DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT CORPS OF ENGINEERS
P.O. BOX 4970
JACKSONVILLE, FLORIDA 32232-0019

REPLY TO ATTENTION OF

Planning Division
Environmental Branch

SEP 25 2009

Mr. Pedro Nieves Miranda
President
Environmental Quality Board
Post Office Box 11488
San Juan, Puerto Rico 00910

Dear Mr. Nieves Miranda:

This is in reference to the conference call conducted on September 17, 2009, between the Environmental Quality Board (EQB), the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (Corps) staff regarding the information requested in order to finalize the *Thermal Reduction Plan for the Clearing and Grubbing of the Portugués Dam Site* and initiate the public participation process.

Please find the Final Thermal Reduction Plan, which includes all the information requested by your agency and EPA, enclosed. Based on our analysis, the Corps has concluded that the air curtain thermal reduction will be the best alternative for the disposal of vegetative material from the site. This alternative presents the best solution for the disposal of the vegetative material from the public health, environmental and economic point of view.

The Corps considers itself a partner with the EQB in this effort and many others. My staff and I will strive to continue our collaborative working relationship and look forward on helping you assure the continued high standard of environmental quality for the Commonwealth of Puerto Rico.

Sincerely,

Eric Summa
Chief, Environmental Branch

Enclosures

Copies Furnished:

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Thermal Reduction Plan for the Clearing and Grubbing of the Portugues Dam Construction Ponce, Puerto Rico

Revision 09/25/2009

US Army Corps of Engineers
Jacksonville District

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Thermal Reduction Plan for the Clearing and Grubbing of the Portugues Dam Construction, Ponce, Puerto Rico (Revision 09/25/09)

1.0 Purpose and Needs

The construction of the Portugues Dam Flood Control Project was scheduled to start in the year 2008 and will be located north of the city of Ponce, Puerto Rico, on the river channel of the Portugues River (see Figure 1 in the Appendix).

The construction of the Portugues Dam Flood Control Project is the last phase of the Portugues and Bucana Rivers canalization and flood control project authorized by Congress in 1970. The project consists primarily of three major features. First the construction of the Cerrillos dam, northeast of the city of Ponce, completed 1992. Second the canalization of the Bucana River, southeast of the city of Ponce, completed 1997. The last feature is the construction of the Portugues dam. Due to the extended period of planning and time needed for the allocation of funds, new Puerto Rico environmental laws have emerged that can affect the completion of this project. The US Army Corps of Engineers (USACE) is requesting a waiver to the thermal reduction activities during clearing and grubbing operations in the construction of the Portugues Dam project, Ponce, Puerto Rico. The USACE have completed the National Environmental Policy Act (NEPA) process, Water Quality Certification, and cultural resources recovery investigations at the site.

The Portugues dam reservoir pool will cover approximately 72 acres during normal operation, with a maximum flood pool capacity of 215 acres during an extreme rain event. In order to construct the reservoir, there is a need to clear and grub approximately 150 acres of timber and brush vegetation in the river valley during construction, plus an additional 50 acres for establishment of the reservoir pool. The volume of biomass generated from the clearing and grubbing of this project is too large to be handled and received in the region's landfills. Mechanical reduction of this large volume of biomass can be very expensive and the region's landfills would not have the capacity to take it. The tailpipe emissions from the mechanical reduction, from hauling this material by trucks, and emissions from natural decay of the vegetative material, could potentially exceed National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO), sulfur dioxide (SO_2), nitro dioxide (NO_2), and particulate matter (PM_{10} & $PM_{2.5}$) in the area. Other possible problems can be the potential for naturally occurring fires and termite infestation, among other pests. Both of these scenarios can present a health threat to the local environment.

The USACE, Jacksonville District, has analyzed the potential alternatives for the disposal of this large amount of brush and timber, and has determined that thermal reduction is the most advantageous option for the project from both the environmental and economical point of view. Also, the USACE have utilized thermal reduction in Puerto Rico during emergency operations (hurricanes), without compromising the air quality of the region.

2.0 Alternative Analysis for the Disposal of Timber Material

The U.S. Army Corps of Engineers (USACE), Jacksonville District, has analyzed the environmentally and cost-effective alternatives for the disposal of this large amount of brush and timber material.

2.1 Alternatives – Leaving the Vegetation On-site

The Construction of the Portugues Dam requires the removal of a large volume of timber material. Many factors contribute to the need for removal of this material from the proposed reservoir site. The major effects of leaving the vegetation in place both on and off site are listed below.

2.1.1 Within Dam Reservoir Pool

Vegetation Remains Standing In-place:

The project was designed to provide a very high degree of flood protection to the Municipality of Ponce and surrounding areas. Leaving the vegetation standing in the pool of the reservoir will significantly decrease the total storage capacity, water quality, and recreation in the reservoir. The main risks associated with the reservoir storage capacity reduction, are: reservoirs are designed to decrease the extent of the peak flood discharge during rainy season and/or extreme rain events to protect downstream areas from flood damage, if the vegetation is left in-place the reservoir would not have capacity to retain the necessary amount of water, this might cause the loss of property and/or life in the downstream areas, and; if in the future the Commonwealth of Puerto Rico decides to move forward with the use of the dam for water supply, a water shortage could occur and the cost for the removal and disposal of the left vegetation will be extremely high.

Also, the water quality could be affected due to the decomposition of organic matter (timber material) remaining in the pool. Anoxic conditions (water depleted of dissolved oxygen) could occur and affect fish population and in-stream fauna. This alternative would also produce hazardous conditions to small boat operation and recreation.

The woody debris and the muck accumulated at the bottom of the dam reservoir can interfere with the dam outflow gates and culverts, increasing maintenance on the dam, and potentially cutting off the required environmental water flows to the environment.

Vegetation Mulched and Left Sitting in Pool:

Mulching of the vegetation could result as much as 156,960 yd^3 (120,000 m^3) of vegetative material in the bottom of the pool. As the main purpose of the project, to reduce flood damages, the resulting deposition of this mulched material will greatly diminished the storage capacity in the reservoir. This alternative could also affect the water quality, as discussed in the previous section.

According to recent studies, reservoirs can contribute to greenhouse gas emissions when not properly constructed. The initial filling of a reservoir floods any existing plant material, leading to the death and decomposition of the carbon-rich vegetation (woody debris). The rotting organic matter releases large amounts of carbon into the atmosphere. The decaying plant matter itself then settles to the non-oxygenated bottom of the stagnant reservoir, and the decomposition produces and eventually releases dissolved methane. According to the Environmental Protection Agency (EPA), methane is a greenhouse gas about 21 time's more likely to contribute to global warming than CO_2.

2.1.2 Out of Dam Reservoir Pool

On-site Deposition:

This alternative discusses the option of cutting the vegetation and moving to a disposal location on-site (within the project limits) in a chipped and un-chipped form. The potential for chipped vegetation left within the project limits to self combust is a significant possibility. Residue from forestry operations that is subsequently processed through a chipper or tub grinder is highly susceptible to biological "soft heating". Many piles of this material were found to be spontaneously combusting in the Klamath/Lake region as well as the Central Oregon area in 1991 to 1992. When the vegetation is mulched into finely ground pieces the surface area of the material (organic matter) is dramatically increased. This organic matter then reacts with the oxygen in the air and in the process releases heat. The possibility for self combustion presents a large threat to the surrounding forests and communities. Fire management and prevention practices such as frequent watering of the woody debris piles and turning it with heavy machinery would be difficult and more prone to human error as more than 7,500 truckloads of material would require management. For these reasons, leaving the vegetation on-site, especially in the form of mulch, is not a viable option.

Other possible problems can be termite infestation, among other pests. These scenarios can present a health threat to the local environment.

2.1.3 Open Burning

Open burning is a fairly simple process as well. According to the Puerto Rico Environmental Quality Board (EQB) and EPA open burning means, "the combustion of any material without the following characteristics: (1) control of combustion air to maintain adequate temperature for efficient combustion; (2) containment of the combustion reaction in an enclosed device to provide sufficient residence time and mixing for complete combustion, and; (3) control of emissions of the gaseous combustion products".

Generally, open burning is when all the debris is collected in a pile(s) on site then burned to ash in a regulated manner. Then the ashes produced may be distributed on site, sold as fertilizer or disposed of at a landfill. The economics, human health and environmental risk associated with this method of debris disposal are significant. Open burning is commonly thought of as producing too many pollutants, because it lacks any type of environmental control (BSE, 2008; PC, 2004). The opacity (cloud of smoke) produced by open thermal reduction averages 60% to 80% (Air Burners, 2008). By increasing air pollution and smoke emissions, open thermal reduction negatively impacts the health of area residents (ESE, 2008). In studies examined by Miller and Lemieux (2007), carbon monoxide emissions associated with open thermal reduction ranged from 16 to 110 g/kg and particulate matter emissions ranged from 6 to 19 g/kg; levels which greatly exceed those produced by an air curtain thermal reduction operation. Open burning, as a practice, also increases the opportunity for wildfire as sparks from the open burn pile can not be sequestered and will be distributed in the surrounding environment.

Based on the human health and safety and environmental risk associated, this alternative was not considered.

2.2 Alternatives – Off-site Disposal

There are two off-site (out of project limits) disposal alternatives, which are: direct landfill disposal and land acquisition for vegetative material disposal.

2.2.1 Direct Landfill Disposal

The process of landfill disposal is straight forward; the debris is packed into hauling trucks and then transported to the landfill. Landfill disposal would appear to be the most logical and ideal means of debris disposal, however several factors suggest otherwise. Two of the most important factors are that not all landfills allow vegetative material debris and many landfills do not have the capacity for such large amount of debris (PC, 2004). The amount of space available at landfill sites around the World is decreasing at an alarming rate: the amount of human waste produced is gradually surpassing the amount of space available to contain the waste leaving little room for vegetative debris. The Ponce Landfill is the closes landfill available for the disposal of solid waste. According to the PR Solid Waste Management Authority (PRSWMA) information, *Descripción de Sistemas de Relleno Sanitario en Operación, Puerto Rico,* Ponce Landfill had a lifetime of approximately 6-10 years in 2003 and EPA's LMOP Landfill/Project Database suggests that the Ponce Landfill closure will occur in 2009. Also, PRSWMA information indicates that Salinas and Guayama landfills, which are the next closest available to the project, have similar lifetimes.

In general, landfills are one of the most expensive means of disposal, because the cost includes transportation and disposal fees (BSE, 2008). Another factor is that vegetative waste dramatically reduces the overall life of a landfill (BSE, 2008). Also the emissions associated with the transportation of the timber material, and the decomposition of the material can be high. Decomposing wood is known to produce high levels of greenhouse gases (BSE, 2008). Other possible problems associated with decomposing vegetative material in landfills can be the potential for naturally occurring fires and pest infestation (SCAQMD, 2003).

The emissions calculations from transportation, allowing natural decay of the vegetative waste in the landfill and incineration immediately after receiving the vegetative material in a landfill were calculated, as follow:

<u>Phase I; Loading and transportation logistics for the green timber in a volumetric analysis</u>:

Note: Volumetric analysis for transportation of trees in dump truck can greatly vary, due to the size of dump box, and how the trees fit inside in the dump box (to much voids). Field estimates for transportation of the green timber are in the order of 60,000 m^3 to 120,000 m^3 (78,480 yd^3 to 156,960 yd^3) for total combined disposal of clearing and grubbing of Phases I and V.

<u>Transportation of 78,480 yd^3 (60,000 m^3) for Phase I:</u>

Average dump truck volume = 20 yd^3/truck
Typical density of tree trimmings waste (including voids) = 139.7 lb/yd^3 (3)

Tree trimming per acre (trees plus voids) = tree mass per acre/density of tree trimmings waste
= (52,400 lb/acre) / (139.7 lb/yd^3) = 375 yd^3/acre

Number of trucks hauling needed per acre = 375 yd^3/(20 yd^3/truck) = 18.75 trucks/acre
Number of one way truck trips to disposal facility = 200 acres x 18.75 truck/acre = 3,750 truck trips
Total truck trips = 3,750 x 2 trips/roundtrip = **7,500 truck trips**
Travel time from the Portugues Dam to the Ponce landfill is 20 minutes by car, for a truck we assume 10 minutes more for the driving inside the sites, and overall slower speed.

Time per trip = 30 minutes = 0.5 hr (without traffic)

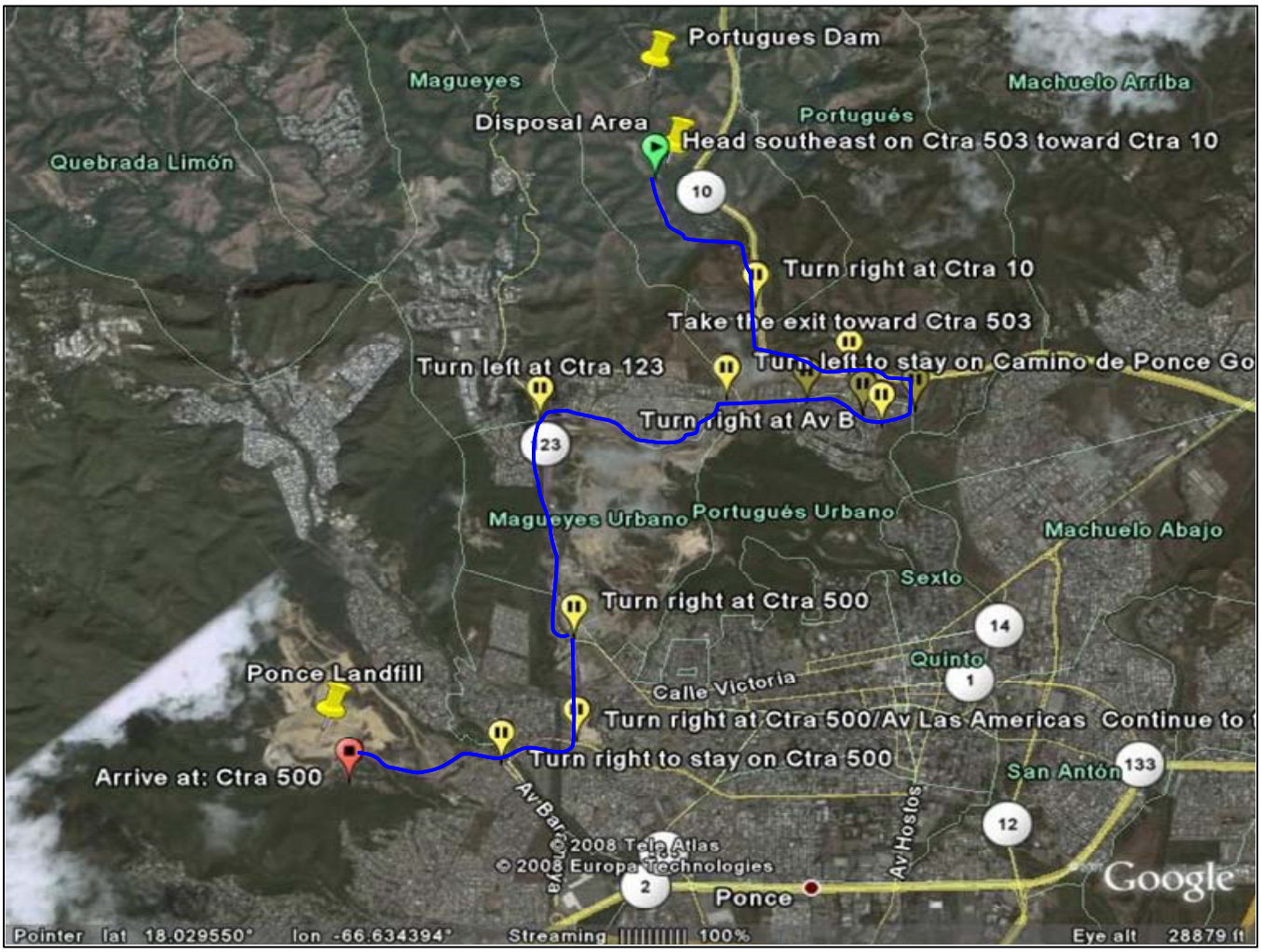


Figure 1. Truck Route

Truck emissions were calculated from the "Emission Standards Reference Guide for Heavy-Duty and Nonroad Engines" EPA420-F-97-014, September 1997. The SO_2 diesel engine emissions were calculated using EPA's Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, section 3.3 Gasoline and Diesel Industrial Engines.

HEAVY-DUTY HIGHWAY ENGINES—CI AND URBAN BUSES

	Year	CO (g/bhp-hr)	Idle CO (percent exhaust gas flow)	HC (g/bhp-hr)	NMHC + NOx (g/bhp-hr)	NOx (g/bhp-hr)	PM (g/bhp-hr)	Smoke[a] (percentage)	Useful Life	Warranty Period
Federal[b]	1990	15.5	0.5[c]	1.3[d]		6.0 (NCP)	0.60 (NCP)	20/15/50	1990-97 and 1998+ for HC, CO, and PM: LHDDE: 8 years/110,000 miles MHDDE: 8 years/185,000 miles HHDDE: 8 years/290,000 miles 1994+ urban buses for PM only: 10 years/290,000 miles 1998+ for NOx: LHDDE: 10 years/110,000 miles MHDDE: 10 years/185,000 miles HHDDE: 10 years/290,000 miles	5 years/100,000 miles (but not less than the basic mechanical warranty for the engine family)
	1991-93	15.5	0.5[c]	1.3		5.0 (ABT, NCP)	0.25 (ABT, NCP), 0.10[e]	20/15/50		
	1994-97	15.5	0.5[c]	1.3		5.0 (ABT, NCP)	0.10 (ABT, NCP), 0.07[f], 0.05[g]	20/15/50		
	1998+	15.5	0.5[c]	1.3		4.0 (ABT, NCP)	0.10 (ABT, NCP), 0.05[g]	20/15/50		
Proposed Federal[h]	2004+	15.5	0.5		2.4 or 2.5 with a limit of 0.5 on NMHC (ABT)		0.10 (ABT, NCP), 0.05[g]	20/15/50	LHDDE: 10 years/110,000 miles MHDDE: 10 years/185,000 miles HHDDE and urban buses: 435,000 miles, 13,000 hours, or 10 years (but not less than 290,000 miles)	5 years/100,000 miles (but not less than the basic mechanical warranty of the engine)
European Union[i]	10/96	3.0		0.8		5.2	0.19	42/2.25[k] 100/1.495[k] 200/1.065[k]		
	10/98						0.11[i]			
California	1987-90[l]	15.5	0.5[m]	1.3/1.2[n]		6.0	0.60	20/15/50	LHDDE: 8 years/110,000 miles MHDDE: 8 years/185,000 miles HHDDE: 8 years/290,000 miles	5 years, 100,000 miles, or 3,000 hours (for 1994 and earlier engines greater than 8,500 lbs and for 1995+ engines greater than 14,000 lbs)
	1991-93[l,o]	15.5	0.5[m]	1.3/1.2[n]		5.0	0.25[p]/0.10[q]			
	1994+[l,o]	15.5	0.5[m]	1.3/1.2[n]		5.0	0.10			
	1994-95[p,q]	15.5	0.5[m]	1.3/1.2[n]		5.0 (0.5-3.5[r])	0.07[p]			
	1996+[p,q]	15.5	0.5[m]	1.3/1.2[n]		4.0[s] (0.5-2.5[r])	0.05			

Our model truck is a Mack 300, 1998+, with capacity of 20 yd^3 and rated at 300 bhp.

CO = 15.5 g/bhp-hr x 300 bhp x 7,500 trips x 0.5 hr/trip = 17,437,500 g x (lb/454g) = **38,408.6 lb**
HC(VOCs) = 0.5 g/bhp-hr x 300 bhp x 7,500 trips x 0.5 hr/trip = 562,500 g x (lb/454g) = **1,239 lb**
NO_2 = 4.0 g/bhp-hr x 300 bhp x 7,500 trips x 0.5 hr/trip = 4,500,000 g x (lb/454g) = **9,912 lb**
PM_{10} = 0.1 g/bhp-hr x 300 bhp x 7,500 trips x 0.5 hr/trip = 112,500 g x (lb/454g) = **247.8 lb**
SO_2 = 300 hp x 0.00205 lb/hp-hr x 0.5 x 7,500 trips x 0.5 hr/trip = **1,153.12 lb**

<u>For Phase V we expect to transport the same amount as Phase I; 78,480 yd^3 (60,000 m^3)</u>

Grand total of truck emission from transporting material from Phases I &V (double of Phase I) is:

CO = 76,817.2 lb
HC(VOCs) = 2,478 lb
NO_2 = 19,824 lb
PM_{10} = 495.6 lb
SO_2 = 2,306.24 lb

Disposal in a municipal sanitary landfill and allowing natural decay of the vegetative waste in the landfill before thermally reducing it:

Calculation basis a total of 200 acres of clearing and grubbing:

Volatile Matter (VOCs) = 19,259.86 lb/acre x (200 acres) = **3,851,972 lb**
Fixed Carbon (CO, CO_2) = 5,773.31 lb/acre x (200 acres) = **1,154,662 lb**
Sulfur emissions (H_2S, SO_2, SO_3) = 429.51 lb/acre x (200 acres) = **85,902 lb**
Plus the emissions of the truck trips to the disposal facility

Disposal in a municipal solid waste facility and incineration immediately after receiving the vegetative waste:

Calculation basis a total of 200 acres of clearing and grubbing:

Volatile Matter (VOCs) = 22,139 lb/acre x (200 acres) = **4,427,800 lb**
Fixed Carbon (CO, CO_2) = 3,799 lb/acre x (200 acres) = **759,800 lb**
Sulfur emissions (SO_2, SO_3) = 52.4 lb/acre x (200 acres) = **10,480 lb**
Plus the emissions of truck trips to the disposal facility

The landfill disposal alternatives were not considered practicable, for the following reasons:

- The volume of biomass to be generated from the clearing and grubbing of the Portugues Dam construction is too large to be handled, received and could significantly reduce the overall life of the region's sanitary landfills. It is important to highlight that most of Puerto Rico landfills do not allow vegetative material.

- The large amount of vegetative waste could contribute in the reduction of the overall life of the used landfill.

- General public living among the trucking route will be affected by noise and emission generated by the vehicles volume movement.

- Allowing the vegetative material to degrade in the landfill will generate methane gas, according to the Environmental Protection Agency (EPA) web site, methane is a greenhouse gas about 21 time's more likely to contribute to global warming than CO_2. The landfill presents an additional fire hazard from the methane gas generated from the decomposition solid waste.

- Independent of the emissions calculated for Direct Landfill Disposal scenarios using proximate analysis, the emissions from the thermal reduction in the landfill will be able to reach a highly populated area in Ponce, therefore the total emissions will be similar or higher to the thermal reduction emissions in the project site plus the additional emission of trucking the material from the project site to the landfill.

- Cost of loading and transporting the vegetative material from the dam site to the landfill and landfill fees are extremely high to be cost effective and justifiable.

2.2.2 Land Acquisition for Vegetative Material Disposal

This alternative would involve the acquisition of adequate property (approximately 14 acres). It was estimated that at least 7 acres will be needed for the storage and management of the vegetative material piles and up to an additional 7 acres to properly space the piles far enough from each other. This will prevent the spread of fire to other piles in the event of a single pile catches fire and for other safety issues. There will be approximately 10 piles (20 feet height by ½ acre footprint), as well as access roads and staging areas needed to maintain and manage the operation. Also, we have to take into consideration the costs and time limitations associated with the real estate acquisition process, site preparation, fencing, clearing vegetation (which will increase the amount of vegetative material to be disposed), access roads, fire management and prevention practices, heavy equipment/machinery and maintenance, among others which would increase the costs even further. This could also exceed the Congress authorized funds for the project and the Commonwealth of Puerto Rico will be responsible for any additional costs.

Finally, both off-site disposal alternatives present significant air quality issues. It was estimated a total off 7,500 truck trips going one way will be necessary to remove the material, and will take the trucks past Ponce or in a surrounding area for both alternatives. For detailed information about loading and transportation logistic and emissions to be generated by allowing natural decay of the vegetative material, please refer to Direct Landfill Disposal Alternative above.

2.3 Alternative – Chipping/Mulching

This activity consists of piling the raw-wood waste in an established area and cut the trees. The trees are cut in approximately 2 or 3 feet above the root ball. Then a portable tub grinder will be towed to site where it will be set up to chip stumps and large branches into 1 to 2 inch diameter sized chips/mulch. After chipping, the ground wood residue will be left on site to be loaded on trucks for disposal, since the chipper emits the resulting wood chips/mulch in the immediate area of the raw wood waste pile.

This alternative appears to be the environmentally beneficial alternative for the disposal of timber material, but we have to take into consideration that it is estimated that approximately 5,240 tons of timber material will be generated. Puerto Rico does not have facilities that can handle or receive this volume of material in a timely manner, as required by the project.

As an alternative to the less than cost effective alternatives described with chipping and removing all the material, the USACE has identified approximately 5,000 m^3 (a pile of 20 feet height by a diameter of 100 feet, or approximately 250 truckloads of mulched material) of wood that can be utilized as mulch or giving other use or application, which is environmentally beneficial for that matter. This material will be left on-site temporarily for use by the public. It would be the responsibility of the municipalities, agencies, or public to have the necessary equipment and personnel for hauling and managing the material. Additionally, the Puerto Rico Department of Natural and Environmental Resources (DNER) as sponsor and other Agencies are welcome to harvest any suitable timber at their own cost and risk before the project starts. Also the contractor will have on site a mulching machine to process wood into mulch, which will be offered to the municipalities, agencies and to the general public. These efforts will be coordinated with the sponsor and mitigate the amount of material to be burned via the thermal reduction process.

2.4 Alternative – Air Curtain Thermal Reduction:

Air curtain thermal reduction technologies' are a commonly used for vegetative debris disposal (Miller and Lemieux, 2007). The design of the air curtain technologies may vary, but the operation is fundamentally the same. The traditional setup of an air curtain thermal reduction consists of a pit, air blower, and continuous air monitoring devices (Miller and Lemieux, 2007). The design varies in that the pit may be manufactured and portable or the pit may be dug out on site. The later requires additional resources and regulations (ie. dimensions, lining, etc.), while a portable air curtain pit is less costly and "ideal for areas with high water tables, sandy soils and where opacity must be kept to a minimum." An air curtain pit "operates by burning the combustible material (trees) in an enclosed space with an open top, over which a high velocity 'curtain' of air is directed to reduce the escape of large particles and to improve air circulation into the burning debris" (Miller and Lemieux, 2007).

Thermal reduction can be implemented without compromising the air quality of the region. The emissions of particulate matter (PM) and carbon monoxide (CO) per unit mass of debris produced by air curtain thermal reduction are significantly lower than those of open pile burning (Miller and Lemieux, 2007; CDPHE, 2008). The use of an air curtain thermal reduction reduces the emission of PM and CO by improving combustion conditions, as compared to open thermal reduction (Miller and Lemieux, 2007). An air curtain thermal reduction averages 10% opacity (Air Burner, 2008). The ashes produced via thermal reduction can be recycled as fertilizer or for any other eco-friendly purpose; only after being analyzed and cleared of heavy metal contaminants (BSE, 2008). The remaining ashes can be disposed of properly at a landfill.

Based on the ability to dispose of a large amount of debris economically, it's ability to significantly limit emissions and prevent nearby forest fires, and its value to the local community of reducing truck trips emissions, and not contribute to already strained landfill capacity, thermo-reduction of the vegetative material is believed to be the least damaging practicable alternative.

Emissions estimates were steer into a very conservative approach. The emission calculations for thermal reduction operations at the Portugues Dam construction project were based on the highest emission value, found from the different tools, used to mimic the extreme highs for this type of operation. The USACE has estimated emissions for an air curtain operation based on the principles of complete combustion and by using emission factors for wood residue combustion boilers. We compare our numbers with numbers from a technical paper published by the U.S. Department of Agriculture (USDA) Forest Service; the variance in values can be attributed to several factors like, type of vegetative material, parameters of operation, loading frequency, air temperature, and others.

Complete combustion of the vegetative waste in a thermal pit, due to the excess of oxygen available. Calculation basis a total of 200 acres of clearing and grubbing:

Ash = 262 lb lb/acre x (200 acres) = 52,400 lb x (ton/2,000 lb) = 26.2 tons
H_2O = 41,291.2 lb/acre x (200 acres) = 8,258,240 lb x (ton/2,000 lb) = 4,129.12 tons
CO_2 = 48,451.4 lb/acre x (200 acres) = 9,690,280 lb x (ton/2,000 lb) = 4,845.14 tons
VOCs = 0.704 lb/acre x (200 acres) = 140.8 lb x (ton/2,000 lb) = 0.0704 tons
CO = 143.37 lb/acre x (200 acres) = 28,674 lb x (ton/2,000 lb) = 14.337 tons
NO_2 = 94.78 lb/acre x (200 acres) = 18,956 lb x (ton/2,000 lb) = 9.478 tons
SO_2 = 52.974 lb/acre x (200 acres) = 10,594.8 lb x (ton/2,000 lb) = 5.2974 tons
PM_{10} = 118.516 lb/acre x (200 acres) = 23,703.2 lb x (ton/2,000 lb) = 11.8515 tons
{$PM_{2.5}$ = 101.4 lb/acre x (200 acres) = 20,280 lb x (ton/2,000 lb)} = 10.14 tons}

In addition, per EQB's request the USACE re-calculated the values of CO and $PM_{2.5}$ emissions of the USDA Forest Service emission data by replacing the 0.5 adjustment factor that we used to correct for the 50% moisture content by weight found in green timber with a factor of 1.0, which assuming 100% dry wood. Both of these emission radii are less than our estimated maximum potential impact radii of 0.8 km emission calculations. All the emissions of CO, SO_2, NO_2, PM_{10} and $PM_{2.5}$ from the thermal reduction operations are within the NAAQS at a conservative scenarios radius ("rings") of 0.8 km (**Figures 2-4:** Maximum Potential Emission Impacts for the Conservative Scenario).

All modeled emissions of CO, SO_2, NO_2, PM_{10} and $PM_{2.5}$ from the thermal reduction operations that have a potential to exceed NAAQS for the conservative scenarios (aka worst case scenario) are within a maximum radius of 0.8 km. The following NAAQS and conservative scenarios radius distances were used in our calculations:

Pollutant	NAAQS	Thermal Reduction Emissions Mass Rate (g/s)	Conservative Scenarios Radius Distance (Kilometers)
CO	10 mg/m^3	1.8 – 4.68*	0.0265 – 0.049*
SO_2	80 µg/m^3	0.67	0.271
NO_2	100 µg/m^3	1.2	0.3210
PM_{10}	150 µg/m^3	1.5	0.281
$PM_{2.5}$	15 µg/m^3	0.21* - 1.28	0.337*-0.801

*Value using U.S. Forest Service data comparison.

The most stringent pollutant standard within conservative scenarios radius is $PM_{2.5}$ with a concentration of 15 µg/m^3 and an impact distance of approximately 0.8 km. The USACE has used the most stringent NAAQS measures for the above mentioned pollutants.

Based on the calculations presented on the above table it is expected that most of the emissions will be within less than 0.5 km radius and impacts to human health and the environment are not expected. For detailed information, please refer **Section 14** and to the Gaussian Plume, Two-dimension Spreading Model Figures.

It is important to highlight that all properties within the project limits were acquired by the Commonwealth of Puerto Rico for the development of the Portugues Dam. In addition, per EQB's request the USACE confirmed with Mr. Efrain Reyes, Director of the Infrastructure Area of the Puerto Rico Department of Education that the former Julio Collazo Silva School is abandoned (**Figure 5**).

Based on the measures established on the project's Contingency Plan the nearest communities outside the project limits that shall be notified if the emissions reach the action levels are (**Figure 6**): Tibes (North), Machuelo Arriba (East), Portugués (Southeast), and Magueyes (Southwest).

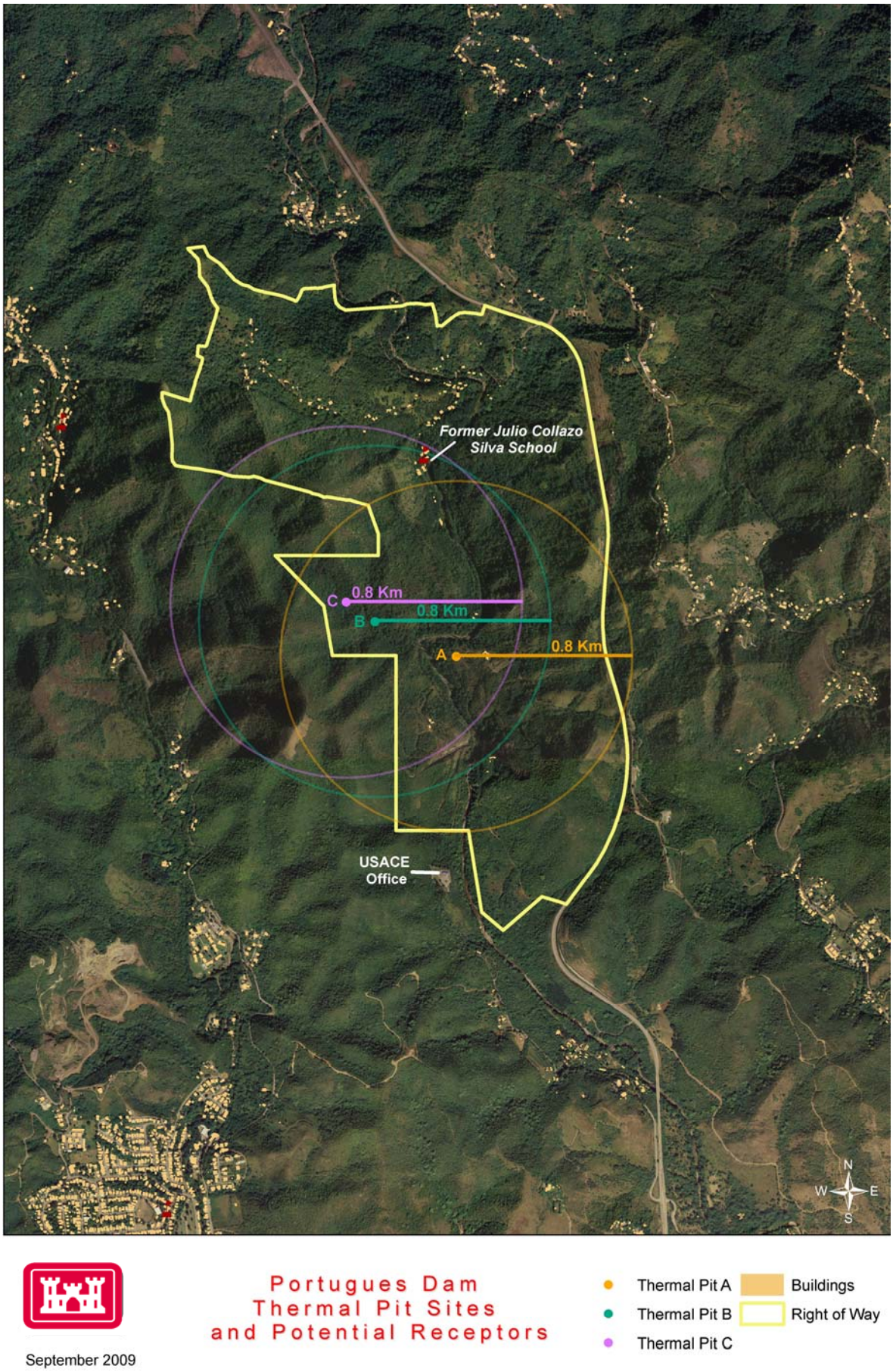
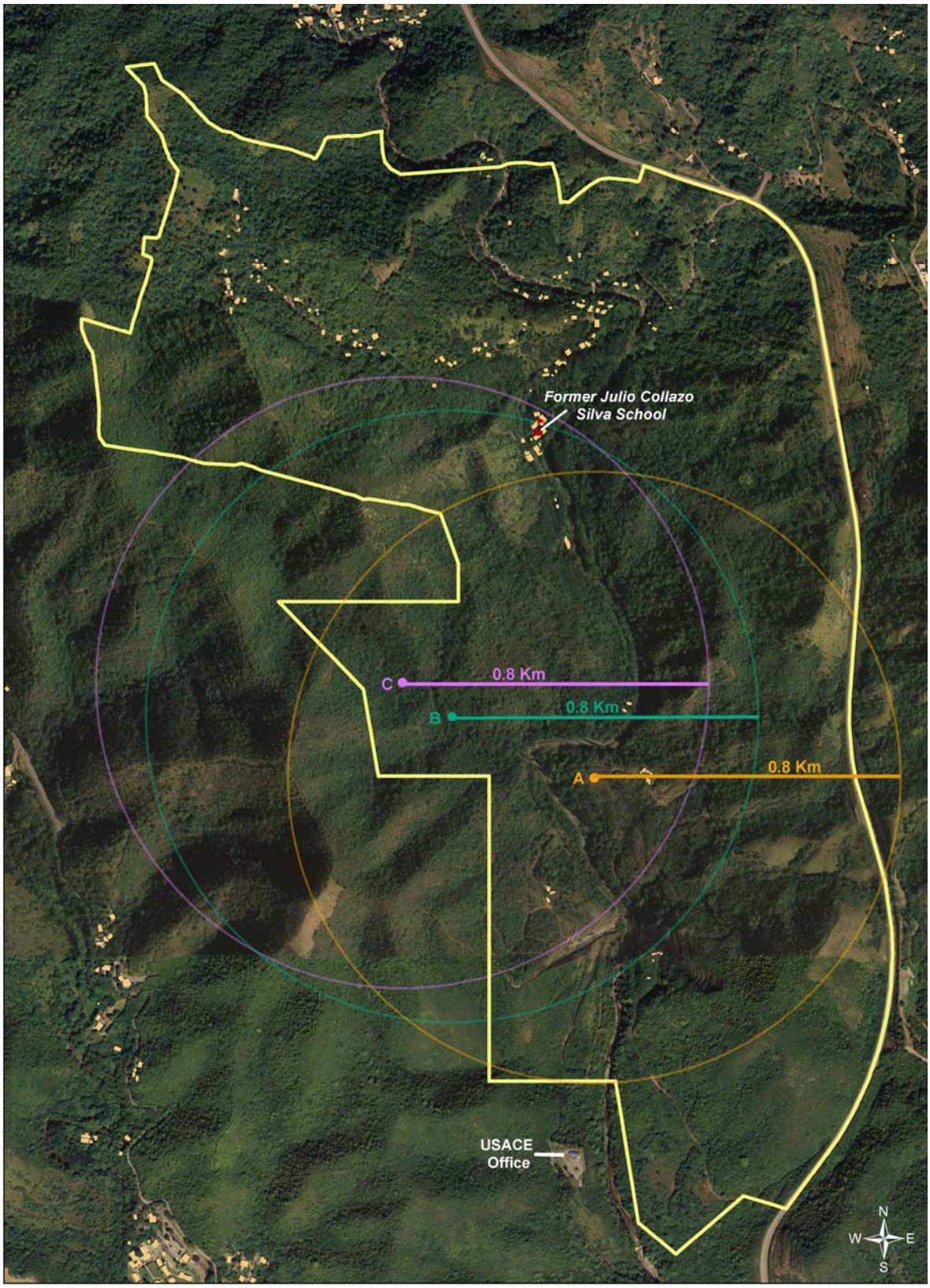


Figure 2 – Maximum Potential Emission Impacts for the Conservative Scenario.

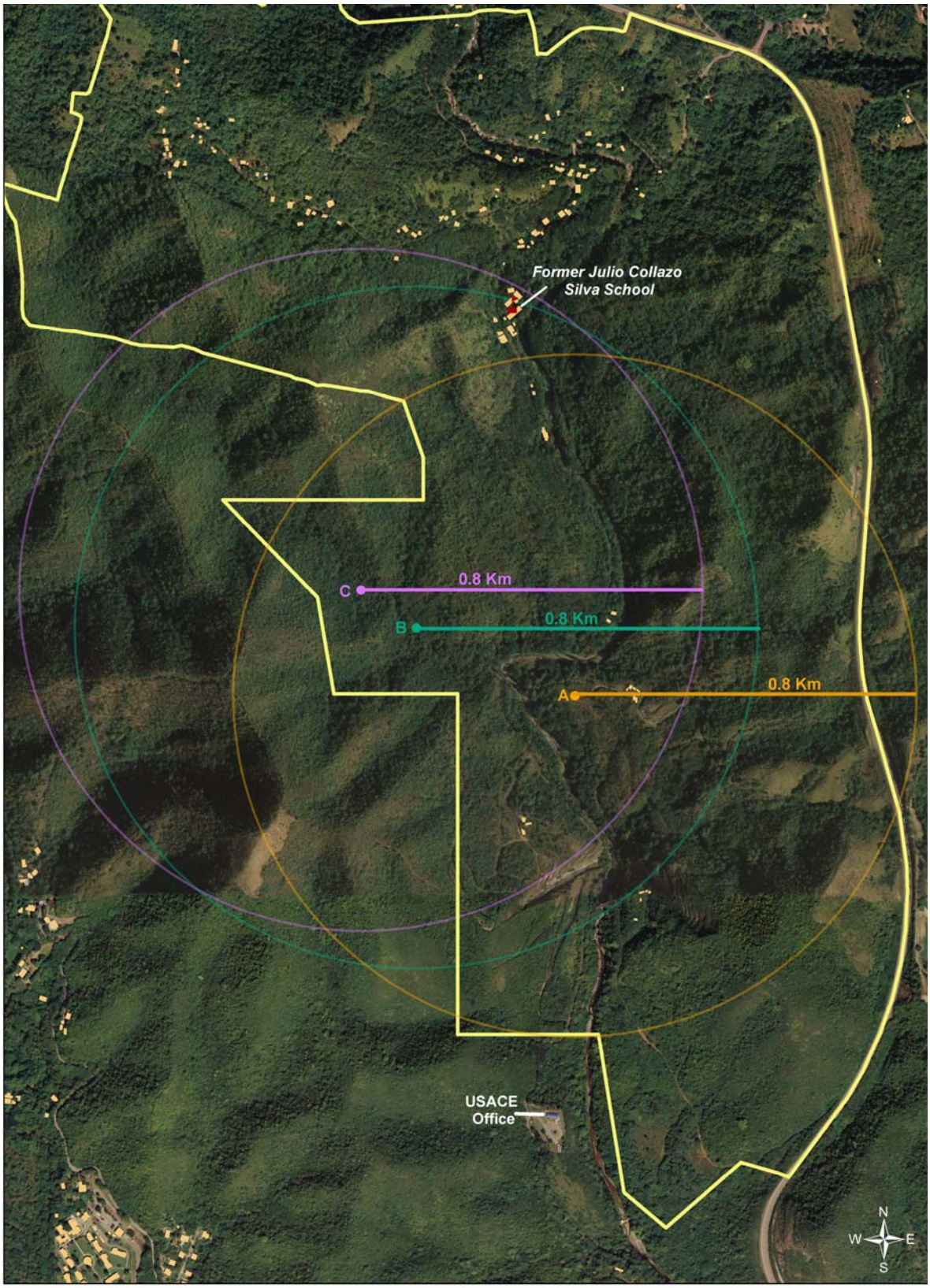


Portugues Dam
Thermal Pit Sites
and Potential Receptors

Thermal Pit A
Thermal Pit B
Thermal Pit C
Buildings
Right of Way

September 2009

Figure 3 – Maximum Potential Emission Impacts for the Conservative Scenario.



Portugues Dam
Thermal Pit Sites
and Potential Receptors

Thermal Pit A
Thermal Pit B
Thermal Pit C
Buildings
Right of Way

September 2009

Figure 4 – Maximum Potential Emission Impacts for the Conservative Scenario.

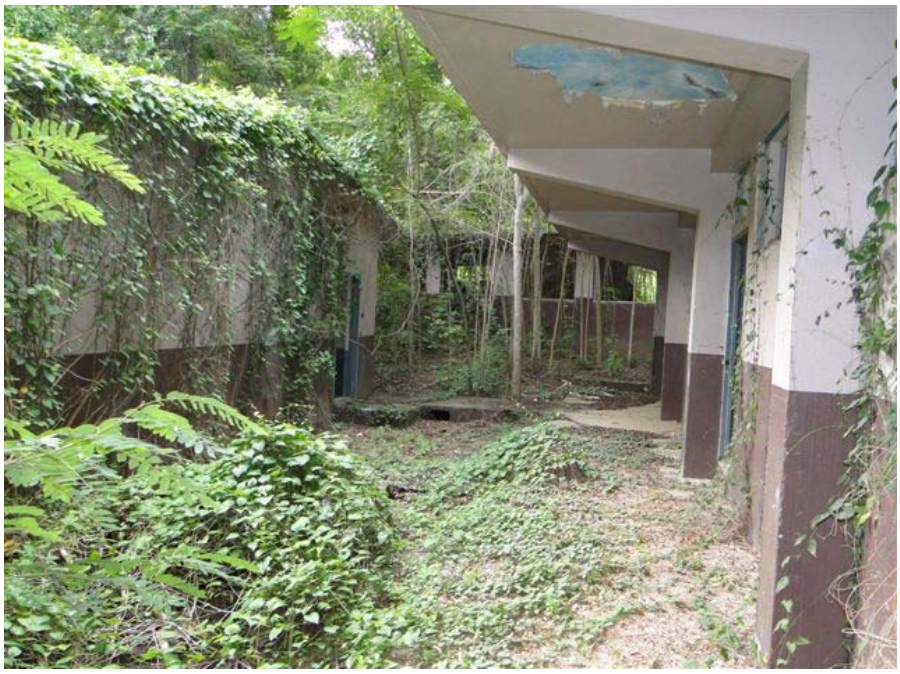


Figure 5. Pictures of Former Julio Collazo Silva School, Ponce, Puerto Rico

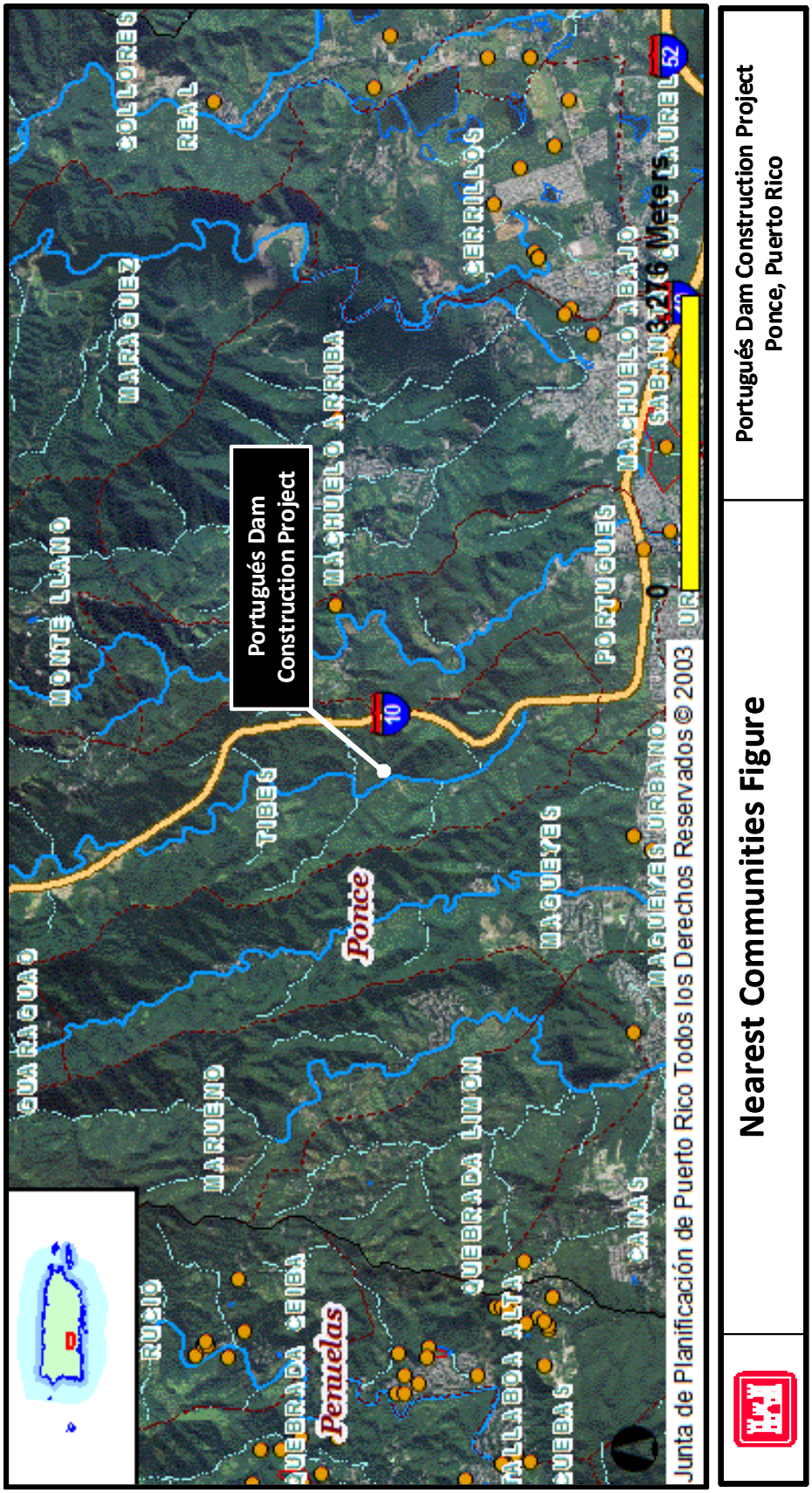


Figure 6 – Nearest Communities.

3.0 Thermal Reduction Setup

The vegetative material will be stockpiled in three designated areas. Each area will have a fully functional air curtain thermal pit for the thermal reduction of only vegetative material. The USACE will use air curtain thermal pit setup similar to those utilized in the past during emergency operations for hurricanes George and Jeanne. This traditional setup consists of a pit, air blower, and continuous air monitoring devices (see Figures 5 to 10 in Appendix).

4.0 Air Quality and Thermal Reduction Pit Operations

The air quality in the City of Ponce is classified by the US Environmental Protection Agency as attainment (good air). In the Portugues Dam site there are no significant sources of air pollution in the Portugues river valley, and air quality is consistently good, due to a combination of an on shore sea breeze during the day and cool mountain air moving down the valley at night.

The contractor will contact the National Weather Service (NWS) to verify if the weather conditions are appropriate to conduct thermal reduction with the purpose of minimizing impacts, maintain emissions under control, and protect human health of the workers and the nearby communities. Conditions to consider, but not limited, are; meteorological conditions prior to thermal reduction operations like air stagnation (no wind condition), atmospheric inversion (mostly in Fall), high natural background levels of particles from events like Sahara dust, or volcanic ash, accidental air pollutants releases from industrial complexes found in the south of Puerto Rico, and/or accidental fires in the area.

Based on the emissions data collected by the real-time monitoring stations, each thermal pit will operate optimally to ensure that NAAQS are met. In the case of wind direction steer towards populated areas, and/or emissions from a thermal reduction pit are reaching 75% of the NAAQS, the operator shall slow down the operation of the pit and adjust the process. Should the operation not meet 90% or lower of the NAAQS in two hour periods subsequent to the operator adjustments, the thermal pit shall cease operations for the rest of the day.

The Contractor shall maintain continuous thermal reduction activity from sunrise to sunset in the active thermal pits, to reduce start up emissions:

a) Only kerosene, diesel fuel, drip torch fuel, clean dry wood or lightered pine, virgin oil, natural gas, or liquefied petroleum gas may be used to start the fire in the incinerator. The use of used oil, chemicals, gasoline, or tires to start the fire is prohibited.

b) An air curtain incinerator must be located at least 300 feet from any occupied building and 50 feet from any wildlands, brush, combustible structure, or paved public roadway.

c) Incinerators equipped with refractory-lined walls, shall begin charging no earlier than sunrise and must end no later than sunset.

d) Incinerators not equipped with refractory lined walls shall begin charging no earlier than sunrise and must end one hour before sunset.

e) Regardless of the air curtain incinerator type, after charging ceases, air flow shall be maintained until all material within the air curtain incinerator has been reduced to coals, and flames are no longer visible. A log shall be maintained on site, and available upon request, that documents daily beginning and ending times of charging.

f) If the air curtain incinerator employs an earthen trench, the pit walls (width and length), shall be vertical, and maintained so that the combustion of the waste within the pit will be maintained at an adequate temperature and with sufficient air re-circulation to provide enough residence time and mixing for proper combustion and control of emissions. Pit width shall not exceed twelve (12) feet.

g) The waste material shall not be loaded into the air curtain incinerator such that it protrudes above the level of the air curtain in the pit.

h) Ash shall not be allowed to build up in the pit of the air curtain incinerator to higher than 1/3 the pit depth or to the point where the ash begins to impede combustion, whichever occurs first.

i) Excessive visible emissions are not allowed except for a period of up to 30 minutes during start ups.

j) The air curtain incinerator shall be attended at all times while materials are being burned or flames are visible within the incinerator.

k) The Contractor shall have available a water truck and/or heavy equipment to turn off the fire.

5.0 Air Contaminants of Concerns during Thermal Reduction

The purpose of utilizing controlled thermal reduction technologies is to reduce the overall volume of solid waste generated from the clearing and grubbing operation and protect air quality in the area. During combustion, several air contaminants of concern to human health and the environment, such as CO, SO_2, NO_2, PM_{10} and $PM_{2.5}$, have the potential to be generated.

6.0 Construction Contractor's Responsibility

The Prime Contractor would be responsible, but not limited, of hiring a sub-contractor for the air quality monitoring, the construction of the furnaces, clearing and grubbing, the proper disposal of solid waste and vegetative material, the proper testing and disposal of the ashes, and to provide for the safety of employees.

7.0 Monitoring of Air Quality

The monitoring will be conducted by a sub-contractor hired by prime construction contractor. The sub-contractor shall be responsible for meeting air quality standards, setting the rate of operations of the furnaces, and monitor the rate of exposure of the employees working directly on furnace related activities. The air monitoring sub-contractor will work closely with to the safety officer of the main contractor to ensure the human safety in the area, and both will report to the USACE contracting officer representative.

8.0 Proposed Location of the Air Monitoring Devices

The ambient air monitoring will be performed at monitoring stations upwind and downwind of the thermal reduction pit sites, taking into consideration the direction of the prevailing wind. The monitoring stations will be installed on open areas at the thermal reduction pit sites, with low wind flow disturbances to facilitate representative sampling. The typical upwind stations will be located approximately 1,500 feet from the thermal reduction sites. Typical downwind stations will be located approximately 700-800 feet from the thermal reduction sites. Other stations will be located approximately 50-150 feet downwind from the thermal reduction site. The Figures 3 & 4 of the appendix depicts the proposed monitoring station locations. Location of the monitoring stations could be changed or modified in case weather conditions preclude the collection of the best representative data, or to avoid cross contamination from heavy equipment operating in the area.

9.0 Disposal of Solid Waste

The ashes will be tested for heavy metals content, and offer to the public to be recycled as fertilizer or for any other environmental friendly activity. The remainder ashes will be properly disposed at landfill facility in Ponce, Puerto Rico. Other solid waste like cars, tires, household appliances, construction debris, and garbage, won't be subject to thermal reduction and will be properly disposed at a landfill facility in Ponce, Puerto Rico.

10.0 Schedules for Thermal Reduction

The Prime Contractor shall maintain continuous thermal reduction activity from sunrise to sunset in the active thermal pits, to reduce start up emissions. Due to the fact that it will take some time to collect and to pile up the green timber, it is expected that one to two thermal pits will operate daily. The contractor shall operate in the most efficient, and effective way to reduce unnecessary air emissions, and that the activities may take up to two hundred days to be completed.

11.0 Portugues Dam Phases of Construction

Phases of construction shall be as follows:

Phase 1 Items of Work (Started on April 2008)

- Initial mobilization and preparatory work including Contractor's office and compound, access and haul roads, and equipment for excavation, transportation, and disposal of quarry overburden.
- Fencing of the entire project as specified.
- Security of the site.
- Constructing government facilities including utilities.
- Clearing and grubbing of the quarry area, upstream disposal area(s) for quarry overburden placement, Contractor's work areas, and downstream disposal area.
- Demolition of all specified items.
- Excavation and disposal of quarry overburden.
- Power line relocation from PR-503 to PR-10.
- Power line relocation at quarry.

Phase 2 Items of Work (Started on September 2008)

- Mobilization and preparatory work including quarry rock excavation equipment, rock crushing and processing equipment, hauling equipment, conventional concrete batch plant, RCC concrete batch plant, chillers, Government concrete testing laboratory.
- Security of the site
- Construction/furnishing Government concrete testing laboratory.
- Aggregate production for foundation treatment plus 20% of RCC.
- Excavation of the foundation to grade, valve house area, spillway discharge areas, foundation treatment areas.
- Diversion and care of water for foundation excavation & treatment concrete.
- Slope stabilization of excavated areas.
- Placing dental concrete in foundation and spillway discharge area.
- Placing RCC test section.
- Construction of concrete pipe encasement with embedded R.O. pipes.
- Installation of 2-500 KCMIL copper ground wires in concrete pipe encasement.
- Foundation consolidation grouting.
- Geotechnical Instrumentation installation.

The coffer dam is under construction and will be completed in September 2009. It is critical that the project area be cleared of all vegetative material and disposed off (thermally reduced) as soon as possible to avoid modifications to the project cost.

Phase 3 Items of Work (September 2009)

- Mobilization and preparatory work, including remaining equipment to place RCC.
- Security of the site.
- Continued aggregate production.
- Diversion system for dam construction.
- RCC placement in dam between November and April to elevation 440.00 (approximately 187,000 cubic yards).
- RCC placement in the valve house area.
- Slope stabilization slab - spillway discharge area.
- Slope stabilization - shotcrete at valve house area.
- Structural Instrumentation installation.
- Instrumentation monitoring.

Phase 4 Items of Work (May 2010)

- Mobilization and preparatory work for foundation grouting and drains, spillway construction.
- Security of the site.
- Continued aggregate production.
- Continued operation of diversion system for dam construction.
- RCC placement in dam between November and April from elevation 440.00 to elevation 533.00 (approximately 183,000 cubic yards).
- Structural Instrumentation installation.
- Geotechnical Instrumentation installation.
- Geotechnical Instrumentation monitoring.
- Foundation curtain and contact grouting.
- Foundation drains.
- Drilling of dam drains.
- Spillway and top of dam reinforced concrete w/electrical embeds.
- Demobilization of RCC batch plant, chillers, other equipment related to RCC.

Phase 5 Items of Work (October 2010)

- Second stage concrete in gallery.
- Restoration of quarry.
- Clearing and grubbing crest access road and initial reservoir pool limits.
- Security of the site.
- Instrumentation, installation of monitoring reflectors, wet well, accelerographs, parshall flume, and ADAS system.
- Geotechnical Instrumentation monitoring.
- Electronic Security System.
- Intake Structure.
- Bulkhead system installation and testing.
- Valve house site work.

- Valve house water and sanitary system.
- Valve house, control room, generator building construction.
- Valve house HVAC.
- Dam HVAC including louvers.
- Downstream pipe encasement and bridge.
- Reservoir Outlet pipes and valves.
- Crest access road and bridge including rock anchors at bridge abutment.
- Electrical Grounding Grid.
- Final electrical (bulkhead system, lights, gallery electrical).
- Gallery doors/louvers.
- Miscellaneous Metals - Dam/intake structure/valve house.
- Optional slope protection on quarry disposal.
- Electrical - crest lighting, gallery lighting, and final electrical.
- Electrical-Valve house, including mcc.
- Final cleanup.

12.0 Overall Cost

This alternative presents the best solution for the disposal of the vegetative material from the public health, environmental and economical point of view. It was estimated that thermal reduction will cost less than one million dollars, which is significantly less than other disposal alternatives. Due to Federal Contracting regulations the actual estimates cannot be disclose.

13.0 Plan Selection

According to the aforementioned supporting disposal scenarios, environmental analysis, and previous experience in thermal reduction, we have demonstrated and believe that thermal reduction process is the best solution from the environmental and economical point of view for the clearing and grubbing operations at the Portugues Dam construction site. Detailed emission calculations to support USACE determination are presented in the next section.

14.0 Calculations of Possible Emission – Per Acre Clearing and Grubbing

Total Clearing and grubbing areas = 200 acres [(1)]
Estimated number of trees per acre = 65 trees/acre [(1)]
Estimated average tree size = 11 inches diameter by 33 feet tall [(1)]
Wood density = 37 lb/ft^3 [(2, 3)]
Typical density of tree trimmings waste = 250 lb/yd^3 [(3)]
Typical density of ashes = 1,255 lb/yd^3 [(3)]

<u>Proximate analysis for wood (rotten timber/logs) in municipal solid waste, weight % [(2)]</u>
Moisture content = 26.80 %
Volatile Matter = 53.81 %
Fixed Carbon = 16.13 %
Non-Combustible = 2.06 %
Sulfur = 1.2 %

Proximate analysis for wood (green timber/logs) in municipal solid waste, weight % [2, 3]
Moisture content = 50.00 %
Volatile Matter = 42.25 %
Fixed Carbon = 7.25 %
Non-Combustible = 0.4 %
Sulfur = 0.1 %

Ultimate analysis for wood (green timber/logs), weight % (dry basis) [3]
C = 50.1 %
H = 6.4 %
O = 42.3 %
N = 0.1 %
S = 0.1 %
Ash = 1.0 %

Tree assumptions:
The tree density is (green wood + bark mass)/(green wood + bark volume) can vary from species to species, the density of 37 lb/ft^3 was found on reference (2) and a similar value was interpolated from reference (3), also similar values were found on the internet.

Estimated volume of an average tree:
Cylinder volume (tree volume) = circular area x cylinder height
Circular area = (pi x diameter^2)/4 = [3.14 x (11/12)^2]/4 = 0.66 ft^2
Tree volume = 0.66 ft^2 x 33 ft = 21.78 ft^3/tree
Estimated tree mass:
Tree mass = tree density x tree volume
Tree mass = 37 lb/ft^3 x 21.78 ft^3 = 805.86 lb/tree
Tree mass per acre = tree mass x number of trees per acre
Tree mass per acre = (805.86 lb/tree) x (65 trees/acre) = 52,380.9 lb ~ 52,400 lb/acre
Tree volume per acre (just the trees, no voids) = tree volume x number of trees per acre
Tree volume per acre = (21.78 ft^3/tree) x (65 trees/acre) = 1415.7 ft^3/acre = 52.43 yd^3/acre

Direct Landfill Disposal Scenario 1: Disposal in a municipal solid waste facility and allowing natural decay of the vegetative waste in the landfill before thermally reducing it; calculation basis 1 acre of clearing and grubbing. Assuming that the green timber lost approximated 31.694 % of its water content due to drying and decay them the weight of the rotten timber is approximately;

Rotten timber weight = 52,400 x (1 - 0.31964) = 35,792.35 lb
(Water loss due to drying and decaying = 16,607.65 lb)

Moisture content (H_2O) = 26.80 % x 35,792.35 lb = 9,592.35 lb
Volatile Matter (VOCs) = 53.81 % x 35,792.35 lb = 19,259.86 lb
Fixed Carbon (CO, CO_2) = 16.13 % x 35,792.35 lb = 5,773.31 lb
Non-Combustible (ash) = 2.06 % x 35,792.35 lb = 737.32 lb
Sulfur emissions (H_2S, SO_2, SO_3) = 1.2 % x 35,792.35 lb = 429.51 lb
Water balance check = water loss due to drying + water in rotten timber
= 16,607.65 + 9,592.35 = 26,200 lb

Direct Landfill Disposal Scenario 2: Disposal in a municipal solid waste facility and incineration immediately after receiving the vegetative waste; calculation basis 1 acre of clearing and grubbing;

Moisture content (H_2O) = 50.00 % x 52,400 lb = 26,200 lb
Volatile Matter (VOCs) = 42.25 % x 52,400 lb = 22,139 lb
Fixed Carbon (CO, CO_2) = 7.25 % x 52,400 lb = 3,799 lb
Non-Combustible (ash) = 0.4 % x 52,400 lb = 209.6 lb
Sulfur emissions (SO_2, SO_3) = 0.1 % x 52,400 lb = 52.4 lb

Air Curtain Thermal Reduction (conservative scenario): Complete combustion of the vegetative waste in a thermal pit, due to the excess of oxygen available. Calculation basis 1 acre of clearing and grubbing;

Emission calculations using the ultimate analysis:

Moisture content (H_2O) = 50.00 % x 52,400 lb = 26,200 lb
Dry wood = 52,400 – 26,200 = 26,200 lb

C = 50.1 % x 26,200 lb = 13,126.2 lb x (44 lb CO_2/12 lb C) = 48,129.4 lb CO_2
H = 6.4 % x 26,200 lb = 1,676.8 lb x (18 lb H_2O/2 lb H) = 15,091.2 lb H_2O
O = 42.3 % x 26,200 lb = 11,082.6 lb O_2 (consumed in the process)
N = 0.1 % x 26,200 lb = 26.2 lb x (46 lb NO_2/14 lb N) = 86.1 lb NO_2
S = 0.1 % x 26,200 lb = 26.2 lb x (64 lb SO_2/32 lb S) = 52.4 lb SO_2
Ash = 1.0 % x 26,200 lb = 262 lb ash
O_2 + N_2 from air being blown
Note: The generation of NO_2 from air is not likely to occur due to the fact that the thermal pit may never reach the high temperature and pressure necessary for the formation of such contaminants.

Disposal of the ash from thermal reduction in a disposal facility:

Thermal reduction provides a reduction of 99.5% [(1-262/52,400) x 100] by mass, generating only 262 pounds of ash from 52,400 pounds of green timber per acre.

Typical density of ashes = 1,255 lb/yd^3 [(3)]

Volume of ash per acre = (262 lb/acre)/(1,255 lb/yd^3) = 0.209 yd^3/acre
Number of trucks hauling needed per acre = (0.209 yd^3/acre)/(18 yd^3/truck) = 0.0116 truck/acre
Number of truck trips to disposal facility = 200 acres x 0.0116 truck/acre = 2.32 trips ~ 3 trips
Reality, pit maintenance will require removal of ashes at least 3 times per pit during the project, this means; 4 pits times 3 maintenance sections is equal to 12 truck roundtrips.

Emission calculations for air curtain thermal reduction using EPA's air pollutant emission factors:

The PM_{10}, $PM_{2.5}$, NO_2, SO_2, and CO emissions were calculated using EPA's Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources. From section 1.6 Wood Residue Combustion in Boilers.

The general equation for emissions estimation is:

$$E = A \times EF \times (1-ER/100)$$

Where:

E = emissions;
A = activity rate;
EF = emission factor, and
ER = overall emission reduction efficiency, %

Heating values for wet wood is 4,500 Btu/lb

MMBTU = 1,000,000 Btu

Assume an ER of 0%, for the conservative scenario.

$$E = A \times EF$$

Table 1.6-1. EMISSION FACTORS FOR PM FROM WOOD RESIDUE COMBUSTION[a]

Fuel	PM Control Device	Filterable PM		Filterable PM-10[b]		Filterable PM-2.5[b]	
		Emission Factor (lb/MMbtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMbtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMbtu)	EMISSION FACTOR RATING
Bark/Bark and Wet Wood	No Control[c]	0.56[d]	C	0.50[e]	D	0.43[e]	D
Dry Wood	No Control[c]	0.40[f]	A	0.36[e]	D	0.31[e]	D
Wet Wood	No Control[c]	0.33[g]	A	0.29[e]	D	0.25[e]	D
Bark	Mechanical Collector	0.54[h]	D	0.49[e]	D	0.29[e]	D
Bark and Wet Wood	Mechanical Collector	0.35[i]	C	0.32[e]	D	0.19[e]	D
Dry Wood	Mechanical Collector	0.30[j]	A	0.27[e]	D	0.16[e]	D
Wet Wood	Mechanical Collector	0.22[k]	A	0.20[e]	D	0.12[e]	D
All Fuels[m]	Electrolyzed Gravel Bed	0.1[m]	D	0.074[e]	D	0.065[e]	D
All Fuels[m]	Wet Scrubber	0.066[n]	A	0.065[e]	D	0.065[e]	D
All Fuels[m]	Fabric Filter	0.1[o]	C	0.074[e]	D	0.065[e]	
All Fuels[m]	Electrostatic Precipitator	0.054[p]	B	0.04[e]	D	0.035[e]	
		Condensible PM					
All Fuels[m]	All Controls/No Controls	0.017[q]	A				

Table 1.6-2. EMISSION FACTORS FOR NO_x, SO_2, AND CO FROM WOOD RESIDUE COMBUSTION[a]

Source Category[c]	NO_X[b]		SO_2[b]		CO[b]	
	Emission Factor (lb/MMbtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMBtu)	EMISSION FACTOR RATING	Emission Factor (lb/MMbtu)	EMISSION FACTOR RATING
Bark/bark and wet wood/wet wood-fired boiler	0.22[d]	A	0.025[e]	A	0.60[g,i,j]	A
Dry wood-fired boilers	0.49[h]	C	0.025[e]	A	0.60[g,i,j]	A

PM_{10} = 52,400 lb x 0.50 lb/MMBtu x 4,500 Btu/lb x MMBtu/10^6 Btu = 117.9 lb PM_{10}
{$PM_{2.5}$ = 52,400 lb x 0.43 lb/MMBtu x 4,500 Btu/lb x MMBtu/10^6 Btu = 101.4 lb $PM_{2.5}$**}**
NO_2 = 52,400 lb x 0.22 lb/MMBtu x 4,500 Btu/lb x MMBtu/10^6 Btu = 51.9 lb NO_2
SO_2 = 52,400 lb x 0.025 lb/MMBtu x 4,500 Btu/lb x MMBtu/10^6 Btu = 5.9 lb SO_2
CO = 52,400 lb x 0.60 lb/MMBtu x 4,500 Btu/lb x MMBtu/10^6 Btu = 141.5 lb CO

Combine the highest of the emission of each calculation for the conservative scenario per acre:

CO_2 = 48,129.4 lb CO_2
CO = 141.5 lb CO
O_2 = 11,082.6 lb (consumed)
H_2O = 26,200 + 15,091.2 = 41,291.2 lb H_2O
NO_2 = 86.1 lb NO_2
SO_2 = 52.4 lb SO_2
PM_{10} = 117.9 lb PM_{10}
{$PM_{2.5}$ = 101.4 lb $PM_{2.5}$}
Ash = 262 lb ash
O_2 + N_2 from air being blown

The typical air blower comes in a 20 ft and a 40 ft air manifold configuration, and they are powered by diesel engines. Due to the topography it is very likely that the contractor will use the traditional 20 ft air manifold unit powered by 56 hp diesel engine. This unit is capable of processing 1 to 4 tons (2.5 tons average) of vegetative waste per hour.

The diesel engine emissions were calculated using EPA's Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources.
From section 3.3 Gasoline and Diesel Industrial Engines.

The general equation for emissions estimation is:

$$E = A \times EF \times (1-ER/100)$$

Where:

E = emissions;
A = activity rate;
EF = emission factor, and
ER =overall emission reduction efficiency, %

Tree mass per acre = (805.86 lb/tree) x (65 trees/acre) = 52,380.9 lb ~ 26 tons/acre

A working day is typically between 8 to 12 hours. The average rate of vegetative waste that can be processes in one thermal reduction pit is (26 tons/acre) / (2.5 tons/hr) = 10.4 hrs/acre.

Assuming it will take one 10-hour day of thermal reduction per acre of clearing and grubbing, the estimated length of thermal reduction for 200 acres of clearing and grubbing, with be approximately 200 days.

Table 3.3-1. EMISSION FACTORS FOR UNCONTROLLED GASOLINE AND DIESEL INDUSTRIAL ENGINES[a]

Pollutant	Gasoline Fuel (SCC 2-02-003-01, 2-03-003-01)		Diesel Fuel (SCC 2-02-001-02, 2-03-001-01)		EMISSION FACTOR RATING
	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	Emission Factor (lb/hp-hr) (power output)	Emission Factor (lb/MMBtu) (fuel input)	
NO_x	0.011	1.63	0.031	4.41	D
CO	0.439	62.7	6.68 E-03	0.95	D
SO_x	5.91 E-04	0.084	2.05 E-03	0.29	D
PM-10[b]	7.21 E-04	0.10	2.20 E-03	0.31	D
CO_2[c]	1.08	154	1.15	164	B
Aldehydes	4.85 E-04	0.07	4.63 E-04	0.07	D
TOC					
Exhaust	0.015	2.10	2.47 E-03	0.35	D
Evaporative	6.61 E-04	0.09	0.00	0.00	E
Crankcase	4.85 E-03	0.69	4.41 E-05	0.01	E
Refueling	1.08 E-03	0.15	0.00	0.00	E

Assume an ER of 50%, we found most new diesel engines are in the range of 50% to 58%.

NO_2 = 56 hp x 0.031 lb/hp-hr x 0.5 x 10 hr = 8.68 lb NO_2
CO = 56 hp x 0.00668 lb/hp-hr x 0.5 x 10 hr = 1.87 lb CO
SO_2 = 56 hp x 0.00205 lb/hp-hr x 0.5 x 10 hr = 0.574 lb SO_2
PM_{10} = 56 hp x 0.00220 lb/hp-hr x 0.5 x 10 hr = 0.616 lb PM_{10}
CO_2 = 56 hp x 1.15 lb/hp-hr x 0.5 x 10 hr = 322 lb CO_2
VOCs (TOC) = 56 hp x 0.0025141 lb/hp-hr x 0.5 x 10 hr = 0.704 lb VOCs

Total mass emissions from the blower are 334.444 lb/10hr

Total combined mass emissions from thermal reduction per acre of clearing and grubbing are:

CO_2 = 48,129.4 + 322 = 48,451.4 lb CO_2
CO = 141.5 + 1.87 = 143.37 lb CO
NO_2 = 86.1 + 8.68 = 94.78 lb NO_2
Ash = 262 lb Ash
VOCs = 0.704 lb VOCs
H_2O = 41,291.2 lb H_2O
SO_2 = 52.4 + 0.574 = 52.974 lb SO_2
PM_{10} = 117.9 + 0.616 = 118.516 lb PM_{10}
{$PM_{2.5}$ = 101.4 lb $PM_{2.5}$}
O_2 + N_2 from air being blown

A typical 20 feet manifold air curtain setup, blows air at a minimum of 17,000 cubic feet per minute, and operates at low end temperature of around 1,500 ^oF.

Example of maximum concentration (Cmax) calculation:

Volume of the blower 17,000 ft^3/min, at ambient temperature of 77 ^oF, is equal to 8.03 m^3/s

Minimum volume coming out the thermal pit is 8.03 m^3/s x (1,500+460)/(77+460) = 29.31 m^3/s, due to thermal expansion.

Mass of SO_2 is 52.974 lb/10hr that is equal to 0.668 g/s

$Cmax_{SO2}$ = (0.668 g/s)/(29.31 m^3/s) = 0.0227 g/m^3

Example of emission calculation:

The individual emission volumes were calculated by:

$$V = W \times R \times T / (MW * P)$$

Were:

V = volume in ft^3
W = mass of gas in lb
MW = molecular weight in lb/lbmol
P = atmospheric pressure (atm) (1 atm)
T = absolute temperature in Rankine (^oR) (1,500 ^oF + 460 = 1,960 ^oR)

$$R = 0.7302 \frac{atm\ ft^3}{lbmol\ \ ^oR}$$

Total volume is the sum of all volumes; $V_{total} = V_{O2} + V_{N2} + V_{H2O} + \ldots\ldots$

The emission concentration is the mass of the emission divided by the total volume:

$$C_{SO2} = (\text{mass } SO_2)/(V_{total}) = (52.974 \text{ lb/10hr})/(40{,}414{,}369.92 \text{ ft}^3\text{/10hr}) = 1.31 \times 10^{-6} \text{ lb/ft}^3$$
$$= 1.31 \times 10^{-6} \text{ lb/ft}^3 \times (35.29 \text{ ft}^3/\text{m}^3) \times (454 \text{ g/lb}) = 0.021 \text{ g/m}^3$$

Background pollutant contribution calculations:

PM_{10} = (108 ug/m^3) x (m^3/35.29ft^3) x (17,000ft^3/min) x (60min/hr) x (g/10^6ug) x (lb/454g) =
= 0.0068757 lb/hr = 0.068757 lb/10hr

PM_{10} total input = $117.90_{trees} + 0.616_{blowers} + 0.068757_{background}$ = 118.584757 lb/10hr

Estimated maximum background contribution to combustion gases is:
(108 ug/m^3) x (77+460)/(1,500+460) = 29.5898 ug/m^3

Contribution check:

PM_{10} w/background – PM_{10} w/o background = 47,011.116597 – 46,983.858965 = 27.25763 ug/m^3

or

(0.068757 lb/10hr) / (40,414,369.92 ft^3/10hr) = 1.701299×10^{-9} lb/ft^3 = 27.25763 ug/m^3

14.1 Calculation Comparison Between EPA's Emissions Factors and USDA Forest Service Emission Data

Emission estimates data from the United States Department of Agriculture (USDA), Forest Service technical paper "THE USE OF AIR CURTAIN DESTRUCTORS FOR FUEL REDUCTION AND DISPOSAL" by Susan M. Zahn—Fuels Management Specialist.

Forest Service jargon: Fuel is dead vegetation classified as dry grasses, brush, timber, and slash that have the potential to combust. In this paper they evaluated the use of air curtain destructors to destroy dry timber made of a combination of Jeffery Pine and Douglas Fir and compared with broadcast and pile burning (results are in Table 1).

Table 1— Average emission factors for different management tools (pounds per ton).

	CO_2	CO	CH_4	NMHC	$PM_{2.5}$	CE (%)
Broadcast burning—Ponderosa Pine	3,286	179.8	6.6	5.4	36.0	90
Pile burning—Ponderosa Pine	3,268	178.5	13.9	9.9	25.5	89
LLC Air Curtain	3,616	26.3	1.4	1.1	1.1	99
McPherson Air Curtain	3,613	30	1.1	0.6	1.4	99

Explanation of emission factors
CO_2 = carbon dioxide
CO = carbon monoxide
CH_4 = methane based gases, such as propane and butane.
NMHC = nonmethane gases, such as benzene.
CE = combustion efficiency.
$PM_{2.5}$ = particulate matter expressed in pounds per ton. U.S. Environmental Protection Agency regulates particulate matter 2.5 and below.

Table 2— Average emission factors for the air curtain technologies (pounds per ton).

Air Curtain technologies (lb/ton)	CO_2	CO	CH_4	NMHC	$PM_{2.5}$	CE (%)
LLC Air Curtain	3,616	26.3	1.4	1.1	1.1	99
McPherson Air Curtain	3,613	30	1.1	0.6	1.4	99
Average Air Curtain performance	3,615	28.2	1.3	0.9	1.3	99

Emission comparison for an acre of the Portugues dam:
Base: one acre/10 hr
Weight: 26.2 ton of green timber/acre

Adjustment: Green timber contains as much as 50% water by weight, which means each ton of green timber can only produce ½ ton of dry timber. Therefore, 50% of the green timber mass load becomes dry wood in the thermal reduction, creating only 50% of emission of a similar mass load of dry wood. A correction of 0.5 is required in the calculations of green timber to correct for the excess moisture present in the green timber, excess moisture that is not present in dry wood. Correction of 0.5 has to be used in order to compare the data.

VOCs = 1.3 + 0.9 = 2.2 lb/ton

CO_2 = 3,615 lb/ton x (0.5) x 26.2 ton/acre = 47,356.5 lb CO_2/acre

CO = 28.2 lb/ton x (0.5) x 26.2 ton/acre = 369.42 lb CO/acre

$PM_{2.5}$ = 1.3 lb/ton x (0.5) x 26.2 ton/acre = 17.03 lb $PM_{2.5}$/acre

VOCs = 2.2 lb/ton x (0.5) x 26.2 ton/acre = 28.82 lb VOCs/acre

First the CO2 emission comparison:

EPA's AP-42 factors: Conservative scenario estimated CO_2 emission was 48,129.4 lb CO_2/acre
USDA Forest Service factors estimated CO_2 emission is 47,356.5 lb CO_2/acre

We can see the amount of CO_2 emitted is about the same, which validates the need for a correction for the moisture differences between green timber and dry wood.

Second the CO emission comparison:

EPA's AP-42 factors: Conservative scenario estimated CO emission was 141.5 lb CO/acre
USDA Forest Service factors estimated CO emission is 369.42 lb CO/acre

The USDA estimate indicates that we can expect about 2 ½ times more CO emission per acre than the emissions calculated by EPA emission factors.

Third the $PM_{2.5}$ emission comparison:

EPA's AP-42 factors: Conservative scenario estimated $PM_{2.5}$ emission was 101.4 lb $PM_{2.5}$/acre
USDA Forest Service factors estimated $PM_{2.5}$ emission is 17.03 lb $PM_{2.5}$/acre

The USDA estimate indicates that we can expect about **83%** ((1-17/101) x 100%)) **reduction of the $PM_{2.5}$ emission per acre** than the emissions calculated by EPA emission factors.

Emission Estimate worksheet for the Thermal Reduction in the Portugues Dan

Tree mass (lb/10hr)	52,400.00	(52,400 typ)	
Water mass (lb/10hr)	26,200.00		
Dry wood mass (lb/10hr)	26,200.00		
CO2 (lb/10hr)	48,129.40		
CO (lb/10hr)	141.50		
H2O (lb/10hr)	15,091.20		
O2 (lb/10hr)	11,082.60		
NO2 (lb/10hr)	86.10		
SO2 (lb/10hr)	52.40		
PM10 (lb/10hr)	117.90		
Ash (lb/10hr)	262.00		
Total Combustion Mass (lb/10hr)	74,963.10		
Minus Oxygen Consumed (lb/10hr)	11,082.60		
Minus Solids (lb/10hr)	26,200.00		
Additional Oxygen Required (lb/10hr)	37,680.50		
		MW	mass
Air Composition	Fraction	(lb/lbmol)	(lb/lbmol)
Oxygen	0.21	32.00	6.72
Nitrogen	0.79	28.00	22.12
Air Molecular Weight (MW) (lb/lbmol)			28.84
Additional Air Required (lb/10hr)	161,712.15		
Air Forced by Blower (ft3/min)	17,000	(17,000 typ)	
(m3/s)	8.03		
Temperature (F)	1,500	(1,500 typ)	
Air Forced by Blower (ft3/10hr) @ 77 F	10,200,000.00		
Air Forced (lb/10hr)	750,203.89		
Nitrogen Forced (lb/10hr)	575,399.10		
Oxygen Forced (lb/10hr)	174,804.79		
Oxygen Balance (lb/10hr)	174,804.79		
Oxygen Needed (lb/10hr)	37,680.50		
Excess of oxygen in combustion (lb/10hr)	137,124.29		

Emission Estimate worksheet for the Thermal Reduction in the Portugues Dam

Pit Operational Parameters									
Air Forced by Blower (ft3/min)	17,000								
(m3/s)	8.03								
Temperature (F)	1,500								
Thermal Reduction of trees only	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
O2	137,124.29	1,729.29	59.01	32	6,132,849.62	0.00	54.38	54,375.48	54,375,479.80
N2	575,399.10	7,256.42	247.63	28	29,410,949.72	0.01	228.17	228,169.66	228,169,656.38
H2O	41,291.20	520.73	17.77	18	3,283,090.84	0.00	16.37	16,373.68	16,373,676.77
CO2	48,129.40	606.97	20.71	44	1,565,509.37	0.00	19.09	19,085.31	19,085,307.25
CO	141.50	1.78	0.06	28	7,232.63	0.00	0.06	56.11	56,110.63
NO2	86.10	1.09	0.04	46	2,678.82	0.00	0.03	34.14	34,142.23
SO2	52.40	0.660822	0.022551	64	1,171.788450	0.000001	0.020779	20.778778	20,778.777624
PM10	117.90	1.486850	0.050739	0	0.000000	0.000003	0.046752	46.752250	46,752.249655
ASH	262.00	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.000000	0.000000
Total emission mass (lb/10hr)	802,603.89			Total volume	40,403,482.78				
Mass Balance Check									
Tree mass input (lb/10hr)	52,400.00								
Air mass input (lb/10hr)	750,203.89								
Total mass input (lb/10hr)	802,603.89								
Thermal Reduction of trees plus blower emissions	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
O2	137,124.29	1,729.29	59.01	32	6,132,849.62	0.00	54.36	54,360.83	54,360,831.71
N2	575,399.10	7,256.42	247.63	28	29,410,949.72	0.01	228.11	228,108.19	228,108,190.26
H2O	41,291.20	520.73	17.77	18	3,283,090.84	0.00	16.37	16,369.27	16,369,265.90
CO2	48,451.40	611.03	20.85	44	1,575,983.09	0.00	19.21	19,207.82	19,207,817.88
CO	143.370000	**1.808055**	0.061700	28	7,328.214180	**0.000004**	**0.056837**	**56.836848**	**56,836.847850**
SO2	52.974000	**0.668061**	0.022798	64	1,184.624453	**0.000001**	**0.021001**	**21.000734**	**21,000.733613**
NO2	94.780000	**1.195281**	0.040789	46	2,948.877777	**0.000002**	**0.037574**	**37.574084**	**37,574.084113**
VOC	0.704000	**0.008878**	0.000303	29	34.936171	**0.000000**	**0.000279**	**0.279090**	**279.090053**
PM10	118.516000	**1.494618**	0.051004	0	0.000000	**0.000003**	**0.046984**	**46.983859**	**46,983.858965**
ASH	262.000000	0.000000	0.000000	0	0.000000	0.000000	0.000000	0.000000	0.000000
Total emission mass (lb/10hr)	802,938.34		Total combustion volume (ft3/10hr)		40,414,369.92				
Mass Balance Check									
Total emissions from trees (lb/10hr)	802,603.89								
Total emissions from blower (lb/10hr)	334.44								
Total combined emissions (lb/10hr)	802,938.34								

Emission Estimate worksheet for the Thermal Reduction in the Portugues Dam

Pit Operational Parameters									
Air Forced by Blower (ft3/min)	17,000								
(m3/s)	8.03								
Temperature (F)	1,500								
Total combustion volume (ft3/10hr)	40,414,369.92								
PM2.5 sub-set of PM10 for the trees only	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
PM2.5	101.394000	**1.278691**	0.043635284	0	0.000000	**0.000003**	**0.040196**	**40.196103**	**40,196.103445**
Background PM contribution	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
PM10 (108 ug/m3)	0.068757	0.000867	0.000029590	0	0.000000	**0.000000**	**0.000027**	**0.027258**	**27.257631**
PM2.5 (16 ug/m3)	0.010186	0.000128	0.000004384	0	0.000000	**0.000000**	**0.000004**	**0.004038**	**4.038168**
PM for the site including background	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
PM10 (background = 108 ug/m3)	118.584757	**1.495486**	0.051033390	0	0.000000	**0.000003**	**0.047011**	**47.011117**	**47,011.116597**
PM2.5 (background = 16 ug/m3)	101.404186	**1.278819**	0.043639668	0	0.000000	**0.000003**	**0.040200**	**40.200142**	**40,200.141613**
Forest Service approximation	mass rate	mass rate	Cmax	MW	Volume	C	C	C	C
Gas emitted	(lb/10hr)	(g/s)	(g/m3)	(lb/lbmol)	(ft3/10 hr)	(lb/ft3)	(g/m3)	(mg/m3)	(ug/m3)
CO*	371.290000	**4.682379**	0.159786030	0	0.000000	**0.000009**	**0.147192**	**147.192252**	**147,192.252482**
PM2.5*	17.040186	**0.214896**	0.007333307	0	0.000000	**0.000000**	**0.006755**	**6.755322**	**6,755.321692**

*Note: includes a contribution of 1.87 lb/10hr of CO from the blower engine
*Note: includes a contribution of 0.010186 lb/10hr PM2.5 from the background

Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

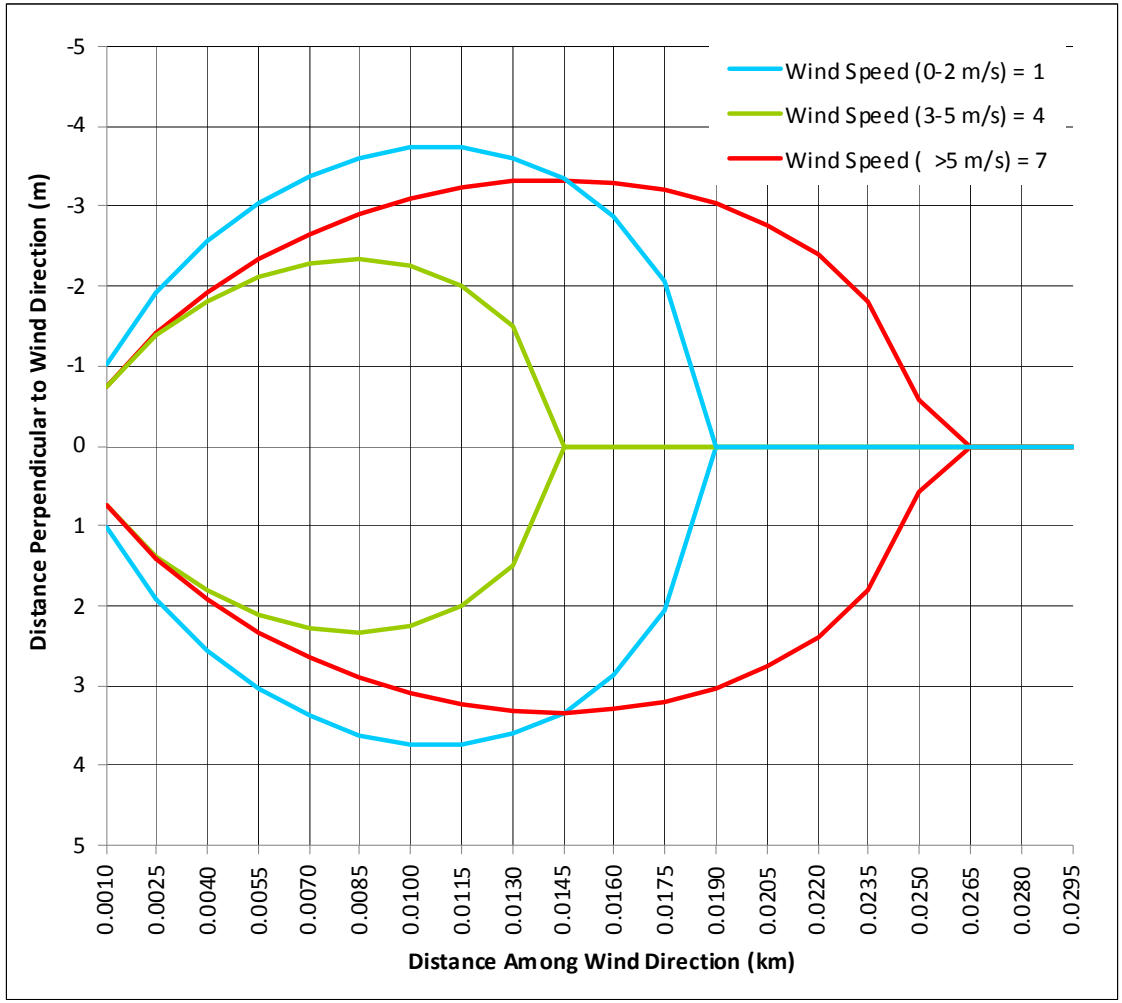
X <= 1 km

Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	1.81	CO
C (g/m3) =	0.010000	CO NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.0015	

Xmin (km)= 0.001

Xmax (km)= 0.0295

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
1.808055	CO	0.010000	**10**	10,000
0.668061	SO2	0.000080	0.080	**80**
1.195281	NO2	0.000100	0.100	**100**
1.495486	PM10	0.000150	0.150	**150**
1.278819	PM2.5	0.000015	0.015	**15**



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

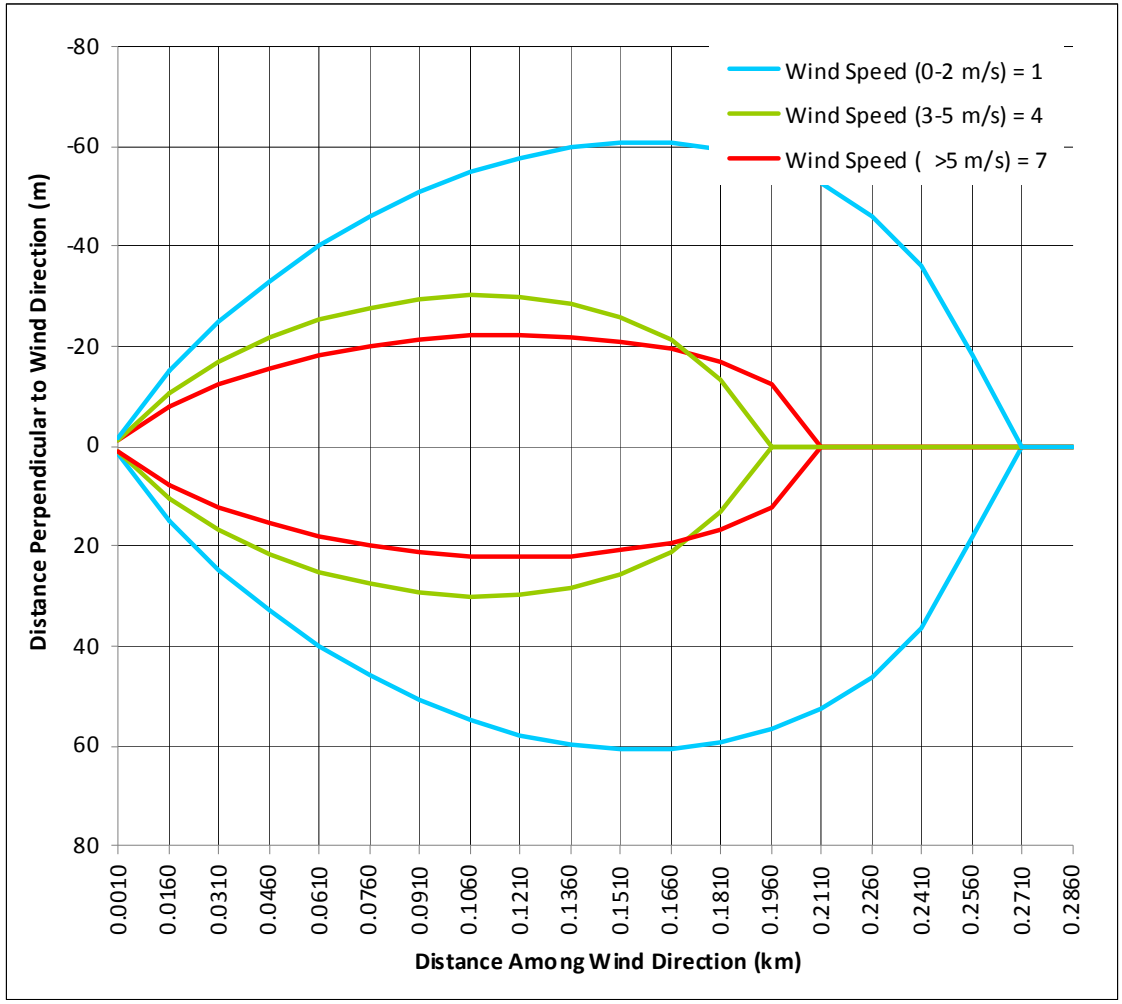
X <= 1 km

Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	0.67	SO2
C (g/m3) =	0.000080	SO2 NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.015	

Xmin (km)= 0.001

Xmax (km)= 0.286

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
1.808055	CO	0.010000	**10**	10,000
0.668061	SO2	0.000080	0.080	**80**
1.195281	NO2	0.000100	0.100	**100**
1.495486	PM10	0.000150	0.150	**150**
1.278819	PM2.5	0.000015	0.015	**15**



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

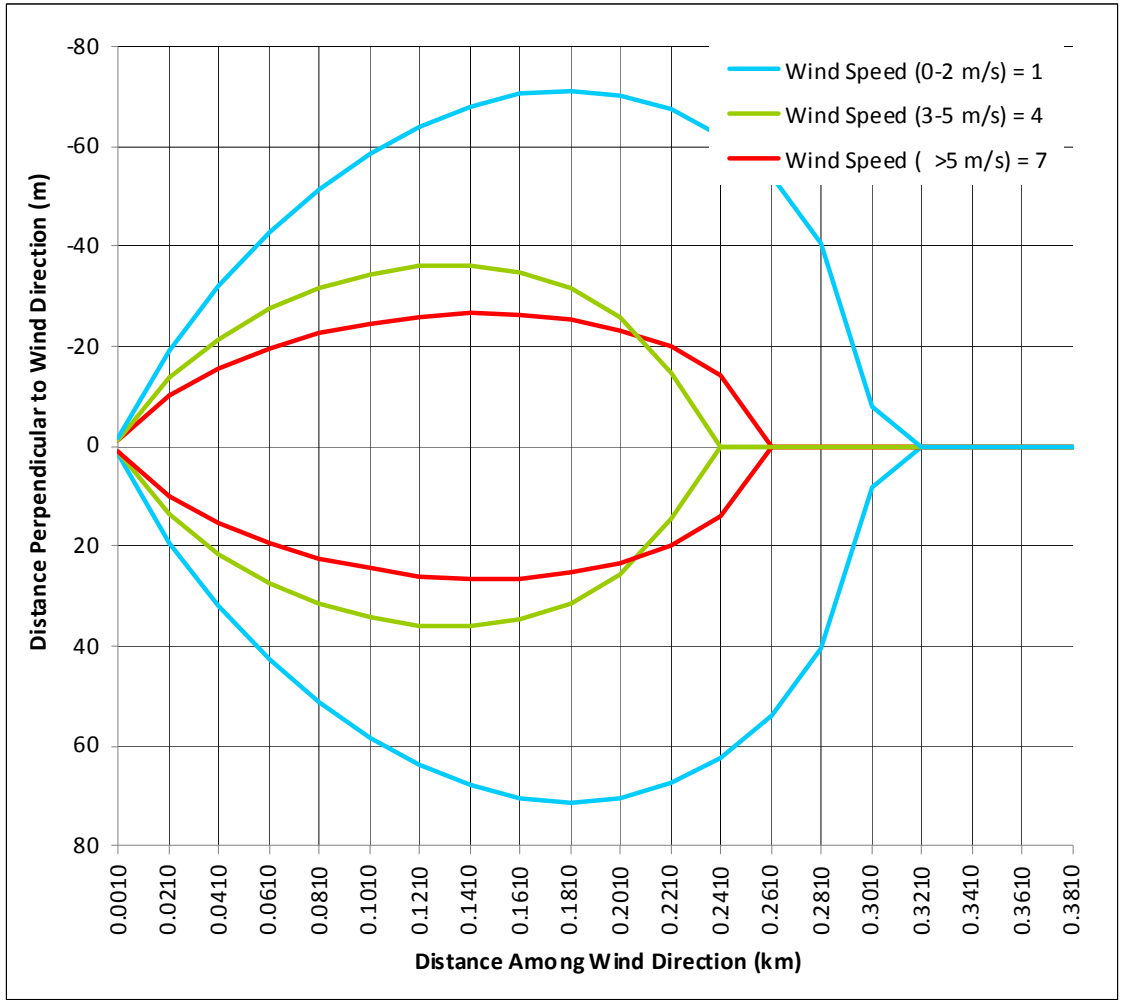
X <= 1 km

Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	1.2	NO2
C (g/m3) =	0.000100	NO2 NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.02	

Xmin (km)= 0.001

Xmax (km)= 0.381

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
1.808055	CO	0.010000	**10**	10,000
0.668061	SO2	0.000080	0.080	**80**
1.195281	NO2	0.000100	0.100	**100**
1.495486	PM10	0.000150	0.150	**150**
1.278819	PM2.5	0.000015	0.015	**15**



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

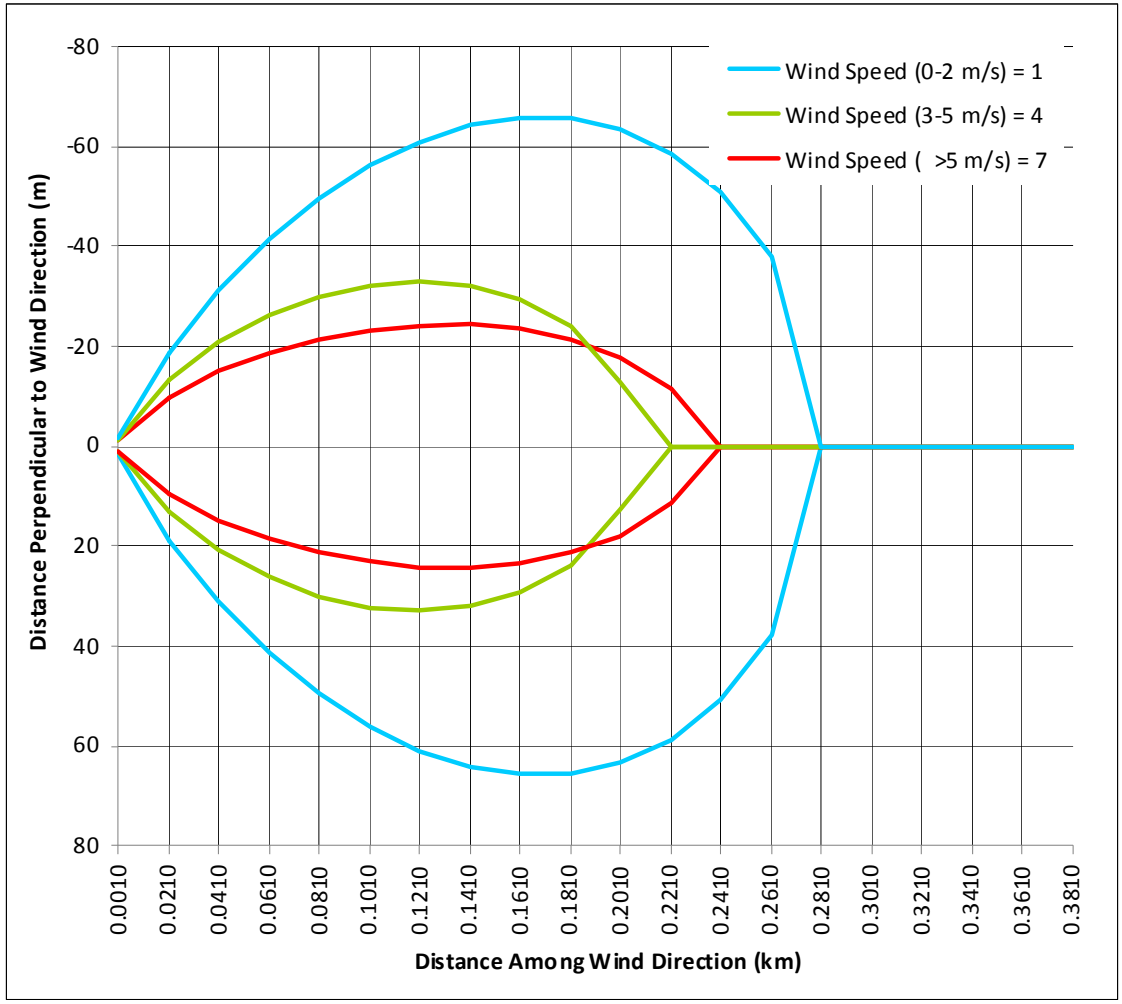
X <= 1 km

Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	1.5	PM10
C (g/m3) =	0.000150	PM10 NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.02	

Xmin (km)= 0.001

Xmax (km)= 0.381

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
1.808055	CO	0.010000	**10**	10,000
0.668061	SO2	0.000080	0.080	**80**
1.195281	NO2	0.000100	0.100	**100**
1.495486	PM10	0.000150	0.150	**150**
1.278819	PM2.5	0.000015	0.015	**15**



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

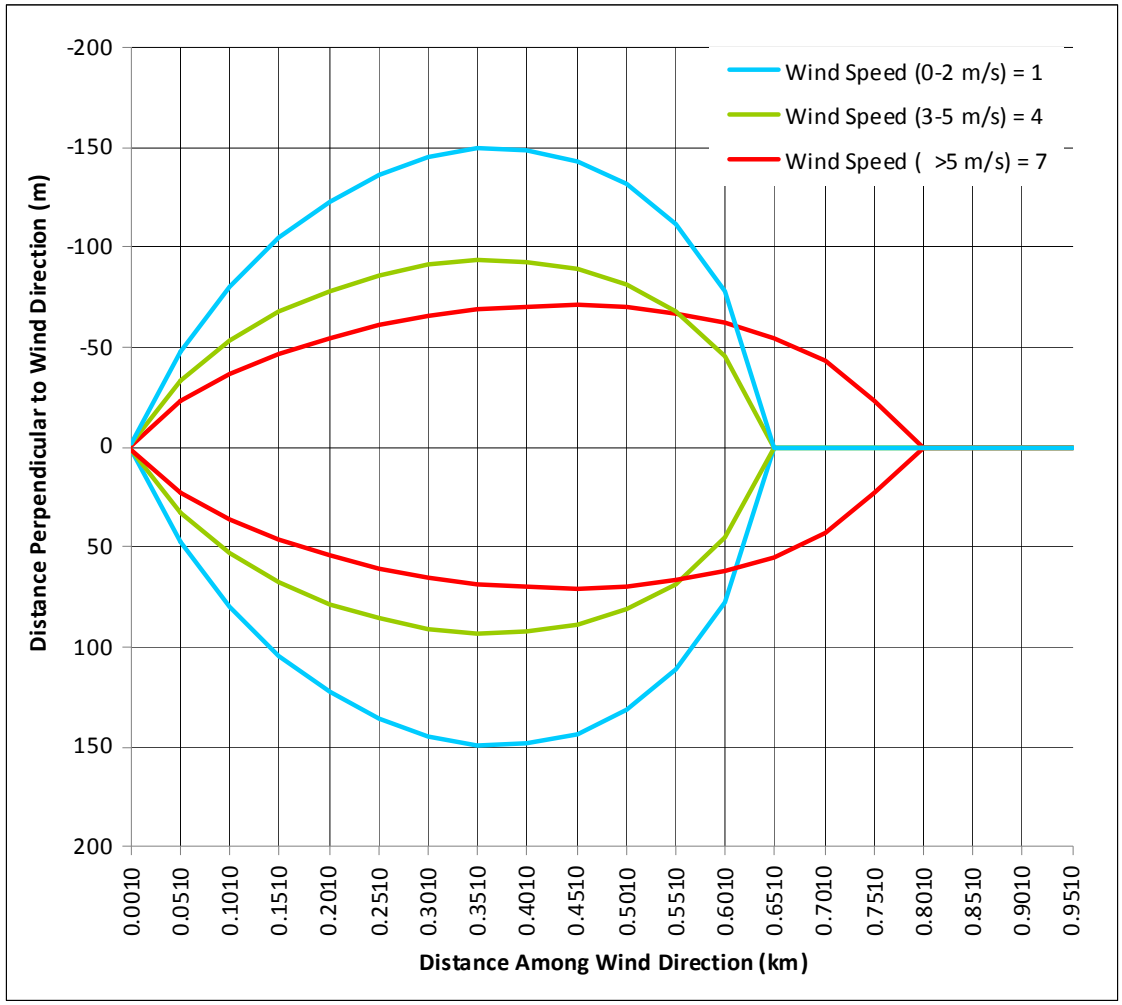
X <= 1 km

Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	1.3	PM2.5
C (g/m3) =	0.000015	PM2.5 NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.05	

Xmin (km)= 0.001

Xmax (km)= 0.951

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
1.808055	CO	0.010000	**10**	10,000
0.668061	SO2	0.000080	0.080	**80**
1.195281	NO2	0.000100	0.100	**100**
1.495486	PM10	0.000150	0.150	**150**
1.278819	PM2.5	0.000015	0.015	**15**



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

X <= 1 km

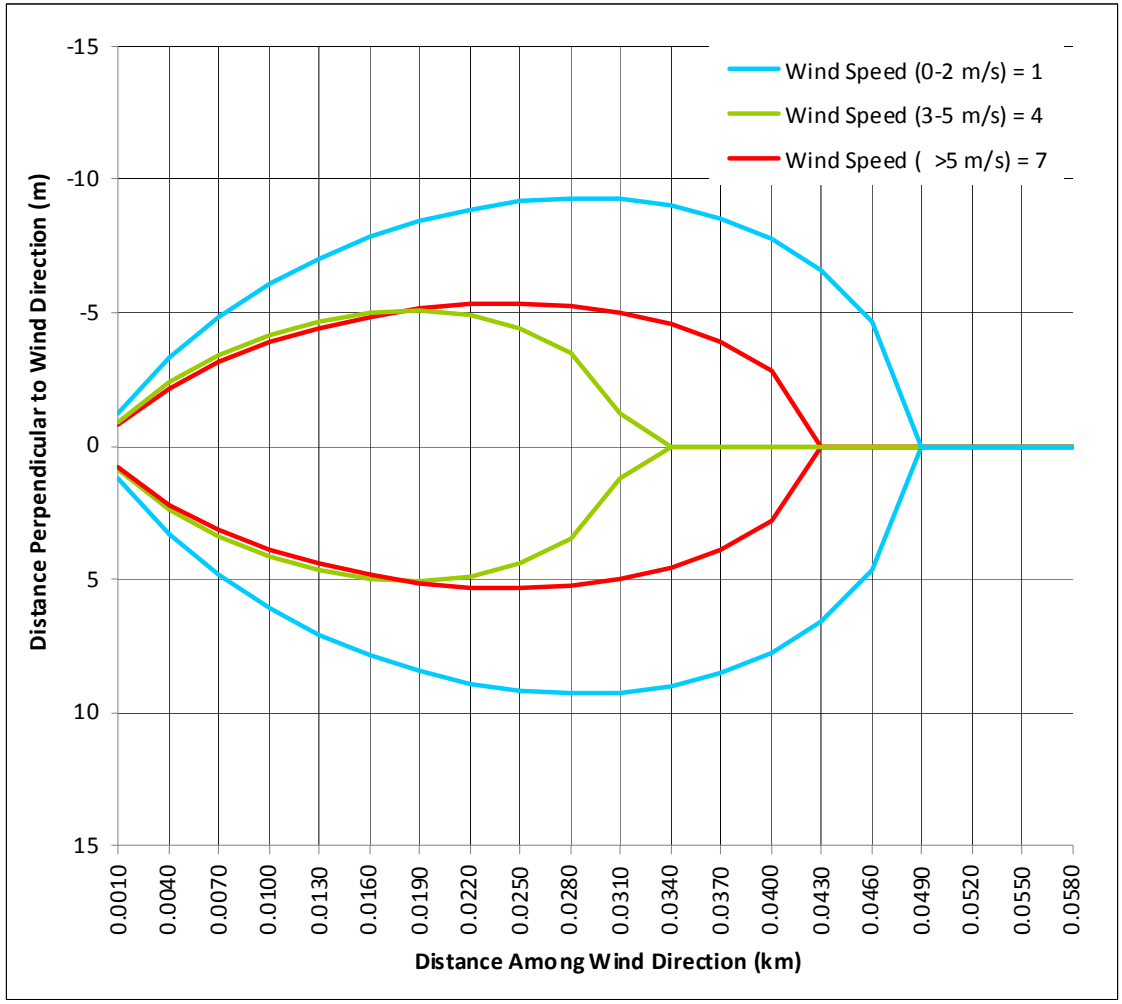
Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	4.700000	CO
C (g/m3) =	0.010000	CO NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.003	

Xmin (km)= 0.001

Xmax (km)= 0.058

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
4.682379	CO	0.010000	**10**	10,000
N/A	SO2	0.000080	0.080	**80**
N/A	NO2	0.000100	0.100	**100**
N/A	PM10	0.000150	0.150	**150**
0.214896	PM2.5	0.000015	0.015	**15**

Using Forest Service data comparison



Gaussian plume, two-dimension spreading model

Model category: Day with strong incoming solar radiation

Outputs: Generates dispersion profiles in the horizontal plane over land (double the concentration of a stack emission)

Restrictions:

X <= 1 km

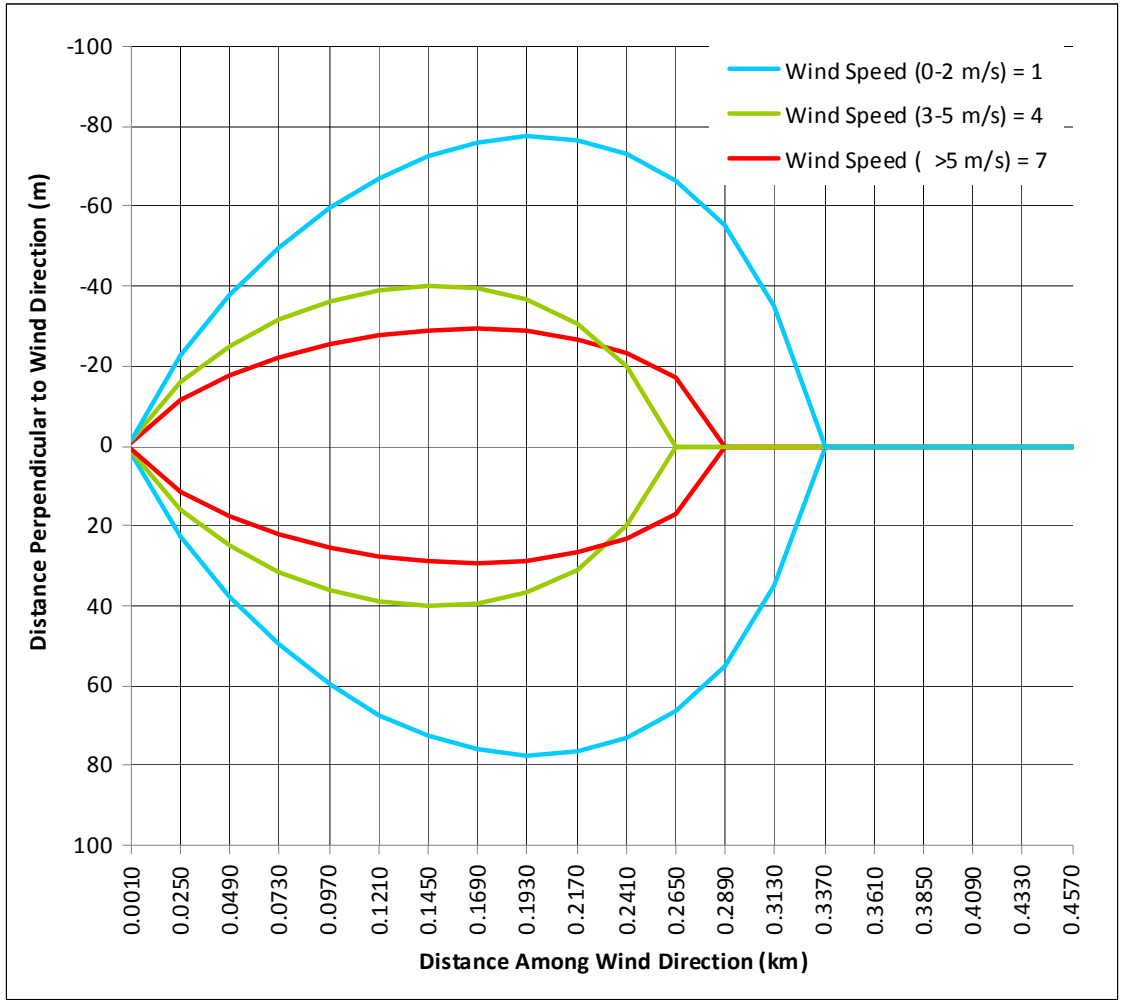
Wind Speed (0-2 m/s) =	1	
Wind Speed (3-5 m/s) =	4	
Wind Speed (>5 m/s) =	7	
Q (g/s) =	0.220000	PM2.5
C (g/m3) =	0.000015	PM2.5 NAAQS
Xmin (km) =	0.001	
Xincrement (km) =	0.024	

Xmin (km)= 0.001

Xmax (km)= 0.457

mass rate (g/s)	Gas emitted	NAAQS (g/m3)	NAAQS (mg/m3)	NAAQS (ug/m3)
4.682379	CO	0.010000	**10**	10,000
N/A	SO2	0.000080	0.080	**80**
N/A	NO2	0.000100	0.100	**100**
N/A	PM10	0.000150	0.150	**150**
0.214896	PM2.5	0.000015	0.015	**15**

Using Forest Service data comparison



15.0 Request to Complete Project

The construction of the Portugues Dam Flood Control Project is the last phase of the Portugues and Bucana Rivers canalization and flood control project authorized by Congress in 1970. The project consisted primary of three major features. First the construction of the Cerrillos dam, northeast of the city of Ponce, completed 1992. Second the canalization of the Bucana River, southeast of the city of Ponce, completed 1997. The last feature is the construction of the Portugues dam. Due to the extended period of planning and time needed for the allocation of funds, new Puerto Rico environmental laws have emerged that can affect the completion of this project. The US Army Corps of Engineers is requesting a waiver to the thermal reduction activities during clearing and grubbing operations in the construction of the Portugues Dam project, Ponce, Puerto Rico. The US Army Corps of Engineers for this project have completed the NEPA process, Water Quality Certification, and currently is complying with cultural resources recovery investigations.

16.0 Disclosure

The "Thermal Reduction Plan for the Clearing and Grubbing of the Portugues Dam Construction" prepared by the undersigned as Environmental Engineer of the U.S. Army Corps of Engineers (Corps), Jacksonville District, in Jacksonville, Florida.

The plan presents a very conservative scenario for the thermal reduction of trees in the footprint of the Portugues Dam Construction based on the site conditions and the following assumptions:

1) Complete combustion of vegetative material in a thermal pit, due to excess oxygen from air being blown into the thermal pit
2) No generation of NO_2 from air due to the fact that the thermal pit may never reach the high temperature and pressure necessary for the formation of such contaminants
3) All nitrogen and sulfur potentially found in the vegetative material could produce NO_2, and SO_2 in the combustion process
4) The emissions were calculated using the proximate analysis, the ultimate analysis, and air pollutants emission factors.

The diffusion modeling of the thermal reduction emissions was conducted using Gaussian plume diffusion model, adapted to the Portugues Dam site conditions. The Gaussian plume diffusion model is the heart of many air pollution models. The equations and coefficients for the model were obtained from the book, "*Air Pollution Control Engineering*," by Noel De Nevers. The equations and coefficients were programmed in Microsoft Excel and plotted at different wind speeds.

The estimates and calculations to address this issue were prepared with criteria acceptable to academia and government standards by Mr. Javier Cortes who is a Registered Environmental Manager (REM 11809) and a Certified Hazardous Material Manager (CHMM 12756). The calculations were reviewed and approved by Mr. Ivan Acosta who is also a Registered Environmental Manager (REM 11297), Registered Hazardous and Chemical Materials Manager (RHCMM 3153), and Mr. Cortes' Supervisor. The plan and modeling were revised by the Environmental Quality Board's professionals and accepted for the purposes of the thermal reduction waiver.

Prepared By:

Signed: _____ Date: 09/25/09
Javier Cortes, REM 11809, CHMM 12756
US Army Corps of Engineers

Reviewed and Approved By:

Signed: _____ Date: 9/25/09
Ivan Acosta, REM 11297, RHCMM 3153
Chief, Special Projects Section
US Army Corps of Engineers

This document revision has 44 pages and supersedes any previous revisions. The document submitted and the technical information therein was prepared by the Corps, Jacksonville District. The initials or signatures and registration designations of individuals that appear on these project documents are within the scope of their employment as required by ER 1110-1-8152.

17.0 Document History

Original document finalized: 11/07/2007
First revision: 12/19/07, added emissions from blowers to the calculations
Second revision: 07/03/08, converted total emissions from pounds to tons in page 7
Third revision: 10/07/08, added footnote of who prepared the calculations, added in pages 8 & 9 Disclosure with signature block, and References used
Fourth revision: 03/06/09, added emissions of PM, SO_2, NO_2 from the thermal reduction of the trees, calculated gas concentrations, included background pollutant contribution calculations, included outputs of the programming in Microsoft Excel, removed text of $COCL_2$, SOx, NOx, H_2S, VOC's.
Fifth revision: 09/11/09, updated figures, incorporated EQB and EPA's comments
Final revision: 09/25/09, incorporated other alternatives.

09/25/09

18.0 References

(1) Information from Cerrillos Dam construction by the U.S. Army of Engineers, Jacksonville District, 1990.

(2) Standard Handbook of Environmental Engineering by Robert A. Corbitt, 1990 by McGraw-Hill, Inc, pages 8.28 & 8.29.

(3) Integrated Solid Waste Management, Engineering Principles and Management Issues by George Tchobanoglous, Hilary Theisen, and Samuel Vigil, 1993 by McGraw-Hill, Inc, pages 70 – 80.

(4) Air Pollution Control Engineering by Noel De Nevers, 1995 by McGraw-Hill, Inc, pages 105-140.

(5) Environmental Protection Agency's Compilation of Air Pollutant Emission Factors: AP-42, Fifth Edition, Volume I: Stationary Point and Area Source.
http://www.epa.gov/ttn/chief/ap42/index.html Accessed: 12/2007

(6) United States Environmental Protection Agency. (USEPA) Climate Change, Methane, Science.
http://www.epa.gov/methane/scientific.html Accessed: 12/2008

(7) The Use of Air Curtain Destructors for Fuel Reduction and Disposal by Susan M. Zahn, 2005, USDA, Forest Service, National Technology and Development Program, Fire Management Tech Tips # 5100.
http://www.fs.fed.us/eng/pubs/pdf/hi_res/05511303hi.pdf
http://www.fs.fed.us/eng/pubs/html/05511303/05511303.html Accessed: 03/2008

(8) Air Burners LLC. Forest Service – Air Curtain Burners, Destructors, Air Curtain Incinerators.
http://www.airburners.com/ab-forests.htm Accessed: November 21, 2008.

(9) Blue Sky Environmental, Inc. (BSE) 2008a. Save Time & Money on land clearing, wood, and slash disposal. Granby, CO.

(10) Blue Sky Environmental, Inc. (BSE) 2008b. Open Pile Burning vs. Air Curtain Technology. Granby, CO.

(11) Colorado Department of Public Health and Environment. (CDPHE) Colorado Smoke Management Program. Air Curtain Burner Permits.
http://www.cdphe.state.co.us/ap/smoke/ACB.html Accessed: 12/12/08.

(12) Concept Products Corporation. (CPC) Air Curtain Destructor CP2000T.
http://www.conceptproducts.com/AirCurtainCP2000T.htm Accessed: 12/12/08.

(13) Dennis, A., Fraser, M., Anderson, S., and Allen, D. Air pollutant emissions associated with forest, grassland and agricultural burning in Texas. Atmospheric Environment. 36:3779-3792.

(14) Fountainhead Engineering. 2000. Final Report Describing Particulate and Carbon Monoxide Emissions from the Whitton S-127 Air Curtain Destructor 00-21. Fountainhead Engineering. Chicago, IL.

(15) Gerstle, R.W. and Kemnitz, D. A. 1967. Atmospheric emissions from open burning. Journal of Air Pollution Control Association. 17:324-327.

(16) Lambert, M. B., Efficiency and economy of an air curtain destructor used for slash disposal in the Northwest. Presented at American Society of Agricultural Engineers Winter Meeting. Chicago, IL. Dec 11-15, 1972.

(17) Lemieux, P. M., Lutes, C. C. and Santoianni, D. A. 2004. Emission of organic air toxics from open burning: A comprehensive review. Progress in Energy and Combustion Science. 30:1-32.

(18) Lutes, C. C. and Kariher, P. H. 1996. Evaluation of the Emissions from the Open Burning of Land-Clearing Debris. EPA-600/R-96-128. National Risk Management Research Laboratory. U.S. Environmental Protection Agency: Research Triangle Park, NC.

(19) Miller, C. A. and P. Lemieux, 2007. Emissions from the Burning of Vegetative Debris in Air Curtain Destructors. Journal of Air and Waste Management Association. 57:959-967.

(20) Pottawatomie County. (PC) 2004. Debris Removal Plan.

(21) South Coast Air Quality Management District. (SCAQMD) Board Meeting Date March 7, 2003. Agenda No. 34. http://www.aqmd.gov/hb/2003/030334a.html. Accessed: 12/12/08.

(22) United States Environmental Protection Agency. (USEPA) Climate Change, Methane, Science. http://www.epa.gov/methane/scientific.html Accessed: 12/12/08.

Appendix

Figure 1. Project Location

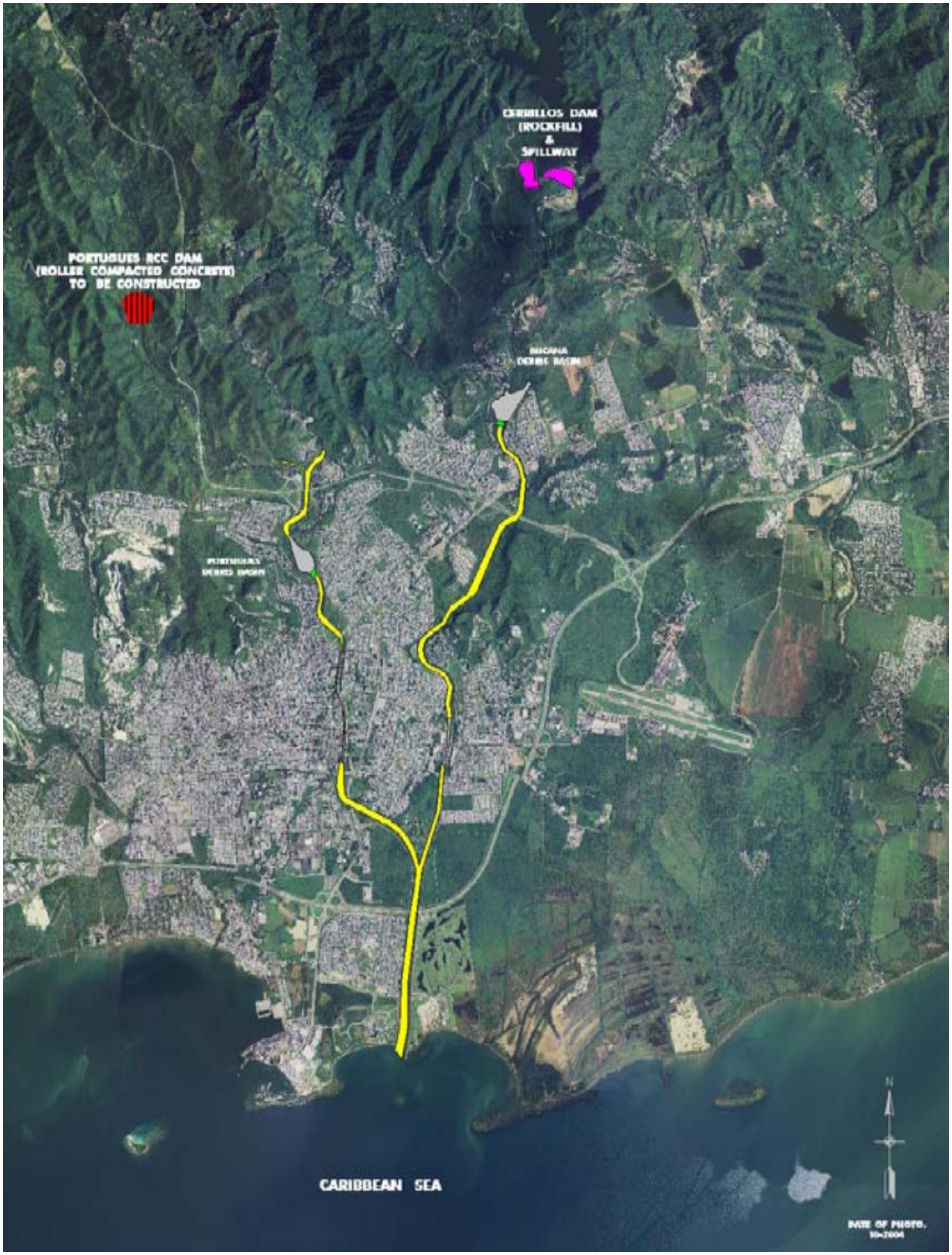
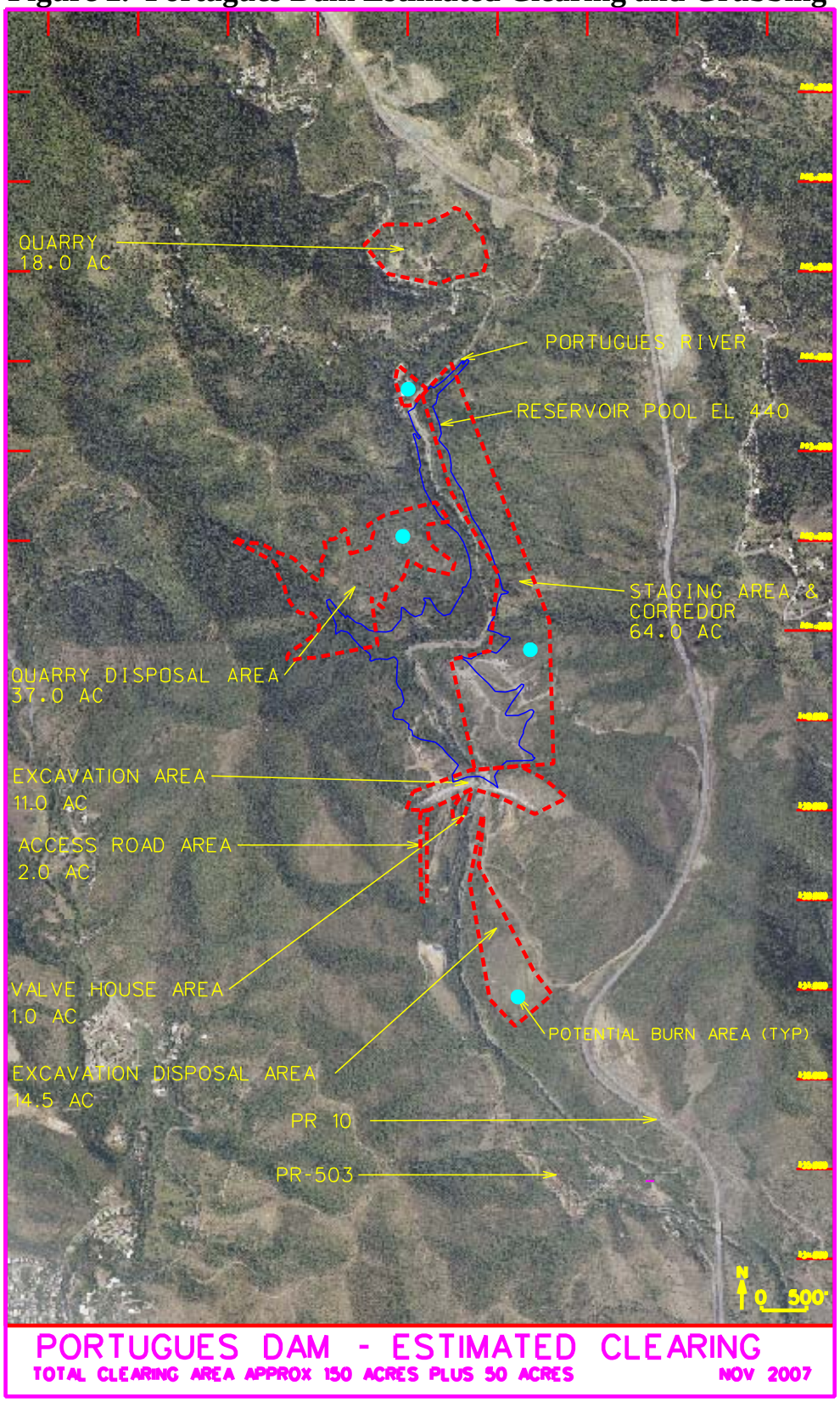


Figure 2. Portugues Dam Estimated Clearing and Grubbing



Total Clearing Area is Approximated 200 (150 + 50) Acres as of Nov 2007

Figure 3. Portugues Dam Proposed Monitoring Locations

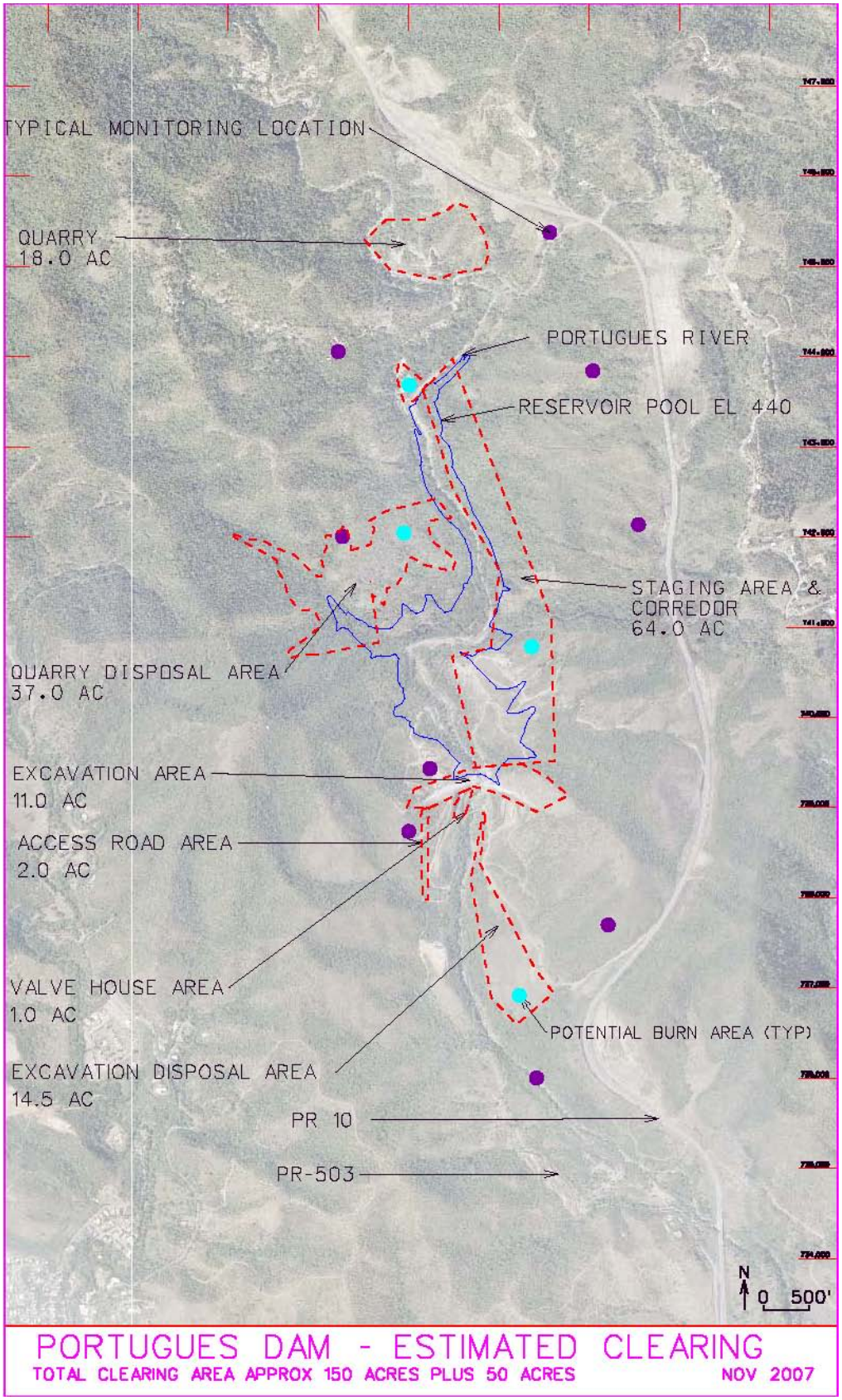


Figure 4. Portugues Dam Property Boundaries

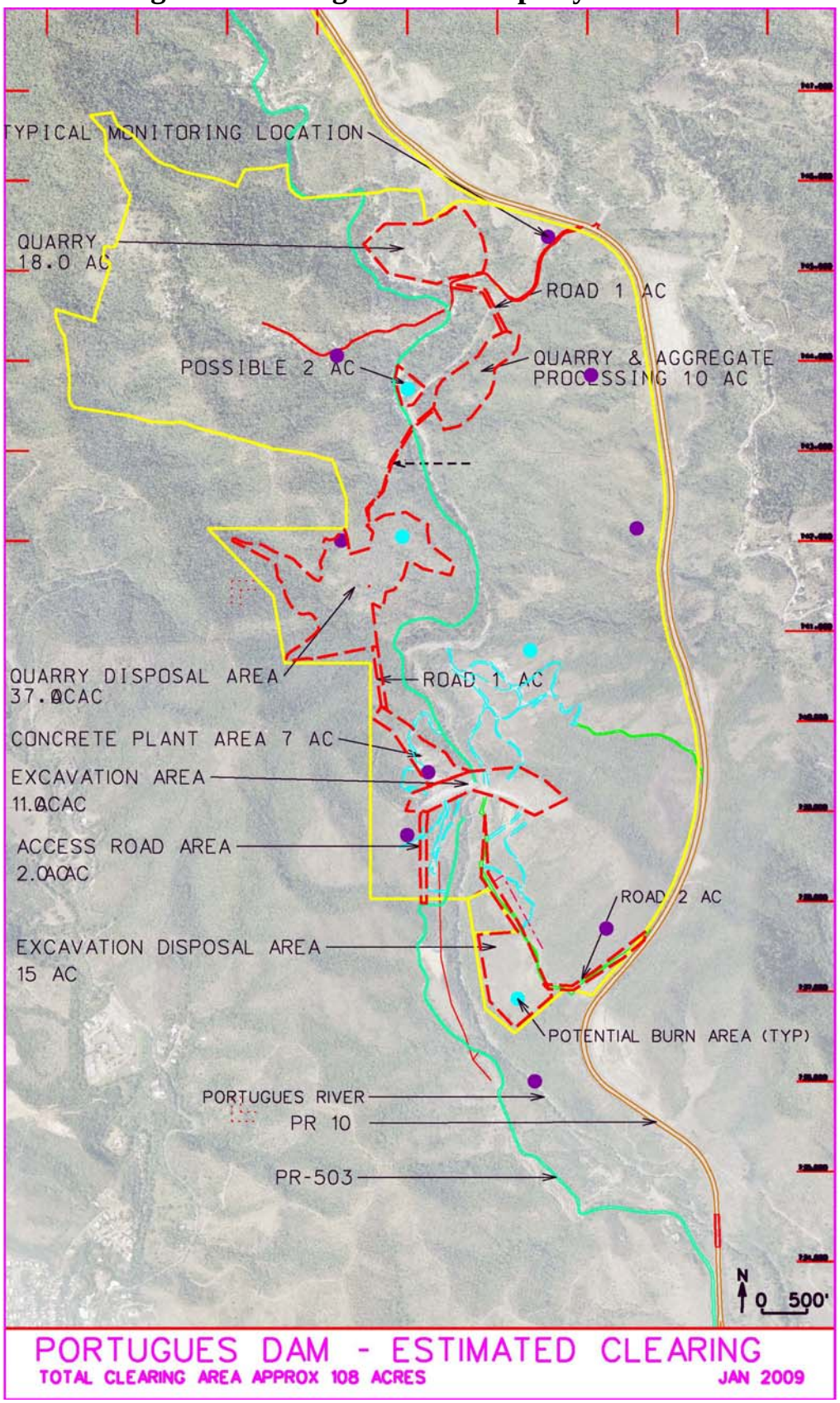


Figure 5. Flow Diagram for Thermal Reduction Operation

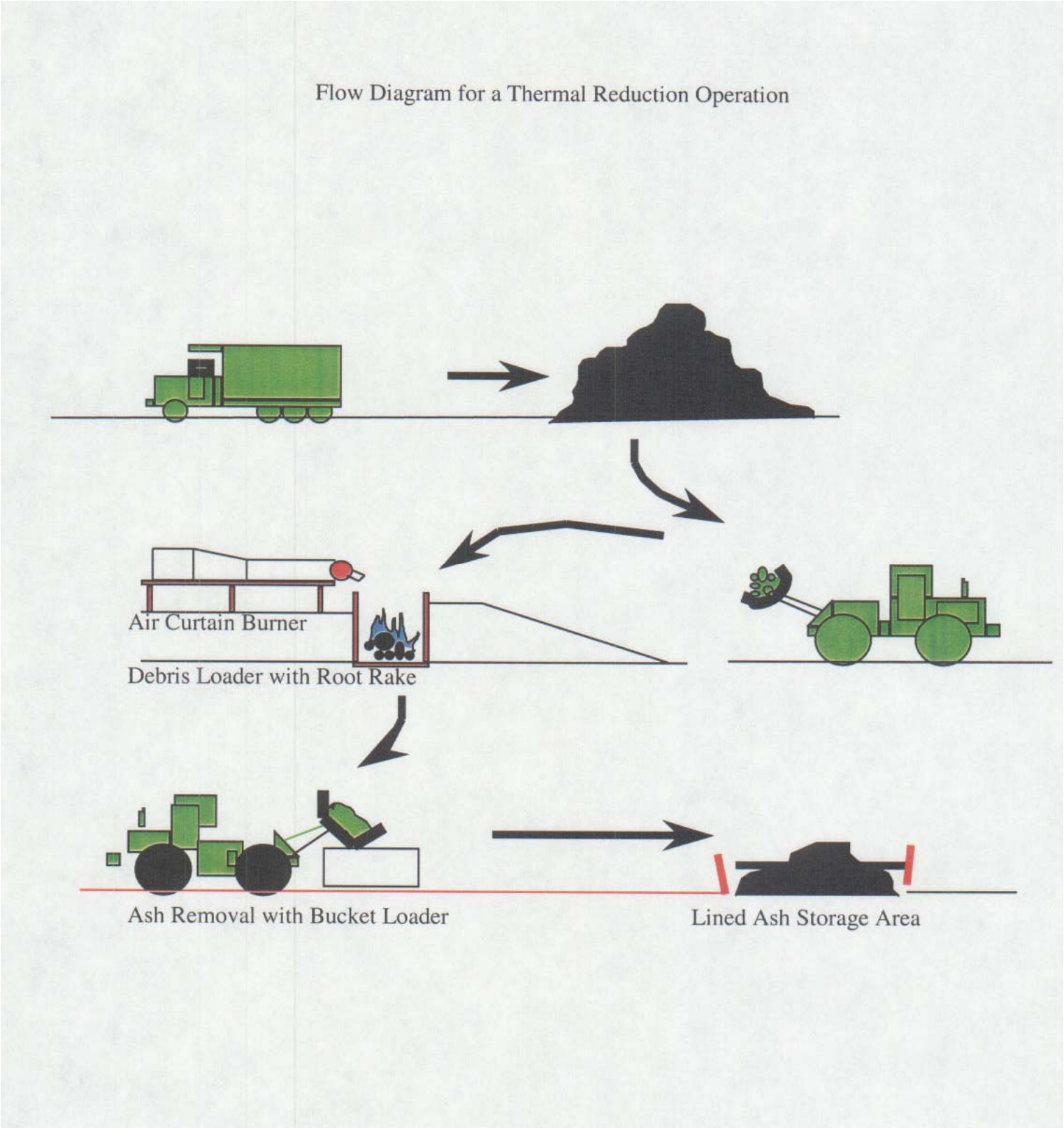
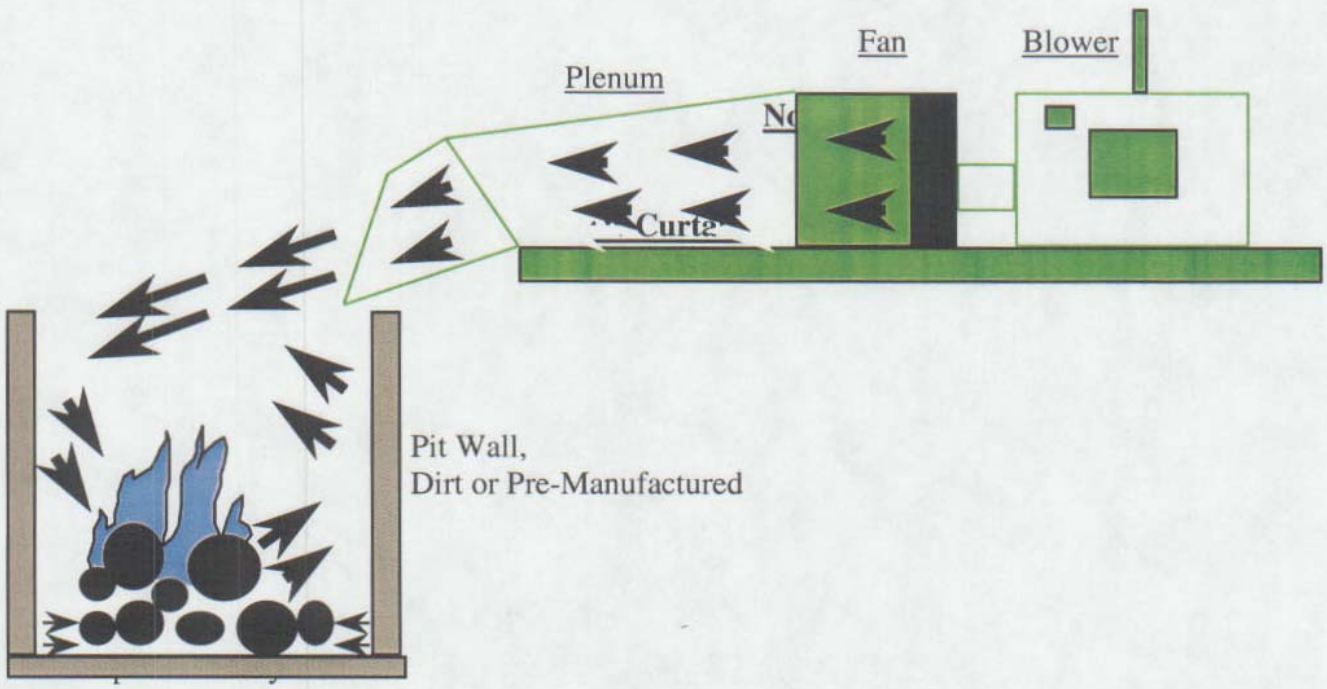


Figure 6. Overview of an Air Curtain Operation



A power source, either electric motor or diesel power unit, drives a fan which in turn creates an air curtain by forcing air through a plenum and nozzle. This high velocity air travels across the top of the pit which a fire has been started.

The air curtain traps smoke and small particles and re-circulates them to enhance combustion and reduce smoke. The very large volume of air accelerates combustion and provides for high pit temperatures between 1800 degrees F and 2200 degrees F.

The pit provides a safe combustion chamber that helps prevent heat loss.

Figure 7. Air Curtain Thermal Pit

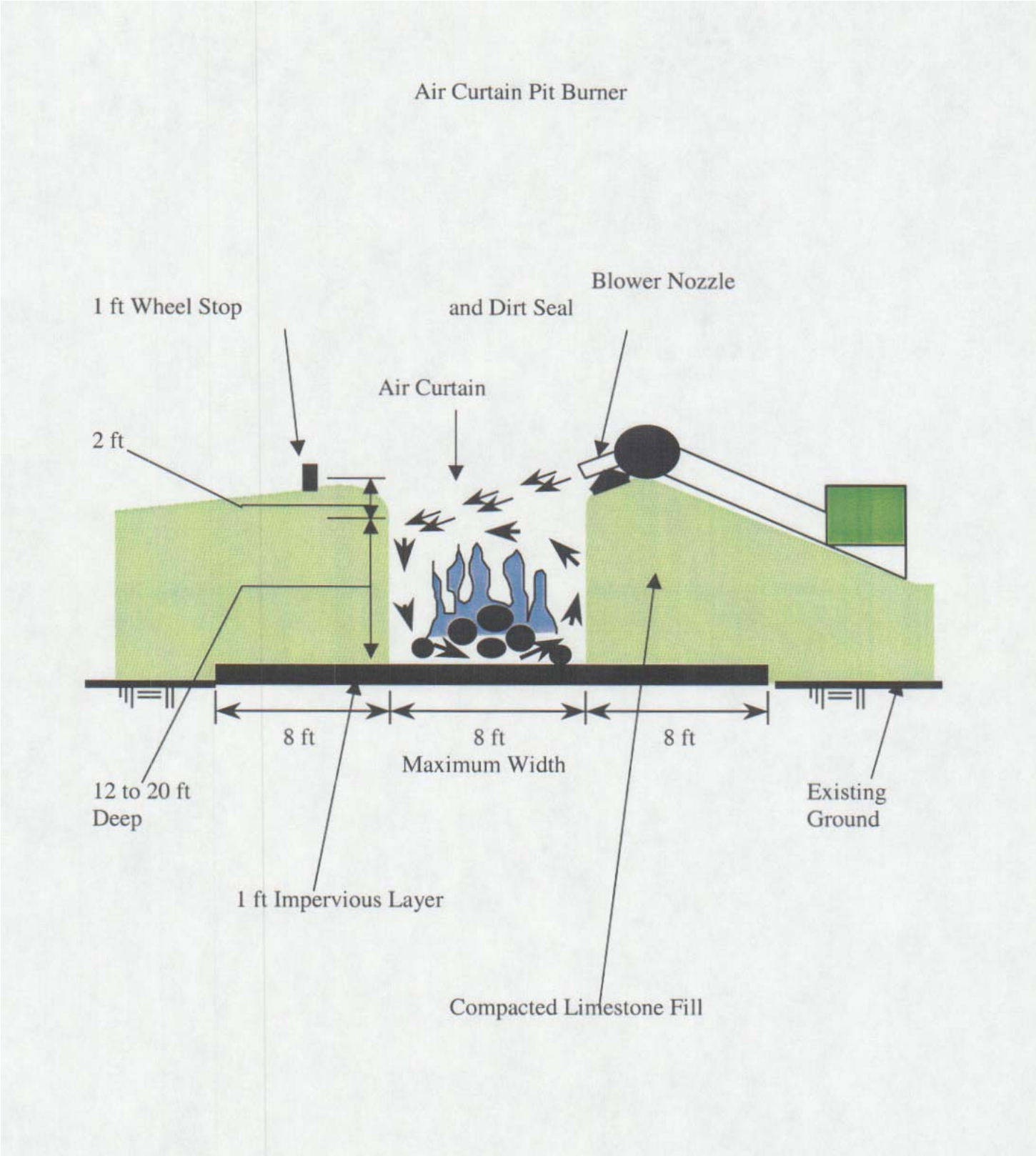


Figure 8. Air Curtain Incinerator

Air Thermal Incinerator operates in a quick, safe, clean, and economical manner to deliver an efficient Thermal Reduction process

Pit may be constructed above or below ground depending on conditions existing at the job site

Figure 9. Air Curtain Incinerator

The extremely high temperatures coupled with the fast air flow directed into the trench at the proper angle enables the A.C.I. (Air Curtain Incinerator) to meet or exceed all state and federal environmental regulations. Pit emissions are less than 20% opacity under correct operating procedures

Portable Air Curtain blower

Figure 10. Air Curtain Incinerator

Portable A.C.I

Portable A.C.I being loaded with vegetative debris

Results from Previous Thermal Reduction Performed in Puerto Rico:

Following is the summary results (for reference only) taken from the TS (Tropical Storm) Jeanne (2004) and the Hurricane Georges (Salinas Debris Reduction Site 1998) Thermal Reduction/Air Monitoring OSC Reports. In tropical storm Jeanne, thermal reduction was used to reduce the volume of vegetative material only. During hurricane Georges, thermal reduction was used for the reduction of woody waste. The TS Jeanne report comprises a table outlining a summary result for ambient air monitoring/sampling and soil sampling vs. EPA action level and the summary results for ambient air monitoring/sampling analysis result for the 1998-1999 Thermal Reduction events for comparison purposes. The Hurricane Georges Ambient Air Monitoring and Sampling Salinas Debris Reduction Site includes a table showing values by station number and based on event number, date, and time.

TS (Tropical Storm) Jeanne (2004)
SUMMARY RESULTS FOR AMBIENT AIR MONITORING/SAMPLING AND SOIL SAMPLING VS ACTION LEVELS AND 1998-1999 THERMAL REDUCTION AMBIENT AIR MONITORING/SAMPLING RESULTS

ANALYTE	METHODOLOGY	December 2004 ANALYSIS RESULTS	EPA ACTION LEVELS	October 1998 ANALYSIS RESULTS	March 1999 ANALYSIS RESULTS
Mercury (Hg)	Ambient Air Monitoring	0.000056 mg/m³ *	0.05 mg/m³ **	ND	ND
Carbon Monoxide (CO)	Ambient Air Monitoring	13 ppm*	9 ppm (10 mg/m³)	16 ppm	35 ppm
Particulate Matter (PM10) Particulate Matter (PM2.5)	Ambient Air Monitoring	777 µg/m³*	50 µg/m³ Annual 150 µg/m³ 24-hour 15.0 µg/m³ Annual 65 µg/m³ 24-hour	920 µg/m³	311 µg/m³
Benzene	Ambient Air Sampling (Sorbent Tubes)	0.0012 ppm*	0.01 ppm **	0.0099 ppm	ND
Toluene	Ambient Air Sampling (Sorbent Tubes)	0.0014 ppm*	100 ppm ** (375mg/ m³)	0.0027 ppm	ND
Chloromethane	Ambient Air Sampling (SUMMA canister)	0.00144 ppm*	100 ppm (OSHA)	0.0075 ppm	ND
Toluene	Ambient Air Sampling (SUMMA canister)	0.0012 ppm*	100 ppm** (375mg/ m³)	0.0013 ppm	.260 ppm
Alkanes	Ambient Air Sampling (SUMMA canister)	0.0044 ppm*	No Level Established	< 0.005 ppm	.130 ppm
Acetone	Ambient Air Sampling (SUMMA canister) as TIC	0.006 ppm*	250 ppm (590 mg/m³)	ND	ND
Dioxin / Furan	Ambient Air Sampling (PUF filter) on TEQs basis	0.000000041 µg/m³*	0.00020 µg/m³	ND	ND
Formaldehyde	Ambient Air Sampling (450 mg Silica gel tubes)	0.007 ppm*	0.016 ppm **	ND	ND
Aluminum	Ambient Air Sampling (MCE filter)	7.1 µg/m³*	10 mg/m³ **	ND	ND
Zinc	Ambient Air Sampling (MCE filter)	6.3 µg/m³*	1 mg/m³ ** (Zinc Oxide)	ND	ND
Hydrochloric Acid	Ambient Air Sampling (600 mg Silica gel tubes)	0.0078 mg/m³ *	4.7 ppm (5 mg/m³) **	ND	ND
PCBs	Soil Sampling	111 ppm	50 ppm	ND	ND

ND – Non Detected
NC – Not Collected
*Test basis to the incinerator of wet soil and debris mixture
**NIOSH Recommended Exposure Limits (RELs). Unless otherwise noted RELs are in Time-Weighted Average (TWA) concentrations for up to 10-hour work day during a 40-hour workweek

Ambient Air Monitoring Summary Results/Second Mobilization
Event #1 (1130-hrs on 17 November 1998)
Puerto Rico Thermal Test/Salinas Debris Reduction Site
March 1999

Air Monitoring Instrument	Station #1 (UW)	Station#2 (DW)	Station#3 (DW)	Station #A[a] (DW)
MicroTip/TVOCs (ppm)	ND	15	12	4
Cannonball-2 (% O2)	20.8	20.8	20.8	20.7
Cannonball-2/CO (ppm)	ND	19	35	2
Cannnonball-2 (% LEL)	ND	ND	ND	ND
Carbon Dioxide (ppm)	600	1000	1200	700
Hydrogen Sulfide (ppb)	ND	ND	ND	ND
Sulfur Dioxide (ppm)	ND	ND	ND	ND
Phosgene (ppm)	ND	ND	ND	ND
Jerome/Hg ($\mu g/m^3$)	ND	ND	ND	ND
DataRAM ($\mu g/m^3$)	19	311	300	104

ppm – parts per million
ppb – parts per billion
ND – not detected
$\mu g/m^3$ - micrograms per cubic meter
[a] – this was a temporary check station located approximately 200-300 feet downwind from Station #2 and #3

SUMMA Canister Sampling Summary Results
Puerto Rico Thermal Test/Salinas Debris Reduction Site
Salinas, Puerto Rico
March 1999
All concentration in parts per billion by volume (ppbv)

SAMPLE NUMBER	18870	18872	18875	18830	12121	12122
Sample Location	Test Thermal Pit Event#2	Station #2 Event #3	Test Thermal Pit Event #3	Test Thermal Pit Event #4	Station #2 Event #1	Station #3 Event #1
Date	10/30/98	10/30/98	10/30/98	10/31/98	11/17/98	11/17/98
Chloromethane	63	U	66	75	19	5.6
Benzene	160	2.0	81	260	33	8.9
Toluene	88	22	36	130	16	4.2
Ethylbenzene	11	12	4.8	17	2.1	0.5
M,p-Xylene	20	75	6.5	24	2.8	0.9
o-Xylene	8.4	32	2.5	10	1.2	0.3
Styrene	16	U	8.5	33	4.3	0.6
1,2,4-Trimethylbenzene	3.9	110	1.6	4.0	0.6	0.3

U = The compound was analyzed for but not detected at the detection limit

U.S. Army Corps of Engineers
Jacksonville District

Air Monitoring Plan

Rio Portugues Flood Control Project
Ponce, Puerto Rico

Purpose

This ambient air monitoring plan has been prepared for the proposed thermal reduction of vegetation product of the construction of the Portugues Dam. The Portugues Dam project is located north of the city of Ponce, Puerto Rico, on the channel of the Portugues River. During normal operations the reservoir's pool will cover approximately 72 acres, with a maximum flood pool area of 215 acres during an extreme rain event.

Construction of the dam and reservoir will require clearing and grubbing of approximately 150 acres of timber and brush vegetation in the river valley and an additional 50 acres for establishment of the reservoir pool. The volume of biomass generated from the clearing and grubbing of the project site has been estimated at 5,240 tons (26.2 tons per acre). This volume is extremely large to be received and handled by the region's sanitary landfills. Mechanical reduction of this large volume of biomass would be extremely costly and the region's sanitary landfills may not have the capacity or process capability to take this large of load. Tailpipe emissions from the mechanical reduction, from loading and truck transportation, and emissions from natural decay of the vegetative material, could potentially exceed National Ambient Air Quality Standards (NAAQS) for CO, SO_2, NO_2, $PM_{10,}$ and $PM_{2.5}$ in the area.

Allowing natural decay of the vegetation from the clearing and grubbing activities of the Portugues Dam site, will allow the generation of flammable methane gas. Methane is 21 times more adverse greenhouse gas than CO_2. Other possible problems from the natural decay of this large volume of vegetation would be the potential of naturally-occurring wild fires and termite infestation. Both of these scenarios would represent environmental health and safety threat to the vicinity.

The U.S. Army Corps of Engineers (COE), Jacksonville District, has analyzed the potential alternatives for the disposal of this large amount of brush and timber, and has decided that thermal reduction is the most advantageous option for the project from the environmental and economic point of view. The COE has in the past utilized thermal reduction in Puerto Rico during emergency operations (hurricanes) and during the construction of large projects like the Cerrillos dam, without compromising the air quality of the region.

Ambient Air Monitoring

Ambient air monitoring activities will consist of real-time monitoring of particulates (PM_{10} & $PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2).

Air Monitoring Methodologies

Monitoring for SO_2, and CO, would be performed using the MultiRAE PLUS multi gas monitor PGM-50 or equivalent. Monitoring for particulate matter would be performed using the Thermo Electron DataRAM4 ™ Nephelometric Particulate Monitor or MIE DataRAM 4 DR-4000 or equivalent. Other alternative real-time ambient air monitoring equipment for SO_2, could be Zellweger/MDA Scientific Single Point Monitor (SPM™) Tape meters equipped with a chemcassette and chemkey specific for SO_2 and other compounds. Other alternative real-time ambient air monitoring for CO, could be Biosystems Cannonball™ -2 gas analyzer or equivalent. Contractor shall employ industry-accepted real-time air monitoring equipment capable of performing the tasks of protecting personnel, the environment, and monitor the air contaminants of concern.

Meteorological Monitoring and Data Acquisition

Meteorological data will be obtained to support the needs of the thermal reduction operation. The weather data will be collected utilizing a 3-meter portable meteorological station or equivalent deployed at the site. In addition, meteorological data will be collected for confirmation from the meteorological station at the Mercedita Airport in Ponce. The meteorological station will be located on site, approximately 500 feet of the thermal reduction site. The meteorological station will record wind speed, wind direction, temperature, barometric pressure, and relative humidity.

Monitoring Locations

The ambient air monitoring will be performed at monitoring stations upwind and downwind of the thermal reduction pit sites, taking into consideration the direction of the prevailing wind. The monitoring stations will be installed in open areas at the thermal reduction pit sites, with low wind flow disturbances to facilitate representative sampling. The typical upwind stations will be located approximately 1,500 feet from the thermal reduction sites. Typical downwind stations will be located approximately 700-800 feet from the thermal reduction sites. Other stations will be located approximately 50-150 feet downwind from the thermal reduction site. The attached site map depicts the proposed monitoring station locations. Location of the monitoring stations could be changed or modified in case of weather conditions preclude the collection of the best representative data, or to avoid cross contamination from heavy equipment operating in the area.

Thermal Reduction Pit Operation

Based on the emissions data collected by the real-time monitoring stations, each thermal pit will operate optimally to ensure that NAAQS are met. In the case of wind direction steer towards populated areas, and/or emissions from a thermal reduction pit are reaching the 75% of the NAAQS, the operator shall slow down the operation of the pit and adjust the process accordingly. Should the operation not meet 90% or lower of the NAAQS in two hours period subsequent to the operator adjustments, the thermal pit operations shall be cease for the rest of the day.

U.S. Army Corps of Engineers
Jacksonville District

Contingency Plan for Thermal Reduction Activities
(Revised – September 2009)

Río Portugués Flood Control Project
Ponce, Puerto Rico

Typical Thermal Reduction Setup

Air curtain thermal reduction technologies' are a commonly used for vegetative debris disposal (Miller and Lemieux, 2007). The design of the air curtain technologies may vary, but the operation is fundamentally the same. The traditional setup of an air curtain thermal reduction consists of a pit, air blower, and continuous air monitoring devices (Miller and Lemieux, 2007). The design varies in that the pit may be manufactured and portable or the pit may be dug out on site. The later requires additional resources and regulations (ie., dimensions, lining, etc.), while a portable air curtain pit is less costly and "ideal for areas with high water tables, sandy soils and where opacity must be kept to a minimum." An air curtain pit "operates by burning the combustible material (trees) in an enclosed space with an open top, over which a high velocity 'curtain' of air is directed to reduce the escape of large particles and to improve air circulation into the burning debris" (Miller and Lemieux, 2007).

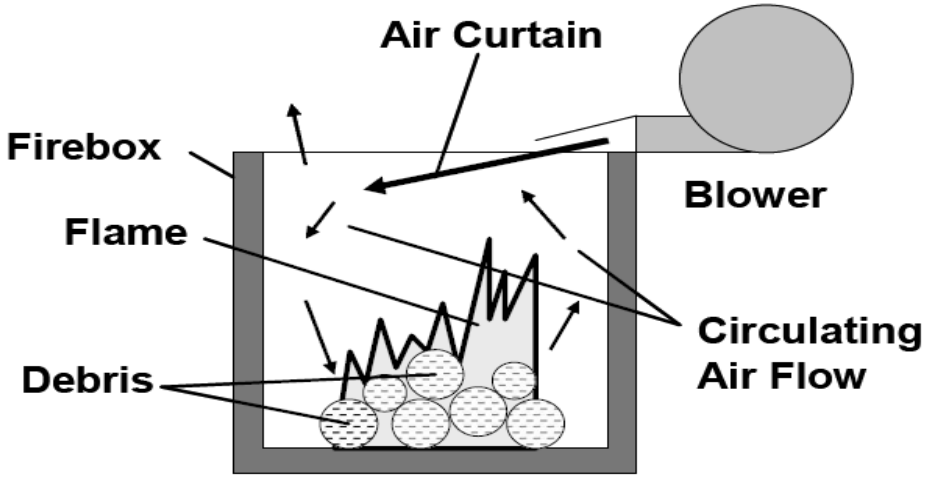


Figure 1. Schematic diagram of air curtain incinerator operation (Miller and Lemieux, 2007).

Thermal reduction can be implemented without compromising the air quality of the region. The emissions of particulate matter and carbon monoxide per unit mass of debris produced by thermal reduction in an air curtain incinerator are significantly lower than those of open pile burning (Miller and Lemieux, 2007; CDPHE, 2008). The use of an air curtain incinerator reduces the emission of PM and CO by improving combustion conditions, as compared to open thermal reduction (Miller and Lemieux, 2007). An air curtain incinerator averages 10% opacity (Air Burner, 2008). The ashes produced via thermal reduction can be recycled as fertilizer or for any other eco-friendly purpose; only after being analyzed and cleared of heavy metal contaminants (BSE, 2008). The remaining ashes can be disposed of properly at a landfill.

Ambient Air Monitoring

Ambient air monitoring activities will consist of real-time monitoring of particulates (PM_{10} & $PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), and nitrogen dioxide (NO_2).

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Thermal Reduction Pit Operation

The contractor will contact the National Weather Service, to verify if the weather conditions are appropriate to conduct thermal reduction with the purpose of minimizing impacts, and protect human health of the workers and the nearby communities. Conditions to consider but not limited are; meteorological conditions prior thermal reduction operations like air stagnation (no wind condition), atmospheric inversion (mostly in Fall), high natural background levels of particles from events like Sahara dust, or volcanic ash, accidental air pollutants releases from industrial complexes found in the south of Puerto Rico, and/or accidental fires in the area.

Based on the emissions data collected by the real-time monitoring stations, each thermal pit will operate optimally to ensure that NAAQS are met. In the case of wind direction steer towards populated areas, and/or emissions from a thermal reduction pit are reaching the 75% of the NAAQS, the operator shall slow down the operation of the pit and adjust the process. Should the operation not meet 90% or lower of the NAAQS in two hours period subsequent to the operator adjustments, the thermal pit shall be cease operations for the rest of the day.

The Contractor shall maintain continuous thermal reduction activity from sunrise to sunset in the active thermal pits, to reduce start up emissions:

a. Only kerosene, diesel fuel, drip torch fuel, clean dry wood or lightered pine, virgin oil, natural gas or liquefied petroleum gas may be used to start the fire in the incinerator. The use of used oil, chemicals, gasoline, or tires to start the fire is prohibited.

b. An air curtain incinerator must be located at least 300 feet from any occupied building and 50 feet from any wildlands, brush, combustible structure, or paved public roadway.

c. Incinerators equipped with refractory-lined walls, shall begin charging no earlier than sunrise and must end no later than sunset.

d. Incinerators not equipped with refractory lined walls shall begin charging no earlier than sunrise and must end one hour before sunset.

e. Regardless of the air curtain incinerator type, after charging ceases, air flow shall be maintained until all material within the air curtain incinerator has been reduced to coals, and flames are no longer visible. A log shall be maintained on site, and available upon request, that documents daily beginning and ending times of charging.

f. If the air curtain incinerator employs an earthen trench, the pit walls (width and length), shall be vertical, and maintained so that the combustion of the waste within the pit will be maintained at an adequate temperature and with sufficient air re-circulation to provide enough residence time and mixing for proper combustion and control of emissions. Pit width shall not exceed twelve (12) feet.

g. The waste material shall not be loaded into the air curtain incinerator such that it protrudes above the level of the air curtain in the pit.

h. Ash shall not be allowed to build up in the pit of the air curtain incinerator to higher than 1/3 the pit depth or to the point where the ash begins to impede combustion, whichever occurs first.

i. Excessive visible emissions are not allowed except for a period of up to 30 minutes during start ups.

j. The air curtain incinerator shall be attended at all times while materials are being burned or flames are visible within the incinerator.

k. The Contractor shall have available a water truck and/or heavy equipment to turn off the fire.

Additional Contingency Actions

1. Public Notice – In coordination with the P.R. Department of Natural and Environmental Resources (DNER), P.R. Environmental Quality Board (EQB) and the U.S. Environmental Protection Agency (EPA), the public will be informed prior to initiate the activities. The public notice shall be published in a local newspaper of general circulation.

2. Additional Monitoring Efforts and Notifications – The Corps will install several monitoring stations upwind and downwind of the thermal reduction pit sites. These stations will be used to determine if contingency actions will be required. In addition, the EQB air quality monitoring network could be used to obtain additional information, as necessary. The monitoring station for the Municipality of Ponce is EQB Station 56. The data obtained by EQB is analyzed and then published at EQB's web site, http://www.gobierno.pr/JCA/Inicio/, to inform the public of the daily air quality index and recommended measures. In order to prevent adverse impacts to public health, the reduction activities will be coordinated with EQB's Ponce Office. The monitoring data from EQB Station 56 could be used to determine if the activities are compromising the air quality. However, the trigger for contingency course of action will be based on data obtained from the Corps monitoring stations. If is determined that the activities are compromising the air quality, the measures to be taken by sensitive persons shall be notified via EQB's web site and local radio. Some of the recommended measures to be taken are:

a. Avoid exposure to tobacco smoke.
b. Minimize time spent outdoors.
c. Stay indoors.
d. Avoid prolonged or heavy exertion activities (indoors and outdoors).
e. Avoid dusting
f. Turn air conditioning to recirculation mode in home (if available).
g. Keep ample supply of respiratory medication available**.**
h. If driving is unavoidable, drive with air conditioner on recirculation mode (if possible).
i. It is recommended that sensitive persons move to clean-air facilities, such as: recreational areas (e.g. beaches, parks) and shopping malls, among others.

The nearest communities outside the project limits that shall be notified if the emissions reach the action levels are: Tibes (North), Machuelo Arriba (East), Portugués (Southeast), and Magueyes (Southwest).

3. External emission sources (i.e. Sahara dust, volcano ashes, wildfires, heavy equipment emissions, accidents and spills, among others) – Previous to the commencement of thermal reduction activities, the meteorological conditions shall be verified to ensure that the conditions are favorable. The activities shall not be initiated if it is determined that there are no favorable conditions. In addition, as part of the monitoring efforts, contractor personnel will have to be aware of any external events that could have an effect on the air quality. If the contractor personnel discovers or its notified of external events that could affect the air quality, the following actions shall be performed:

   a. Weather and monitoring stations readings will be taken and recorded during the operation in interval periods between one hour or 30-minutes intervals thereof.

   b. If the emissions from a thermal reduction pit are reaching the 75% of the NAAQS, the operator shall slow down the operation of the pit and adjust the process.

   c. Should the operation not meet 90% or lower of the NAAQS in two hours period subsequent to the operator adjustments, the thermal pit shall cease operations for the rest of the day.

4. On-Site Documentation – The thermal reduction activities schedule, technologies information and monitoring data logs shall be available on site and available for the public upon request.

5. P.R. Environmental Index Scale – As part of this Plan, the Air Quality Index (AQI) level for air pollutants established by EPA and EQB for PM_{10}, $PM_{2.5}$, SO_2, CO, and NO_2 will be used as a guidance (table below). For more information, please see table below and/or refer to P.R. Environmental Index Scale and Possible Health Effects at http://www.prtc.net/~jcaaqs/Index.html.

Pollutant	Unhealthy for Sensitive Groups	Unhealthy
PM_{10}	150 µg/m^3	250 µg/m^3
$PM_{2.5}$	35.5 µg/m^3	55.5 µg/m^3
CO	9 ppm (10 mg/m^3)	12 ppm (12 mg/m^3)
NO_2*	0.247 ppm (465 ug/m^3)	0.309 ppm (580 ug/m^3)**
SO_2	0.14 ppm (365 ug/m^3)	0.18 ppm (455 ug/m^3)**

*The NO_2 values were extrapolated using the SO_2 NAAQS.

SO_2 = 0.14 ppm (365 ug/m^3) 24-hour

SO_2 = 0.03 ppm (80 ug/m^3) Annual arithmetic mean

NO_2 = 0.053 ppm (100 ug/m^3) Annual arithmetic mean

NO_2 = (0.14/0.03) x (0.053) = 0.247 ppm ~ (465 ug/m^3)

**The unhealthy values were calculated using a 25% over the values of unhealthy for sensitive groups.

6. Solid Waste Disposal and Pit Closeout: – After thermal reduction activities have been completed, the ashes will be tested for heavy metals content, and offer to the public to be recycled as fertilizer or for any other environmental friendly activity. The remainder ashes will be properly disposed at landfill facility in Ponce, Puerto Rico. Other solid waste like cars, tires, household appliances, construction debris, and garbage, won't be subject to thermal reduction and will be properly disposed at a landfill facility in Ponce, Puerto Rico. The pit will be backfill with same dirt that came out the pit.

7. Emergency Contacts – In case of emergency the following agencies, but not limited to, will be contacted:

   a. Firefighters Department of Ponce: (787) 842-2022 / 842-2025 / 842-2005
   b. State Office for Emergency and Disaster Management: (787) 724-0124
   c. Police Department: (787) 343-2020
   d. EQB Ponce Office: (787) 840-4070 / 840-3141
   e. EQB Environmental Emergencies: (787) 767-8181 extensions 3236 / 3248 / 3232
   f. EPA Puerto Rico Office: (787) 977-5870
   g. DNER Ponce Office: (787) 844-4051 / 840-4660

References

1. Air Burners LLC. Forest Service – Air Curtain Burners, Destructors, Air Curtain Incinerators. http://www.airburners.com/ab-forests.htm Accessed: November 21, 2008.
2. Air Pollution Control Engineering by Noel De Nevers, 1995 by McGraw-Hill, Inc, pages 105-140.
3. Blue Sky Environmental, Inc. (BSE) 2008a. Save Time & Money on land clearing, wood, and slash disposal. Granby, CO.
4. Blue Sky Environmental, Inc. (BSE) 2008b. Open Pile Burning vs. Air Curtain Technology. Granby, CO.
5. Colorado Department of Public Health and Environment. (CDPHE) Colorado Smoke Management Program. Air Curtain Burner Permits. http://www.cdphe.state.co.us/ap/smoke/ACB.html Accessed: 12/12/08.
6. Concept Products Corporation. (CPC) Air Curtain Destructor CP2000T. http://www.conceptproducts.com/AirCurtainCP2000T.htm Accessed: 12/12/08.
7. Dennis, A., Fraser, M., Anderson, S., and Allen, D. Air pollutant emissions associated with forest, grassland and agricultural burning in Texas. Atmospheric Environment. 36:3779-3792.
8. Fountainhead Engineering. 2000. Final Report Describing Particulate and Carbon Monoxide Emissions from the Whitton S-127 Air Curtain Destructor 00-21. Fountainhead Engineering. Chicago, IL.
9. Gerstle, R.W. and Kemnitz, D. A. 1967. Atmospheric emissions from open burning. Journal of Air Pollution Control Association. 17:324-327.
10. Lambert, M. B. Efficiency and economy of an air curtain destructor used for slash disposal in the Northwest. Presented at American Society of Agricultural Engineers Winter Meeting. Chicago, IL. Dec 11-15, 1972.
11. Lemieux, P. M., Lutes, C. C. and Santoianni, D. A. 2004. Emission of organic air toxics from open burning: A comprehensive review. Progress in Energy and Combustion Science. 30:1-32.
12. Lutes, C. C. and Kariher, P. H. 1996. Evaluation of the Emissions from the Open Burning of Land-Clearing Debris. EPA-600/R-96-128. National Risk Management Research Laboratory. U.S. Environmental Protection Agency: Research Triangle Park, NC.
13. Miller, C. A. and P. Lemieux, 2007. Emissions from the Burning of Vegetative Debris in Air Curtain Destructors. Journal of Air and Waste Management Association. 57:959-967.
14. Pottawatomie County. (PC) 2004. Debris Removal Plan.
15. South Coast Air Quality Management District. (SCAQMD) Board Meeting Date March 7, 2003. Agenda No. 34. http://www.aqmd.gov/hb/2003/030334a.html. Accessed: 12/12/08.
16. United States Environmental Protection Agency. (USEPA) Climate Change, Methane, Science. http://www.epa.gov/methane/scientific.html Accessed: 12/12/08.