Type based on underlying Hydrologic Soil Group (HSG) classification. Runoff Curve Numbers (CN) are assigned to each Land Cover/HSG complex, with higher CN values indicative of increased runoff. This method is more detailed than the Rational Method, as it accounts for a greater variety of land cover types based on soil classifications (Rational Method is commonly used where undeveloped land is converted to a traditional land development site with large areas of impervious cover such as buildings, roads, and paved parking areas).

The summary below discusses each of the input parameters and comparison of existing to proposed conditions:

Drainage Area

Grading will be limited to local high/low areas and mass grading is not proposed to measurably change drainage areas therefore the drainage area remains constant. For this analysis, the entire fenced array area was used in the runoff calculations. Note that at this preliminary stage the entire array area was analyzed however during final design, smaller individual drainage areas based on final topography will be reviewed as necessary to compare runoff volumes.

Rainfall Depth

Gustin Township Zoning Ordinance references the use of the 10-year storm event for stormwater management. NOAA rainfall data = 2.99 inches (10-year, 24-hour storm).

Land Cover/HSG

The table below provides the different cover / HSG values used for the comparison. For existing undeveloped area (woods/meadow), the Woods CN value was used to be conservative (Woods CN < Meadow CN for each HSG classification).

Existing Conditions

Land Cover Type	Soil Type	CN (from TR-55)
Woods / Meadow	A	30
Crops	A	67
Woods / Meadow	B	55
Crops	B	78
Woods / Meadow	D	77
Crops	D	89
TOTAL:	N/A	

Post-Development Conditions

Land Cover Type	Soil Type	CN*
Impervious	N/A	98
Grassland / Meadow	A	30
Grassland / Meadow	B	58
Grassland / Meadow	D	78
TOTAL:		

Since the change from crop to meadow land cover yields significant reductions in CN values and thus runoff volume, the calculation results in Table 1 include only areas where wooded and non-farmed land (based on a review of aerial imagery) is proposed for array placement.

The proposed conditions assume an impervious cover of 3% to account for equipment pads and gravel roads. Typically, the actual coverage is less than 2% so the calculation results are conservative.

Table 1 – EGLE Runoff Volume Comparison Calculation Summary

Area	1	2	3	3A	4	5
Proposed Array, ac	44.8	31.3	34.0	23.9	29.7	12.9
Ex. Ag. Cropland	0%	88%	72%	0%	91%	94%
Ex. Woods/Meadow	100%	12%	28%	100%	9%	6%
Existing CN	59	85	80	55	88	88
Proposed CN	63	74	69	59	79	79
Ex. 10-yr runoff, cf*	58	182	156	18	196	86
Pr. 10-yr runoff, cf*	82	110	93	31	126	55
Runoff change, cf*	23	-72	-63	13	-70	-31
Runoff Increase	Yes	No	No	Yes	No	No

Area	6	7	8	9	11	15
Proposed Array, ac	93.6	23.5	14.4	48.2	236.6	30.9
Ex. Ag. Cropland	93%	0%	79%	43%	78%	81%
Ex. Woods/Meadow	7%	100%	21%	57%	22%	19%
Existing CN	86	71	86	68	82	83
Proposed CN	75	73	77	62	72	73
Ex. 10-yr runoff, cf*	580	71	87	128	1,302	168
Pr. 10-yr runoff, cf*	351	81	59	85	846	103
Runoff change, cf*	-229	10	-29	-44	-456	-65
Runoff Increase	No	Yes	No	No	No	No

* multiply volume by 1,000

Conclusion

The calculations show that converting the existing land use (agricultural crop development, wooded, and meadow classifications) to a solar PV array with grassy ground cover and limited gravel access drives generally does not increase stormwater runoff that would require the need for permanent stormwater management facilities (i.e. detention / retention basins), and would reduce runoff to downstream land. This is due to the reduction in the site runoff curve number (CN), which is the key parameter that affects runoff for equivalent drainage areas. It's important to note that the drainage area is assumed to remain unchanged since the tributary area and general flow path and length would not be expected to noticeably change based on any limited grading required for array construction.

In areas where all or nearly all the proposed array is sited in land currently categorized as wooded or meadow, the proposed solar array may result in a calculated increase in stormwater runoff. For those areas it is recommended that permanent stormwater management facilities such as detention basins or retention/infiltration BMPs be provided to properly manage the increased runoff volume. The selection of detention basins with restricted outlets would need to consider the downstream receiving lands to ensure basin discharge does not negatively impact adjacent properties or watercourses. Retention basins or infiltration BMPs would need to consider the capacity of the existing soils to adequately infiltrate stormwater into the ground and soil testing by a licensed geotechnical engineer is recommended to confirm in-situ infiltration rates.

In addition to the calculation results, the American Society of Civil Engineers (ASCE) published a study – "Hydrologic Response of Solar Farms" (Cook & McCuen, 2013) – comparing the runoff effects of installing a solar array on an existing field area. The study conclusion stated that "*a model was created to simulate storm-water runoff over a land surface without panels and then with solar panels added*", and "*the addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly but not enough to require storm-water management facilities*." It's important to note that the ASCE study compared an array installed on the same land cover (grassy field, no change in CN) and did not address how a change in land use (i.e. conversion of cropland to grassy field) would also affect runoff conditions from the site.

Considering the results of Table 1, the land cover condition is the key factor determining any potential change in runoff at the site, therefore it is imperative that the proposed array be properly vegetated and maintained in a condition that will be consistent with the assumptions made in this memorandum – particularly the establishment of a meadow type condition.

Over the life of the project, it would be expected that the overall water quality from site runoff would be improved compared to agricultural use since cropland is tilled and disturbed yearly for crop production. This agricultural use leaves soils exposed and more readily eroded for sediment displacement into nearby waterways. The permanent solar array grassy meadow will minimize exposed soil and the root structure will protect soil from erosion. However, during construction it will be necessary to implement adequate temporary soil erosion and sedimentation control BMPs to protect sensitive areas and adjacent properties from the effects of erosion and sediment displacement. It should be noted that the construction activities for the solar array are not generally more disturbing than typical agricultural crop rotation and cultivation in which case there are no installed BMPs.

The conclusion that post-development runoff from the site will not result in an increase in downstream flow rates and volumes and therefore not require permanent stormwater management facilities is consistent with the conclusion from the ASCE study and is a generally accepted practice for projects of this type. During construction, effective soil erosion and sediment control (SESC) measures will be critical and shall be implemented in accordance with any required permits from the local SESC authority. Alcona County does not have stormwater standards specific to solar projects, however in our opinion the proposed conversion of land use from primarily crop development with areas of woods and meadow to vegetated solar array with narrow distributed roadways meets the intent of commonly accepted stormwater goals for post-development water quantity and quality. Coordination with the County and Township are recommended to gain acceptance of the proposed stormwater management plan for the Project prior to final design.

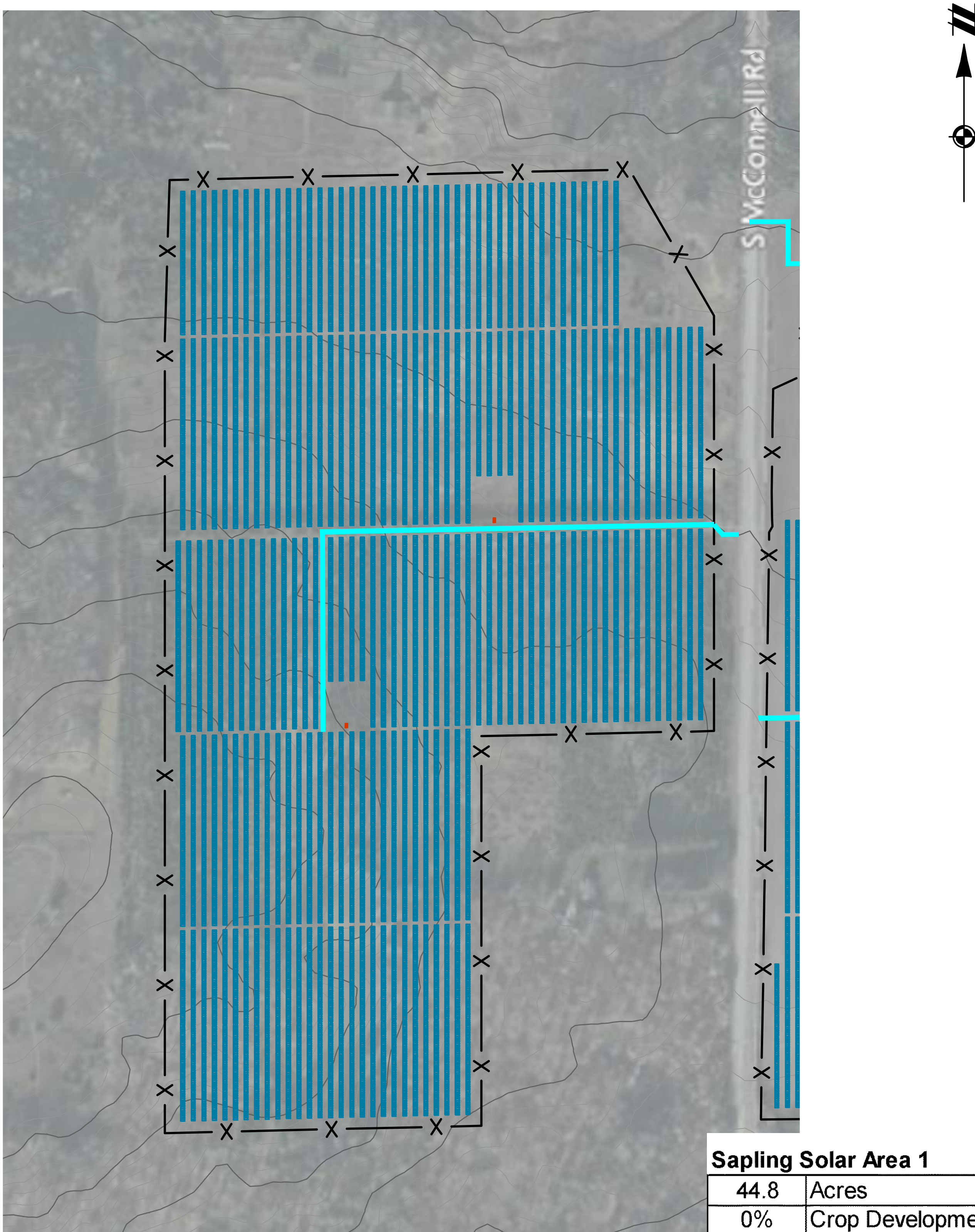
END

Appendices

- Solar Arrays 1-15 (includes only areas where non-cropland converted to solar array)
    - Site Map
    - EGLE Calculation Worksheet
    - NRCS Soils Data (Hydrologic Soil Group classification)

- EGLE CN Values ("Computing Flood Discharges for Small Ungaged Watersheds")
  Table 6.1 – Runoff curve numbers for hydrologic soil-cover complexes (AMC-II conditions)

- ASCE "Hydrologic Response of Solar Farms" (Cook & McCuen, 2013)



Sapling Solar Area 1

44.8	Acres
0%	Crop Development
100%	Woods / Meadow
59	CN Existing
63	CN Proposed
23,465	Δ Runoff, cf
Yes	Stormwater Detention

LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

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Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 1

EGLE

Fenced Array Area: **44.8** **acres**

Design Rainfall Event: **2.99** **in (10-year per Gustin Twp)**
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**		30	23.3	**0.000**	**0**
Crops	A	**0**		67	4.9	**0.580**	**0**
Woods / Meadow	B	**1,581,228**	36.30	55	8.2	**0.192**	**25,321**
Crops	B	**0**		78	2.8	**1.122**	**0**
Woods / Meadow	D	**370,260**	8.50	77	3.0	**1.064**	**32,833**
Crops	D	**0**		89	1.2	**1.891**	**0**
TOTAL:	**N/A**	**1,951,488**	**44.80**			**0.36**	**58,154**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**58,545**	1.34	98	0.2	**2.758**	**13,457**
Grassland / Meadow	A	**0**		30	23.3	**0.000**	**0**
Grassland / Meadow	B	**1,533,791**	35.21	58	7.2	**0.271**	**34,590**
Grassland / Meadow	D	**359,152**	8.25	78	2.8	**1.122**	**33,572**
TOTAL:		**1,951,488**	**44.80**			**0.50**	**81,619**

Runoff Volume Increase (ft3): 23,465

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

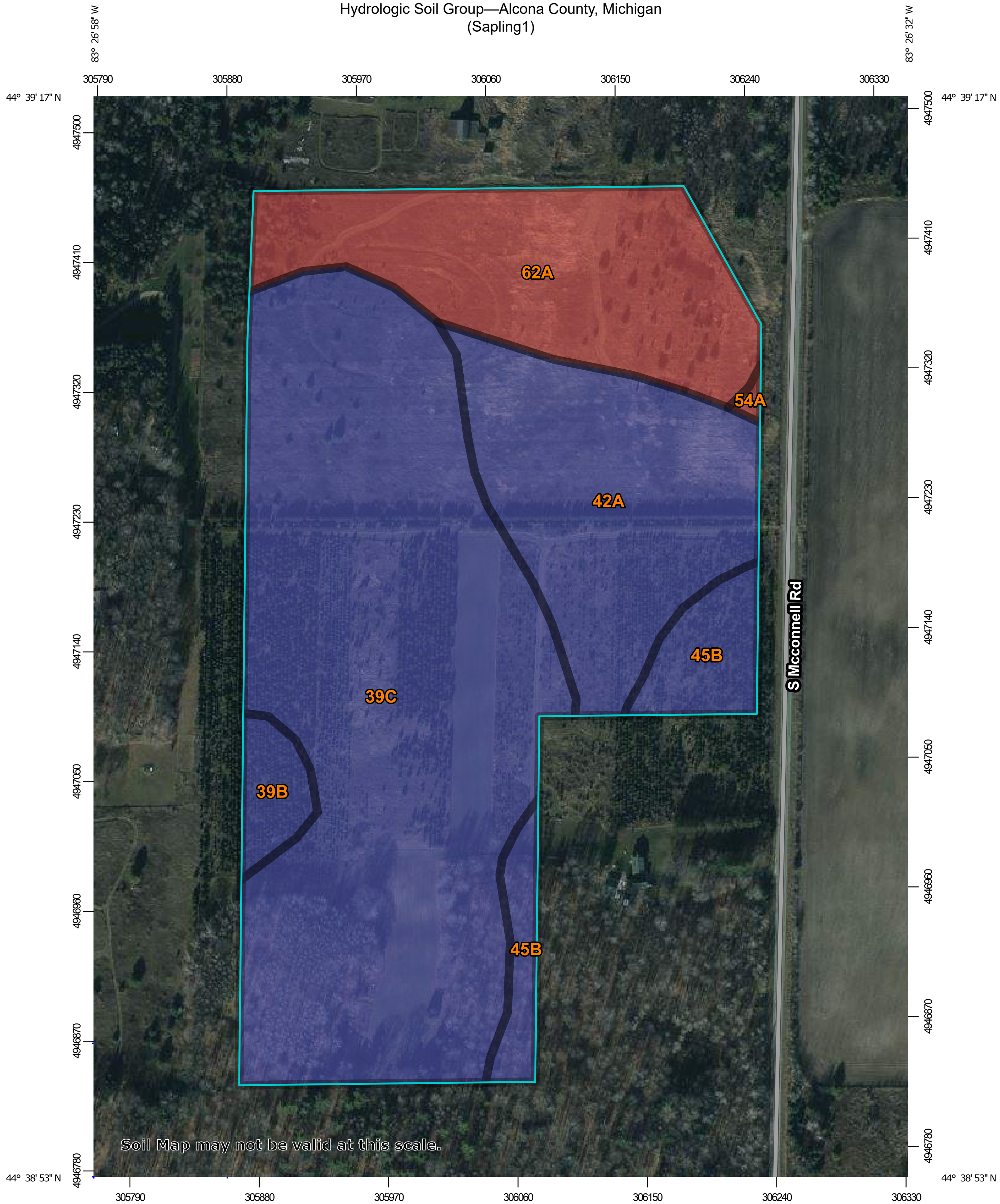
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling1)



Map Scale: 1:3,650 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 50, 100, 200, 300

Feet: 0, 150, 300, 600, 900

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
39B	Glennie loamy sand, 0 to 6 percent slopes	B	1.0	2.3%
39C	Glennie loamy sand, 6 to 12 percent slopes	B	24.1	53.9%
42A	Killmaster sandy loam, 0 to 3 percent slopes	B	8.5	19.0%
45B	Hoist sandy loam, 0 to 6 percent slopes	B	2.6	5.9%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	0.1	0.2%
62A	Allendale loamy sand, 0 to 3 percent slopes	D	8.4	18.7%
Totals for Area of Interest			**44.8**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

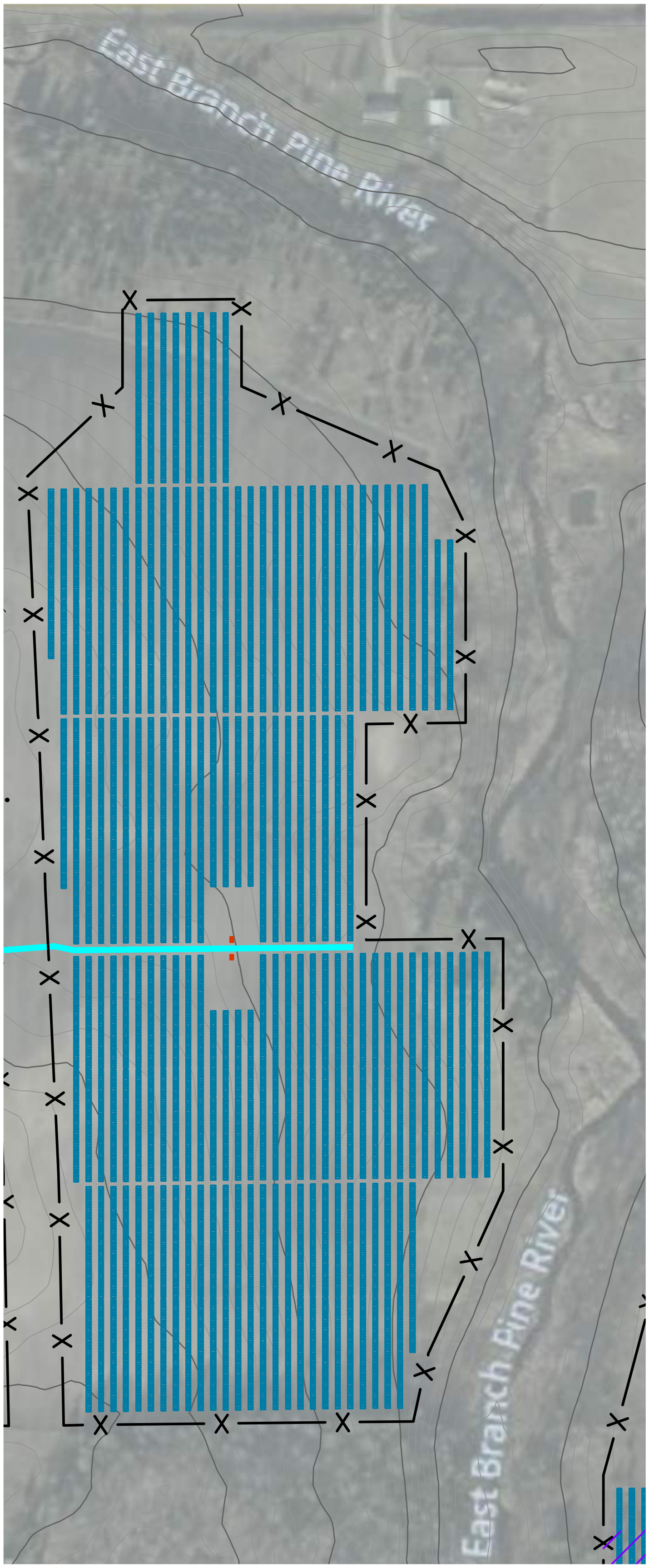
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



Sapling Solar Area 2

31.3	Acres
88%	Crop Development
12%	Woods / Meadow
85	CN Existing
74	CN Proposed
-71,999	Δ Runoff, cf
No	Stormwater Detention

LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

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Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 2

Fenced Array Area: 31.3 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**0**	0.00	55	8.2	**0.192**	**0**
Crops	B	**339,768**	7.80	78	2.8	**1.122**	**31,760**
Woods / Meadow	D	**165,528**	3.80	77	3.0	**1.064**	**14,678**
Crops	D	**858,132**	19.70	89	1.2	**1.891**	**135,212**
TOTAL:	**N/A**	**1,363,428**	**31.30**			**1.60**	**181,651**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**40,903**	0.94	98	0.2	**2.758**	**9,402**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**329,575**	7.57	58	7.2	**0.271**	**7,433**
Grassland / Meadow	D	**992,950**	22.80	78	2.8	**1.122**	**92,817**
TOTAL:		**1,363,428**	**31.30**			**0.97**	**109,652**

Runoff Volume Increase (ft3): -71,999

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

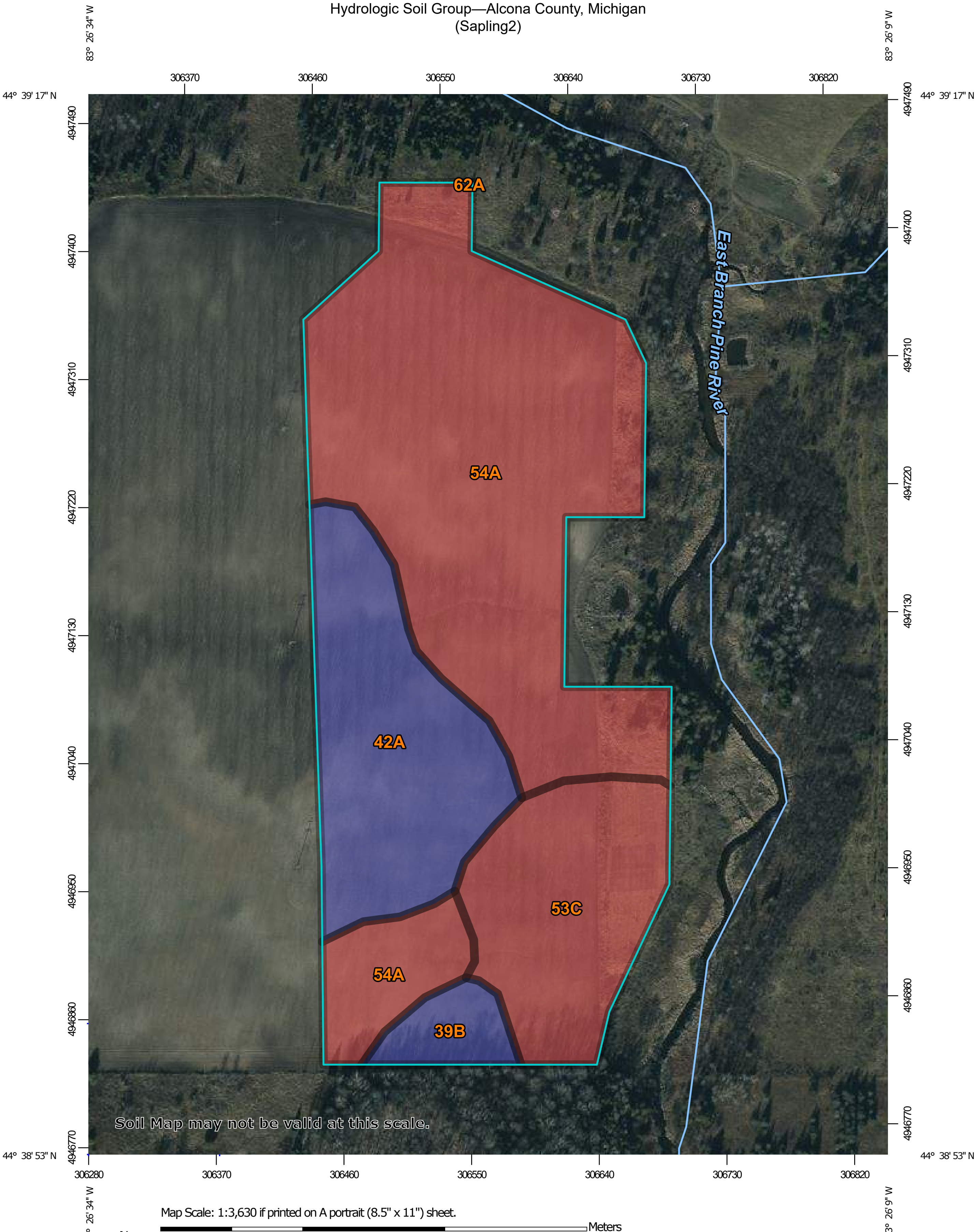
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling2)



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Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
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Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

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Please rely on the bar scale on each map sheet for map measurements.

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Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
39B	Glennie loamy sand, 0 to 6 percent slopes	B	1.1	3.5%
42A	Killmaster sandy loam, 0 to 3 percent slopes	B	6.7	21.4%
53C	Negwegon silt loam, 6 to 12 percent slopes	D	5.5	17.4%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	18.1	57.7%
62A	Allendale loamy sand, 0 to 3 percent slopes	D	0.0	0.0%
Totals for Area of Interest			**31.3**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

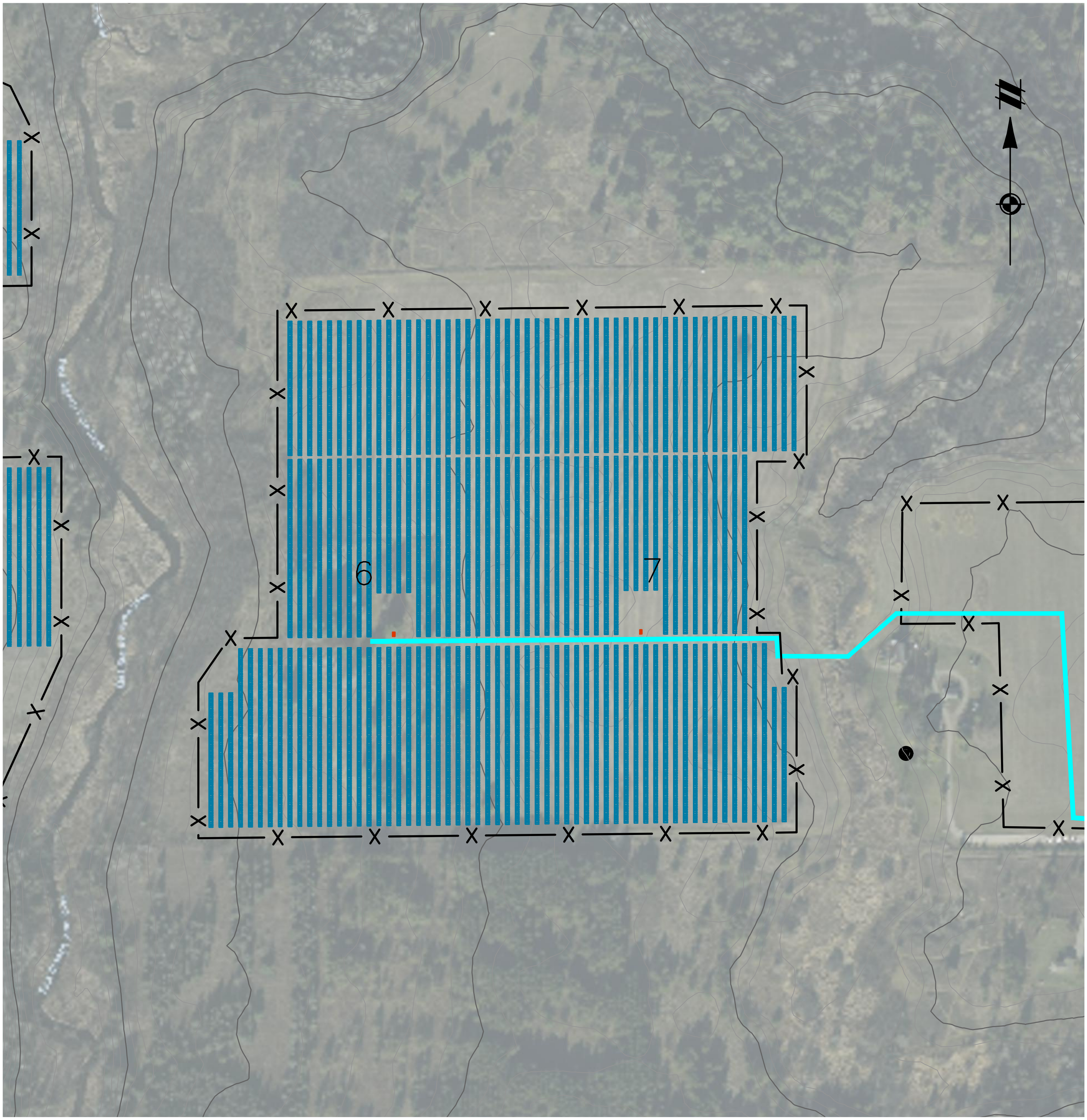
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



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LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

Sapling Solar Area 3

34	Acres
72%	Crop Development
28%	Woods / Meadow
80	CN Existing
69	CN Proposed
-63,379	Δ Runoff, cf
No	Stormwater Detention

Calculations for Storm Water Runoff Volume Control

SITE NAME: **Sapling Solar Area 3**

Fenced Array Area: **34** **acres**

Design Rainfall Event: **2.99** **in (10-year per Gustin Twp)**
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P-0.2S)^2}{(P+0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**21,780**	0.50	55	8.2	**0.192**	**349**
Crops	B	**727,452**	16.70	78	2.8	**1.122**	**67,999**
Woods / Meadow	D	**396,396**	9.10	77	3.0	**1.064**	**35,151**
Crops	D	**335,412**	7.70	89	1.2	**1.891**	**52,849**
TOTAL:	**N/A**	**1,481,040**	**34.00**			**1.27**	**156,349**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**44,431**	1.02	98	0.2	**2.758**	**10,213**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**726,581**	16.68	58	7.2	**0.271**	**16,386**
Grassland / Meadow	D	**710,028**	16.30	78	2.8	**1.122**	**66,371**
TOTAL:		**1,481,040**	**34.00**			**0.75**	**92,970**

Runoff Volume Increase (ft3): **-63,379**

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

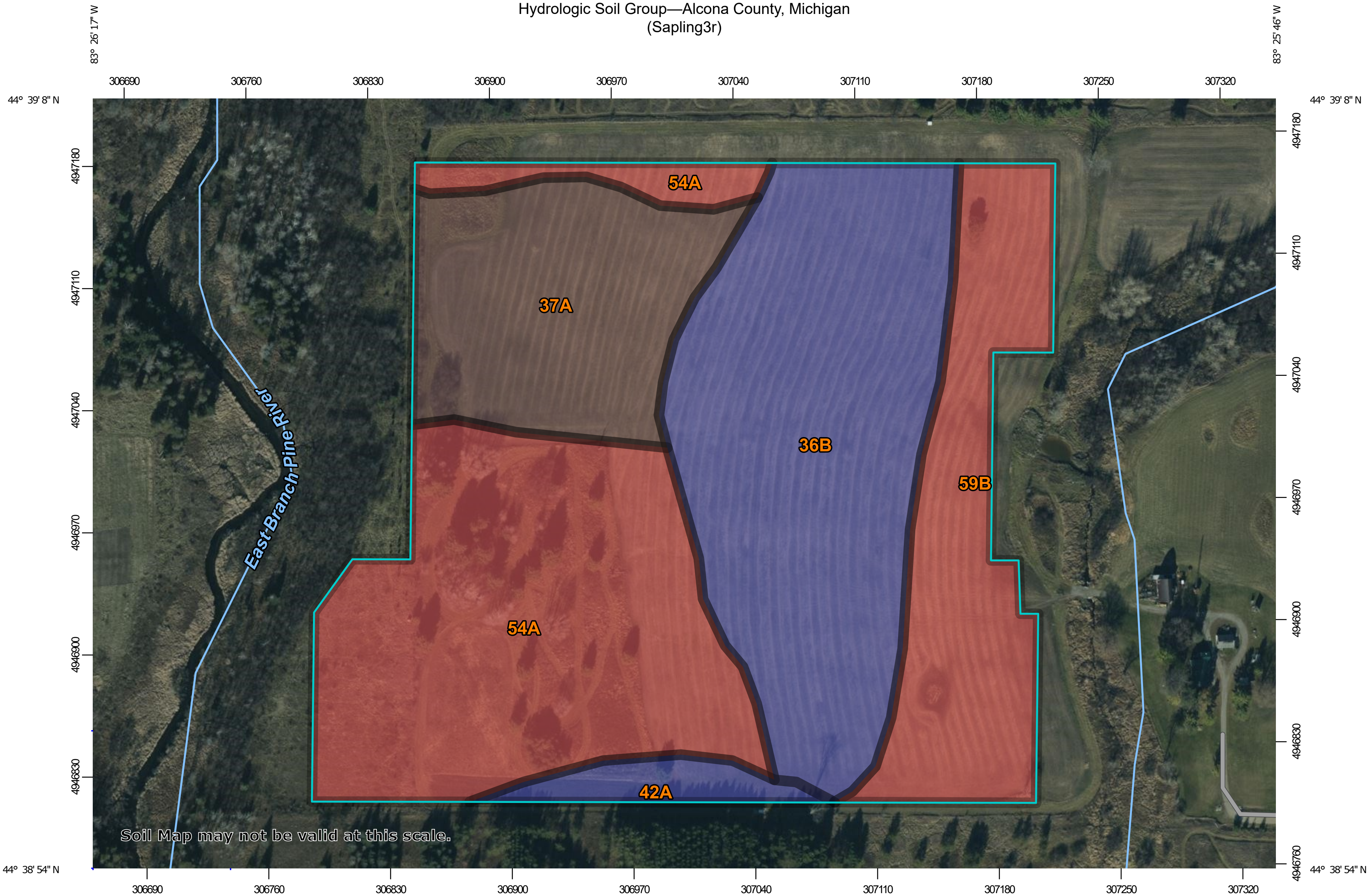
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

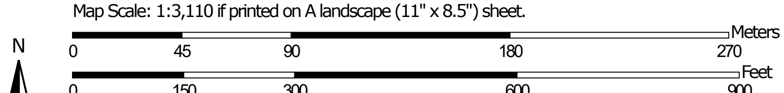
Where:
- P = 100-Year, 24-Hour Rainfall (in)
- S = 1000/ CN - 10
- CN = Curve Number
- Q = Runoff (in)
- Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling3r)



Map Scale: 1:3,110 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
36B	Annalake loamy very fine sand, 0 to 6 percent slopes	B	10.7	31.6%
37A	Richter loamy fine sand, 0 to 3 percent slopes	B/D	5.6	16.4%
42A	Killmaster sandy loam, 0 to 3 percent slopes	B	0.9	2.6%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	11.2	33.0%
59B	Algonquin-Springport complex, 0 to 6 percent slopes	D	5.5	16.3%
Totals for Area of Interest			**34.0**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

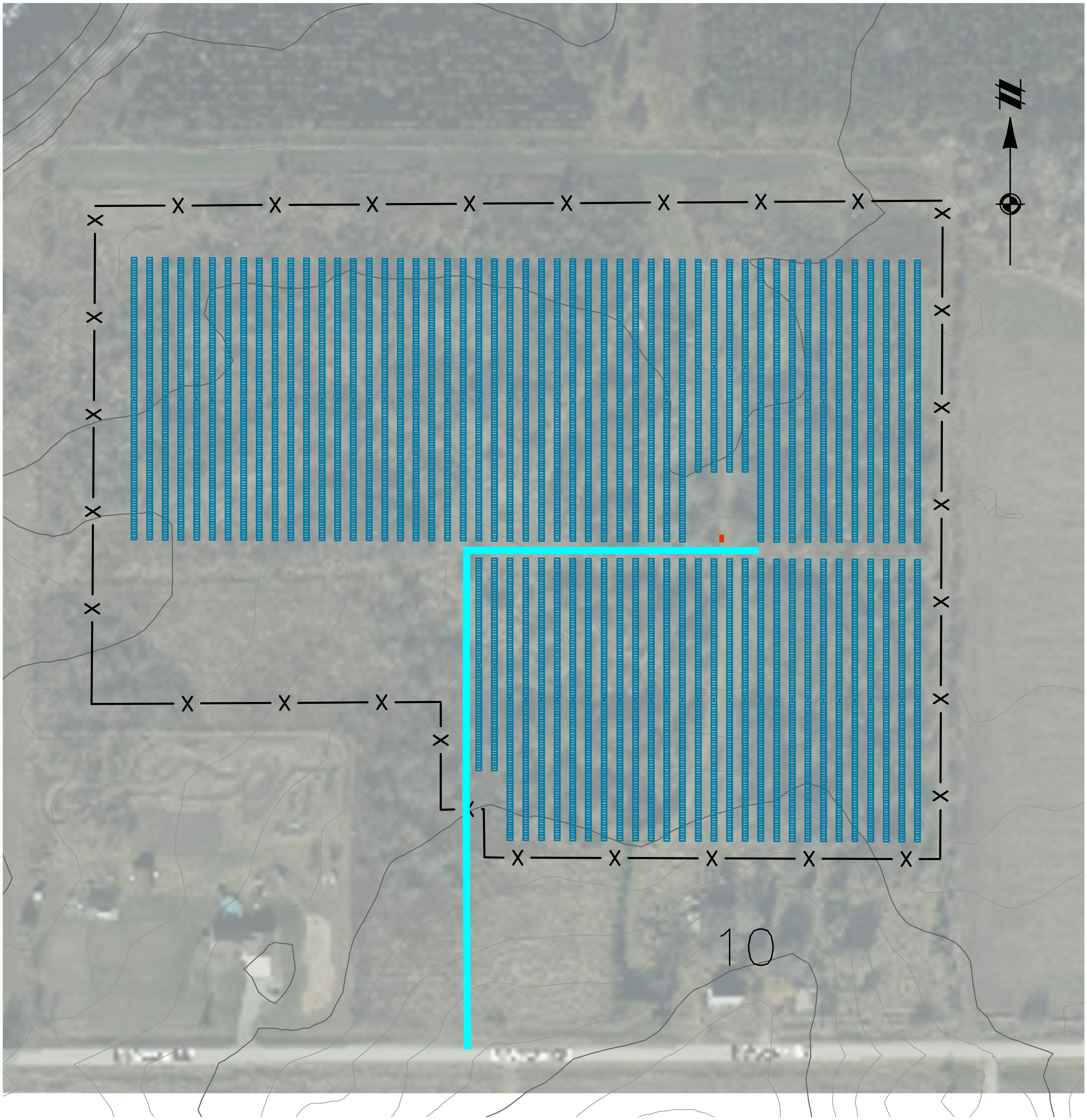
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



Sapling Solar Area 3A

23.9	Acres
0%	Crop Development
100%	Woods / Meadow
55	CN Existing
59	CN Proposed
12,926	Δ Runoff, cf
Yes	Stormwater Detention

LEGEND

SECURITY FENCE

ACCESS DRIVE

PV TRACKER

EQUIPMENT PAD

ATWELL

866.850.4200 www.atwell-group.com

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 3A

Fenced Array Area: 23.9 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**1,028,016**	23.60	55	8.2	**0.192**	**16,462**
Crops	B	**4,356**	0.10	78	2.8	**1.122**	**407**
Woods / Meadow	D	**8,712**	0.20	77	3.0	**1.064**	**773**
Crops	D	**0**	0.00	89	1.2	**1.891**	**0**
TOTAL:	**N/A**	**1,041,084**	**23.90**			**0.20**	**17,642**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**31,363**	0.72	98	0.2	**2.758**	**7,209**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**1,001,444**	22.99	58	7.2	**0.271**	**22,585**
Grassland / Meadow	D	**8,276**	0.19	78	2.8	**1.122**	**774**
TOTAL:		**1,041,084**	**23.90**			**0.35**	**30,567**

Runoff Volume Increase (ft3): 12,926

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

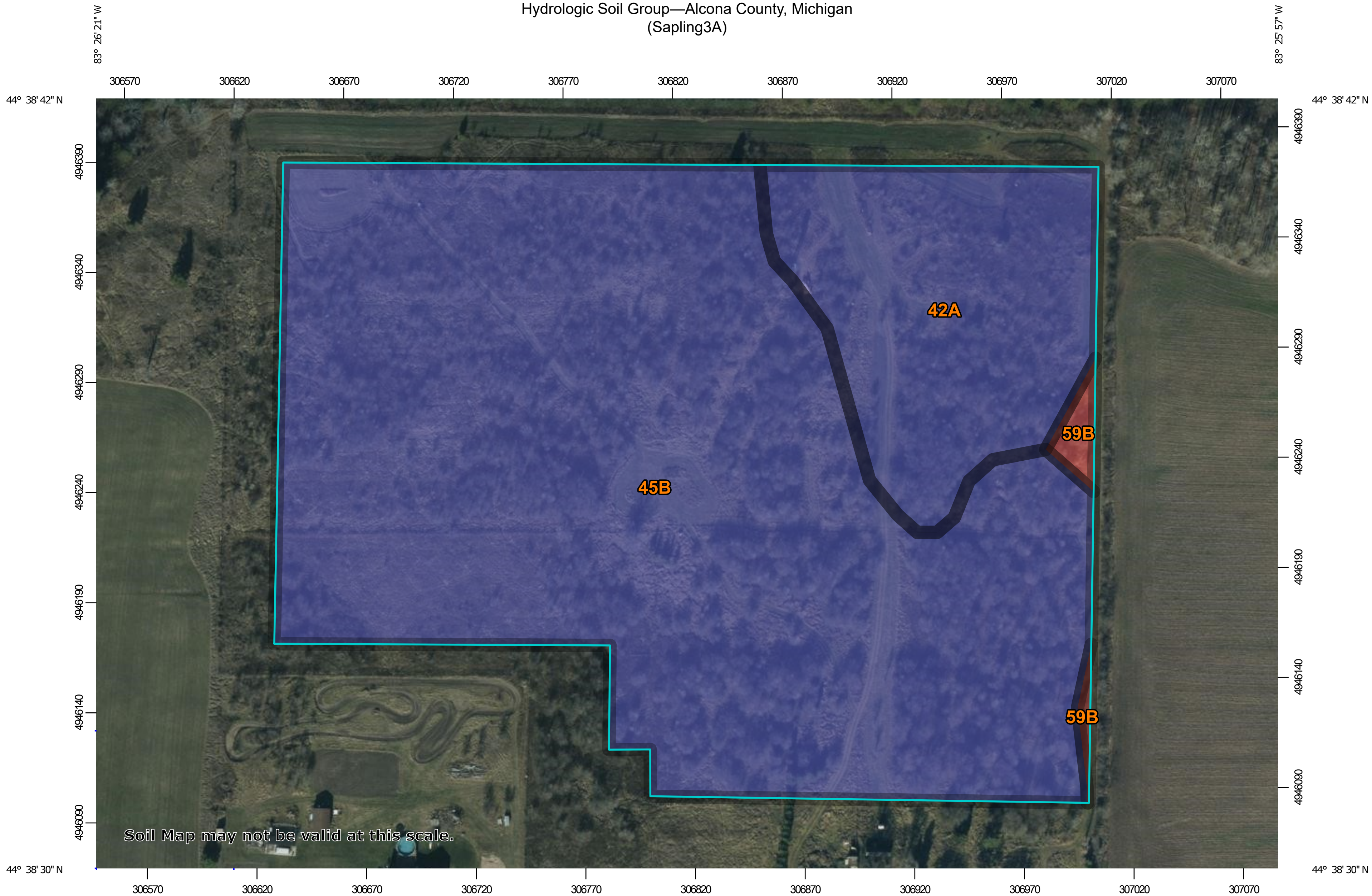
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling3A)



Map Scale: 1:2,460 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0, 35, 70, 140, 210

Feet: 0, 100, 200, 400, 600

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
42A	Killmaster sandy loam, 0 to 3 percent slopes	B	4.5	18.8%
45B	Hoist sandy loam, 0 to 6 percent slopes	B	19.2	80.3%
59B	Algonquin-Springport complex, 0 to 6 percent slopes	D	0.2	0.9%
Totals for Area of Interest			**23.9**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

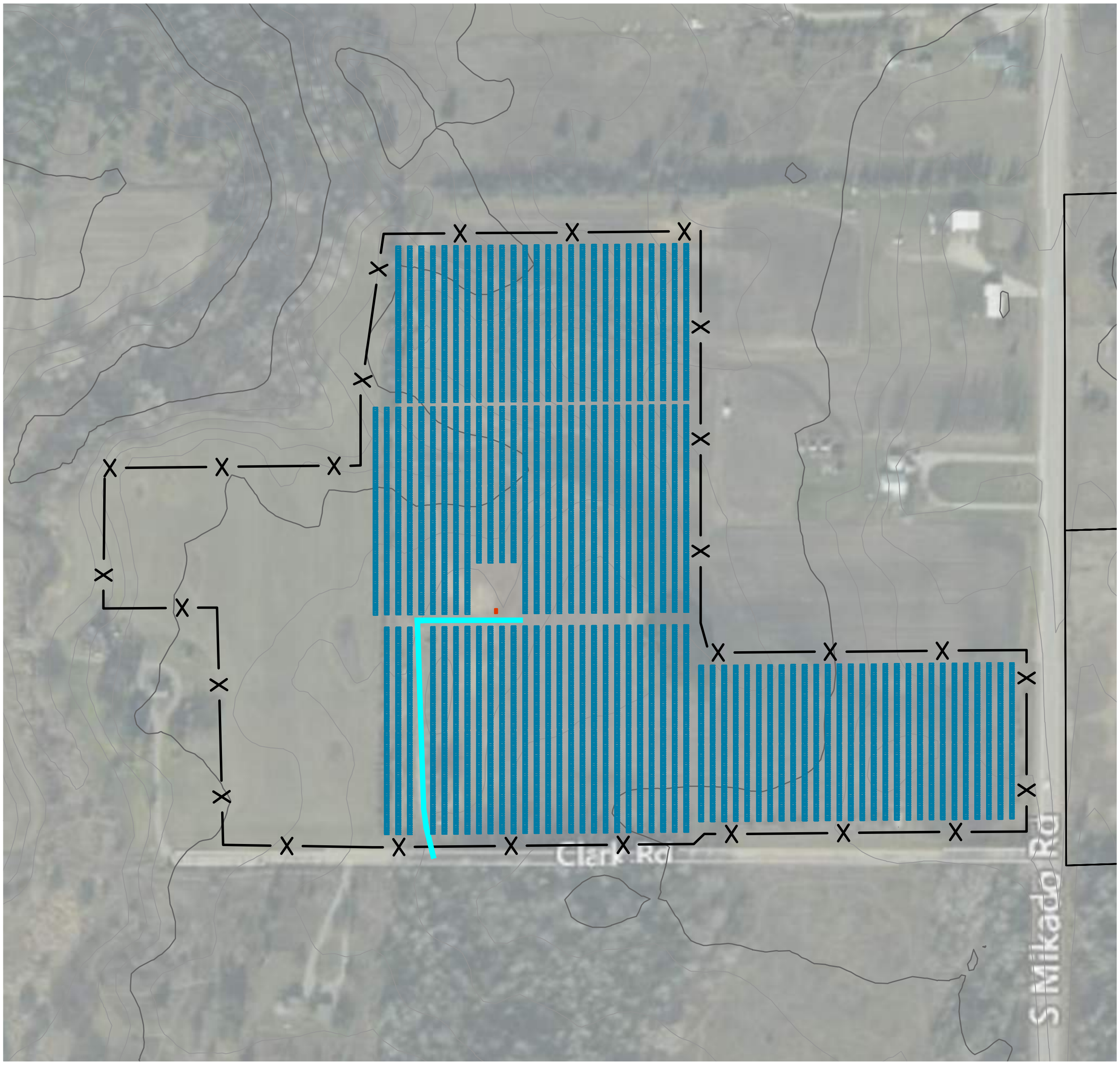
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



Sapling Solar Area 4

29.7	Acres
91%	Crop Development
9%	Woods / Meadow
88	CN Existing
79	CN Proposed
-69,819	Δ Runoff, cf
No	Stormwater Detention

LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

ATWELL
866.850.4200 www.atwell-group.com

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 4

Fenced Array Area: 29.7 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**0**	0.00	55	8.2	**0.192**	**0**
Crops	B	**0**	0.00	78	2.8	**1.122**	**0**
Woods / Meadow	D	**113,256**	2.60	77	3.0	**1.064**	**10,043**
Crops	D	**1,180,476**	27.10	89	1.2	**1.891**	**186,003**
TOTAL:	**N/A**	**1,293,732**	**29.70**			**1.82**	**196,046**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**38,812**	0.89	98	0.2	**2.758**	**8,921**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**0**	0.00	58	7.2	**0.271**	**0**
Grassland / Meadow	D	**1,254,920**	28.81	78	2.8	**1.122**	**117,305**
TOTAL:		**1,293,732**	**29.70**			**1.17**	**126,227**

Runoff Volume Increase (ft3): -69,819

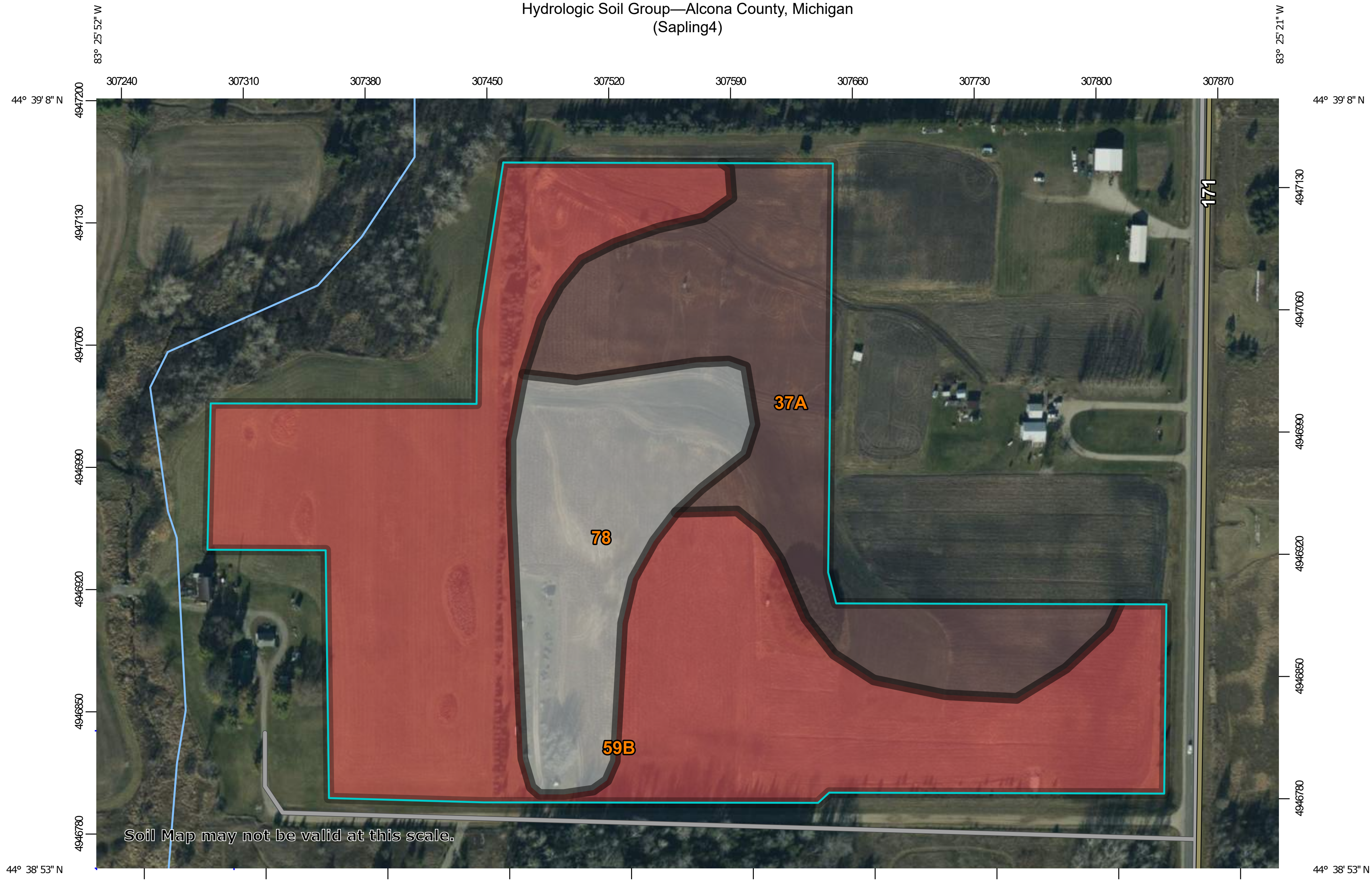
Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)



Map Scale: 1:3,110 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 45, 90, 180, 270

Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
37A	Richter loamy fine sand, 0 to 3 percent slopes	B/D	7.0	23.7%
59B	Algonquin-Springport complex, 0 to 6 percent slopes	D	17.7	59.4%
78	Pits, borrow		5.0	16.9%
Totals for Area of Interest			**29.7**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

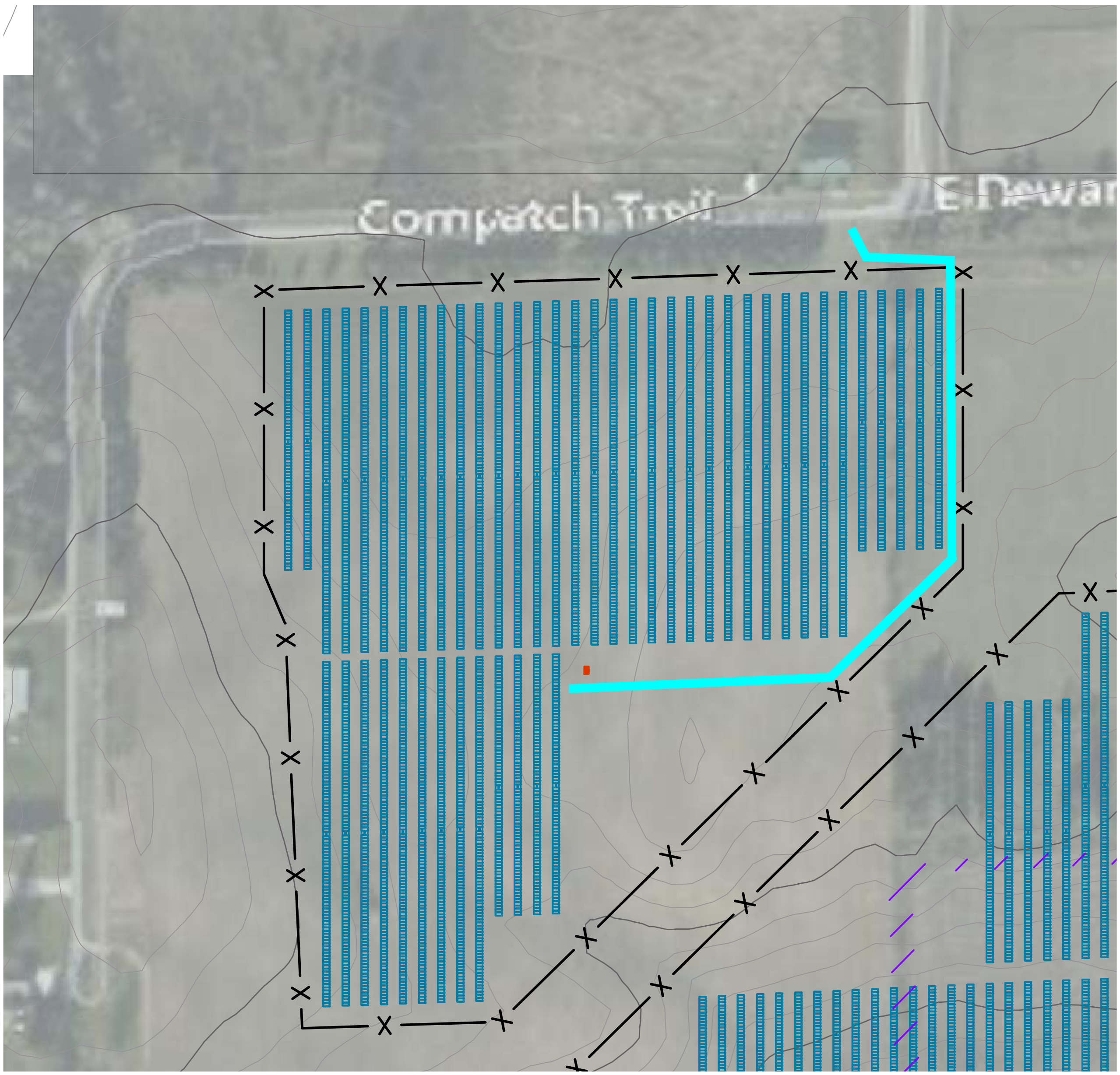
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



LEGEND

SECURITY FENCE

ACCESS DRIVE

PV TRACKER

EQUIPMENT PAD

Sapling Solar Area 5

12.9	Acres
94%	Crop Development
6%	Woods / Meadow
88	CN Existing
79	CN Proposed
-31,314	Δ Runoff, cf
No	Stormwater Detention

ATWELL
866.850.4200 www.atwell-group.com

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 5

Fenced Array Area: 12.9 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**0**	0.00	55	8.2	**0.192**	**0**
Crops	B	**0**	0.00	78	2.8	**1.122**	**0**
Woods / Meadow	D	**34,848**	0.80	77	3.0	**1.064**	**3,090**
Crops	D	**527,076**	12.10	89	1.2	**1.891**	**83,049**
TOTAL:	**N/A**	**561,924**	**12.90**			**1.84**	**86,139**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**16,858**	0.39	98	0.2	**2.758**	**3,875**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**0**	0.00	58	7.2	**0.271**	**0**
Grassland / Meadow	D	**545,066**	12.51	78	2.8	**1.122**	**50,951**
TOTAL:		**561,924**	**12.90**			**1.17**	**54,826**

Runoff Volume Increase (ft3): -31,314

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling5)

Map Scale: 1:1,960 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0, 25, 50, 100, 150

Feet: 0, 50, 100, 200, 300

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
53B	Negwegon silt loam, 2 to 6 percent slopes	D	3.0	23.2%
53C	Negwegon silt loam, 6 to 12 percent slopes	D	5.2	40.1%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	4.7	36.7%
Totals for Area of Interest			**12.9**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

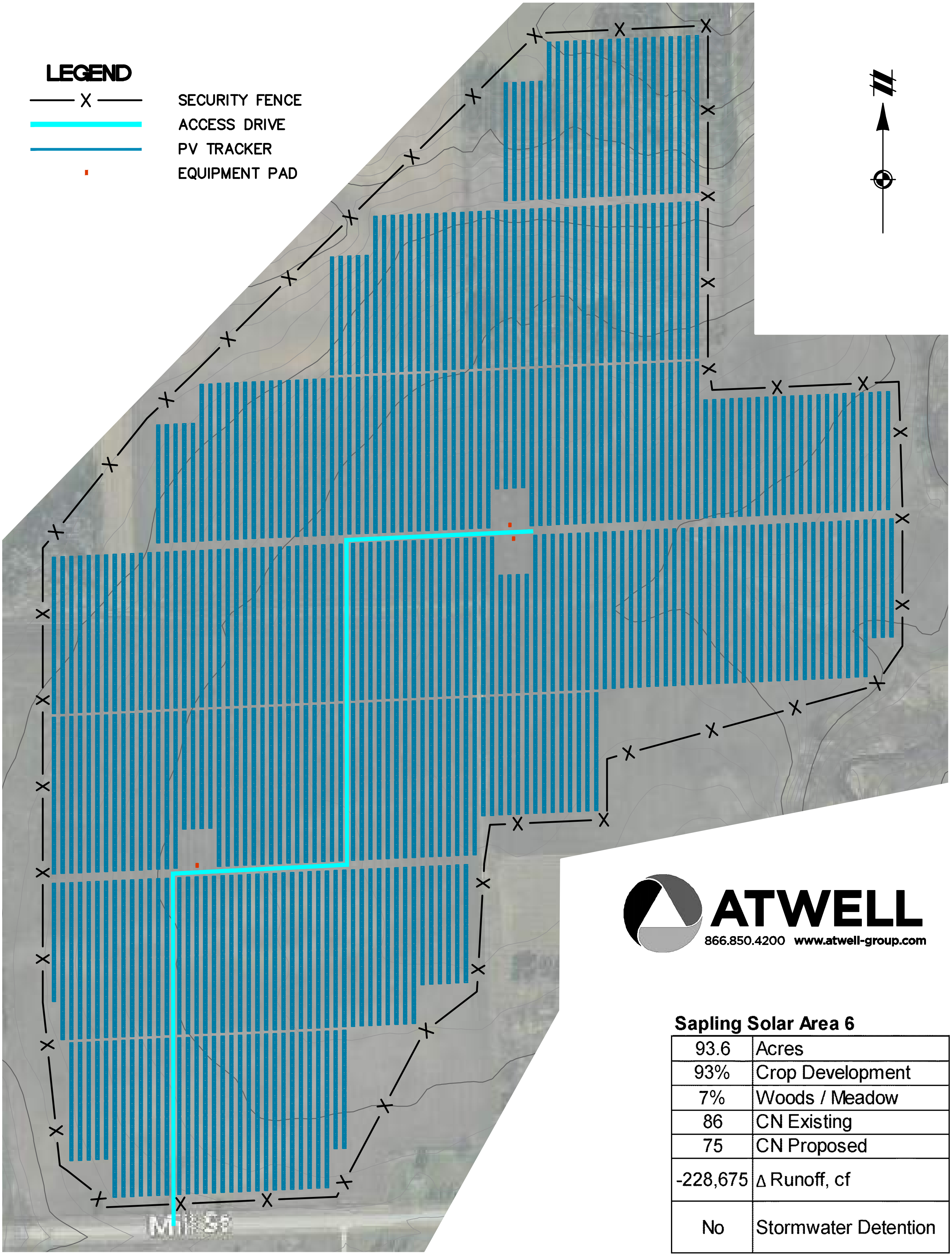
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



ATWELL
866.850.4200 www.atwell-group.com

Sapling Solar Area 6

93.6	Acres
93%	Crop Development
7%	Woods / Meadow
86	CN Existing
75	CN Proposed
-228,675	Δ Runoff, cf
No	Stormwater Detention

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 6

Fenced Array Area: 93.6 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**60,984**	1.40	55	8.2	**0.192**	**977**
Crops	B	**614,196**	14.10	78	2.8	**1.122**	**57,413**
Woods / Meadow	D	**209,088**	4.80	77	3.0	**1.064**	**18,541**
Crops	D	**3,192,948**	73.30	89	1.2	**1.891**	**503,099**
TOTAL:	**N/A**	**4,077,216**	**93.60**			**1.71**	**580,030**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**122,316**	2.81	98	0.2	**2.758**	**28,116**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**654,925**	15.04	58	7.2	**0.271**	**14,770**
Grassland / Meadow	D	**3,299,975**	75.76	78	2.8	**1.122**	**308,469**
TOTAL:		**4,077,216**	**93.60**			**1.03**	**351,355**

Runoff Volume Increase (ft3): -228,675

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

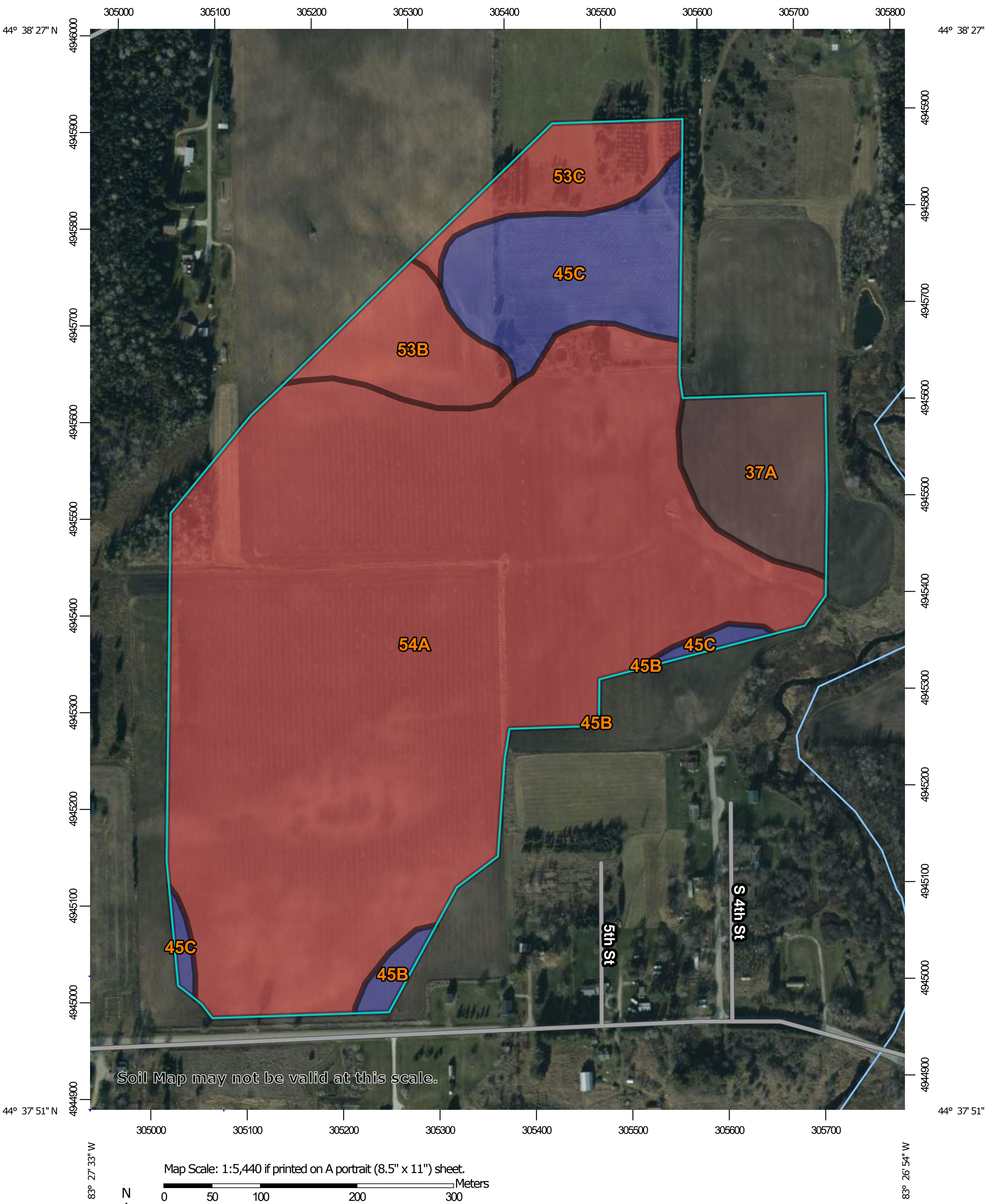
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling6)



Map Scale: 1:5,440 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 250 500 1000 1500

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

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Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
37A	Richter loamy fine sand, 0 to 3 percent slopes	B/D	5.7	6.1%
45B	Hoist sandy loam, 0 to 6 percent slopes	B	0.8	0.8%
45C	Hoist sandy loam, 6 to 12 percent slopes	B	9.0	9.7%
53B	Negwegon silt loam, 2 to 6 percent slopes	D	4.6	4.9%
53C	Negwegon silt loam, 6 to 12 percent slopes	D	4.2	4.5%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	69.3	74.0%
Totals for Area of Interest			**93.6**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

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Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

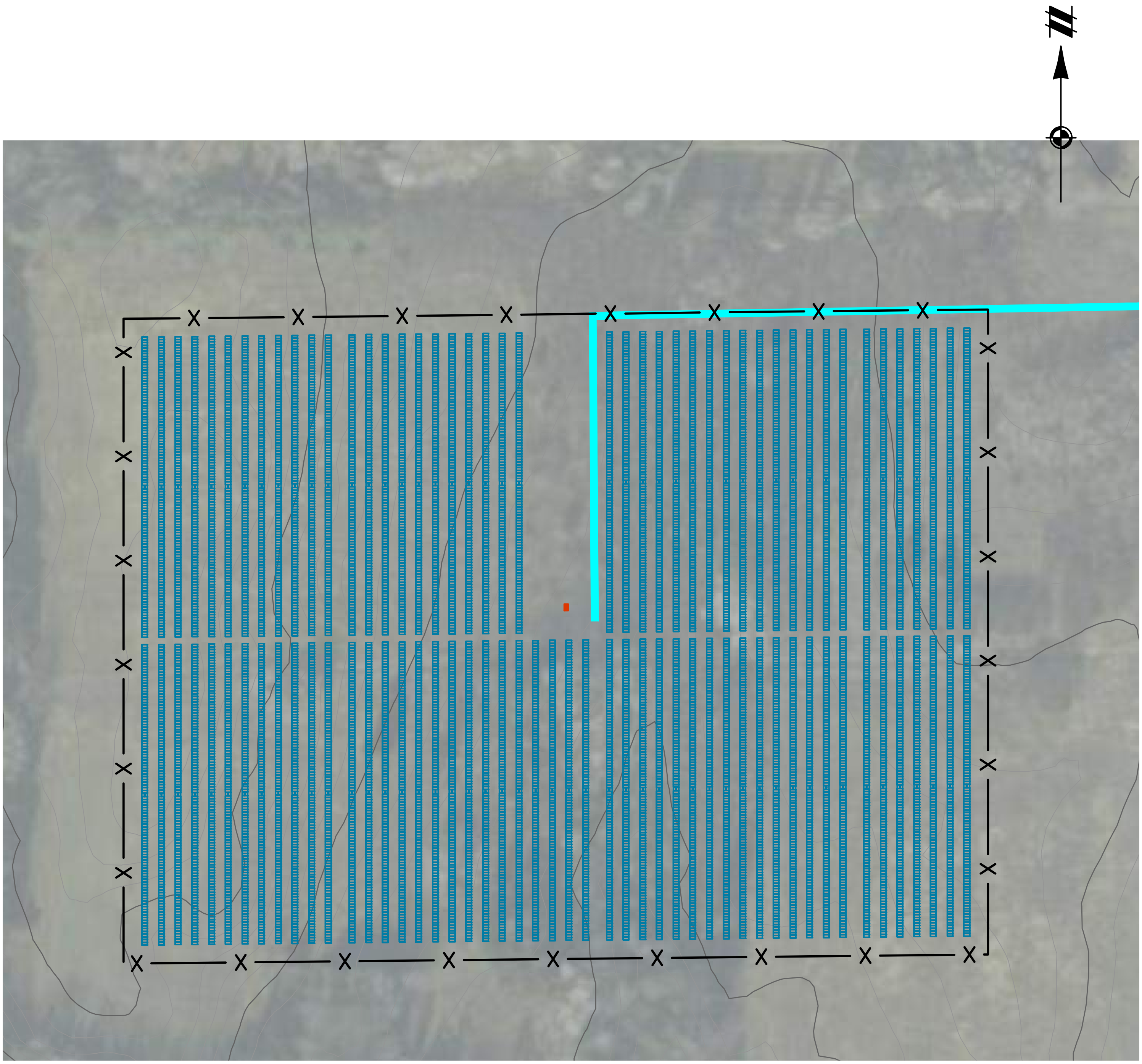
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



Sapling Solar Area 7

23.5	Acres
0%	Crop Development
100%	Woods / Meadow
71	CN Existing
73	CN Proposed
10,180	Δ Runoff, cf
Yes	Stormwater Detention

LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

ATWELL
866.850.4200 www.atwell-group.com

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 7

Fenced Array Area: 23.5 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**278,784**	6.40	55	8.2	**0.192**	**4,464**
Crops	B	**0**	0.00	78	2.8	**1.122**	**0**
Woods / Meadow	D	**744,876**	17.10	77	3.0	**1.064**	**66,053**
Crops	D	**0**	0.00	89	1.2	**1.891**	**0**
TOTAL:	**N/A**	**1,023,660**	**23.50**			**0.83**	**70,517**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**30,710**	0.71	98	0.2	**2.758**	**7,059**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**270,420**	6.21	58	7.2	**0.271**	**6,099**
Grassland / Meadow	D	**722,530**	16.59	78	2.8	**1.122**	**67,539**
TOTAL:		**1,023,660**	**23.50**			**0.95**	**80,697**

Runoff Volume Increase (ft3): 10,180

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

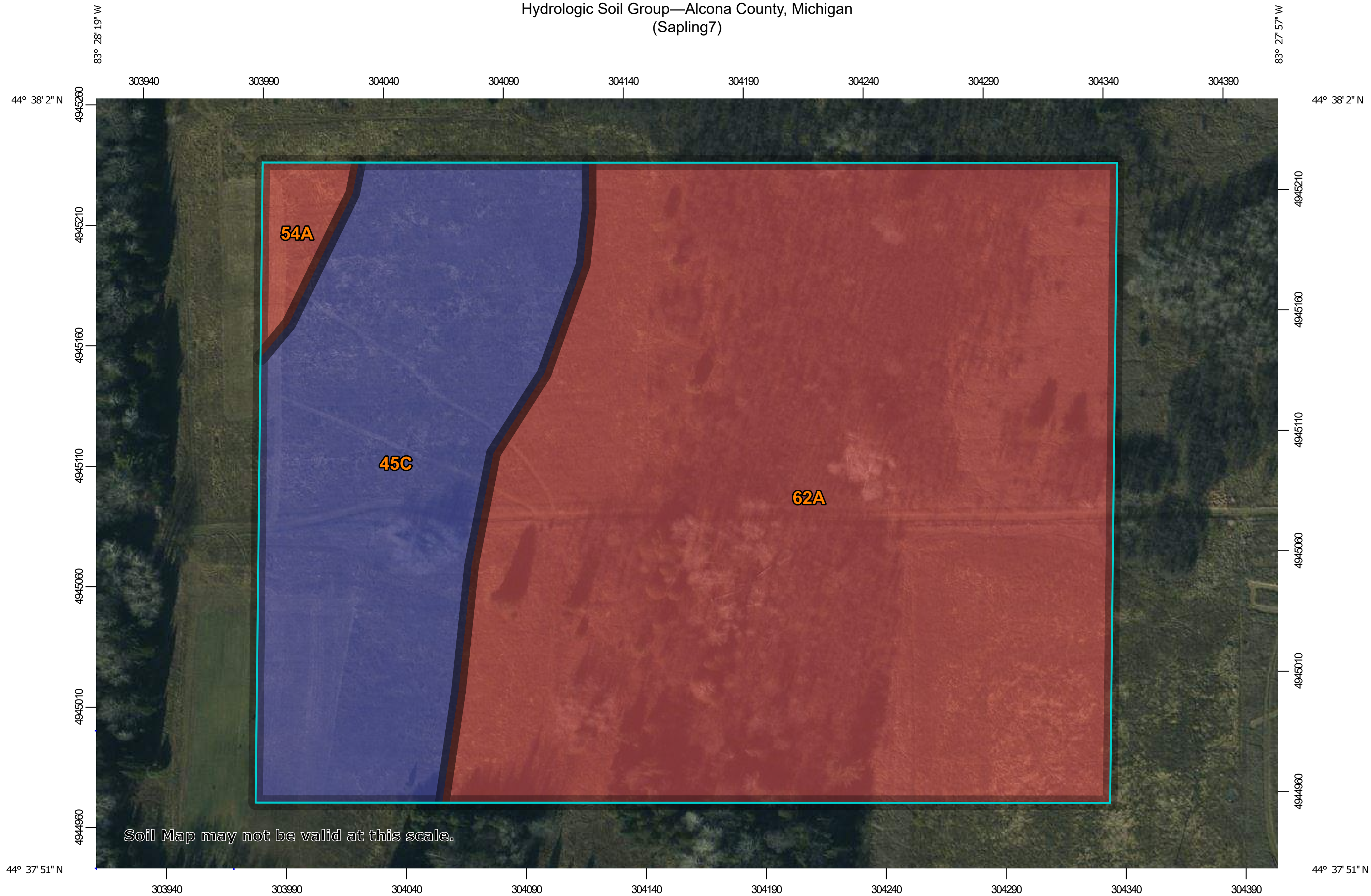
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

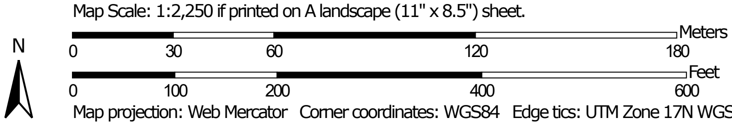
Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling7)



Map Scale: 1:2,250 if printed on A landscape (11" x 8.5") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

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Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

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Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
45C	Hoist sandy loam, 6 to 12 percent slopes	B	6.4	27.2%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	0.5	2.0%
62A	Allendale loamy sand, 0 to 3 percent slopes	D	16.6	70.8%
Totals for Area of Interest			**23.5**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Sapling Solar Area 8

14.4	Acres
79%	Crop Development
21%	Woods / Meadow
86	CN Existing
77	CN Proposed
-28,817	Δ Runoff, cf
No	Stormwater Detention

LEGEND

SECURITY FENCE

ACCESS DRIVE

PV TRACKER

EQUIPMENT PAD

ATWELL

866.850.4200 www.atwell-group.com

Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 8

Fenced Array Area: 14.4 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**0**	0.00	55	8.2	**0.192**	**0**
Crops	B	**39,204**	0.90	78	2.8	**1.122**	**3,665**
Woods / Meadow	D	**130,680**	3.00	77	3.0	**1.064**	**11,588**
Crops	D	**457,380**	10.50	89	1.2	**1.891**	**72,067**
TOTAL:	**N/A**	**627,264**	**14.40**			**1.67**	**87,320**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**18,818**	0.43	98	0.2	**2.758**	**4,325**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**38,028**	0.87	58	7.2	**0.271**	**858**
Grassland / Meadow	D	**570,418**	13.10	78	2.8	**1.122**	**53,321**
TOTAL:		**627,264**	**14.40**			**1.12**	**58,504**

Runoff Volume Increase (ft3): -28,817

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

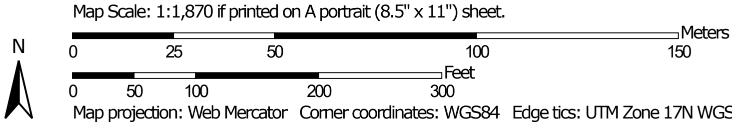
2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling8)

Map Scale: 1:1,870 if printed on A portrait (8.5" x 11") sheet.



Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
- Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

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Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

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Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
45C	Hoist sandy loam, 6 to 12 percent slopes	B	0.9	5.9%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	13.5	94.1%
Totals for Area of Interest			**14.4**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Sapling Solar Area 9

48.2	Acres
43%	Crop Development
57%	Woods / Meadow
68	CN Existing
62	CN Proposed
-43,680	Δ Runoff, cf
No	Stormwater Detention

LEGEND

- SECURITY FENCE
- ACCESS DRIVE
- PV TRACKER
- EQUIPMENT PAD

ATWELL
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Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 9

Fenced Array Area: 48.2 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**967,032**	22.20	55	8.2	**0.192**	**15,485**
Crops	B	**779,724**	17.90	78	2.8	**1.122**	**72,886**
Woods / Meadow	D	**226,512**	5.20	77	3.0	**1.064**	**20,086**
Crops	D	**126,324**	2.90	89	1.2	**1.891**	**19,904**
TOTAL:	**N/A**	**2,099,592**	**48.20**			**0.73**	**128,362**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**62,988**	1.45	98	0.2	**2.758**	**14,478**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**1,694,353**	38.90	58	7.2	**0.271**	**38,211**
Grassland / Meadow	D	**342,251**	7.86	78	2.8	**1.122**	**31,992**
TOTAL:		**2,099,592**	**48.20**			**0.48**	**84,682**

Runoff Volume Increase (ft3): -43,680

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

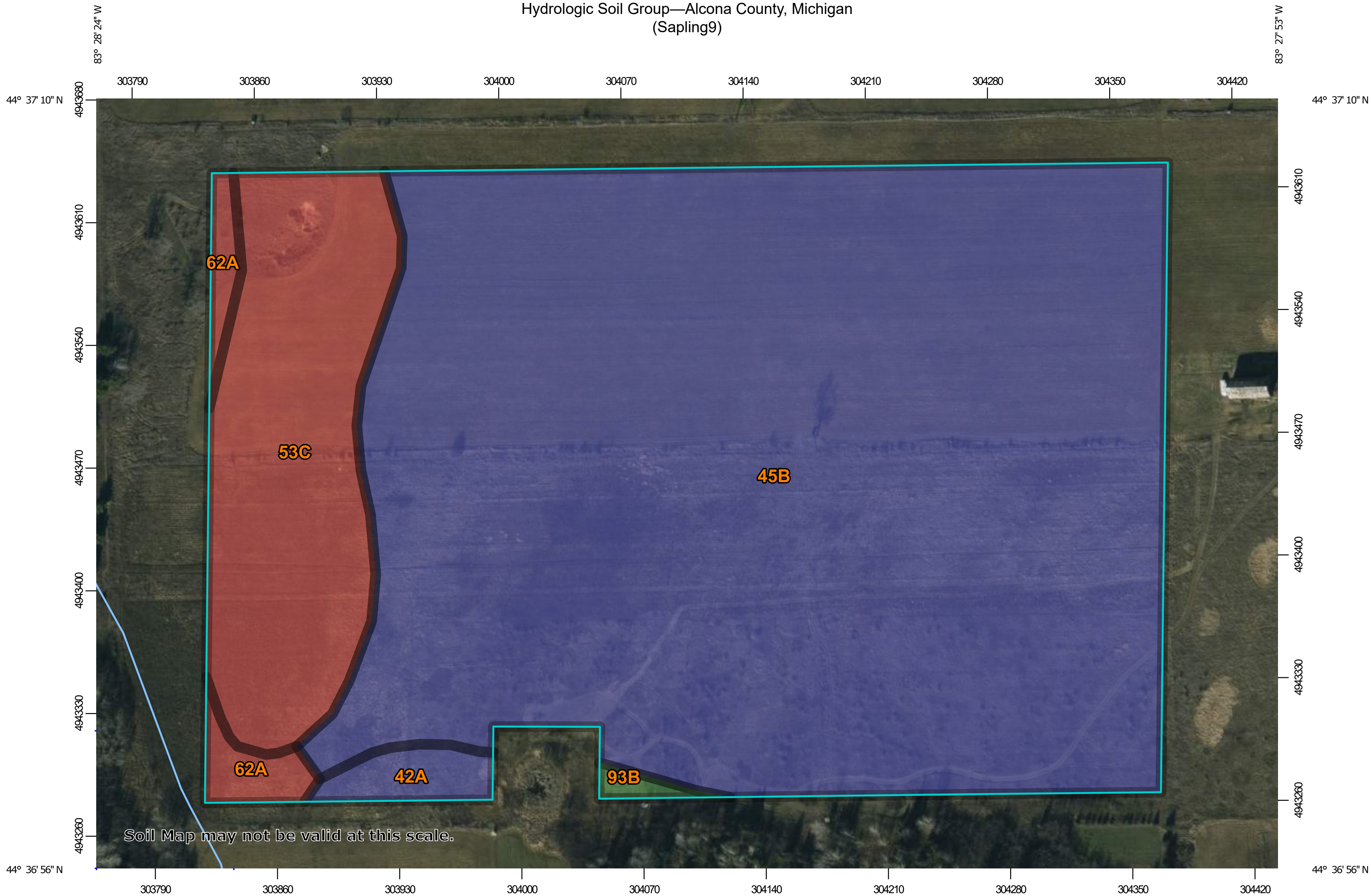
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling9)



Map Scale: 1:3,090 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 45, 90, 180, 270

Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
42A	Killmaster sandy loam, 0 to 3 percent slopes	B	0.7	1.4%
45B	Hoist sandy loam, 0 to 6 percent slopes	B	39.4	81.7%
53C	Negwegon silt loam, 6 to 12 percent slopes	D	7.1	14.6%
62A	Allendale loamy sand, 0 to 3 percent slopes	D	0.9	1.9%
93B	Tacoda-Wakeley complex, 0 to 4 percent slopes	A/D	0.2	0.4%
Totals for Area of Interest			**48.2**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

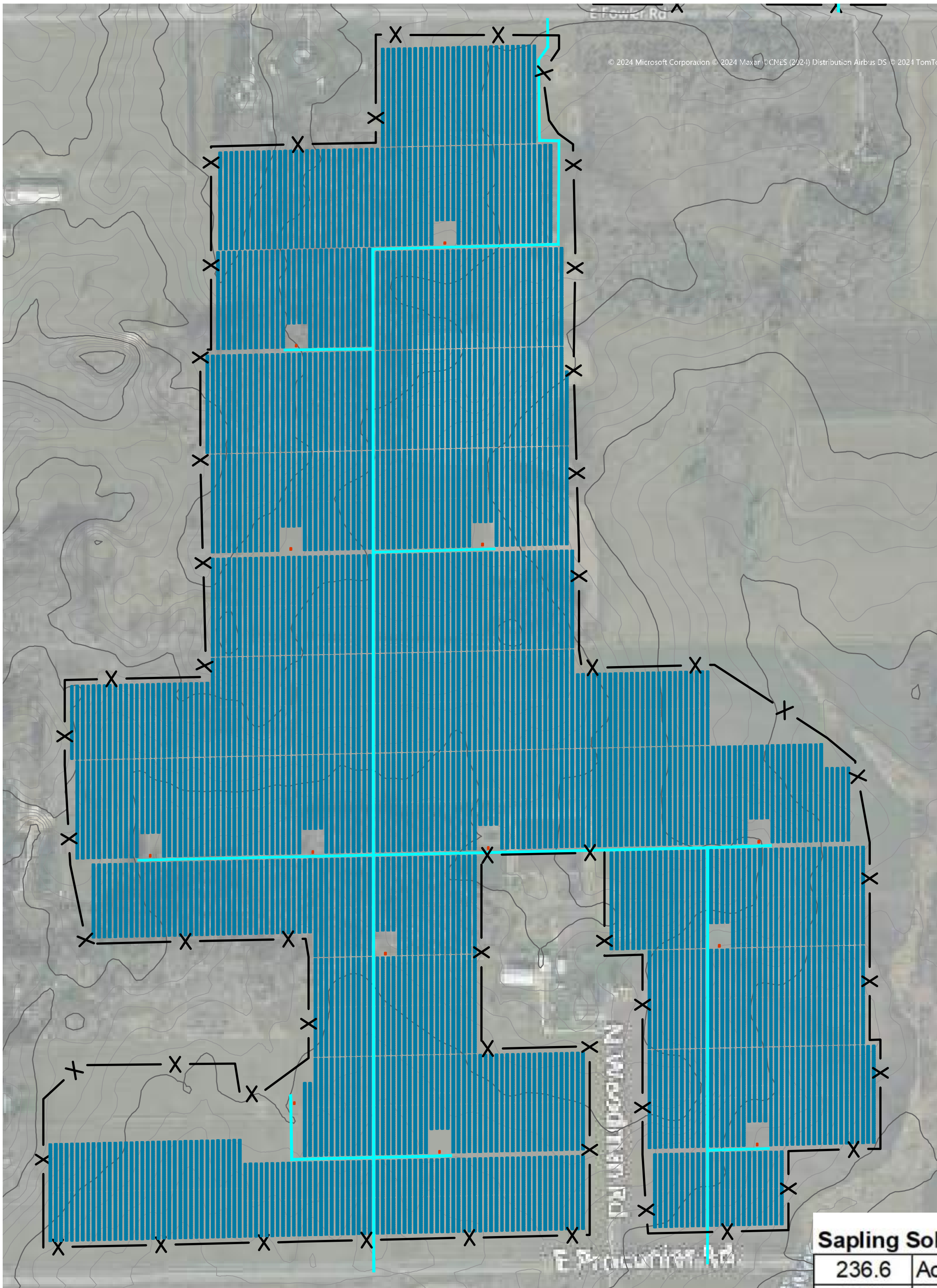
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



LEGEND

- SECURITY FENCE
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- EQUIPMENT PAD

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Sapling Solar Area 11

236.6	Acres
78%	Crop Development
22%	Woods / Meadow
82	CN Existing
72	CN Proposed
-456,156	Δ Runoff, cf
No	Stormwater Detention

Calculations for Storm Water Runoff Volume Control

SITE NAME: **Sapling Solar Area 11**

Fenced Array Area: **236.6** **acres**

Design Rainfall Event: **2.99** **in (10-year per Gustin Twp)**
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**278,784**	6.40	30	23.3	**0.000**	**0**
Crops	A	**609,840**	14.00	67	4.9	**0.580**	**29,477**
Woods / Meadow	B	**409,464**	9.40	55	8.2	**0.192**	**6,557**
Crops	B	**740,520**	17.00	78	2.8	**1.122**	**69,221**
Woods / Meadow	D	**1,537,668**	35.30	77	3.0	**1.064**	**136,355**
Crops	D	**6,730,020**	154.50	89	1.2	**1.891**	**1,060,420**
TOTAL:	**N/A**	**10,306,296**	**236.60**			**1.52**	**1,302,030**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**309,189**	7.10	98	0.2	**2.758**	**71,070**
Grassland / Meadow	A	**861,965**	19.79	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**1,115,484**	25.61	58	7.2	**0.271**	**25,156**
Grassland / Meadow	D	**8,019,657**	184.11	78	2.8	**1.122**	**749,648**
TOTAL:		**10,306,296**	**236.60**			**0.98**	**845,874**

Runoff Volume Increase (ft3): -456,156

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

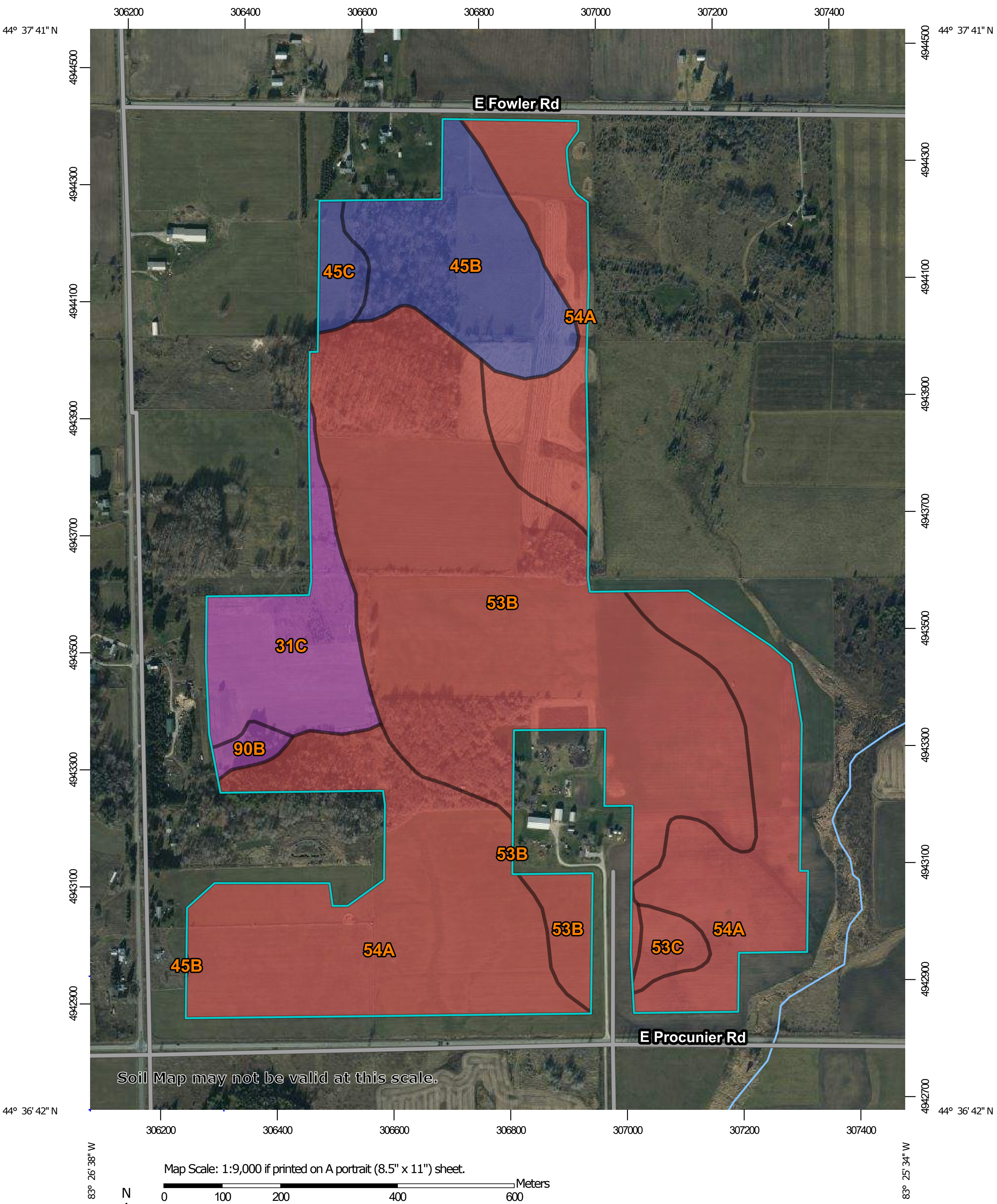
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling11)



Map Scale: 1:9,000 if printed on A portrait (8.5" x 11") sheet.

Meters: 0, 100, 200, 400, 600

N

Feet: 0, 400, 800, 1600, 2400

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils

Soil Rating Polygons
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points
- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features
- Streams and Canals

Transportation
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background
- Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

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Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

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Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
31C	Klacking loamy sand, 6 to 12 percent slopes	A	18.7	7.9%
45B	Hoist sandy loam, 0 to 6 percent slopes	B	22.8	9.6%
45C	Hoist sandy loam, 6 to 12 percent slopes	B	3.6	1.5%
53B	Negwegon silt loam, 2 to 6 percent slopes	D	92.5	39.1%
53C	Negwegon silt loam, 6 to 12 percent slopes	D	3.0	1.3%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	94.3	39.8%
90B	Chinwhisker sand, 0 to 4 percent slopes	A	1.7	0.7%
Totals for Area of Interest			**236.6**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

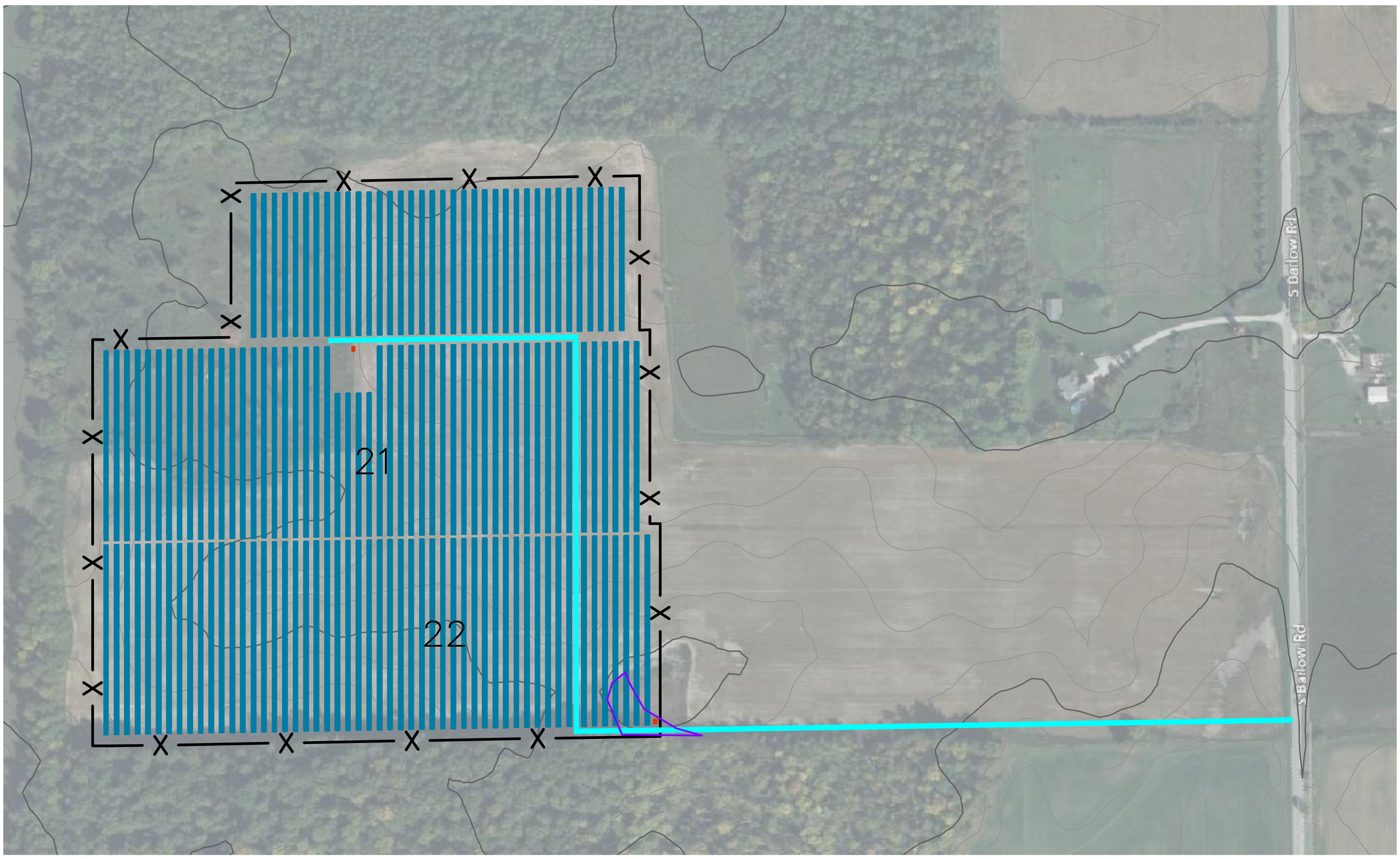
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher



Sapling Solar Area 15

30.9	Acres
81%	Crop Development
19%	Woods / Meadow
83	CN Existing
73	CN Proposed
-64,563	Δ Runoff, cf
No	Stormwater Detention

LEGEND

SECURITY FENCE
ACCESS DRIVE
PV TRACKER
EQUIPMENT PAD

ATWELL
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Calculations for Storm Water Runoff Volume Control

SITE NAME: Sapling Solar Area 15

Fenced Array Area: 30.9 acres

Design Rainfall Event: 2.99 in (10-year per Gustin Twp)
(see Rainfall Tab or Section 2.0 for aid in using ATLAS 14 for determining local or site specific rainfall events)

Existing Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN (from TR-55)	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
					$\frac{1000}{CN} - 10$	$\frac{(P - 0.2S)^2}{(P + 0.8S)}$	$Q \times 1/12 \times A$
Woods / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Crops	A	**0**	0.00	67	4.9	**0.580**	**0**
Woods / Meadow	B	**8,712**	0.20	55	8.2	**0.192**	**140**
Crops	B	**400,752**	9.20	78	2.8	**1.122**	**37,461**
Woods / Meadow	D	**252,648**	5.80	77	3.0	**1.064**	**22,404**
Crops	D	**683,892**	15.70	89	1.2	**1.891**	**107,758**
TOTAL:	**N/A**	**1,346,004**	**30.90**			**1.50**	**167,762**

Post-Development Conditions

Land Cover Type	Soil Type	Area (sf)	Area (ac)	CN*	S	Q Runoff[1] (in)	Runoff Volume[2] (ft^3)
Impervious	N/A	**40,511**	0.93	98	0.2	**2.758**	**9,312**
Grassland / Meadow	A	**0**	0.00	30	23.3	**0.000**	**0**
Grassland / Meadow	B	**396,832**	9.11	58	7.2	**0.271**	**8,949**
Grassland / Meadow	D	**908,662**	20.86	78	2.8	**1.122**	**84,938**
TOTAL:		**1,346,004**	**30.90**			**0.92**	**103,199**

Runoff Volume Increase (ft3): -64,563

Runoff Volume Increase = (Post-Dev. Runoff Volume) MINUS (Existing Runoff Volume)

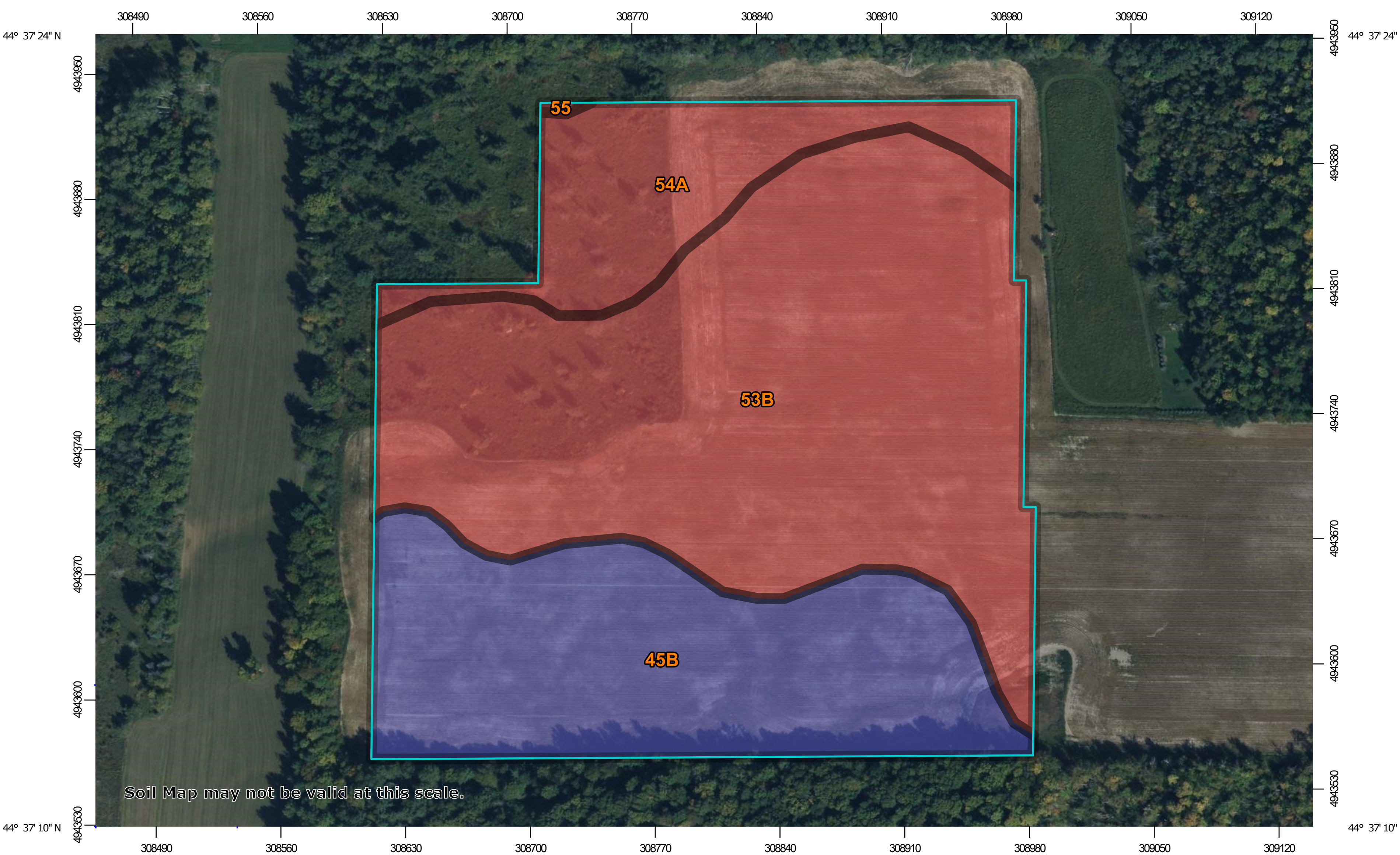
1. Runoff (in) = Q = (P - Ia)2 / (P- Ia)+S
Ia =0.2S therefore;
Runoff (in) = Q = $(P - 0.2S)^2 / (P + 0.8S)$

2. Runoff Volume (ft^3) = Q x 1/12 x Area

Where:
P = 100-Year, 24-Hour Rainfall (in)
S = 1000/ CN - 10
CN = Curve Number
Q = Runoff (in)
Area = Area of specific land cover (ft^2)

* Runoff Volume must be calculated separately for pervious and impervious areas (without using a weighted CN)

Hydrologic Soil Group—Alcona County, Michigan
(Sapling15r)



Map Scale: 1:3,120 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 45, 90, 180, 270

Feet: 0, 150, 300, 600, 900

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Rating Polygons

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Lines

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Soil Rating Points

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

Water Features

Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

Background

Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

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Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Alcona County, Michigan
Survey Area Data: Version 23, Aug 24, 2023

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Sep 15, 2020—Nov 12, 2020

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
45B	Hoist sandy loam, 0 to 6 percent slopes	B	9.4	30.5%
53B	Negwegon silt loam, 2 to 6 percent slopes	D	17.3	56.1%
54A	Algonquin silt loam, 0 to 3 percent slopes	D	4.1	13.3%
55	Springport clay loam	D	0.0	0.1%
Totals for Area of Interest			**30.9**	**100.0%**

Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

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Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

Rating Options

Aggregation Method: Dominant Condition

Component Percent Cutoff: None Specified

Tie-break Rule: Higher

Table 6.1 – Runoff curve numbers for hydrologic soil-cover complexes (AMC-II conditions)

Land use	Treatment or practice	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow soil	Straight row		77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured and terraced	Poor	66	74	80	82
		Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured and terraced	Poor	61	72	79	82
		Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and terraced	Poor	63	73	80	83
		Good	51	67	76	80
Pasture or range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
	Contoured	Poor	47	67	81	88
		Fair	30	59	75	83
		Good	30	35	70	79
Meadow			30	58	71	78
Woods		Poor	45	66	77	83
		Fair	36	60	73	79
		Good	30	55	70	77
Residential	⅛ acre		77	85	90	92
	¼ acre		61	75	83	87
	1/3 acre		57	72	81	86
	½ acre		54	70	80	85
	1 acre		51	68	79	84
Open spaces (parks, golf courses, cemeteries, etc.)	Good condition: Grass cover > 75% of area		39	61	74	80
	Fair condition: Grass cover 50-75% of area		49	69	79	84
Commercial or business area (85% impervious)			89	92	94	95
Industrial district (72% impervious)			81	88	91	93
Farmsteads			59	74	82	86
Paved areas (roads, drive-ways, parking lots, roofs)			98	98	98	98
Water surfaces (lakes, ponds, reservoirs, etc.)			100	100	100	100
Swamp	At least 1/3 is open water		85	85	85	85
	Vegetated		78	78	78	78

Hydrologic Response of Solar Farms

Lauren M. Cook, S.M.ASCE[1]; and Richard H. McCuen, M.ASCE[2]

Abstract: Because of the benefits of solar energy, the number of solar farms is increasing; however, their hydrologic impacts have not been studied. The goal of this study was to determine the hydrologic effects of solar farms and examine whether or not storm-water management is needed to control runoff volumes and rates. A model of a solar farm was used to simulate runoff for two conditions: the pre- and postpaneled conditions. Using sensitivity analyses, modeling showed that the solar panels themselves did not have a significant effect on the runoff volumes, peaks, or times to peak. However, if the ground cover under the panels is gravel or bare ground, owing to design decisions or lack of maintenance, the peak discharge may increase significantly with storm-water management needed. In addition, the kinetic energy of the flow that drains from the panels was found to be greater than that of the rainfall, which could cause erosion at the base of the panels. Thus, it is recommended that the grass beneath the panels be well maintained or that a buffer strip be placed after the most downgradient row of panels. This study, along with design recommendations, can be used as a guide for the future design of solar farms. **DOI: 10.1061/(ASCE)HE.1943-5584.0000530.** © *2013 American Society of Civil Engineers.*

CE Database subject headings: Hydrology; Land use; Solar power; Floods; Surface water; Runoff; Stormwater management.

Author keywords: Hydrology; Land use change; Solar energy; Flooding; Surface water runoff; Storm-water management.

Introduction

Storm-water management practices are generally implemented to reverse the effects of land-cover changes that cause increases in volumes and rates of runoff. This is a concern posed for new types of land-cover change such as the solar farm. Solar energy is a renewable energy source that is expected to increase in importance in the near future. Because solar farms require considerable land, it is necessary to understand the design of solar farms and their potential effect on erosion rates and storm runoff, especially the impact on offsite properties and receiving streams. These farms can vary in size from 8 ha (20 acres) in residential areas to 250 ha (600 acres) in areas where land is abundant.

The solar panels are impervious to rain water; however, they are mounted on metal rods and placed over pervious land. In some cases, the area below the panel is paved or covered with gravel. Service roads are generally located between rows of panels. Altlhough some panels are stationary, others are designed to move so that the angle of the panel varies with the angle of the sun. The angle can range, depending on the latitude, from 22° during the summer months to 74° during the winter months. In addition, the angle and direction can also change throughout the day. The issue posed is whether or not these rows of impervious panels will change the runoff characteristics of the site, specifically increase runoff volumes or peak discharge rates. If the increases are hydrologically significant, storm-water management facilities may be needed. Additionally, it is possible that the velocity of water draining from the edge of the panels is sufficient to cause erosion of the soil below the panels, especially where the maintenance roadways are bare ground.

The outcome of this study provides guidance for assessing the hydrologic effects of solar farms, which is important to those who plan, design, and install arrays of solar panels. Those who design solar farms may need to provide for storm-water management. This study investigated the hydrologic effects of solar farms, assessed whether or not storm-water management might be needed, and if the velocity of the runoff from the panels could be sufficient to cause erosion of the soil below the panels.

Model Development

Solar farms are generally designed to maximize the amount of energy produced per unit of land area, while still allowing space for maintenance. The hydrologic response of solar farms is not usually considered in design. Typically, the panels will be arrayed in long rows with separations between the rows to allow for maintenance vehicles. To model a typical layout, a unit width of one panel was assumed, with the length of the downgradient strip depending on the size of the farm. For example, a solar farm with 30 rows of 200 panels each could be modeled as a strip of 30 panels with space between the panels for maintenance vehicles. Rainwater that drains from the upper panel onto the ground will flow over the land under the 29 panels on the downgradient strip. Depending on the land cover, infiltration losses would be expected as the runoff flows to the bottom of the slope.

To determine the effects that the solar panels have on runoff characteristics, a model of a solar farm was developed. Runoff in the form of sheet flow without the addition of the solar panels served as the prepaneled condition. The paneled condition assumed a downgradient series of cells with one solar panel per ground cell. Each cell was separated into three sections: wet, dry, and spacer.

The dry section is that portion directly underneath the solar panel, unexposed directly to the rainfall. As the angle of the panel from the horizontal increases, more of the rain will fall directly onto

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the ground; this section of the cell is referred to as the wet section. The spacer section is the area between the rows of panels used by maintenance vehicles. Fig. 1 is an image of two solar panels and the spacer section allotted for maintenance vehicles. Fig. 2 is a schematic of the wet, dry, and spacer sections with their respective dimensions. In Fig. 1, tracks from the vehicles are visible on what is modeled within as the spacer section. When the solar panel is horizontal, then the length longitudinal to the direction that runoff will occur is the length of the dry and wet sections combined. Runoff from a dry section drains onto the downgradient spacer section. Runoff from the spacer section flows to the wet section of the next downgradient cell. Water that drains from a solar panel falls directly onto the spacer section of that cell.

The length of the spacer section is constant. During a storm event, the loss rate was assumed constant for the 24-h storm because a wet antecedent condition was assumed. The lengths of the wet and dry sections changed depending on the angle of the solar panel. The total length of the wet and dry sections was set equal to the length of one horizontal solar panel, which was assumed to be 3.5 m. When a solar panel is horizontal, the dry section length would equal 3.5 m and the wet section length would be zero. In the paneled condition, the dry section does not receive direct rainfall because the rain first falls onto the solar panel then drains onto the spacer section. However, the dry section does infiltrate some of the runoff that comes from the upgradient wet section. The wet section was modeled similar to the spacer section with rain falling directly onto the section and assuming a constant loss rate.

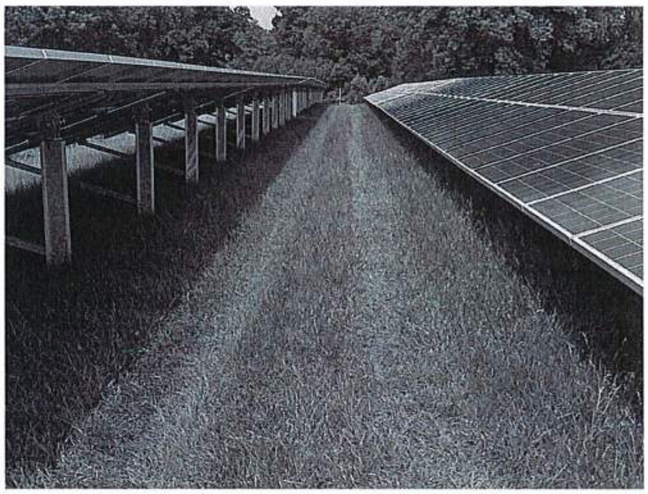

Fig. 1. Maintenance or "spacer" section between two rows of solar panels (photo by John E. Showler, reprinted with permission)

For the presolar panel condition, the spacer and wet sections are modeled the same as in the paneled condition; however, the cell does not include a dry section. In the prepaneled condition, rain falls directly onto the entire cell. When modeling the prepaneled condition, all cells receive rainfall at the same rate and are subject to losses. All other conditions were assumed to remain the same such that the prepaneled and paneled conditions can be compared.

Rainfall was modeled after an natural resources conservation service (NRCS) Type II Storm (McCuen 2005) because it is an accurate representation of actual storms of varying characteristics that are imbedded in intensity-duration-frequency (IDF) curves. For each duration of interest, a dimensionless hyetograph was developed using a time increment of 12 s over the duration of the storm (see Fig. 3). The depth of rainfall that corresponds to each storm magnitude was then multiplied by the dimensionless hyetograph. For a 2-h storm duration, depths of 40.6, 76.2, and 101.6 mm were used for the 2-, 25-, and 100-year events. The 2- and 6-h duration hyetographs were developed using the center portion of the 24-h storm, with the rainfall depths established with the Baltimore IDF curve. The corresponding depths for a 6-h duration were 53.3, 106.7, and 132.1 mm, respectively. These magnitudes were chosen to give a range of storm conditions.

During each time increment, the depth of rain is multiplied by the cell area to determine the volume of rain added to each section of each cell. This volume becomes the storage in each cell. Depending on the soil group, a constant volume of losses was subtracted from the storage. The runoff velocity from a solar panel was calculated using Manning's equation, with the hydraulic radius for sheet flow assumed to equal the depth of the storage on the panel (Bedient and Huber 2002). Similar assumptions were made to compute the velocities in each section of the surface sections.

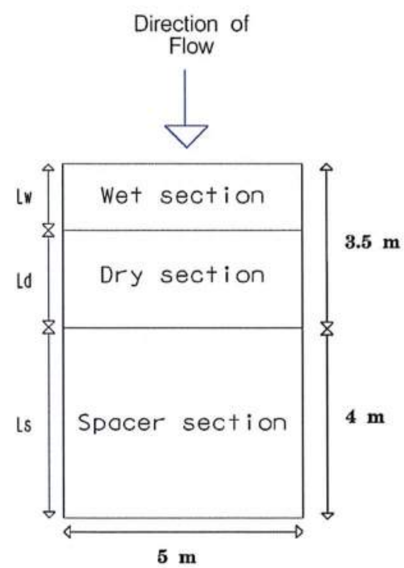

Fig. 2. Wet, dry, and spacer sections of a single cell with lengths *Lw*, *Ls*, and *Ld* with the solar panel covering the dry section

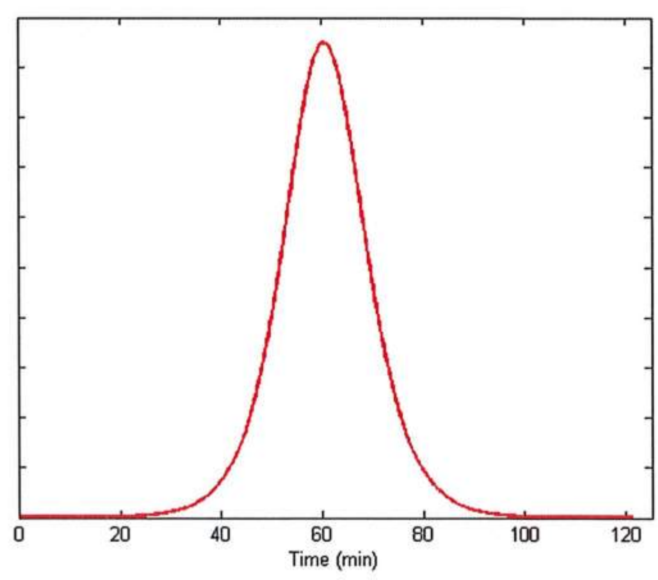

Fig. 3. Dimensionless hyetograph of 2-h Type II storm

Runoff from one section to the next and then to the next downgradient cell was routed using the continuity of mass. The routing coefficient depended on the depth of flow in storage and the velocity of runoff. Flow was routed from the wet section to the dry section to the spacer section, with flow from the spacer section draining to the wet section of the next cell. Flow from the most downgradient cell was assumed to be the outflow. Discharge rates and volumes from the most downgradient cell were used for comparisons between the prepaneled and paneled conditions.

Alternative Model Scenarios

To assess the effects of the different variables, a section of 30 cells, each with a solar panel, was assumed for the base model. Each cell was separated individually into wet, dry, and spacer sections. The area had a total ground length of 225 m with a ground slope of 1% and width of 5 m, which was the width of an average solar panel. The roughness coefficient (Engman 1986) for the silicon solar panel was assumed to be that of glass, 0.01. Roughness coefficients of 0.15 for grass and 0.02 for bare ground were also assumed. Loss rates of 0.5715 cm/h (0.225 in./h) and 0.254 cm/h (0.1 in./h) for B and C soils, respectively, were assumed.

The prepaneled condition using the 2-h, 25-year rainfall was assumed for the base condition, with each cell assumed to have a good grass cover condition. All other analyses were made assuming a paneled condition. For most scenarios, the runoff volumes and peak discharge rates from the paneled model were not significantly greater than those for the prepaneled condition. Over a total length of 225 m with 30 solar panels, the runoff increased by 0.26 m^3, which was a difference of only 0.35%. The slight increase in runoff volume reflects the slightly higher velocities for the paneled condition. The peak discharge increased by 0.0013 m^3, a change of only 0.31%. The time to peak was delayed by one time increment, i.e., 12 s. Inclusion of the panels did not have a significant hydrologic impact.

Storm Magnitude

The effect of storm magnitude was investigated by changing the magnitude from a 25-year storm to a 2-year storm. For the 2-year storm, the rainfall and runoff volumes decreased by approximately 50%. However, the runoff from the paneled watershed condition increased compared to the prepaneled condition by approximately the same volume as for the 25-year analysis, 0.26 m^3. This increase represents only a 0.78% increase in volume. The peak discharge and the time to peak did not change significantly. These results reflect runoff from a good grass cover condition and indicated that the general conclusion of very minimal impacts was the same for different storm magnitudes.

Ground Slope

The effect of the downgradient ground slope of the solar farm was also examined. The angle of the solar panels would influence the velocity of flows from the panels. As the ground slope was increased, the velocity of flow over the ground surface would be closer to that on the panels. This could cause an overall increase in discharge rates. The ground slope was changed from 1 to 5%, with all other conditions remaining the same as the base conditions.

With the steeper incline, the volume of losses decreased from that for the 1% slope, which is to be expected because the faster velocity of the runoff would provide less opportunity for infiltration. However, between the prepaneled and paneled conditions, the increase in runoff volume was less than 1%. The peak discharge and the time to peak did not change. Therefore, the greater ground slope did not significantly influence the response of the solar farm.

Soil Type

The effect of soil type on the runoff was also examined. The soil group was changed from B soil to C soil by varying the loss rate. As expected, owing to the higher loss rate for the C soil, the depths of runoff increased by approximately 7.5% with the C soil when compared with the volume for B soils. However, the runoff volume for the C soil condition only increased by 0.17% from the prepaneled condition to the paneled condition. In comparison with the B soil, a difference of 0.35% in volume resulted between the two conditions. Therefore, the soil group influenced the actual volumes and rates, but not the relative effect of the paneled condition when compared to the prepaneled condition.

Panel Angle

Because runoff velocities increase with slope, the effect of the angle of the solar panel on the hydrologic response was examined. Analyses were made for angles of 30° and 70° to test an average range from winter to summer. The hydrologic response for these angles was compared to that of the base condition angle of 45°. The other site conditions remained the same. The analyses showed that the angle of the panel had only a slight effect on runoff volumes and discharge rates. The lower angle of 30° was associated with an increased runoff volume, whereas the runoff volume decreased for the steeper angle of 70° when compared with the base condition of 45°. However, the differences (~0.5%) were very slight. Nevertheless, these results indicate that, when the solar panel was closer to horizontal, i.e., at a lower angle, a larger difference in runoff volume occurred between the prepaneled and paneled conditions. These differences in the response result are from differences in loss rates.

The peak discharge was also lower at the lower angle. At an angle of 30°, the peak discharge was slightly lower than at the higher angle of 70°. For the 2-h storm duration, the time to peak of the 30° angle was 2 min delayed from the time to peak of when the panel was positioned at a 70° angle, which reflects the longer travel times across the solar panels.

Storm Duration

To assess the effect of storm duration, analyses were made for 6-h storms, testing magnitudes for 2-, 25-, and 100-year return periods, with the results compared with those for the 2-h rainfall events. The longer storm duration was tested to determine whether a longer duration storm would produce a different ratio of increase in runoff between the prepaneled and paneled conditions. When compared to runoff volumes from the 2-h storm, those for the 6-h storm were 34% greater in both the paneled and prepaneled cases. However, when comparing the prepaneled to the paneled condition, the increase in the runoff volume with the 6-h storm was less than 1% regardless of the return period. The peak discharge and the time-to-peak did not differ significantly between the two conditions. The trends in the hydrologic response of the solar farm did not vary with storm duration.

Ground Cover

The ground cover under the panels was assumed to be a native grass that received little maintenance. For some solar farms, the area beneath the panel is covered in gravel or partially paved because the panels prevent the grass from receiving sunlight. Depending on the volume of traffic, the spacer cell could be grass, patches of grass, or bare ground. Thus, it was necessary to determine whether or not these alternative ground-cover conditions would affect the runoff characteristics. This was accomplished by changing the Manning's n for the ground beneath the panels. The value of n under the panels, i.e., the dry section, was set to 0.015 for gravel, with the value for the spacer or maintenance section set to 0.02, i.e., bare ground. These can be compared to the base condition of a native grass ($n = 0.15$). A good cover should promote losses and delay the runoff.

For the smoother surfaces, the velocity of the runoff increased and the losses decreased, which resulted in increasing runoff volumes. This occurred both when the ground cover under the panels was changed to gravel and when the cover in the spacer section was changed to bare ground. Owing to the higher velocities of the flow, runoff rates from the cells increased significantly such that it was necessary to reduce the computational time increment. Fig. 4(a) shows the hydrograph from a 30-panel area with a time increment of 12 s. With a time increment of 12 s, the water in each cell is discharged at the end of every time increment, which results in no attenuation of the flow; thus, the undulations shown in Fig. 4(a) result. The time increment was reduced to 3 s for the 2-h storm, which resulted in watershed smoothing and a rational hydrograph shape [Fig. 4(b)]. The results showed that the storm runoff increased by 7% from the grass-covered scenario to the scenario with gravel under the panel. The peak discharge increased by 73% for the gravel ground cover when compared with the grass cover without the panels. The time to peak was 10 min less with the gravel than with the grass, which reflects the effect of differences in surface roughness and the resulting velocities.

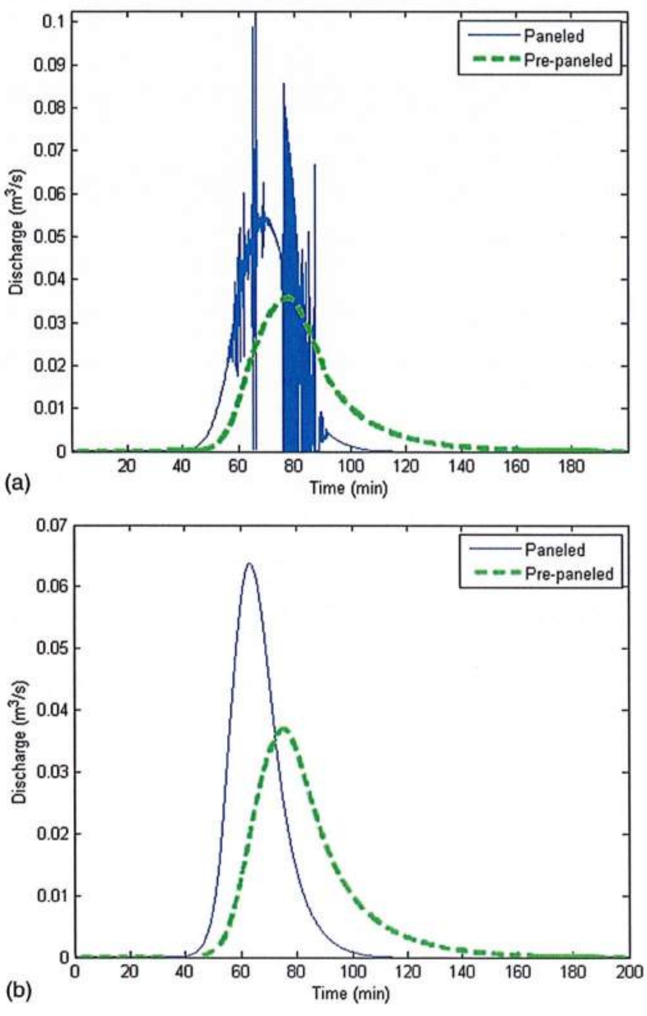

Fig. 4. Hydrograph with time increment of (a) 12 s; (b) 3 s with Manning's n for bare ground

If maintenance vehicles used the spacer section regularly and the grass cover was not adequately maintained, the soil in the spacer section would be compacted and potentially the runoff volumes and rates would increase. Grass that is not maintained has the potential to become patchy and turn to bare ground. The grass under the panel may not get enough sunlight and die. Fig. 1 shows the result of the maintenance trucks frequently driving in the spacer section, which diminished the grass cover.

The effect of the lack of solar farm maintenance on runoff characteristics was modeled by changing the Manning's n to a value of 0.02 for bare ground. In this scenario, the roughness coefficient for the ground under the panels, i.e., the dry section, as well as in the spacer cell was changed from grass covered to bare ground ($n = 0.02$).The effects were nearly identical to that of the gravel. The runoff volume increased by 7% from the grass-covered to the bare-ground condition. The peak discharge increased by 72% when compared with the grass-covered condition. The runoff for the bare-ground condition also resulted in an earlier time to peak by approximately 10 min. Two other conditions were also modeled, showing similar results. In the first scenario, gravel was placed directly under the panel, and healthy grass was placed in the spacer section, which mimics a possible design decision. Under these conditions, the peak discharge increased by 42%, and the volume of runoff increased by 4%, which suggests that storm-water management would be necessary if gravel is placed anywhere.

Fig. 5 shows two solar panels from a solar farm in New Jersey. The bare ground between the panels can cause increased runoff rates and reductions in time of concentration, both of which could necessitate storm-water management. The final condition modeled involved the assumption of healthy grass beneath the panels and bare ground in the spacer section, which would simulate the condition of unmaintained grass resulting from vehicles that drive over the spacer section. Because the spacer section is 53% of the cell, the change in land cover to bare ground would reduce losses and decrease runoff travel times, which would cause runoff to amass as it

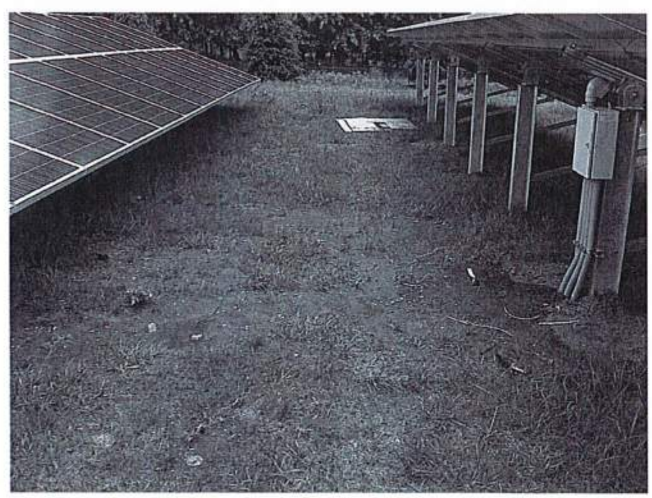

Fig. 5. Site showing the initiation of bare ground below the panels, which increases the potential for erosion (photo by John Showler, reprinted with permission)

moves downgradient. With the spacer section as bare ground, the peak discharge increased by 100%, which reflected the increases in volume and decrease in timing. These results illustrate the need for maintenance of the grass below and between the panels.

Design Suggestions

With well-maintained grass underneath the panels, the solar panels themselves do not have much effect on total volumes of the runoff or peak discharge rates. Although the panels are impervious, the rainwater that drains from the panels appears as runoff over the downgradient cells. Some of the runoff infiltrates. If the grass cover of a solar farm is not maintained, it can deteriorate either because of a lack of sunlight or maintenance vehicle traffic. In this case, the runoff characteristics can change significantly with both runoff rates and volumes increasing by significant amounts. In addition, if gravel or pavement is placed underneath the panels, this can also contribute to a significant increase in the hydrologic response.

If bare ground is foreseen to be a problem or gravel is to be placed under the panels to prevent erosion, it is necessary to counteract the excess runoff using some form of storm-water management. A simple practice that can be implemented is a buffer strip (Dabney et al. 2006) at the downgradient end of the solar farm. The buffer strip length must be sufficient to return the runoff characteristics with the panels to those of runoff experienced before the gravel and panels were installed. Alternatively, a detention basin can be installed.

A buffer strip was modeled along with the panels. For approximately every 200 m of panels, or 29 cells, the buffer must be 5 cells long (or 35 m) to reduce the runoff volume to that which occurred before the panels were added. Even if a gravel base is not placed under the panels, the inclusion of a buffer strip may be a good practice when grass maintenance is not a top funding priority. Fig. 6 shows the peak discharge from the graveled surface versus the length of the buffer needed to keep the discharge to prepaneled peak rate.

Water draining from a solar panel can increase the potential for erosion of the spacer section. If the spacer section is bare ground, the high kinetic energy of water draining from the panel can cause soil detachment and transport (Garde and Raju 1977; Beuselinck et al. 2002). The amount and risk of erosion was modeled using the velocity of water coming off a solar panel compared with the velocity and intensity of the rainwater. The velocity of panel

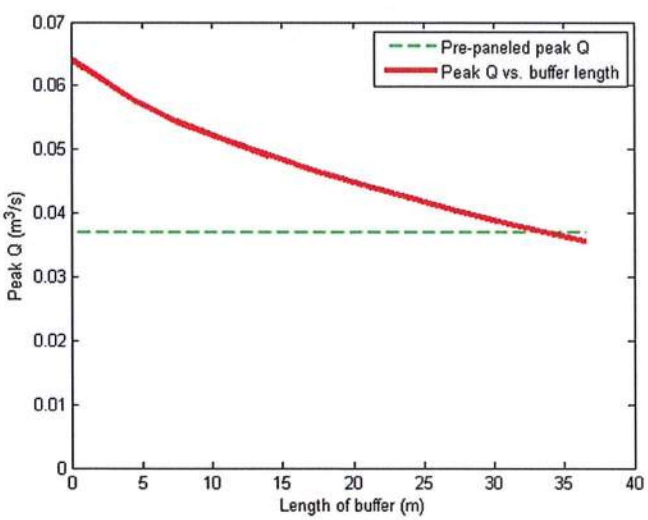

Fig. 6. Peak discharge over gravel compared with buffer length

runoff was calculated using Manning's equation, and the velocity of falling rainwater was calculated using the following:

$$V_t = 120\, d_r^{0.35} \tag{1}$$

where d_r = diameter of a raindrop, assumed to be 1 mm. The relationship between kinetic energy and rainfall intensity is

$$K_e = 916 + 330 \log_{10} i \tag{2}$$

where i = rainfall intensity (in./h) and K_e = kinetic energy (ft-tons per ac-in. of rain) of rain falling onto the wet section and the panel, as well as the water flowing off of the end of the panel (Wischmeier and Smith 1978). The kinetic energy (Salles et al. 2002) of the rainfall was greater than that coming off the panel, but the area under the panel (i.e., the product of the length, width, and cosine of the panel angle) is greater than the area under the edge of the panel where the water drains from the panel onto the ground. Thus, dividing the kinetic energy by the respective areas gives a more accurate representation of the kinetic energy experienced by the soil. The energy of the water draining from the panel onto the ground can be nearly 10 times greater than the rain itself falling onto the ground area. If the solar panel runoff falls onto an unsealed soil, considerable detachment can result (Motha et al. 2004). Thus, because of the increased kinetic energy, it is possible that the soil is much more prone to erosion with the panels than without. Where panels are installed, methods of erosion control should be included in the design.

Conclusions

Solar farms are the energy generators of the future; thus, it is important to determine the environmental and hydrologic effects of these farms, both existing and proposed. A model was created to simulate storm-water runoff over a land surface without panels and then with solar panels added. Various sensitivity analyses were conducted including changing the storm duration and volume, soil type, ground slope, panel angle, and ground cover to determine the effect that each of these factors would have on the volumes and peak discharge rates of the runoff.

The addition of solar panels over a grassy field does not have much of an effect on the volume of runoff, the peak discharge, nor the time to peak. With each analysis, the runoff volume increased slightly but not enough to require storm-water management facilities. However, when the land-cover type was changed under the panels, the hydrologic response changed significantly. When gravel or pavement was placed under the panels, with the spacer section left as patchy grass or bare ground, the volume of the runoff increased significantly and the peak discharge increased by approximately 100%. This was also the result when the entire cell was assumed to be bare ground.

The potential for erosion of the soil at the base of the solar panels was also studied. It was determined that the kinetic energy of the water draining from the solar panel could be as much as 10 times greater than that of rainfall. Thus, because the energy of the water draining from the panels is much higher, it is very possible that soil below the base of the solar panel could erode owing to the concentrated flow of water off the panel, especially if there is bare ground in the spacer section of the cell. If necessary, erosion control methods should be used.

Bare ground beneath the panels and in the spacer section is a realistic possibility (see Figs. 1 and 5). Thus, a good, well-maintained grass cover beneath the panels and in the spacer section is highly recommended. If gravel, pavement, or bare ground is deemed unavoidable below the panels or in the spacer section, it may necessary to add a buffer section to control the excess runoff volume and ensure adequate losses. If these simple measures are taken, solar farms will not have an adverse hydrologic impact from excess runoff or contribute eroded soil particles to receiving streams and waterways.

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