O S&E Odor Science & Engineering, Inc.

REVIEW OF ODOR MITIGATION AT THE PROPOSED MARIJUANA CULTIVATION FACILITY IN GREAT BARRINGTON, MASSACHUSSETTS

Prepared for the Town of Great Barrington

Prepared by:
Ned Ostojic, Ph.D.,P.E.

December 29, 2019

OS&E Project No. 2156-M-00

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SUMMARY AND CONLUSIONS

Fulcrum Enterprises, LLC (Fulcrum) seeks to develop a marijuana cultivation and manufacturing facility at 22 Deusenville Road in Great Barrington, Massachusetts. The Town of Great Barrington has retained Odor Science & Engineering, Inc., (OS&E) to conduct an assessment of the adequacy of the odor mitigation measures planned for the proposed facility.

On September 18, 2019, OS&E submitted a draft report presenting its findings from the review of the original Fulcrum submittal. The report identified several shortcomings in the proposed odor mitigation plan, stemming mainly from unsubstantiated claims of performance of the proposed odor mitigation technology.

The Applicant made a conscientious effort to address these shortcomings. This included several investigations, the results of which were incorporated into a 276-page December 5, 2019, submittal. This report presents OS&E's findings from review of that submittal.

The Applicant conducted odor emission testing at an existing cannabis cultivation facility in California which resembles the proposed facility in Great Barrington both in design and in operation. OS&E participated in the preparation of the testing protocol. Odor samples were collected by Environmental Permitting Specialists (EPS) and were shipped overnight to the OS&E olfactory laboratory where they were analyzed the next day by dynamic dilution olfactometry. The results of the odor analysis were presented in the October 8, 2019 Project Note No. 1 prepared by Ned Ostojic.

Following this test, EPS conducted odor dispersion modeling to evaluate potential odor impacts from the proposed facility in Great Barrington. In addition, Fulcrum retained Bosarge Environmental to conduct off-site and on-site odor evaluation at the same California facility utilizing a portable olfactometer (Nasal Ranger). The December 5 Fulcrum submittal also includes an updated odor control plan and system design prepared by NCM Environmental Solutions (NCM).

The following conclusions were based on the review of the above materials.

CONCLUSIONS

- When the odor concentrations measured in the samples collected by EPS at the California cannabis facility, are used as input to the odor dispersion model, potentially significant odor impacts are predicted in the area surrounding the proposed Great Barrington facility area under the most unfavorable meteorological conditions. Even though such impacts may not be frequent, they highlight the need for an effective odor mitigation technology at the proposed facility.

- This finding is in contrast with the findings from the investigation conducted by Bosarge Environmental at the same California facility, using Nasal Ranger. Bosarge findings indicate that the odor levels generated in cannabis cultivation are far too low to warrant any odor control, even during the peak odor emission phase in the plants' growing cycle.

- Odor concentration readings taken by Bosarge using Nasal Ranger are more than one hundred times lower than the odor concentrations measured by dynamic dilution olfactometry in the samples collected by EPS at the same facility under comparable conditions and within the same time frame. A discussion of the factors which may have contributed to the unrealistically low odor concentration readings reported by Bosarge is provided in Section 4 of this report.

- Bosarge also conducted several off-site odor surveys in the area surrounding the California facility. Off-site odor surveys can be used to document the "odor footprints" of existing facilities. This is best accomplished by systematically traversing the facility's odor plume at increasing distances from the facility, until the odor is no longer detectable. In contrast, the Bosarge surveys were structured as a series of Nasal Ranger readings at fixed locations in the surrounding area. Limiting the readings to fixed locations carries a risk of missing the odor plume entirely or in part. This indeed happened on a number of surveys in which the observation locations were upwind from the facility or otherwise out of the path of the odor plume. No facility related odors were found off-site.

- As first communicated in the OS&E's October 8 Project Note, analysis of the odor samples collected by EPS at the cannabis cultivation facility in California, showed no appreciable change in odor concentration, odor character and odor intensity as a result of the odor neutralizer addition to the greenhouse exhaust. Accordingly, this form of odor treatment was not found to be capable of providing an effective protection against potentially objectionable odors.

- The December 5, 2019 Fulcrum submittal includes a revised odor control plan prepared by NCM. The plan relies essentially on the same odor neutralizer treatment as originally proposed. Section 4 of the plan presents "administrative controls" including a newly added Section 4.1, "Monitoring". That section describes proposed measures aimed at increasing the awareness of the facility's operators of ambient odors in the area surrounding the facility. As such, the section addresses one of the shortcomings in the originally proposed plan, which relied to a large extent on odor complaint follow-up investigations for that purpose. This welcome addition to the proposed odor mitigation plan could be improved by some re-structuring as discussed in Section 5.

- The main shortcoming of the revised odor control plan is its continued reliance on the odor neutralizer in a manner which was found not to be effective based on the analysis of the samples collected by EPS at the California facility. Thus, even if the facility's operating staff were made aware of a potential odor occurrence, their ability to mitigate it would be limited.

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1.0. Introduction

Fulcrum Enterprises, LLC (Fulcrum) seeks to develop a marijuana cultivation and manufacturing facility at 22 Deusenville Road in Great Barrington, Massachusetts. The Town of Great Barrington has retained Odor Science & Engineering, Inc., (OS&E) to conduct an assessment of the adequacy of the odor mitigation measured planned for the proposed facility. .

On September 18, 2019, OS&E submitted a draft report presenting its findings from the review of the original Fulcrum submittal. The report identified several shortcomings in the proposed odor mitigation plan, stemming mainly from unsubstantiated claims of performance of the proposed odor mitigation technology. The absence of the evidence of the actual effectiveness of the neutralizer made it impossible to reach a conclusion regarding the adequacy of the proposed odor mitigation plan.

The Applicant made a conscientious effort to address the shortcomings identified in the OS&E report. This included several investigations, the results of which were incorporated into a 276-page December 5, 2019, submittal. The submittal was made available as a pdf document[1] . To facilitate access to selected materials in that document, references to the associated pages in the document have occasionally been provided in this report as "pdf page…".

The additional investigations performed by the Applicant included odor emission testing at an existing marijuana cultivation facility in California. In design and operation that facility resembles the proposed facility in Great Barrington. OS&E participated in the preparation of the testing protocol. Odor samples were collected by Environmental Permitting Specialists (EPS) and were shipped overnight to the OS&E olfactory laboratory where they were analyzed the next day by dynamic dilution olfactometry The results of the odor analysis were presented in the October 8, 2019 Project Note No. 1 (Project Note), prepared by Ned Ostojic and are also presented in Section 2 below.

Following this test, EPS conducted odor dispersion modeling to evaluate potential odor impacts from the proposed facility in Great Barrington. They presented their findings in a report included in the December 5 Fulcrum submittal (pdf page 65). A discussion of that report is presented in Section 3 below.

1) https://www.dropbox.com/s/z0qf29a9h92m0vh/Fulcrum%20new%20submittal%20December%205%202019.pdf?dl=0

In addition, Fulcrum retained Bosarge Environmental to conduct off-site and on-site odor evaluation at the same California facility utilizing a portable olfactometer (Nasal Ranger). A report with the results of that investigation was also included in the December 5 Fulcrum submittal (pdf page 133). A discussion of that report is presented in Section 4 of this report.

The December 5 Fulcrum submittal also included an updated odor control plan and system design prepared by NCM Environmental Solutions (NCM) (pdf page 180). A discussion of this updated plan is presented in Section 5 below.

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2.0. Odor Emissions Testing at the California Facility

NCM identified a cannabis cultivation facility in California, California, very similar in design and operation to the proposed facility in Great Barrington, with the same odor neutralization technique for odor control as is being proposed in Great Barrington. The facility thus offered an ideal opportunity to measure the odor levels in the exhausts from the greenhouses and to evaluate the effectiveness of the odor neutralization system.

The test was carried out on October 1, 2019, in accordance with a protocol which included the Updated Testing Procedure provided in Appendix A. The samples were shipped overnight to the OS&E olfactory laboratory where they were analyzed the next day by dynamic dilution olfactometry in accordance with ASTM E679-04. The analytical procedure is described in Appendix B
.
Two sets of three tests were conducted under the following conditions:

> **Test 1**: Normal neutralizer addition rate, judged to provide the highest level of odor neutralization. The neutralizer formulation did not contain an aroma (Samples 1A and 2A).
> **Test 2**: The addition of the neutralizer to the water flowing to the nozzles was discontinued, allowing only the water to flow to the nozzles. This tested any effect which water alone may have on odor suppression (Samples 1B and 2B).
> **Test 3**: The flow of the water to the nozzles was discontinued. This measured the odor level in absence of any treatment, i.e. the uncontrolled odor emissions (Samples 1C and 2C).

This sequence of operation was selected so that the ventilation exhaust would contain progressively higher levels of odor, starting with maximum level of control in Test 1 to no control in Test 3.

In addition, two samples were collected with normal neutralizer operation with addition of a citrus aroma (Samples C1 and C2). The samples were collected at a distance of approximately 12 ft from the greenhouse exhaust fan.

The results of the analysis are presented in Table 2-1 and in Figures 2-3 through 2-3. As seen in Table 2-1, there was no appreciable difference in the odor concentration and in the odor character for the three tested operating conditions. The data reflect variability which would be expected when samples are collected some distance from the source.

Figures 2-1 through 2-3 show the relationship between odor concentration and odor intensity. Odor intensity was measured using the n-butanol odor intensity scale in accordance with ASTM E544-10. The procedure is described in Appendix C. As seen in the figures, odor intensity increases with odor concentration. If a neutralizer had the effect of reducing odor intensity, the intensity data points would lie on a curve below the curve for the untreated odor. For example, Figure 2-1 shows trendlines for untreated greenhouse exhaust ("1C") and for a hypothetical case where the odor intensity would be reduced by 50% relative to the untreated exhaust ("50%").

As seen in Figures 2-1 and 2-2, no appreciable difference in odor intensity is apparent for the three tested scenarios.

Figure 2-3 combines the data for all the samples, including the sample with aroma addition (C1). No appreciable difference in the odor intensity pattern for that sample is apparent either.

Figure 2-4 provides a comparison of the odor concentrations for the three test conditions. No significant difference in the odor concentration levels is evident between the samples of treated and untreated greenhouse exhaust.

In conclusion, no appreciable change in odor concentration, odor character and odor intensity is evident as a result of neutralizer addition to the greenhouse exhaust.

Table 2-1. Results of the dynamic dilution analysis			
sample ID	time	odor concentration (D/T)[a]	odor character[b]
1A - neutralizer (no aroma)	10:40	230	skunk, weed, pot, burnt pot, cannabis
1B - water only	11:20	177	skunk, weed, pot, burnt pot, cannabis
1C - untreated exhaust[c]	12:01	230	skunk, weed, pot, burnt pot, cannabis
2A - neutralizer (no aroma)	12:36	193	skunk, weed, pot, burnt pot, cannabis, mercaptan
2B - water only	13:10	273	skunk, weed, pot, burnt pot, cannabis
2C – untreated exhaust[d]	13:40	230	skunk, weed, pot, burnt pot, cannabis, musty
C1 neutralizer (with aroma)	13:55?	273	skunk, weed, pot, burnt pot, cannabis, wet newspaper
C2 neutralizer (with aroma)*	14:00?		

a) D/T = dilutions to threshold
b) Description of odor character provided by the panelists in the course of the olfactometry analysis
c) Sample identified on the sampling bag as “3A” with no time of sampling. Sample ID and time shown in the table are based on the Chain of Custody
d) Sample identified on the sampling bag as “3B” with no time of sampling. Sample ID and time shown in the table are based on the Chain of Custody

* sample bag arrived empty

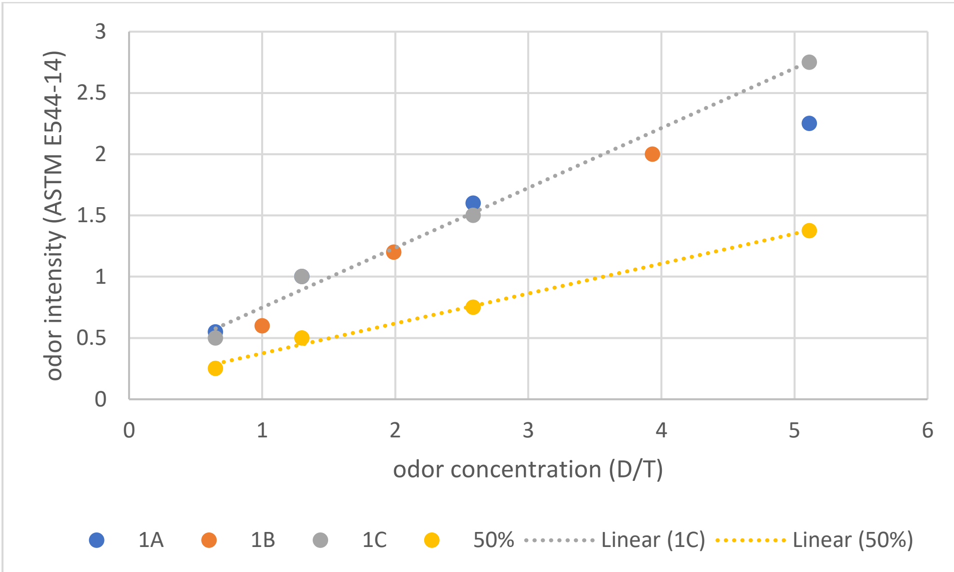


Figure 2-1. Relationship between odor concentration and odor intensity – Samples 1A – 1C

1A – normal neutralizer addition (no aroma)
1B – no neutralizer added (water only)
1C – untreated exhaust
50% - example of a 50% reduction in odor intensity

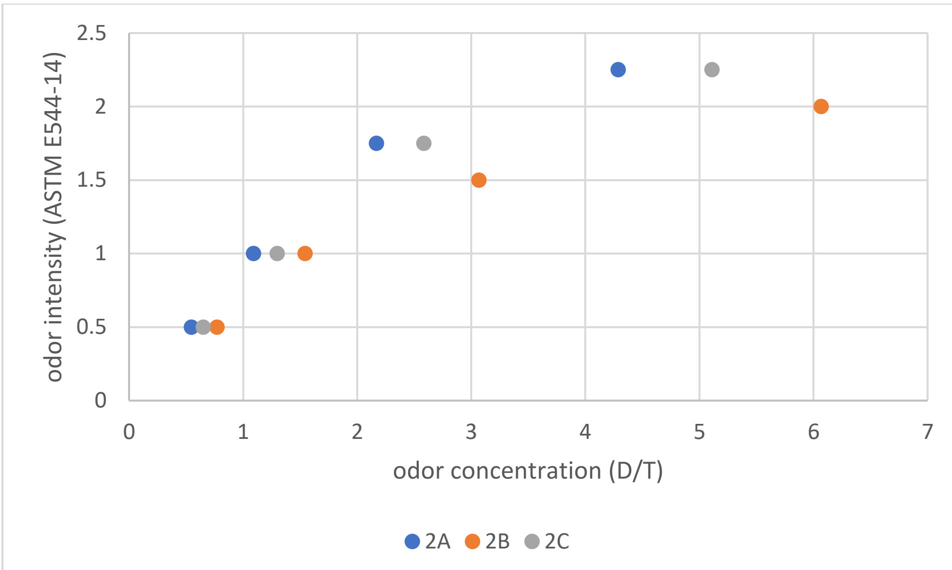


Figure 2-2. Relationship between odor concentration and odor intensity – Samples 2A – 2C

2A – normal neutralizer addition (no aroma)
2B – no neutralizer added (water only)
2C – untreated exhaust

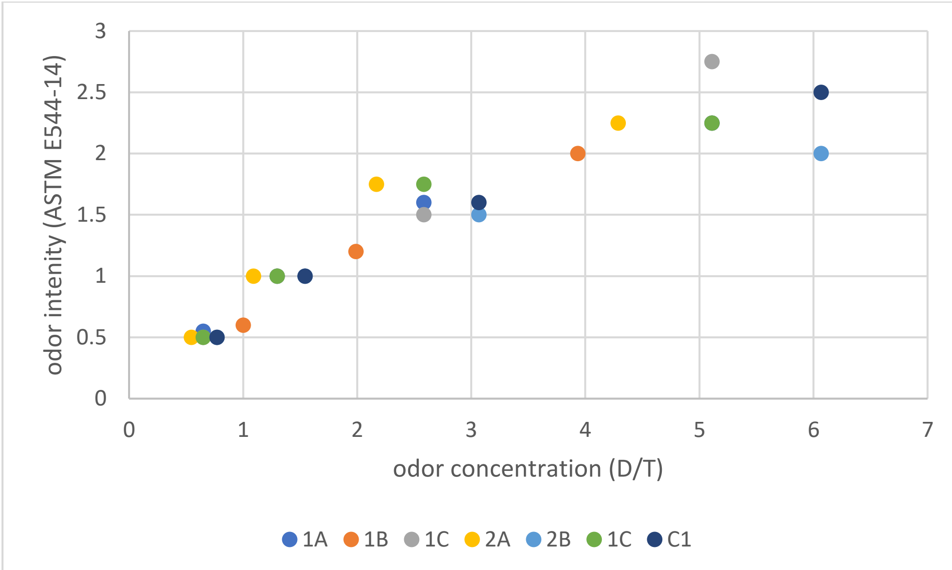


Figure 2-3. Relationship between odor concentration and odor intensity – Samples 1A – C1

1A,2A – normal neutralizer addition (no aroma)
1B,2B – no neutralizer added (water only)
1C,2C – untreated exhaust
C1- normal neutralizer addition with a citrus aroma

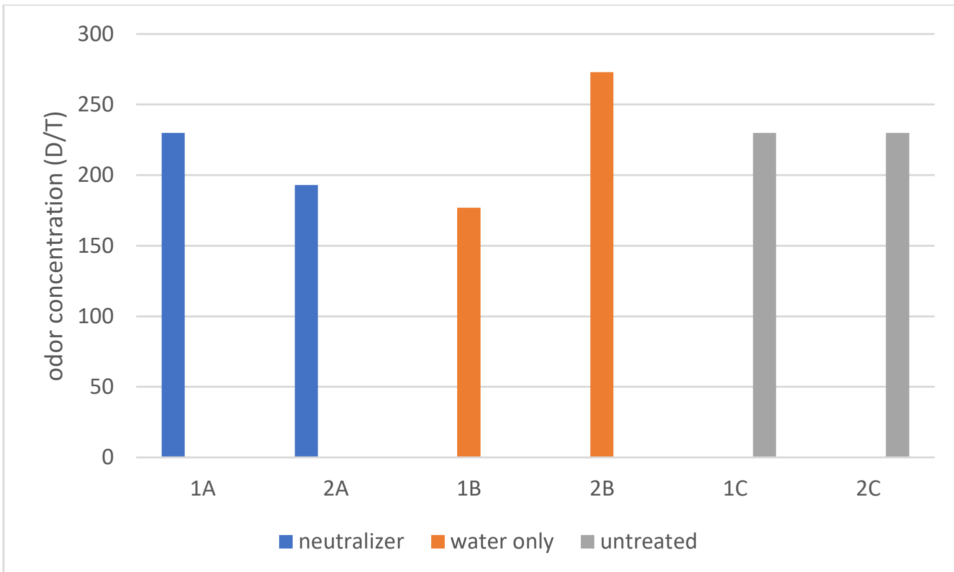


Figure 2-4. Comparison of odor concentration measurements for the three test conditions

3.0. Odor Dispersion Modeling

Fulcrum retained Environmental Permitting Specialists (EPS) to evaluate the potential odor impacts from the odors from the proposed facility in the surrounding area. The results of that evaluation were presented in the November 22 EPS report which was incorporated into the Fulcrum December 5 submittal. (pdf page 65). As part of their work, EPS collected odor samples from an existing marijuana cultivation facility in California. The samples were analyzed by OS&E and the results presented in Section 2 of this report. EPS also conducted odor dispersion modeling to evaluate potential odor impacts from the proposed facility.

The modeling used AERMOD dispersion model with a 52,584 hours of meteorological data from the area of Pittsfied, Massachusetts. Modeling covered a rectangular area 2,500 meters x 1,800 meters, shown in Figure 3-1. The proposed facility, shown as red points in the figure, was in the approximate center of the area. The area was divided into 25 meter square cells which provided a total of 7,200 grid cells. Odor impacts were predicted at each grid cell ("receptor") for each of the 52,584 hours of weather data.

The results of the odor dispersion modeling are presented in Figure 3–2, which was adapted from Figure 3–3 in the EPS report (pdf page 79). The blue contours in the figure represent the largest odor footprint from the proposed facility based on operation of 12 greenhouses. The fact that the proposed facility plans to use 13 greenhouses, has only a minor net effect of proportionately underpredicting the impact by some 8 percent. The contours are based on the highest odor impacts predicted for each receptor under any of the 52,584 hours of weather data used in the modeling. For many of the receptors these peak impacts were predicted to occur at different times, often in different years.

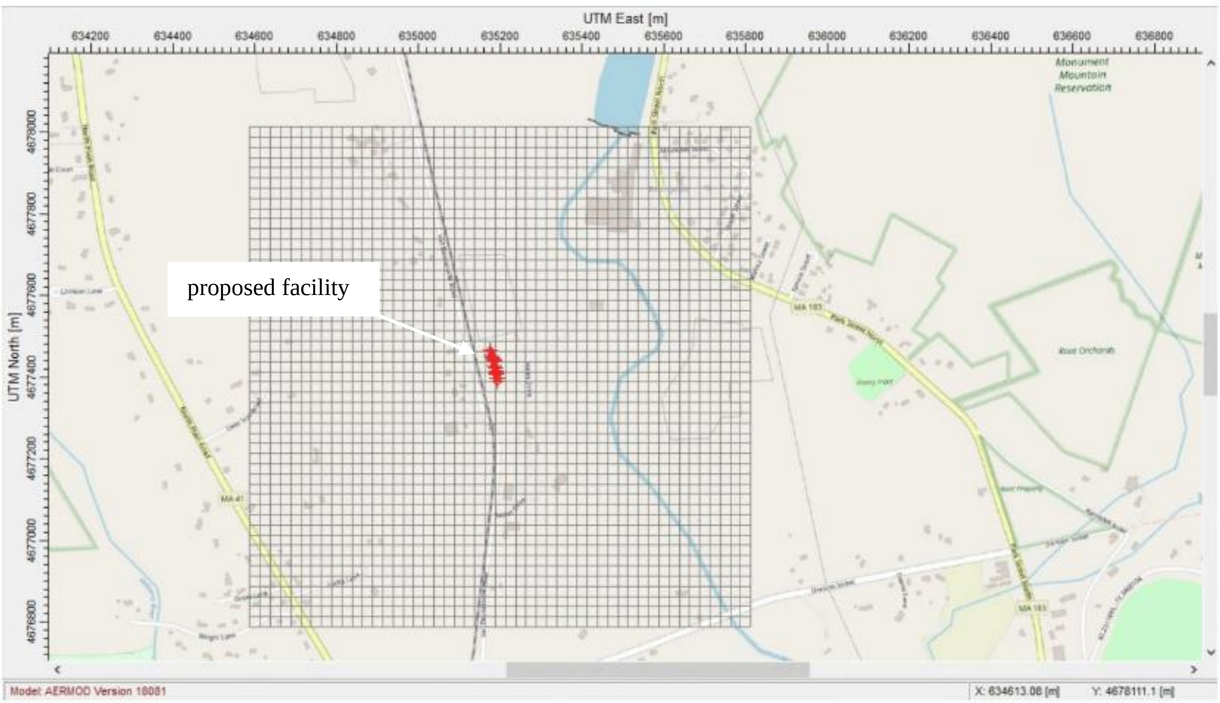
The numerical values associated with the contours in the Figure 3-2 do not represent odor levels directly but can be converted into dilutions to threshold using the key provided in the legend in the figure. The conversion process is explained in Appendix D.

For example, the 2,500 corresponds to an odor concentration of 10 DT. That contour is interrupted at several points when it reaches the edge of the modeled area, indicating that it would extend beyond the modeled area. For improved visibility, these points are marked with small orange circles. The orange circle furthest away from the proposed facility is marked in the figure at a distance of more than one half mile. The 10 D/T contour extends into the residential area to the northeast of the proposed facility.

Figures 2-1 through 2-3 in Section 2 indicate that, by extrapolation, the odor concentration of 10 DT would correspond approximately to an odor intensity of 3 on the n-butanol scale. The odors of that intensity are very likely to be considered objectionable.

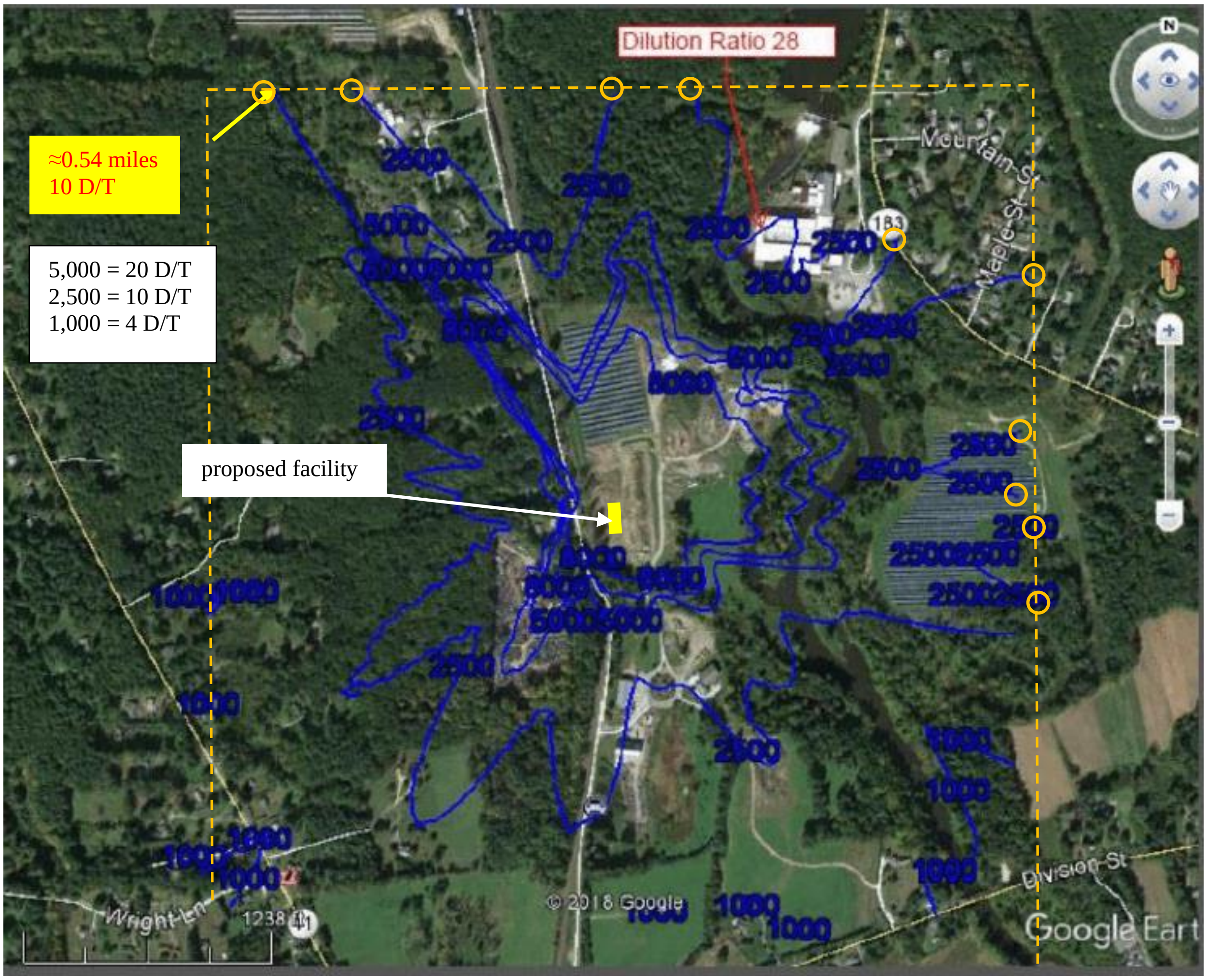
The 1,000 contour in Figure 3-2, corresponding to odor concentration of 4 DT, is almost entirely outside of the receptor grid. This odor would correspond to an intensity of 2, which could also be considered objectionable, especially in the communities which have been exposed to the odor with some frequency

Figure 3-2 should not be interpreted to suggest that the community around the proposed facility is likely to be inundated with objectionable odors at all times or even with significant frequency. Rather, the figure calls attention to the fact that potential for objectionable odors exists and that adequate odor mitigation measures need to be implemented to prevent actual occurrence of such impacts. The adequacy of the proposed mitigation measures is discussed in Section 5.



Source: EPS report, Figure 1 (pdf page 117)

Figure 3-1. The receptor grid used in odor dispersion modeling



Note: This figure was adapted from Figure 3-3 in the EPS report (pdf page 79); The dotted orange line shows the approximate boundary of the modeled area; The small orange circles indicate locations where the 2,500 (10 D/T) contour extends beyond the modeled area; The scale in the lower left corner is in feet.

Figure 3-1. Results of odor dispersion modeling

4.0. Discussion of the Bosarge Environmental Report

Fulcrum retained Bosarge Environmental, LLC (Bosarge) to conduct an evaluation of odors associated with a cannabis cultivation facility in northern California (the same facility where odor samples were collected by EPS). The evaluation was conducted on three days from October 1 through October 3, 2019, using a portable olfactometer (Nasal Ranger). This time period overlapped with the time when odor samples were collected by EPS and analyzed by dynamic dilution olfactometry as described in Section 2.

Bosarge performed a number of on-site and off-site odor measurements at pre-selected locations. Three of the on-site locations, designated in the report as A, B and C, are of particular interest. These locations were directly in line of the horizontal ventilation exhaust from a greenhouse at distances of 6, 12 and 24 feet from the discharge fan respectively. These were the locations where the highest odor levels were recorded. These readings were comprised of two 7 dilutions-to-threshold (D/T) readings and three 4 D/T readings. All other readings were at 2 D/T and less (<2D/T). In instances where no odor was detectable, no readings with Nasal Ranger were attempted and such observations were recoded as “non detectable” (ND).

Nasal Ranger readings at locations A, B and C are summarized in Table 4-1, complied from the material in the Bosarge report. The table also includes the process conditions and the time when the readings were taken.

As stated in the Bosarge report, the ventilation in the greenhouses was turned off overnight, allowing the odors to build up. Perhaps the most remarkable finding from the report was that the highest odor concentration resulting from this buildup was only 7 D/T (row 23 in Table 4-1). The fact that this measurement was obtained during the high odor generation phase in the cannabis growth cycle, is of added significance. As stated in the EPS report (pdf page 71): “Samples were collected October 1, 2019 while the cannabis plants were in full bloom. This is the period associated with the highest odors”. Photos taken at the testing facility show high density of plants inside the greenhouses. This indicates that during other phases in the cannabis growth cycle, the peak potential odor level would be even lower.

Because of the long time over which the odor was allowed to build up inside a greenhouse, essentially the same peak equilibrium odor value of 7 D/T could be expected to be reached in any unventilated greenhouse with a comparable plant density and at the comparable plant growth stage, irrespective of the design and structure of the greenhouse. This would indicate that 7 D/T represents the highest odor level which one would expect to encounter in the cannabis cultivation industry. In the field of industrial odor control, the odors of that magnitude are far below the level considered to require any form of odor control.

Measurements made by Bosarge indicate that the odors in the greenhouse exhaust dispersed rapidly at increased distances from the fan as evident by the data in rows 2, 3 and 4 and 23, 24 and 25 in Table 4-1.

As indicated by the data in the rows 17, 18 and 19, shortly after the start of ventilation, the odor levels of the uncontrolled exhaust stabilized at 2 D/T. Since this level is already barely above threshold, any further odor control would clearly be unnecessary

The fact that the potential for objectionable odors from cannabis cultivation facilities has been a recognized concern in a number of communities surrounding those facilities, indicates that the odor emission potential based on the results from the Bosarge report is unrealistically low.

EPS samples with odor concentration in the range from 177 D/T to 273 D/T were collected during continuous operation of the greenhouse ventilation system with the odor neutralizer system turned on and off. Row 1 in Table 4-1 provides an example. It shows the odor concentration value of 273 D/T measured in the last sample collected by EPS, less than an hour before the first Bosarge reading later that day. Under comparable conditions, Bosarge readings were 2 D/T or lower. This is a discrepancy of approximately one hundred times.

Aside from the analysis of the samples from the California facility, presented in this report, OS&E's experience with the odor levels in the cannabis cultivation industry has been limited, in part because the industry has only recently been legalized. During the odor assessment we conducted for a proposed cannabis cultivation and production facility in the Town of Charlton, Massachusetts, we learned from the applicant's odor consultant that the odor levels they measured at other cannabis cultivation facilities ranged from 200 to 1,000 D/T. This is generally in line with the 177 to 273 D/T range seen in the samples collected by EPS from the exhaust of a greenhouse in California.

The unrealistically low Nasal Ranger readings compared to the results from dynamic dilution olfactometry analysis of the samples from the same source under comparable conditions, are difficult to explain, even when the differences in the measuring methodology are taken into account.

Measurements made by dynamic dilution olfactometry are made by an odor panel. Odor panel members are unaware of what kind of odor they are evaluating and of its source. Olfactory sensitivity of individual members is automatically checked against that of the group at every step of the analysis.

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In contrast, readings using portable olfactometers such as Nasal Ranger are made by a single person. Consequently, some of the factors which could affect the readings could include:

- temporary or permanent impairment of the observer's olfactory sensitivity to specific odors or in general;

- enhanced potential for conscious or unconscious bias due to subjective nature of the measurement technique;

- In the case of the California greenhouse, where Nasal Ranger readings were taken directly in the high volume greenhouse exhaust, the instrument had likely been exposed to the fine mist from the odor neutralizer system. This could have compromised the instrument's inner air flow balance and/or the adsorption effectiveness of the activated carbon;

- Olfactory sensitivity could be reduced through a process of adaptation which results from a prolonged exposure to odors. A common example of this effect is the aroma occasionally noticed when entering a restaurant. After a while, even a relatively strong aroma could become unnoticeable inside the restaurant because of the adaptation effect.

  Nasal ranger incorporates features designed to counter the adaptation effect when the instrument is properly used. As mentioned above, however, the instrument may have been compromised due to exposure to fine mist in the greenhouse exhaust

- Making Nasal Ranger readings while standing directly in the exhaust from a greenhouse, carries a risk of contaminating one's clothing, hair and other surfaces exposed to the fine mist from neutralizer application. That contamination could then become a source of prolonged odor that could remain detectable even when one reenters the odor free environment.

  It may help if the readings were taken starting at a location furthest away from the fan where the odors would be the weakest and then moving closer in towards higher odors. As seen in Table 4-1, however, in most of the cases the readings were taken in the opposite order.

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4.1 Off-site surveys

Bosarge also conducted several off-site odor surveys in the area surrounding the California facility. Off-site odor surveys offer an effective tool for establishing and evaluating the "odor footprints" of existing facilities. This is best accomplished by systematically traversing the facility's odor plume at increasing distances from the facility, until the odor is no longer detectable. Measurement of odor intensity in accordance with ASTM E544-10 (described in Section 2), provides an effective tool for quantifying the odor impacts. This can be supplemented by odor concentration readings using a portable olfactometer such as Nasal Ranger when the odor plume is sufficiently steady.

The Bosarge surveys were structured as a series of Nasal Ranger readings at fixed locations in the surrounding area. Limiting the readings to fixed locations carries a risk of missing the odor plume entirely or in part. This indeed happened on several surveys in which the observation locations were upwind from the facility or otherwise out of the path of the odor plume.

No detectable odors were reported off-site.

4.2 Conclusion

In conclusion, taken at face value, the findings from the Bosarge report indicate that the odor emission potential from cannabis cultivation is too low to warrant any odor control. Acceptance of those findings without effective odor control safeguards, however, would run the risk of exposing the Great Barrington community to potentially objectionable odors from the proposed facility.

Table 4-1. Nasal Ranger Readings at Locations A, B and C*						
	time	process conditions			distance from fan (ft)	D/T [a]
		fan	water	neutralizer		
	October 1- last sample collected by EPS					
1	14:00	on	on	on	12	273[b]
	October 1 -"Test Round 1"					
	?	off [c]	off [c]	off [c]		
	14:45 (ventilation turned on)	on	off	off		-
2	14:50	on	off	off	6	7
3	14:52	on	off	off	12	4
4	14:54	on	off	off	24	2
5	15:02	on	on	off	6	4
6	15:04	on	on	off	12	2
7	15:06	on	on	off	24	<2
8	15:14	on	on	on	6	<2
9	15:17	on	on	on	12	<2
10	15:20	on	on	on	24	ND
11	15:22	on	on	on	6	<2
12	15:24	on	on	on	12	<2
13	15:26	on	on	on	24	ND

Table 4-1. Nasal Ranger Readings at Locations A, B and C* (continued)						
	time	process conditions			distance from fan (ft)	D/T [a]
		fan	water	neutralizer		
	October 2 - Test Round 6					
14		off [d]	off [d]	off [d]	6	<2
15		off [d]	off [d]	off [d]	12	<2
16		off [d]	off [d]	off [d]	24	<2
	11:45 (ventilation turned on)	on	off	off		-
17	11:55	on	off	off	6	2
18	11:57	on	off	off	12	2
19	11:59	on	off	off	24	2
20	12:24	on	on	on	6	<2
21	12:23	on	on	on	12	<2
22	12:22	on	on	on	24	<2
	October 3 - "Round 11"					
		off [d]	off [d]	off [d]		
	10:29 (ventilation turned on)	on	off ?	off ?	-	-
23	10:33	on	off ?	off ?	6	7
24	10:34	on	off ?	off ?	12	4
25	10:35	on	off ?	off ?	24	2

* The table was assembled from the narrative in the Bosarge report. Locations A, B and C correspond to distances from the discharge of the ventilation fan of 6, 12 and 24 ft respectively

a) D/T = dilutions to threshold
b) This 273 D/T sample was the last of the seven samples collected by EPS and analyzed by dynamic dilution olfactometry as described in Section 2. The last (eighth) sample was collected at 14:00 but the bag arrived to the lab empty and the sample could not be analyzed.
c) Greenhouse ventilation and neutralizer addition turned off to allow the odors to build up within the greenhouse; time unavailable
d) The ventilation system had been off overnight

5.0. Revised NCM Odor Control Plan and System Design (November 22, 2019)

The December 5, 2019 Fulcrum submittal includes a revised odor control plan prepared by NCM. The plan relies essentially on the same odor neutralizer control technique as originally proposed. Section 4 of the plan presents “administrative controls” including a newly added Section 4.1, “Monitoring”. That section addresses one of the shortcomings of the originally proposed plan, by implementing measures to increase the awareness of the facility’s operators of ambient odors in the area surrounding the facility. The proposed monitoring plan is structured in a way similar to the Bosarge evaluation. It relies principally on the use of Nasal Ranger at pre-selected monitoring locations and thus suffers from the same shortcomings discussed in the previous section.

Inclusion of pro-active odor monitoring is a welcome addition to the odor mitigation plan. It could be significantly improved by re-structuring and inclusion of odor intensity readings in the monitoring procedure. For improved effectiveness, the monitoring plan should include a systematic comprehensive documentation of the odor plume, as indicated in the previous section.

The main shortcoming of the revised odor control plan is its continued reliance on the odor neutralizer in a manner which was found not to be effective based on the analysis of the samples collected by EPS at the California facility. Thus even if the facility’s operating staff were made aware of a potential odor occurrence, their ability to mitigate it would be limited.

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APPENDICES

APPENDIX A – Procedure for Collecting Odor Samples from a Greenhouse Exhaust

MEMO

TO: Ray Kalahi
FROM: Ned Ostojic
SUBJECT: Updated Testing Procedure
DATE: September 30, 2019

Following up on our discussion earlier today, this memo presents an update of the procedure for the testing to be conducted at a marijuana cultivation facility in California, California. The objective of the testing is to determine the effectiveness of the NCM odor neutralizers in control of cannabis odors. The facility contains a number of greenhouses with the same ventilation and odor control system as proposed for a future facility in Great Barrington, Massachusetts. The ventilation exhaust from each greenhouse is discharged horizontally through large fans mounted on the end walls of the greenhouse.

The greenhouse selected for testing should be one likely to have the highest odor emissions. It is likely that the highest odor emissions could be expected from a greenhouse with the largest number of plants and the highest proportion of flowering plants. If a greenhouse has more than one fan, the test can be conducted on one fan only. This should be the fan closest to the portion of the greenhouse with the highest density of the plants and the highest proportion of flowering plants.

Testing approach

Two sets of three tests will be conducted under the following conditions:

> **Test 1**: Normal neutralizer addition rate judged to provide the highest level of odor neutralization. **IMPORTANT**: In accordance with the discussion during the initial conference call on September 26th, ***the neutralizer formulation should not contain an aroma.***
>
> **Test 2**: The addition of the neutralizer to the water flowing to the nozzles is discontinued, allowing only the water to flow to the nozzles. This should test any effect which water alone may have on odor suppression.
>
> **Test 3**: The flow of the water to the nozzles is discontinued. This will measure the odor level in absence of any treatment, i.e. the uncontrolled odor emissions.

With this sequence of operation, the ventilation system should experience progressively higher odors, starting with maximum level of control in Test 1 to no control in Test 3.

Each tested arrangement should be in operation for a minimum of five minutes before the start of sampling, to allow the conditions in the odor control system to equilibrate and to purge any residual effects of the previous test conditions.

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A series of tests 1 through 3 will be performed twice in sequence.

Sampling procedure

The samples will be collected using the "evacuated drum" arrangement. Two "split samples" will be collected for each tested condition. One sample will be shipped overnight to the OS&E olfactory laboratory where it will be analyzed the next day by dynamic dilution olfactometry in accordance with ASTM Standard Practice for Determination of Odor and Taste Thresholds by Forced-Choice Ascending Concentration Series of Limits (ASTM E679-04). The analytical procedure is described in Appendix B. The second sample will be sent to another laboratory. The samples will be collected in Tedlar bags. Each sampling bag will have a separate ¼ inch polypropylene sampling line. To minimize entrainment of water droplets, the inlets to the two sampling lines will be placed into a "protector", constructed out of a capped pipe as illustrated in Figure 1. The figure shows only one ¼ inch sampling line in a ½ inch pipe protector. For this testing both sampling lines will be placed into the same larger pipe, 1 inch in diameter. In this way the same gas will be collected in the two bags.

The ¼ inch polypropylene sampling lines and the 1 inch capped-pipe protectors are disposable and will be replaced with new lines and protectors for each sample. Since no re-usable fittings or other equipment exposed to the flow of sampled gas will be used, this procedure will eliminate any cross-contamination between samples.

The samples will be collected immediately downstream of the fan, at an approximate distance of 3 ft from fan discharge. All samples will be collected by traversing the exhaust in as reproducible a manner as possible. The fan discharge velocity and the temperature of the exhaust will be measured using a hand-held anemometer. Photos and/or videos of sample collection would be very helpful.

Sampling bags will be placed into a drum and each will be attached to its dedicated sampling line. The sampling lines will enter the inside of the drum through ¼ inch holes drilled in the wall of the drum, which provide a tight seal. The drum will then be sealed and evacuated using a vacuum pump. The vacuum in the drum will draw the samples into the bags.

IMPORTANT: *Once the initial samples are collected, the bags will be removed from the drum and the contents of the bags homogenized by applying manual pressure on the bags. The samples will then be expelled from the bags. This will serve to pre-condition the bags and will minimize potential sample loss due to adsorption on the inner walls of the bags*. The bags will then again be placed into the drum and the second and final samples collected.

It would be helpful if additional information were collected during sampling, including:

- The quantity of the plants in the greenhouse. This could be a percentage of the maximum. A photo or a video of the inside of the greenhouse would be very helpful;
- Approximate proportion of the flowering plants;

- Description of the ventilation system and the odor control including:
  - The number and positions of the neutralizer nozzles (photos);
  - Nozzle operating pressure and flow rate (design and actual) and spray pattern;
  - Fan nominal flow rate (the actual exhaust velocity and temperature will be measured);
  - If the fan speed is variable, method for speed adjustment and the setting at which the fan was operating during testing;
- The weather data at the time of sampling including temperature, dew point, relative humidity, wind direction and speed and cloud cover.

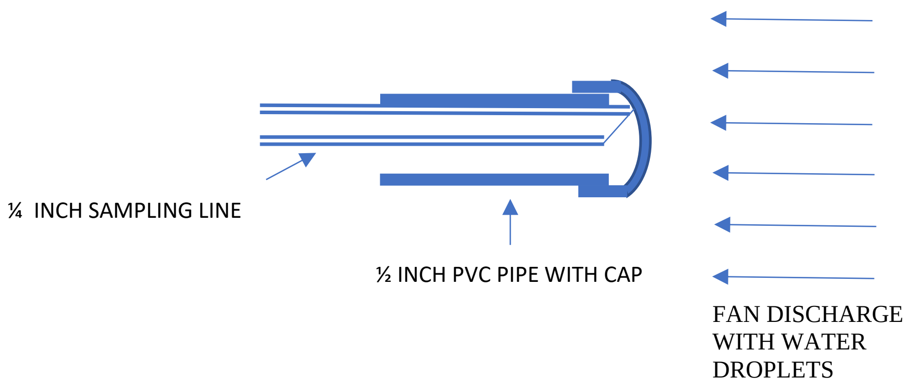

Figure 1. The sampling arrangement for prevention of droplet entrainment

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APPENDIX B: Measurement of Odor Concentration

Odor concentration is defined as the number of dilutions with odor-free air, which is needed to make an odor undetectable to a given fraction, typically 50%, of a panel of odor observers, representative of normal human population. Accordingly, odor concentration is expressed in self explanatory dimensionless units of "dilutions to threshold", also designated D/T.

If the odor is estimated to be sufficiently strong, typically above 30 D/T, odor concentration is often measured by dynamic dilution olfactometry. In that case a sample of the odor is collected in a suitable container, typically a bag made of impervious and chemically inert plastic material, such as Tedlar. The samples are shipped overnight to an odor laboratory where they are measured with a panel of screened and trained odor observers. This procedure is used primarily for analysis of odors collected directly from industrial sources.

Dynamic Dilution Olfactometry

Measurement of odor concentration is performed by means of a dynamic dilution olfactometer. In the olfactometer, known dilutions of the odor sample are prepared by mixing a stream of odor-free air with a stream of the odor sample. The odor-free air is generated by passing room air through a bed of activated charcoal. The odor-free air stream is split into three streams. Odor from the sample bag is added to one of these streams in a known ratio and the diluted odor is presented to odor panelists in one of the three sniff ports, chosen at random. The other two odor free-air streams are directed to the remaining two sniff ports. Presented with three identical sniff ports, two of which provide a stream of odor-free air and the third one a known dilution of the odor sample, a panelist is asked to identify the sniff port which is different from the other two, i.e. the one which contains the odor.

The analysis starts at high odor dilutions and initially a panelist is unlikely to correctly identify the sniff port which contains an odor. Odor concentration in each subsequent evaluation is increased by a factor of 2. As the concentration of the odor increases, the likelihood of an error is reduced and at one point the response at every subsequent higher concentration becomes consistently correct. The lowest odor concentration at which this consistency is first noticed by a panelist, represents the detection odor threshold for that panelist.

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As the odor concentration is increased further in the subsequent steps, the panelist becomes aware of the odor character, i.e. becomes able to differentiate the analyzed odor from other odors. The lowest odor concentration at which odor differentiation first becomes possible, represents the recognition odor threshold for the panelist. Essentially all of OS&E's work is done with recognition odor threshold. The panelists typically arrive at threshold values at different concentrations. To interpret the data statistically, the geometric average of the individual panelists' thresholds is used.

The olfactometer and the odor presentation procedure should meet the recommendations of ASTM Standard Practice for Determination of Odor and Taste Thresholds by Forced-Choice Ascending Concentration Series of Limits (ASTM E679-04).

Portable olfactometers

The above procedure is not well suited for the low level ambient level odors, in large part due to potential deterioration of such samples associated with sample storage and transport. For this reason the analysis of ambient odors is typically performed in the field using portable olfactometers such as Scentometer or a Nasal Ranger.

Portable olfactometers operate on a principle of dynamic dilution. As the observer inhales through the nostrils, ambient air is drawn into the instrument. The air then passes through two activated carbon beds, which remove the odor. The odor-free air enters the central chamber of the instrument where it is mixed with odorous air in known dilution ratios. The odorous air enters the instrument though a set of holes of increasing diameter, located on the instrument's back plate.   After having adjusted to breathing the odor-free air, the observer opens the smallest hole. This admits the smallest amount of odorous air into the instrument for mixing with the odor-free air. If the observer does not detect an odor at that dilution level, he closes the hole, opens the next larger hole and again attempts to detect an odor. This procedure is continued until an odor is detected. The highest dilution level at which the odor was first detected, is reported as odor concentration.

APPENDIX C: Measurement of Odor Intensity

Odor intensity was determined using the reference sample method with n-butanol as the reference compound in accordance with the ASTM Standard Method E544-10 (Standard Recommended Practices for Referencing Suprathreshold Odor Intensity). The n-butanol odor intensity scale is based on an eight step series of n-butanol vapor concentrations. The concentration increases by a factor of two at each intensity step, starting with approximately 15 ppm at step 1 and ending at approximately 2,000 ppm at step 8.

The following description is provided as an aid in interpreting the odor intensity measurements reported in this study.

odor intensity (E544-10)	description of perceived odor
0.5 – 1	odor is detectable and recognizable but would generally be noticed only if looked for, such as during an odor survey
2	odor is clearly recognizable but is likely not to be considered objectionable except in sensitized communities
3 and higher	odor is sufficiently intense to cause a distraction of a person fully occupied by some activity, such as conversation. Odor would typically be considered objectionable and would be expected to cause odor complaints

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<u>Relationship between odor concentration and odor intensity</u>

The intensity and concentration of odor are interrelated. The intensity increases with concentration but the relationship is generally not linear. The increase in odor intensity is typically the steepest at low odor levels. It starts to level off as the concentration of odor increases until no further increase in intensity is perceived.

This relationship between odor concentration and odor intensity, known as Steven's Law, is developed from the data generated in the course of the dynamic dilution olfactometry analysis. The starts at high dilutions at which no panelist is able to detect the diluted odor. The dilution is reduced by a factor of two for each new round of odor observations. At one point the odor becomes detectable, making it possible to rate its intensity. Such ratings are carried out at several subsequent dilution steps when the odor becomes progressively more concentrated and thus more intense. Pairs of odor concentration and the corresponding odor intensity values are generated in that fashion.

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In most cases the relationship is best approximated by a power function:

$$I = a\,C^b$$

where:

I = odor intensity on the n-butanol scale (ASTM E544-10)_
C = odor concentration in dilutions to threshold (D/T)
a and b are constants specific to each odor

Other mathematical functions, such as logarithmic, have also been found to describe the odor concentration – intensity relationship.

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APPENDIX D: Conversion of Dispersion Modeling Contours into Dilutions to Threshold

As used in this evaluation, the odor dispersion model predicted concentrations of a hypothetical pollutant (in mg/m^3) based on the emission rate of 1 g/sec of that pollutant at the source. The procedure for converting the predicted values to odor concentrations (in dilutions to threshold (D/T)) consisted of two steps:

1. Calculating the number of dilutions the pollutant underwent while traveling from the source to the impact location ("receptor"), often referred to as "source-to-receptor" dilution.
2. Substituting the actually measured odor concentration at the source for the calculated concentration of the hypothetical pollutant at the source.

Step 1: Calculating the source-to-receptor dilution ratio (DR)

$DR = C_{Sp} / C_{Rp}$

Where:

C_{Sp} = pollutant concentration at the source used as model input (ug/m^3)

$C_{Sp} = E / F$

Where

E = pollutant emission rate (g/sec)

F = greenhouse ventilation flow rate (m^3/sec)

For E = 1 g/sec and F = 14.16 m^3/sec (30,000 CFM), C_{Sp} = 70,630 ug/m^3

C_{Rp} = model predicted pollutant concentration (ug/m^3) at a receptor

For example, for the 2,500 ug/m^3 contour, discussed in Section 3, DR = 70,630 ug/m^3 / 2,500 ug/m^3 = 28.25

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Step 2: Calculate the predicted odor concentration at a receptor (C_R)

Once the source-to- receptor dilution ratio (DR) has been determined, the odor concentration at the receptor (C_{Ro}) is obtained by dividing the actually measured odor concentration at the source (C_{So}) by the dilution ratio.

$$C_{Ro} = C_{So} / DR$$

For example, for a source odor concentration of 280 D/T, used for the purpose of the discussion in Section 3, the receptor odor concentration corresponding to the 2,500 contour in Figure 3-2 (with a dilution ratio of 28.25), is 10 D/T:

$$C_{Ro} = 280 \text{ D/T} / 28.25 = 10 \text{ D/T}$$

The source odor concentration of 280 D/T, used in discussion in Section 3, was based on the odor emission testing at the California facility, described in Section 2. The odor concentration in the samples collected at the facility ranged from 177 D/T to 273 D/T. The selected value of 280 D/T is slightly above the measured range. In part, this was done for convenience of obtaining round numbers for the odor impact contours. Choosing a value at the high end of the range, however, is also supported by several other factors discussed below.

- The odor samples were collected at an approximate distance of 12 feet from the greenhouse exhaust fan. As a result, the odors have experienced some dilution from the entrained ambient air before the samples were collected. Such dilution would not have occurred, for example, had the exhaust been traveling through a duct. The consequence of this was that the source odor concentration was somewhat understated and the model-predicted impacts were correspondingly under-predicted.
- Choosing a higher source odor concentration also compensated for the fact that modeling was conducted for 12 greenhouses, instead of 13 as planned for the proposed facility.
- Some under-prediction of odor impacts resulted from an averaging time of one hour for the impacts predicted by AERMOD. In the course of one hour, odor levels fluctuate, reflecting the fluctuating path of the odor plume. Accordingly, in one hour the peak odor

levels will occasionally exceed the one-hour average value. Under the conditions of low wind speed and stable atmosphere, for which the majority of the highest odor impacts shown in Figure 3-1 were likely to have been predicted, this peak-to-mean discrepancy is typically not very pronounced but it is still a contributing factor to impact underprediction.

- Selection of the source odor concentration at the high end of the measured range was also in keeping with the overall approach to modeling which deliberately focused on predicting the worst-case odor impacts.

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