D13 FIU SITE CHARACTERIZATION: SUMMARY

PREPARED BY	ORGANIZATION	DATE
E. Ayres	FIU	11/08/2014
H. Luo	FIU	11/08/2014
H. Loescher	FIU	11/08/2014
M.Gebremedhin	FIU	11/08/2014
N. Durden	FIU	11/08/2014

APPROVALS (Name)	ORGANIZATION	APPROVAL DATE
Hanne Buur	CCB DIR SE	01/16/2015
Dave Tazik	CCB PROJ SCI	12/12/2014

RELEASED BY (Name)	ORGANIZATION	RELEASE DATE
Judy Salazar	CM	01/20/2015

See Configuration Management System for approval history.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	01/28/2011	ECO-00066	INITIAL RELEASE
B	09/26/2011	ECO-00279	Update to new document number's/template throughout document.
C	10/30/2012	ECO-00681	Change the Fraser relocatable site to Winter Park relocatable site; include exclusion zone info.
D	01/20/2015	ECO-02469	Change the Winter Park relocatable site to a new Fraser relocatable site.

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1 DESCRIPTION

1.1 Purpose

The data summarized here is used to inform the site design activities for NEON project Teams, EHS (permitting), FCC, ENG and FSU. This document summarizes the FIU site characterization data collected, analyzed, and described in the FIU D13 Site Characterization: Supporting Data (AD[01]).

1.2 Scope

This document summarizes the FIU site characterization data for three D13 tower locations: Niwot Ridge site (Advanced), Moab site (Relocatable 1), and Winter Park Experimental Forest site (Relocatable 2). Issues and concerns for each site that need attention are also addressed in this document according to our best knowledge.

Disclaimer: all latitude and longitude points are subject to the tolerances of our measurement system, i.e., GPS

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	NEON.DOC.011063	FIU D13 Site Characterization Supporting Data.docx
AD[02]	NEON.DOC.011018	WID between FIU and FCC
AD[03]	NEON.DOC.011008	FIU Tower Science Requirements
AD[04]	NEON.DOC.011029	FIU Precipitation Collector Site Design Requirements

2.2 Reference Documents

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]		
RD[04]		

2.3 Acronyms

m.a.s.l.	Meters above sea level
m.a.g.l.	Meters above ground level

2.4 Verb Convention

"Shall" is used whenever a specification expresses a provision that is binding. The verbs "should" and "may" express non-mandatory provisions. "Will" is used to express a declaration of purpose on the part of the design activity.

3 NIWOT RIDGE ADVANCE TOWER SITE

3.1 Desired ecosystem

Table 1. Ecosystem at the Niwot Ridge Advanced tower site.

Ecosystem Type	Management activity
Alpine tundra	Wildland

The terrain at the Niwot Ridge site is extremely complex mountainous terrain, which will complicate interpretation of tower flux data. However, existing PI driven eddy covariance research is being made at both the AmeriFlux site and at a nearby ridge line, and substantial gains in understanding complex flows have been made. This site meets the other tower requirements for incident climate and chemical climate, micrometeorology, and soil scale measurements. The tundra in the vicinity of the tower consists of a mixture of dry and wet tundra. Tree islands (primarily Engelmann spruce and subalpine fir) are common at the tower site. The site is accessible to the public. The site is heavily used by researchers and many research plots are located near the NEON tower site.

Table 2. Ecosystem and site attributes for Niwot Ridge Advanced tower site.

Ecosystem attributes	Measure and units
Mean canopy height	0.6 m
Surface roughness[a]	0.1 m
Zero place displacement height[a]	0.3 m
Structural elements	Alpine tundra ecosystem, consists of a mixture of dry and wet tundra
Time zone	Mountain time zone
Magnetic declination	9° 22' E changing by 0° 7' W/year

Note, [a] From field observation.

3.2 Site Design and Tower Attributes

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 3. Site design and tower attributes for Niwot Ridge Advanced site.

0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed area			185° to 305°		Clockwise from first

					angle
Tower location	40.05425,	-105.58237	--	--	new site
Instrument hut	40.05435°,	-105.58218°			
Instrument hut orientation vector	--	--	225° - 45°		
Instrument hut distance z	--	--	--	19	
Anemometer/Temperature boom orientation	--	--	225°	--	
DFIR	40.05399,	-105.58212			
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				1.0	m.a.g.l.
Level 3				4.0	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the SW will be best to capture signals from all wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure.

DFIR location is at 40.05399, -105.58212, which is ~35 m southeast toward tower. **Wet deposition collector** will collocate at the top of the tower. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36" (0.914 m). The boardwalk to access the tower is not on any side that has a boom.

Specific Boardwalks at Niwot Ridge Advance site:

- ***Raised boardwalks drift snow that can affect the long term ecology. However, damage to the access path and surrounding areas can also occur from marked paths and melting snowpack. Suggest material for a path/boardwalk be placed directly on the tundra, like that used at Barrow Alaska. This decision should be vetted among EHS, FCC, FIU and the host institutions.***
- Marked path from the road to instrument hut, pending landowner decision. Markers need to be tall enough to remain visible during winter.
- Marked path from the instrument hut to the tower to intersect on north face of the tower

- Marked path to the soil array
- No path from the soil array marked path to the individual soil plots
- Marked path needed to DFIR site

The relative locations between tower, instrument hut and boardwalk can be found in the Figure below:

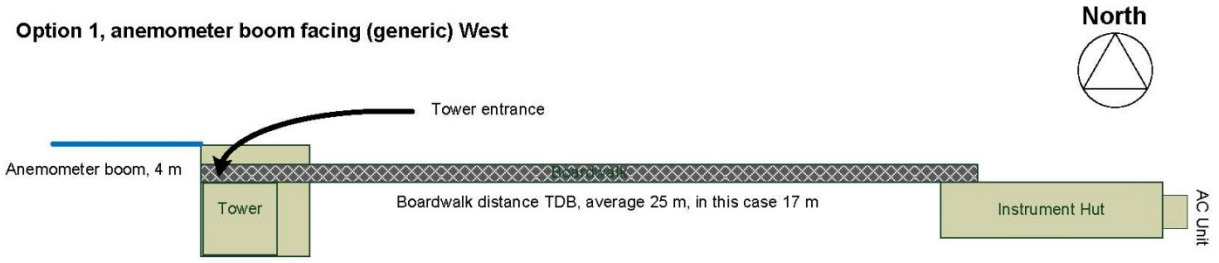


Figure 1. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Niwot Ridge Advanced site, the boom angle will be 225°, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~19 m. The instrument hut vector will be SW-NE (225°-45°, longwise).

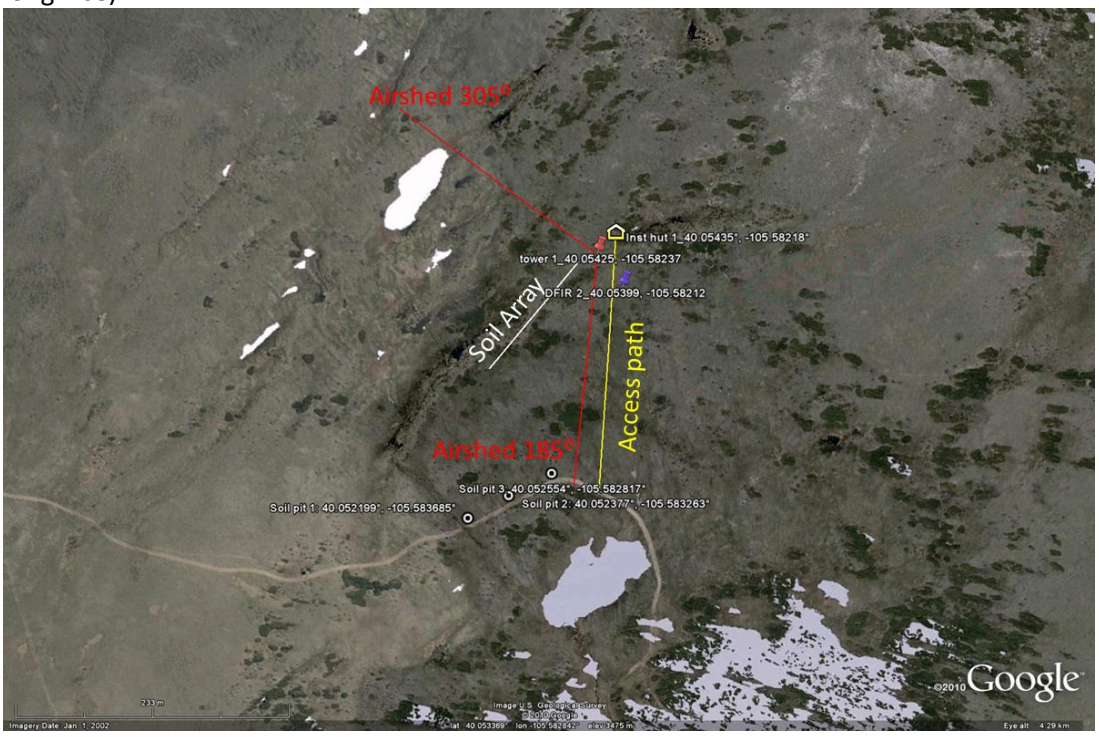


Figure 2. Site layout for Niwot Ridge Advanced tower site.
i) Tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 185° to 305° (clockwise from 185°, major airshed) are the airshed areas that would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access marked path to

instrument hut along powerline (according to EHS). The actual layout of this path will be the joint responsibility of FCC and FIU. iv) Purple pin is DFIR location

3.3 Soil Attributes

The soil array vector is ***from*** the soil plot closest to the tower ***toward*** the farthest soil plot. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc).

Dominant soil series at the site: Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Cryepts
Great group: Humicryepts
Subgroup: Typic Humicryepts
Family: Loamy-skeletal, mixed, superactive Typic Humicryepts
Series: Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes

Table 4. Summary of soil array and soil pit information at Niwot Ridge. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	25 m
Distance from tower to closest soil plot: y	16 m
Latitude and longitude of 1st soil plot OR direction from tower	40.054200°, -105.582550°
Direction of soil array	120°
Latitude and longitude of FIU soil pit 1	40.052199°, -105.583685° (primary location)
Latitude and longitude of FIU soil pit 2	40.052377°, -105.583263° (alternate 1)
Latitude and longitude of FIU soil pit 3	40.052554°, -105.582817° (alternate 2)
Dominant soil type	Moran family-Lithic Cryorthents-Rubble land complex, 5 to 40 percent slopes
Expected soil depth	0.25-1.50 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths** *§
0-0.20 m (Very stony fine sandy loam)	0.10 m†
0.20-0.33 m (Very stony fine sandy loam)	0.27 m†
0.33-0.69 m (Very cobbly sandy loam)	0.51 m†
0.69-1.07 m (Very stony sandy loam)	0.88 m
1.07-1.52 (Weathered bedrock)	2.59 m
1.52 m	1.52 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
†Expected depth of soil CO_2 sensors

[§]Soil sensors will be placed up to 3 m deep at this site if soil depth allows

Because the ecosystem has a height of the mean plant canopy < 1.75 m, the Tower has been sited to i) the minimize the remove foliage during the tower establishment, ii) optimize the temporal coverage of flow-based measurements over the representative environment, iii) minimize flow distortions caused by local ecosystem structure or topography (orography), and iv) allow the sensors on the tower booms to measure the representative surrounding environment. The location identified here and its final placement (e.g., construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

To avoid edge effect on science measurements, tower, soil array, and sensor locations have been sited such that the meteorological sensors and soil sensors are ≥ 60 m away from the edge of the representative ecosystem in interest, and flux sensors are ≥ 180 m from the edge of the representative ecosystem. The sensor locations identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

DFIR location at this site has been chosen to meet USCRN class 1 or class 2 criteria. The DFIR location identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

3.4 Information for ecosystem productivity plots

The tower at this site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (alpine tundra ecosystem). Based on our best knowledge, major airshed area at this site is from 185° to 305° (clockwise from 185°), and 80% of the information for flux measurements are within a distance of 500 m (90% within 850 m) from tower. We suggest FSU Ecosystem Productivity plots are placed within the major airshed boundaries of 185° to 305° (clockwise from 185°) from tower.

3.5 Exclusion Zone

To meet our Product Assurance metrics, our high quality Terrestrial Instrument System (TIS) measurements, and TIS requirements, no sampling, observations, or experiment shall be conducted within the tower exclusion zone without consulting and resolving any issues with TIS scientists as according to the 'NEON Research Collaboration Document' NEON.DOC.004312. The intent is to limit any activities that can either affect the wind flows (e.g., disturbance, buildings, structures, clear cutting, affect changes in structure), or the natural/expected process rates that would adversely affect NEON's data products. Because we cannot think of all such future activities, each will have to be evaluated on a case-by-case basis.

The exclusion zone is an area with these features:

a) The shape of the exclusion zone appears as a pie splice (plan view) with center point of the tower foundation (plan view) as its origin.

b) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.
c) The exclusion zone is a sub-area (i.e., inside) the total tower source area
d) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 185 degrees to 305 degrees.

There are two criteria to determine the distance of the exclusion zone from the tower:

1) For all activities mentioned above, the distance from the tower is the maximum value of 90% cumulative flux of the source area at mean maximum wind speed under daytime convective (expected unstable) atmospheres, which is 850 m at this site.
2) Some large disturbance activities also cannot occur in the nighttime tower footprint (because the nighttime tower footprint extends out much farther than the daytime source area). For all high impact activities, the distance from the tower is the maximum value of 80% cumulative flux of the source area at mean maximum wind speed under nighttime, thermally stratified, (expected) stable atmospheric conditions, which is 495 m at this site.

3.6 Issues and attentions

The high elevation means that this site is often extremely cold and windy, especially during winter. Blizzards and blowing snow can reduce visibility to very short distance. Lightning is also a concern, particularly during the summer. Weather conditions can change rapidly at the site. A light on the tower could act as beacon to aid locating the tower under low visibility conditions, but it would have to be possible to turn off the light when it was not needed to minimize affects on tower based measurements.

Even though this is a short, potetnially self standing tower, we require guy wires here. Due to the high winds that can occur at the site guy wires are needed to increase the stability of the tower, instrument hut, and other equipment.

Many research plots (both active and inactive) are found in the area of the NEON site. The NEON design has been approved by site personnel, therefore, the locations are not expected to overlap with any research plots. However, caution should be used during construction and operation to avoid or minimize disturbance to research plots.

The tundra ecosystem is fragile and very susceptable to disturbance, therefore, maintaining strict access route is particularly important at this site. Site personnel suggested boardwalk would not be suitable since it would increase snow accumulation on the leeward side (see Boardwalk section of this report).

Gas tanks and other large equipment may need to be transported to the NEON site in winter using snowmobiles to avoid damaging the tundra. In other words, Field OPS will have to transport 1 years worth of tanks during the winter, rather than every 6 months.

There is concern from site personnel about the impact of contruction on the site. Strategies need to be developed to minimize distrubance. For example, it may be best to transport large items (e.g. instrument hut, tower, etc) to the site in winter when there is a layer of snow protecting the tundra.

4 MOAB, RELOCATABLE TOWER 1

4.1 Desired ecosystem

Table 5. Ecosystem at the Moab tower site.

Ecosystem Type	Management activity
Desert grassland	Wildland

The terrain at the tower site is flat with a very shallow slope towards the southwest. Vegetation is a mix of grasses (including *Boutilua* spp.) and forbs with a uniform distribution. Canopy height is ~ 20 cm. Bare ground accounts for ~30-60% of the surface. The site has a large fetch area to the east (predominant nighttime wind direction), south, and west, which is suitable to measure dust generation and deposition. Vegetation surface coverage and roughness are key factors affecting dust generation and deposition. The structure of this type of vegetation is representative of the dominant vegetation of the Colorado Plateau.

Table 6. Ecosystem and site attributes for Moab Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height	0.2 m
Surface roughness [a]	0.01 m
Zero place displacement height [a]	0.15 m
Structural elements	Grass and forbs, uniform
Time zone	Mountain time zone
Magnetic declination	10° 51' E changing by 0° 7' W/year

Note, [a] From field survey.

4.2 Site Design and Tower Attributes

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. . The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 7. Site design and tower attributes for Moab Relocatable site

0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed area			75° to 105° (major) and 170° to 290° (secondary) airshed).		Clockwise from first angle

Tower location	38.24833,	-109.38827	--	--	new site
Instrument hut	38.24846,	-109.38815			
Instrument hut orientation vector	--	--	90° - 270°		
Instrument hut distance z	--	--	--	18	
Anemometer/Temperature boom orientation	--	--	180°	--	
Height of the measurement levels					
Level 1				0.2	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				4.0	m.a.g.l.
Level 4				6.0	m.a.g.l.
Tower Height				6.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the south will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. W**et deposition collector** will be collocated at the top of the tower. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. Here FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36' wide footprint. While the final design is not yet known, there are some general criteria that can be outlined. We assume that the boardwalk width is 36" (0.914 m). Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.

Specific boardwalks at the Moab Relocatable site

- Boardwalk from the access road to instrument hut, pending landowner decision
- Boardwalk from the instrument hut to the tower to intersect on north face of the tower
- Boardwalk to the soil array
- Boardwalk to individual soil plots, this is because all the soil plots will be in the immediate airshed of the tower, and that the key Relocatable design is dust generation and collection.

The relative locations between tower, instrument hut and boardwalk can be found in the diagram below:

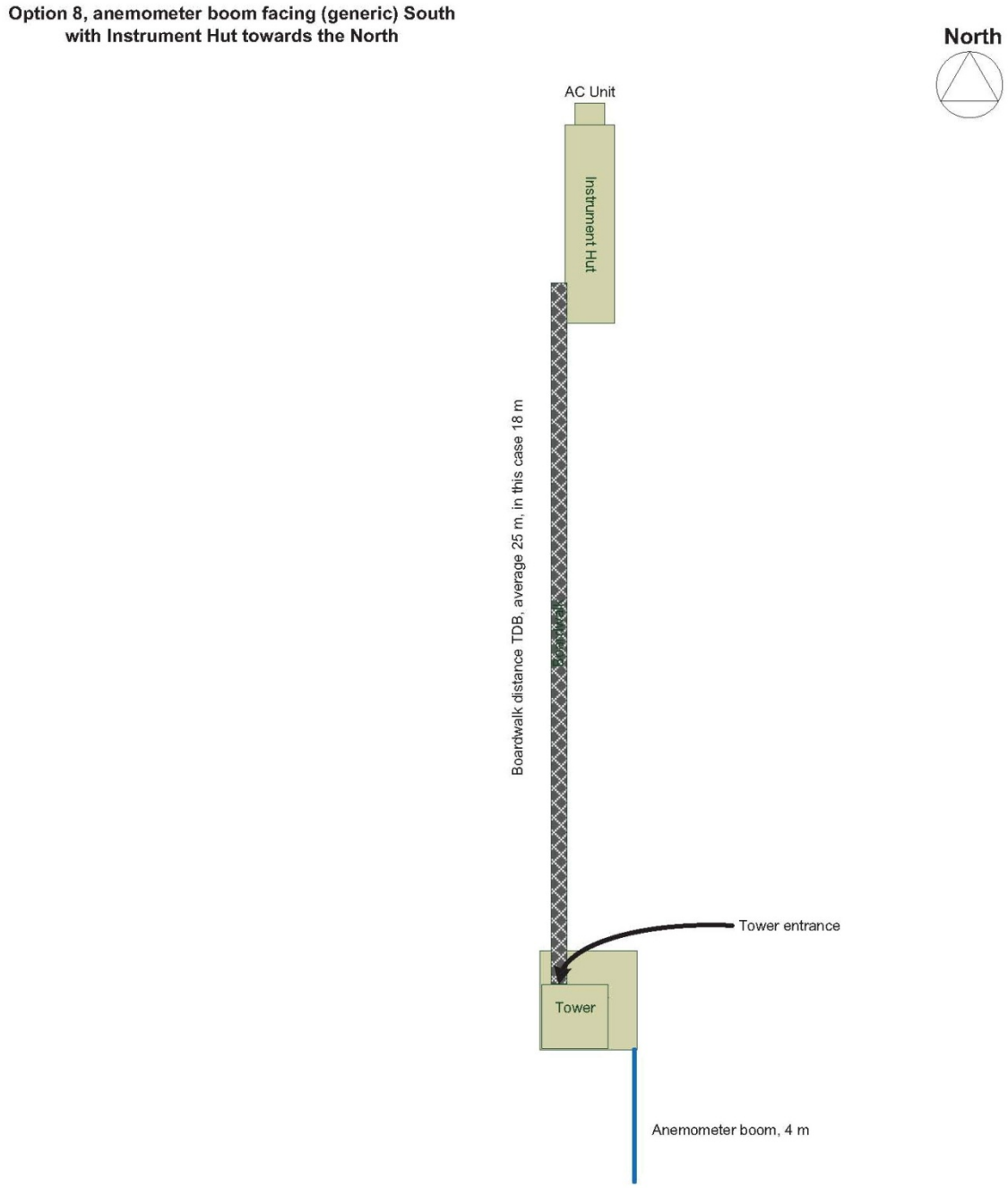


Figure 3. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing south and instrument hut on the north towards the tower.

This is just a generic diagram. The actual layout of boardwalk (or path if no boardwalk required) and instrument hut position will be the joint responsibility of FCC and FIU. At Moab Relocatable site,

the boom angle will be 180°, instrument hut will be on the northeast towards the tower, the distance between instrument hut and tower is ~18 m. The instrument hut vector will be E-W (90°-270°, longwise).

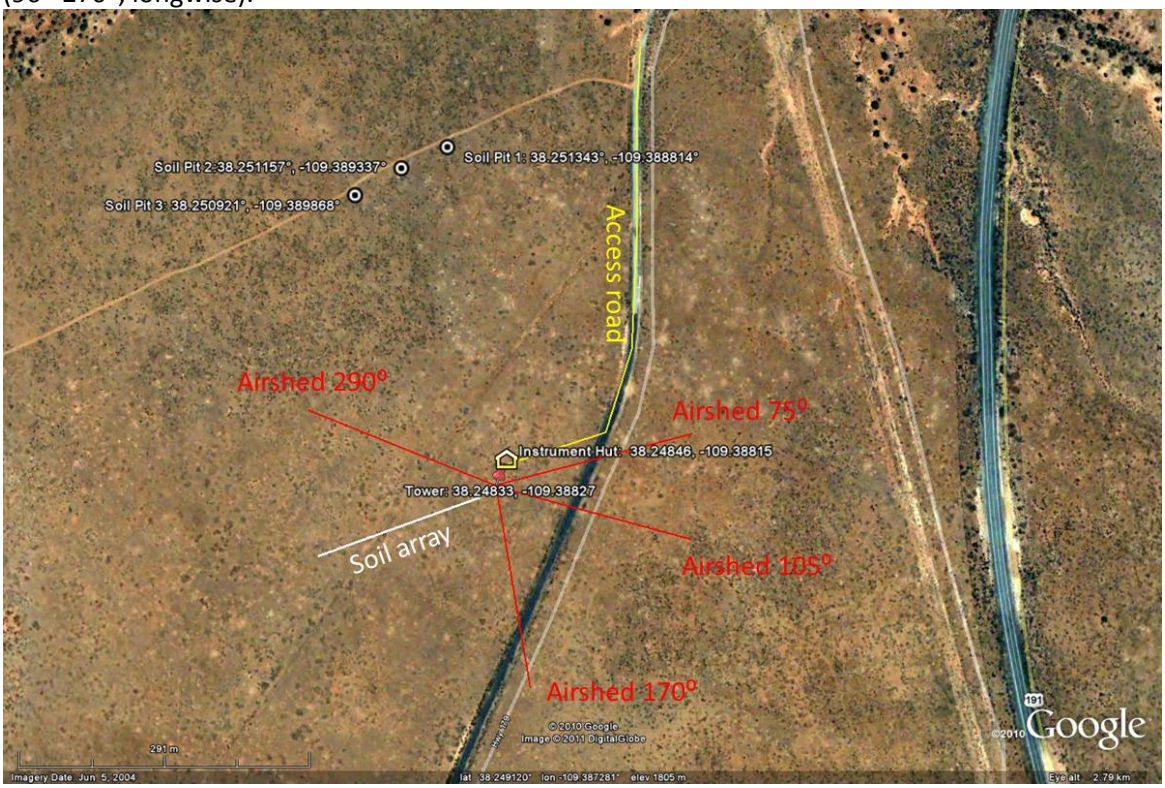


Figure 4. Site layout for Moab Relocatable site.

i) new tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors 75° to 105° (clockwise from 75°, major airshed) and 170° to 290° (clockwise from 170°, secondary airshed) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access road to instrument hut.

4.3 Soil Attributes

The soil array vector is ***from*** the soil plot closest to the tower ***toward*** the farthest soil plot. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc).

Dominant soil series at the site: Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes. The taxonomy of this soil is shown below:
Order: Aridisols
Suborder: Argids- Calcids- Cambids
Great group: Calciargids- Haplocalcids- Haplocambids
Subgroup: Ustic Calciargids- Ustic Haplocalcids- Ustic Haplocambids
Family: Coarse-loamy, mixed, superactive, mesic Ustic Calciargids- Coarse-loamy, mixed, superactive, mesic Ustic Haplocalcids- Coarse-loamy, mixed, superactive, mesic Ustic Haplocambids
Series: Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes

Table 8. Summary of soil array and soil pit information at Moab. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	37 m
Distance from tower to closest soil plot: y	19 m
Latitude and longitude of 1st soil plot OR direction from tower	38.24823, -109.38844
Direction of soil array	250°
Latitude and longitude of FIU soil pit 1	38.251343°, -109.388814° (primary location)
Latitude and longitude of FIU soil pit 2	38.251157°, -109.389337° (alternate 1)
Latitude and longitude of FIU soil pit 3	38.250921°, -109.389868° (alternate 2)
Dominant soil type	Windwhistle-Sazi very fine sandy loams, 1 to 3 percent slopes- Begay fine sandy loam, 2 to 6 percent slopes
Expected soil depth	0.50 to >2 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.05 m (Very fine sandy loam)	0.03 m†
0.05-0.64 m (Very fine sandy loam)	0.35 m†
0.64-0.97 m (Loamy very fine sand)	0.81 m†
0.97-1.07 m (Unweathered bedrock)	1.02 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.
†Expected depth of soil CO_2 sensors

Because the ecosystem has a height of the mean plant canopy < 1.75 m, the Tower has been sited to i) the minimize the remove foliage during the tower establishment, ii) optimize the temporal coverage of flow-based measurements over the representative environment, iii) minimize flow distortions caused by local ecosystem structure or topography (orography), and iv) allow the sensors on the tower booms to measure the representative surrounding environment. The location identified here and its final placement (e.g., construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

To avoid edge effect on science measurements, tower, soil array, and sensor locations have been sited such that the meteorological sensors and soil sensors are ≥ 60 m away from the edge of the representative ecosystem in interest, and flux sensors are ≥ 180 m from the edge of the representative ecosystem. The sensor locations identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

4.4 Information for ecosystem productivity plots

The tower at Moab relocatable site has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (grass and forbs). According to wind roses, wind can blow from any direction, but higher frequency winds can come from east (from 75^o to 105^o, clockwise from 75^o, major airshed, especially at nighttime) and between 170^o and 290^o (clockwise from 170^o, secondary airshed). This site is one of the NEON sites across D13 to measure dust generation, transportation and deposition. According to local people's experience, dust is generated from south and west direction. 80% signals for flux measurements during daytime are within a distance of ~400 m from tower (90% within ~700 m). We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 75^o to 105^o (clockwise from 75^o, major airshed, especially at nighttime) and 170^o to 290^o (clockwise from 170^o, secondary airshed) from tower.

4.5 Exclusion Zone

To meet our Product Assurance metrics, our high quality Terrestrial Instrument System (TIS) measurements, and TIS requirements, no sampling, observations, or experiment shall be conducted within the tower exclusion zone without consulting and resolving any issues with TIS scientists as according to the 'NEON Research Collaboration Document' NEON.DOC.004312. The intent is to limit any activities that can either affect the wind flows (e.g., disturbance, buildings, structures, clear cutting, affect changes in structure), or the natural/expected process rates that would adversely affect NEON's data products. Because we cannot think of all such future activities, each will have to be evaluated on a case-by-case basis.

The exclusion zone is an area with these features:

a) The shape of the exclusion zone appears as a pie splice (plan view) with center point of the tower foundation (plan view) as its origin.
b) There may be more than one exclusion zone per tower, depending on the diurnal, seasonal and annual wind patterns.
c) The exclusion zone is a sub-area (i.e., inside) the total tower source area
d) Windrose analyses determine the wind vectors that bound the outside of the exclusion zone, which is clockwise from 75 degrees to 105 degrees at this site (major), and clockwise from 170 degrees to 290 degrees (secondary).

There are two criteria to determine the distance of the exclusion zone from the tower:

1) For all activities mentioned above, the distance from the tower is the maximum value of 90% cumulative flux of the source area at mean maximum wind speed under daytime convective (expected unstable) atmospheres, which is 800 m at this site.
2) Some large disturbance activities also cannot occur in the nighttime tower footprint (because the nighttime tower footprint extends out much farther than the daytime source area). For all high impact activities, the distance from the tower is the maximum value of 80% cumulative flux of the source area at mean maximum wind speed under nighttime, thermally stratified, (expected) stable atmospheric conditions, which is 1900 m at this site.

4.6 Issues and attentions

Dust generation and deposition is the important science theme at this site. The soil, especially the soil crust, is sensitive to disturbance, which results in increased dust generation. **Extra care** must be taken to minimize distrubance at this NEON site.

There was evidense of development of a residential subdivision about 2 km north of the NEON site, but this is not expected to significantly affect NEON data.

5 FRASER, RELOCATEABLE TOWER 2

5.1 Desired ecosystem

Table 9. Ecosystem at the Winter Park Relocatable site.

Ecosystem Type	Management activity
Spruce and fir and pine forest	Wildland

Similar to Niwot ridge core site, the terrain at Fraser relocatable site is complex mountainous terrain. The forest in the vicinity of the tower is dominated by Engelmann spruce (*picea engelmannii)* and mixes with the Lodgepole pine forest, and has a mixed age structure with active recruitment. Many beetle killed trees standing in this forest ecosystem or falling on the forest floor. Tree height ranges from few centimeters on the ground to 22 m above ground without obvious strata. Average top canopy height is ~ 22 m around the proposed tower site with lowest branch level height is at ~2 m for mature spruce trees and ~10m for mature pine trees. We do not expect top canopy height will increase dramatically during the NEON operation at this site, e.g., ~10 y. The vegetation and shrubs at forest floor are ~ 0.20 m to 1 m in height.

Table 10. Ecosystem and site attributes for the Fraser Relocatable site.

Ecosystem attributes	Measure and units
Mean canopy height [a]	22 m
Surface roughness [a]	2 m
Zero place displacement height [a]	18 m
Structural elements	Spruce, pine and fir forest, semi-open canopy, mixed age and height
Time zone	Mountain time zone
Magnetic declination	8.96° E changing by 0.13° W per year

Note, [a] From field survey. Although the forest actively recruits, we do not expect mean canopy height for the top mature canopy change dramatically. Therefore, 22 m canopy height at site characterization is used here for tower height estimate.

5.2 Site Design and Tower Attributes

The site layout is summarized in the table below. Assume the projected area of the tower is square. **Anemometer/temperature boom arm direction** is ***from*** the tower ***toward*** the prevailing wind direction or designated orientation. . The side of the tower with the anemometer boom is perpendicular to the boom direction. **Instrument hut orientation vector** is parallel to the long side of the instrument hut. **Instrument hut distance z** is the distance from the center of tower projection to the center of the instrument hut projection on the ground. The numbering of the **measurement levels** is that the lowest is level one, and each subsequent increase in height is numbered sequentially.

Table 11. Site design and tower attributes for Fraser Relocatable site

0° is true north with declination accounted for. Color of Instrument hut exterior shall be tan or best match the surrounding environment.

Attribute	lat	long	degree	meters	notes
Airshed			170° to 220°		Clockwise from first angle.
Tower location	39.89267	-105.89171	--	--	new site
Instrument hut	39.89255	-105.89143			
Instrument hut orientation vector	--	--	200°-20°		
Instrument hut distance z	--	--	--	25	
Anemometer/Temperature boom orientation	--	--	300°	--	
Height of the measurement levels					
Level 1				0.3	m.a.g.l.
Level 2				2.0	m.a.g.l.
Level 3				10.0	m.a.g.l.
Level 4				21.0	m.a.g.l.
Level 5				25.0	m.a.g.l.
Level 6				34.0	m.ag.l.
Tower Height				34.0	m.a.g.l.

See AD 03 for technical requirement to determine the boom height for the bottom most measurement level.

Eddy covariance, sonic wind and air temperature **boom arms** orientation toward the 300° will be best to capture signals from all major wind directions. **Radiation boom arms** should always be facing south to avoid any shadowing effects from the tower structure.

Secondary **precipitation collector** for bulk precipitation collection will be located the top of tower at this site. **Wet deposition collector** will be collocated at the tower top. See AD 04 for further information and requirements for bulk precipitation collection and wet deposition collection.

Boardwalks. Ultimately, the decision to use a boardwalk will be, in part, based on owner's preferences. There are strong science requirements that minimize site disturbance to the surrounding area, which will be difficult to manage over a 30-y period. Traffic control is key to minimizing the site disturbance. Confining foot traffic to boardwalks minimizes site impact; this is particularly true in places where wear caused by foot traffic becomes noticeable and grows. For example, in places with snow part of the year, worn footpaths tend to have low places that collect water, or places where the snow pack becomes uneven causing personnel to walk farther and farther around the sides of the original path, causing the path to grow in width. This is a very common phenomenon. FIU assumes that all conduits will be either buried, or placed inside the boardwalk such that it does not extend beyond the 36' wide footprint.

While the final design is not yet known, there are some general criteria that can be outlined. We assume that the boardwalk width is 36" (0.914 m). Material is not known, but must be fire proof, and in some locations the site is seasonally flooded and inundated with water. Boardwalks may also provide a scratching structure for grazing animals that in turn, would wear and unduly impact the site. Site by site evaluations must be done.

- Boardwalk or on-grade boardwalk from the access dirt road to instrument hut, pending landowner decision.
- Boardwalk from the instrument hut to the tower pending landowner decision
- Boardwalk or on-grade boardwalk to soil array

No boardwalk from soil array boardwalk to individual soil plots.

The relative locations between tower, instrument hut and boardwalk can be found in the diagram below:

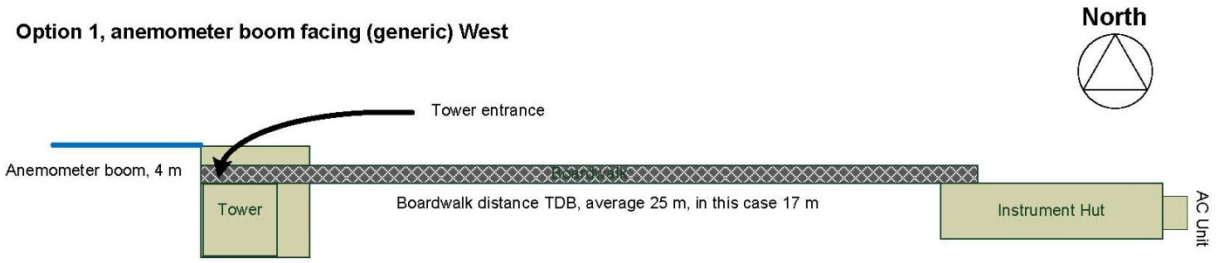


Figure 5. Generic diagram to demonstration the relationship between tower and instrument hut when boom facing west and instrument hut on the east towards the tower.

This is just a generic diagram when boom facing west and instrument hut on the eastern side of the tower. The actual design of boardwalk (or path) and instrument hut position will be joint responsibility of FCC and FIU. At Fraser Relocatable site, the boom angle will be 300 degrees, instrument hut will be on the southeast side of the tower, the distance between instrument hut and tower is ~25 m. The instrument hut vector will be SW-NE (200°-20°, longwise).

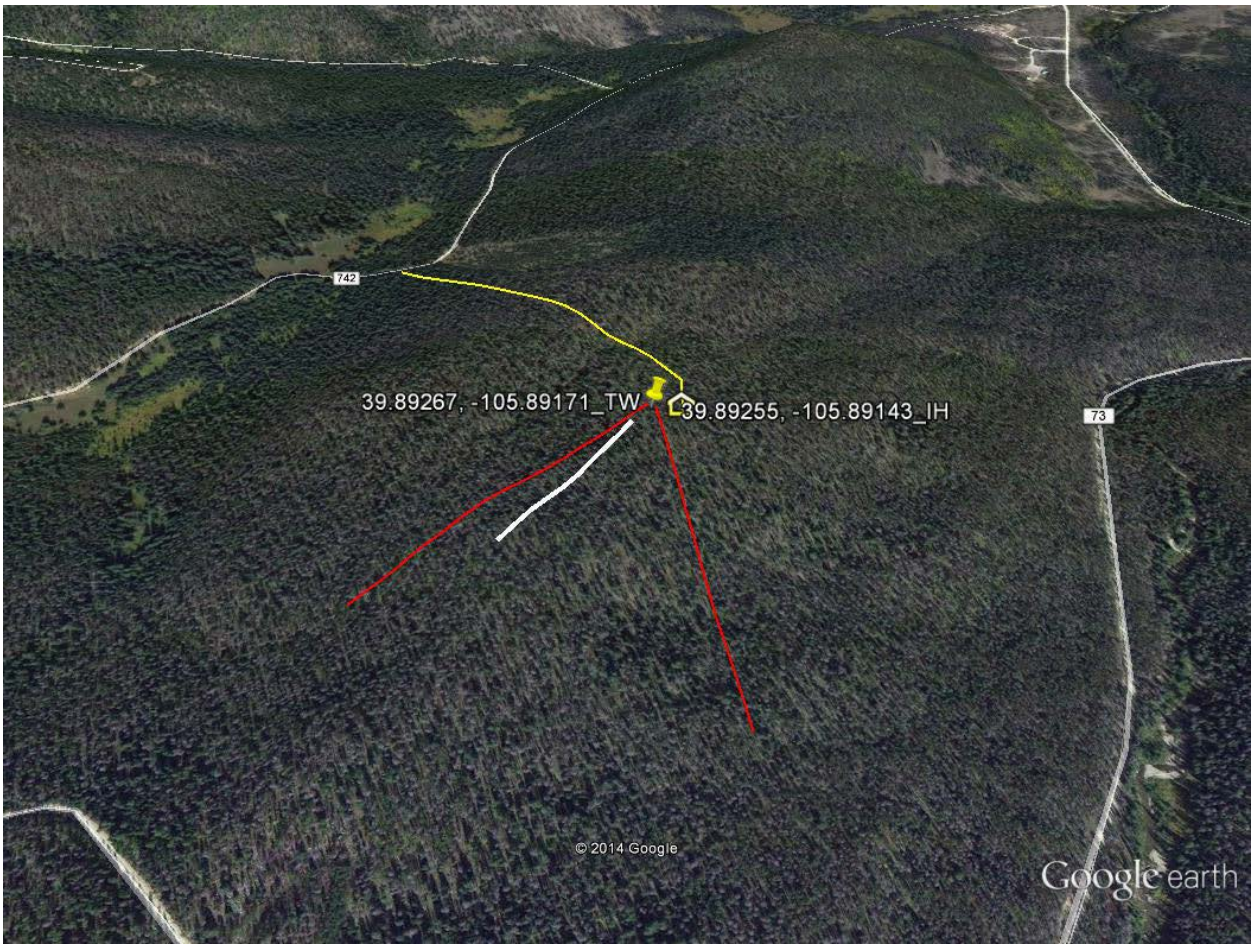


Figure 6. Site layout for Fraser Relocatable site.
i) tower location is presented (red pin), ii) red lines indicate the airshed boundaries. Vectors from 170^{o} to 220^{o} (clockwise from 170^{o}, major airshed) would have quality wind data without causing flow distortions, respectively. iii) Yellow line is the suggested access way to instrument hut.

5.3 Soil Attributes

The soil array vector is ***from*** the soil plot closest to the tower ***toward*** the farthest soil plot. The exact location of each soil plot will be chosen by an FIU team member during site construction to avoid placing a soil plot at an unrepresentative location (e.g., rock outcrop, drainage channel, large tree, etc).

Dominant soil series at the site: Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes. The taxonomy of this soil is shown below:
Order: Inceptisols
Suborder: Cryepts
Great group: Dystrocryepts
Subgroup: Typic Dystrocryepts
Family: Loamy-skeletal, mixed, superactive Typic Dystrocryepts
Series: Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes

Table 12. Summary of soil array and soil pit information at Fraser site. 0° represents true north and accounts for declination.

Soil plot dimensions	5 m x 5 m
Soil array pattern	B
Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	22 m
Latitude and longitude of 1st soil plot OR direction from tower	39.89253°, -105.89188°
Direction of soil array	210°
Latitude and longitude of FIU soil pit 1	TBD, will be picked along site access route during site design process
Latitude and longitude of FIU soil pit 2	TBD, will be picked along site access route during site design process
Latitude and longitude of FIU soil pit 3	TBD, will be picked along site access route during site design process
Dominant soil type	Leighcan family, till substratum, 5 to 40 percent slopes - Leighcan family, 5 to 40 percent slopes
Expected soil depth	0.51-1.52 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.05 m (cobbly silt loam)	0.03 m
0.05-0.23 m (very cobbly silt loam)	0.14 m
0.23-0.71 (very cobbly sandy loam)	0.47 m
0.71-1.14 m (extremely stony loamy sand)	0.93 m
1.14-1.52 m (extremely stony loamy sand)	1.33 m

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.

Because the ecosystems has a height of the mean plant canopy > 1.75 m and the tower has to pass through the plant canopy vertically, tower has been sited to i) allow the tower pass through the canopy with minimizing the remove foliage during the tower establishment, ii) optimize the temporal coverage of flow-based measurements over the representative environment, iii) minimize flow distortions caused by local ecosystem structure or topography (orography), and iv) allow the sensors on the tower booms to measure the representative surrounding environment. The location identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

To avoid edge effect on science measurements, tower, soil array, and sensor locations have been sited such that the meteorological sensors and soil sensors are ≥ 60 m away from the edge of the representative ecosystem in interest, and flux sensors are ≥ 180 m from the edge of the representative ecosystem. The sensor locations identified here and its (final) placement (e.g., during reviews, construction activities, FCC micrositing) will have to be evaluated against these conditions and requirements.

5.4 Information for ecosystem productivity plots

The tower has been positioned to optimize the collection of the air/wind signals both temporally and spatially over the desired ecosystem (mixed spruce and fir and pine conifer forest). Prevailing winds blow from south (170^{o} to 220^{o}, clockwise from 170^{o}). We expect that 80% for flux measurements are ~480 m during daytime and >3 km from tower during night time in summer seasons, and 90% signals are ~820 m from tower during daytime and >3 km during nighttime. However, during the winter seasons, 80% signals are within 630 m during daytime and over 3km for nighttime, while 90% signals are come from larger distance ~1km during daytime and > 3km during night time. We suggest FSU Ecosystem Productivity plots are placed within the boundaries of 170^{o} to 220^{o} (clockwise from 170°) from tower.

5.5 Issues and attentions

The road to the site is unpaved, as a result 4-wheel drive and high ground clearance is recommended to access the site.

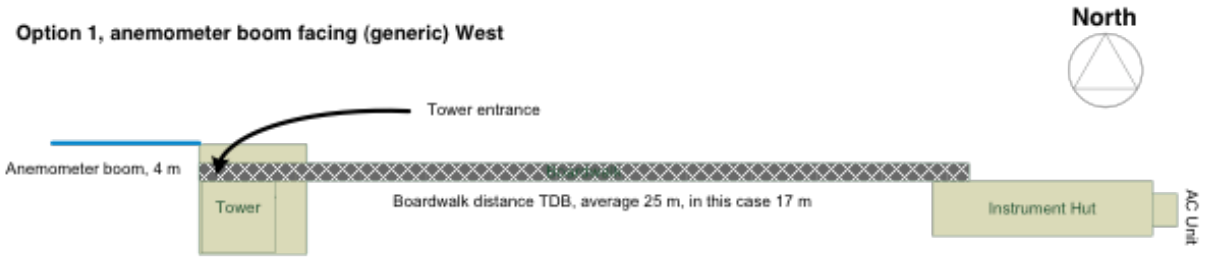
Boardwalks can be used at the site, but it is not unusual to have very deep snow in forest clearings, so route markers will be needed for winter access.

Beetle killed trees are common in this region. Many already fell on the ground (access harzard) and many are still standing, but could fall or snap any time under windy conditions (safety harzard).

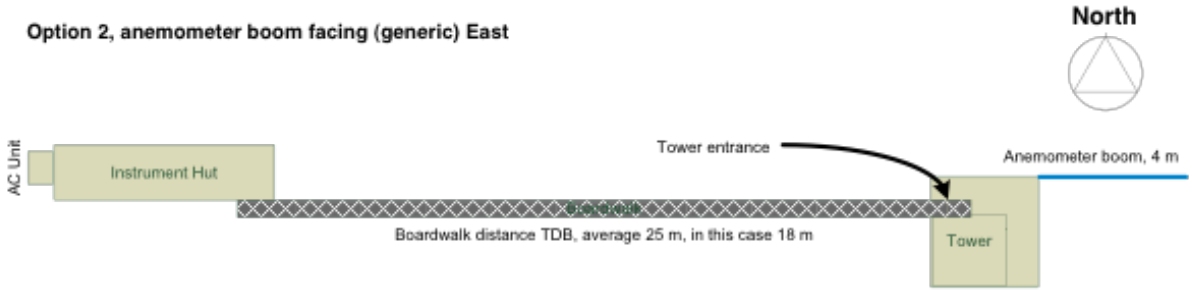
There are few beetle killed trees around tower location. They likely come down in next few years either by wind force or gravity. Consideration will be needed to protect tower, guy wires, booms and sensors.

One of the key science themes at this site supposes be a middle elevation (9000’ to 1100’) to capture the dust transport cross the Rocky Mountains. This tower location is at ~9,500’, which is toward the low end of the range and similar to the low elevation site at CASTNET (~9,000’). From this science theme, this site is less ideal.

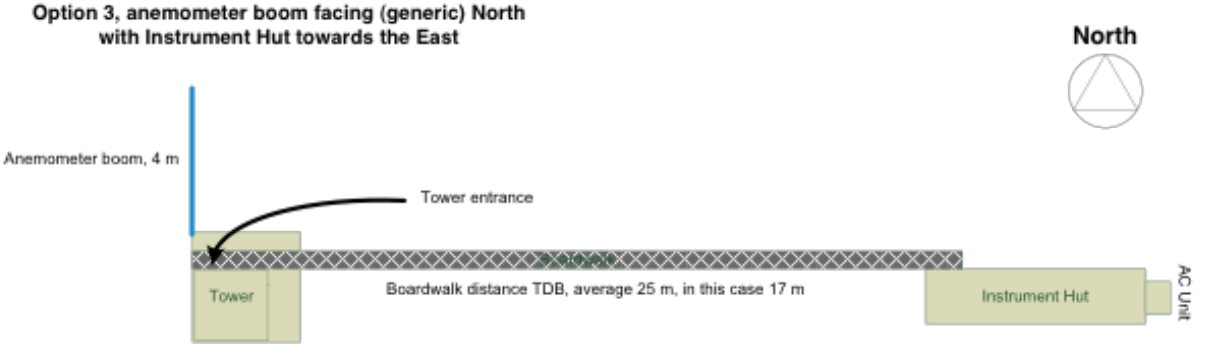
Option 1, anemometer boom facing (generic) West



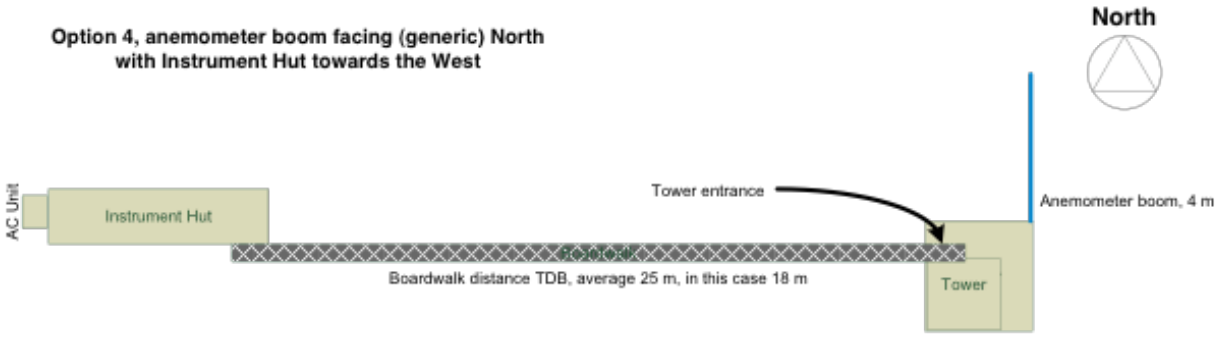
Option 2, anemometer boom facing (generic) East



Option 3, anemometer boom facing (generic) North with Instrument Hut towards the East



Option 4, anemometer boom facing (generic) North with Instrument Hut towards the West



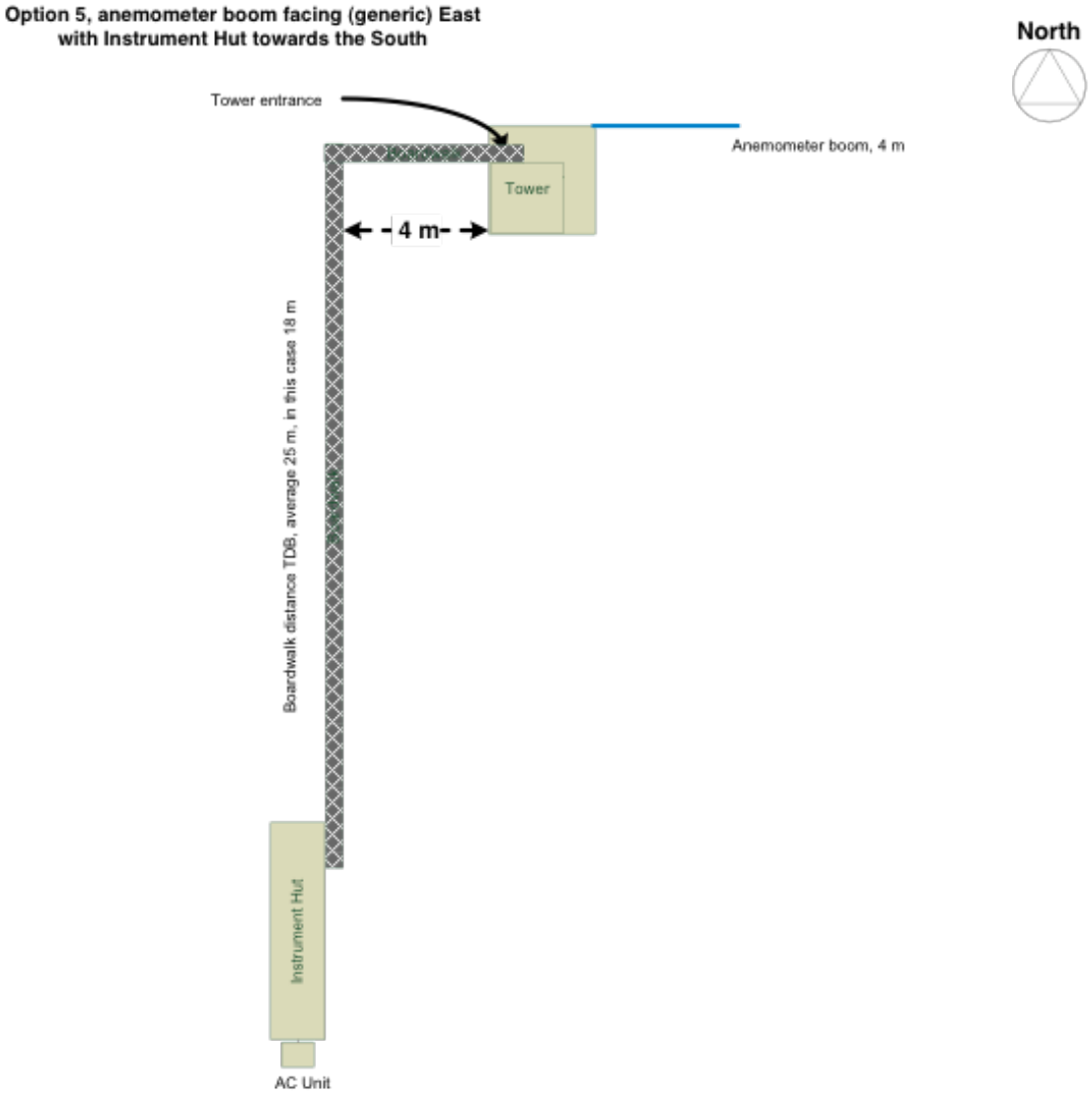
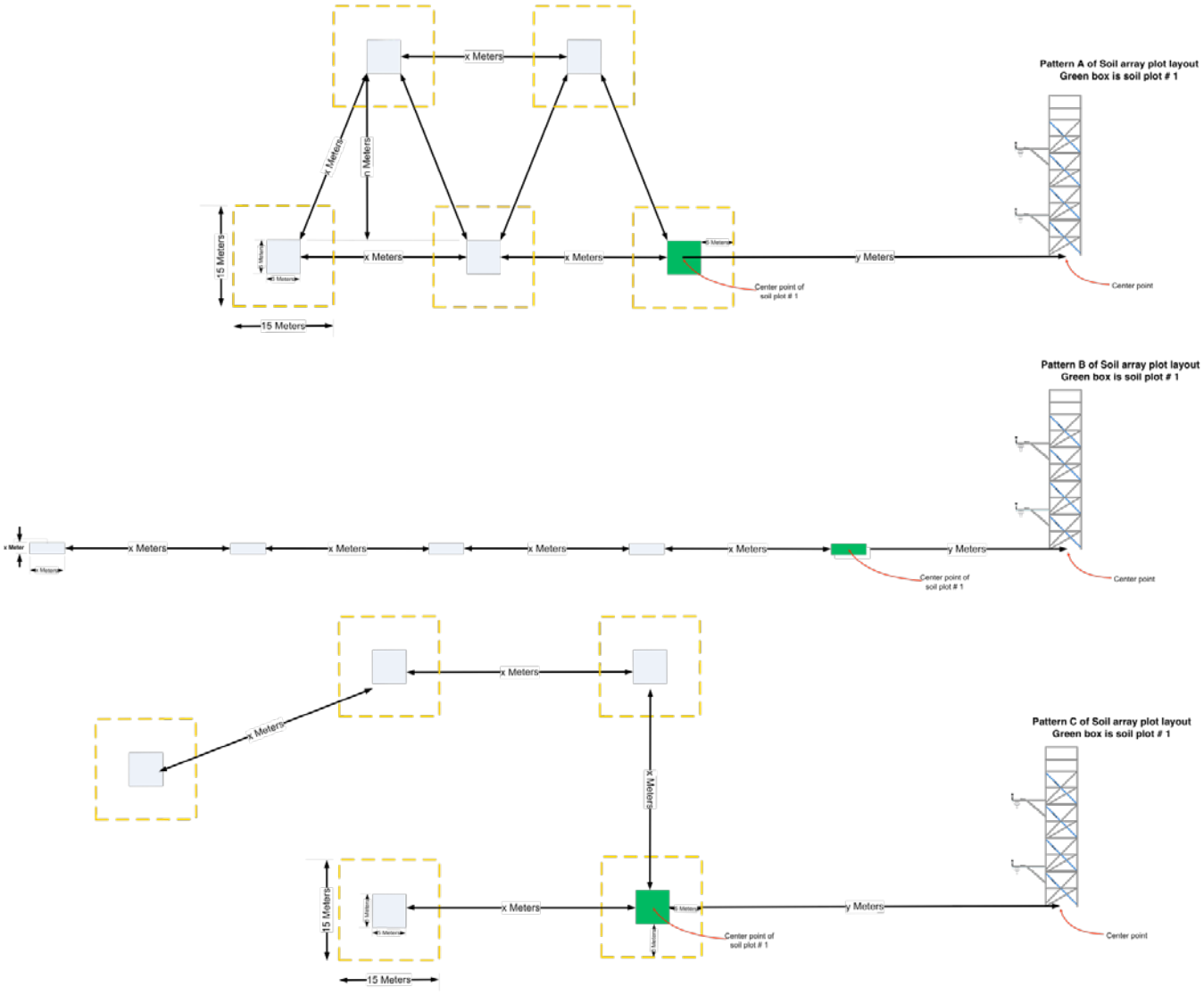


Figure 7. Generic patterns for the boardwalk configuration

These generic configurations are from the instrument hut to the tower based on 5 generic scenarios. The five options are based on anemometer boom orientation and the leeward side of the tower where the instrument hut is located. The tower entrance is always on the North side of the tower. Exact tower and instrument hut location and orientation will be specified at each location and presented in the site characterization document.


Pattern A of Soil array plot layout
Green box is soil plot # 1
x Meters
x Meters
n Meters
15 Meters
15 Meters
x Meters
x Meters
y Meters
Center point of soil plot # 1
Center point
Pattern B of Soil array plot layout
Green box is soil plot # 1
x Meter
x Meters
x Meters
x Meters
x Meters
y Meters
Center point of soil plot # 1
Center point
Pattern C of Soil array plot layout
Green box is soil plot # 1
x Meters
x Meters
x Meters
15 Meters
15 Meters
x Meters
y Meters
Center point of soil plot # 1
Center point

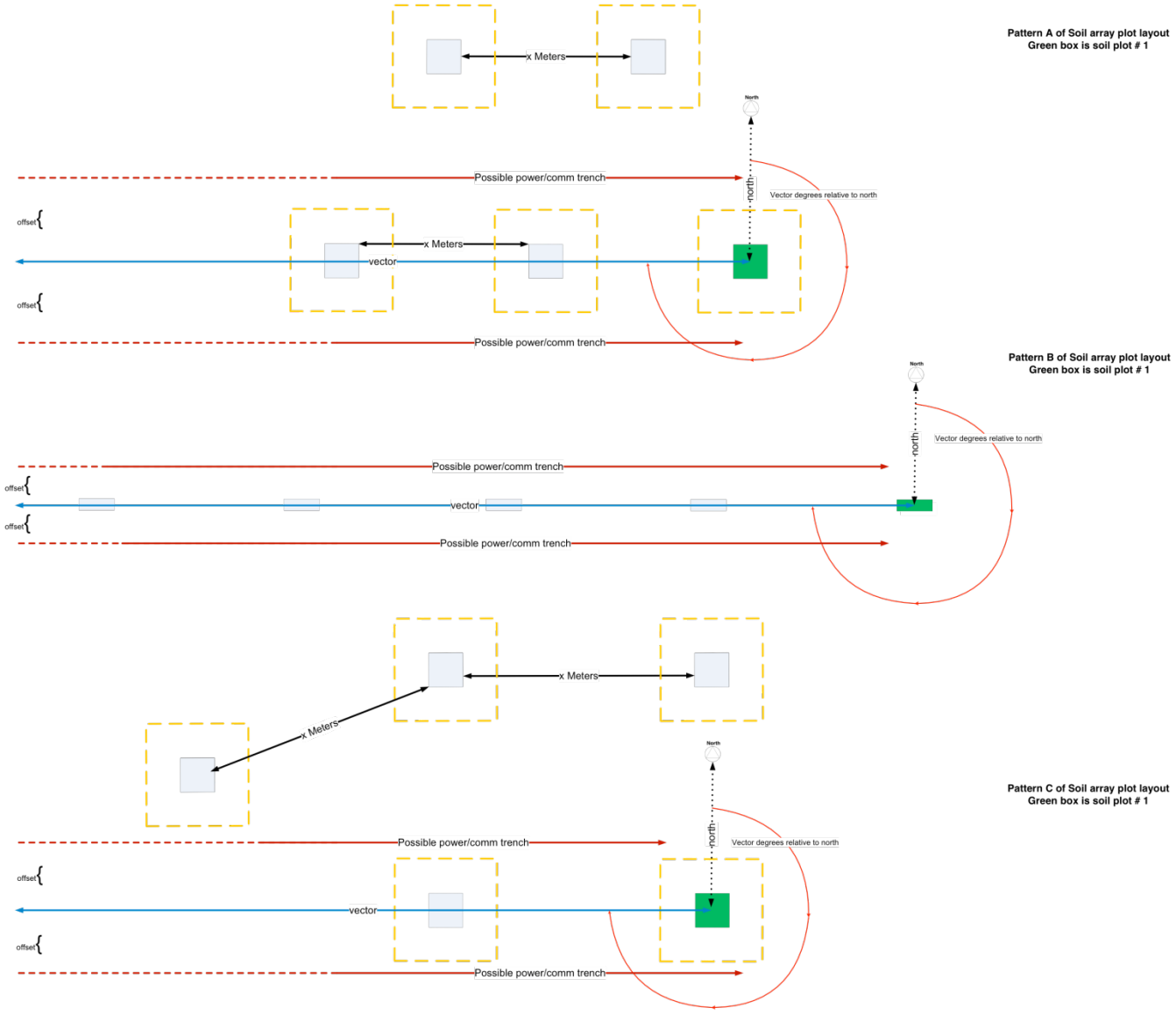


Figure 8. Conceptual diagram of Soil Array Patterns

Outlines the orientation for the soil array and instrument hut from the center point of the tower. The x, y, z distances are i) the distance between soil plots, ii) distance between the tower centerpoint and the closest edge of soil plot, and iii) the distance between the tower centerpoint and the closest edge of the instrument hut, respectively. The yellow outline around each soil plot is the 5 m perimeter keep out zone.

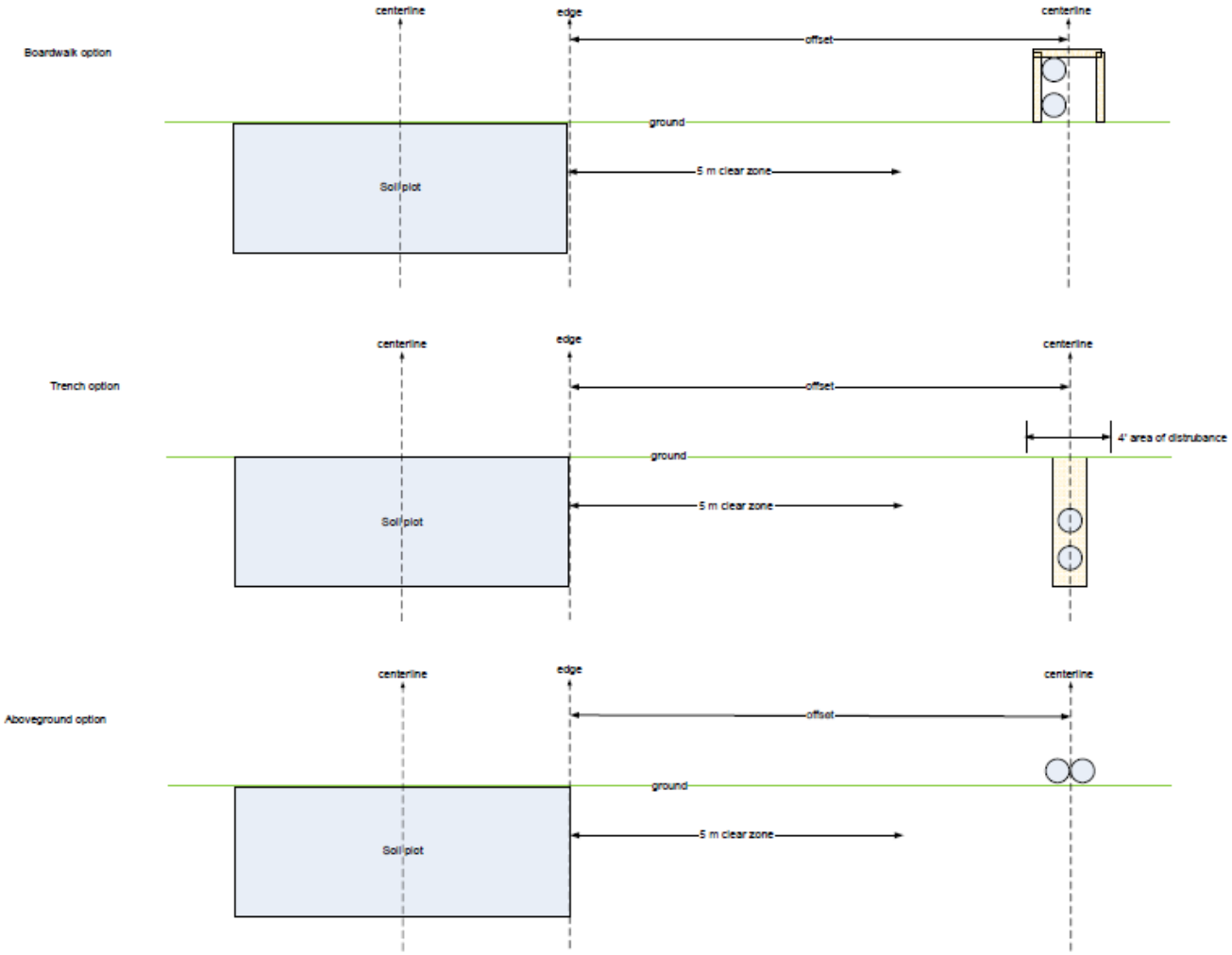


Figure 9. Conceptual diagram of power/communications line and boardwalk/path options in relation to FIU soil plots.

Boardwalk option: When a boardwalk is present the power and communication lines will typically follow the route of the boardwalk and be mounted aboveground (underneath the boardwalk). When no boardwalk is present (or the power/communication lines follow a different route than the boardwalk) the lines can be buried (Trench option) or run aboveground (Aboveground option). The aboveground option will be used instead of the trench option when trenching would be expected to cause significant disturbance to an ecosystem (e.g. cutting the roots of trees), pending landowner approval.

6 APPENDIX A. FCC SUMMARY TABLES

Table 13. FCC Summary Table for FIU site components at D13 Niwot Ridge Advanced site

Site Component				**units**
Tower location	40.05425,	-105.58237		Lat, Long, in degrees
Tower location	40° 3' 15.3"	-105° 34' 56.5314"		Lat, Long in deg min sec
Tower height[f]	6			meters
Tower guying	yes	Due to the high winds that can occur at the site guy wires are needed to increase the stability of the tower.		yes/none, notes
Instrument Hut location	40.05435°,	-105.58218°		Lat, Long, in degrees
Instrument Hut location	40° 3' 15.6594"	-105° 34' 55.8474"		Lat, Long in deg min sec
IH orientation[a]	225° - 45°			vector
boom orientation[b]	225°			degrees
distance from center of tower to IH center (z)		19	option 1	distance (m), option #, (location chosen to meet National Park approval)
how the Bwalk intersects the tower access	No BW. Marked path intersects the north-side of the tower from the northeast. Suggest material for a path be placed directly on the tundra, like that used at Barrow Alaska (but this requires landowner approval).			description
Air shed vector(s)[c]	185° to 305°			Vector, clock wise from first angle
Boardwalk from AP to IH	No BW. Use marked path.			yes/none, notes
Boardwalk to soil array	No BW. Use marked path.			yes/none, notes
Boardwalk needed to DFIR	No BW. Use marked path.			yes/none
Power and Communication trench	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest [e], line above ground.		offset, notes

DFIR location	40.05399,	-105.58212		Lat, Long in degrees, notes
DFIR location	40° 3' 14.3634"	-105° 34' 55.632"		Lat, Long in deg min sec
DFIR power supply	30 amp AC power from tower			description
Soil plot 1st location	40.054200°,	-105.582550°		Lat, Long in degrees (center point)
Soil plot 1st location	40° 3' 15.12"	-105° 34' 57.1794"		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	25 m	16 m		x, y (meters)
Soil array pattern and vector[d]	B	120°		A, B, or C, vector
Soil plot dimensions	5 m x 5 m			L x W (meters)
Soil profile pit primary	40.052199°,	-105.583685°	>2 m (3 m if possible)	Lat, Long, and expected depth
Soil profile pit primary	40° 3' 7.9164"	-105° 35' 1.266"		Lat, Long in deg min sec
Soil profile pit alternative 1	40.052377°,	-105.583263°	>2 m (3 m if possible)	Lat, Long, and expected depth
Soil profile pit alternative 1	40° 3' 8.5566"	-105° 34' 59.7468"		Lat, Long in deg min sec
Soil profile pit alternative 2	40.052554°,	-105.582817°	>2 m (3 m if possible)	Lat, Long, and expected depth
Soil profile pit alternative 2	40° 3' 9.1944"	-105° 34' 58.1412"		Lat, Long in deg min sec
Fencing needs	none	none	none	IH, Soil Arrays, Guy anchors
Presence of large grazing animals	Possible			description
Site management*	Managed as a wild land			description
Any additional site specific information	Alpine tundra ecosystem consists of a mixture of dry and wet tundra. Tundra recovery is very slow. Disturbance should be minimized.			description
Magnetic declination	9° 22' E changing by 0° 7' W/year			At time of site visit

Table 14. FCC Summary Table for FIU site components at D13 Moab Relocatable 1

Site Component				**units**
Tower location	38.24833,	-109.38827		Lat, Long in degrees
Tower location	38° 14' 53.988"	-109° 23' 17.772"		Lat, Long in deg min sec
Tower height[f]	6 m			meters
Tower guying	No			yes/none, notes
Instrument Hut location	38.24846,	-109.38815		Lat, Long in degrees
Instrument Hut location	38° 14' 54.456"	-109° 23' 17.3394"		Lat, Long in deg min sec
IH orientation[a]	90°-270°			vector
boom orientation[b]	180°			degrees
distance from center of tower to IH center (z)		18	Option 8	vector, distance (m), option #
how the Bwalk intersects the tower access	Boardwalk intersects the north-side of the tower from the IH on northeast.			description
Air shed vector(s)[c]	75° to 105° (major) and 170° to 290° (secondary) airshed)			vector, clockwise from first angle
Boardwalk from AP to IH	yes			yes/none, notes
Boardwalk to soil array	yes	BW from soil array BW to individual soil plots.		yes/none, notes
Boardwalk needed to DFIR	NA			yes/none
DFIR location	NA			Lat, Long
Power and Communication line	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest[e], line above ground		offset, notes
DFIR power supply	na.			description
Soil plot 1st location	38.24823,	-109.38844		Lat, Long (center point)
Soil plot 1st location	38° 14' 53.6274"	-109° 23' 18.384"		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	37 m	19 m		x, y (meters)
Soil array pattern and vector[d]	B	250°		A, B, or C, vector
Soil plot dimensions	5 m x 5 m			L x W (meters)

Soil profile pit primary	38.251343°,	-109.388814°	>2 m	Lat, Long, and expected depth
Soil profile pit primary	38° 15' 4.8342"	-109° 23' 19.7298"		
Soil profile pit alternative 1	38.251157°,	-109.389337°	>2 m	Lat, Long, and expected depth
Soil profile pit alternative 1	38° 15' 4.1646"	-109° 23' 21.6126"		Lat, Long in deg min sec
Soil profile pit alternative 2	38.250921°,	-109.389868°	>2 m	Lat, Long, and expected depth
Soil profile pit alternative 2	38° 15' 3.315"	-109° 23' 23.5248"		Lat, Long in deg min sec
Fencing needs	none	none	none	IH, Soil Arrays, Guy anchors
Presence of large grazing animals	Yes, lightly grazed, possibly by deer			description
Site management*	Managed as wild land			description
Any additional site specific information	Dust generation and deposition is the important science theme at this site. The soil, especially the soil crust, is sensitive to disturbance, which results in increased dust generation. **Extra care** must be taken to minimize distrubance at this NEON site.			description
Magnetic declination	10° 51' E changing by 0° 7' W/year			At time of site visit

Table 15. FCC Summary Table for FIU site components at D13 Fraser Relocatable 2

Site Component				**units**
Tower location	39.89267	-105.89171		Lat, Long in degrees
Tower location	39°53'33.61"	105°53'30.16"		Lat, Long in deg min sec
Tower height[f]	34			meters
Tower guying	yes			yes/none, notes
Instrument Hut location	39.89255	-105.89143		Lat, Long in degrees
Instrument Hut location	39°53'33.18"	105°53'29.15"		Lat, Long in deg min sec
IH orientation[a]	200° - 20°			vector
boom orientation[b]	300°			degrees
distance from center of tower to IH center (z)		25	Option 1	distance (m), option #
how the Bwalk intersects the tower access	Boardwalk intersects the north-side of the tower from IH on southeast.			description
Air shed vector(s)[c]	170° to 220°			vector, Clockwise from first angle
Boardwalk from AP to IH	Yes			yes/none, notes
Boardwalk to soil array	Yes	No BW to individual soil plots		yes/none, notes
Boardwalk needed to DFIR	NA			yes/none
Power and Communication line	10 m from edge of soil plot to the centerline of the power/comms line	whichever side is easiest [e], line above ground		offset, notes
DFIR location	NA			Lat, Long
DFIR power supply	NA			description
Soil plot 1st location	39.89253°	-105.89188°		Lat, Long in degrees (center point)
Soil plot 1st location	39°53'33.11"	-105°53'30.77"		Lat, Long in deg min sec
Soil plot distance between plots (x) and from tower (y)	40 m	22 m		X, Y (meters)
Soil array pattern and vector[d]	B	210°		A, B, or C, vector, notes
Soil plot dimensions	5 m x 5 m			L x W (meters)
Soil profile pit primary	TBD, will be picked			Lat, Long, and expected depth

	along site access route during site design process			
Soil profile pit primary	TBD			
Soil profile pit alternative 1	TBD			Lat, Long, and expected depth
Soil profile pit alternative 1	TBD			Lat, Long in deg min sec
Soil profile pit alternative 2	TBD			Lat, Long, and expected depth
Soil profile pit alternative 2	TBD			Lat, Long in deg min sec
Fencing needs	none	none	none	IH, Soil Arrays, Guy anchors
Presence of large grazing animals	Possibly some wild animals, like deer, elks, etc			description
Site management*	Managed as wild land			description
Any additional site specific information	Spruce and fir and pine forest, open canopy, mixed age and height; a lot of beetle killed trees either standing or falling on the ground.			description
Magnetic declination	8.96° E changing by 0.13° W per year			At time of site visit

Notes;

[a]parallel to the long side of the IH

[b]From tower point to this direction

[c]Clockwise from first angle, recommend reviewing FIU site characterization summary report

[d]From 1st plot toward other plots if pattern B, from 1st plot toward nearest neighbor (see diagram of the patterns)

[e]see Appendix A. Options for Soil Array, second figure.

[f]Tower Height is for FIU requirements; actual tower height will increase toward the next section height.

IH = instrument hut

AP = auxillary portal

*burn information that may affect boardwalk, IH, or tower infrastructure, or other management activities