Appendix G

Bowlby & Associates, Inc., Noise Study

Bowlby & Associates, Inc.

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October 26, 2001

Mr. Robert G. Campbell
Robert G. Campbell & Associates, L.P.
7523 Taggart Lane
Knoxville, Tennessee 37938

RE: Bull Run Creek (Melton Hill Lake) Water Pump Noise Study, Hallsdale-Powell Utility District, Oak Ridge, TN

Dear Mr. Campbell:

This letter documents the noise study methods and results that led to the design recommendations in our September 28, 2001, letter to you. Those recommendations are summarized here as well. This letter should be in a form and of a level of detail suitable for review by TVA.

The study site is shown in Figure 1. (All figures and tables are at the end of the letter, before the appendices.) The site is small in size and is located immediately adjacent to and east of New Henderson Road. A farm (referred to as the Duncan property) borders the site on the south and east sides, with Bull Run Creek (Melton Hill Lake) on the north side of the site. In your letter of February 7, 2001, you indicated that the nearest residences on the same shore as the pump are approximately 700 feet from the proposed site. On the opposite shore are homes approximately 750 feet from the proposed site. The pump facility will be 12 feet from the Duncan property line on the east side and 7 feet on the south side.

Our work was aimed at meeting the goals explained to me by Mr. Jay McFeters of TVA in a telephone conversation after his review of our initial report in our June 6, 2001 letter to you. Mr. McFeters explained that the design goals should be:

1. to not exceed the background sound level at the property line by more than 3 dB, and

2. to keep the sound level of the facility at the property line below 55 dBA.

One issue was the time period that should be considered (and the resulting period over which the sound level data is averaged). If a facility was not going to be operating during the night, then only daytime levels needed to be considered. If it were to be operating during the day

and the night, then both day and night levels should be considered. The Bull Run Creek facility is expected to operate during both day and night.

A convenient way of addressing combined day and night levels that Mr. McFeters suggested and that relates back to U.S. Environmental Protection Agency criteria is the Day-Night Level (DNL). DNL is a single number in decibels that represents the average of the sound energy represented by all of the daytime and nighttime sound levels, with 10 dB added to all nighttime levels to account for people's increased sensitivity to noise at night. Night is defined as from 10 p.m. to 7 a.m. Thus, DNL was used for this study.

If a source is expected to vary in level by time of year, then an accepted method is to look at an annual average DNL. This sound level variation is expected with the Bull Run Creek facility because the pump usage was modeled by you to be seasonal. Thus, annual average DNL was used for this study.

Having selected the appropriate sound level "descriptor," we then needed to compute the background level and the outdoor sound level due to the noise inside the facility.

Background Sound Level

The background level would actually be the ambient sound level due to all current sources. The major source was traffic on New Henderson Road, plus natural sources such as insects, birds and frogs, which became more important at night when traffic was light.

To compute the background level, we made a 24-hour measurement at the eastern border of the site on August 20-21, 2001. This location was 100 feet from the edge of pavement of New Henderson Road. For the measurement, we used a Norsonic 121 (ANSI Type 1) sound analyzer. The measurement procedure was:

1. Record measurement and site information on data sheets: equipment parameters, calibration, time, date, distance to key sources or other landmarks and weather parameters (temperature, wind speed and direction).

2. Set microphone on a tripod at height of approximately 1.5 meters above the ground; place a windscreen on the microphone, which was oriented 70 degrees from the horizontal per manufacturer's recommendations.

3. Calibrate before and after the measurements with a Norsonic 114 dB, 1000 Hz calibrator.

4. Measure for a 24-hour period (we periodically checked the instrument during the 24 hours).

5. Check data sheet for completeness.

Figure 2 shows the results, in terms of 1-hour levels. The L_{Aeq1h} is the single number in decibels that represents the average of the sound energy represented by all of the A-weighted sound levels in each hour. The L_{Aeq1h} values are the building blocks of the DNL. The L_{10} and the L_{90} are statistical measures of the sound level variation; they represent the level exceeded for 10% and 90%, respectively, of each hour (e.g., for the 12:00 - 1:00 hour on August 20, the L_{90} was 45 dBA; that means that for 90 percent of the hour, the sound level was higher than 45 dBA, and for 10 percent of the hour, the level was lower than 45 dBA).

Figure 2 shows that the L_{Aeq1h} ranged from a low of 41-42 dBA for the hours of 3 a.m. and 4 a.m. to a high of 54-57 dBA for the hours of 8 p.m., 9 p.m. and 10 p.m. (20:00, 21:00 and 22:00). These high evening hour levels are attributable to insects and frogs. The other reason for the fluctuation of the sound levels over the 24 hours is that the facility will be very close to New Henderson Road. During the daytime hours from the morning rush hour through the afternoon rush hour, L_{Aeq1h} ranged from 50-55 dBA, due to traffic. The DNL for this period was 56 dBA.

Traffic noise will remain relatively constant throughout the year, but the evening insect and frog noise will be less in winter time. Our earlier measurements in early May showed the L_{Aeq1h} for the hours of 10 p.m. through 4 a.m. to range between 36 and 47 dBA. Insect and frog noise was considerably less than in August. If we were to substitute these levels for these hours in the August data, the DNL would be 53 dBA. To get a lower limit on the anticipated DNL in the winter, with no insect or frog noise, we used the lowest May L_{Aeq1h} of 36 dBA in the DNL calculation for all hours between 7 p.m. and 4 a.m. The resulting DNL was 52 dBA.

Thus, we concluded that we could expect a range in background DNL from 52-56 dBA over the year. From this range, we computed an annual average DNL of 54 dBA. (This level does not include any future increase in traffic noise from New Henderson Road due to increased traffic volumes; a 2% percent per year growth would raise the DNL by 1.4 dB over 20 years.)

The first TVA goal was to not exceed the background sound level at the property line by more than 3 dB, which would mean an annual average DNL of 57 dBA. However, the second TVA goal was to keep the sound level of the facility at the property line below 55 dBA. Thus, the second goal took precedence, and was used in our design.

Outdoor Sound Level Due to the Noise Inside the Facility

The next step was to compute the outdoor sound level at the property line due to the noise inside the facility. Figure 3 shows the building plan.

The building will be divided into two main rooms. The building walls will be poured-in-place concrete and the roof will be made of precast span-deck planking.

The pumps will be in the rear room, with no doors to the outside and a non-operable window facing the lake. There will be three 1,000-horsepower pumps with motor speeds of 1,800 rpm. During operation, the noise of the pump motor dominates. Pump motor noise, in turn, depends largely on the motor frame size, which is a function of horsepower, motor speed and voltage. The pumps will have 6808P frames. For the WP-I model, its reference "no load" sound pressure level is 90 dB for 1,800 rpm. No spectral data was provided by the manufacturer, so we used a spectrum shape from our May measurements of the Madison, TN, pumps to compute octave band sound pressure levels that would sum to a total level of 90 dB.

There will be hatches in the roof to allow a pump to be hoisted out for maintenance or repair. A metal roll-up door will separate the pump room from the front room.

The front room with have some relatively quiet drive units. This room will also have a non-operable window facing the lake. It will also have a large double door on the New Henderson road side that opens up to allow a small truck to back inside, and a pedestrian door on the same side.

On the roof will be mounted three air conditioning systems, made by Carrier, model 50HJ015, as shown in Figure 4. These units will cool the facility, eliminating the need for louvered openings in the walls, which is typically the major source of noise escaping from inside.

You provided us with typical expected pump usage (% of hour) by number of pumps, time of day and month of year. From these data, we computed an adjustment to go from the level of three pumps running constantly during a daytime hour to an annual average DNL for the three pumps. This adjustment was +4.1 dBA. Thus, all predicted future pump levels were adjusted upward by 4.1 dB. Tables showing these data and the adjustment calculation are in Appendix A.

We computed the total direct plus reflected octave band sound pressure levels inside the pump room near the south and east walls based on the amount of sound absorption on the walls,

floors and ceilings for poured concrete[1]. We then computed the property line levels outside the pump room based on the wall construction and the distance to the property line.

For the area near the main double doors entering into the facility, we first computed the octave band levels in the front drive room due to the noise in the pump room. These levels were a function of the wall construction, the type of door between the two rooms, the dimensions of the drive room, and the building materials in the drive room. We then computed the outdoor property line level based on the drive room wall dimensions and materials and door dimensions and materials.

We then applied the A-weighting adjustment to each octave band sound pressure level, and combined the adjusted octave band levels to get the total overall A-weighted sound level on the south and east sides of the building due to the interior pump noise. Finally, we adjusted this overall A-weighted sound level by the annual average DNL adjustment computed based on the forecasts of the expected usage of the pumps by season and time of day.

Table 1 summarizes the annual average DNL for the No Abatement case, and also includes the DNL for the With Abatement case to be discussed shortly. The No Abatement DNL were calculated to be 44 dBA on the south and east sides, but 57 dB on the west side (actually, this position is along the southern property line, but represents an area affected by noise coming from the west side of the building). The 57 dBA is caused by noise coming through the doors. The DNL 30 feet to the north (actually within the property boundary near the shore was calculated as 42 dBA.

These results do not consider the fact that the receptor points are very close to the walls and are thus in the "acoustic near field," where the sound propagation may vary from what is calculated. Thus, the actual levels may be higher than calculated, leading us to be conservative in designing the needed noise abatement.

Next, we computed the south and east property line sound level contributions from the roof-mounted air conditioning systems. We were provided with sound power spectral data for these units. We then used outdoor noise propagation and barrier attenuation formulas[2] in a spreadsheet to compute property line levels without any roof-mounted noise barriers around the

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[1] Using formulas from C. M. Harris' Handbook of Acoustical Measurements and Noise Control, 3rd edition, McGraw Hill, and from A. Thumann's and R. K. Miller's Secrets of Noise Control, 2nd edition, The Fairmont Press.

[2] Using formulas from C. M. Harris' Handbook of Acoustical Measurements and Noise Control, 3rd edition, McGraw Hill.

air conditioner units. The level for each air conditioner had to be computed separately due to their different locations on the roof. The total air conditioner level was then computed by summing the individual units' contributions by "decibel addition."

The calculations were done based on the barriers being located at the edge of the roof. However, to minimize the needed barrier length, we are recommending that the barriers be installed as close to the AC units as possible, given clearances for air flow and maintenance. As shown in Figure 4, these clearances ranged from 4 to 7 feet. The shift means the barriers will be somewhat more effective than calculated.

Given data by you on time-of-day usage by season (10:30 a.m. to 6 p.m., April through September), we computed an adjustment to the level to represent the annual average DNL due to the roof-mounted air conditioning systems. This adjustment was -7.8 dBA. Thus, all predicted future air conditioner levels were adjusted downward by 7.8 dB. Tables showing the usage data and the adjustment calculation are in Appendix B.

Table 2 summarizes the levels for the Without Barrier case, and also includes the DNL for the With Barrier case to be discussed shortly. The levels in most of the columns in the table are in reference to single units. The next to last column shows the DNL Adjustment and the last column shows the adjusted DNL.

The first two sets of data in the table are for the southern and eastern property lines, and show the Without Barrier DNL due to the air conditioners to be calculated as 65 and 60 dBA, respectively. (The south data were representative for the southern property line area near the west side of the building by the doors.) These levels exceed the TVA goal of 55 dBA.

To test the effect of moving slightly farther away from the property line, we also computed levels at 20 feet from the south wall and from the east wall. These levels are shown by the third and fourth sets of data in the table; the levels did indeed decrease slightly due to the increased distance, meaning that the property line locations were the critical design locations.

To get the total annual average DNL due to the combined pump and air conditioning system noise, we summed the individual contributions by "decibel addition." Table 3 shows the results. The Total No Abatement levels all exceed the TVA goal of 55 dBA.

Noise Abatement and Control

Once we established these total exterior property line DNL values, we considered the need for noise abatement and control in order to achieve the established goal of not exceeding an annual average DNL of 55 dBA.

We considered the following strategies in addition to the use of poured-in-place concrete walls and the use of air conditioning to eliminate louvered ventilation openings:

1. Use of sound absorption on the interior walls of the pump room.
2. Use of acoustical doors for the exterior double door system and the pedestrian door.
3. Use of acoustical windows for the two windows facing the creek.
4. Use of roof-mounted noise barriers around the air conditioning units located on the roof.

For sound absorption on the interior walls of the pump room, we calculated the effect of surface-mounting 2-inch thick Durisol sound-absorbing panels on the walls of the pump room. These panels reduced the calculated A-weighted sound level by 12 dB, as shown in the last column of Table 1.

This sound absorption reduced the noise propagating into the front room of the building, and thus also reduced the level at the west side study location. However, the exterior level was still too high, and the effectiveness of acoustical doors was tested. Use of STC 43 or higher Industrial Acoustics Noise-lock doors was found to be effective for the double-door between the drive room and the exterior of the building. Also, moving the exterior pedestrian door from the south wall (facing the Duncan property) to the west wall (facing New Henderson Road) and using an STC 30, 18-gauge, hollow core steel door with good seals was found to be effective.

While levels off the north wall were not too high, we felt that use of improved windows would help prevent a problem along the northern portion of the eastern property line. We found use of an STC 35 or higher window for the 4x4 window in the pump room and an STC 31 or higher for the 4x4 window in the drive room to be effective.

The combined effect of the sound absorption, and the acoustical doors and windows are shown in the With Abatement column of Table 1. The DNL are reduced to 41 dBA or less.

Finally, we determined that six-foot high sound-absorbing Durisol noise barriers around the perimeter of the area for the three air conditioners would be effective. As shown in the fourth -from-last column in Table 2, this barrier system would reduce the air conditioner property line sound level contributions by 12 to 17 dB, resulting in air conditioner DNL of 48 and 49 dBA at the southern and eastern property lines, respectively.

The combined effect of the building treatments and the roof-mounted noise barriers is shown in the last column of Table 3. The total With Abatement annual average DNL would be reduced to 48-50 dBA along the southern and eastern property lines, including near the west side of the building. These levels will be sufficiently below the 55 dBA goal to provide a margin of

safety due to any near field effects and any inherent limitations in the modeling process or equations.

Recommendations

Based on the above analysis and design, the following recommendations are made for this pump facility:

1. *Walls.* Construct the pump building with 8-inch thick poured-in-place concrete walls instead of masonry block.

2. *Air conditioning.* Air condition the pump room and the drive room to eliminate louvered openings in the exterior walls.

3. *Sound-absorbing panels on pump room walls.* Add 2-inch thick Durisol sound-absorbing panels to the pump room walls.

4. *Exterior double door.* Use STC 43 or higher Industrial Acoustics Noise-lock doors for the double-door between the drive room and the exterior of the building.

5. *Exterior pedestrian door.* Move the exterior pedestrian door from the south wall (facing the Duncan property) to the west wall (facing New Henderson Road). Then, use an STC 30, 18-gauge, hollow core steel door with good seals for the pedestrian door between the drive room and the exterior of the building.

6. *Interior roll-up door.* Use as heavy a gauge steel roll-up door as possible between the pump room and the drive room (at least 18-gauge)

7. *Windows.* Install an STC 35 or higher window for the 4x4 window in the pump room that faces the river. Install an STC 31 or higher for the 4x4 window in the drive room that faces the river.

8. *Trap-door on roof.* Make sure that the trap-door on the roof into the pump room is heavy duty and is well sealed when closed to prevent noise leaks.

9. *Noise barrier for the roof-mounted air conditioners.* Erect a 6-foot high sound-absorbing Durisol noise barrier around the perimeter of the footprint of the three roof-mounted air conditioners. This barrier should be positioned as close as possible to the air conditioners, while allowing adequate space for air flow and maintenance access around each unit. This barrier needs to be sound-absorbing on only the side facing air

conditioners. Maintenance access through the barrier also needs to be provided. Access could be accomplished by an opening in the barrier with an overlap of the panels on the side facing the road. The overlap should be sufficient so as to not allow a direct view of any part of the air conditioners from the outside, and the opening of the overlap should point toward the river. Alternatives to the overlap would be a swinging or sliding gate made out of the Durisol panels.

Finally, while not calculated, there is possible concern over "structure-borne" noise caused by the vibration of the motors and any duct work or piping that might be rigidly mounted to the floor, walls or ceilings. We recommend use of vibration isolation mounts for the pump motors, and vibration isolation straps or mounts for the piping and ducts.

This concludes my report. Please give me a call with any questions. We appreciate this opportunity to be of service to you and the Hallsdale-Powell Utility District.

Sincerely yours,

William Bowlby, Ph.D., P.E.
President

Attachments

N:\BA\BA Projects\2001 Projects\01-10 Campbell TVA Pump Noise, Oak Ridge\Acoustical design\01-10 sept 28 design method ltr.wpd

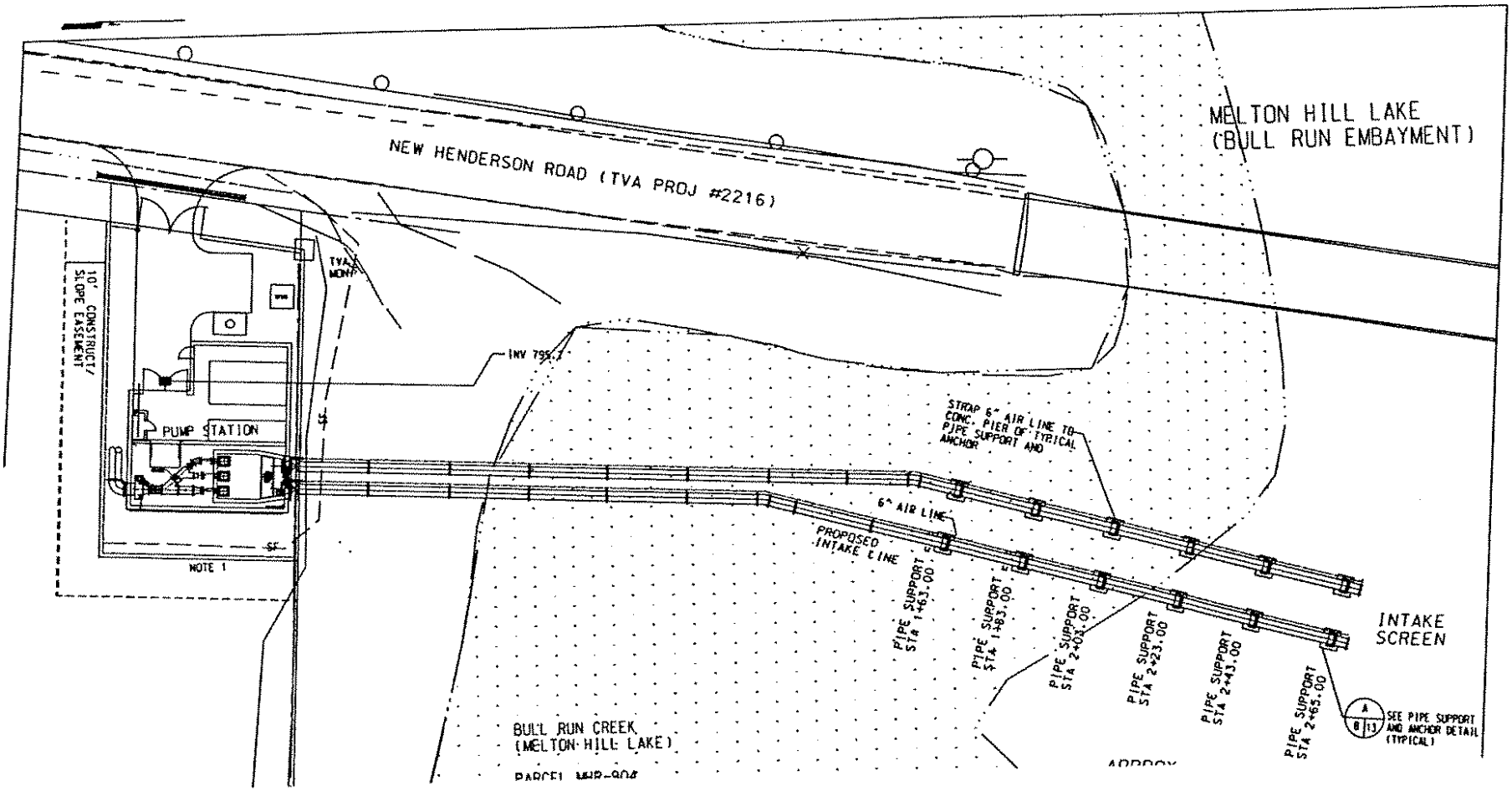
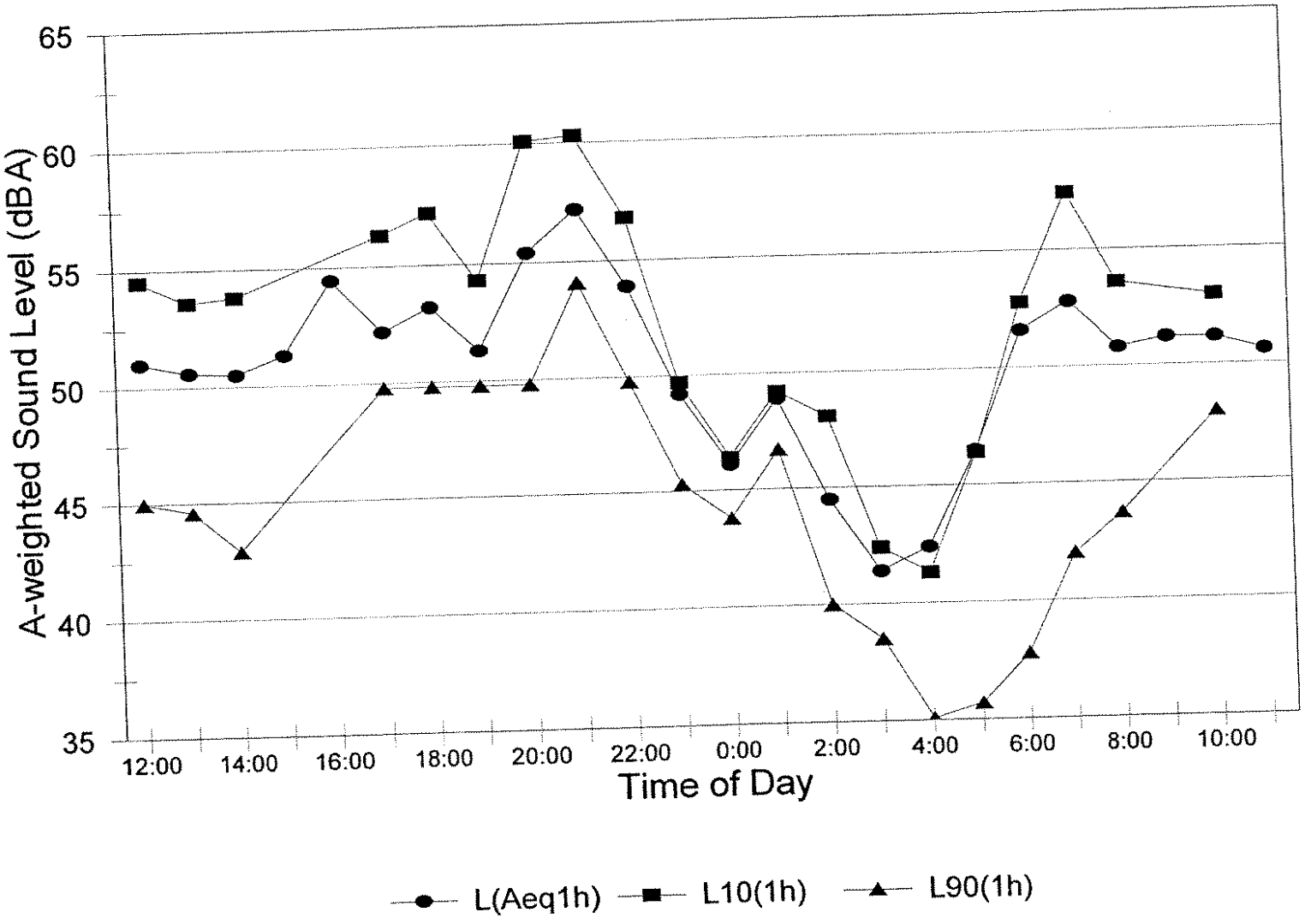


Figure 1. Site location.

Figure 2. 24-hr noise measurement, Duncan property line, Bull Run Creek, August 20-21, 2001



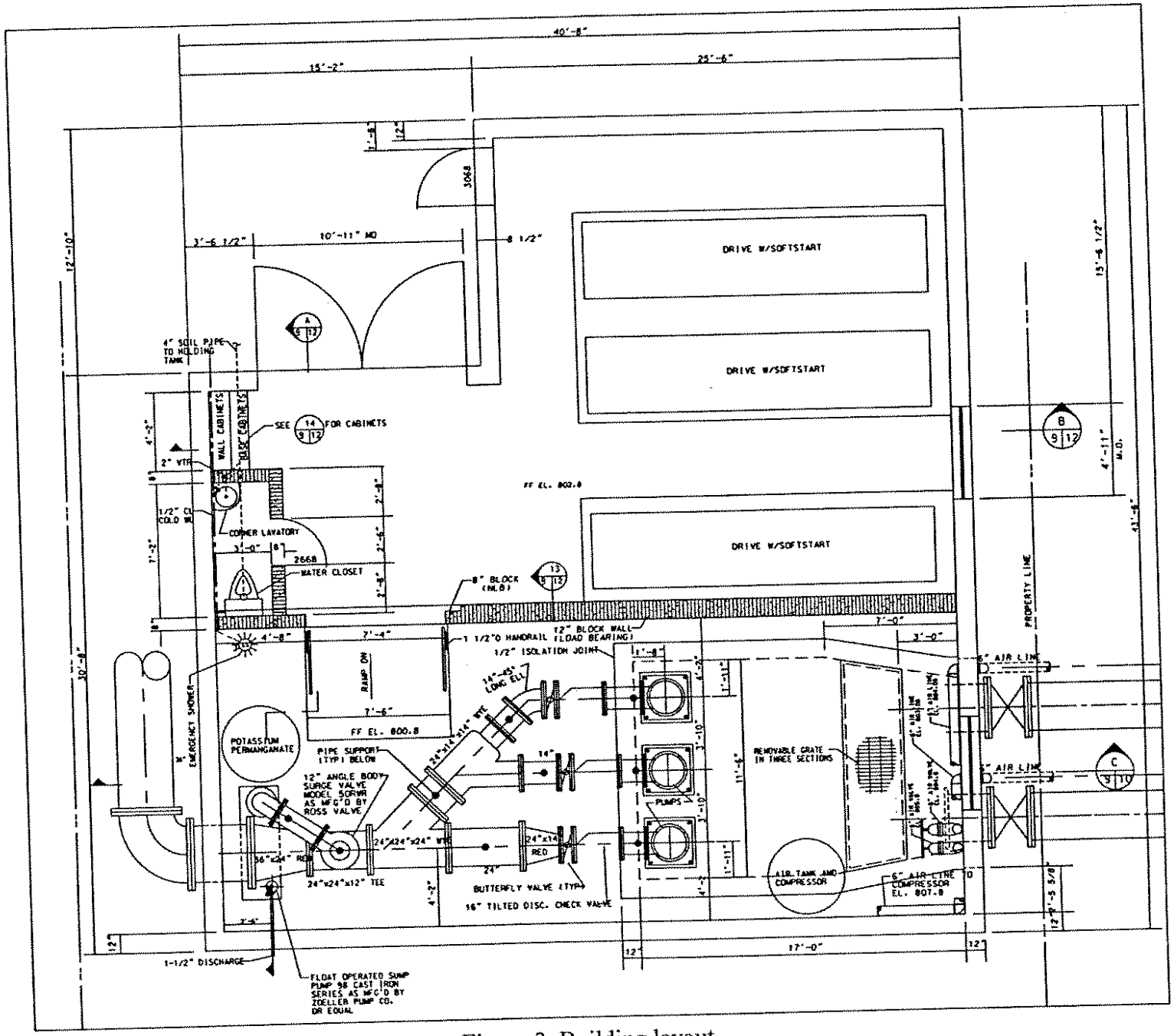


Figure 3. Building layout.

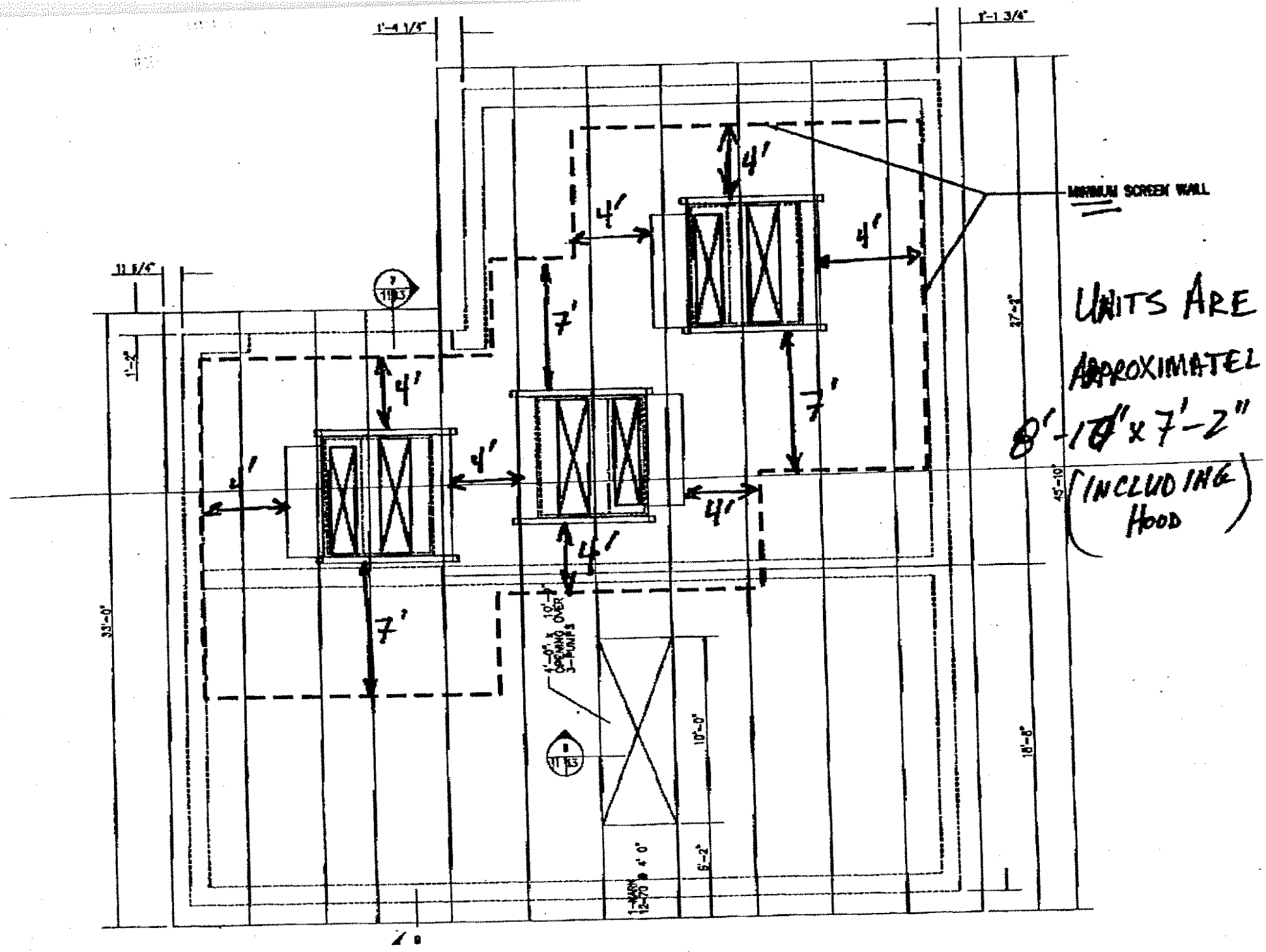


Figure 4. Location of roof- mounted air conditioners and needed clearances.

Table 1
Average Annual DNL With and Without Abatement

Side of Building	Adjacent land use	Distance from building (feet)	DNL (dBA)	
			No Abatement	With Abatement
East	Duncan property	12	44	32
South	Duncan property	7	44	32
West	New Henderson Road	10 to Duncan property at southern end of the west building wall	57	41
North	Shore of lake	30	42	29

Table 2
Bull Run Creek Water Pump Noise Study, Oak Ridge, TN: Roof-Top Air Conditioners
09/28/01

Case	Distance Source-barrier (feet)	Distance Source-Recr (feet)	Barrier Height (feet)	Overall SPL (dB) Without Barrier	Overall SPL (dB) With Barrier	Overall SPL (dB) Attenuation (dB)	A-weighted Level (dB) Without Barrier	A-weighted Level (dB) With Barrier	A-weighted Level (dB) Attenuation (dB)	DNL Adj (dB)	Average Annual DNL Without Barrier	Average Annual DNL With Barrier
Barrier at edge of bldg wall												
South side at 7 feet										**-7.8**	63.0	46.9
AC #1	7	14	6	78.7	68.9	9.8	70.8	54.7	16.1	-7.8	58.0	41.1
AC #2	18	25	6	73.7	63.3	10.3	65.8	48.9	16.9	-7.8	55.9	42.5
AC #3	12	32	6	71.5	63.5	8.0	63.7	50.3	13.3		64.8	49.0
Total				80.5	70.8		72.6	56.8				
East side at 12 feet										-7.8	56.4	43.7
AC #1	7	30	6	72.1	64.3	7.7	64.2	51.5	12.8	-7.8	56.1	43.5
AC #2	4	31	6	71.8	64.2	7.6	63.9	51.3	12.6	-7.8	53.9	41.7
AC #3	12	40	6	69.6	62.1	7.4	61.7	49.5	12.2		60.4	47.8
Total				76.1	68.4		68.2	55.6				
South side at 20 feet										-7.8	57.3	44.2
AC #1	7	27	6	73.0	65.0	7.9	65.1	52.0	13.2	-7.8	54.4	40.8
AC #2	18	38	6	70.0	61.9	8.1	62.2	48.6	13.5	-7.8	55.9	42.5
AC #3	12	32	6	71.5	63.5	8.0	63.7	50.3	13.3		60.8	47.5
Total				76.4	68.4		68.6	55.3				
East side at 20 feet										-7.8	54.4	42.4
AC #1	7	38	6	70.0	62.7	7.3	62.2	50.2	12.0	-7.8	54.2	42.1
AC #2	4	39	6	69.8	62.4	7.4	62.0	49.9	12.1	-7.8	52.3	40.9
AC #3	12	48	6	68.0	60.9	7.1	60.1	48.7	11.5		58.5	46.6
Total				74.1	66.9		66.3	54.4				

Table 3
Summary of Total Average Annual DNL With and Without Abatement

Location	No Abatement			With Abatement		
	Pumps	Air conditioners	Total	Pumps	Air conditioners	Total
South side at 7 feet	44	65	65	32	49	49
East side at 12 feet	44	60	60	32	48	48
West at 10 feet to southern property line	57	65	66	41	49	50

Appendix A – Average Annual DNL Adjustment for Pumps, Bull Run Creek

Average Annual DNL Adjustment for Pumps, Bull Run Creek

The Leq of **1** pump is hypothetical. The needed value for DNL increase over Leq of 1 pump is accurate however, since it is relative.

Month	**# of months rep.**	**LDN**	**Weighted energy**		
June	3	98.9	23045222247.44		
Sep	4	99.7	37747851308.47		
Dec	3	98.5	21206371433.34		
Mar	2	97.3	10717660999.19		
		Sum energy	92717105988.43		
		Annual Average DNL	**98.9**	**dB**	
		LEQ of 3 pumps	94.8		3 pumps
		DNL adj.	**4.1**		

Average Annual DNL Adjustment for Pumps, Bull Run Creek

Month = June Year = +20

Hour	# of pumps	LEQ of 1 pump	LEQ of N pumps	Percent of usage	Usage Adj.	Adj LEQ	Night penalty	Energy
12:00 AM	2	90	93.0	88.5%	-0.5	92.5	10	17696168956.5
01:00 AM	2	90	93.0	73.7%	-1.3	91.7	10	14746807463.7
02:00 AM	2	90	93.0	59.0%	-2.3	90.7	10	11797445971
03:00 AM	2	90	93.0	59.0%	-2.3	90.7	10	11797445971
04:00 AM	2	90	93.0	73.7%	-1.3	91.7	10	14746807463.7
05:00 AM	2	90	93.0	88.5%	-0.5	92.5	10	17696168956.5
06:00 AM	3	90	94.8	100.0%	0.0	94.8	10	30000000000
07:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
10:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
11:00 AM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
12:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
01:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
02:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
03:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
04:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
05:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
06:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
07:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 PM	2	90	93.0	88.5%	-0.5	92.5	0	1769616895.65
10:00 PM	2	90	93.0	73.7%	-1.3	91.7	10	14746807463.7
11:00 PM	2	90	93.0	73.7%	-1.3	91.7	10	14746807463.7
							Sum energy	184361777979
							LDN	**98.9 dB**

Average Annual DNL Adjustment for Pumps, Bull Run Creek

Month = Sep Year = 20

Hour	# of pumps	LEQ of 1 pump	LEQ of N pumps	Percent of usage	Usage Adj.	Adj LEQ	Night penalty	Energy
12:00 AM	2	90	93.0	100.0%	0.0	93.0	10	20000000000
01:00 AM	2	90	93.0	98.7%	-0.1	93.0	10	19739162615.1
02:00 AM	2	90	93.0	79.0%	-1.0	92.0	10	15791330092.1
03:00 AM	2	90	93.0	79.0%	-1.0	92.0	10	15791330092.1
04:00 AM	2	90	93.0	98.7%	-0.1	93.0	10	19739162615.1
05:00 AM	3	90	94.8	83.2%	-0.8	94.0	10	24967373253.8
06:00 AM	3	90	94.8	100.0%	0.0	94.8	10	30000000000
07:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
10:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
11:00 AM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
12:00 PM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
01:00 PM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
02:00 PM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
03:00 PM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
04:00 PM	3	90	94.8	83.2%	-0.8	94.0	0	2496737325.38
05:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
06:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
07:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 PM	2	90	93.0	100.0%	0.0	93.0	0	2000000000
10:00 PM	2	90	93.0	98.7%	-0.1	93.0	10	19739162615.1
11:00 PM	2	90	93.0	98.7%	-0.1	93.0	10	19739162615.1
							Sum energy	226487107851
							LDN	**99.7 dB**

Average Annual DNL Adjustment for Pumps, Bull Run Creek

Month = Dec Year = 20

Hour	# of pumps	LEQ of 1 pump	LEQ of N pumps	Percent of usage	Usage Adj.	Adj LEQ	Night penalty	Energy
12:00 AM	2	90	93.0	78.5%	-1.1	92.0	10	15699226895.9
01:00 AM	2	90	93.0	65.4%	-1.8	91.2	10	13082689079.9
02:00 AM	2	90	93.0	52.3%	-2.8	90.2	10	10466151264
03:00 AM	2	90	93.0	52.3%	-2.8	90.2	10	10466151264
04:00 AM	2	90	93.0	65.4%	-1.8	91.2	10	13082689079.9
05:00 AM	2	90	93.0	78.5%	-1.1	92.0	10	15699226895.9
06:00 AM	3	90	94.8	100.0%	0.0	94.8	10	30000000000
07:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
10:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
11:00 AM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
12:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
01:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
02:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
03:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
04:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
05:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
06:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
07:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 PM	2	90	93.0	78.5%	-1.1	92.0	0	1569922689.59
10:00 PM	2	90	93.0	65.4%	-1.8	91.2	10	13082689079.9
11:00 PM	2	90	93.0	65.4%	-1.8	91.2	10	13082689079.9
							Sum energy	169650971467
							LDN	**98.5 dB**

Average Annual DNL Adjustment for Pumps, Bull Run Creek

Month = Mar Year = +20

Hour	# of pumps	LEQ of 1 pump	LEQ of N pumps	Percent of usage	Usage Adj.	Adj LEQ	Night penalty	Energy
12:00 AM	2	90	93.0	58.5%	-2.3	90.7	10	11705342774.8
01:00 AM	1	90	90.0	93.9%	-0.3	89.7	10	9393176300.77
02:00 AM	1	90	90.0	75.1%	-1.2	88.8	10	7514541040.62
03:00 AM	1	90	90.0	75.1%	-1.2	88.8	10	7514541040.62
04:00 AM	1	90	90.0	93.9%	-0.3	89.7	10	9393176300.77
05:00 AM	2	90	93.0	58.5%	-2.3	90.7	10	11705342774.8
06:00 AM	3	90	94.8	75.4%	-1.2	93.5	10	22619784010.8
07:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
09:00 AM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
10:00 AM	3	90	94.8	75.4%	-1.2	93.5	0	2261978401.08
11:00 AM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
12:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
01:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
02:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
03:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
04:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
05:00 PM	3	90	94.8	75.4%	-1.2	93.5	0	2261978401.08
06:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
07:00 PM	3	90	94.8	100.0%	0.0	94.8	0	3000000000
08:00 PM	3	90	94.8	75.4%	-1.2	93.5	0	2261978401.08
09:00 PM	2	90	93.0	58.5%	-2.3	90.7	0	1170534277.48
10:00 PM	1	90	90.0	93.9%	-0.3	89.7	10	9393176300.77
11:00 PM	1	90	90.0	93.9%	-0.3	89.7	10	9393176300.77
							Sum energy	128611931990
							LDN	**97.3 dB**

Appendix B – Average Annual DNL Adjustment for Air Conditioners, Bull Run Creek

Average Annual DNL Adjustment for Roof-Mounted Air Conditoners, Bull Run Creek

The Leq of 1 AC is hypothetical. The needed value for DNL increase over Leq of 1 pump is accurate however, since it is relative.

Month	**# of months rep.**	**LDN**	**Weighted energy**
Month = Apr-June	3	94.0	7544796281.423
Month = Jul-Sep	3	94.0	7544796281.423
Month = Oct-Dec	3	5.2	9.890552824069
Month = Jan-Mar	3	5.2	9.890552824069
		Sum energy	15089592582.63
		Annual Average DNL	**91.0 dB**
		LEQ of N AC	98.8
		DNL adj.	**-7.8**

Average Annual DNL Adjustment for Roof-Mounted Air Conditoners, Bull Run Creek

Month = Apr-June

Hour	# of AC units	LEQ of 1 AC		LEQ of N AC	Percent of usage	Usage Adj	Adj LEQ	Night penalty	Energy
12:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
01:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
02:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
03:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
04:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
05:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
06:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
07:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
08:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
09:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
10:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
11:00 AM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
12:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
01:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
02:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
03:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
04:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
05:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
06:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
07:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
08:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
09:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
10:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
11:00 PM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
								10	7535659.29453
								Sum energy	60358370251.4
								LDN	**94.0 dB**

Average Annual DNL Adjustment for Roof-Mounted Air Conditoners, Bull Run Creek

Month = Jul-Sep

Hour	# of AC units	LEQ of 1 AC		LEQ of N AC	Percent of usage	Usage Adj	Adj LEQ	Night penalty	Energy
12:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
01:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
02:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
03:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
04:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
05:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
06:00 AM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
07:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
08:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
09:00 AM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
10:00 AM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
11:00 AM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
12:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
01:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
02:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
03:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
04:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
05:00 PM	3	94		98.8	100.0%	0.0	98.8	0	7535659294.53
06:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
07:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
08:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
09:00 PM	3	94		98.8	0.01%	-40.0	58.8	0	753565.929453
10:00 PM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
11:00 PM	3	94		98.8	0.01%	-40.0	58.8	10	7535659.29453
								Sum energy	60358370251.4
								LDN	**94.0 dB**

Average Annual DNL Adjustment for Roof-Mounted Air Conditoners, Bull Run Creek

Month = Oct-Dec

Hour	# of AC units	LEQ of 1 AC	LEQ of N AC	Percent of usage	Usage Adj	Adj LEQ	Night penalty	Energy
12:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
01:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
02:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
03:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
04:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
05:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
06:00 AM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
07:00 AM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
08:00 AM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
09:00 AM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
10:00 AM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
11:00 AM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
12:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
01:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
02:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
03:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
04:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
05:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
06:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
07:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
08:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
09:00 PM	3	94	98.8	0.00%	-100.0	-1.2	0	0.75356592945
10:00 PM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
11:00 PM	3	94	98.8	0.00%	-100.0	-1.2	10	7.53565929453
							Sum energy	79.1244225926
							LDN	**5.2 dB**

Average Annual DNL Adjustment for Roof-Mounted Air Conditoners, Bull Run Creek

Month = Jan-Mar

Hour	# of AC units	LEQ of 1 AC		LEQ of N AC	Percent of usage	Usage Adj	Adj LEQ	Night penalty	Energy
12:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
01:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
02:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
03:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
04:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
05:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
06:00 AM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
07:00 AM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
08:00 AM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
09:00 AM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
10:00 AM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
11:00 AM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
12:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
01:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
02:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
03:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
04:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
05:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
06:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
07:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
08:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
09:00 PM	3	94		98.8	0.00%	-100.0	-1.2	0	0.75356592945
10:00 PM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
11:00 PM	3	94		98.8	0.00%	-100.0	-1.2	10	7.53565929453
								Sum energy	79.1244225926
								LDN	**5.2 dB**