Technical Support Document
for the
Proposed Action on the Federal Implementation Plan for the Regional Haze Program in the State of Hawaii

Air Division

U.S. EPA Region 9
May 14, 2012

For information on this technical support document, please contact:

Carol Bohnenkamp
Office of Air Quality Assessment and Analysis
U.S. Environmental Protection Agency – Region 9
75 Hawthorne Street
San Francisco, California 94105
(415) 947-4130
bohnenkamp.carol@epa.gov

Greg Nudd
Office of Air Planning
U.S. Environmental Protection Agency – Region 9
75 Hawthorne Street
San Francisco, California 94105
(415) 947-4107
nudd.gregory@epa.gov

Table of Contents

Appendix A

Subject-to-Best Available Retrofit Technology (BART) Modeling for the State of Hawaii, Application of the CALPUFF Modeling System

Prepared for Hawaii State Department of Health, Environmental Management Division Clean Air Branch by Alpine Geophysics, LLC. March 3, 2010.

Appendix B

MM5 Application for 2005 Over the Hawaiian Islands,
Prepared for Hawaii State Department of Health, Environmental Management Division, Clean Air Branch by Alpine Geophysics, LLC

Technical Support Document
for the
Proposed Action on the Federal Implementation Plan for the Regional Haze Program in the State of Hawaii

I. Regional Haze and Hawaii

I.A. Background on Regional Haze

Regional haze is visibility impairment that is produced by a multitude of sources and activities that are located across a broad geographic area and emit fine particulates ($PM_{2.5}$) (e.g., sulfates, nitrates, organic carbon (OC), elemental carbon (EC), and soil dust), and their precursors (e.g., sulfur dioxide (SO_2), nitrogen oxides (NO_x), and in some cases, ammonia (NH_3) and volatile organic compounds (VOC)). Fine particle precursors react in the atmosphere to form $PM_{2.5}$, which impairs visibility by scattering and absorbing light. Visibility impairment reduces the clarity, color, and visible distance that one can see. $PM_{2.5}$ can also cause serious health effects and mortality in humans and contributes to environmental effects such as acid deposition and eutrophication.

Data from the existing visibility monitoring network, the "Interagency Monitoring of Protected Visual Environments" (IMPROVE) monitoring network, show that visibility impairment caused by air pollution occurs virtually all the time at most national parks (NPs) and wilderness areas (WAs). The average visual range[1] in many Class I areas (*i.e.*, NPs and memorial parks, WAs, and international parks meeting certain size criteria) in the western United States is 100-150 kilometers, or about one-half to two-thirds of the visual range that would exist without anthropogenic air pollution. In most of the eastern Class I areas of the United States, the average visual range is less than 30 kilometers, or about one-fifth of the visual range that would exist under estimated natural conditions. 64 FR 35715 (July 1, 1999).

I.B. Regional Haze Requirements

The Regional Haze Rule (RHR) sets out specific requirements for states' initial regional haze implementation plans. In particular, each state's plan must establish a long-term strategy that ensures reasonable progress toward achieving natural visibility conditions in each Class I area affected by the emissions from sources within the state. In addition, for each Class I area within the state's boundaries, the plan must establish a reasonable progress goal (RPG) for the first planning period that ends on July 31, 2018. The long-term strategy must include enforceable emission limits and other measures as necessary to achieve the RPG. Regional haze plans must also give specific attention to certain stationary sources that were in existence on August 7, 1977, but were not in operation before August 7, 1962. These sources, where appropriate, are required

---

[1] Visual range is the greatest distance, in kilometers or miles, at which a dark object can be viewed against the sky.

to install Best Available Retrofit Technology (BART) controls to eliminate or reduce visibility impairment. More details on regional haze plan requirements are summarized in the Federal Register notice for this action.

I.C. Visibility Impairment Goals

The goal of the regional haze rule is to restore natural visibility conditions by 2064 through implementation of measures that make "reasonable progress" toward this goal by reducing anthropogenic emissions that cause haze. Baseline visibility is determined (through a calculation using the IMPROVE equation) from particulate concentration data that is converted into visibility data (reconstructed light extinction).

I.C.1. Natural, Baseline, and Current Visibility Conditions

The goal of the regional haze rule is to restore natural visibility conditions at the 156 Class I areas identified in the 1977 Clean Air Act Amendments. 40 CFR 51.301(q) defines natural conditions: "Natural conditions include naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration." The regional haze SIPs must contain measures that make "reasonable progress" toward this goal by reducing anthropogenic emissions that cause haze.

For each Class I area, there are three metrics of visibility that are part of the determination of reasonable progress: 1) natural conditions, 2) baseline conditions, and 3) current conditions.

"Natural" visibility is determined by estimating the natural concentrations of visibility pollutants and then calculating total light extinction. Natural background visibility, as defined in *Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program*, EPA-454/B-03-005, September 2003, is based on annual average concentrations of fine particle components. Natural background visibility for the 20% worst days is estimated by assuming that fine particle concentrations for natural background are normally distributed and the 90th percentile of the annual distribution represents natural background visibility on the 20% worst days.

The natural visibility value estimations for 2064 for Hawaii do not include an estimate of the visibility impairment from the emissions from the Kilauea volcano, which is located in the Hawaii Volcanoes National Park. The emissions from the volcano vary from year to year, and it is therefore not possible to estimate the emissions from the volcano or the effect they will have on Class I area visibility in the year 2064.

"Baseline" visibility is the starting point for the improvement of visibility conditions. EPA requires the calculation of baseline conditions [(40 CFR 51.308(d)(2)(i) and (ii)]. The baseline condition for each Class I area is defined as the five year average (annual values for 2000 - 2004) of Interagency Monitoring of Protected Visual Environments IMPROVE monitoring data (expressed in deciviews)[2] for the most-impaired (20% worst) days and the least-impaired (20% best) days. The comparison of initial baseline conditions to natural visibility conditions indicates the amount of improvement necessary to attain natural visibility by 2064. The baseline conditions for this first regional haze FIP submittal for Hawaii are the reference

---

[2]A one deciview change in the haze index is likely humanly perceptible under ideal conditions regardless of background conditions. The deciview is discussed in greater detail in Measures of Visibility, below.

point against which visibility improvement is tracked. For subsequent RH SIP updates (in the year 2018 and every 10 years thereafter), baseline conditions will be used to calculate progress from the beginning of the regional haze program.

"Current conditions" are assessed every five years as part of the SIP review where actual progress in reducing visibility impairment is compared to the reductions committed to in the SIP. Current conditions for the best and worst days are calculated from a multiyear average, based on the most recent 5-years of monitored data available [40 CFR 51.308(f)(1)]. This value will be revised at the time of each periodic SIP revision, and will be used to illustrate: (1) The amount of progress made since the last SIP revision, and (2) the amount of progress made from the baseline period of the program.

I.C.2. Estimation of Visibility Impairment - The Original and the Revised IMPROVE Equations

Each IMPROVE monitor collects particulate concentration data which are converted into reconstructed light extinction (b_{ext}, defined in greater detail in the following section) through a complex calculation using the IMPROVE equation. The IMPROVE equation is used to convert measured or modeled concentrations into extinction for each pollutant chemical species, and then total them, accounting for the effect of relative humidity; it also includes the Rayleigh scattering that occurs in pure air. The extinction total is then used to calculate deciviews for use in visibility progress assessments.

In December 2005 the IMPROVE Steering Committee revised the IMPROVE equation after a scientific assessment of its implications for regional haze planning. In particular, when compared to nephelometer direct measurements of visibility extinction, the original IMPROVE equation over-predicts for low extinction conditions and under-predicts for high extinction. These biases have direct relevance for estimates for the best 20% and worst 20% visibility days that are used to assess progress.

Original IMPROVE equation:

$$
\begin{aligned}
b_{ext} \quad &= 3 * f(RH) * [\textit{sulfate}] \\
&+ 3 * f(RH) * [\textit{nitrate}] \\
&+ 4 * [\textit{organic mass}] \\
&+ 10 * [\textit{elemental carbon}] \\
&+ 1 * [\textit{fine soil}] \\
&+ 0.6 * [\textit{coarse mass}] \\
&+ 10
\end{aligned}
$$

Each term in the equation is the extinction due to a particular measured component; bracketed quantities are concentrations of as measured at IMPROVE monitors. The organic mass is assumed to be 1.4 times the organic carbon mass that is measured by IMPROVE monitors. The 10 is for Rayleigh scattering which is due to the interaction of light with molecules of air itself with no pollutants, and is assumed to be the same for all locations, The f(RH) is a water growth factor for sulfate and nitrate, which are hygroscopic (their particles tend to attract water). Its value depends on relative humidity, ranging from 1 at low humidity to 18 at 98% humidity.

New IMPROVE equation:

$$
\begin{aligned}
b_{ext} \quad = \;& 2.2 * f_s(RH) * [\text{small sulfate}] + 4.8 * f_L(RH) * [\text{large sulfate}] \\
& + 2.4 * f_s(RH) * [\text{small nitrate}] + 5.1 * f_L(RH) * [\text{large nitrate}] \\
& + 2.8 * [\text{small organic mass}] + 6.1 * [\text{large organic mass}] \\
& + 10 * [\textit{elemental carbon}] \\
& + 1 * [\textit{fine soil}] \\
& + 1.7 * f_{ss}(RH) * [\text{sea salt}] \\
& + 0.6 * [\textit{coarse mass}] \\
& + \text{Rayleigh scattering (site-specific)} \\
& + 0.33 * [NO_2 \text{ (ppb)}]
\end{aligned}
$$

Sulfate is assumed to be all "large sulfate" if total sulfate is over 20 $\mu g/m^3$, otherwise its fraction of the total is assumed to increase uniformly between 0 and 1 when the total is in the range between 0 and 20. *I.e.*, large sulfate = (total sulfate/20)*total. A similar definition applies for nitrate and for organic mass. The organic mass is assumed to be 1.8 times the organic carbon mass that is measured by IMPROVE monitors, an increase over the original 1.4. Sea salt is estimated as 1.8 * [chloride] (or chlorine if chloride not available). Finally, the f_s, f_L, f_{ss} are water growth factors for small ("S") and large ("L") fractions of sulfate and nitrate, and for sea salt ("SS"). Their values depend on relative humidity, ranging from 1 at low humidity to over 5 at 95% humidity.

The new equation has five changes: 1) greater completeness though the inclusion of sea salt, which can be important for coastal sites; 2) increased organic carbon mass estimate, based on more recent data for remote areas; 3) Rayleigh scattering using site-specific elevation and temperature, a refinement over the older network-wide constant; 4) separate estimates for small and large particles of visibility impacts and humidity-dependent particle size growth rates, which could affect estimates at the low and high ends; and 5) greater completeness though the inclusion of NO_2 (Pitchford, 2006)[3].

The new equation shows broader scatter overall, but less bias in matching visibility measurements under high and low visibility conditions. That is, though it has a somewhat worse fit considering all the data, it has a better fit under visibility conditions most relevant to regional haze planning, the best and worst 20% of days. The looser overall fit can cause a slightly different set of days to be the ones chosen than the 20% worst, but the chemical species composition for such days is little changed (IMPROVE technical subcommittee for algorithm review, 2001, pp. 11-12), and so this makes little difference for assessing the contribution of emission sources to current conditions, and for projecting the effect of emission controls. The split between small and large particles was the main factor in reducing the biases.

The organic carbon (OC) measured by the IMPROVE network does not include all organic matter (OM); based on 1970s urban data, a scaling factor of 1.4 is embedded in the original equation to account for the full mass. Based on recent data more relevant to relatively remote Class I areas, the revised IMPROVE equation embeds an OM/OC factor of 1.8. In practice, for the worst days, the biggest effect of switching to the revised IMPROVE equation is

[3] Pitchford, Marc, 2006, "New IMPROVE algorithm for estimating light extinction approved for use", *The IMPROVE Newsletter*, Volume 14, Number 4, Air Resource Specialists, Inc.; web page: http://vista.cira.colostate.edu/improve/Publications/news_letters.htm
direct link: http://vista.cira.colostate.edu/improve/Publications/NewsLetters/IMPNews4thQtr2005.pdf

this increased organic carbon mass, since the worst days are dominated by organic carbon from fires, rather than the sulfates and nitrates that come more from anthropogenic sources.

EPA is using the new IMPROVE equation for the Hawaii Regional Haze FIP.

I.C.3. Measures of Visibility

As discussed in Section 2. Estimation of Visibility Impairment - The Original and the Revised IMPROVE Equations, above, particulate concentration data are converted into reconstructed light extinction through a complex calculation using the IMPROVE equation. The relationship between of measures of visibility; light extinction (Mm^{-1}), haze index (dv), and visual range, is discussed below.

Light Extinction **(b_{ext})**. Light extinction is the attenuation of light due to scattering and absorption as it passes through a medium. Reconstructed light extinction (denoted as b_{ext}) is expressed in units of inverse megameters (1/Mm or Mm^{-1}). Light extinction is the most useful measure for evaluating the relative contributions of pollutants to visibility impairment. Light extinction affects the clarity and color of objects being viewed.

Haze Index (deciview). The Regional Haze Rule requires the tracking of visibility conditions in terms of the Haze Index (HI) metric, expressed in the deciview (dv) unit. Generally, a one deciview change in the haze index is likely humanly perceptible under ideal conditions regardless of background conditions. The deciview is a useful measure for tracking progress in improving visibility, because each deciview change is an equal incremental change in visibility perceived by the human eye.

Relationship between extinction (Mm^{-1}) and haze index (dv). There is a logarithmic relationship between the haze index and reconstructed light extinction expressed by the following conversion equation:

HI = 10 ln(b_{ext}/10)

Where: HI is the Haze Index
ln is the natural log
Bext is the reconstructed light extinction

Visual Range. Visual range is the greatest distance, in kilometers or miles, at which a dark object can be viewed against the sky.

The relationship between extinction (Mm^{-1}), haze index (dv) and visual range (km) are indicated by on the scale in Figure I-1. Relationship between extinction Mm^{-1}), haze index (dv) and visual range (km).

Figure I-1 Relationship between extinction Mm^{-1}), haze index (dv) and visual range (km)
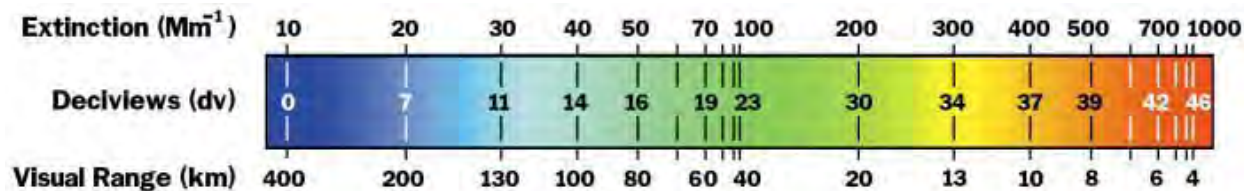
I.D. Unique Nature of Regional Planning in Hawaii

Nonanthropogenic emissions are a significant fraction of total SO_2, VOC, and PM emissions in Hawaii. The Kilauea volcano dominates statewide SO_2 emissions. Emissions from the volcano were estimated to be above 900,000 tons per year, and comprised over 96% of the SO_2 emissions in 2005. On days when the volcano is erupting and the winds are carrying those emissions over the Class I area monitors, these natural emissions dominate the measurements. Nonanthropogenic sources also comprise the majority of VOC and PM emissions.

In addition to the difficulty of assessing the effect of nonanthropogenic emissions on visibility in the National Parks, there are several unique challenges for Hawaii regional haze planning in this planning period. There is no modeling available for this planning period that can reliably predict the change in visibility due to changes in the emission inventory for all sources (shipping, mobile sources, point sources, etc.).[4] In absence of reliable visibility modeling for 2018, EPA is using the island-specific inventories as a surrogate for judging whether reasonable progress is being made during this planning period. Visibility projections for 2018 are based on EPA's estimate of the effect that the changes in the island specific inventories will have on the aerosol composition for each of the parks.

II. Description of Hawaii's National Parks

EPA has reviewed IMPROVE monitoring data, the Causes of Haze Assessment provided through the Western Regional Air Partnership (WRAP), and information from the National Park Service (NPS), and the National Oceanic and Atmospheric Administration (NOAA) as a basis for this technical support document. In addition, EPA reviewed visibility assessments of each park by the Hawaii Department of Health (HDOH).

II.A. HALEAKALA NATIONAL PARK

---

[4] There is acceptable modeling for point sources for the BART and the reasonable progress analysis for point source. This modeling is discussed in Identify BART Subject Sources.

Figure II.A-1. HALEAKALA NATIONAL PARK

National Park Service Photo

II.A.1. Park Description [5]

Haleakala National Park consists of 30,183 acres in central to eastern portions of the island of Maui, 24,719 acres of which are designated wilderness. The slopes of the Haleakala, or East Maui, volcano comprise the central and western Park areas. The Kipahulu Valley occupies eastern Park areas. Park elevations range from 3,055 m (10,023 ft) at the summit of Haleakala to sea level at the mouth of Kipahulu Valley on the extreme eastern boundary. The Park thus includes a wide variety of climate zones, from high mountain elevations above the Marine Boundary Layer, to leeward lowlands that are dry relative to windward lowlands at the same elevation.

Air quality in Haleakala NP is generally excellent, with few man-made sources of air pollution nearby. By far the largest source of air pollution is Kilauea Volcano on the island of Hawaii. Southeasterly "kona" winds transport volcanic gases and particles to Haleakala NP. This volcanic smog, or "vog," contains sulfur dioxide, sulfuric acid, and sulfate particles and affects air quality and visibility. Locally, anthropogenic sources can affect air quality and visibility. [6]

---

[5] http://www.coha.dri.edu/web/state_analysis/Hawaii/HaleakalaNP_metdesc.html
[6] http://www.nature.nps.gov/air/permits/aris/hale/?CFID=16689542&CFTOKEN=67492682

Figure II.A-2. The Haleakala National Park Visibility Monitoring Sites: IMPROVE sites: HALE1 and HACR1.

Visibility Monitoring Sites

    Currently there are two IMPROVE monitoring sites operating in or near the Haleakala National Park. The Haleakala (HALE1) IMPROVE monitoring site is located well outside of the Haleakala National Park near to the Maui Central Valley, at an elevation of 1153 meters. The HALE1 IMPROVE monitoring site began operation at end of 2000. The Haleakala Crater (HACR1) IMPROVE monitoring site is at the park's Western boundary, at an elevation of 2158 meters. The HACR1 IMPROVE monitoring site began operation in 2007. A discussion comparing the data collected at the HALE1 and HACR1 IMPROVE monitoring sites is presented in Section VIII.B. Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site.

Nearby Population/Industrial Centers and Local Sources

    Kahului and the Wailuku area are about 24 km west-northwest and downslope from HALE1, with no major intervening terrain features. The major active volcano, Kilauea on the

Big Island, is 188 km southeast of HALE1. With northeasterly trade winds, SO_2 emissions from Kilauea have been observed to be eddy-transported clockwise around the west side of the Big Island, and impact on Haleakala National Park is possible Sea salt spray is a natural aerosol source.

Wind Patterns

During trade-wind conditions, which predominate 80 to 95% of the time from May through September, and 50 to 80% during the rest of the year, prevailing wind directions at HALE1 should be generally northeast to southwest, typically with speeds of 5 mps or greater. Downslope winds from Haleakala should be evidenced at the site by nighttime southeasterly directions, and daytime northwesterly directions. Exceptions to these conditions would occur during frontal passages associated with synoptic weather systems, and, at the site elevation, during upper atmosphere low-pressure system passages.

Monthly Kahului wind roses show typical wind patterns at this sea level station 24 km northwest of HALE1, with northeasterly surface flow year round and an additional southerly component in the winter.

Inversions/Trapping

The predominant inversion phenomenon is the Trade-layer inversion, or Marine Boundary Layer. The Marine Boundary Layer is more constant and has less diurnal variability than continental inversions because of the oceanic influence. Typical trade-layer inversion heights in the vicinity of Haleakala NP are around 2000 m above sea level, with some variability (+/- ~1000 m) due to seasonal effects. The HALE1 site, at an elevation of 1158 m (3799 ft), would thus probably be within this layer most of the time when trade-wind conditions predominate. During this condition, relative humidity will be typically be high, 70% or greater. When the Marine Boundary Layer height is below the monitoring site, relative humidity will be much lower.

II.A.2. Visibility Conditions

Baseline Conditions at HALE1 in deciview (20% best and worst days)

The baseline visibility is determined from the HALE1 monitoring site for the 20% worst and the 20% best days for the years 2001 through 2004 as specified in the Regional Haze regulations under 40 CFR §51.308(d)(2)(i). Data from the year 2000 is not being used because data from that year is not complete. The baseline visibility for the Haleakala National Park is calculated at 13.3 deciviews for the 20% worst day and 4.6 deciviews for the 20% best days. Figure II.A-3 below, shows the baseline data for the 20% worst days for each of the years 2001-2004. Figure II.A-4, below, shows the baseline for the 20% best days for each of the years 2001-2004.

Figure II.A-3: Haleakala National Park (HALE1); Baseline Visibility for the 20% Worst Days 2001 - 2004.
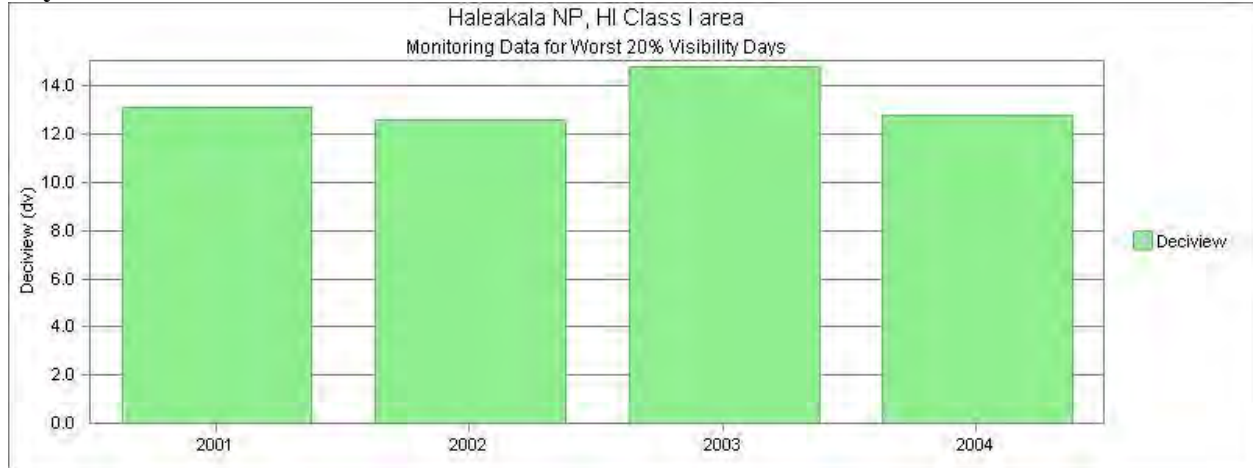
Figure II.A-4: Haleakala National Park (HALE1); Baseline Visibility for the 20% Best Days 2001 - 2004.
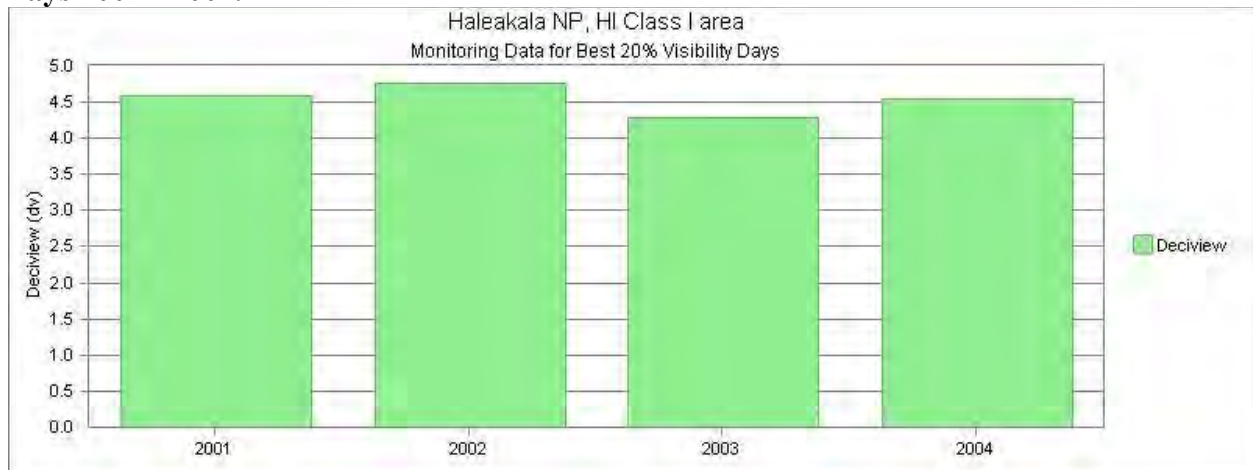
Natural Condition in deciview (20% best and worst days)

Natural visibility represents the visibility condition that would be experienced in the absence of human-caused impairment. Based on EPA guidance,[7] the natural visibility for the Haleakala National Park is 2.7 deciviews for the 20% best days and 7.4 deciviews for the 20% worst days.

The natural visibility value estimations for 2064 do not include an estimate of the visibility impairment from the emissions from the Kilauea volcano, which is located in the Hawaii Volcanoes National Park. The emissions from the volcano vary from year to year, and it is not possible to estimate the emissions from the volcano or the effect they will have on Class I area visibility in the year 2064.

---

[7] http://www.epa.gov/ttn/oarpg/t1/memoranda/rh_envcurhr_gd.pdf

II.A.3. Causes of Haze

The aerosol composition measured at the Haleakala (HALE1) IMPROVE monitor on the 20% best and 20% worst days for the years 2001-2004 is presents in Figures II.A-5 through II.A-7, below. The charts show the contribution of aerosol species to light extinction (b_{ext})

Figure II.A-5: Haleakala National Park; Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for years 2001-2004.
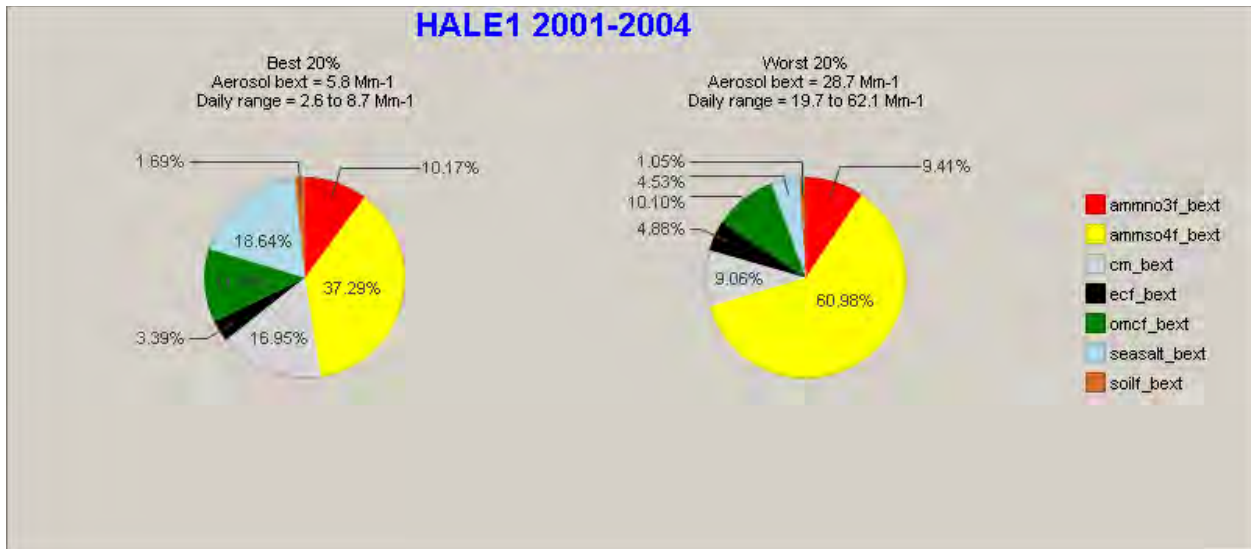
Figure II.A-6: Haleakala National Park (HALE1); Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2004.
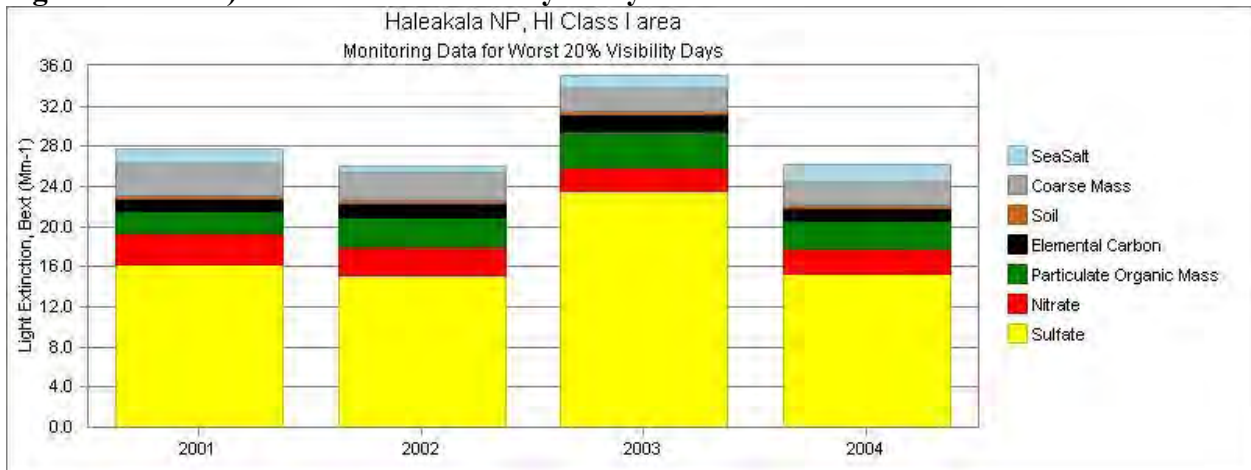
Figure II.A-7: Haleakala National Park (HALE1); Aerosol Composition (contribution to Light Extinction) on the 20% Best Days for years 2001-2004.
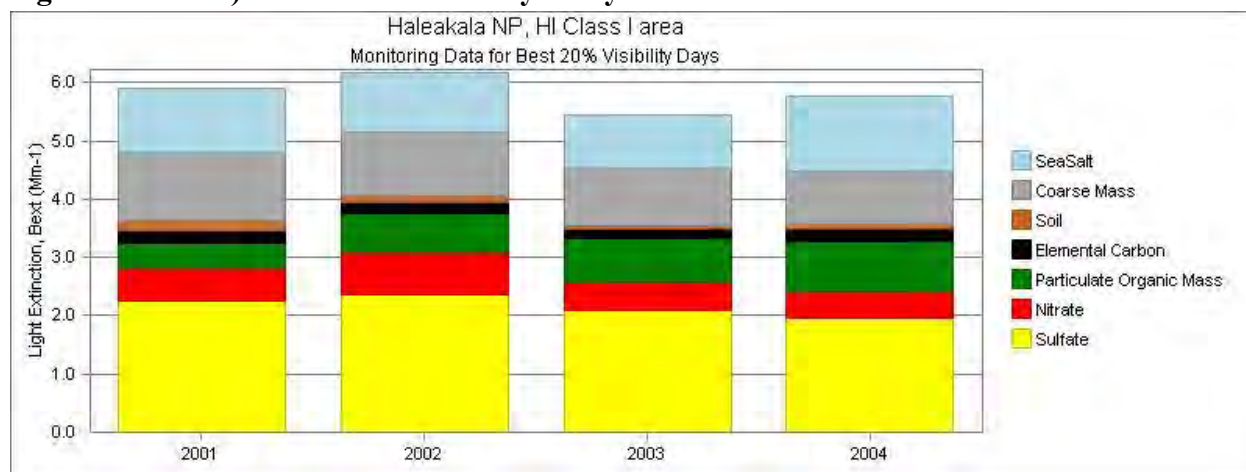
Sulfate is the largest cause of visibility degradation on the 20% worst days at Haleakala National Park, contributing to approximately 60% of the visibility degradation. Sulfate is also the largest cause of visibility degradation on the 20% best days at the park, contributing to approximately 37% of the visibility degradation. Natural causes of sulfate include the emissions from the Kilauea volcano, located in the Hawaii Volcanoes National Park, and natural marine sulfates. The emissions of the volcano vary substantially from year to year. Source apportionment assessments have estimated that the volcano causes approximately 60% of the visibility impairment at Haleakala National Park on the 20% worst days.[89] The contribution from natural marine sulfate is expected to be much smaller.[10] International transport may also contribute to sulfur visibility impairment. The major anthropogenic sources of sulfur are point sources (oil combustion) and shipping.

Nitrate contributes 9% to the visibility degradation on the 20% worst days at Haleakala. The major anthropogenic sources of nitrate on Maui are point sources, on-road and non- road mobile sources, and shipping. Non-anthropogenic sources of NO_x include wildfires and biogenic emissions.

Coarse mass contributes to 9% of the visibility degradation on the 20% worst days and 17% on the 20% best days at the Haleakala. The local sources of coarse mass include fugitive dust from paved and unpaved roads. The understanding of the sources that contribute to the coarse mass at Haleakala is fairly uncertain. For the next planning period, a detailed study of the source contribution to coarse mass and soil measured at the Haleakala Crater Class 1 area monitors may be needed to address this uncertainty.

Organic Carbon contributes 10% of the visibility degradation at the Haleakala (HALE1) monitor for the year 2001-2004. Sources of organic carbon include agricultural burning,

---

[8] Haleakala National Park Visibility Assessment, and IMPROVE PMF Factor Identification notes Positive Matrix Factorization Analysis of HALE1 & HAVO1 IMPROVE data sets April 20, 2012, State of Hawaii, Department of Health, Clean Air Branch

[9] M. Pitchford, "Causes of Haze for Hawaii's Two Class I Areas", presented at United States Department of Agriculture, Agricultural Air Quality Task Force Meeting, Wailea, Hawaii, November 13 and 15, 2005; http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_008844.pdf

[10] Yvon and Saltzman 1996, Atmospheric Sulfur Cycling in the Tropical Marine Boundary Layer. J. Geophys. Res. 101, 6911-6918.

wildfires, oil combustion, and international transport. A comparison of recent monitoring data at the Haleakala Crater monitoring site (HACR1) shows approximately half the level of organic carbon measured at the HALE1 site.[11] This is discussed in greater detail in Section II. D.2., Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site, below.

Elemental Carbon contributes to 5% of the visibility degradation at the Haleakala (HALE1) IMPROVE monitoring site monitor, which is located outside of the park. A comparison of recent data collected at the Haleakala Crater monitoring site (HACR1) shows lower levels of elemental carbon than data measured the HALE1 site.[12] This is discussed in greater detail in VIII.B. Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site.

Soil contributes to 1% of the visibility degradation at the Haleakala National Park. The soil impact varies seasonally, with the highest levels in the springtime, and appears to be associated with international transport.

Sea Salt contributes to 1% of visibility impairment of the 20% worst days at Haleakala National Park, and 18% on the 20% best days.

II.A.4. Comparison of Baseline 2001-2004 data to 2005 Data

For the Hawaii Regional Haze SIP, Hawaii DOH and EPA have selected 2005 as the base year inventory because Hawaii's 2005 inventory includes a more accurate inventory of point sources emissions than Hawaii's 2002 inventory. Since 2005 is not within the baseline period of 2000-2004, it is necessary to compare the level and the aerosol composition of visibility impairing pollutants in the year 2005 to the year 2001-2004 baseline time period.

The Haleakala National Park (HALE1); Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for the year 2005 is presented in the figure below. The level of light extinction is comparable for the 20% best days (4.6 Mm^{-1} in 2005 compared to 5.8 Mm^{-1} in 2001-2004) and 20% worst days (29 Mm^{-1} in 2005 compared to 28.7 Mm^{-1} in 2001-2004). The aerosol composition is similar for the two time periods.

---

[11] Review of VIEWS2.0 2009-2010 Haleakala National Park Organic and Elemental Carbon Data, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch, and Comparison of Haleakala National Park HALE1 and HACR1 IMPROVE Monitoring Site 2007-2008 Data Sets, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch.

[12] Ibid.

Figure II.A-8: Haleakala National Park (HALE1); Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for the year 2005.
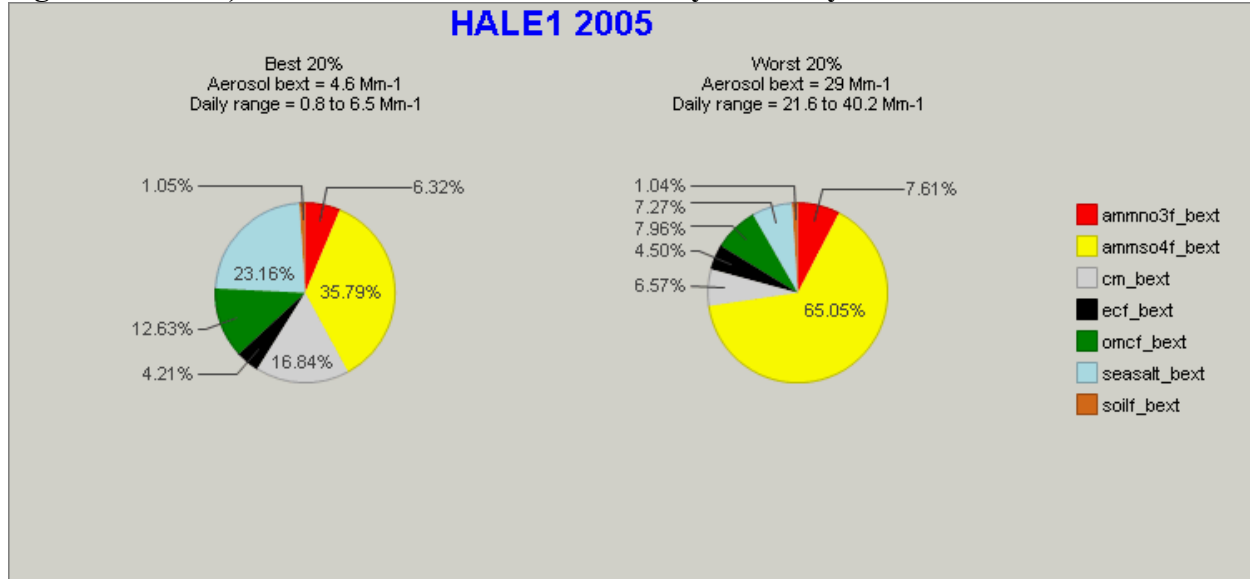

Since the measured visibility impairing pollution in 2005 was consistent with the baseline years, it is reasonable to assume that for the purposes of Regional Haze Planning that the 2005 emissions were sufficiently consistent with the emissions in 2000-2004 for this year to be used as the baseline for the Regional Haze Plan.

II.A.4. Uniform Rate of Progress

The Regional Haze Rule requires that, in setting RPGs, states must consider the rate of progress needed to reach natural visibility conditions by 2064 (referred to as the "uniform rate of progress" (URP) or the "glide path") and the emission reduction measures needed to achieve that rate of progress over the period of the SIP. 40 CFR 51.308(d)(1)(i)(B).

For the 20% worst days, the URP in deciviews per year (i.e. slope of the glide path) is determined by the following equation:

URP = [Baseline Condition - Natural Condition] / 60 years

By multiplying the URP by the number of years in the planning period one can calculate the amount of progress needed by 2018 to be on the path to achieving natural visibility conditions by 2064. This first Regional Haze implementation plan covers the fourteen-year period of 2004-2018. Thus:

2018 UPG = [URP] x [14 years]

See EPA's *Guidance for Setting Reasonable Progress Goals Under the Regional Haze Rule* § 2.2 (June 1, 2007). For the best days at each Class I area, the State must ensure no degradation in visibility for the least-impaired (20% best) days over the same period. As with natural conditions, the URP can be adjusted as new visibility information becomes available.

Figure II-9 shows the 2018 URP chart for the worst 20% days at Haleakala National Park.

Figure II.A-9: Haleakala National Park: Uniform Rate of Progress, Worst 20% Visibility Days.[13]
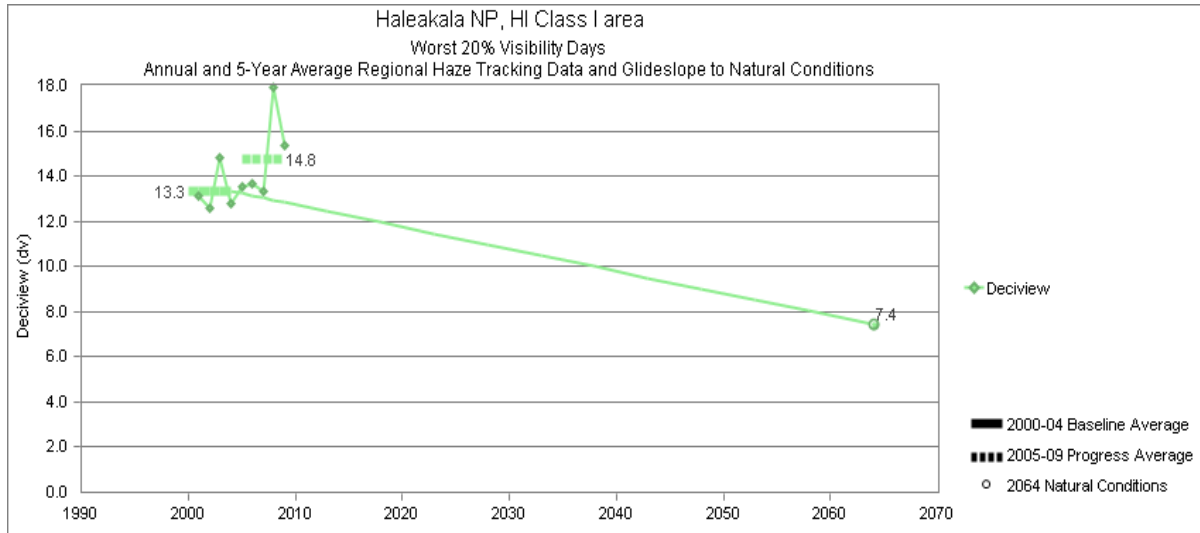
Table II.A-1 shows the Haleakala National Park URP for the Worst 20% Visibility Days and Table II.A- 2 shows the Baseline and Natural Conditions for the Best 20% Visibility Days.[14]

Table II.A-1: Haleakala National Park- Summary of Uniform Rate of Progress for 20% Worst Days

Baseline Condition (deciview)	Natural Visibility (deciview)	Total Improve-ment by 2064 (deciview)	URP (deciview/ year)	2018 URP Goal (deciview)	Improve-ment needed by 2018 (deciview)
13.3	7.4	5.9	0.098	11.92	1.38

Table II.A-2: Haleakala National Park- Summary of Baseline and Natural for 20% Best Days

Class I Area	Baseline Condition (deciview)	Natural Visibility (deciview)
Haleakala National Park	4.6	2.7

---

[13] http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx

[14] http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx

II.A.5. Visibility Trends at Haleakala from 2001-2009

The Haze Index (in deciview) at Haleakala National Park, shown in Figure II.A-10 appears to indicate that the visibility on the worst 20% days is not improving over the year 2001 through 2009. The monitoring data indicates that the level of light extinction due to sulfates is increasing, most likely due to the increase in volcano activity, as shown in Figure II.A-11: Haleakala National Park; Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009. The degree of light extinction due to species other than sulfate appear to be approximately level, as shown in Figure II.A-12: Haleakala National Park; Non – sulfate Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009. The monitoring data for the 20% Best days shows that the visibility has changed very little over from 2001 to 2009.

Figure II.A-10: Haleakala National Park; Haze Index (in deciview) on the 20% Worst Days for years 2001-2009.
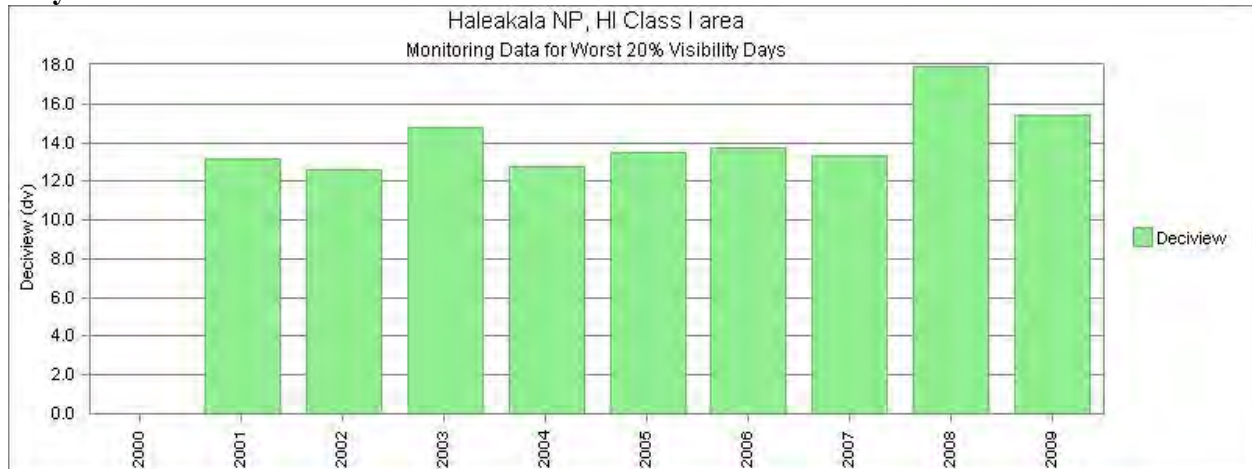
Figure II.A-11: Haleakala National Park; Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009

16
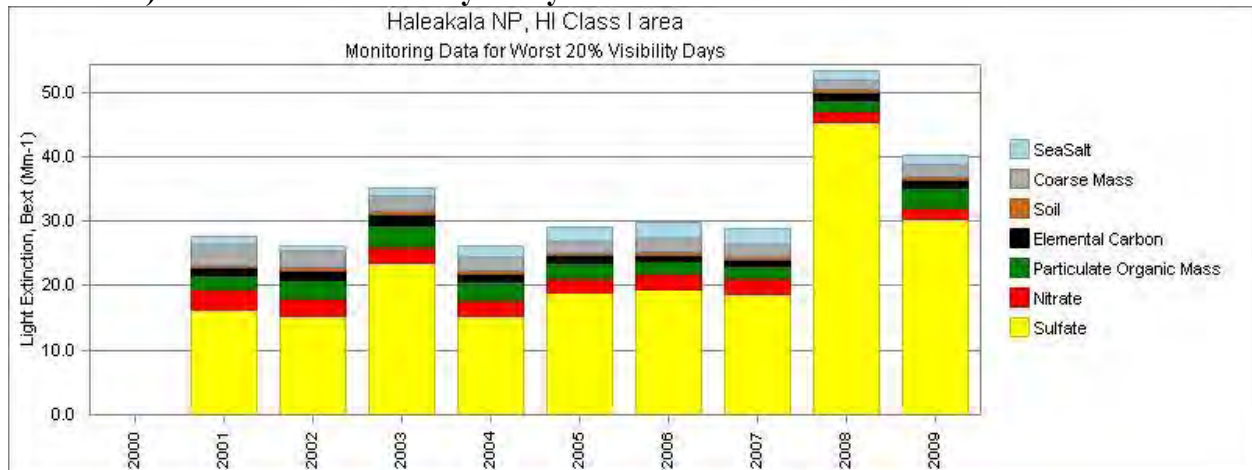
Figure II.A-12: Haleakala National Park; Non – sulfate Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009
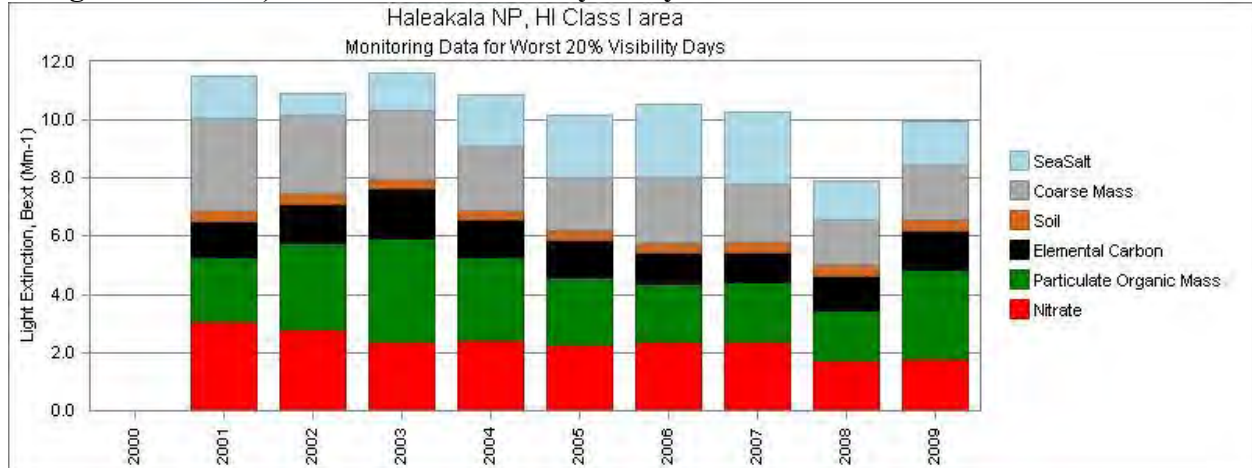
Figure II.A-13: Haleakala National Park; Aerosol Composition (contribution to Light Extinction) on the 20% Best Days for years 2001-2009
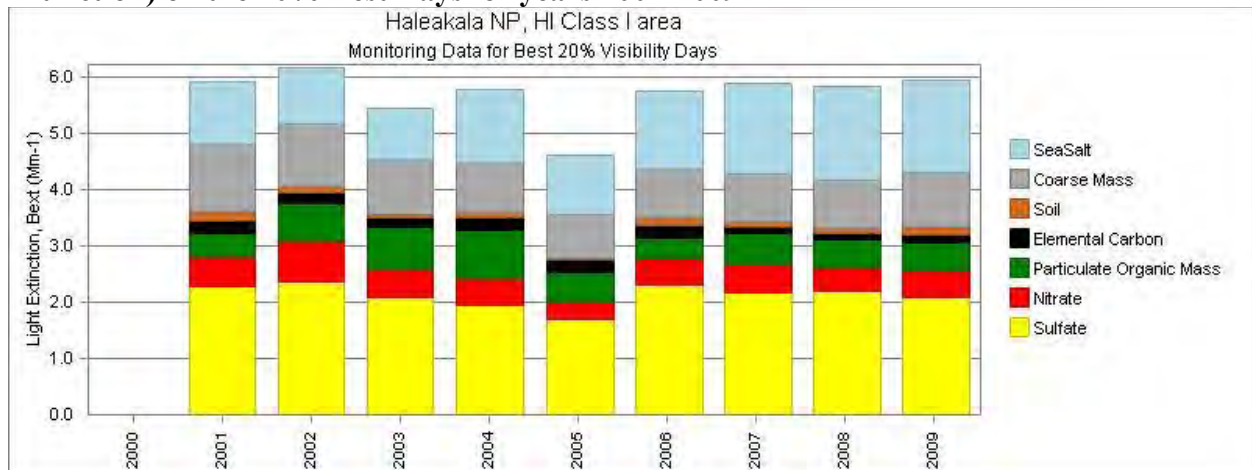
<u>Organic and Elemental Carbon at the two IMPROVE monitors (HALE1 and HACR1) at Haleakala National Park, 2009-2010[15]</u>

     Currently there are two IMPROVE monitoring sites operating in or near the Haleakala National Park. The Haleakala (HALE1) IMPROVE monitoring site is located outside of the Haleakala National Park near to the Maui Central Valley, at an elevation of 1153 meters. The HALE1 IMPROVE monitoring site began operation at end of 2000, and will close in May of 2012. The Haleakala Crater (HACR1) IMPROVE monitoring site is at the park's Western boundary, at an elevation of 2158 meters. A comparison of the data for all species is discussed in

---

[15] A comparison of the data for all species is discussed in detail in the Section VIII.B. Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site.

detail in the Section VIII.B. of this document, Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site.

Organic and elemental carbon data for the two IMPROVE monitors (HALE1 and HACR1) at Haleakala National Park for 2009 and 2010 is presented in Figures II.A-14 through II.A-17, below. The levels of organic and elemental carbon are low at both monitoring sites for most days. At the HALE1 site, the measured fine organic mass is below 1 µg/m3, except for 5 days. At the HACR1 site, the measured levels of organic carbon are below 1 µg/m3 for all days. (Note that the vertical axis scale differs between the HALE1 and HACR1 graphs). At the HALE1 site, the measured elemental carbon is below 0.2µg/m3, except for 5 days. At the HACR1 site, the measured elemental carbon is below 0.2 µg/m3 for all days.

Figure II.A-14: Haleakala National Park (HALE1); Organic carbon (µg/m3)
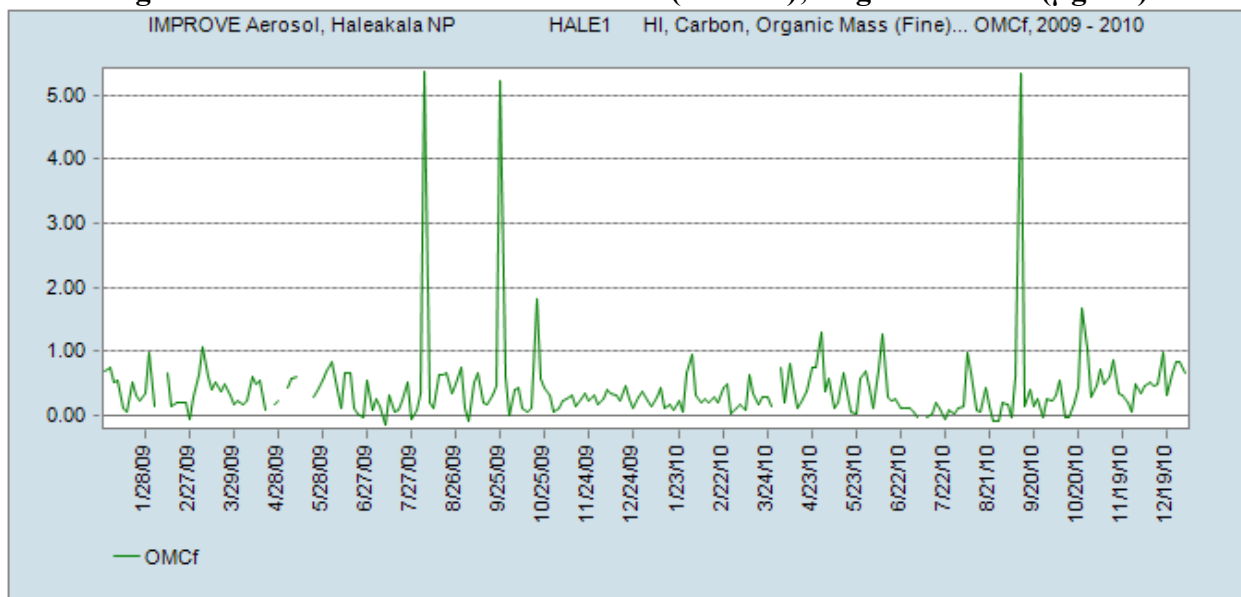
Figure II.A-15: Haleakala National Park (HACR1); Organic carbon (µg/m3)
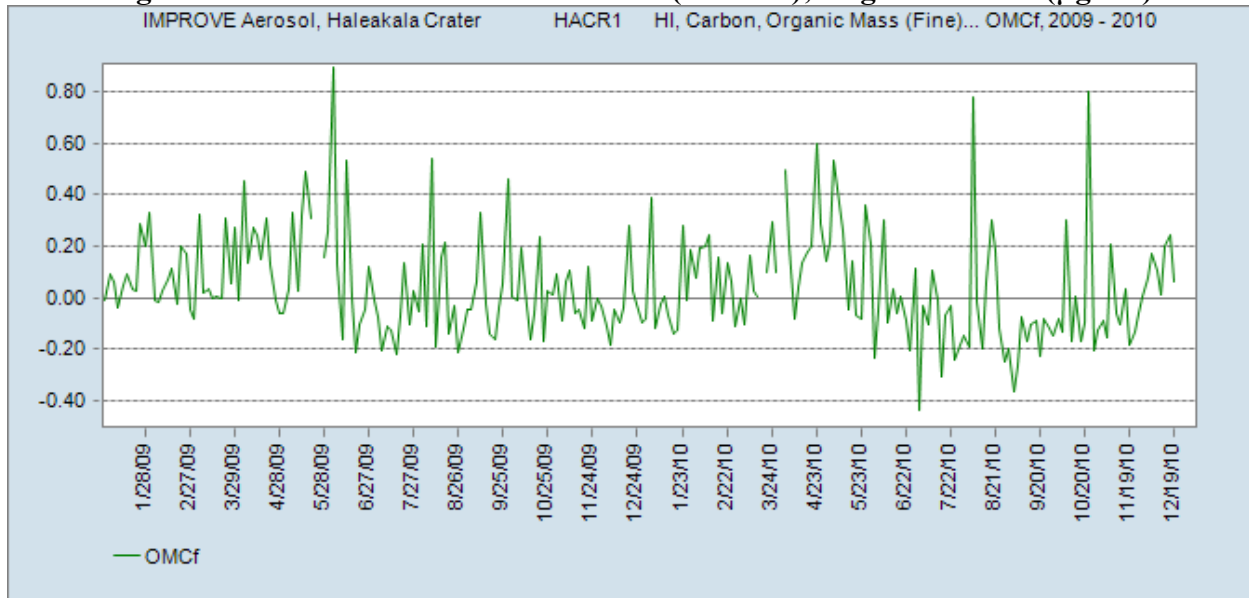
Figure II.A-16: Haleakala National Park (HALE1); Elemental carbon (µg/m3)
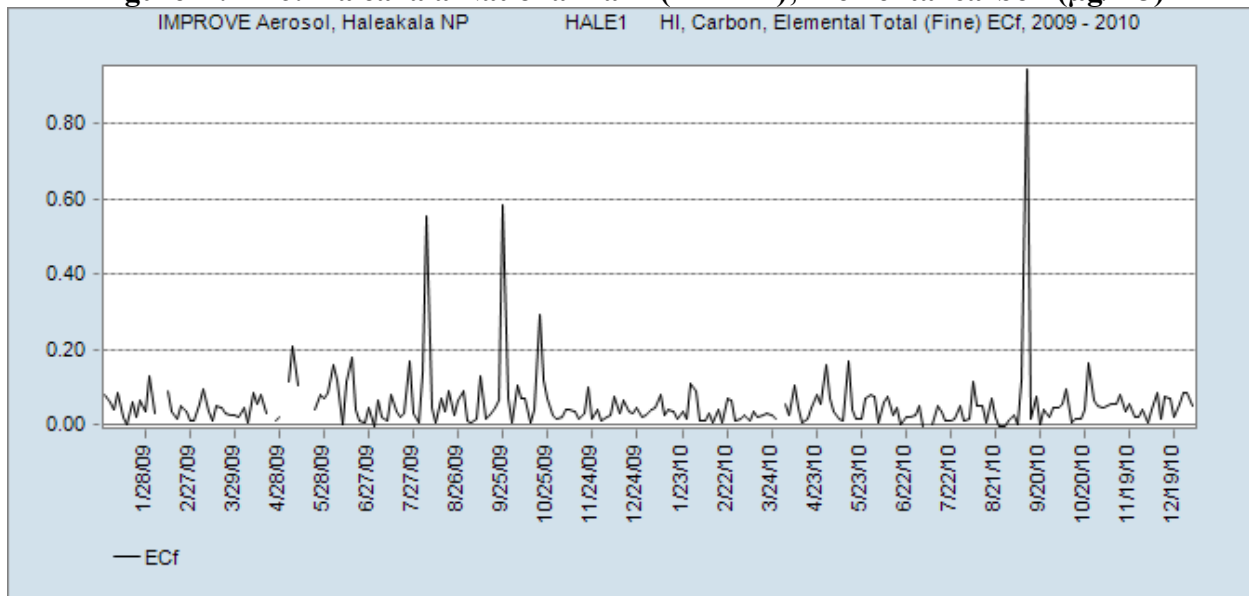
Figure II-17: Haleakala National Park (HACR1); Elemental carbon (µg/m3)

IMPROVE Aerosol, Haleakala Crater   HACR1   HI, Carbon, Elemental Total (Fine) ECf, 2009 - 2010

—— ECf
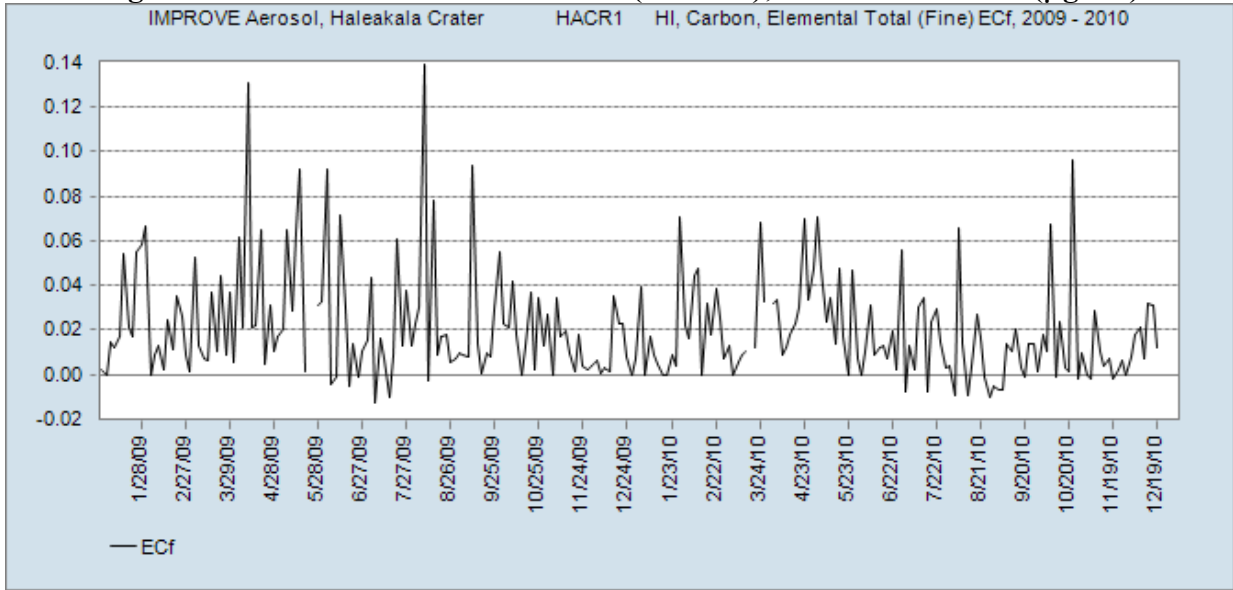
II.B. HAWAII VOLCANOES NATIONAL PARK

II.B.1. Hawaii Volcanic National Park Description[16]

Hawaii Volcanoes National Park (NP) was first established as Hawaii NP in 1916 to protect the volcanoes, Kilauea and Mauna Loa on Hawaii and Haleakala on Maui.[17] The park now encompasses 209,695 acres ranging over varied ecosystems from the volcano's summit to the Pacific Ocean, with many unique plant and wildlife species.

Air quality in Hawaii Volcanoes NP is affected by a number of emission sources, primarily Kilauea Volcano. Currently the volcano emits between 1,000 and 2,000 tons of sulfur dioxide each day, as well as other gases, including hydrogen sulfide, hydrogen chloride, hydrogen fluoride, and trace metals like mercury. Sulfur dioxide reacts with sunlight, oxygen, dust particles, and water in the air to form a mixture known as volcanic smog or "vog." The vog not only creates a haze that obscures visibility, but it is very acidic, causing acid rain and affecting human health, cultural resources, and vegetation. Adding to the haze are marine aerosols, which can further diminish visibility. In addition, when hot lava reaches seawater, large clouds of mist are formed, called laze, which contain hydrochloric acid and other airborne contaminants harmful to human health. Although the volcano dominates total emissions, local anthropogenic sources like power generating stations and automobiles can also affect air quality and visibility, releasing nitrogen oxides, particulates, and other pollutants as well as sulfur dioxide.

Sulfur dioxide is a significant health concern in Hawaii Volcanoes NP and downwind, so sulfur dioxide is monitored at two locations, Jaggar Museum and the Kilauea Visitor Center. The park posts current sulfur dioxide concentrations from both monitors on its website.

Visibility Monitor Location

The Hawaii Volcanoes National Park IMPROVE Site is located on the east to southeastern slopes of Mauna Loa on the island of Hawaii[18]. More specifically, it is situated on the northeastern rim of the Kilauea crater. The site elevation is 1204 m (3949 ft), some 124 m above the crater floor at 1080 m (3542 ft). Volcanic emissions (SO_2) from the Kilauea crater (caldera) presently amount to 100 to 200 metric tons per day. This area is all part of the active Kilauea Volcano. There are other sources, including lava flows and other craters along the East Rift Zone extending out to ~ 20 km to the east-southeast from the monitoring site. The most recent and continuing activity, which has been in progress since 1983, is along the East Rift Zone extending out to ~ 20 km to the east-southeast from the monitoring site. The most recent and continuing activity, which has been in progress since 1983, is centered on the Pu'u O'o crater some 20 km (12 miles) east-southeast from the monitoring site. SO_2 Emissions from Pu'u O'o

---

[16] http:// www.coha.dri.edu/web/state_analysis/Hawaii/HawaiiVolcanoesNP_metdesc.html, Hollingshead, Anette T., S. Businger, R. Draxler, J. Porter, and D. Stevens. Dispersion Modeling of the Kilauea Plume. Boundary Layer Meteorology 108: 124-144. 2003.,and Okamura, Arnold, Hawaii Volcanoes Observatory, personal conversation with Dan Freeman

[17] http://www.nature.nps.gov/air/Permits/aris/havo/?CFID=16689542&CFTOKEN=67492682

[18] http://www.coha.dri.edu/web/state_analysis/Hawaii/HawaiiVolcanoesNP_metdesc.html

amount to 1000 to 2000 metric tons per day, mostly from the main vent at an elevation of ~ 600 m (2000 ft) (Okamura, 2003).

Besides the Kilauea Volcano system, the major terrain feature affecting meteorology and air quality at the monitoring site is the 4170 m (13,681 ft) high Mauna Loa cone, about 35 km (22 mi) to the west of the monitoring site.

Wind

Located on the Southeast slope of Mauna Loa, the monitoring site is well exposed to the east-to-west trade-wind flow. During trade-wind conditions, which predominate 80 to 95% of the time from May through September, and 50 to 80% during the rest of the year, prevailing wind directions should thus be generally east to west, typically with speed of 5 mps or greater. During northeast trade-wind conditions, a clock-wise eddy is produced to the west of the island that has significant effects on transport of local (volcanic) emissions to the islands lee-side (west side). Mountain-valley slope flow should be evidenced at the site by nighttime westerly to northerly drainage flow and daytime easterly to southerly upslope flow. Exceptions to these conditions would occur during frontal passages associated with synoptic weather systems, and, at the site elevation, during upper atmosphere low-pressure system passages.

Inversions

The predominant inversion phenomenon is the Trade-layer inversion, or Marine Boundary Layer. The marine layer will have much less diurnal variability than continental inversions because of the oceanic influence. Typical trade-layer inversion heights in the vicinity of Volcanoes NP are probably near 2000m above sea level, with some variability due to seasonal effects. At the site elevation of 1204 m the monitoring site would thus probably be within this layer most of the time, when trade-wind conditions predominate. During this condition, relative humidity will be typically be high, 70% or greater. When the trade-wind layer height is below the monitoring site, relative humidity will be much lower.

If more continental types of inversions occur, say within the Kilauea crater during periods when the trade winds are absent or light and variable, they would occur over a much smaller scale, with significant diurnal variability. Over a period of time aerosol concentrations could presumably build up due to SO_2 emissions within the crater, although it is not clear that such conditions can occur with any frequency.

Meteorological Indicators

A unique atmospheric phenomenon of this region is the so-called vog (volcanic smog) that occurs when SO_2 and other volcanic pollutants react with oxygen and atmospheric moisture. Information on this phenomenon is available at: http://wrgis.wr.usgs.gov/fact-sheet/fs169-97/

Thus, volcanic emissions are a likely candidate for the source of aerosols monitored at the IMPROVE site, which are typically high in particulate sulfate composition. There are nevertheless other potential sources, particularly sea salt sulfate or transported Asian dust, that also typically have high sulfate composition. Asian dust emissions have been detected at the NOAA Mauna Loa Observatory. A good indicator of Asian dust as a significant aerosol source at the monitoring site would be high correlation with Asian dust events, or occurrence during low relative humidity conditions, when the site is above the trade-wind layer. Local volcanic emissions might be indicated by a strong correlation of high mass concentrations with wind direction from sources to the east southeast clockwise to southwest and low or negligible

concentrations during light downslope (northerly) winds, or by buildup during calm or light wind periods. At low concentrations, a significant sea sulfate contribution might be indicated by high correlation with Haleakala NP measurements when both sites are within the trade-wind layer and have similar relative humidity measurements. (Note however that significant volcanic plume impaction has been observed at Haleakala NP when transported from the vicinity of Volcanoes NP). (Hollingshead et al., 2003)

<u>Nearby Data Stations</u>

Meteorology is monitored at the site, in addition to aerosol composition, and this is probably the best source for representative surface meteorological data (wind direction, wind speed, temperature, relative humidity, etc.) For information on regional vertical structure, especially the height of the marine layer at the monitoring site, twice-daily upper air sounding data are collected at the NWS upper air site at Hilo. Vertical temperature profile data from Hilo are probably the best routinely collected and long-term data representative of conditions at Volcanoes NP.

II.B.2. Visibility Conditions: baseline and natural (20% best and worst days)

Baseline Conditions for the 20% best and worst days at HAVO1 in deciview

Baseline visibility for this plan is determined from the HAVO1 monitoring site for the 20% best and the 20% worst days for the years 2001 through 2004, as specified in the Regional Haze regulations under 40 CFR §51.308(d)(2)(i). The baseline visibility for the Hawaii Volcanoes National Park is calculated at 4.1 deciviews for the 20% best days and 18.9 deciviews for the 20% worst days. . Figure II.B-1, below, shows the baseline for the 20% worst days for each of the years 2001-2004. Figure II.B-2, below, shows the baseline for the 20% best days for each of the years 2001-2004.

The natural visibility value estimations for 2064 do not include an estimate of the visibility impairment from the emissions from the Kilauea volcano, which is located in the Hawaii Volcanoes National Park. The emissions from the volcano vary from year to year, and it is not possible to estimate the emissions from the volcano or the effect they will have on Class I area visibility in the year 2064.

Figure II.B-1: Hawaii Volcanoes National Park; Baseline Visibility for the 20% Worst Days 2001 - 2004
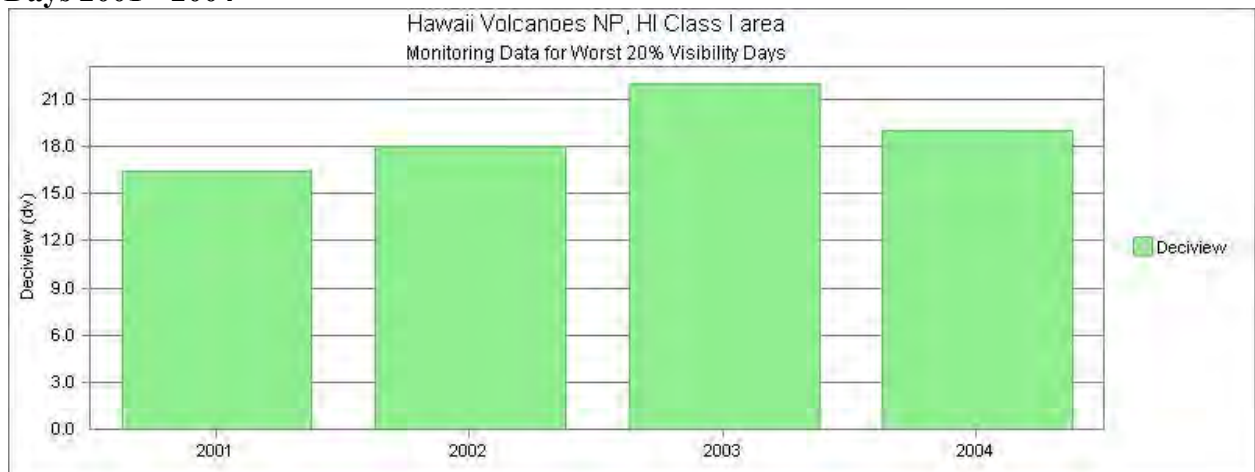
Figure II.B-2: Hawaii Volcanoes National Park; Baseline Visibility for the 20% Best Days 2001 - 2004
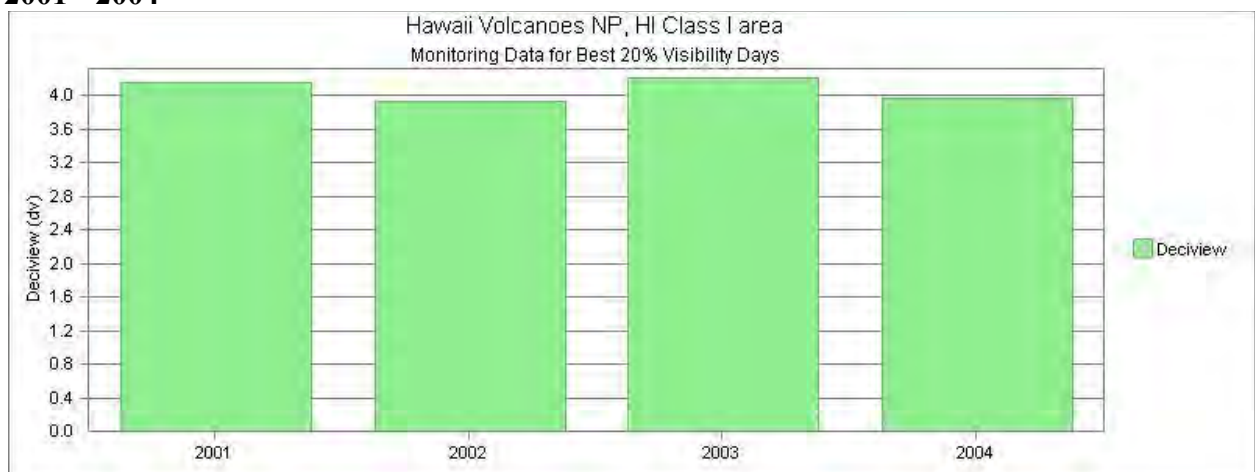
Natural Conditions (20% best and worst days)

Natural visibility represents the visibility condition that would be experienced in the absence of human-caused impairment. Based on EPA guidance, the natural visibility for the Hawaii Volcanoes National Park is 2.2 deciviews for the 20% best days and 7.2 deciviews for the 20% worst days.

II.B.3 Causes of Haze

The aerosol composition measured at the Hawaii Volcanoes National Park (HAVO1) IMPROVE monitor on the 20% best and 20% worst days for the years 2001-2004 is presents in Figures II.B-3 through II.B-5 II.A.2.c.1-3, below. The charts show the contribution of aerosol species to light extinction (b_{ext}).

Figure II.B-3: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for years 2001-2004
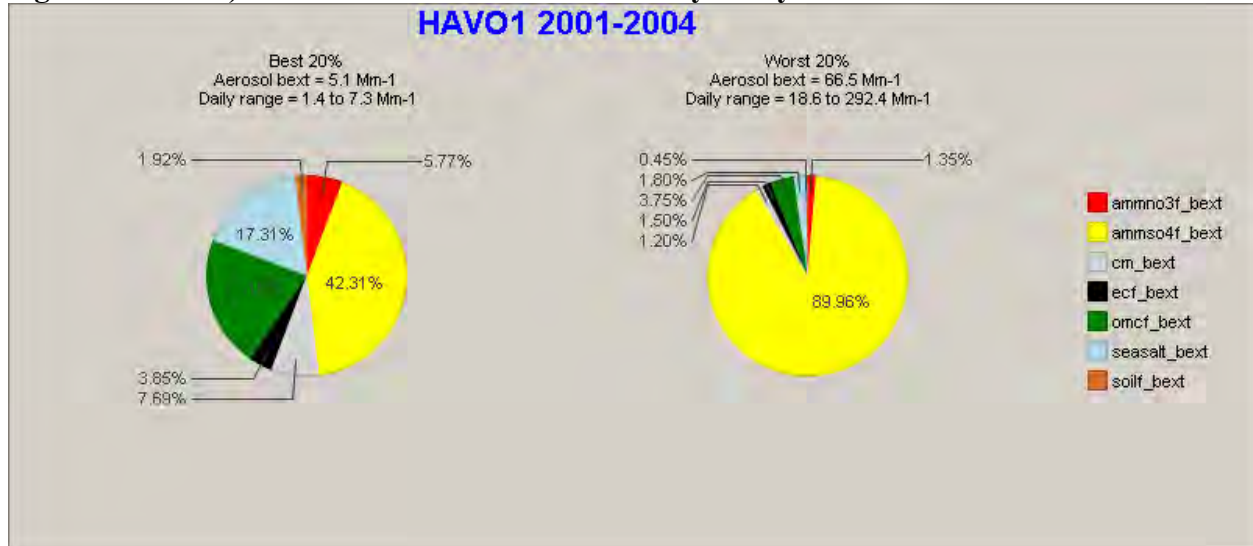
Figure II.B-4: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Worst Days for years 2001-2004
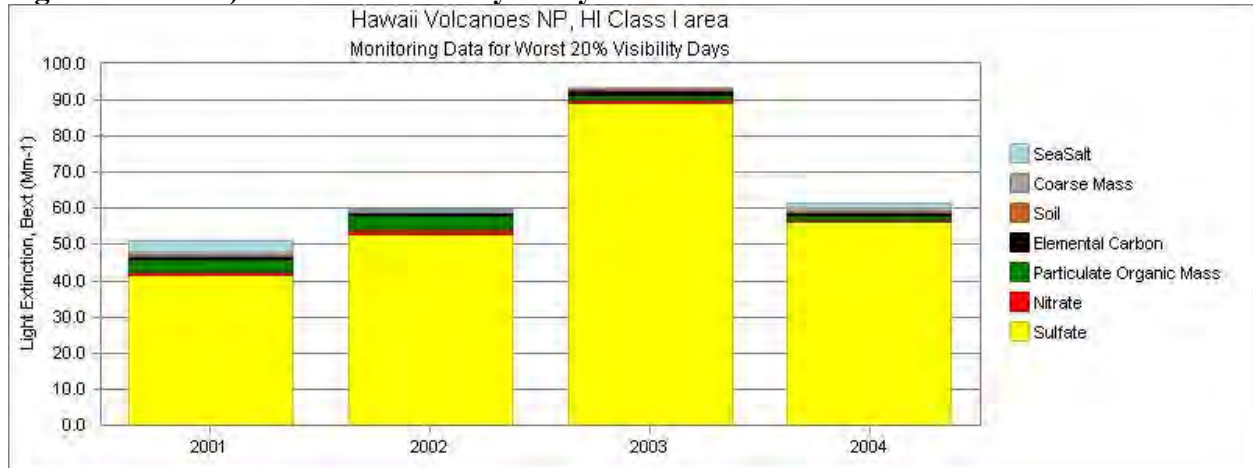
Figure II.B-5: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Best Days for years 2001-2004
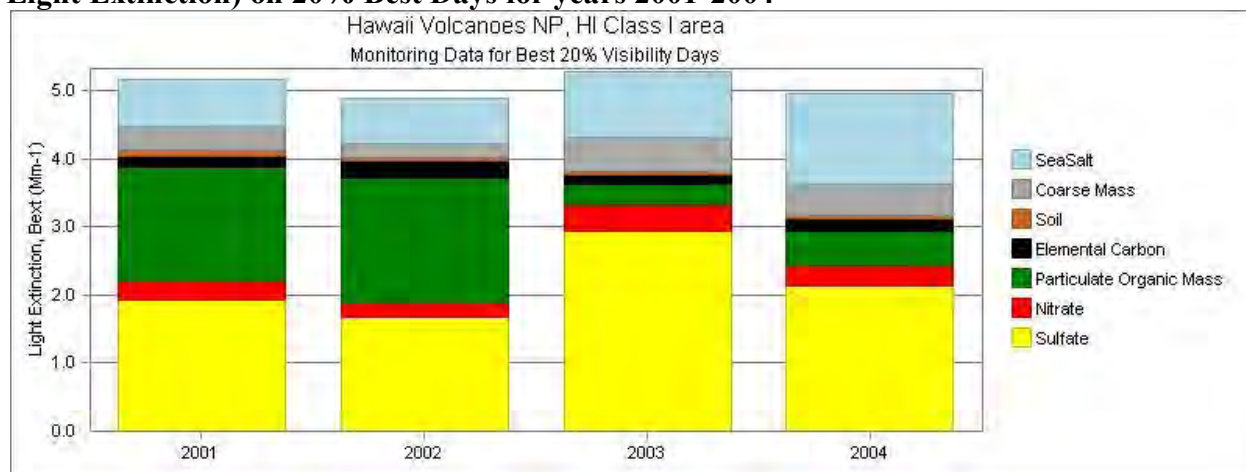
Sulfate is the largest cause of visibility degradation on the 20% worst days at Hawaii Volcanoes National Park, contributing to approximately 90% of the visibility impairment. Sulfate is the also the largest cause of visibility degradation on the 20% best days at the park, contributing to approximately 42% of the visibility impairment. Natural causes of sulfate include the emissions from the Kilauea volcano, located in the Hawaii Volcanoes National Park, and natural marine sulfates. The emissions and impact of the volcano varies substantially from year to year. Source apportionment assessments have estimated that the volcano causes approximately 90% of the visibility impairment at Hawaii Volcanoes National Park on the 20% worst days.[19, 20] The natural marine sulfate impact is expected to be much smaller.[21] Anthropogenic sources of sulfur on the Island of Hawaii include point sources (oil combustion), and shipping.

Nitrate contributes 1% to the visibility degradation on the 20% worst days at Hawaii Volcanoes National Park.

Organic Carbon contributes 4% of the visibility degradation at the Hawaii Volcanoes National Park during the 2001 – 2004 time period. Natural sources of organic carbon comprise the majority of the emission inventory and include wildfires and biogenic emissions. Anthropogenic sources of emissions include area sources and mobile sources.

Elemental Carbon contributes to 1% of the visibility degradation at Hawaii Volcanoes National Park.

Coarse mass contributes to 1% of the visibility degradation at the Hawaii Volcanoes National Park. The sources of coarse mass include fugitive dust, for paved and unpaved roads.

Soil contributes to 1% of the visibility degradation at each of the Class I Areas. The soil impact varies seasonally, with the highest levels in the springtime, and appears to be associated with international transport.

---

[19] Hawaii Volcanoes National Park Visibility Assessment, and IMPROVE PMF Factor Identification notes Positive Matrix Factorization Analysis of HALE1 & HAVO1 IMPROVE data sets April 20, 2012, State of Hawaii, Department of Health, Clean Air Branch
[20] M. Pitchford, "Causes of Haze for Hawaii's Two Class I Areas", presented at United States Department of Agriculture, Agricultural Air Quality Task Force Meeting, Wailea, Hawaii, November 13 and 15, 2005;
[21] Yvon and Saltzman 1996, Atmospheric Sulfur Cycling in the Tropical Marine Boundary Layer. J. Geophys. Res. 101, 6911-6918.

Sea Salt contributes to 1% of visibility impairment of the 20% worst days at Hawaii Volcanoes National Park, and 17% on the 20% best days.

II.B.4. Comparison of Baseline 2001-2004 data to 2005 Data

For the Hawaii Regional Haze SIP, Hawaii DOH and EPA have selected 2005 as the base year inventory because Hawaii's 2005 inventory includes a more accurate inventory of point sources emissions than Hawaii's 2002 inventory. Since 2005 is not within the baseline period of 2000-2004, EPA has performed a comparison of the aerosol composition of the 2005 data and 2001-2004 data for Hawaii Volcanoes National Park.

The Hawaii Volcanoes National Park (HAVO1); Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for the year 2005 is presented in the figure below. The level of light extinction is comparable for the 20% best days (4.3 Mm^{-1} in 2005 compared to 5.8 Mm^{-1} in 2001-2004) and 20% worst days (90.9 Mm^{-1} in 2005 compared to 66.5 Mm^{-1} in 2001-2004). The level of organic carbon is lower on 2005 than for the 2001-2004 time period, but similar to the level of organic carbon for the years 2003 and 2004. The difference in the level of sulfate reflects the difference in volcano activity. The levels of nitrate, coarse mass, elemental carbon, sea salt and soil are similar for the two time periods.

Figure II.B-6: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Best and 20% Worst Days for the year 2005
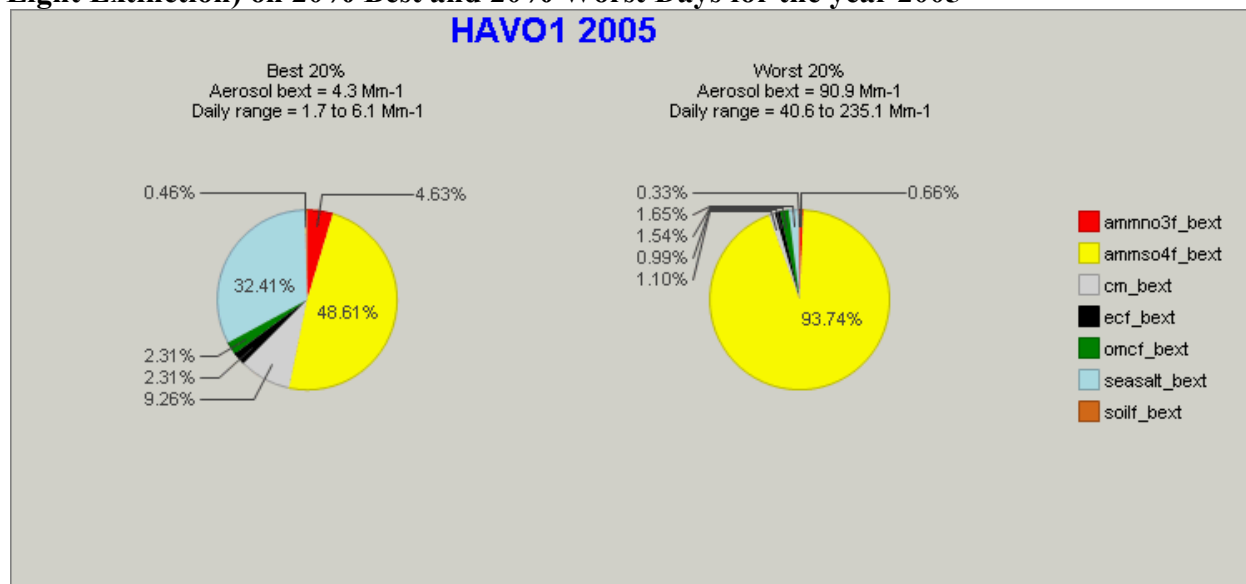

Since the measured visibility impairing pollution in 2005 was consistent with the baseline years, it is reasonable to assume that for the purposes of Regional Haze Planning, that the 2005 emissions were sufficiently consistent with the emissions in 2000-2004 for this year to be used as the baseline for the Regional Haze Plan.

II.B.4. Uniform Rate of Progress

Figure II.B-6 shows the 2018 URP for the Worst 20% days at Hawaii Volcanoes National Park.

(See section II.A.4 for an explanation of URP). Table II.B-1, Summary of Uniform Rate of Progress for 20% Worst Days, shows the Uniform Rate of Progress for Hawaii Volcanoes National Park.

Figure II.B-6: Hawaii Volcanoes National Park: Uniform Rate of Progress, Worst 20% Visibility Days.[22]
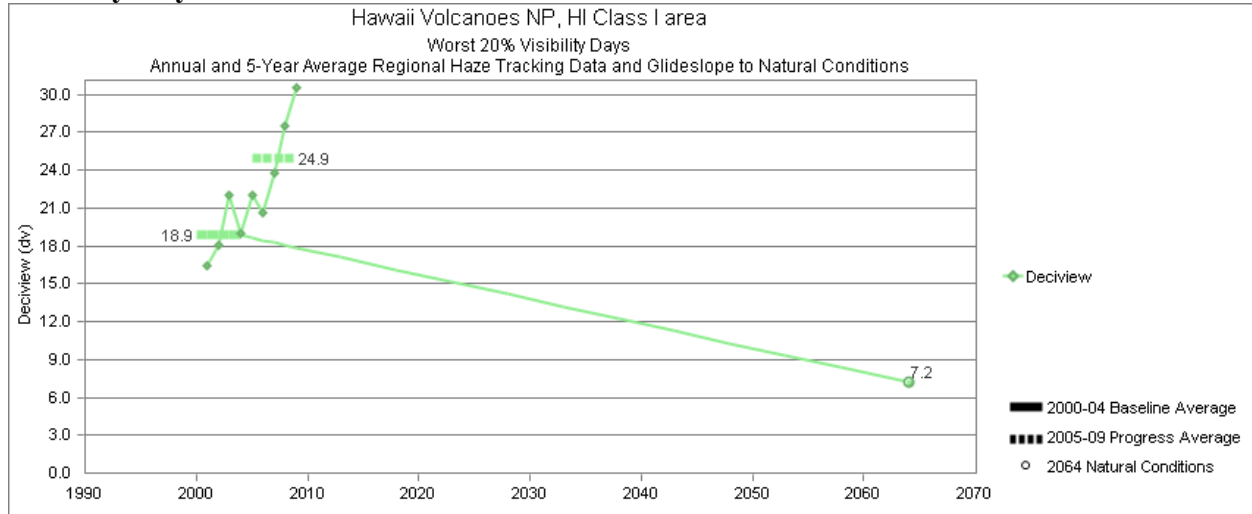
Table II-B-1 shows the Hawaii Volcanoes National Park URP for the Worst 20% Visibility Days and Table II.B-2 shows the Baseline and Natural Conditions for the Best 20 % Visibility Days.[23]

Table II.B-1: Hawaii Volcanoes National Park- Summary of Uniform Rate of Progress for 20% Worst Days

Class I Area	Baseline Condition (deciview)	Natural Visibility (deciview)	Total Improvement by 2064 (deciview)	URP (deciview /year)	2018 URP Goal (deciview)	Improve-ment needed by 2018 (deciview)
Volcanoes	18.9	7.2	11.7	0.19	16.17	2.73

Table II.B-2: Hawaii Volcanoes National Park- Baseline and Natural Conditions for 20% Best Days

Class I Area	Baseline Condition (deciview)	Natural Visibility (deciview)
Hawaii Volcanoes National Park	4.1	2.2

---

[22] http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx
[23] http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx

Figures II.B-7 and Figures II.B-8 show historic visibility photos that are representative of the Worst 20% days and the Best 20% days at Hawaii Volcanoes National Park.

Figure II.B-7: Photograph of Hawaii Volcanoes National Park- Worst 20% days [24]: 19 deciview

---

[24] Hawaii Volcanoes National Park, Hawaii, Photographic Archive 1986 – 1990
http://vista.cira.colostate.edu/Datawarehouse/IMPROVE/Data/Photos/HAVO/html/IMG0003.htm

Figure II.B-8: Photograph of Hawaii Volcanoes National Park- Best 20% days: 4 deciview

II.B.5. Visibility Trends from 2001-2009

The Haze Index (in deciview) at Hawaii Volcanoes National Park, shown in Figure II.B-9 appears to indicate that the visibility on the worst 20% days is not improving over the years 2001 through 2009. The monitoring data indicates that the level of light extinction due to sulfates is increasing, most likely due to the increase in volcano activity, as shown in Figure II.B-11: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009.

The degree of light extinction due to species other than sulfate appears to be approximately level, as shown in Figure II.B-11: Hawaii Volcanoes National Park; Non – sulfate Aerosol Composition (contribution to Light Extinction) on the 20% Worst Days for years 2001-2009. The light extinction attributed to particulate organic mass is higher in the years 2001-2002 than in the following years 2003-2009. The monitoring data for the 20% Best days show that the visibility is fairly constant from 2001 to 2009.

Figure II.B-9: Hawaii Volcanoes National Park; Haze Index on 20% Worst Days for years 2001-2009
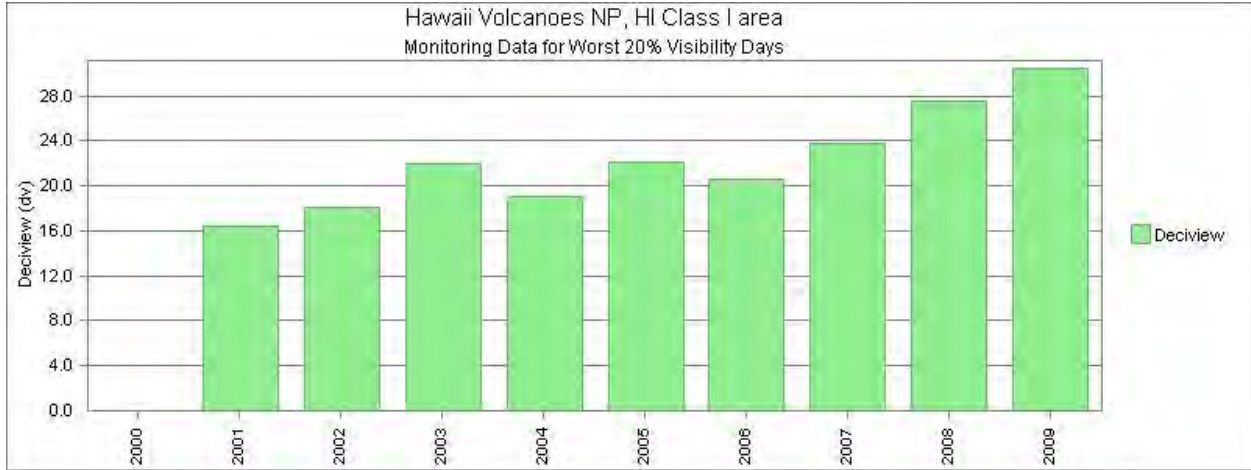
Figure II.B-10: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Worst Days for years 2001-2009

31
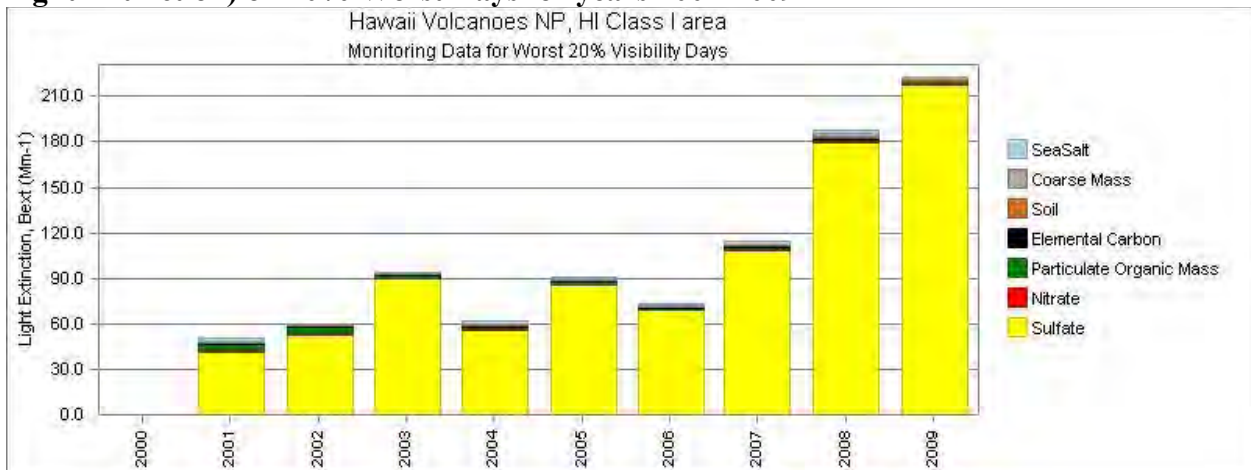
Figure II.B-11: Hawaii Volcanoes National Park; Non-sulfate Aerosol Composition (contribution to Light Extinction) on 20% Worst Days for years 2001-2009
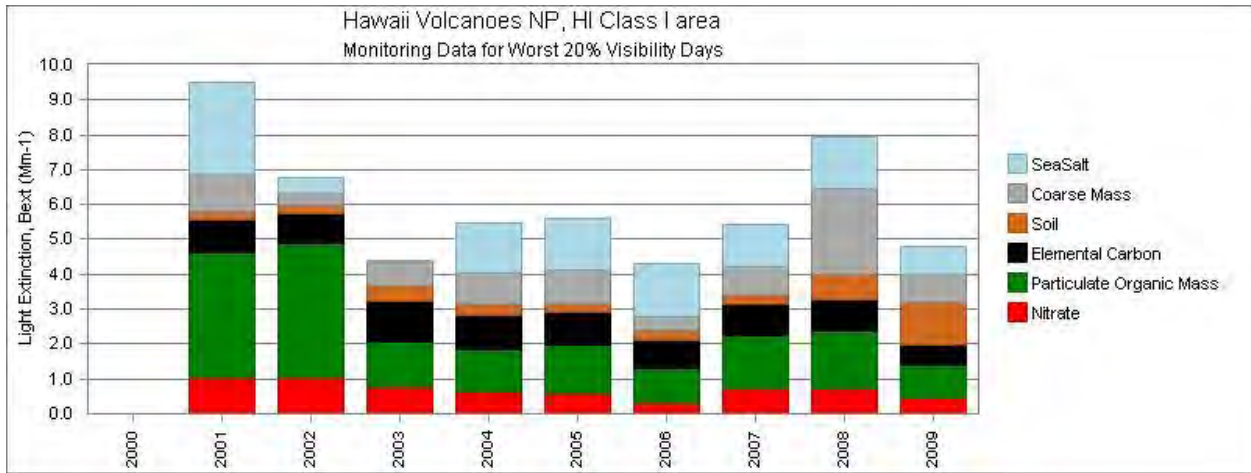
Figure II.B-12: Hawaii Volcanoes National Park; Aerosol Composition (contribution to Light Extinction) on 20% Best Days for years 2001-2009
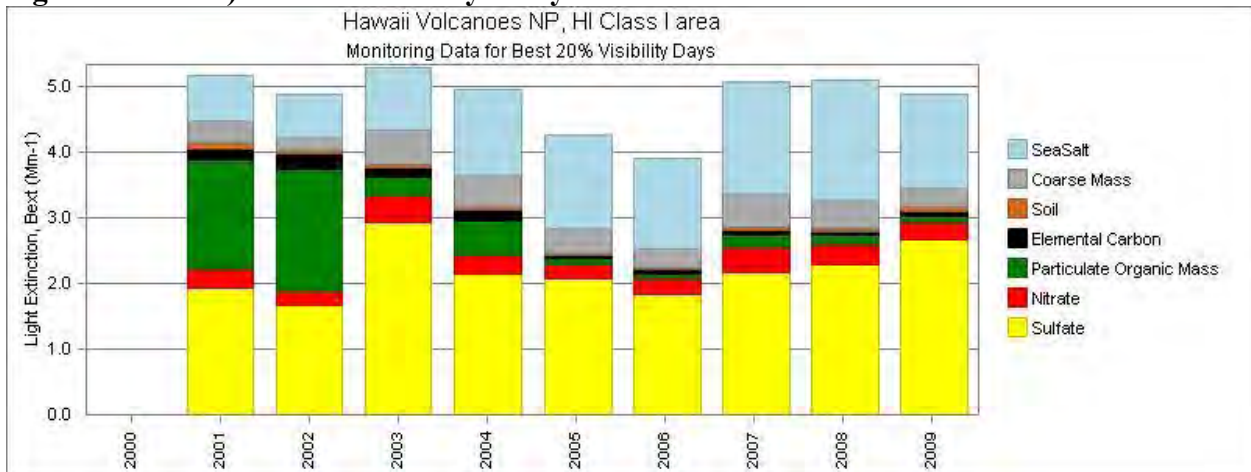
III. Summary of Previous Visibility Assessments at the Haleakala and Hawaii Volcanoes National Parks.

The causes of visibility impairment at the Haleakala and Hawaii Volcanoes National Parks have been assessed by the NOAA and also by the Hawaii DOH. The results of these studies are briefly summarized below. EPA reviewed these assessments as part of the basis for determining causes of haze for the Haleakala National Park and the Hawaii Volcanoes National Park.

III.A. NOAA Assessment of Causes of Haze for Hawaii's Two Class I Areas

The causes of haze for the Haleakala and Hawaii Volcanoes National Parks were examined by Marc Pitchford of NOAA in 2005.[25] This work identified the possible causes of visibility impairment within each of Hawaii's two Class I National Parks, based on wind trajectories and a source apportionment analysis using Positive Matrix Factorization (PMF).

Pitchford found that "wind trajectories provided a good indication that the SO2 was primarily coming from the Kilauea volcano's Pu'u ‚O'o rift zone." Particle trajectory calculations for key days indicated that there were some days when high sulfate concentrations were detected at both HAVO1 and HALE1, and other days where high sulfate concentrations were only detected at HAVO1. These results indicated that "volcanic sulfate is likely impacting haze on at least some of the worst days for Haleakala".

The Positive Matrix Factorization (PMF) analysis used combined IMPROVE PM2.5 data from both the HALE1 and HAVO1 monitors to determine six PMF factors: Volcano Sulfate, Sulfate & Nitrate, Smoke, Nitrate, Dust, and Sea Salt. The results for each of the 6 factors were based on PM2.5 concentrations at HALE1 and HAVO1 on the Worst 20% Days, as well as all days, and are shown in Table III-1: Contribution to PM2.5 Concentration, below. The results indicate that:

- Hawaii Volcanoes National Park has much greater impacts from the "volcano" PMF factor than Haleakala National Park.

- The "volcano" PMF factor is responsible for most of the haze impacts on worst visibility days at Hawaii Volcanoes National Park, and many, but not all of the worst case days at Haleakala National Park.

- Haleakala National Park has greater impacts from "smoke", "dust", and "sulfate/nitrate" PMF factors compared to Hawaii Volcanoes National Park.

---

[25] M. Pitchford, "Causes of Haze for Hawaii's Two Class I Areas", presented at United States Department of Agriculture, Agricultural Air Quality Task Force Meeting, Wailea, Hawaii, November 13 and 15, 2005; http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_008844.pdf
http://vista.cira.colostate.edu/tss/Results/HazePlanning.aspx
http://www.powershow.com/view/4f998-YmIxN/Causes_of_Haze_Update_flash_ppt_presentation

Table III-1. Contribution to PM2.5 by PMF Source Factors

	Volcano Sulfate %	Sulfate and Nitrate %	Smoke %	Nitrate %	Dust %	Sea Salt %
HAVO1 Worst 20% Days	88	3	3	4	1	1
HAVO1 All Days	70	7	7	6	3	7
HALE1 Worst 20% Days	41	20	19	11	7	2
HALE1 All Days	33	16	22	14	8	7

Pitchford finds that for the year of 2003 at Haleakala IMPROVE Monitor (HALE1), "about half of worst case days are associated with volcano emissions, while the others are associated with different factors (e.g. smoke, secondary sulfate and nitrate)." For the Hawaii Volcanoes IMPROVE monitor (HAVO1) in 2003 he find that "all worst haze days are dominated by the volcano sulfate factor". The recommendations for follow-on work include: examination of the smoke factor with respect to burning (e.g. agricultural) events; attribution of dust to local (e.g. high winds) or global (e.g. Asian dust) sources; including coarse mass into the PMF calculations to support possible attribution to local and non-local (e.g Asian dust) sources; and attribution of the "nitrate" and "sulfate/nitrate" PMF factors.

III.B. Hawaii Department of Health Source Apportionment Results

Hawaii Department of Health has conducted visibility assessments for the Haleakala and Hawaii Volcanoes National Parks.[26] The purpose of these efforts was to identify candidate sources of visibility impairment for Haleakala National Park and Hawaii Volcanoes National Park and estimate the associated impacts.

The visibility assessments discuss the potential sources of visibility impairment for the two National Parks, examine pollutant monitoring data and visibility impacts, present pollutant source apportionment results, and examine additional select pollution sources that could potentially impact visibility. The effort fused pollutant monitoring data, particle trajectories based on gridded wind data and select pollutant sources (forest fire and agricultural burning).

---

[26] Haleakala National Park Visibility Assessment, Hawai'i Volcanoes National Park Visibility Assessment, and IMPROVE PMF Factor Identification notes Positive Matrix Factorization Analysis of HALE1 & HAVO1 IMPROVE data sets April 20, 2012, State of Hawaii, Department of Health, Clean Air Branch.

The effort sought to gather information about all pollutants and sources. The large magnitude and temporal variability of Kilauea volcano emissions from the island of Hawaii are significant drivers for the work.

The source apportionment analysis was based on IMPROVE data and associated Positive Matrix Factorization (PMF) analyses. The PMF categorized visibility impacts into 8 source types for Haleakala National Park, and 6 source types for Hawaii Volcanoes National Park. The results provide insight into potential sources, both within and external to the islands of Hawaii.

Summaries of the results for each park are presented below. EPA has reviewed the Hawaii DOH Visibility Assessment for Haleakala and Hawaii Volcanoes National Park. EPA concurs with Hawaii DOH that the Volcano PMF factor and the Asian Dust PMF factors appear to be most reliable. The remaining six factors are less certain. For example, power plants and ships burn similar fuels, so as noted by Hawaii DOH, this PMF factor may have been incorrectly attributed to shipping versus other potentially consistent PMF factors.

III.B.1. Hawaii DOH Park Visibility Assessment of Haleakala National Park - Summary of Results

The estimation of contribution to light extinction (Bext for 2005/2003-2008 data sets, respectively) are presented below, and are base on IMPROVE data for the worst 20% Days visibility.

(1) The Volcano PMF Factor (46%/56% aerosol Bext for 2005/2003-2008 data sets, respectively) should be attributed to emissions from the Kilauea volcano on the island of Hawaii. The very high sulfur content of this factor, and the relatively good correspondence with the time history of one of the HAVO1 volcano factors are the two primary reasons for this attribution.

(2) The Dust (Asian) PMF Factor (10%/2% aerosol Bext) should be attributed to emissions from Asia. The good correspondence between with the HAVO1 Dust (Asian) factor time history indicates a very large plume size consistent with long range transport. The seasonal nature of the time history, and the presence of dust constituents (Al, Ca, Fe, Si, Ti) are also key reasons for this attribution. Source apportionment calculations combined particle trajectory calculations with pollutant concentration levels and indicated several potential source areas in Asia.

For the next five PMF factors, the results were inconclusive in a number of cases. In some cases, there appeared to be strong indications that at least portions of the source were located beyond the islands of Hawaii. In one case, there are indications that the source is close, likely small, and unlikely to contribute significantly to visibility impairment. Despite these indications, the results are not yet sufficiently conclusive to attribute the visibility impacts to other than local sources. For the same reason, visibility impacts are treated as if they impacted the entire National Park. Future source attribution analyses (using new monitoring data and gridded wind modeling results) could help resolve these uncertainties and perhaps enable better attribution of visibility impacts.

(3) The Nitrate/Sulfate-Rich Secondary PMF factor (7%/16% aerosol Bext) appears consistent with potential sources beyond the islands of Hawaii. Trajectory and source apportionment calculations indicated that impacts were consistent with sources in Asia and Western CONUS.

(4) The Smoke PMF factor (14%/6% aerosol Bext) is likely due to Maui sources. Two likely sources of smoke impacts, agricultural burning and forest fires, were investigated and found to not correspond well to the IMPROVE measurements at HALE1. Due to the presence of bromine in the factor, automobile exhaust is a possible contributor. An examination of the measurement differences between the primary IMPROVE site on Maui, HALE1, and the newer HACR1 site found that HALE1 concentration levels were generally approximately twice those of HACR1. It is believed likely that the elevated smoke levels at HALE1 are due to nearby sources that would not impact overall visibility within the National Park.

(5) The Oil Combustion PMF factor (15%/10% aerosol Bext) appears consistent with potential sources both on the island of Hawaii and beyond the islands of Hawaii. The 2008 National Emission Inventory identified fuel (oil) combustion for power generation as significant contributors to local anthropogenic emissions.

(6) The Sea Salt/Nitrate-Rich Secondary PMF factor (4%/6% aerosol Bext) appears consistent with sources beyond the islands of Hawaii.

(7) The Shipping PMF factor (2%/3% aerosol Bext) could be the result of sources on Maui, beyond the islands of Hawaii, or a combination of sources. This factor was attributed to shipping largely upon the relatively large quantity of zinc, which was also a characteristic in a prior PMF assessment of Hawaii emission sources. However, this PMF factor may have been incorrectly attributed to shipping, versus other potentially consistent PMF factors (e.g. Nitrate/Sulfate-Rich Secondary, Oil Combustion, or Sea Salt/Nitrate-Rich Secondary).

(8) The Brush Fire/Burning Vegetation PMF factor (2%/0% aerosol Bext) is likely the result of sources on Maui.

III.B.2. Hawaii DOH Park Visibility Assessment of Hawai'i Volcanoes National - Summary of Results

The estimation of contribution to light extinction (Bext for 2005/2003-2008 data sets, respectively) are presented below, and are based on IMPROVE data for Worst 20% Days visibility.

(1) The three Volcano PMF Factors (93.4%/94.2% aerosol Bext for 2005/2003-2008 data sets, respectively) should be attributed to non-anthropogenic emissions from the Kilauea volcano on the island of Hawaii. The very high sulfur content of two of these factors is the primary reasons for this attribution. Source apportionment modeling for these two factors indicates emission sites that are consistent with the volcanic emissions and associated inter-island "vog" visibility impairment. For the third volcanic faction, the fraction of total sulfur is relatively low (~1%), but the source apportionment strongly indicates an emission site consistent with the Kilauea volcano.

(2) The Dust (Asian) PMF Factor (1.3%/0.4% aerosol Bext) should be attributed to emissions from Asia. The good correspondence between with the HALE1 Dust (Asian) factor time history indicates a very large plume size consistent with long range transport. The seasonal nature of the

time history, and the presence of dust constituents (Al, Ca, Fe, Si, Ti) are also key reasons for this attribution. Source apportionment calculations combined particle trajectory calculations with pollutant concentration levels and indicated several potential source areas in Asia.

For the remaining four PMF factors, the results were inconclusive in a number of cases. In some cases, there appeared to be strong indications that at least portions of the source were located beyond the islands of Hawaii. Despite these indications, the results are not yet sufficiently conclusive to attribute the visibility impacts to other than local sources. For the same reason, visibility impacts are treated as if they impacted the entire National Park. Future source attribution analyses (using new monitoring data and gridded wind modeling results) could help resolve these uncertainties and perhaps enable better attribution of visibility impacts.

(3) The Smoke PMF factor (1.2%/1.4% aerosol Bext) could be the result of on-island emissions, but there are some indications of potential sources beyond the islands of Hawaii. Forest fires were investigated and found to not correspond well to the IMPROVE measurements at HAVO1. The fire data did not match well with either the spatial locations indicated by the PSCF results, or the time-histories associated with any of the HAVO1 IMPROVE visibility impacting species or PMF Factors. Due to the presence of bromine in the factor, automobile exhaust is a possible contributor.

(4) The Oil Combustion PMF factor (1.1%/1.5% aerosol Bext) could be the result of sources on Hawaii, the Americas, Asia, or a combination of those source regions. The emissions inventory in Section IV of this document identifies fuel (oil) combustion for power generation as significant contributors to local anthropogenic emissions.

(5) The Sea Salt/Nitrate-Rich Secondary PMF factor (1.5%/2.0% aerosol Bext) appears consistent with sources beyond the islands of Hawaii.

(6) The PMF Shipping PMF factor (1.4%/0.4% aerosol Bext) could be the result of sources on Hawaii, Maui, beyond the islands of Hawaii, or a combination of sources. This factor was attributed to shipping largely upon the relatively large quantity of zinc, which was also a characteristic in a prior PMF assessment of Hawaii emission sources. However, this PMF factor may have been incorrectly attributed to shipping, versus other potentially consistent PMF factors (e.g. Nitrate/Sulfate-Rich Secondary, Oil Combustion, or Sea Salt/Nitrate-Rich Secondary).

IV. Emissions Inventory

IV.A. Statewide Emissions Inventory

40 CFR 51.308(d)(4)(v) requires that EPA maintain a statewide inventory of emissions of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I Federal area. The inventory must include emissions for a baseline year, emissions for the most recent year for which data are available, and estimates of future projected emissions. The Regional Haze Rule does not specify the baseline year for the inventory, but EPA

has recommended that 2002 be used as the inventory base year.[27] 2002 is generally appropriate as the baseline year for Regional Haze SIPs because it corresponds with the 2000-2004 period for establishing baseline visibility conditions, based on available ambient monitoring data, pursuant to 40 CFR 51.308(d)(2)(i).

For this first Hawaii Regional Haze implementation plan, Hawaii DOH initially selected 2005 as their base year because it was the most recent year with a full inventory when they began their technical work.[28] Since 2005 is not within the baseline period of 2000-2004, EPA has performed a comparison of the aerosol composition of the 2005 data and 2001-2004 data for each Class I Area in Sections II.A., II.B, and III.B of this document. That analysis found that the 2005 inventory is sufficiently representative of the base period that it is appropriate to use as the base inventory for the plan. That is, since the measured visibility impairing pollution in 2005 was consistent with the baseline years, it is reasonable to assume that for the purposes of Regional Haze Planning, that the 2005 emissions were sufficiently consistent with the emissions in 2000-2004 for this year to be used as the baseline for the Regional Haze Plan.

The majority of the 2005, 2008 and 2018 inventories were derived from a 2010 study conducted by consulting firm Environ on behalf of the Hawaii DOH.[29] The numbers developed by Environ were then refined and improved by HI DOH.[30] Between the time when the Environ Study was conducted and the development of this FIP, the EPA finalized a new model for the estimation of emissions from on road vehicles. This new model, MOVES provides for a more accurate estimation of emissions from these sources. So, the EPA worked with the University of North Carolina (UNC) and consulting firm ICF International to develop a new emissions inventory for on road vehicles for Hawaii for the years 2005, 2008 and 2018.[31] Tables III-1 through III-3 reflect these revised emissions numbers.

The EPA also worked with UNC and ICF to improve the 2018 emissions estimates for marine sources. The Environ work used the best data that was available at the time, but failed to account for the impact of the economic recession on marine vessel activity, cruise ships in particular. In addition, the Environ work did not take into account the impact of the North American Emissions Control Area (NA ECA). The United States Government, together with Canada and France, established the NA ECA under the auspices of Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL Annex VI), a treaty developed by the International Maritime Organization. This ECA will require use of lower sulfur fuels in ships operating within 200 nautical miles of the majority of the U.S. and Canadian coastline, including the U.S. Gulf Coast and Hawaii, beginning in August 2012. The ECA will result in lower NO_x and SO_2 emissions from marine sources in Hawaii. Therefore, UNC and ICF have

---

[27] Memorandum from Lydia N. Wegman, "2002 Base Year Emission Inventory SIP Planning: 8-Hour Ozone, PM2.5 and Regional Haze Programs" (Nov. 18, 2002).

[28] E-mail from Priscilla Ligh, Hawaii DOH, to Gregg Nudd, EPA, May 3, 2012.

[29] "Final Emission Inventory Report: Data Population for Air System for Hawaii Emissions Data (AirSHED)", Environ International Corporation, April 12, 2010.

[30] See email from Priscilla Ligh, HI DOH to Greg Nudd, USEPA, on 11/18/2011 and associated document: "RevA Emissions inventory response to EPA 11-17-11 for EPA.doc" The document also explains any differences between the Hawaii DOH numbers and the emissions inventory in the National Emission Inventory for Hawaii.

[31] Technical Analysis for Hawaii's Regional Haze FIP Report – Task 16: On-Road Mobile Emissions Inventory, ICF International, March 23, 2012

updated the 2018 inventory to include the benefits of the ECA. The 2018 marine emissions estimates in Table III-3 are based on this more recent work by UNC and ICF.[32]

Table III-1 Statewide Inventory for 2005

Source Category	NO$_x$	SO$_2$	VOC	PM	NH$_3$
Point Sources	22,745	27,072	2,695	3,536	12
Area Sources	1,509	3,716	16,920	33,408	11,136
Windblown Dust				46,808	
Wildfire	2,156	591	4,729	9,771	540
Agricultural Burning	406	178	535	1,567	60
Other fire	1		7	7	
On Road Mobile Sources	20,642	321	12,066	638	1,085
Non Road Mobile Sources	4,750	534	6,121	484	5
Aircraft	1,541	135	262	165	
In and Near Port Marine	2,572	2,201	92	183	
Underway Marine (<30 nm[33])	3,052	1,418	117	215	
Trains	5				
Volcano		961,366			
Sea Spray				382,637	
Biogenic	4,617		130,153		
Total	63,996	997,532	173,697	479,419	12,838
Anthropogenic Total	59,379	36,166	43,544	96,782	12,838

Table III-2 Statewide Inventory for 2008

Source Category	NO$_x$	SO$_2$	VOC	PM	NH$_3$
Point Sources	20,246	25,849	2,544	3,389	12
Area Sources	1,166	15,767	18,025	34,917	11,275
Windblown Dust				46,808	
Wildfire	2,156	591	4,729	9,771	540
Agricultural Burning	406	178	535	1,567	60
Other fire	1		8	7	
On Road Mobile Sources	14,239	97	8,526	547	1,124
Non Road Mobile Sources	4,573	78	4,912	422	5
Aircraft	2,568	260	628	123	
In and Near Port Marine	12,432	2,638	308	605	
Underway Marine (<30nm)	562	282	18	42	
Trains	5				
Volcano		1,195,314			
Sea Spray				382,637	

---

[32] "Technical Analysis for Hawaii's Regional Haze FIP Report – Task 16: Commercial Marine Inventory", ICF International, April 2, 2012
[33] nautical miles

Source Category	NOₓ	SO₂	VOC	PM	NH₃
Biogenic	4,617		130,153		
Total	62,971	1,241,054	170,386	480,835	13,017
Anthropogenic Total	58,354	45,740	40,233	98,198	13,017

Table III-3 Statewide Inventory for 2018

Source Category	NOₓ	SO₂	VOC	PM	NH₃
Point Sources	28,594	36,212	4,157	5,052	13
Area Sources	1,723	3,524	20,054	43,506	12,530
Windblown Dust				46,808	
Wildfire	2,156	591	4,729	9,771	540
Agricultural Burning	406	178	535	1,567	60
Other fire	1		8	7	
On Road Mobile Sources	5,058	72	3,883	400	1,478
Non Road Mobile Sources	3,090	7	4,579	297	7
Aircraft	1,920	167	466	194	
In and Near Port Marine	2,097	117	92	50	
Underway Marine (<30nm)	1,867	68	78	33	
Trains	5				
Volcano		683,746			
Sea Spray				421,222	
Biogenic	4,617		130,153		
Total	51,533	724,681	168,734	528,908	14,628
Anthropogenic Total	46,916	40,935	38,581	107,686	14,628

IV. B. Review of the Emissions Inventory for Completeness and Accuracy

The EPA has reviewed the methods used by Environ, the Hawaii Department of Health and the ICF Corporation in developing this inventory. We propose to find that the best available emissions factors and activity data were used in developing the emissions estimates. We also propose to find that the inventory captures all of the emissions sources relevant to the development of a Regional Haze Plan.

IV.C. Assessment of the Emissions Inventory

There are a few interesting and relevant facts to draw from the results in Tables III-1 through III-3.

First, nonanthropogenic emissions are significant for SO_2, VOC and PM. As one can see from the tables above, the volcano dominates statewide SO_2 emissions. Emissions from the volcano comprise over 96% of the SO_2 emissions in 2005 and 2008. On days when the volcano is erupting and the winds are carrying those emissions over the Class I area monitors, these

natural emissions will dominate the measurements. Nonanthropogenic sources also comprise the majority of VOC and PM emissions.

Second, total statewide anthropogenic emissions of NO_x and VOC are decreasing. Human-made NOx pollution is projected to be 21% lower in 2018 than in 2005. Human-made VOC pollution is projected to decrease by 11%. These reductions are primarily due to EPA regulations for on-road vehicles. Emissions from cars and trucks are decreasing dramatically, even accounting for economic and population growth. This is due to older, higher emitting vehicles being replaced by ones with more modern air pollution controls. NO_x emissions in this category are projected to decrease by over 15,000 tpy and VOC emissions by over 8,000 tpy between 2005 and 2018.

However, anthropogenic SO_2 emissions are expected to increase between 2005 and 2018, largely due to increased emissions from point sources. The lower sulfur marine fuels required by the ECA are expected to result in a 95% reduction in emissions from shipping, but those reductions are overwhelmed by the increases from point source emissions. The growth rate of point source emissions is very sensitive to assumptions about future economic growth. The Environ report, from which this data is derived, assumes robust economic growth between 2005 and 2018. Given the economic recession that began in late 2008 this level of emission growth will likely over-predict future anthropogenic emissions. Nevertheless, this is the best data available.

Our analysis of the monitoring data indicates that SO_2 is the principal pollutant of concern for the regional haze plan. (See sections II.A., II.B, and III.B of this TSD.) The visibility impacts of NO_x and VOC emissions are of secondary importance. The increase in anthropogenic SO_2 emissions indicates that some additional pollution reductions are needed to ensure reasonable progress toward the goal of eliminating anthropogenic visibility impairment in Hawaii's mandatory class I areas. Our proposal to achieve these reductions is set forth in section VII of this TSD.

V. Causes of Haze in Hawaii (including volcanic emissions)

V.A. Island-Specific Emissions Inventory

The island specific emission inventory for the years 2005 and 2018 is presented below. These tables are derived from the same set of references and assumptions as in the Emissions Inventory section.

Table V-1. Hawaii (Big Island) Anthropogenic Emissions Inventory[34]

Source Category	2005 Inventory		2018 Inventory	
	NO_x	SO_2	NO_x	SO_2
Point	1,036	4,551	1,736	5,266
Nonpoint	1,849	808	1,882	872
On-Road Mobile	3,217	53	839	11
Non-Road Mobile	784	95	428	1

---

[34] Does NOT include volcano SO2 emissions of 961,366 tons/year.

Aircraft	177	18	207	21
Agricultural Burning	2	0	2	0
Wildfires	1,712	469	1,712	469
in/near port Marine	537	418	546	20
Total	9,314	6,412	7,352	6,661

Table V-2. Maui Anthropogenic Emissions Inventory

	2005 Inventory		2018 Inventory	
Source Category	**NO_x**	**SO_2**	**NO_x**	**SO_2**
Point	4,492	4,559	4,597	4,625
Nonpoint	462	481	548	571
On-Road Mobile	2,957	47	758	10
Non-Road Mobile	496	57	305	2
Aircraft	310	27	376	33
Agricultural Burning	298	132	298	132
Wildfires	52	14	52	14
in/near port Marine	699	569	836	32
Total	9,765	5,887	7,770	5,420

V.B. Synthesis of Emissions Inventory, Monitoring Data, and PMF analysis

Sulfate is the largest cause of visibility degradation on the 20% worst days at both Haleakala National Park and Hawaii Volcanoes National Park. Natural causes of sulfate include the emissions from the Kīlauea volcano, located in the Hawaii Volcanoes National Park, and natural marine sulfates. The emissions and impact of the volcano varies substantially from year to year. Source apportionment assessments have estimated that the volcano causes approximately 90% of the visibility impairment at Hawaii Volcanoes National Park and approximately 60% of the visibility impairment at Haleakala National Park on the 20% worst days. The natural marine sulfate impact is expected to be much smaller.[35] International transport may also contribute to sulfur visibility impairment. Anthropogenic sources of sulfur include oil combustion, and shipping.

Nitrate contributes 9% to the visibility degradation on the 20% worst days at Haleakala. Nitrate contributes 1% to the visibility degradation on the 20% worst days at Hawaii Volcanoes National Park. The major anthropogenic sources of nitrate are point sources, on-road sources, and marine emissions. The natural sources of nitrate include wildfire and biogenic emissions.

Organic Carbon contributes 10% of the visibility degradation at the Haleakala (HALE1) monitor, which is located outside of the park. Sources of organic carbon include agricultural burning, oil combustion, and international transport. A comparison of recent monitoring at the Haleakala Crater monitoring site at Park (HACR1) shows a lower level of organic carbon than

---

[35] Yvon and Saltzman 1996, Atmospheric Sulfur Cycling in the Tropical Marine Boundary Layer. J. Geophys. Res. 101, 6911-6918.

the HALE1 site. [36] Organic Carbon contributes 4% of the visibility degradation at the Hawaii Volcanoes National Park during the 2001 – 2004 time period. Organic carbon levels measured at the park from 2003-2009 are much lower, as discussed in the section regarding visibility trends at Hawaii Volcanoes Park, above.

Elemental Carbon contributes to 5% of the visibility degradation at the Haleakala (HALE1) monitor, which is located outside of the park. A comparison of recent monitoring at the Haleakala Crater monitoring site at Park (HACR1) shows a lower level of elemental carbon of the HALE1 site. [37]

Coarse mass contributes to 9% of the visibility degradation at the Haleakala (HALE1) monitor and 1% of the visibility degradation at the Hawaii Volcanoes National Park. The potential sources of coarse mass include fugitive dust, international transport, and shipping.

Soil contributes to 1% of the visibility degradation at the Hawaii Volcanoes National Park. The soil impact varies seasonally, with the highest levels in the springtime, and appears to be associated with international transport.

V.C. Visibility Impairing Pollutants Subject to Evaluation

EPA has evaluated the six particulate pollutants (ammonium sulfate, ammonium nitrate, organic carbon (OC), elemental carbon (EC), fine soil and coarse mass (CM)) that contribute to visibility impairment at Hawaii's two mandatory Class I federal areas. Sulfate is the primary cause of visibility impairment at each of Hawaii's Class I Areas, and EPA proposes that the first Regional Haze Plan RP evaluation should focus on primarily on significant sources of SO2 (sulfate precursor). NOx (nitrate precursor) is a secondary concern, as it contributes to 9% of the visibility degradation on the 20% worst days at Haleakala.

Coarse mass contributes to 9% of the visibility degradation at the Haleakala, and is also of concern. However, the sources of coarse mass (CM) are uncertain because of emission inventory limitations associated with natural sources (predominantly wildfires) and uncertainty of fugitive (windblown) emissions. Because of the difficulty in attributing the sources of visibility impairment for this pollutant, EPA has determined that it is not reasonable in this planning period to recommend emission control measures for coarse mass. Coarse mass contribution to visibility impairment, emissions sources, and potential control measures should be addressed in future Regional Haze plan updates.

Because fine soil appears to be primarily attributable to international transport, EPA has determined that it is not reasonable in this planning period to recommend emission control measures for fine soil. Although organic and elemental carbon contribute to base year visibility impairment, recent monitoring at the Haleakala Crater (HACR1) monitoring site and the Hawaii Volcanoes (HAVO1) show low contributions to visibility impairment from organic and elemental carbon.

---

[36] Review of VIEWS2.0 2009-2010 Haleakala National Park Organic and Elemental Carbon Data, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch, and Comparison of Haleakala National Park, HALE1 and HACR1 IMPROVE Monitoring Site 2007-2008 Data Sets, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch.
[37] Ibid.

VI. Best Available Retrofit Technology (BART)

VI.A. BART Requirements

Section 169A of the CAA directs states, or EPA if implementing a FIP, to evaluate the use of retrofit controls at certain larger, often uncontrolled, older stationary sources in order to address visibility impacts from these sources. Specifically, section 169A(b)(2)(A) of the CAA requires states to revise their SIPs, or for EPA to implement a FIP, to contain such measures as may be necessary to make RP towards the natural visibility goal, including a requirement that certain categories of existing major stationary sources[38] built between 1962 and 1977 procure, install, and operate the "Best Available Retrofit Technology" as determined by the state, or EPA if implementing a FIP. Under the Regional Haze Rule, states, or EPA if implementing a FIP, are directed to conduct BART determinations for such "BART-eligible" sources that may be anticipated to cause or contribute to any visibility impairment in a Class I area.

On July 6, 2005, EPA published the *Guidelines for BART Determinations Under the Regional Haze Rule* at Appendix Y to 40 CFR Part 51 (hereinafter referred to as the "BART Guidelines") to assist states, or EPA if implementing a FIP, in determining which of their sources should be subject to the BART requirements and in determining appropriate emission limits for each applicable source. 70 FR 39104. In making a BART determination for a fossil fuel-fired electric generating plant with a total generating capacity in excess of 750 megawatts (MW), a state, or EPA if implementing a FIP, must use the approach set forth in the BART Guidelines. A state, or EPA if implementing a FIP, is encouraged, but not required, to follow the BART Guidelines in making BART determinations for other types of sources. Regardless of source size or type, a state, or EPA if implementing a FIP, must meet the requirements of the CAA and our regulations for selection of BART, and the state's, or EPA's if implementing a FIP, BART analysis and determination must be reasonable in light of the overarching purpose of the regional haze program.

The process of establishing BART emission limitations can be logically broken down into three steps: first, states, or EPA if implementing a FIP, identify those sources which meet the definition of "BART-eligible source" set forth in 40 CFR 51.301[39]; second, states, or EPA if implementing a FIP, determine which of such sources "emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility in any such area" (a source which fits this description is "subject to BART"); and third, for each source subject to BART, states, or EPA if implementing a FIP, then identify the best available type and level of control for reducing emissions.

States, or EPA if implementing a FIP, must address all visibility-impairing pollutants emitted by a source in the BART determination process. The most significant visibility impairing pollutants are SO_2, NO_x, and PM.

Under the BART Guidelines, states, or EPA if implementing a FIP, may select an exemption threshold value for their BART modeling, below which a BART-eligible source would not be expected to cause or contribute to visibility impairment in any Class I area. The

---

[38] The set of "major stationary sources" potentially subject to BART is listed in CAA section 169A(g)(7).

[39] BART-eligible sources are those sources that have the potential to emit 250 tons or more of a visibility-impairing air pollutant, were not in operation prior to August 7, 1962, but were in existence on August 7, 1977, and whose operations fall within one or more of 26 specifically listed source categories. 40 CFR 51.301.

state, or EPA if implementing a FIP, must document this exemption threshold value in the SIP, or FIP, and must state the basis for its selection of that value. Any source with emissions that model above the threshold value would be subject to a BART determination review. The BART Guidelines acknowledge varying circumstances affecting different Class I areas. States, or EPA if implementing a FIP, should consider the number of emission sources affecting the Class I areas at issue and the magnitude of the individual sources' impacts. Any exemption threshold set by the state, or EPA if implementing a FIP, should not be higher than 0.5 deciview. 40 CFR part 51, appendix Y, section III.A.1.

A regional haze SIP, or FIP, must include source-specific BART emission limits and compliance schedules for each source subject to BART. Once a state, or EPA if implementing a FIP, has made its BART determination, the BART controls must be installed and in operation as expeditiously as practicable, but no later than five years after the date of EPA approval of the regional haze SIP, or FIP. CAA section 169(g)(4) and 40 CFR 51.308(e)(1)(iv). In addition to what is required by the Regional Haze Rule, general SIP, or FIP, requirements mandate that the SIP, or FIP, must also include all regulatory requirements related to monitoring, recordkeeping, and reporting for the BART controls on the source. See CAA section 110(a).

VI.B. Identify BART Eligible Sources

In 2008, the Hawaii DOH conducted a survey of the major sources in the state to identify which sources were BART eligible. This survey was completed and certified by the responsible official at each major source. Through that process, the following facilities were identified as BART eligible: HC&S Puunene facility, Chevron Refinery, Tesoro Refinery, Hu Honua Bioenergy –Pepeekeo facility, MECO – Kahului facility, HELCO Kanoelehua Hill, HECO – Waiau facility, HECO – Kahe facility.

These sources were further analyzed to determine which were subject to BART.

VI.C. Identify BART- Subject Sources

On 6 July 2005, the U.S. Environmental Protection Agency (EPA) published final amendments to its 1999 RH Rule in the Federal Register, including 40 CFR Part 51, Appendix Y, the final guidance for BART determinations (BART Guideline; EPA, 2005; 70 FR 39104-39172). The rule applies to any BART-eligible source that "emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility" in any mandatory Class I federal area. States retain the authority to exempt certain BART-eligible sources based on dispersion modeling demonstrating that the source cannot reasonably be anticipated to cause or contribute to visibility impairment in a Class I area.

According to 40 CFR Part 51, Appendix Y, a BART-eligible source is considered to "contribute" to visibility impairment in a Class I area if the modeled 98th percentile change in deciviews is equal to or greater than the "contribution threshold." Any BART-eligible source, through modeling, determined to cause or contribute to visibility impairment above the threshold in any Class I area is subject to BART. The EPA BART Guidelines suggest a contribution threshold of no greater than a 0.5 change in deciview be used. The State of Hawaii chose to use the recommended 0.5 deciview threshold for Subject-to-BART determination.

Generally, if a source is a smaller emitter or is located far from a Class I area, and its Q/D is less than 10[40], the source is not expected to contribute to visibility impairment at a Class I area. Using this approach, the Hawaii DOH determined that the Kauai Utilities Port Allen facility should not be Subject-to-BART. For the other BART eligible sources, the contribution to any impairment of visibility" in the Hawaii Class I areas is based on dispersion modeling.

VI.C.1. Subject to BART Modeling for the State of Hawaii

CALPUFF Modeling System

Subject to BART Modeling was performed by Alpine Geophysics on behalf of Hawaii DOH[41], EPA proposes to use this modeling as a basis to determine which sources are subject to BART. This modeling is described briefly below, and in greater detail in the modeling protocol and final report which are included in Appendix A of this document.

CALPUFF was applied separately for each Class I Area (Haleakala National Park and Hawaii Volcanoes National Park) on the island of Maui and Hawaii. The CALPUFF modeling system, shown in Table 1, was the regulatory approved versions, except for the CALPOST processor. CALPOST version 6.221which was used to enable the application to use the most up-to-date FLAG (6-29-2008) guidance. The CALMET model was run using the August 20, 2009, "EPA-FLM Recommended CALMET input File Values." Detailed parameter settings for CALPUFF, CALMET, and CALPOST are provided in Appendix A to this document.

Table VI-1: CALPUFF Modeling System

Program	Version	Level
CALMET	5.8	060911
CALPUFF	5.8	060911
CALPOST	6.221	080724
POSTUTIL	1.56	070627

The application generally followed the recommendation of the IWAQM and FLAG guidance documents:

1) The calendar year 2005 CALMET input file were developed by Alpine Geophysics, LLC and be provided as input-ready to CALPUFF.

---

[40] Q = Potential Emissions (tons/year) of SO_2+NOx+PM_{10} from all eligible units within a facility
 D = Distance (kilometers) between the eligible source and the boundary of the nearest Class I area
[41] Subject-to-Best Available Retrofit Technology (BART) Modeling for the State of Hawaii, Application of the CALPUFF Modeling System; Prepared for: Hawaii State Department of Health, Environmental Management Division Clean Air Branch by Alpine Geophysics, LLC. March 3, 2010.

2) The Subject-to-BART modeling examined the visibility impairment on Class I areas within 300km of each single source or facility. The computational modeling domain is sufficient to include all Class I areas within a 300km radius of a source.
3) Pasquill-Gifford Dispersion coefficients are used.
4) MESOPUFF-II chemistry algorithms are used.
5) Puff splitting is not used, following the recommendations of the FLMs.
6) Source elevations are based on the same terrain files as the receptor elevations.
7) The CALUTIL is used to perform HNO3/NO3 repartitioning using the parameters in Appendix B.

Natural Background

The BART Guideline references EPA's "Guidance for Estimating Natural Conditions under the Regional Haze Rule" (EPA, 2003a). This guidance lists three sets of Natural Conditions corresponding to Annual Average, Best 20% Days and Worst 20% Days. Due to limited access to available meteorological data, the 20% best natural days were used, in lieu of annual average natural days, to represent natural visibility background in Class I areas. This definition of natural background is consistent with the intent of the BART Guideline.[42]

Table VI-2: 20% Best Natural Conditions – Concentrations and Rayleigh Scattering By Class I Area.

| Class I Area | Background Extinction Coefficients (20% Best Days) | | | | | | | |
	$(NH_4)_2SO_4$ µg/m3	NH_4NO_3 Mg/m3	OM µg/m3	EC µg/m3	Soil µg/m3	CM µg/m3	Sea Salt µg/m3	Rayleigh Mm-1
Haleakala National Park	0.05	0.04	0.24	0.01	0.11	1.59	0.13	10
Hawaii Volcanoes National Park	0.03	0.04	0.27	0.01	0.06	0.64	0.11	10

Background ozone was assumed to be at an annual constant level of 40 ppb. A review of the ammonia emissions inventory for Hawaii in comparison with mainland agricultural areas indicate a background of 1.5 ppb to be representative based on land use and agricultural and livestock activity.

Meteorological Data

Alpine was contracted to apply the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model (MM5) (Dudhia, 1993; Grell et al., 1994: UCAR, 2003a) for calendar year 2005 to provide data for the CALMET/CALPUFF modeling as well as for additional modeling and analytical studies conducted for the Hawaiian Islands. A

---

[42] Federal Register Vol. 70, No. 128, p 39125.

complete description of the modeling approach and a statistical evaluation of the annual MM5 model are described in McNally and Wilkinson, 2008[43], in Appendix B of this document.

VI.C.2. Review of Subject to BART Modeling

EPA proposes to use a contribution threshold of 0.5 deciviews for determining which sources are subject to BART. EPA believes this threshold is appropriate, considering the number of sources affecting the Class I areas and the magnitude of the individual sources impacts. This is consistent with the State of Hawaii's recommendation to use a 0.5 deciview threshold for the Subject-to-BART determination.

The U.S. EPA Region 9, U.S. National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS) were consulted during development of the modeling protocol for the CALPUFF modeling used for the subject to BART determination. The EPA has reviewed the methods used by Alpine for the Hawaii Department of Health in the application of the CALPUFF modeling for the subject to BART analysis. EPA proposes to find the modeling procedures appropriate for the subject to BART determination.

VI.C.3. Assessment of Subject to BART Modeling

EPA believes the CALPUFF modeling used for the subject to BART determination is the most appropriate modeling to use for the proposed Regional Haze FIP. However, the modeling was based on a single year of mesoscale meteorological data. A minimum of three years of mesoscale meteorological model output is recommended for conducting the initial step in the first-level analysis. However, meteorological data sets for more than 2005 were unavailable for the modeling domain at the time the CALPUFF modeling was performed for Hawaii DOH. More recently, three years (2005 -2007) of MM5 meteorological data for Hawaii were developed by JCA.[44] This data may be an appropriate basis for the mesoscale meteorological modeling for future regional haze plans.

VI.C.4. Results of Subject to BART Modeling

Table VI-3: Individual BART-Eligible Source Visibility Impacts on Hawaii Class I Areas

Source and Unit	Class I Area	Maximum 24-Hour 98th Percentile Visibility	Subject to BART or Exempt

---

[43] MM5 Application for 2005 Over the Hawaiian Islands, prepared for Hawaii State Department of Health, Environmental Management Division, Clean Air Branch Prepared by: Alpine Geophysics, LLC., October 31, 2008.
[44] MM5 Meteorological Dataset Development For Hawaii, Draft December 2008, JCA, Prepared for Hawaiian Electric Company, Inc., Maui Electric Company, Inc. Hawaiian Electric Light Company, Ltd.

		Impact (deciview)	
HC&S Puunene facility (Bagasse)	Haleakala Hawaii Volcanoes	0.059 0.008	Exempt
HC&S Puunene facility (Coal)	Haleakala Hawaii Volcanoes	0.133 0.039	Exempt
Chevron Refinery	Haleakala Hawaii Volcanoes	0.021 0.016	Exempt
Tesoro Refinery	Haleakala Hawaii Volcanoes	0.025 0.017	Exempt
Hu Honua Bioenergy – Pepeekeo facility	Haleakala Hawaii Volcanoes	0.323 0.540	Subject to BART
MECO – Kahului facility,	Haleakala Hawaii Volcanoes	0.232 0.108	Exempt
HELCO Kanoelehua Hill	Haleakala Hawaii Volcanoes	0.808 2.334	Subject to BART
HECO – Waiau facility	Haleakala Hawaii Volcanoes	0.083 0.038	Exempt
HECO – Kahe facility	Haleakala Hawaii Volcanoes	0.221 0.132	Exempt

The Hu Honua Bioenergy – Pepeeko facility has had its permit revoked. The facility has been issued a new permit to burn exclusively biomass materials. This new permit included the application of Best Available Control Technology. As a result of these changes, the facility is no longer BART eligible. The one remaining facility that is subject to BART is the HELCO Kanoelehua Hill facility. This facility was analyzed to determine BART controls.

VI.D. BART Determination and Federally Enforceable Limits

   The third step of a BART evaluation is to perform the BART analysis. The BART Guidelines (70 FR 39164 (July 6, 2005)) describe the BART analysis as consisting of the following five steps:

- Step 1: Identify All Available Retrofit Control Technologies;

- Step 2: Eliminate Technically Infeasible Options;
- Step 3: Evaluate Control Effectiveness of Remaining Control Technologies;
- Step 4: Evaluate Impacts and Document the Results; and
- Step 5: Evaluate Visibility Impacts.

In determining BART, the state, or EPA if implementing a FIP, must consider the five statutory factors in section 169A of the CAA: (1) the costs of compliance; (2) the energy and non-air quality environmental impacts of compliance; (3) any existing pollution control technology in use at the source; (4) the remaining useful life of the source; and (5) the degree of improvement in visibility which may reasonably be anticipated to result from the use of such technology. *See also* 40 CFR 51.308(e)(1)(ii)(A). The actual visibility impact analysis occurs during steps 4 and 5 of the process.

As mentioned previously, the only source in Hawaii subject to BART is the Kanoelehua Hill Generating Station on the Big Island. Specifically, there are two residual fuel-oiled fired boilers at this plant that are subject to BART (Hill 5 & Hill 6). Hill 5 is a 14 MW front-fired boiler. Hill 6 is a 21 MW tangentially fired boiler. Both boilers currently burn residual (~ No. 6) oil with sulfur content not to exceed 2% by weight. Table V-1 summarizes the baseline emission rates and modeled visibility impact of these sources. The annual emissions are based on 2009 operations.

Table VI-1 Baseline Emissions and Visibility Impacts of Hill

SO_2 emissions	tons per year [tpy]	2,778
NO_x emissions	[tpy]	735
PM emissions	tpy	70
Visibility impact on Haleakala[45]	Δ deciview [Δ/dv]	0.44
Visibility impact on Volcanoes	[Δ/dv]	1.56

Trinity Consulting, on behalf of the Hawaii Electric Company, the plant operator, performed a five-factor analysis for this plant[46]. 2009 was used as the baseline for the analysis because that was the most current, complete year available when Trinity performed the BART analysis in 2010. We have reviewed this analysis and believe it appropriately addresses the five BART factors. Although the BART guidelines are not mandatory for Hill because the plant's total generating capacity is less than 750 megawatts, the Trinity analysis generally adheres to the guidelines. Our analysis of the five factors is largely based on the Trinity work.

VI.D.1 BART for NO_x and Particulate Matter (PM)

The Trinity report appropriately examined BART controls for NO_x and PM. However,

---

[45] These results are from Trinity's modeling. These indicate a lower impact than was indicated by the Alpine modeling. But, even in Trinity's modeling, the baseline impacts are high enough to make the source subject to BART.

[46] BART FIVE FACTOR ANALYSIS Prepared for Hawaiian Electric Light Company, October 2010, Trinity Consultants

due to the overwhelming contribution of sulfate to visibility impairment at the nearby Hawaii Volcanoes Class I area, it is unlikely that reductions in these pollutants from this site would have a measurable impact on visibility at that area.

For PM, the Trinity report considered the following technologies: Dry Electrostatic Precipitator (ESP), Wet Electrostatic Precipitator (ESP), Fabric Filter, Wet Scrubber, Cyclone and Fuel Switching. Dry ESPs, Cyclones and Fabric Filters are not appropriate for the type of particulate emitted by this plant. A wet scrubber would work, but these types of devices are better suited to larger particulate than is emitted from an oil-fired boiler and their control efficiency would be small. A wet ESP would have good control efficiency and is technically feasible. Similarly, switching to distillate fuel would be an effective and technically feasible control for PM. Trinity estimated the cost effectiveness of a wet ESP as $13,000 per ton of PM controlled. They estimated the cost effectiveness of switching to distillate fuel as $170,000 per ton. Neither of these controls would be cost effective for PM.

For NOx, the Trinity report considered both combustion controls such as flue gas recirculation and low-NOx burners as well as post-combustion controls such as selective catalytic reduction (SCR). There were no technical barriers to implementing any of these controls. The post-combustion controls were not found to be cost effective. Low-NOx burners were found to be cost effective by the Trinity report. However, given the monitoring data on Hawaii, EPA finds that the emission reductions provided by low-NO_x burners is unlikely to provide a measurable visibility benefit at Hawaii Volcanoes or Haleakala.

Based on our consideration of the five BART factors, EPA has determined that no control for NO_x and PM at the Hill plant is consistent with BART, given the unique conditions in Hawaii. NO_x reductions may need to be pursued in future planning periods as anthropogenic sulfates are reduced and nitrates become a larger portion of anthropogenic visibility impairment.

VI.D.2 BART for SO$_2$

The principal visibility-impairing pollutant from the Hill Plant is SO$_2$. Sulfates are the largest component of visibility impairment at Hawaii Volcanoes and at Haleakela, even on the best days. The Hill Plant is by far the largest source of anthropogenic SO$_2$ emissions on the Big Island.

The Trinity report considered both flue gas desulfurization (FGD) and fuel switching as possible controls. The report found that no other oil-fired electric generating unit had installed FGD technology and due to the lack of industry experience, the technology was infeasible. Even if it were feasible, the control effectiveness would be in question. EPA agrees that FGD technology is unproven for this application and concurs with Trinity's decision to focus on fuel switching. However, the Trinity analysis only looked at switching to distillate fuel oil. Distillate fuel oil is substantially more expensive than residual fuel oil and it provides less energy per gallon. As a result, it is not a cost effective control measure.

EPA requested HECO to consider switching to lower sulfur residual fuel oil, which would be a less expensive option. HECO responded with their cost effectiveness estimate[47]. The lowest cost option, residual fuel oil no more than 1% sulfur by weight had a cost effectiveness of between $6,677/ton and $7,363/ton.

---

[47] Letter from Brenner Munger, Manager, Environmental Department, Hawaiian Electric Company to Tom Webb, U.S. EPA Region 9, January 27, 2012

EPA considered this cost estimate too high in light of available market data and conducted our own analysis, which is summarized in Table VI-2, below. Based on this analysis, we estimate the cost effectiveness of this control to be approximately $5,600/ton.

Table VI-2: Cost and Benefits of Switching Hill to 1% Fuel Oil

Baseline Weight % S	1.57
Baseline Fuel Consumption [gal/yr]	18,650,604
Baseline Emissions [tons SO_2/yr]	2,344
New Fuel Weight % S	1.00
Cost Differential [$/gal]	0.255
Controlled Emissions [tons SO_2/yr]	1493
Annual Costs [$/yr]	$4,755,904
Annual Emission Reductions [tons SO_2/yr]	851
Cost Efficiency [$/ton SO_2 reduced]	$5,587

In Table VI-2, the baseline sulfur content is the average of two years of fuel oil analysis conducted by the electric utility for fuel they have received at Maui and the Big Island. This is more representative than taking the actual fuel sulfur content for the year 2009. The fuel is guaranteed by the suppliers to be less than 2% sulfur, but the actual sulfur content varies depending on feedstock. The fuel consumption numbers are from the Trinity BART analysis. The SO_2 emissions were calculated based on stack testing conducted at Kanoelehua Hill, and adjusting for sulfur input for the new fuel. The new fuel is conservatively assumed to have exactly 1% sulfur, although in practice the actual sulfur content is likely to be lower.

The key assumption in Table VI-2 is the cost differential between the current residual fuel oil and the cost of a lower sulfur fuel, which is estimated here as 0.255 $/gallon, based on the following analysis. Removing sulfur from the crude oil feedstock is a cost for the refinery, so a lower sulfur level usually means a higher cost. The Energy Information Agency (EIA) tracks the prices of refinery products over time. The 5 year average cost differential between residual fuel oil with a sulfur content greater and 1% and residual fuel oil with a sulfur content less than 1% is 0.184 $/gal (2005-2010). The ten year average is 0.165 $/gal (2000-2010)[48]. But the EIA data is for the continental United States. However, the EIA data is for the continental United States and does not reflect various factors that influence fuel oil supply and costs in Hawaii. In order to obtain a more accurate estimate of the cost differential for Hawaii, EPA looked at the long-term average costs of residual fuel oil delivered to Oahu, Maui and the Big Island.

All of the state's fuel is received or refined on Oahu and is shipped by barge to the neighboring islands. Because of the additional distance, fuel oil delivered to the Big Island is roughly 0.050 to 0.060 $/gal more expensive than fuel delivered to Maui. The more difficult question is how to estimate the cost differential due to the lower sulfur. EPA looked at the cost differential between the lower sulfur fuel burned on Oahu and the 2% sulfur fuel burned on Maui. The power plants on Oahu burn oil that is no more than 0.5 sulfur by weight. This is waxier oil that can't be burned in power plants on Maui or the Big Island without some modification of the storage and shipping infrastructure. Nevertheless, it is reasonable to assume that 1% sulfur fuel oil would cost no more than the 0.5% sulfur fuel burned on Oahu. So, using the Oahu product as an upper limit, EPA assumes that 1% sulfur fuel oil will on average cost

---

[48] http://www.eia.gov/dnav/pet/PET_PRI_RESID_DCU_NUS_M.htm

0.190 $/gal more than the 2% sulfur fuel oil currently being burned. This is the six-year (2006-2011) average cost differential between 0.5% fuel oil used on Oahu and the 2% fuel oil used on Maui and the Big Island. This 0.190 $/gal estimate is consistent with and a little higher than the EIA data. Since Hill is on the Big Island, we needed to account for transportation costs. So, we added 0.065 $/gal to the estimate for a total of 0.255 $/gal. The 0.065 $/gal estimate is derived from the six-year (2006-2011) cost differential between residual fuel oil delivered to Maui and the same oil delivered to the Big Island[49]. EPA considers this estimate to be reasonable and conservative.

Figure VI-1 Fuel Oil Costs Over Time
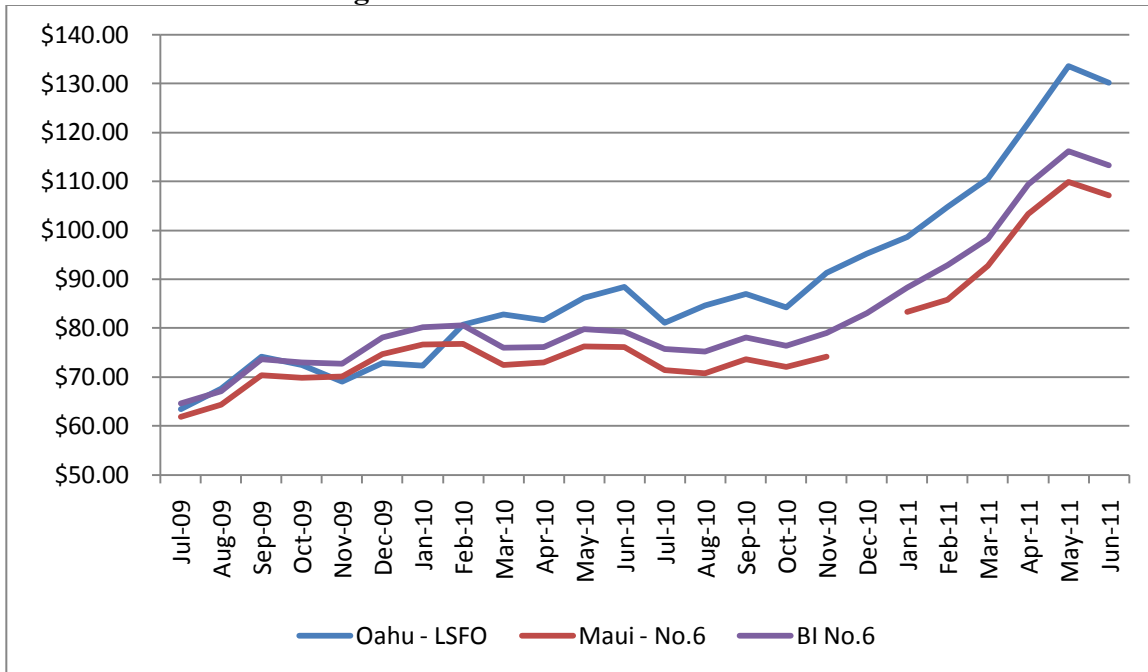
Figure VI-1 shows the variation in costs between low sulfur fuel oil delivered to Oahu (LSFO) and the 2% sulfur residual fuel oil (also known as number 6 fuel oil or No. 6) delivered to Maui and the Big Island (BI). The costs are in $/barrel. There are 42 gallons in a barrel of oil.

     With these assumptions, EPA estimates an annual increase in fuel costs of over $4.8 million/year. EPA contracted with energy economics consulting firm Energy Strategies to estimate the impact of these increased fuel costs on electric rates. Based on their analysis[50], these increased costs would translate into a roughly 1% increase in retail electric rates on the Big Island. The benefit of this change would be a reduction in SO_2 emissions of 851 tons per year.

     The next factors to consider are (2) the energy and non-air quality environmental impacts of compliance; (3) any existing pollution control technology in use at the source; and (4) the remaining useful life of the source. There are no existing pollution controls at the site for SO_2. We have considered factors (2) and (4) in the context of the Hawaii Clean Energy Initiative, which sets the goal of 70% clean energy by 2030. The Initiative includes the 2009 Clean Energy Omnibus Bill (ACT 155 (09), HB 1464, signed June 25, 2009). This statute calls for 30%

---

[49] EPA Hawaii Residual Fuel Oil Summary Spreadsheet
[50] Fuel Cost Screening Tool (r1 4-18-12), Energy Strategies Incorporated, April 18, 2012

reduction in energy use via efficiency and increases the renewable portfolio standard to 40% by 2030. EPA contracted with UNC and ICF to project the 2018 emissions of power plants considering the requirements of the Clean Energy Omnibus Bill. These projections are compared to the current 2018 projections based on the most recent Integrated Resource Plan (IRP) for Hawaii electric utilities[51]. This IRP predates the 2009 bill and so does not account for its requirements. Table V-5 compares the baseline emission projections for 2018, derived from the current IRP and the projections that take into account the requirements of the Clean Energy Bill.

Table IV-3: Range of 2018 Emissions Projections for Hill [tons per year]

	2018 SO$_2$ Emissions IRP	2018 SO$_2$ Emissions Clean Energy Bill
Kanoelehua Hill Generating Station	3,264	765

The projections based on the goals of the Clean Energy Bill assume that the energy conservation and renewable energy goals will be met in a more or less even fashion year to year. So, by 2018, most of these projects will be in place. This is a fairly optimistic scenario, but it gives some insight into the impact of the Clean Energy Bill on these plants. By 2018 Hill is projected to be operating at a significantly lower capacity factor and/or burning biofuels with much less sulfur.

The final factor to consider is the visibility benefits of controls. Trinity modeled the lower emission rates associated with lower sulfur fuels and estimated the following visibility benefits. The delta deciview [Δ/dv] dropped from 1.56 for baseline conditions to 1.05 when burning the 1% sulfur fuel, which represents approximately 0.5 dv benefit.

Taking into consideration all of these factors, we propose to determine that BART for Hill is no additional controls. In particular, although we consider 0.5 dv to be a significant improvement in visibility, we do not believe it justifies the imposition of a control with a cost effectiveness of approximately $5,600/ton in this case. We are particularly concerned about unduly increasing electricity rates in Hawaii, given that these rates are already three times the national average according to the Energy Information Agency.[52] Therefore, we propose to determine that no BART controls be required for Hill.

VII. Reasonable Progress

VII.A. Unique Regional Haze Planning Challenge for Hawaii

In determining if reasonable progress is being made, states, or EPA if implementing a FIP, are required to consider the following factors established in section 169A of the CAA and in our Regional Haze Rule at 40 CFR 51.308(d)(1)(i)(A): (1) the costs of compliance; (2) the time necessary for compliance; (3) the energy and non-air quality environmental impacts of compliance; and (4) the remaining useful life of any potentially affected sources ("the four RP

---

[51] Email from Juanita Haydel, ICF Corporation to Greg Nudd, U.S. EPA Region 9, April 4, 2012, with spreadsheet titled: "Hawaii Emissions Values_Revised_040412_FTC.xlsx"

[52] http://205.254.135.7/state/state-energy-rankings.cfm?keyid=18&orderid=1

factors"). Once these factors have been considered, the typical method for determining if a state is making reasonable progress is to use meteorological and air quality computer models to predict the visibility at Class I areas for the end of the planning period (2018). Those modeling results are then assessed to ensure that visibility is not degrading on the best days and that it is improving on the worst days at a reasonable rate, taking into consideration the relevant statutory factors, as well as the base period visibility conditions and the goal of zero anthropogenic visibility impairment by 2064.

In the case of Hawaii, though, a different method of determining reasonable progress is required. As explained in sections II.A., II.B, and III.B., the dominant cause of visibility impairment at Hawaii's Class I areas is sulfate compounds and over 96% of the sulfate emissions in Hawaii are from the volcano [see section IV.A. Statewide Emissions Inventory]. However, because the volcanic eruptions vary greatly from year to year with no discernible pattern, it is impossible to predict future volcanic emissions. The emissions vary by hundreds of thousands of tons per year. As a result, there is little value in attempting to model visibility at the Class I areas in 2018.

VII.B. Identification of Pollutants for Reasonable Progress

EPA has evaluated the six particulate pollutants (ammonium sulfate, ammonium nitrate, organic carbon (OC), elemental carbon (EC), fine soil and coarse mass (CM)) that contribute to visibility impairment at Hawaii's two mandatory Class I federal areas. Sulfate is the primary cause of visibility impairment at each of Hawaii's Class I Areas, and EPA has determined that the first Regional Haze Plan RP evaluation should focus on primarily on significant sources of SO2 (sulfate precursor). NOx (nitrate precursor) is a secondary concern, as it contributes to 9% of the visibility degradation on the 20% worst days at Haleakala.

Coarse mass contributes to 9% of the visibility degradation at the Haleakala, and is also of concern. However, the sources of coarse mass (CM) are uncertain because of emission inventory limitations associated with natural sources (predominantly wildfires) and uncertainty of fugitive (windblown) emissions. Because of the difficulty in attributing the sources of visibility impairment for this pollutant, EPA has determined that it is not reasonable in this planning period to recommend emission control measures for coarse mass. Coarse mass contribution to visibility impairment, emissions sources, and potential control measures should be addressed in future Regional Haze plan updates.

Because fine soil appears to be primarily attributable to international transport, EPA has determined that it is not reasonable in this planning period to recommend emission control measures for fine soil. Although organic and elemental carbon contribute to base year visibility impairment, recent monitoring at the Haleakala Crater (HACR1) monitoring site and the Hawaii Volcanoes (HAVO1) show low contributions to visibility impairment from organic and elemental carbon.

VII.C. Determining Reasonable Progress Through Island-Specific Emissions Inventories

Due to the absence of modeling to project visibility at Hawaii's Class I areas in 2018, EPA is focusing its reasonable progress analysis on reducing anthropogenic visibility impairing

pollution. The EPA is focusing on the broader goals of the Regional Haze Program. Specifically, we are focusing on the reduction of anthropogenic visibility impairing pollution. The discussion earlier in this document determined that the key anthropogenic pollutants of concern are SO_2 and NO_x, especially SO_2. So, we will look at trends in the emission of anthropogenic SO_2 and NO_x in order to judge if reasonable progress is being achieved.

Rather than use a full statewide inventory to judge reasonable progress, it makes sense to focus on the inventories for the islands where the Class I areas are located: Maui and the island of Hawaii. Population, economic activity and therefore anthropogenic emissions in the state of Hawaii are concentrated on the island of Oahu. But, as explained below, our analysis indicates that those emissions do not significantly impair visibility at the Class I areas. Prevailing winds at the Honolulu Airport on Oahu are from the east-north-east[53]. The prevailing winds on Maui are from the northeast[54]. The Class I areas are south and west of Oahu. Therefore, these trade winds tend to transport pollution from Oahu away from the Class I areas.

Air quality modeling of sources on Oahu support this determination. In order to identify point sources that may be candidates for additional air pollution control under this Regional Haze Plan, the Hawaii Department of Health (DOH) contracted with Alpine Geophysics to conduct air quality modeling of large pollution sources statewide. This modeling is described more completely elsewhere in this document (see section VI.C.) This modeling was designed to estimate the visibility impact of currently operating individual sources of pollution on the Class I areas in the state. Several of the highest emitting sources on Oahu are shown in Table VII-1, below along with their estimated visibility impacts on the Class I areas. The visibility impacts are expressed in terms of the change in deciviews or Δ deciview [Δ/dv].

Table VII-1: Modeled Visibility Impacts of Major Sources on Oahu

Source	Emissions [tpy]				Impact [Δ/dv]	
	Nox	PM-10	SO2	VOC	HALE	HAVO
HECO - Kahe Power Plant	4,848	694	6,684	83	0.221	0.132
HECO - Waiau Power Plant	2,597	310	2,970	37	0.083	0.038
Chevron Hawaii Refinery	751	133	2,128	1,106	0.021	0.016
Tesoro - Campbell Industrial Park & Barbers Point Marine Loading	1,204	88	816	543	0.025	0.017

The Kahe Power Plant is a very highly polluting source with combined NO_x and SO_2 emissions that exceed 11,500 tons per year. This power plant is 197 kilometers (about 122 miles) from the Haleakala(HALE) monitor. But, even this very large source has a relatively small visibility impact on Haleakela (0.221 deciview change).

Given these modeling results and the prevailing winds in Oahu and Maui for this planning period, we will focus our reasonable progress analysis on the islands that contain the Class I areas. The tables below show the emission inventories for the islands of Maui and Hawaii. These tables are based on methods and assumptions described in the Emissions Inventory chapter of this TSD.

Table VII-2 Maui Anthropogenic Emissions Inventory

---

[53] See prevailing winds data from the Western Regional Climate Center (http://www.wrcc.dri.edu/htmlfiles/westwinddir.html#HAWAII)
[54] Ibid.

Source Category	2005 Inventory		2018 Inventory	
	NOₓ	SO₂	NOₓ	SO₂
Point	4,492	4,559	4,597	4,625
Nonpoint	462	481	548	571
On Road Mobile	2,957	47	758	10
Non-Road Mobile	496	57	305	2
Aircraft	310	27	376	33
Agricultural Burning	298	132	298	132
Wildfires	52	14	52	14
in/near port Marine	699	569	836	32
Total	9,765	5,887	7,770	5,420

Table VII-2.1 Maui Point Source Emissions

	2005		2018	
	NOₓ	SO₂	NOₓ	SO₂
MECO - Kahului Power Plant	536	3,198	542	3,233
Maalaea Generating Station	3,255	913	3,291	923
HC & S - Puunene Sugar Mill	617	424	760	469
Ameron Hawaii Camp 10 Quarry	4	0	4	0
Maui Pineapple Co.	80	24		
Total	4,492	4,559	4,597	4,625

Table VII-3 Hawaii (Big Island) Anthropogenic Emissions Inventory

Source Category	2005 Inventory		2018 Inventory	
	NOₓ	SO₂	NOₓ	SO₂
Point	1,036	4,551	1,736	5,266
Nonpoint	1,849	808	1,882	872
On Road Mobile	3,217	53	839	11
Non-Road Mobile	784	95	428	1
Aircraft	177	18	207	21
Agricultural Burning	2	0	2	0
Wildfires	1,712	469	1,712	469
in/near port Marine	537	418	546	20
Total	9,314	6,412	7,352	6,661

Table VII-3.1 Hawaii (Big Island) Point Source Emissions

	2005		2018	
	NOₓ	SO₂	NOₓ	SO₂
HELCO - Kanoelehua Hill Generating Station	514	2,822	595	3,264

HELCO - Puna Power Plant	241	1,345	279	1,556
HELCO - Keahole Power Plant	154	157	178	182
HELCO - Shipman Power Plant	38	222	28	166
Pepeekeo Power Plant/9-16-10 Hu Honua Bioenergy			420	78
Tradewinds Forest Products, LLC			133	15
HELCO - Waimea Power Plant	89	5	103	5
Total	1,036	4,551	1,736	5,266

VII.C.1. Four Factor Analysis for NO$_x$ sources on Maui and the Big Island

On Maui, NOx emissions are being reduced by almost 2,000 tpy between 2018 and 2005, even while assuming fairly robust economic growth. This is over a 20% reduction in emissions of a pollutant that is of secondary concern for this planning period. In general, EPA finds this to be a reasonable amount of NO$_x$ reductions, considering the small part the pollutant plays in visibility impairment in Hawaii.

Point sources of NO$_x$ in Hawaii are predominantly electric utility units. Emissions from the Camp 10 quarry are quite small and not expected to impact visibility at the Class I areas. The Maui Pineapple plant closed in 2008. The HC&S Puunene Sugar Mill on Maui was modeled by Alpine Geophysics and the modeling indicated that the plant would have no more than a 0.286 deciview impact at the nearest Class I area, Haleakela. Any additional controls are not likely to be cost effective, given the small impact of this source. The other sources are electric utility sources. Considering the costs of compliance and the 20% reduction in emissions from existing regulations, and the small contribution of nitrates to visibility impairment, the EPA does not consider it reasonable to require additional NO$_x$ controls for point sources in this planning period.

Mobile sources of NO$_x$ (on road, non-road, aircraft and marine) constitute the largest fraction of base year emissions on these islands (48%). The NO$_x$ emissions from these categories are projected to drop by over 7,100 tpy between 2005 and 2018. These decreases are largely attributable to a dramatic drop in emissions from on-road mobile sources, resulting from the replacement of older, higher emitting vehicles with new vehicles that must meet more stringent standards under the Clean Air Act. In addition to these requirements for on-road source, EPA regulations also require newer non-road and marine mobile sources to meet stricter control requirements. Collectively, these federal mobile source requirements will result in substantial NOx reductions over the course of the first planning period.

Given this context and taking into consideration the four reasonable progress factors, we believe that requiring additional NO$_x$ controls on mobile sources would not be reasonable at this time. Therefore, we are not proposing any additional NO$_x$ controls for mobile sources for this implementation period.

Agricultural burning is a notable NO_x source on Maui. EPA has evaluated the monitoring data for the Class I areas and determined that there is no evidence that agricultural burning is significantly affecting visibility at the Class I areas. See TSD Sections II.A., II.B, and III.B. The current Hawaii DOH agricultural burning permitting process appears to be sufficient to prevent visibility impacts at the Class I areas.

Wildfires have been included in the anthropogenic emissions inventory because the Hawaii DOH and EPA have not been able to determine if the fires had natural causes or not. Nevertheless, it would not be helpful to introduce further restrictions on wildfires, because these are by definition, not intentional. So, regulations restricting them would not have any appreciable effect.

VII.C.2 Four Factor Analysis for SO$_2$ Emissions on Maui

Our analysis shows that current controls will result in net reductions of anthropogenic emissions of SO_2 on Maui during this first planning period. So it is reasonable to assume that the visibility at Haleakela on the best days is not getting worse. Similarly, with this drop in emissions, it is reasonable to assume that the worst visibility days will be getting better.

VII.C.2.1 Mobile Source SO$_2$ Emissions on Maui

Mobile source SO_2 emissions on Maui (on road, non-road, aircraft and marine) are dropping 89% under current regulations, driven primarily by reductions in marine emissions due to the ECA. This control measure is in addition to the benefits of fleet turnover as described above in the discussion NO_x. Given the existing benefits from the ECA (see section IV.A.) and the fleet turnover benefits that take into account the four factors, EPA finds that no additional SO_2 reductions from mobile sources on Maui are needed in order to show reasonable progress.

VII.C.2.2 Point Source SO$_2$ Emissions on Maui

Point Sources comprise 77% of the SO_2 emissions on Maui and are expected to increase slightly by 2018. However, this increase is more than offset by the reduction in SO_2 from mobile source emissions. The principal point sources on Maui are the Kahului Power Plant and the Maalaea Power Plant, neither of which are BART-eligible. Maalea is downwind of the Class I area and its SO_2 emissions are not expected to impact visibility at Haleakala. Prevailing winds should also transport emissions from Kahului away from Haleakala. Alpine Geophysics estimated the visibility impact of Kahului plant using the CalPUFF computer model. The result was an estimated change in visibility of 0.667 deciviews at Haleakala. The modeling assumed the plant would be running at its maximum 24-hr capacity and burning the highest sulfur content fuel that it is authorized to burn (2% sulfur by weight). While these are very conservative assumptions that are unlikely to occur during normal operations, we believe this level of modeled impact is sufficient to warrant further scrutiny of this source under the four reasonable progress factors.

The first factor to consider in reasonable progress is costs of compliance. The HECO (the electric utility) performed a detailed analysis of the cost of reducing SO_2 emissions at the

Kanoelehua Hill Generating Station as part of the BART analysis for that source[55]. EPA reviewed and largely concurred with the results of that analysis. With Hill, the most cost-effective control measure is to reduce the amount of sulfur in the fuel. This is also true for Kahului. However, even that method is expensive. The lowest cost method for reducing SO_2 emissions at these plants is to switch to a fuel with no more than 1% sulfur by weight. To estimate the total cost of the converting this plant to 1% fuel oil and estimate the impact of those costs on electric rates, EPA developed a base case scenario derived from 2009 operating conditions[56]. This scenario is summarized in Table VII-4 below. This analysis indicates that the cost effectiveness of this control is approximately $4,200 per ton of SO_2 reduced.

Table VII-4: Costs and Benefits from Switching to 1% Sulfur Fuel Oil

	Kahului
Baseline Weight % S	1.57
Baseline Fuel Consumption [gal/yr]	19,790,111
Baseline Emissions [tons SO_2/yr]	2,489
New Fuel Weight % S	1.00
Cost Differential [$/gal]	0.190
Controlled Emissions [tons SO_2/yr]	1,586
Annual Costs [$/yr]	$3,760,121
Annual Emission Reductions [tons SO_2/yr]	904
Cost Efficiency [$/ton SO_2 reduced]	$4,160

In Table VII-4, the baseline sulfur content is the average of two years of fuel oil analysis conducted by the electric utility for fuel they have received at Maui and the Big Island. This is more representative than taking the actual fuel sulfur content for the year 2009. The fuel is guaranteed by the suppliers to be less than 2% sulfur, but the actual sulfur content varies depending on feedstock. The fuel consumption numbers are from emissions inventory reports submitted by the utility to the Hawaii Dept. of Health. The SO_2 emissions were calculated based on stack testing conducted at Kanoelehua Hill and assuming that Kahului also had a more than 99% conversion rate of fuel sulfur to SO_2. The new fuel is conservatively assumed to have exactly 1% sulfur, although in practice the actual sulfur content is likely to be lower. In Table VII-4, we assume that the cost differential between the current fuel and the 1% sulfur fuel to be 0.190 $/gal based on an analysis of prices historically paid for lower sulfur fuel in Hawaii, as described in the BART analysis for Hill. The price is lower than for Hill, because the fuel is delivered to Maui, not the Big Island.

With these assumptions, EPA estimates an increase in fuel costs of over $3.7 million/year. EPA contracted with energy economics consulting firm Energy Strategies to estimate the impact of these increased fuel costs on electric rates. Based on their analysis[57], these increased costs would translate into a roughly 1% increase in retail electric rates on Maui. The benefit of this change would be a reduction in SO_2 emissions of 900 tons per year.

---

[55] BART Five-Factor Analysis Prepared for Hawaiian Electric Light Company, October 2010, Trinity Consultants.
[56] 2009 was selected because it was consistent with the year used in the BART analysis for Hill. It is also a year where the actual capacity factors for the electric plants on the Big Island were comparable to the 4-year average.
[57] Fuel Cost Screening Tool (r1 4-18-12), Energy Strategies Incorporated, April 18, 2012

The second factor to consider is the time necessary for compliance. The switch to a lower sulfur version of the residual fuel oil currently being burned does not require any capital investment or construction, but it does require time to get new fuel contracts into place with the new sulfur limits. It may take time for the fuel suppliers to secure the new fuel and it will take time for the current fuel inventory to be consumed.

The third and fourth factors to consider are the energy and non-air quality impacts of control measures and the remaining useful life of the source. EPA considered these factors in the context of the Hawaii Clean Energy Initiative that sets the goal of 70% clean energy by 2030. The Initiative includes the 2009 Clean Energy Omnibus Bill (ACT 155 (09), HB 1464, signed June 25, 2009). This statute calls for 30% reduction in energy use via efficiency and increases the renewable portfolio standard to 40% by 2030. EPA contracted with UNC and ICF to project the 2018 emissions of power plants considering the requirements of the Clean Energy Omnibus Bill[58]. These projections are compared to the current 2018 projections based on the most recent Integrated Resource Plan (IRP) for Hawaii electric utilities. This IRP predates the 2009 bill and so does not account its requirements. Table VII-5 compares the baseline emission projections for 2018, derived from the current IRP and the projections that take into account the goals of the Clean Energy Bill.

Table VII-5: Range of 2018 Emissions Projections for Key Power Plants on the Maui [tons per year]

	2018 SO$_2$ Emissions IRP	2018 SO$_2$ Emissions Clean Energy Bill
Kahului Power Plant	2,822	0
Maalaea Generating Station	923	591

The projections based on the goals of the Clean Energy Bill assume that the energy conservation and renewable energy goals will be met in a more or less even fashion year to year. So, by 2018, most of these projects will be in place. Under this scenario, Kahului will cease operations by 2018 and Maalaea will operate at a significantly lower capacity factor and/or burn biofuels that contain much less sulfur than their current fuel.

VII.C.2.3 Conclusion of Reasonable Progress Analysis for SO$_2$ Emissions on Maui

Based on the foregoing analysis for the four RP factors, we propose to determine that it is not reasonable to require additional SO$_2$ controls for point sources on Maui in this planning period. In addition, as mentioned above, electric utility rates in Hawaii are over three times the national average. Even in the absence of the Hawaii Clean Energy Bill, emissions on Maui are projected to decrease during this planning period. Therefore, based on our consideration of the four RP factors, EPA proposes to determine that this level of emissions reduction is reasonable for this planning period.

---

[58] Email from Juanita Haydel, ICF Corporation to Greg Nudd, U.S. EPA Region 9, April 4, 2012, with spreadsheet titled: "Hawaii Emissions Values_Revised_040412_FTC.xlsx"

VII.C.3 Four Factor Analysis for SO$_2$ emissions on the Big Island (Hawaii)

Unlike on Maui, EPA is projecting that without additional controls SO$_2$ emissions on the Big Island will increase between 2005 and 2018. As noted above, SO$_2$ is the key anthropogenic visibility-impairing pollutant in Hawaii. Therefore, we propose to determine that additional SO$_2$ control measures are needed on the Big Island in order to ensure reasonable progress toward the national goal of no anthropogenic visibility impairment.

VII.C.3.1 Mobile Source SO$_2$ Emissions on the Big Island (Hawaii)

Mobile source emissions of SO$_2$ on the Big Island are dropping 91% under current regulations, driven primarily by reductions in marine emissions due to the ECA. This control measure is in addition to the benefits of fleet turnover as described above in the discussion NO$_x$. Given the existing benefits from the ECA and the fleet turnover benefits and taking into account the four reasonable progress factors, EPA proposes to determine that no additional SO$_2$ reductions from mobile sources on the Big Island are needed in order to show reasonable progress.

VII.C.3.2 Point Source SO$_2$ Emissions on the Big Island (Hawaii)

Point sources comprise roughly 71% of the anthropogenic SO$_2$ emissions on the Big Island. All of these emissions come from electric power plants. Therefore, all of these power plants were considered for additional controls. Because of their relatively low emission rates and distance from the Class I areas, EPA eliminated the Keohole and Waimea Power Plants. Due to their emission rates and positions close to and upwind of Hawaii Volcanoes National Park, Hill, Shipman and Puna are the focus of the review. Alpine Geophysics estimated the visibility impact of these plants using the CalPUFF computer model. The results are summarized below:

Table VII-6: Modeled Visibility Impacts of Key Power Plants on Hawaii

	Visibility Impact [Δ/dv]	
	HAVO	HALE
HELCO - Kanoelehua Hill Generating Station	2.334	0.808
HELCO - Puna Power Plant	1.594	0.358
HELCO - Shipman Power Plant	0.777	0.321

These plants were also modeled with the same conservative assumptions as Kahului. The results for Hill and Puna indicate that these plants may be causing visibility impairment at Hawaii Volcanoes. In addition, the results indicate that Hill may be contributing to impairment at Haleakala and Shipman may be contributing to visibility impairment at Hawaii Volcanoes.

The first factor to consider in reasonable progress is the costs of compliance. The HECO (the electric utility) performed a detailed analysis of the cost of reducing SO$_2$ emissions at Hill as part of the BART analysis for that source[59]. EPA reviewed and largely concurred with the results of that analysis. As described previously, the most cost-effective control measure is to reduce the amount of sulfur in the fuel. This is also true for Shipman and Puna. Table V-7 provides the full

---

[59] BART Five-Factor Analysis Prepared for Hawaiian Electric Light Company, October 2010, Trinity Consultants

cost/benefit calculation for the Big Island sources. Based on this analysis, EPA estimates that the cost effectiveness of this control is approximately $5,500 per ton of SO_2 reduced for sources on the Big Island.

Table V-7: Costs and Benefits from Switching to 1% Sulfur Fuel Oil

	Hill	Shipman	Puna
Baseline Weight % S	1.57	1.57	1.57
Baseline Fuel Consumption [gal/yr]	18,650,604	2,241,876	9,930,648
Baseline Emissions [tons SO_2/yr]	2,344	282	1,249
New Fuel Weight % S	1.00	1.00	1.00
Cost Differential [$/gal]	0.255	0.255	0.255
Controlled Emissions [tons SO_2/yr]	1493	180	796
Annual Costs [$/yr]	$4,755,904	$571,678	$2,532,315
Annual Emission Reductions [tons SO_2/yr]	851	102	454
Cost Efficiency [$/ton SO_2 reduced]	$5,587	$5,583	$5,583
Total Annual Cost	$7,859,89		
Total Annual Emissions Reduction	1,407		

In Table V-7, most of the assumptions are the same as in Table V-4, but the cost differential is a bit higher due to the extra transport costs. We added 0.065 $/gal to the estimate for a total of 0.255 $/gal. The 0.065 $/gal estimate is derived from the six-year (2006-2011) cost differential between residual fuel oil delivered to Maui and the same oil delivered to the Big Island.

With these assumptions, EPA estimates an annual increase in fuel costs of over $7.9 million/year. EPA contracted with energy economics consulting firm Energy Strategies to estimate the impact of these increased fuel costs on electric rates. Based on their analysis[60], these increased costs would translate into a 2% increase in retail electric rates on the Big Island. The benefit of this change would be a reduction in SO_2 emissions of at least 1,400 tons per year.

The second factor to consider is the time necessary for compliance. The considerations here are the same as for Maui.

The third and fourth factors to consider are the energy and non-air quality impacts of control measures and the remaining useful life of the source. In order to fully consider the energy and non-air quality impacts of control measures and the remaining useful life of the source, EPA is taking into account the anticipated results of the Clean Energy Bill described above. Table VII-8 compares the baseline emission projections for 2018 and the projections that take into account the goals of the Clean Energy Bill.

---

[60] Fuel Cost Screening Tool (r1 4-18-12), Energy Strategies Incorporated, April 18, 2012

Table VII-8: Range of 2018 Emissions Projections for Key Power Plants on the Big Island [tons per year]

	2018 SO$_2$ Emissions IRP	2018 SO$_2$ Emissions Clean Energy Bill
HELCO - Kanoelehua Hill Generating Station	3,264	765
HELCO - Puna Power Plant	1,566	365
HELCO - Shipman Power Plant	166	0

Again, these are optimistic assumptions, but they are useful. Under this scenario, Shipman is projected to cease operations by 2018 and Hill and Puna are projected to be operating at a significantly lower capacity factor and/or burning biofuels with much lower sulfur content than their current fuel.

VII.C.3.3 Conclusion of Reasonable Progress Analysis for SO$_2$ Emissions on the Big Island (Hawaii)

Some additional, federally enforceable SO$_2$ reductions are needed on the Big Island to ensure reasonable progress. Based on the above analysis of the four reasonable progress factors, EPA believes that any control measure for SO$_2$ should be structured so that it could be achieved through increased energy efficiency and increased reliance on renewable energy. Therefore, EPA is proposing to cap total emissions at the fuel oil-fired boilers at Hill, Shipman and Puna at 3,500 tons per year, beginning in January 1, 2018. This is a reduction of 1,400 tons per year from the baseline estimate of emissions in 2018. If HECO is on track with implementing the Hawaii Clean Energy Bill, it should be able to meet this cap with no additional costs to the ratepayers. In the worst case scenario where the cap has to be met with a lower sulfur fuel oil, the utility should be able to meet this cap at a cost of roughly $7.9 million/year. EPA is structuring this control requirement to allow the utility to minimize costs. We are taking the other three factors into account by structuring the control requirement to be consistent with the State's goals for energy conservation and reduced dependence on fossil fuels.

VII.D. Benefits of the Emission Control Area on Emissions from In Transit Marine Vessels

In addition to reducing emissions from ships in and near ports, the ECA also significantly reduces emissions from ships traveling from port-to-port. As part of the evaluation of the benefits of the ECA, EPA asked UNC and ICF to calculate the 2005 and 2018 emissions from ships passing within 150 km of each of the Class I areas. Table V-9 summarizes these results. Since the 150 km includes some ports and those ports are already accounted for in the "In and Near Port Marine" category in the island-specific inventories, those emissions have been excluded from Table V-9.
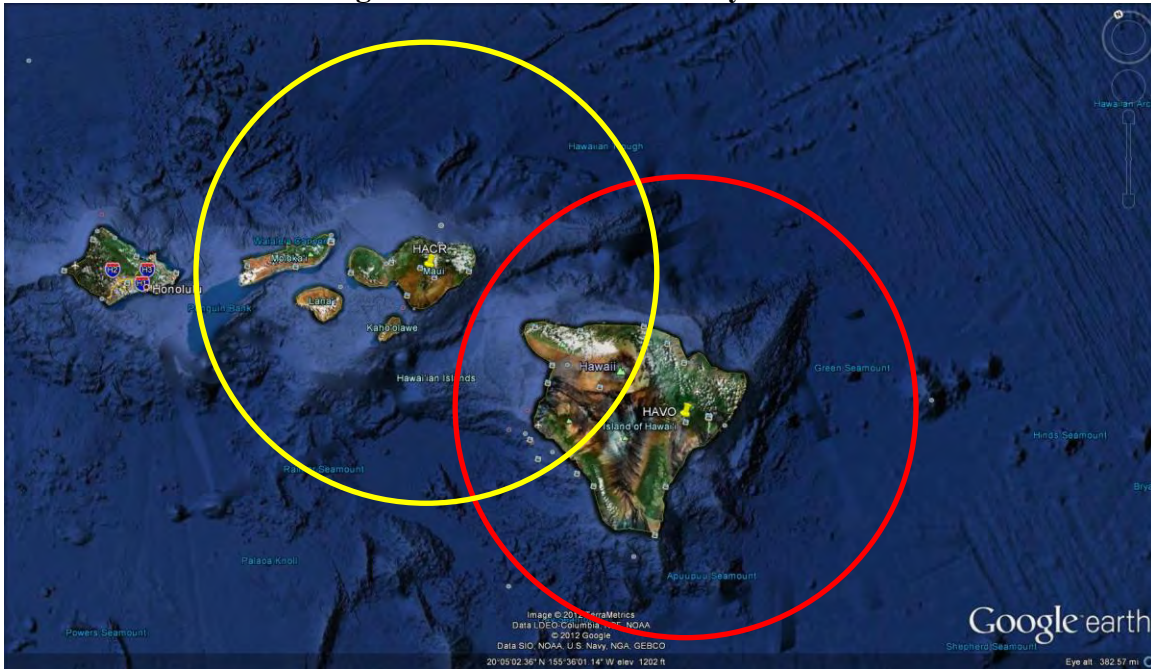
Figure VII-2: Class I Visibility Areas

Table VII-9: Benefits of the ECA from In Transit Shipping within 150 km of the Class I Areas

Class I area	2005		2018	
	NO$_x$	SO$_2$	NO$_x$	SO$_2$
Haleakala	2,740	2,610	3,419	141
Hawaii Volcanoes	566	530	447	15

EPA considered this as supplemental information when determining whether reasonable progress is being made with existing regulations. These emission reductions are expected to benefit visibility at the Class I areas, but it is difficult to determine by how much. For example, prevailing winds may transport the emissions away from the Class I areas. Specifically, much of the reductions for the Haleakala zone are from ships traveling to and from Oahu. These SO$_2$ emission reductions from shipping in the vicinity of Maui support our decision not to require additional SO$_2$ controls on that island in this planning period.

VII.E. Reasonable Progress Goals - 2018 Visibility Projections

There is no modeling available for this planning period that can reliably predict the change in visibility due to changes in the emission inventory for all sources (shipping, mobile sources, point sources, etc.).[61] In absence of reliable visibility modeling for 2018, EPA is using projections based on the island-specific inventories as a surrogate for judging whether reasonable progress is being made.

---

[61] EPA believes that there is acceptable modeling for point sources for identifying BART Subject Sources and for the reasonable progress analysis. This modeling is discussed in Section IVC: Identify BART Subject Sources, above.

In order to show the how the future emission changes may affect the aerosol levels in each of the parks, EPA estimated the effect that the changes in the island specific inventories for NOx and SO2 may have on the levels of nitrate and sulfate for each of the parks. EPA projected visibility conditions in 2018 using the following assumptions:

1. Sea salt, Soil, Coarse mass, Organic Carbon, and Elemental Carbon are assumed to be constant for the 20% best days and 20% worst days for both the Haleakala and Hawaii Volcanoes National Parks.

2. Nitrate is projected based on the change (in percentage) in the 2018 anthropogenic NOx inventory, compared to the 2005 inventory on each island. Nonanthropogenic emissions are assumed to be unchanged from the year 2005 inventory. Benefits from the ECA in transit shipping emissions are not considered in the projections.

3. Sulfate for Haleakala National Park. Sulfate visibility impact is projected based on the reductions in the 2018 anthropogenic SOx inventory, compared to the 2005 inventory on the island of Maui. The anthropogenic visibility impact is assumed to be 33% of the total for the Island of Maui on the 20% worst days, and 70% of the total on the 20% best days. The FIP option projection is based on a 1400 ton per year reduction of SO2 on the Island of Hawaii. Although this reduction would likely reduce sulfate at Haleakala National Park to some extent, this reduction is not reflected in the projections for 2018.

4. Sulfate at Hawaii Volcanoes National Park. Sulfate visibility impact is projected based on the percentage reductions in the 2018 anthropogenic SO_2 inventory, compared to the 2005 inventory on the island of Hawaii. The anthropogenic visibility impact is assumed to be 10% of the total on the Island of Hawaii on the 20% worst days and 70% of total on the 20% best days. The FIP option assumed a 1400 ton per year reduction of SO2 on the Island of Hawaii. This reduction is reflected in the 2018 projections for the FIP option.

The visibility projections for 2018, based on these assumptions, are shown below.

Visibility Projection Results

The projected visibility (light extinction (b_{ext}) in Mm-1) in the year 2018 is shown in the figures below. At Hawaii Volcanoes National Park, the projected visibility for the year 2018, without the emission reductions form the FIP, is slightly worse than the visibility for the year 2005. With the emission reductions from the FIP, there is a slight improvement in visibility conditions in the year 2018 compared to the year 2005 for both the 20% best and 20% worst days. At Haleakala National Park, there is a slight improvement in visibility conditions in the year 2018 compared to the year 2005 for both the 20% best and 20% worst days.

Figure VII-3: Projected Visibility (light extinction, bext Mm-1) for Hawaii Volcanoes National Park – 20% best days.
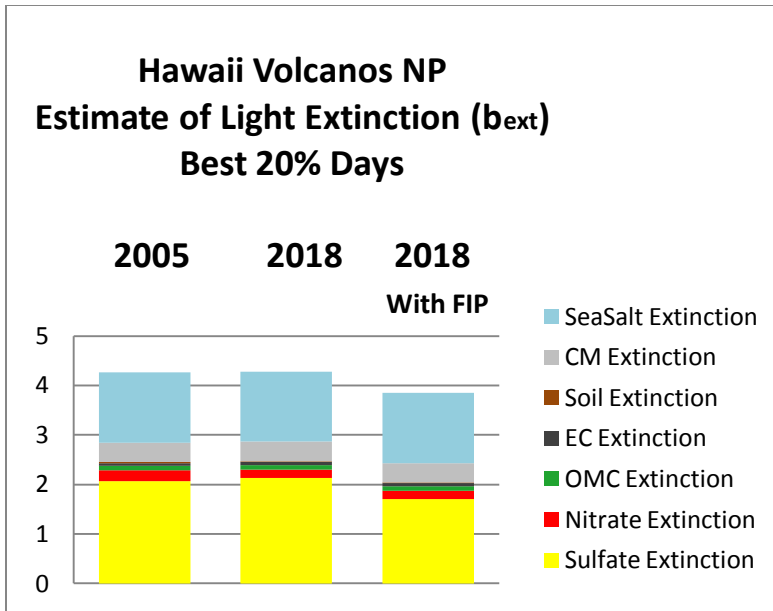
Figure VII-3: Projected Visibility (light extinction, bext Mm-1) for Hawaii Volcanoes National Park – 20% worst days.
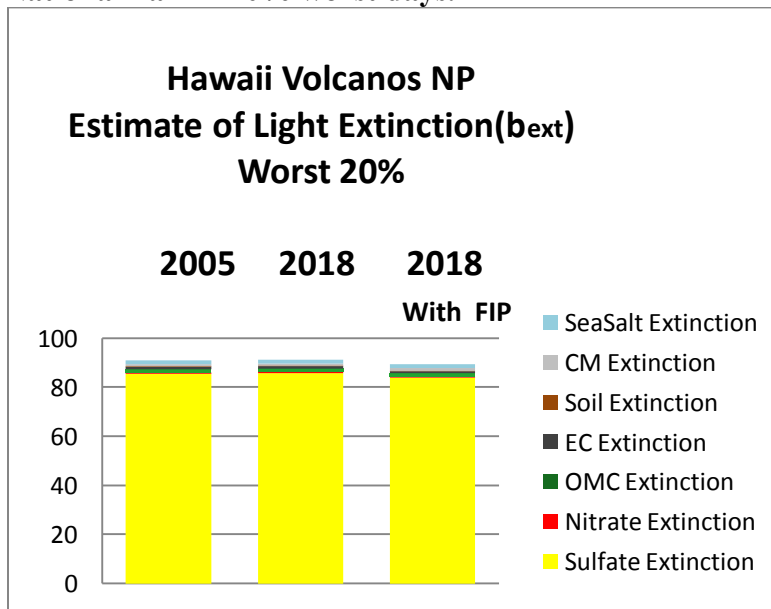

Figure VII-4: Projected Visibility (light extinction, bext Mm-1) for Hawaii Volcanoes National Park – 20% worst days – with revised axis to highlight changes from 2005 to 2018.

Hawaii Volcanos NP
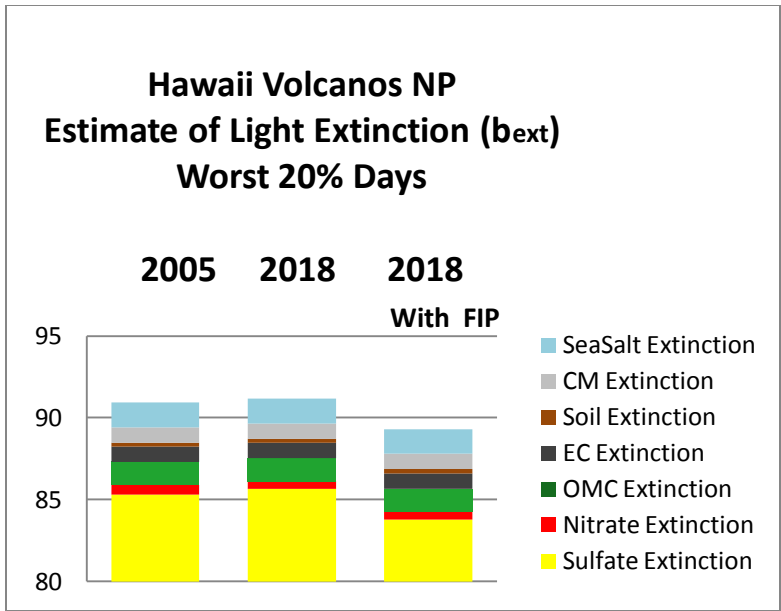Estimate of Light Extinction (b_{ext})
Worst 20% Days

Figure VII-5: Projected Visibility (light extinction, bext Mm-1) for Haleakala National Park – 20% best days.

Haleakala NP
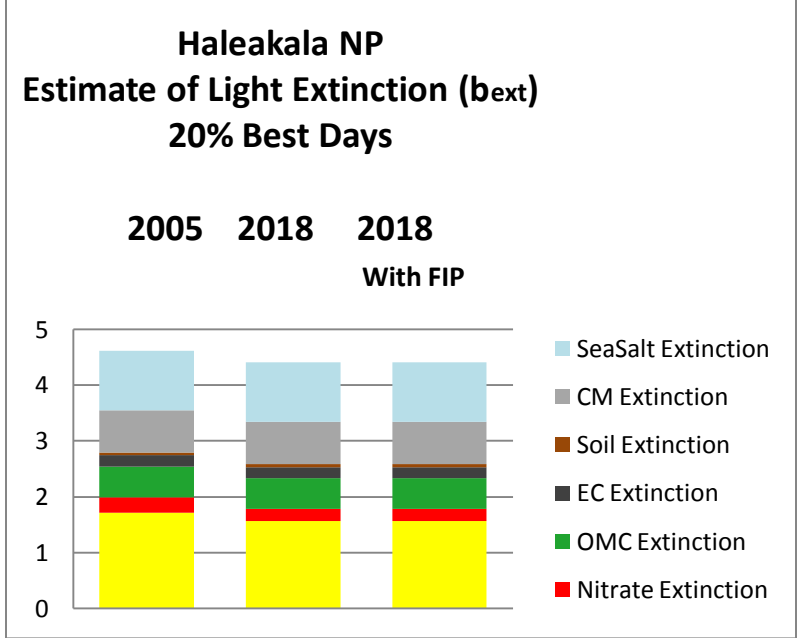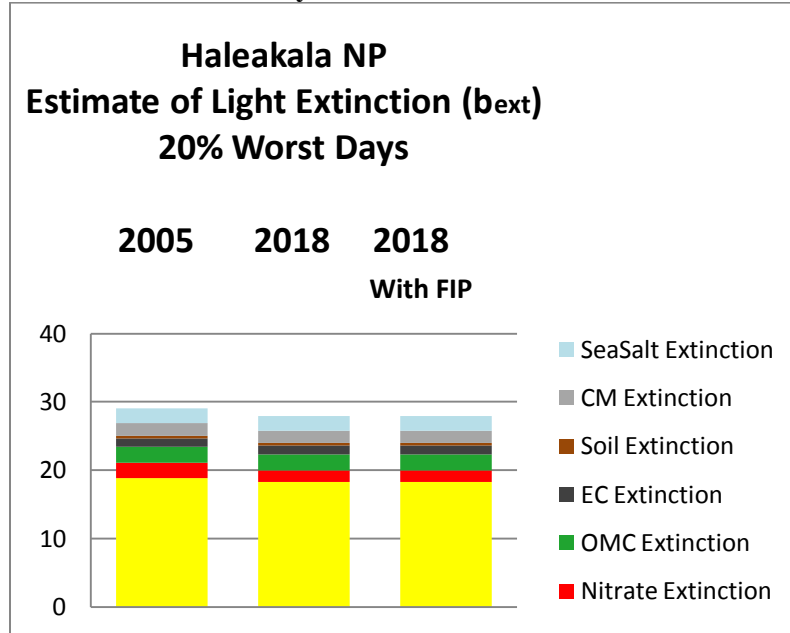Estimate of Light Extinction (b_{ext})
20% Best Days

Figure VII-6: Projected Visibility (light extinction, bext Mm-1) for Haleakala National Park – 20% worst days.

VII.F. Visibility Improvement Compared to URP and Number of Years to Reach Natural Conditions

The amount of improvement needed (Δ deciview) to meet the Uniform Rate of Progress for 2018 for Haleakala National Park is 1.38 Δ deciview. Based on the projections of visibility, discussed above, the amount of improvement by 2018 would be 0.25 Δ deciview. This would result in a 2018 level of visibility of 13.0 deciview. The amount of improvement needed (Δ deciview) to meet the Uniform Rate of Progress for 2018 for Hawaii National Park is 2.73 Δ deciview. Based on the projections of visibility, discussed above, the amount of improvement by 2018 would be 0.18 Δ deciview. This would result in a 2018 level of visibility of 18.7 deciview.

Based on the projections for 2018, discussed above, the URP will not be met at either National Park. Because RPGs are not achieving URP by 2018 and natural conditions by 2064, EPA is required by the Regional Haze rule to re-calculate and state the length of time necessary to achieve natural conditions, as shown below. EPA has calculated the number of years it would take to reach natural conditions, based on the rate of visibility improvement in this first planning period. Because the baseline conditions include the effect of the emissions from the volcano, the calculation of number of years to reach natural conditions may not represent a realistic scenario in this case. In addition, the visibility projections for 2018, discussed above, are based on very simplified assumptions.

Instead of achieving natural conditions in 2064 (60 years) at the two Class I areas, the year and the length of time is re-calculated. The rate of improvement at Haleakala is approximately 0.018 Δ deciview per year and the needed improvement to reach natural conditions is 5.9 deciview. Therefore, at this rate of improvement natural conditions would be met in approximately 300 years. The rate of improvement at Hawaii Volcanoes National Park is 0.013

Δ deciview per year, and the needed improvement to reach natural conditions is 11.7 deciview. Therefore, at this rate of improvement natural conditions would be met in approximately 900 years.

VIII. Monitoring Strategy

VIII.A. IMPROVE Monitoring Network

The Regional Haze SIP is to be accompanied by a strategy for monitoring regional haze visibility impairment. Specifically, the regional haze rule states at 40 CFR 51.308(d)(4):

"(4) Monitoring strategy and other implementation plan requirements. The State must submit with the implementation plan a monitoring strategy for measuring, characterizing, and reporting of regional haze visibility impairment that is representative of all mandatory Class I Federal areas within the State. This monitoring strategy must be coordinated with the monitoring strategy required in §51.305 for reasonably attributable visibility impairment. Compliance with this requirement may be met through participation in the IMPROVE network. The implementation plan must also provide for the following:

  (i) The establishment of any additional monitoring sites or equipment needed to assess whether reasonable progress goals to address regional haze for all mandatory Class I Federal areas within the State are being achieved.

  (ii)-(vi) [Other implementation plan requirements that pertain to reporting and use of monitoring data and an emission inventory.]"

Such monitoring is intended to provide the data needed to satisfy four objectives:

  1. Track the expected visibility improvements resulting from emissions reductions identified in this SIP.

  2. Better understand the atmospheric processes of importance to haze

  3. Identify chemical species in the ambient particulate matter and relate them to emissions from sources

  4. Evaluate regional air quality models for haze and construct relative response factors for using those models

The primary monitoring network for regional haze, both nationwide and in Hawaii is the IMPROVE network. Given that IMPROVE monitoring data from 2001-2004 serves as the baseline for the regional haze program, the future regional haze monitoring strategy must necessarily be based on, or directly comparable to, IMPROVE. The IMPROVE measurements

provide the only long-term record available for tracking visibility improvement or degradation and therefore EPA and Hawaii intend to rely on the IMPROVE network for complying with the regional haze monitoring requirement in the Regional Haze Rule.

Data produced by the IMPROVE monitoring network will be used nearly continuously for preparing the 5-year progress reports and the 10-year SIP revisions, each of which relies on analysis of the preceding five years of data. Consequently, the monitoring data from the IMPROVE sites needs to be readily accessible and to be kept up to date. Presumably, IMPROVE will continue to process information from its own measurements at about the same pace and with the same attention to quality as it has shown in the recent past. The VIEWS web site has been maintained by the WRAP and the other Regional Planning Organizations to provide ready access to the IMPROVE data and data analysis tools.

There are two IMPROVE monitoring sites currently operating in or near the Haleakala National Park. The Haleakala (HALE1) IMPROVE monitoring site is located outside of the Haleakala National Park and the Haleakala Crater (HACR1) IMPROVE monitoring at the park's Western boundary. In this proposal, EPA is using monitoring data from the HALE1 monitoring site, as the HACR1 site was not yet in operation for the base year time period of 2000-2004.

Hawaii DOH has prepared two reports comparing data from the two sites. The conclusions from these reports are summarized section II.D. 2. Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site, below. The reports conclude that, based on the available data, the HACR1 IMPROVE monitoring site is more representative of visibility conditions within the Haleakala National Park than the HALE1 IMPROVE monitoring site.

VIII.B. Analysis of the Haleakala (HALE1) IMPROVE monitoring site and newer Haleakala Crater (HACR1) Monitoring site

Currently there are two IMPROVE monitoring sites operating in or near the Haleakala National Park. The Haleakala (HALE1) IMPROVE monitoring site is located outside of the Haleakala National Park near to the Maui Central Valley, at an elevation of 1153 meters. The HALE1 IMPROVE monitoring site began operation at end of 2000, and will close in May 2012. The Haleakala Crater (HACR1) IMPROVE monitoring site is at the park's Western boundary, at an elevation of 2158 meters. The HACR1 IMPROVE monitoring site began operation in 2007. In this proposal, EPA is using monitoring data from the HALE1 monitoring site, as the HACR1 site was not yet in operation for the base year time period of 2000-2004.

Figure VIII-A: HALE and HACR Monitoring Locations

HALE, LAT: 20.808600°, LON: -156.282300°

HACR, LAT: 20.758500° LON: -156.247900°

Haleakala

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Data MBARI
Data LDEO-Columbia, NSF, NOAA
Image © 2012 TerraMetrics

13.06 mi

Google

lat 20.787729° lon -156.315306° elev 2789 ft

Eye alt 56.10 mi

Hawaii DOH has prepared two reports comparing the two IMPROVE monitoring sites at Haleakala National Park[62], including a detailed comparison of organic and elemental carbon data at the two sites.[63] The reports find that the most significant difference between data measured at the two sites appears to be that HALE1 site has higher levels of organic and elemental carbon. The levels of the other species are generally lower at the HACR1 IMPROVE monitoring site than at the HALE1 monitoring site. The reports conclude that, based on the available data, the HACR1 IMPROVE monitoring site is more representative of visibility conditions within the Haleakala National Park than the HALE1 IMPROVE monitoring site.

---

[62] Comparison of Haleakala National Park HALE1 and HACR1 IMPROVE Monitoring Site 2007-2008 Data Sets, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch

[63] Review of VIEWS2.0 2009-2010 Haleakala National Park Organic and Elemental Carbon Data, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch, and Comparison of Haleakala National Park HALE1 and HACR1 IMPROVE Monitoring Site 2007-2008 Data Sets, March 30, 2012, State of Hawaii, Department of Health, Clean Air Branch

Background Information on the Haleakala HALE1 IMPROVE Site[64]

HALE1 is located at an elevation of 1,158 m (3,799 ft) on the northward slope of Haleakala, ~5.7 km northwest of the Park Boundary. In general, aerosol measurements at HALE1 should be representative of ambient concentrations at National Park locations at the same elevation. However, the extreme climate variability over the range of elevation and exposure in the National Park compels caution in aerosol source attribution, especially with the sensitivity of particle size to moisture. Rainfall gradients in Hawaii are among the steepest in the world. The HALE1 site has exposure to northeasterly trade winds and may be more susceptible to rain caused by orographic lifting than are most National Park areas on the leeward side. Being at an elevation that is lower than the typical Marine Boundary Layer height most of the time, the HALE1 IMPROVE site may frequently be more representative of aerosols near the surface with different back trajectories than those of upper air aerosols transported from distant global scale source regions by upper level winds.

Hawaii DOH Comparison of the Haleakala (HALE1) and Haleakala Crater (HACR1) IMPROVE Monitoring Sites -Summary

Hawaii DOH examined the 2007 - 2008 IMPROVE Data from the HACR1, HALE1, and HAVO1 monitoring sites using the EPA Positive Matrix Factorization (PMF) 3.0 code. The monitoring data from each site was analyzed separately. The focus of the Hawaii DOH document was the correspondence between monitored values at the HACR1 and HALE1 site.

For the 7 visibility impacting mass concentrations (e.g. Ammonium Sulfate), the mean HALE1 values are typically about a factor of two larger than for HACR1. The exception to this is Fine Soil, which is approximately equal. This approximate equivalence in Fine Soil measurements appears consistent with long-range transport of dust (e.g. Asian Dust). The most significant difference between mean data measured at the two sites appears to be that HALE1 is impacted more by organic and elemental carbon associated with the Positive Matrix Factorization Smoke factor. This appears to be consistent with the relatively close proximity and location of the HALE1 monitor with respect to agricultural burning in the Central Valley of Maui.

For HACR1, the largest organic carbon and elemental carbon IMPROVE measurements occurred in late January 2007. The character of the organic carbon and elemental carbon time histories for HACR1 appear significantly different than for those of HALE1. The HACR1 measurements show a few very large mass concentrations in January and April 2007 followed by much lower values throughout the rest of 2007 and 2008. The HALE1 measurements, while showing variability, do not have such large outliers. While the average HACR1 mass concentrations for organic carbon and elemental carbon are approximately 50% of those for HALE1, the maximum HACR1 organic carbon mass concentration is approximately 600% the HALE1 value and the maximum HACR1 elemental carbon mass concentration is approximately 300% the HALE1.

The HACR1 IMPROVE measurements appear consistent with a 2291acre forest fire in Census Tract 303 that was also produced numerous MODIS detections. The second largest organic carbon and elemental carbon IMPROVE measurements at HACR1 occurred in early April 2007. These measurements appear consistent with a HC&S field burns that was also

---

[64] http://www.coha.dri.edu/web/state_analysis/Hawaii/HaleakalaNP_metdesc.html

produced 2 MODIS detections. While the details of why HACR1 was impacted significantly more than HALE1 for these two isolated cases during 2007 and 2008 would require a more extensive examination of the winds patterns for those days, the available data seems sufficient to conclude that these few measurements are not representative of HACR1 measurements.

The remaining HACR1 and HALE1 monitoring measurements appear consistent with the general observation that HACR1 IMPROVE monitoring values are generally much lower than those at HALE1. The available data indicates that HACR1 IMPROVE monitoring data is more representative of visibility conditions within the Haleakala National Park.

Appendix A

Subject-to-Best Available Retrofit Technology (BART) Modeling for the State of Hawaii, Application of the CALPUFF Modeling System

Prepared for Hawaii State Department of Health, Environmental Management Division Clean Air Branch by Alpine Geophysics, LLC. March 3, 2010.

Appendix B

MM5 Application for 2005 Over the Hawaiian Islands,
Prepared for Hawaii State Department of Health, Environmental Management Division, Clean
Air Branch by Alpine Geophysics, LLC, October 31, 2008