Existing Research and Data Regarding the Status of Air Quality in the Greater Yellowstone Ecosystem:

A Bibliography

Prepared by: Katrina Hettinger

Supervised by: Lloyd Dorsey

Greater Yellowstone Coalition
P.O. Box 4857
Jackson, WY 83001

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Scott Copeland; USDA Forest Service, Lander, WY

Project Intern and Author:
Katrina Hettinger; Greater Yellowstone Coalition, Jackson, WY

Project Supervisor:
Lloyd Dorsey; Greater Yellowstone Coalition, Jackson, WY

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ABBREVIATIONS AND ACRONYMS

μeq/L	microequivalencies per liter
μm	micrometer
Al	aluminum
ANC	acid-neutralizing capacity
AQD	Air Quality Division
AQRVs	Air Quality Related Values
BLM	Bureau of Land Management
Ca	calcium
CAA	Clean Air Act
Cl^-	chloride
CASAC	Clean Air Scientific Advisory Committee
CO	carbon monoxide
CO_2	carbon dioxide
Cr	chromium
FWS	U.S. Fish and Wildlife Service
EPA	U.S. Environmental Protection Agency
GRTE/GTNP	Grand Teton National Park
GRYN	Greater Yellowstone Network
GYA	Greater Yellowstone Area
GYACAP	GYA Clean Air Partnership
GYCC	Greater Yellowstone Coordinating Committee
GYE	Greater Yellowstone Ecosystem
HAPs	hazardous air pollutants
Hg	mercury
I&M	Inventory & Monitoring

IMPROVE	Interagency Monitoring of Protected Visual Environments
INL	Idaho National Laboratory
JIO	Jonah Interagency Office
kg/ha/yr	kilogram per hectare per year
K	potassium
KYNF	Keep Yellowstone Nuclear Free
Mg	magnesium
N	nitrogen
Na	sodium
NAAQS	National Ambient Air Quality Standards
NADP	National Atmospheric Deposition Program
ng/g	nanogram per gram
NH_4^+	ammonium
NO_2	nitrogen dioxide
NO_3^-	nitrate
NO_x	nitrogen oxides
NPS	National Park Service
NTN	National Trends Network
OSVs	over-snow vehicles
PAHs	polycyclic aromatic hydrocarbons
PAPO	Pinedale Anticline Project Office
$PM_{2.5}$	particulate matter less than 2.5 microns
PM_{10}	particulate matter less than 10 microns
ppm	parts per million
PSD	Prevention of Significant Deterioration
QA/QC	quality assurance/quality control
S	sulfur

SEIS	Supplemental Environmental Impact Statement
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring Stations
SO_2	sulfur dioxide
SO_4^{2-}	sulfate
TACs	toxic air contaminants
UGRB	Upper Green River Basin
UGWOS	Upper Green Winter Ozone Study
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
WDEQ	Wyoming Department of Environmental Quality
WRAP	Western Regional Air Partnership
YELL/YNP	Yellowstone National Park
Zn	zinc

INTRODUCTION

Purpose:

This bibliography was created during winter 2010-2011 as an intern project, in order to compile available literature and data related to air quality in the Greater Yellowstone Ecosystem (GYE). These citations are meant to provide a wide array of information on both the current and historical status of air quality in the GYE to the public and decision makers. With access to high-quality information, all stakeholders will have an increased capability to effectively engage in regional air quality issues and address associated adverse impacts on the environment and natural resources to protect air quality in the GYE for now and future generations.

In addition to the written bibliography, a further purpose of this project was to provide access to the citations on the internet. By creating a virtual library that archives these documents, the public will have another avenue to access these citations and access each document as a PDF link. The online version of this bibliography was created in cooperation with the Teton Science Schools, and is available to the public under the Conservation Research Center – Research – Projects – Air Quality, at http://www.tetonscience.org/index.cfm?id=crc-projects-airquality.

Methodology:

In order to compile the bibliography, several state and federal agency personnel, academic staff and other non-governmental organizations were contacted and extensive online research was conducted. Due to the broad range of air quality research and monitoring data that exists, the bibliography is organized into sections in order to make the documents accessible by topic. Topics include:

- Comprehensive/National Reports
- Regional Reports
- Impacts on Human Health
- Impacts on Terrestrial/Biological Resources
- Impacts on Physical Resources (Subsections: Surface Water/Atmospheric Deposition, Climate Change, and Visibility)
- Winter Air Quality
- Oil and Gas Exploration/Energy Development
- Monitoring Databases and Programs

Many of the documents overlap between the various sections of the bibliography, but based on professional judgment, the most appropriate section was selected for each citation. Due to time constraints, only the most recent citations (2008-2011) include an abstract or description. The documents do not represent air quality in the GYE prior to 1990, with the exception of a select few. To enhance the historical and baseline data for air quality in the GYE, additional research would need to be done in order to add documents prior to 1990.

In regards to geographical limitations for citations, the boundaries utilized for the GYE during this project are as follows: North to Bozeman, MT and I-90, East to Billings, MT, West to Idaho Falls, ID and Pocatello, ID, South to I-80 in WY, and East to Riverton, WY, Cody, WY, and Wamsutter, WY (See map on page 6).

In the future, if the GYE air quality bibliography project is maintained, documents may be added to the online virtual library, but, in order to add citations to the original bibliography an update will be required. Due to time and funding constraints, the introduction portion of this bibliography is not complete, but rather is a brief overview meant to give the audience a general understanding of air quality in the GYE. Each portion of the introduction offers *only* a minute amount of information and should not be regarded as sufficient or comprehensive. In order to gain a full understanding of topics outlined in the introduction, the cited documents should be read and reviewed.

It should be noted that not all of the citations in this bibliography have been peer reviewed, but based on professional judgment, were deemed to be valuable information sources regarding air quality in the GYE. In addition, some of this work has the potential of being subject to the peer review process in the future.

Air Quality Fundamentals Related to the GYE:

The Greater Yellowstone Ecosystem is one of the largest intact temperate-zone ecosystems on the planet, covering approximately 12-18 million acres of land in the states of Wyoming, Montana, and Idaho (See page 6 for a map of the GYE).[1] It encompasses state and private lands, tribal land, BLM holdings, three wildlife refuges, two national parks, six national forests, and twelve wilderness areas.[1] The ecosystem is host to one of the largest elk herds in North America, the largest herd of wild, free roaming bison in the U.S., one of two grizzly bear populations in the contiguous U.S., and the rare wolverine and lynx species.[1] Furthermore, Yellowstone National Park is on the World Heritage List for its natural heritage, containing "half of all the world's known geothermal features" and "the world's largest concentration of geysers".[5] The wide range of ecosystem components and functions that exist in the GYE are the basis for its immense biological diversity, and resulting ecosystem values. In order to protect these basic values, earth's fundamental natural resources must also be protected, including air quality, which can cause adverse impacts on human health and the environment when degraded, most often as a result of anthropogenic activity.

The Clean Air Act (CAA), 42 U.S.C. §7401 et seq. (1970), last amended in 1990, is the foundation for regulating the nation's air quality.[6] This federal law sets emissions standards for mobile and stationary sources, and authorizes the U.S. Environmental Protection Agency to set national ambient air quality standards (NAAQS) to protect public health and the environment and regulate hazardous air pollutants (HAPs).[6] This law defines EPA's role in not only protecting, but also improving national air quality and the stratospheric ozone layer.[6] The CAA strives for "safe and acceptable ambient air quality" by attaining and maintaining NAAQS[2], which have been set for six criteria pollutants, including ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, lead and particulate matter[4]. There are two types of NAAQS: primary standards, which are set at levels protective of public health, including sensitive populations (asthmatics, children, and elderly) and secondary standards, which are set to protect public welfare, including damage to visibility, vegetation, animals, crops, and buildings.[7] Current NAAQS can be found at http://www.epa.gov/air/criteria.html. For HAPs, also known as air toxics, the EPA does not set national standards, but instead, regulates emissions with industry specific standards through the use of control technologies.[4]

Pursuant to the CAA, the EPA also provides guidance to the states, who are required to administer the CAA at the state level.[4] The states are required to establish monitoring programs for the criteria pollutants in order to assure attainment of the NAAQS; areas that exceed the standards are designated non-attainment, in which case the state is required to develop an implementation plan to regain compliance within a certain period of time.[4] The State Implementation Plan (SIP) is developed by the state and submitted to the EPA for approval to illustrate how the state will address a polluted area and administer cleanup.[2] Access to Wyoming's federally enforceable SIP and air quality standards and regulations can be found at http://www.epa.gov/region8/air/sip.html.

The GYE has several Class I areas that reside within its boundaries, including NPS's Yellowstone National Park (YNP) and Grand Teton National Park (GTNP), FWS Red Rock Lakes refuge, and USFS's North Absaroka, Teton, Fitzpatrick, Washakie, and Bridger Wilderness Areas.[3] These designated Class I areas, pursuant to and classified by the Prevention of Significant Deterioration (PSD) title of the CAA, 42 U.S.C. §§ 7470-7492 (CAA §§ 160-169B), deserve the highest level of air quality protection and may not be redesignated to a less protective category.[2] The PSD title is an authority for resource protection, by establishing ceilings on the addition of air pollutants above baseline in clean areas (see map on page 7), the protection of air quality related values (AQRVs), and specifically visibility.[2] Class II areas are also protected by increment ceilings, but do allow for moderate development[2]; examples of Class II areas that reside within the boundaries of the GYE, include the USFS's Gros Ventre, Jedediah Smith, Winegar Hole, and Popo Agie Wilderness Areas (see map on page 7).

Due to its expanse, the GYE is managed by federal, state, and tribal governments and private land owners.[1] This cross-jurisdictional characteristic warrants a collaborative effort from all stakeholders associated with the GYE, in order to understand and manage air quality effectively in the region. At a federal level, the CAA gives Federal Land Managers the opportunity to participate in regulatory decisions affecting air quality in federally-protected areas.[2] However, the ability of Federal Land Managers to influence regulatory actions is only as good as the science available to support their cause.[2] Therefore, it is critical to continue monitoring and research to provide current data and information on air quality in the GYE.

Issues of Significant or Potential Concern:

Based on literature reviewed and discussions with air quality personnel, seven key GYE air quality issues were identified:

Urban and industrial emissions in Montana, Wyoming, and Idaho are emitted from various mobile and stationary sources, and can be transported to the GYE. Many of these pollutants are from stationary sources and can become concentrated during periods of limited dispersion, such as during inversions.[15] Montana sources are associated mainly with petroleum refining in the Billings/Laurel area and Idaho's are mostly chemical and fertilizer manufacturing in the Soda Springs/Pocatello areas.[15] The major Wyoming sources are associated with oil and gas drilling/production. Non-attainment areas within the GYE include Yellowstone County, MT for SO_2 and Power/Bannock Counties, ID for PM_{10}.[16]

Wyoming is currently a national leader in **oil and gas development**, providing immense economic wealth and jobs to the region, but with potential adverse impacts to human health and the environment. This development within the GYE is localized in SW Wyoming in the Upper Green River Basin (UGRB) and citizens in Sublette County have expressed concern over industry emissions. It has been stated that emission increases from this energy development "is the most pressing air quality issue in the GYA".[15] Emission concerns related to the oil and gas industry include pollutants such as NO_x and VOCs (ozone precursors), HAPs, and other criteria pollutants. HAPs are pollutants that are known or suspected to be carcinogenic and have the potential to cause other serious health effects.

Ground-level **ozone**, a criteria pollutant that is formed by the reaction of NO_x and VOCs in the presence of sunlight, has become a significant problem in the GYE. In the upper atmosphere, ozone protects the earth from damaging UV rays, but near the surface it can cause serious health and environmental effects, such as respiratory problems and vegetation damage. Exceedances of the NAAQS have been observed intermittently during the late winter months in the UGRB in Sublette County since 2005. In March 2009, Wyoming submitted a recommendation to the EPA for non-attainment designation in the Upper Green River Basin for ozone.[8] Currently, all attainment and non-attainment designations have been put on hold while the EPA reviews further input from the Clean Air Scientific Advisory Committee's (CASAC) on the proposed revision for the ground-level ozone NAAQS; a new standard will be set by July 2011.[11] An offset policy[12] for emissions has been implemented by the state to control ozone, which has proven to decrease VOCs, but subsequently cause an increase in NO_x due to VOC tradeoffs.[8]

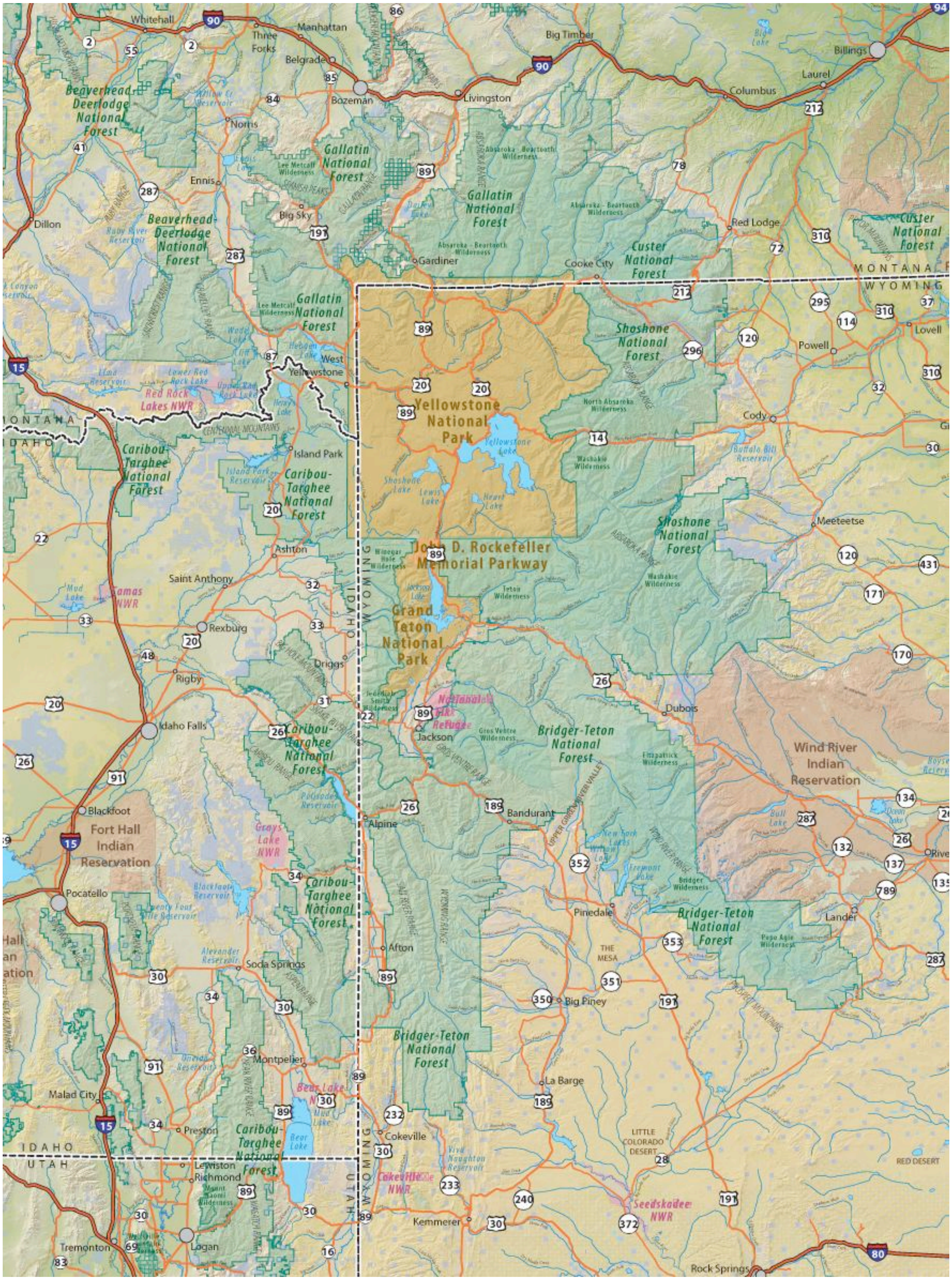
Earth is currently experiencing warming temperatures, commonly referred to as **climate change**, which is thought to be a result of anthropogenic activities and the greenhouse effect. In the GYE, the slightest temperature increase could have implications such as reduced snowpack and earlier melt and subsequently, a large decrease in streamflow.[8] Additionally, the GYE will be characterized by longer, drier summers, and a premature growing season. There will also be an increase in the occurrence and severity of wildfires, which directly impact air quality.[8] Temperature increases can also impact wildlife (e.g. American pika, Salmonids, amphibians) because many species are only physiologically capable of thriving in cold and/or wet habitats. Also, fewer cold days and outbreaks, in combination with increased drought, specifically contribute to mountain pine beetle infestations.

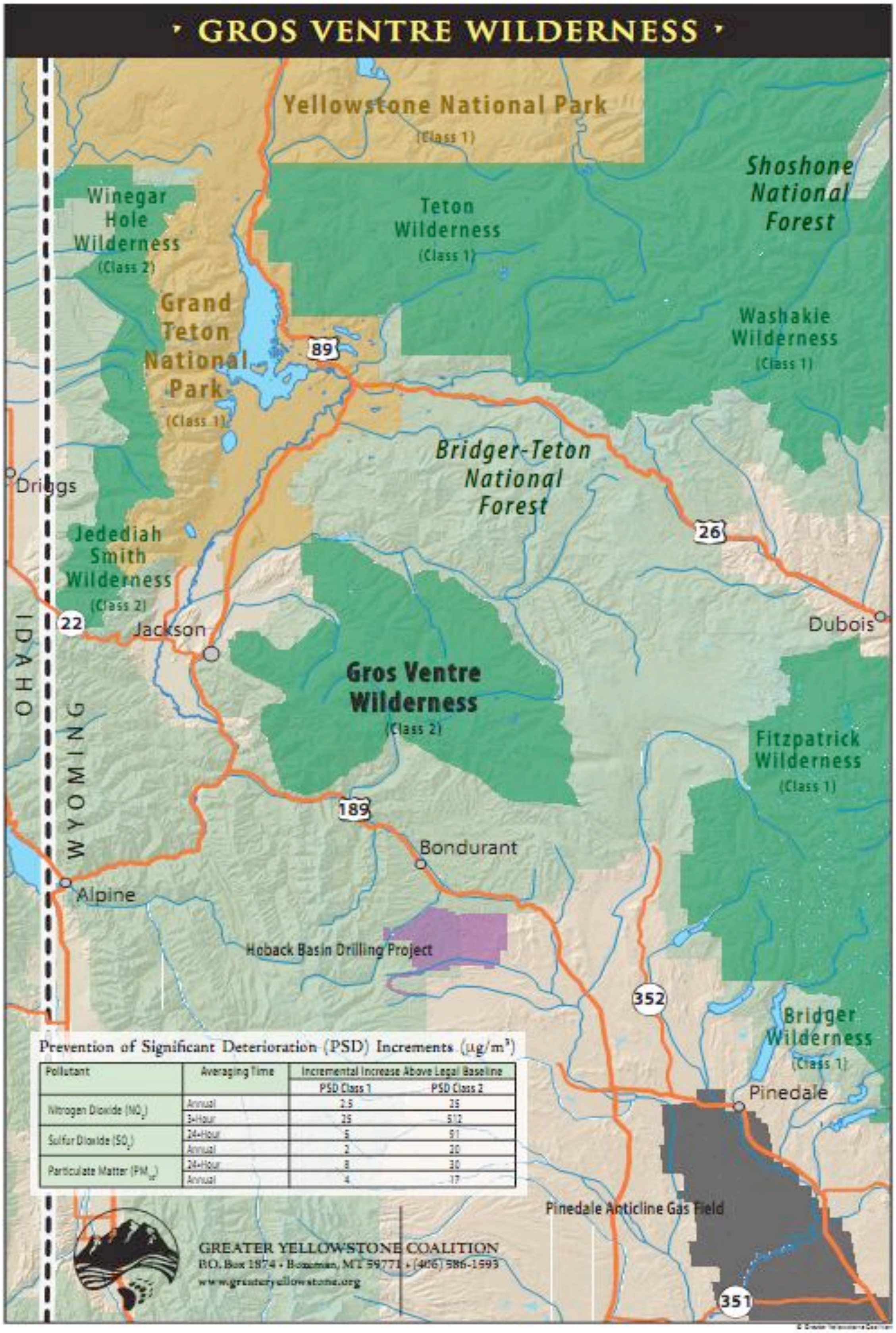
Visibility is a key attribute in the GYE due to numerous scenic vistas. Visibility, which is measured in extinction and visual range, has been adversely impacted in the GYE. Visibility degradation is caused when particles and gases in the atmosphere reflect and absorb light and create regional haze, and varies based on the combination of atmospheric constituents and meteorological conditions.[4] Plume blight, which is the formation of a visible plume resulting from point source pollutants (e.g. particulate matter, nitrogen dioxide), also causes visibility degradation.[13] In the western U.S. the average visual range is approximately 60-90 miles, which is about half of the natural visual range.[13] The EPA's regional haze rule requires revisions of SIPs to ensure that attainment of natural visibility occurs by 2064.[18]

During discussions with project contacts, another concern in the GYE is atmospheric deposition, the process by which air pollutants are deposited on earth's surface as dry or wet deposition of nitrogen and sulfur. A common GYE air quality regulatory gap that was suggested is the need for the establishment of critical loads, which is "a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specific sensitive elements of the environment do not occur according to present knowledge".[13] Therefore, a critical load can be used to evaluate adverse ecological effects from air pollution and at what deposition amounts that environmental degradation occurs. Atmospheric deposition can cause acidic inputs and subsequent nutrient leaching and stream acidification, as well as eutrophication from nutrient inputs, and toxic air contaminant inputs to ecosystems.[13]

The GYACAP 2005 GYA Air Quality Assessment Update also identified prescribed fire and wildfire smoke as a primary air quality issue in the GYA. However, due to time constraints for this project, citations on this topic were not included in the bibliography. To access available information on this topic please visit WDEQ at http://deq.state.wy.us/aqd/smokemanagement.asp and the MT/ID Airshed Group Operating Guide at http://www.smokemu.org/. For a monitoring database visit WRAP's Fire Emissions Tracking System at http://wrapfets.org/ and the Interagency Real Time Smoke Monitoring site at http://satguard.com/usfs/.

The comprehensive/national reports section is intended to show national trends in air quality. However, the GYE's air quality is not degraded when compared to other regions (e.g. East Coast and California). This can be misleading and cause the general audience to assume the overall status of air quality is good in the GYE. However, trends of degradation for certain pollutants and conditions within the GYE, associated with recent energy and industrial development, population growth, and increases in recreation and tourism[4], have caused localized air quality concerns in the GYE. Communities in and around the GYE have become aware of these issues and of preserving air quality to protect public health and the environment. A continuation of air quality monitoring and research in the GYE is important for improvements in existing air quality and for future air quality protection.


Whitehall
Three Forks
Manhattan
Big Timber
Billings
Belgrade
Bozeman
Livingston
Columbus
Laurel
Beaverhead-Deerlodge National Forest
Norris
Gallatin National Forest
Ennis
Big Sky
Dillon
Beaverhead-Deerlodge National Forest
Gardiner
Cooke City
Red Lodge
Custer National Forest
MONTANA
WYOMING
Shoshone National Forest
Powell
Lovell
West Yellowstone
Red Rock Lakes NWR
Yellowstone National Park
Cody
Island Park
Caribou-Targhee National Forest
Yellowstone Lake
Shoshone Lake
Lewis Lake
Heart Lake
Meeteetse
Ashton
John D. Rockefeller Memorial Parkway
Saint Anthony
Camas NWR
Rexburg
Grand Teton National Park
IDAHO
WYOMING
Driggs
Rigby
National Elk Refuge
Dubois
Idaho Falls
Jackson
Bridger-Teton National Forest
Wind River Indian Reservation
Blackfoot
Fort Hall Indian Reservation
Alpine
Bandurant
Grays Lake NWR
Pocatello
Pinedale
Lander
Afton
Soda Springs
Big Piney
Montpelier
La Barge
Malad City
Bear Lake
Preston
Cokeville
IDAHO
UTAH
Lewiston
Richmond
Cokeville NWR
Seedskadee NWR
Kemmerer
Tremonton
Logan
Rock Springs
RED DESERT
LITTLE COLORADO DESERT
THE MESA



Prevention of Significant Deterioration (PSD) Increments ($\mu g/m^3$)

Pollutant	Averaging Time	Incremental Increase Above Legal Baseline	
		PSD Class 1	PSD Class 2
Nitrogen Dioxide (NO_2)	Annual	2.5	25
	3-Hour	25	512
Sulfur Dioxide (SO_2)	24-Hour	5	91
	Annual	2	20
Particulate Matter (PM_{10})	24-Hour	8	30
	Annual	4	17

Key Monitoring Types:

Air quality is determined by the degree to which the air has been contaminated by pollutants in excess of naturally occurring background levels due to anthropogenic activities.[4] In order to determine the concentrations and types of pollutants in the atmosphere, monitoring must be conducted. This section provides a list of *a few* key types of monitoring that take place in the GYE. Please refer to the Monitoring Databases and Programs section of the bibliography to locate monitoring network/program websites; additional information on these monitoring types can be found in various citations throughout all sections of the bibliography.

Regulated Pollutant Monitoring: Pollutants that have ambient air quality standards (i.e. NAAQS) or Wyoming Air Quality Standards and Regulations (WAQSR).[19]

- Ozone: Special studies are conducted to monitor winter ozone formation.

Air toxics (also known as HAPs): Special studies are conducted to monitor air toxics for health risk assessment purposes.

Atmospheric Deposition: Monitoring direct and indirect wet and dry deposition to determine chemical constituents in atmospheric deposition.

- Snow chemistry sampling: Snowpacks are useful for winter bulk atmospheric deposition samples, which allow for the collection of a composite sample that represents the chemistry of a majority of the annual precipitation in high elevation areas. This data can provide winter concentrations and depositional amounts of nutrients and other compounds in snow from atmospheric deposition, long-term trends, and ecological impacts from atmospheric deposition.
- Lake chemistry sampling: Water chemistry usually responds to changes in atmospheric deposition faster than aquatic communities, and provides an efficient index to evaluate potential air pollution impacts on aquatic ecosystems.[17] Long-term lake sampling provides information on lake chemistry trends. Synoptic sampling provides geographic perspective on lake chemistry to determine which lakes are sensitive to atmospheric deposition.[19]
- Bulk deposition sampling: Collecting bulk precipitation (snow and rain).

Visibility: Measured in extinction and visual range.

- Scene monitoring: Images are collected with automatic cameras and still monitors; some monitoring stations collect real-time images.
- Aerosol monitoring: Filters are used to collect particulates that contribute to haze and by observing impacts to visibility over a specified amount of time, the pollutants causing the visibility degradation can be identified.[17]
- Optical monitoring: A nephelometer is often used to calculate visibility parameters by measuring light scattered by aerosols and gases in the air.[19]

Lichen Biomonitoring: Lichens mainly absorb nutrients and water directly from the atmosphere, making them sensitive to atmospheric deposition and therefore, good indicators of air quality degradation. They are characterized by a high retention capacity and accumulate compounds over their lifetime, which provide long term data on chemical concentrations in their tissues.[17] This monitoring also focuses on changes in community composition, physiology, and characteristics.[17] Current, uncompleted projects that are not cited include gas drilling emissions monitoring in the Bridger Wilderness (due 2012) and air quality and climate change monitoring for the Northern Rockies (due 2013), both led by Jill Grenon and Dave Roberts.[10]

Radiation: Small radioactive particles can be transported through the air as a result of industrial emissions. Of importance in the GYE are emissions from the Idaho National Laboratory (INL) and the primary pathway for off-site transport of radionuclides is by air.[20] Samples are generally analyzed for radioactive airborne particulates, gaseous radioiodine, and tritium in water vapor.

During discussions with various air quality contacts for this project, a common data gap was identified: the need for monitoring in Grand Teton National Park. At this time, air quality information for GTNP is based mainly on estimates and characterization from YNP conditions.[14] Opportunely, GTNP is coordinating with Teton Science Schools for installation of an IMPROVE and NADP site during spring 2011. This monitoring location will presumably have the capability to monitor atmospheric deposition, ozone, visibility, and meteorological conditions.

Information Sources:

Please refer to the Monitoring Databases and Programs section of the bibliography for more important links hosted by the entities discussed below. The information provided below is not comprehensive and it is encouraged that interested parties explore these information sources further.

U.S. Environmental Protection Agency (EPA):

At EPA's main page, http://www.epa.gov/, information on air quality can be found under the Learn The Issues, Science & Technology, and Laws & Regulations tabs. Also refer to the Office of Air and Radiation (OAR), http://www.epa.gov/oar/ and associated Office of Air Quality Planning and Standards (OAQPS) at http://www.epa.gov/oar/oaqps/. Under OAQPS, click the Monitoring Information link; information on State and Local Air Monitoring Stations (SLAMS) can be found there. For ambient air monitoring data please go to http://www.epa.gov/air/airpolldata.html, http://www.epa.gov/ttn/, http://www.epa.gov/mxplorer/index.htm, http://www.epa.gov/ttn/amtic/, and http://www.epa.gov/ttn/airs/airsaqs/detaildata/.

Wyoming Department of Environmental Quality (WDEQ):

Under the Air Quality Division link, at http://deq.state.wy.us/aqd/, information includes, but is not limited to, Sublette County ozone, standards and regulations, modeling studies, monitoring programs, visibility, regional haze, and open burning and smoke management. These air quality program links lead to many significant documents for the region, such as public meeting notes, presentations, scientific reports and guidance. This site is also the host for the Wyoming Visibility Monitoring Network, which can be accessed at www.wyvisnet.com.

Montana Department of Environmental Quality:

The air quality division's main page provides access to current conditions for health effects by community for hourly particulate data (Bozeman, Billings and West Yellowstone apply), monitoring, modeling, permitting and compliance, and planning and policies, at http://www.deq.mt.gov/AirQuality/aqinfo.mcpx. An abundance of additional resources and links are available at http://www.deq.mt.gov/AirQuality/airLinks.mcpx. The monitoring link offers monitoring plans, a citizen's guide to Montana's air quality, county programs and monitoring sites; data is available at EPA's AirData database.

Idaho Department of Environmental Quality:

Air quality information can be accessed at http://www.deq.idaho.gov/air/index.cfm. By clicking on the data, reports and guidance link, daily and hourly reports for monitoring locations and additional resources (i.e. monitoring data summaries, network reviews, modeling, dust control, permitting) can be accessed. Regional office air quality managers and state office air quality division contact information can be found on the left side of the webpage under Contact DEQ. Real-time air monitoring can be accessed at http://airquality.deq.idaho.gov/ for data and site specific information. The INL Oversight Program can be accessed at http://www.deq.idaho.gov/inl_oversight/index.cfm. A good place to locate air quality data reports is at http://www.deq.idaho.gov/air/data_reports/publications.cfm.

Greater Yellowstone Science Learning Center:

A collaborative effort between the NPS Inventory & Monitoring Program's Greater Yellowstone Network (GRYN), the Rocky Mountains Cooperative Ecosystem Studies Unit, the Yellowstone Park Foundation, Canon USA, Inc. through the *Eyes on Yellowstone*, and the Yellowstone Association, offering information on the natural and cultural resources in the GRYN. The NPS Research Learning Centers are public-private partnerships that provide scientific information on national parks, including existing research and monitoring, in order to create public awareness and assist management decisions. Information is available for topics such as physical and biological resources, landscape processes, and human use, and for each of those categories are links to resource briefs, fact sheets, projects, data, reference lists, and researchers. The park units represented on this site include Yellowstone, Grand Teton, Big Canyon, and Great Northern LCC. This site can be accessed at http://www.greateryellowstonescience.org/.

Bureau of Land Management (BLM):

The BLM provides significant information on oil and gas leasing in the GYE and several programs of environmental importance, which can be found at http://www.blm.gov/wy/st/en/programs.html. The Pinedale Field Office website has access to several important links at http://www.blm.gov/wy/st/en/field_offices/Pinedale.html. The BLM's Wyoming oil and gas site, http://www.blm.gov/wy/st/en/programs/energy/Oil_and_Gas.html, can provide valuable information on the industry. Resource management plans are available by field office at http://www.blm.gov/wy/st/en/programs/Planning/rmps.html; the Pinedale RMP has several supporting documents of interest, such as an Areas of Critical Environmental Concern (ACEC) evaluation, an Oil & Gas Reasonable Foreseeable Development (RFD)

Scenario, and a Management Situation Analysis (MSA) with several relevant figures on air quality. The Pinedale Anticline Working Group (PAWG) can also be accessed through the BLM at http://www.blm.gov/wy/st/en/field_offices/Pinedale/pawg.html and is chartered by the Federal Advisory Committee Act (FACA), developing and providing recommendations to the BLM regarding oil and gas development in the Pinedale Anticline Project Area (PAPA).

National Park Service (NPS):

From the NPS main page, select Explore Nature and then Air Resources or access the Explore Air webpage at http://www.nature.nps.gov/air/index.cfm. By selecting Air Quality in Parks, the NPS provides extensive air quality information by national park (YNP and GTNP) and ecoregion (GRYN). NPS's Yellowstone winter vehicle use and air quality website provides access to information on winter use documents, data, monitoring reports, and publications and can be accessed at http://www.nature.nps.gov/air/studies/yell/yell AQwinter.cfm. The home page for the NPS GRYN Inventory and Monitoring Network offers excellent information on inventories, monitoring and vital signs at http://science.nature.nps.gov/im/units/gryn/index.cfm. The Federal Land Managers' Air Quality Related Values Work Group (FLAG) is a partnership between the FWS, NPS, and USFS that evaluates air pollution impacts on AQRVs to provide guidance to permitting authorities and applicants on new and existing source impacts on AQRVs; FLAG information is available at http://www.nature.nps.gov/air/permits/flag/index.cfm. Air quality monitoring and access to data is at http://www.nature.nps.gov/air/monitoring/index.cfm.

U.S. Forest Service (USFS):

The Air Resource Management link can be accessed at http://www.fs.fed.us/air/index.htm, providing data, documents, links, contacts, and information on management issues (e.g. effects of air pollution, monitoring). Information can also be accessed based on USFS regions; those relevant to the GYE include Regions 1, 2, and 4. The Forest Service's Watershed, Fish, Wildlife, Air & Rare Plants (WFW) program site offers additional air info at http://www.fs.fed.us/biology/air/index.html.

Keep Yellowstone Nuclear Free (KYNF):

This NGO's mission is to monitor radioactive and hazardous emissions from the U.S. Department of Energy's Idaho National Laboratory (INL), in order to protect the public and environment of Yellowstone, Grand Teton and Jackson Valley. In the near future, an online interface hosting monitoring data from sites in Idaho Falls and Jackson Hole will be available to the general public, as well as reporting on that data. There is valuable information on issues/campaigns and local radiation levels. KYNF can be accessed at http://www.kynf.org/.

Yellowstone-Teton Clean Energy Coalition (YTCEC):

This coalition, at http://www.ytcleanenergy.org/, was created as a result of the U.S. Department of Energy's (DOE) sponsored government-industry Clean Cities program, whose main goal is to reduce petroleum consumption in the transportation sector, which will decrease U.S. dependence on foreign fuel and reduce emissions. This coalition is one of the few rural programs that exists and focuses on introducing alternative fuels and advanced energy technologies. Select the current projects link, which discusses the Idle-Reduction Campaign, ATVs and START Bus, and the fuel & vehicle emissions link to learn more about AFVs.

Western Regional Air Partnership (WRAP):

A voluntary partnership between states, tribes, federal land managers, local agencies, and the U.S. EPA, whose mission is to better comprehend the current status of and emerging issues related to air quality in the West. This site provides information on emissions, regional haze, ozone, and PM, nitrogen, and mercury. Issues addressed include, but are not limited to, climate change impacts, air pollution transport, and domestic and international emission sectors. WRAP develops and provides access to data and results from various sources on air quality. Under the regional haze navigation button, important resources are available to download. This site can be accessed at http://www.wrapair2.org/default.aspx and WRAP's archived site, from 2009 and earlier, can be accessed at http://www.wrapair.org/.

Greater Yellowstone Coordinating Committee (GYCC):

This committee was formed to allow personnel from the National Park Service, Fish and Wildlife Service, and Forest Service to collaborate on the management of federal lands in the Greater Yellowstone area and can be accessed at http://fedgycc.org/. Information can be found on air quality and climate change, with links for conferences, meetings, publications and resources, as well as subcommittees, such as the GYACAP and Sustainable Operations Subcommittee (SOS). The GYACAP serves as a technical advisory committee for the GYCC on air quality issues, information exchange channel, and facilitator for monitoring coordination between federal and state agencies.[9] The GYACAP can also be accessed on the USFS Region 1 website under Land & Resource Management/Resource Management/Air Resource Management - Greater Yellowstone Area Clean Air Partnership, providing presentations and notes from GYACAP meetings and relevant reports. There are also links for air resource monitoring under the USFS GYACAP homepage.

Jonah Interagency Office (JIO) and Pinedale Anticline Project Office (PAPO):

This website provides information on the Jonah and Pinedale Anticline natural gas fields, and was created to provide on-site monitoring and off-site mitigation activities. Information on monitoring and projects can be found at this site. This site can be accessed at http://www.wy.blm.gov/jio-papo/.

Recommendations:

These recommendations are intended for all stakeholders that wish to support or see the potential need for the expansion of this GYE air quality bibliography project. We are hopeful that this project will act as the taking off point for further interest and research on the status of air quality in the GYE.

- Establish a working relationship with the Great Northern Landscape Conservation Cooperative (GNLCC), an alliance of conservation partners, to leverage information and resources concerning air quality in the GYE. By collaborating with the GNLCC, air quality in the GYE can be addressed on a comprehensive landscape conservation level, with a focus on creating ecosystem resilience. The GYC should focus on submitting the organization's information to the GNLCC Resource Directory, which provides information on initiatives and organizations associated with landscape conservation in the Great Northern area.

- Promote public outreach and education on the status of air quality in the GYE (e.g. public meetings, bulletins).

- Collaborate with and communicate concerns to all stakeholders (e.g. states, tribes, federal agencies, NGOs) to discuss and formulate next steps.

- Conduct a 5-year review of the GYE air quality bibliography to provide the most current data on air quality in the region *or* assign personnel to continue research and maintain this project on a regular basis in order to add new scientific reports as they become available.

- Perform a comprehensive review and analysis of documents compiled in this report in order to evaluate and assess the current status of air quality in the Greater Yellowstone Ecosystem, including an annotated version of this bibliography.

- During this project, only a small percentage of the reference pages from the cited documents were reviewed for additional citations. Therefore, a review of references from each of the citations should be conducted in order to obtain additional references.

- Conduct a search for additional scientific data and studies on air quality impacts to wildlife in the GYE, which seems to be lacking based on the initial research completed within the confines of this project.

- Based on reading and discussions with several contacts for this project, a large barrier to research and monitoring is acquiring and maintaining the funds to do so. Therefore, it is vital to continue to seek long-term funding for air quality monitoring programs and research in the GYE, in order to provide current data on air quality issues.

- Promote the analysis of air quality data collected in the GYE. It has been suggested that abundant amounts of data are collected, but not always analyzed. The data analysis process is critical for providing up-to-date information, highlighting key issues, proposing conclusions and recommendations, and assisting with decision making processes.

- Expand the bibliography to include Prescribed Fire and Wildfire Smoke and Air Quality Monitoring and Management Plans/Protocols/Strategies as additional sections.

- Expand bibliography to include citations prior to 1990, in order to fully represent historical and baseline conditions in the GYE.

- Update and expand the GYE air quality contact list in Appendix A.

- Add an appendix with a table listing monitoring programs, contacts, operators, pollutants monitored, and sample techniques under each specific type of monitoring in the GYE (e.g. atmospheric deposition, visibility).

- Contact authors to determine the peer review status for each citation.

- Highlight data validation information for each citation.

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4. Sublette Board of County Commissioners. 2010. Citizen's Guide to Air Quality Management in Sublette County.

5. UNESCO World Heritage Centre. 1992-2011. Yellowstone National Park. Accessed at http://whc.unesco.org/en/list/28

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13. USDA Forest Service. 2010. Sources and Effects of Air Pollution. Accessed at www.fs.fed.us/air/source01.htm

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15. Story, Mark, Julie Shea, Terry Svalberg, Mary Hektner, George Ingersoll, and Darla Potter. 2005. Greater Yellowstone Area Air Quality Assessment Update. Prepared by the Greater Yellowstone Clean Air Partnership, November.

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17. USDA Forest Service. 2010. Monitoring. Accessed at www.fs.fed.us/air/monit.htm

18. Wyoming Outdoor Council. 2009-2011. State Compliance with EPA's Regional Haze Rule. http://www.wyomingoutdoorcouncil.org/html/what_we_do/air_quality/regional_haze.shtml

19. Air Quality Task Group. 2005. Air Quality Monitoring Plan, Pinedale Anticline Project Area. Submitted to the Pinedale Anticline Working Group.

20. GSS. 2001. Environmental Surveillance, Education, and Research Program – Air Sampling. Accessed at http://www.stoller-eser.com/air.htm.

Existing Research and Data Regarding the Status of Air Quality in the Greater Yellowstone Ecosystem: A Bibliography

Greater Yellowstone Coalition

Comprehensive/National Reports

1. U.S. **Environmental Protection Agency. 2010. Our Nation's Air: Status and Trends** Through 2008. EPA-454/R-09-002.

This report is a summary of the EPA's most recent evaluation of national air quality and specifically looks closer at the relationship between air quality and climate change. 2008 compared to 1990 showed a decrease in the six criteria pollutants: 8-hour ozone by 14 percent, annual $PM_{2.5}$ (since 2000) by 19 percent, PM_{10} by 31 percent, lead by 78 percent, NO_2 by 35 percent, 8-hour CO by 68 percent and annual SO_2 by 59 percent. However, about 127 million people still lived in counties exceeding at least one NAAQS. Total emissions for air toxics also declined, by about 40 percent between 1990 and 2005, mainly due to control technologies and programs for mobile sources. There has also been an improvement with acid rain, aided by the EPA's NO_x SIP Call and Acid Rain Program, which has lead to a decrease in atmospheric deposition and improved water quality. Visibility in scenic areas between 1998 and 2007 also showed some improvement nationally, with specific areas seeing an improvement for worst visibility days. Lastly, air pollution effects on climate change have shown that tropospheric ozone (a greenhouse gas) and black carbon particulates have a warming effect, while sulfate and organic carbon aerosols have a cooling effect.

2. National Park Service, Air Resources Division. 2010. Air quality in national parks: 2009 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2010/266. National Park Service, Denver, Colorado.

The NPS determines the status of air quality in national parks by monitoring indicators such as visibility, ozone, and atmospheric deposition and determining trends and conditions. The NPS uses data it collects, as well as data from nearby monitoring locations operated by state and local entities. The NPS considers improvements or no trend of deterioration in air quality as a success and has established performance goals for air quality trends in accordance with the Government Performance and Results Act (GPRA) that are reported on annually. This annual performance report used data collected between 1999 and 2008 for visibility, ozone, and atmospheric deposition. Performance goals were exceeded for 2009, with an improving or not degrading trend for visibility, ozone, and atmospheric deposition in 97%, 100%, and 93% of NPS reporting parks respectively. An index is used to understand areas where the lack of a degrading trend may be a concern and not protective of air quality, by characterizing park air quality as good, moderate (or cautionary), or of significant concern. For visibility, ozone, nitrogen deposition, and sulfur deposition, the percentage of parks in good or moderate condition was 57%, 35%, 29%, and 46% respectively. In regards to parks exhibiting significant concerns, there were no improving trends for visibility, no degrading trends for ozone, three parks with degrading trends for nitrogen deposition and no degrading trends for sulfur deposition.

3. National Park Service, Air Resources Division. 2009. Air quality in national parks: 2008 annual performance and progress report. Natural Resource Report NPS/NRPC/ARD/NRR—2009/151. National Park Service, Denver, Colorado.

This annual performance report utilizes data collected from 1998 to 2007. Performance and progress showed an exceedance of established goals, with stable or improving air quality trends for visibility, ozone, and atmospheric deposition in 99%, 94%, and 83% of NPS reporting parks respectively. For visibility, ozone, nitrogen deposition, and sulfur deposition, the percentage of parks in good or moderate condition was 59%, 32%, 29%, and 48% respectively. In regards to parks exhibiting significant concerns, there were only stable trends for visibility, one park with a degrading trend for ozone, five parks with degrading trends for nitrogen deposition and no degrading trends for sulfur deposition.

4. National Park Service, Air Resources Division. 2007. 2006 Annual Performance & Progress Report: Air Quality in National Parks.

5. National Park Service, Air Resources Division. 2006. 2005 Annual Performance & Progress Report: Air Quality in National Parks.

6. Wenzler, Mark. 2006. Turning Point. Prepared by the National Parks Conservation Association.

7. National Park Service, Air Resources Division. 2005. Air Quality Conditions and Trends in Parks – Annual Report 2004 FY 2004 Annual Performance Report: Government Performance and Results Act (GPRA) Air Quality Goals Ia3, Ia3B (DOI# PEM.1.010), and Ia3C (DOI# PEM.1.011)

8. National Park Service. 2003. AirAtlas Summary Tables for I&M Parks.

9. National Park Service. 2002. Air Quality in the National Parks. Second Edition. National Park Service, Air Resources Division, Lakewood, Colorado. Published September 2002, NPS Document Number D-2266. U.S. Department of the Interior, Washington D.C.

10. USDA Forest Service. 1997. Air Resource Monitoring System Existing Dataset Listing.

Regional Reports

11. Grenon, Jill, Terry Svalberg, Ted Porwoll and Mark Story. 2010. Lake and bulk sampling chemistry, NADP, and IMPROVE air quality data analysis on the Bridger-Teton

National Forest (USFS Region 4). Gen. Tech. Rep. RMRS-GTR 248WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 44 p.

This report is an analysis of existing data from four different air quality monitoring programs, the National Atmospheric Deposition Program (NADP), long-term lake monitoring, bulk deposition (wet and dry), and the Interagency Monitoring of Protected Visual Environments (IMPROVE), with sites located in and around the Bridger-Teton National Forest. The program's goal is to monitor forest health and restore background conditions for regional haze by 2064. This report delineates regional and local trends in air quality, as well as potential effects on the B-T National Forest and the Bridger Wilderness, with the overall goal of providing information to manage and understand air quality in southwest Wyoming. This report also includes, Appendix: Shoshone National Forest Air Quality Data Trend Analysis, for 2008, by Greg Bevenger (Hydrologist, Shoshone NF, Cody, Wyoming).

12. Miller, Dianne, Ken Craig, Jennifer DeWinter, Clinton MacDonald, Steve Reid, and Hilary Hafner. 2010. An Air Parcel Transport Corridor Analysis for Sublette County, Wyoming. Sonoma Technology, Inc. to Cara Keslar, Wyoming Department of Environmental Quality.

Analysis of transport corridors, the pathway of air movement from one location to another, can help determine how often pollution may be transported between certain areas by aligning them with known pollution sources. This study was conducted by Sonoma Technology, Inc. (STI) to understand air parcel transport in and within Sublette County to assist the WDEQ Air Quality Division (AQD) with identifying potential air quality monitoring locations in the northern Wyoming Range and pollutants entering the region. The analyses determined: 1) the frequency of emission impacts from pollutants transported to the region from out-of-state sources was mainly from the local oil and gas industry, the Snake River Plain of southeastern Idaho and the Great Salt Lake area, with high potential emission impacts when originating in large population centers; 2) transport corridors for air parcels into Sublette County was predominantly westerly and northwesterly transport trajectories at all receptor sites; 3) the site specific surface wind data did not accurately represent air transport within and/or above the boundary layer to correlate transport corridor patterns and surface meteorological conditions, warranting the need for modeled wind fields; and 4) uncertainty in the air parcel corridor analysis, including two main factors, the wind data set used to calculate horizontal movement and the method used to calculate vertical movement.

13. **Sublette Board of County Commissioners. 2010. Citizen's Guide to Air Quality** Management in Sublette County.

The oil and gas industry has an extensive history in Sublette County, originally centered on the Big Piney/La Barge area. Today, this region is home to two of the nation's top producing natural gas fields, the Pinedale Anticline and Jonah fields, which hold approximately 35 trillion cubic feet of recoverable natural gas reserves. This industry is a large contributor to the region's economic prosperity and has provided many employment opportunities. However, this collective increase in industrial development, population growth, and recreation and tourism has caused concern over the preservation of natural resources in Sublette County. Emissions from the oil and gas production and operation activities could adversely impact local air quality, therefore, state and county officials and industry partners have committed to addressing community concerns regarding industry impacts to air quality. This citizen's guide to air quality management in Sublette County delineates what is being done to protect air quality in the county, such as regulatory and voluntary industry efforts, and what community members can do as well.

14. Western Regional Air Partnership. 2010. 2008 Regional SO_2 Emissions and Milestone Report.

Pursuant to the Federal Regional Haze Rule, under Section 309, nine western states and tribes within those states have the opportunity to submit plans to reduce regional haze emission that are contributing to visibility impairment of Class I areas on the Colorado Plateau. The WRAP assists the participating states with implementing and managing the emission reduction program, including submitting annual Regional Sulfur Dioxide (SO_2) Emissions and Milestone Reports. All states were operating under their revised plans. The participating four-state region (AZ, NM, UT, WY) milestone (a maximum level of annual emissions for a specific year) for 2008 was 378,398 tons according to the SIP revisions.

The 2006, 2007, and 2008 adjusted emissions data (to account for annual monitoring and calculation method variations from the base year inventory) were averaged for the region and compared to the 2008 milestone; from the milestone and data adjusted it was determined that the three year average was about 30% below the 2008 milestone. In calendar year 2008, the region reported 243,124 tons of SO_2 and 244,189 tons post adjustment, which is lower than both 2006 and 2007 annual adjusted emissions; this is an insignificant difference when compared to total emissions. The average adjusted annual emissions measurement, at 265,662 tons, showed that the participating region met the SO_2 milestone for 2008 under the revision. No smelter (to account for operation variations) or enforcement action (to reduce milestones where base period emissions exceeded allowable emissions) milestone adjustment was required based on the revised provisions. In Section 7, emission changes, in source population or emissions, are recorded from 2007 to 2008 and Appendix B provides information on source additions/removals for the base year inventories.

15. Greater Yellowstone Science. 2009. Air Quality Resource Brief, Greater Yellowstone.

This resource brief, released in July 2009, showed that Yellowstone and Grand Teton National Park's were in compliance for ozone, sulfur dioxide, and particulate matter human health federal standards. But, in regards to ecosystem impacts, monitoring data has shown an increase in nitrogen deposition (in precipitation) as a result of ammonium ion concentrations related to fertilizer and feedlots. In the early 1980's, sediment cores from several alpine lakes revealed a changing algal composition when nitrogen loading reached a critical threshold (1.4 kg/ha/year) and from 1993-2006 loading increased to 1.8 kg/ha/year. For ozone, concentrations peak in the spring in Yellowstone, indicating greater significance of changing meteorological conditions than human influences. But, ozone levels during growing season could be high enough to cause adverse impacts to vegetation, such as biomass loss in sensitive species (i.e. aspen). For visibility, states in the WRAP have developed emission reduction programs to protect Class I areas. The SW Wyoming oil and gas industry hasn't had a detectable effect in Yellowstone due to prevailing winds, but less is known regarding Grand Teton. Natural wildfire smoke is the largest source of particulate matter in Greater Yellowstone and can impair human health. Prescribed fires are managed to minimize smoke in populated areas, and emissions are expected to increase by about 50% in the next ten years, but are less significant than wildfires, which cover more acres and produce more smoke.

16. Grenon, Jill, and Mark Story. 2009. U.S. Forest Service Region 1 Lake Chemistry, NADP, and IMPROVE air quality data analysis. Gen. Tech. Rep. RMRS-GTR-230WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 42 p.

This report is a comprehensive analysis of USFS Region 1 air quality data, including Phase 3 long-term lake monitoring, NADP, and IMPROVE. Trends were evaluated for annual and seasonal data using non-parametric (SAS) protocols; the most significant trends identified were at the NADP sites for consistency in sulfate (SO_4^{2-}) reduction and an increase in ammonium (NH_4^+). Standard visual range increased and extinction decreased at IMPROVE sites and annual visibility was reduced during increased wildfires. Recommendations were made for current and future monitoring and air quality protection in National Forests, such as protocols and site continuation.

17. Western Regional Air Partnership. 2009. 2007 Regional SO_2 Emissions and Milestone Report.

During 2007, the participating four-state region (AZ, NM, UT, WY) either revised or were under the revision process for their Section 309 plans, which modified the annual regional milestone for the year. At the time of this Regional Sulfur Dioxide (SO_2) Emissions and Milestone Report, two of the four states were operating under revised plans; therefore, annual emissions were compared to 2007 milestones under both the revised and 2003 plans. The region's milestone (a maximum level of annual emissions for a specific year) for 2007 was 422,194 tons under the original 2003 plans and 420,637 tons under the revised plans.

The 2005, 2006, and 2007 adjusted emissions data (to account for annual monitoring and calculation method variations from the base year inventory) were averaged for the region and compared to the 2007 milestones. Oregon's emissions were removed from the 2005 emission totals before calculating the average, due to their removal from the program. From the adjusted milestone and data it was determined that the three year emissions average was about 33% below the 2007 four-state regional milestones. In calendar year 2007, the region reported 257,234 tons of SO_2 and 273,663 tons post adjustment, which is lower than both 2005 and 2006 annual adjusted emissions; the difference is approximately 6% of the total reported emissions. The average adjusted annual emissions measurement, at 280,279 tons, showed that the participating region met the SO_2 milestone for 2007 under the 2003 and revised plans. The 2007 period required a smelter adjustment (to account for operation variations) under the 2003 plans that increased the regional milestone by 2,000 tons and no enforcement action (to reduce milestones where base period emissions exceeded allowable emissions) milestone adjustment was required. In Section 7, emission changes, in source population or emissions, are recorded from 2006 to

2007 and Appendix B provides information on source additions/removals for the base year inventories.

18. Western Regional Air Partnership. 2008. 2006 Regional SO_2 Emissions and Milestone Report.

During 2006, Oregon elected not to participate in the SO_2 Milestone and Backstop Trading Program and therefore, those emissions were eliminated from 2004 and 2005 emissions before calculating the average. The participating four-state region (AZ, NM, UT, WY) were operating under the original 2003 plans. For this Regional Sulfur Dioxide (SO_2) Emissions and Milestone Report, the region's milestone (a maximum level of annual emissions for a specific year) for 2006 was 420,194 tons.

The 2004, 2005, and 2006 adjusted emissions data (to account for annual monitoring and calculation method variations from the base year inventory) were averaged for the region and compared to the 2006 milestone; from the adjusted milestone and data it was determined that the three year emissions average was about 30% below the 2006 four-state regional milestone. In calendar year 2006, the region reported 260,392 tons of SO_2 and 279,134 tons post adjustment, which is lower than both 2004 and 2005 annual adjusted emissions; the difference is approximately 7% of the total reported emissions. The average adjusted annual emissions measurement, at 295,740 tons, showed that the participating region met the SO_2 milestone for 2006. The 2006 period required no adjustment for smelters (to account for operation variations) or enforcement actions (to reduce milestones where base period emissions exceeded allowable emissions). In Section 7, emission changes, in source population or emissions, are recorded from 2005 to 2006 and Appendix B provides information on source additions/removals for the base year inventories.

19. ENVIRON. 2007. Southwest Wyoming NO_2 PSD Increment Consumption Analysis Modeling Results for Tasks 3 and 4. ENVIRON International Corporation, Novato, CA, May.

20. Jaffe, D., and J. D. Ray. 2007. Increase in Surface Ozone at Rural Sites in the Western U.S. Atmospheric Environment 41(26):5452-546.

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22. Pollack, Alison K., Lit Chan, Priya Chandraker, John Grant, Chris Lindhjem, Sunja Rao, James Russell, and Cuong Tran. 2006. WRAP Mobile Source Emission Inventories Update. ENVIRON International Corporation, Novato, CA, May.

23. Pollack, A. K., J. Russell, S. Rao, and G. Mansell. 2006. Wyoming 2002 Emissions Inventory: Mobile and Area Source Emissions. Revised Final Report, ENVIRON International Corporation, Novato, CA, April.

24. Stoeckenius, Till, Steve Lau, Ed Tai, Ralph Morris, Michele Jimenez, and James Russell. 2006. Southwest Wyoming NO_2 PSD Increment Consumption Modeling: Results for Sublette County. ENVIRON International Corporation, Novato, CA, May.

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29. Idaho Department of Environmental Quality. 2004. Portneuf Valley PM_{10} Nonattainment Area State Implementation Plan, Maintenance Plan, and Redesignation Request.

30. Kirchstetter, Thomas W., Colette R. Maser, and Nancy J. Brown. 2004. Ammonia Emission Inventory for the State of Wyoming. Atmospheric Sciences Department, Lawrence Berkley National Laboratory.

31. Air Resource Specialists, Inc. 2003. Annual Data Summary, Yellowstone National Park, 2002, National Park Service, Gaseous Air Pollutant Monitoring Network. Report No. NPS D-1003. Air Resources Division, Research and Monitoring Branch, Lakewood, Colorado.

32. EA Engineering, Science, and Technology, Inc. 2003. 2000 Air Emissions Inventory, Grand Teton National Park, Wyoming. Prepared for the National Park Service.

33. EA Engineering, Science, and Technology, Inc. 2003. 2000 Air Emissions Inventory, Yellowstone National Park, Wyoming/Montana/Idaho. Prepared for the National Park Service.

34. Hammer, Bob. 2003. Montana, Idaho, Dakotas National Forests & Grasslands Air Quality Assessment.

35. Nanus, L. and D. H. Campbell. 2003. Analysis of Air Quality Information for Vital Signs Selection in GRYN Parks: Draft Administrative Report.

36. Air Resource Specialists, Inc. 2002. Annual Data Summary, Yellowstone National Park, 2001, National Park Service, Gaseous Air Pollutant Monitoring Network. Report No.

NPS D-982. Air Resources Division, Research and Monitoring Branch, Lakewood, Colorado.

37. Air Resource Specialists, Inc. 2001. Annual Data Summary, Yellowstone National Park, 2000, National Park Service, Gaseous Air Pollutant Monitoring Network. Report No. NPS D-955. Air Resources Division, Research and Monitoring Branch, Lakewood, Colorado.

38. National Park Service, Air Resources Division. 2001. Air Quality-Related Monitoring Considerations for the Greater Yellowstone Network.

39. Air Resource Specialists, Inc. 2000. Annual Data Summary, Yellowstone National Park, 1999, National Park Service, Gaseous Air Pollutant Monitoring Network. Report No. NPS D-775. Air Resources Division, Research and Monitoring Branch, Lakewood, Colorado.

40. Story, Mark T. 2000. USFS Region 1 Eastside National Forests Air Quality Assessment. USDA Forest Service, Gallatin National Forest, Bozeman, MT. 27p.

41. Air Resource Specialists, Inc. 1999. Annual Data Summary, Yellowstone National Park, 1998, National Park Service, Gaseous Air Pollutant Monitoring Network. Report No. NPS D-748. Air Resources Division, Research and Monitoring Branch, Lakewood, Colorado.

42. Greater Yellowstone Area Clean Air Partnership. 1999. Greater Yellowstone Area Air Quality Assessment Document.

43. Idaho Department of Environmental Quality. 1998. Portneuf Valley Particulate Matter (PM_{10}) Air Quality Improvement Plan, 1998-1999.

44. Peterson, D.L., T.J. Sullivan, J.M. Eilers, S. Brace, K. Savig and D. Morse. 1998. Assessment of Air Quality and Air Pollutant Impacts in National Parks of the Rocky Mountains and Northern Great Plains. National Park Service, Air Resources Division. Denver, CO. Available Online: http://www.nature.nps.gov/air/Pubs/regionPark.cfm

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46. National Park Service. (n.d.) Air Quality Pollutant Estimates Greater Yellowstone Network.

47. National Park Service. (n.d.) Sensitive Air Quality Related Values of Greater Yellowstone Network Parks.

48. Wyoming Department of Environmental Quality. (n.d.) Modeling Studies: Southwest Wyoming Technical Air Forum. Available Online: http://deq.state.wy.us/aqd/Modeling%20Studies.asp

The Southwest Wyoming Technical Air Forum (SWWYTAF) approved the Southwest Wyoming Regional Haze Modeling Study in 1997, in order to evaluate impacts on the Bridger and Fitzpatrick Class I Wilderness Areas and the CALPUFF/CALMET dispersion modeling system. Overall, the main purpose of the study is to evaluate degradation of ambient air (i.e. air quality, visibility, AQRVs) in Class I areas from upwind anthropogenic and biogenic sources. In accordance with the WDEQ's request, the website can be cited, but the documents associated with the study cannot. Inquiries and document requests can be directed towards Darla Potter; please see Appendix A for contact information.

Impacts on Human Health

49. Walther, Eric. 2011. Screening Health Risk Assessment, Sublette County, Wyoming. SR2011-01-03. Prepared for Sublette County Commissioners, Wyoming Department of Environmental Quality, and Wyoming Department of Health. Sierra Research, Inc., Sacramento, CA, January.

In Sublette County, the WDEQ monitoring measured ambient ozone concentrations above the NAAQS (>80 ppb 1997 standard) in the winters of 2005 and 2006. Due to the increased development of the natural gas extraction industry in the area, community members expressed concerns over whether or not those activities pose any health risks. Therefore, this ambient monitoring study of ozone and toxic air contaminants (TACs) was contracted by the Sublette County Commissioners (SCC), Wyoming Department of Health (DOH) and the WDEQ. The study took place over a 14-month period, February 2009 thru March 2010, and measured ambient concentrations of 51 TACs at fourteen (14) sites, including two (2) collocated sites, and ozone at five (5) of those sites (see figures in the report for the study area and monitoring locations). The air samples were collected every sixth day over 24-hour periods and at the Marbleton and Pinedale sample locations a second instrument collected air samples for variability and quality assurance purposes. This report discusses data collection and analysis (i.e. design, QA/QC), data quality assessment, selection of screening values, and uncertainty. It was determined that health risk estimates associated with the 51 monitored TACs in the ambient air in and near Sublette County did not warrant a refined health risk assessment. The highest 8-hour average ozone concentration (NAAQS is 75 ppb as of 2008) observed at the Bargeville sample site was 69 ppbv. It was determined that no direct health impacts were associated with the ozone levels measured during this study period, as they were below the NAAQS, which is set to protect public health, including sensitive populations, within an adequate margin of safety.

50. Air Resource Specialists, Inc. 2010. Sublette County Air Toxics Inhalation Project, Final Data Submittal Report February 3, 2009 – March 31, 2010. Prepared for the Sublette

County Commissioners, The Wyoming Department of Environmental Quality and the Wyoming Department of Health. Air Resource Specialists, Inc., Fort Collins, CO, June.

This data submittal report was prepared by Air Resource Specialists, Inc. (ARS) and provides data collected from the Sublette County air toxics monitoring sites for the study period from February 2009 through March 2010. The study that this report discusses is the same study discussed in the previous citation by Eric Walther (Sierra Research). However, the previous report is the health assessment report; no health effect data interpretations are discussed in this report. ARS operated the monitoring portion of the study and this report provides a basic background and data summaries, detailing network set up, data collection statistics, and parameters collected. ARS provided collected data to Sierra Research, who then conducted the screening health risk assessment portion of the study. Data was collected on the EPA sampling schedule and data summaries for ozone and air toxics are provided in this report; see Appendix C and D for tabular summaries of 1-hour and 8-hour ozone averages and Appendix E for air toxics site specific summaries.

51. ATSDR. 2007. Health Consultation: Portneuf Valley Air Toxics Ambient Air Data Evaluation & Health Assessment, Pocatello, Chubbuck and Surrounding Areas.

52. Jensen, Lea, and Ken Meyer. 2006. Summer West Entrance Employee Personal Exposure Monitoring Report, Yellowstone National Park, August.

53. ATSDR. 2005. Health Consultation: Air Contamination at the Eastern Michaud Flats, Bannock County, Idaho; Power County, Idaho; Fort Hall Indian Reservation. CERCLIS NO. IDD984666610. Atlanta: U.S. Department of Health and Human Services.

54. Morris, Ryan, and Brandon Gauthier. 2005. Summer Entrance Employee Air Monitoring Report, Yellowstone National Park, August.

55. Spear, Terry M., and Dale J. Stephenson. 2005. Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU) RM-CESU Cooperative Agreement Number: H1200040001 Yellowstone Winter Use Personal Exposure Monitoring. Prepared for the National Park Service.

56. ATSDR. 2001. Health Consultation: Air Contamination at the Eastern Michaud Flats Contamination Pocatello, Bannock and Power Counties, Idaho. Agency for Toxic Substances and Disease Registry. March, 2001. Available Online: http://www.atsdr.cdc.gov/HAC/pha/PHA.asp?docid=1047&pg=0

Impacts on Terrestrial/Biological Resources

57. Yandow, Leah, Anna Chalfoun, and Daniel Doak. 2010. What are the critical habitat and climate elements for the American pika (*Ochotona princeps*) in the face of climate

change? Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, WY.

The American pika (*Ochotona princeps*), termed an alpine obligate lagomorph, has a unique life history that makes it vulnerable to climate change, including warm temperature sensitivity and limited high and cool elevation habitat. Declines in pika range have been observed as a result of hotter summer temperatures. This study aims to better understand species status, climate influences, and mechanisms for population declines in the Central Rocky Mountains. Sites were established in summer 2010 and are located in the Wind River Range, Wyoming, where predictions can be tested regarding the influence of habitat and climate on pika occurrences and abundances. Surveying will take place at selected sites in 2011 to create a validated best fit predictive statistical model for pika presence. Then predictions can be built on current and future pika populations to identify their status and provide information to land managers.

58. McMenamin S. K., E. A. Hadly, C. K. Wright. 2009. Reply to Patla et al.: Amphibian habitat and populations in Yellowstone damaged by drought and global warming. Proceedings of the National Academy of Sciences 106(9):E23.

This letter is a reply to Patla et al.'s comments (see citation 59) on McMenamin et al.'s study (see citation 61).

59. Patla, Debra A., Charles R. Peterson, and Paul Stephen Corn. 2009. Amphibian decline in Yellowstone National Park. Proceeding of the National Academy of Sciences 106(9):E22.

This letter discusses a long-term amphibian monitoring study conducted in YNP and yields comments on McMenamin et al.'s article (see citation 61). This study documents amphibian population decline in the Lamar Valley of YNP during extended drought, but it is stated that the conclusion in McMenamin et al. of "severe declines in 4 once-common amphibian species" is unsupported and that the McMenamin et al. study wrongly defines sites with one nonbreeding individual as "populations". Patla et al. acknowledge that wetland dynamics unquestionably influence amphibian occurrence, but all species were found at several monitoring locations in 1992-1993 and 2006-2008 and therefore, the data do not demonstrate the loss of a single biological population.

60. Grenon, J.A. 2008. Biomonitoring air quality with lichens in the Jedediah Smith Wilderness and the Winegar Hole Wilderness, Caribou-Targhee NF. Unpublished USFS Report. Driggs, ID., 51 p.

The findings from this report show the presence of many nitrophytic lichen species in 2008 when compared to 1998, potentially signifying a transitioning lichen community. However, sensitive lichen species were found in every plot and the lichen diversity and abundance were typical for the study area and indicate a healthy lichen community and airshed. Slightly elevated N and S levels were measured and attributed to the lack of summer precipitation and Hg (ppb) levels were all below background levels. No ICP analyzed elements were drastically above background levels; slight elevations may be influenced by limestone geology. The South Leigh Lakes Basin showed many elements at levels slightly above background and due to its subalpine and naturally low biotic activity characteristics, the LELAKE-01 plot probably exhibits the highest sensitivity to pollution deposition.

Overall, the lichen community analysis and elemental analysis indicated that Jedediah Smith Wilderness (JSW) and Winegar Hole Wilderness (WHW) airsheds had clean air quality as of 2008. However, the JSW and WHW are located downwind from Teton Valley, warranting continued air quality monitoring and concerns for future health include pollution issues such as rapid growth, wood burning stoves, pesticides, increased traffic, and long distance transport. Recommendations included resampling lichen communities and tissue analysis at the known plot locations in the next 5-8 years due to possible changes in the lichen community and elevated chemistry, paying attention to N concentrations. Also, for future sampling, monitor nitrophytes and sensitive acidophytes, note S, N, Al, Cr, and Zn levels at Leigh Lakes Basin, include arsenic as an analyte, note changes in TAR-01 and WHW-01 due to possible traffic increase and add bulk deposition samplers or passive monitors near plots to calibrate and substantiate the lichen data.

61. McMenamin, S. K., E. A. Hadly, and C. K. Wright. 2008. Climatic change and wetland desiccation cause amphibian decline in Yellowstone National Park. Proceedings of the National Academy of Sciences 105(44):16988–16993.

This article documents the decline of 4 once-common amphibian species native to Yellowstone associated with recent climate warming and resultant wetland desiccation. A combination of climate monitoring over 6 decades, remote sensing, and resurveying of 49 ponds, has shown a trend of decreasing annual precipitation and increasing temperatures during the warmest months. This has caused a shift in the landscape and local ecosystems. Drought is currently more common and severe when compared to the last century. In northern Yellowstone, compared with 16 years ago, the number of permanently dry ponds has increased by 4 times. The proportion of remaining ponds capable of supporting amphibians has greatly declines, as well as the species found in each survey location. The results indicate that even in one of the longest and most protected ecosystems in existence, climate warming has disrupted the biological community and that current species vulnerability assessments do not sufficiently consider those impacts.

62. Tercek, M. T., T. S. Al-Niemi, and R. G. Stout. 2008. Plants exposed to high levels of carbon dioxide in Yellowstone National Park: A Glimpse into the Future? Yellowstone Science 16(1):12-19.

Soil-surface sites, all far removed from human disturbance, in vegetated geothermal areas of Yellowstone, were measured for CO_2 concentrations with portable infrared gas analyzers and many sites had high-CO_2 values, from 450 to greater than 2,000 ppm. These surveys vary from previous studies because numerous high-CO_2 sites can be paired with control site that have background levels of CO_2 and comparable site characteristics. Leaves were collected at the sites mainly from hot springs panic grass (D. lanuginosum), the common dominant YNP geothermal soils plant species. Leaves from the high-CO_2 sites had less RuBisCo (primary photosynthetic enzyme) and higher levels of sucrose (photosynthetic end-product) than those at background sites, supporting the hypothesis that plants in high-CO_2 environments of YNP make physiological adjustments. The findings from this study suggest that YNP can be used as a resource for studying long-term effects of global climate change on plants and their communities. The undisturbed, long-standing survey site environments may provide information on plant adaptations to chronic high temperatures and CO_2 and an indication of future plant and plant community characteristics. This can provide natural resource managers with information to make accurate future plant community projections and provide genetic information to crop breeders and plant genetic engineers to prepare for a warming climate and high-CO_2 environments. Since these studies were initiated in 2004, other researchers have begun investigations in high-CO_2 environments in YNP, including Dr. Cathy Zabinski at Montana State University and Drs. Shikha Sharma and David Williams at the University of Wyoming.

63. Eversman, Sharon. 2007. Lichens in Yellowstone National Park. Yellowstone Science 15(3):14-19, Part II.

64. National Park Service. 2006. Ozone Sensitive Plant Species, by Network.

65. National Park Service. 2006. Ozone Sensitive Plant Species, by Park.

66. National Park Service. 2006. Reassessment of the risk of foliar injury from ozone on vegetation in parks experiencing increases in levels of exposure.

67. National Park Service. 2004. Greater Yellowstone Network: Assessing the Risk of Foliar Injury from Ozone on Vegetation in Parks in the Greater Yellowstone Network.

68. Blett, Tamara, Linda Geiser, and Ellen Porter. 2003. Air Pollution-Related Lichen Monitoring in National Parks, Forests, and Refuges: Guidelines for Studies Intended for Regulatory and Management Purposes. NPS D2292. U.S. Department of the Interior, Denver, CO and U.S. Department of Agriculture, Corvallis, OR.

69. Porter, Ellen. 2003. Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands: Results of a June 24-25, 2003 Workshop Baltimore, Maryland. NPS D1522. Natural Resource Report NPS/NRARD/NRR-2003/01. U.S. Department of the Interior, Denver, CO.

70. St. Clair, Larry L. and Lyndon D. Porter. 2000. Establishment of a lichen biomonitoring program and air quality baseline in the Jedediah Smith Wilderness Area of the Targhee National Forest. U.S. Forest Service Technical Report, 32 p.

71. St. Clair, Larry L. and Lyndon D. Porter. 2000. The Re-Inventory of the Lichen Biomonitoring Program and Baseline for Selected Sites in the Bridger Wilderness Area, Bridger-Teton National Forest, Wyoming.

72. Neitlich, P., Hasselback, L., Szewczak, S., and Rogers, P. 1999. FHM lichen community results from Wyoming, 1997: a preliminary summary. A report to the USDA Forest Service, Rocky Mountain Research Station, Forest Health Monitoring Program. White Mountain Research Station, Bishop, CA. 27 p.

73. Farag, A.M., D. G. Woodward, E.E. Little, B. Steadman, and F.A. Vertucci. 1993. The effects of low pH and elevated aluminum on Yellowstone cutthroat trout (Oncorbynchus clarki Bouvieri). Environmental Toxicology and Chemistry 12(4):719-731.

74. St. Clair, Larry L. and Clayton C. Newberry. 1993. Lichen Biomonitoring Program and Air Quality Baseline in Selected Sites of the Bridger Wilderness Area, Bridger-Teton National Forest.

75. Bunin, J. 1990. Sensitivities of Colorado and Wyoming Wilderness Area Vascular Plants to Sulfur Dioxide, Nitrogen Dioxide, and Ozone: An Overview. USDA Forest Service Region 2.

76. Eversman, S. 1984. Identification of sensitive air pollution receptors in Yellowstone National Park. Unpublished report to National Park Service.

77. Wetmore, Clifford M. 1983. Lichens of the Air Quality Class I National Parks. Supported by National Park Service. University of Minnesota, St. Paul, MN.

78. USDA Forest Service. (n.d.) Region 2 Ozone and SO_2 Sensitive Vascular Plants.

Impacts on Physical Resources

Surface Water/Atmospheric Deposition:

79. Collette, Jeff, and Bret Schichtel. 2011. Research Plan, Summer 2011, Grand Tetons Reactive Nitrogen Deposition Study (GrandTReNDS).

From May through August 2011, in GRTE, this study's objectives are to characterize nitrogen deposition composition and magnitude, along with estimates of relative contributions from emission source categories and geographic regions. Overall, the proposed field study, led by Colorado State University (CSU) investigators, will measure and characterize reactive nitrogen deposition budgets and transport pathways. This effort and sampling network will provide new observations of atmospheric reactive nitrogen species concentrations and spatial distributions and associated deposition fluxes from regional sources of nitrogen, reduced and oxidized, in GRTE. Specifically, this study will aim to:

- Determine the mix of inorganic and organic oxidized and reduced nitrogen in the atmosphere and in surface deposition (dry and wet (precipitation)) on the east and west sides of GRTE.
- Determine the relative contribution from emissions, originating in Wyoming, Idaho and Montana versus other states (specifically Snake River Valley, ID, northern UT, Sublette County, WY, and within GRTE), to atmospheric nitrogen.
- Identify relative contributions of emissions source types to the measured nitrogen species
- Characterize meteorological conditions associated with atmospheric chemistry

- Estimate spatial and temporal variability of atmospheric nitrogen species so that associated deposition rates can be estimated (as a function of emission rates, characteristics, and location) throughout GRTE and the remaining months in 2011
- Assess representativeness of nitrogen deposition during this study to the rest of 2011 and other years

80. Ingersoll, G.P., M.A. Mast, J.M. Swank, and C.D. Campbell. 2011. Rocky Mountain snowpack physical and chemical data for selected sites, 2010. U.S. Geological Survey Data Series 570, 12 p.

The Rocky Mountain Snowpack program established a regional snowpack chemistry monitoring network of sampling sites in the Rocky Mountain region. The purpose is to monitor the chemical compounds and concentrations in snow and understand regional atmospheric deposition impacts on freshwater systems. The U.S. Geological Survey, in cooperation with the NPS, USFS, CDPHE, Teton County in Wyoming, and others, have collected and analyzed snowpack samples since 1993 at approximately 48 sites. Sixty-three snowpack sites were each sampled once and data are provided in the report, including ANC, conductivity, pH, hydrogen ion concentrations, dissolved concentrations of major constituents (Ca, Mg, Na, K, NH_4^+, Cl^-, SO_4^{2-}, and NO_3^-), dissolved organic carbon concentrations, snow-water equivalent, snow depth, total mercury, and ionic charge balance. The report also includes quality-assurance data for sample blanks and replicates for 2010.

81. Naftz, David L. 2011. A 50-year record of NO_X and SO_2 sources in precipitation in the Northern Rocky Mountains. Geochemical Transactions 12(1):4.

Ice-core samples were taken from Upper Fremont Glacier (UFG), Wyoming, and used as proxy records for the chemical composition of atmospheric deposition. The ice-core samples were analyzed for nitrogen ($\delta^{15}N$) and sulfur ($\delta^{34}S$) isotopes and those results, along with deposition rates for sulfate and nitrate from the late-1940's to early-1990's, were used to enhance and expand existing data in western Wyoming from the NADP/NTN. The study showed that the most $\delta^{34}S$ enriched value from an ice-core sample corresponded with snow deposition during the 1980 Mt. St. Helens eruption and the other $\delta^{34}S$ values were comparable to southern Wyoming coal isotopic composition. The $\delta^{15}N$ values ranged from -5.9 to -3.2 ‰ and correlate to values expected from vehicle emissions. This study also shows a nitrate deposition rate of approximately 0.1 kg/ha/yr in the Wind River Mountains during the 1950's. Overall, the nitrate and sulfate deposition data reflect the increase in U.S. emissions data from 1950 to the mid-1970s.

82. Spaulding, S.A., M. Otu, J. Baron, A.P. Wolfe, S. O'Ney, and T. Blett. 2011. Project: Atmospheric deposition of inorganic nitrogen in Grand Teton National Park: determining biological effects on algal communities in alpine lakes. Accessed at http://westerndiatoms.colorado.edu/about/news_story/1151/project_atmospheric_deposition_of_nitrogen_and_diatoms

This project is funded by the National Park Service, Air Resources Division. The purpose is to determine the effects of atmospheric nitrogen deposition (inorganic nitrogen as nitrate and ammonium) on primary producing organisms through the reconstruction of paleolimnological records of diatom species composition in lake sediments. This process can result in fertilization or acidification of aquatic environments, impacting surface water chemistry and biota, causing shifts in species composition. Historically unproductive, nutrient poor lakes in the western Rocky Mountains are now showing signs of biological productivity, where algae are known to be limited by nitrogen. The project takes place in Grand Teton National Park and includes five study lakes. The creation of taxon pages from important lake species is currently in progress, while analysis of the lake sediment cores takes place.

83. Sullivan, T. J., T. C. McDonnell, G. T. McPherson, S. D. Mackey, and D. Moore. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to nutrient enrichment effects from atmospheric nitrogen deposition: Greater Yellowstone Network (GRYN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/308. National Park Service, Denver, Colorado.

The purpose of this report series is to evaluate the relative sensitivity of NPS parks and inventory & monitoring (I&M) networks to potential nutrient enrichment impacts associated with atmospheric nitrogen deposition. This report is a relative risk assessment that considers three factors influencing nutrient enrichment risk to park resources, including nitrogen pollutant exposure, ecosystem sensitivity, and park protection mandates. An overall risk is calculated based on averages of those theme rankings. For the GRYN, specifically GRTE and YELL, the relative ranking for nitrogen pollutant exposure is low, ecosystem sensitivity is very high, and park protection is very high. Nitrogen emissions and deposition are very low for the network, ranging from below 2 kg N/ha/yr in the southeast to 5-10 kg N/ha/yr in and around GRTE and YELL (this analysis includes wet and dry deposition, oxidized and reduced N species). However, ecosystem sensitivity for GRTE and YELL is very high because there are extensive distributions of sensitive vegetation types and high elevation lakes. The summary risk for atmospheric nutrient nitrogen enrichment for GRTE and YELL is very high. For Bighorn Canyon (BICA), pollutant exposure, ecosystem sensitivity, park protection and summary risk are very low, high, moderate, and very low, respectively. Overall, the level of concern for nutrient enrichment from atmospheric nitrogen deposition on I&M parks in the GRYN is very high.

84. Sullivan, T. J., G. T. McPherson, T. C. McDonnell, S. D. Mackey, and D. Moore. 2011. Evaluation of the sensitivity of inventory and monitoring national parks to acidification effects from atmospheric sulfur and nitrogen deposition: Greater Yellowstone Network (GRYN). Natural Resource Report NPS/NRPC/ARD/NRR—2011/357. National Park Service, Denver, Colorado.

The purpose of this report series is to evaluate the relative sensitivity of NPS parks and inventory & monitoring (I&M) networks to potential acidification effects from atmospheric nitrogen and sulfur deposition, specifically nitrate, ammonium, and sulfate. This report is a relative risk assessment that considers three factors influencing acidification risk to park resources, including nitrogen and sulfur pollutant exposure, ecosystem sensitivity, and park protection mandates. An overall risk is calculated based on averages of those theme rankings. For the GRYN, specifically GRTE and YELL, the relative ranking for pollutant exposure is low, ecosystem sensitivity is very high, and park protection is very high. Total S deposition in the GRYN was very low, less than 2 kg S/ha/yr, with only two small areas (see Map J) that ranged from 2-5 kg S/ha/yr. Total N deposition was higher within the GRYN, ranging from less than 2 kg N/ha/yr in the east and up to 5-10 kg N/ha/yr in and around areas of GRTE and SW YELL (this analysis includes wet and dry deposition, oxidized and reduced N species). S and N emissions and deposition are very low within the GRYN, but ecosystem sensitivity is very high because the network is characterized by acid-sensitive waters and geology, with several high-elevation lakes and streams and potentially sensitive low-order streams. The summary risk for N and S acidic deposition for GRTE and YELL is high. For Bighorn Canyon (BICA), pollutant exposure, ecosystem sensitivity, park protection and summary risk are very low, high, moderate, and moderate, respectively. Overall, the level of concern for acidification effects on I&M parks in the GRYN is high.

85. Ingersoll, George P., M. Alisa Mast, James M. Swank, and Chelsea D. Campbell. 2010. Rocky Mountain snowpack physical and chemical data for selected sites, 2009. U.S. Geological Survey Data Series 498, 9 p.

During 2009, snowpack samples were collected and analyzed by USGS in cooperation with the NPS, USFS, CDPHE, Teton County in Wyoming, and others. Sixty-three snowpack sites were each sampled once and data are provided in the report, including ANC, conductivity, pH, hydrogen ion concentrations, dissolved concentrations of major constituents (Ca, Mg, Na, K, NH_4^+, Cl^-, SO_4^{2-}, and NO_3^-), dissolved organic carbon concentrations, snow-water equivalent, snow depth, total mercury, and ionic charge balance. The report also includes quality-assurance data for sample blanks and replicates for 2009.

86. Saros, J.E., D.W. Clow, T. Blett and A.P. Wolfe. 2010. Critical nitrogen deposition loads in high-elevation lakes of the western U.S. inferred from paleolimnological records. Water, Air, & Soil Pollution, doi: 10.1007/s11270-010-0526-6.

Critical loads were determined for atmospheric N deposition for alpine lake ecosystems in the western U.S. from analyzing fossil diatom assemblages in lake sediment cores. Changes in diatom species, starting in 1980, indicated the occurrence of N enrichment for the GYE. To determine the point at which these community changes took place, the critical N load was estimated by modeling wet N deposition rates for the period during the first diatom shifts in each area using deposition data from 1980 to 2007. A critical load of 1.4 kg N ha−1year−1 wet N deposition was determined for the GYE.

87. Allgeier, Andrew R. 2009. Air quality in the Teton and Gros Ventre Wilderness areas; a mixed methods approach. Dissertation, University of Wyoming, 97 p.

During the summers of 2005 and 2006, water and soil samples were collected in 40 lake basins in Wyoming, specifically the Teton and Gros Ventre Wilderness areas. A baseline was developed from analysis of water samples in order for levels of atmospheric NO_x deposition to be determined. The study examined susceptibility of the lakes to acidification effects from atmospheric deposition by using ANC as an indicator and the concept that water quality is a function of both air quality and catchment basin characteristics. A baseline of observed trends relating to AQRV's was established by interviewing 6 permitted outfitters, as well as the feasibility of using long-term resource users as a monitoring tool. Ten lakes in the Teton and Gros Ventre Wilderness areas, five lakes in each, had less than 200 µeq/L ANC and according to EPA guidelines, all are at risk of acidification. Basic air quality trends were determined by integrating the data with the 1984 EPA Western Lakes Survey data, showing increases in ammonium (NH_4^+) and decreases in sulfate (SO_4^{2-}). Also, there was a significant correlation between parent material and ANC (p=0.007). It was shown that outfitters can be used in the monitoring process to depict historical resource conditions and trends by recognizing visible changes in the resources.

88. Ingersoll, George P., M. Alisa Mast, Donald H. Campbell, David W. Clow, Leora Nanus, and John T. Turk. 2009. Rocky Mountain snowpack physical and chemical data for selected sites, 1993–2008. U.S. Geological Survey Data Series 369, 90 p.

During 1993-2008, snowpack samples were collected and analyzed annually by USGS in cooperation with the NPS, USFS, Teton County in Wyoming, Rio Blanco and Pitkin Counties in Colorado, and others. Of the 162 snow-sampling sites, forty-eight have been sampled annually since 1993 for ANC, conductivity, pH, hydrogen ion concentrations, dissolved concentrations of major constituents (Ca, Mg, Na, K, NH_4^+, Cl^-, SO_4^{2-}, and NO_3^-), dissolved organic carbon concentrations, snow/water equivalent, snow depth, stable S isotope ratios, total Hg concentrations (beginning in 2001) and ionic charge balance. QA data is provided for sample blanks and replicates for each year (1993-2008).

89. Nanus, L., M. W. Williams, D. H. Campbell, K. A. Tonnessen, T. Blett, and D. W. Clow. 2009. Assessment of lake sensitivity to acidic deposition in national parks of the Rocky Mountains. Ecological Applications 19(4):961-973.

In five national parks of the Rocky Mountains, high-elevation lakes were evaluated for sensitivity to acidic deposition based on statistical relations between ANC and basin characteristics. A logistic regression model was developed and the results were cross-validated by lake sampling during fall 2004. The model was applied to lake basins >1 hectare, which included GRTE (n=106 lakes) and YELL (n=294 lakes). Lakes with a high probability of exhibiting an ANC at <100 µeq/L, meaning a lake will be sensitive to acidic deposition, are located at elevations >3000 m, with <30% northeast aspect in the catchment, and >80% of the bedrock exhibits low buffering capacity. According to the modeling results, GRTE was identified as one of the two most sensitive lakes to acidic deposition. It was determined that the modeling technique can be useful for creating long-term monitoring plans and atmospheric deposition sensitivity in other remote mountain areas.

90. Ingersoll, George P., M. Alisa Mast, Donald H. Campbell, David W. Clow, Leora Nanus, John T. Turk. 2008. Trends in snowpack chemistry and comparison to National Atmospheric Deposition Program results for the Rocky Mountains, US, 1993-2004. Atmospheric Environment 42:6098–6113.

Seasonal snowpack chemistry data was examined from the Rocky Mountain region to identify long-term trends in snow chemistry and in snow-water equivalent. For 1993-2004, trend comparisons were made between Rocky Mountain Snowpack sites and NADP wetfall sites located nearby. The study was broken down into three subregions in the Rockies: northern, central and southern. The Regional Kendall Test was used to compute trends for several sites simultaneously and a seasonal Kendall test was used to evaluate sites individually. Wetfall and snowpack concentrations and deposition showed significant trends, as well as in precipitation. Significant trends for the network comparison, trends were in reasonable agreement. A common trend was increases in ammonium and nitrate, and decreased sulfate for wetfall and snowpack in all subregions, however, deposition patterns between wetfall and snowpack were often opposite for ammonium and nitrate. For the central and southern Rockies, a decreasing trend in ammonium and nitrate deposition in wetfall occurred (moderately significant; $p<0.11$), while significant snowpack increases occurred ($p<0.02$). These opposite trends can be explained by varying rates of precipitation decline during drought (1999-2004) and concentration increases. Also, dry deposition contributed significantly to total N deposition. In wetfall and snowpack, sulfate deposition had a decreasing trend with moderate to high significance for all subregions. Precipitation trends were consistently downward and significant for the central and southern Rockies ($p<0.03$).

91. Landers, D.H., S.L. Simonich, D.A. Jaffe, L.H. Geiser, D.H. Campbell, A.R. Schwindt, C.B. Schreck, M.L. Kent, W.D. Hafner, H.E. Taylor, K.J. Hageman, S. Usenko, L.K. Ackerman, J.E. Schrlau, N.L. Rose, T.F. Blett, and M.M. Erway. 2008. The Fate, Transport, and Ecological Impacts of Airborne Contaminants in Western National Parks (USA). EPA/600/R-07/138. U.S. Environmental Protection Agency, Office of Research and Development, NHEERL, Western Ecology Division, Corvallis, Oregon.

The purpose of the Western Airborne Contaminants Assessment Project (WACAP) is to determine the risk to ecosystems and food webs from airborne contaminants, as well as function as a screening study to evaluate contaminant concentrations across large-scale spatial gradients and temporal scales, in western U.S. national parks. This assessment was a partnership between the NPS, USEPA, USGS, USFS, Oregon State University, and University of Washington. 8 core parks were sampled, along with 12 secondary parks (or monuments, preserves, or forests) for expanded assessment; the only park relevant to the GYE is GRTE. These locations were sampled for three ecosystem components, including air, lichens, and conifer needles and intended to improve scientific knowledge on global fate, transport, and ecological impacts on sensitive ecosystems associated with airborne contaminants.

For GRTE, dominant semi-volatile organic compounds (SOCs) in vegetation were PAHs (bdl-931 ng/g lipid) and current-use pesticides (CUPs) endosulfans (3-165) and dacthal (5-50). Compared to other WACAP parks, GRTE lichen SOC concentrations were at or above the median, needle concentrations were at or below medians, except for fir collected at GRTE2. All other SOCs detected in WACAP vegetation were also detected at GRTE. Lichen N concentrations were within background levels, indicating non-elevated levels of N deposition. The air sampler was located at sample location GRTE5 and measured concentrations of detected SOCs above medians for the 20 parks, but PAHs were low. More information on this project can be accessed at http://www.nature.nps.gov/air/Studies/air_toxics/wacap.cfm.

92. Story, Mark T. and Jill Grenon. 2008. Phase 3 Lake Water Chemistry Monitoring Absaroka Beartooth, Cabinet Mountains, and Selway Bitterroot Wilderness Areas

1994-2007. Gallatin National Forest, Bozeman, MT.

The USFS Region 1 Air Resource Monitoring Program monitors lake chemistry to provide diagnostic indication of atmospheric deposition and a chemical record of air pollution impacts that help improve understanding of changes in lake composition. Monitoring changes in lake chemistry is important because it can adversely impact microorganisms, invertebrates, and native flora, and subsequently affects fish health and productivity. This report is a summary of the Region 1 lake sampling program data from 1993-2007 with focus on the Phase 3 lakes. The only data relevant to the GYE in this report are for the Absaroka Beartooth Wilderness area (ABW) and the associated Stepping Stone Lake and Twin Island Lake. The Cabinet Mountains and Selway Bitterroot Wilderness areas lay outside the boundaries of the GYE.

For the ABW lakes, analyses show that pH has been increasing slightly, Stepping Stone Lake showed a decrease in ANC and conductivity, and Twin Island Lake showed a slight increase in ANC and conductivity. For sulfate and nitrate, which are acidifying anions, the overall western trend is decreasing for sulfate. However, for this study, none of the lakes showed a decreasing sulfate trend, possibly due to bedrock weatherization or distance from sulfate sources that wouldn't be impacted by emission decreases. No discernable, strong trends appeared for nitrate and ammonium; a slight increase in ammonium appeared in the ABW and nitrate is stable or decreasing for all study lakes except Twin Island Lake in the ABW. Based on the MAGIC (Model of Acidification of Groundwater in Catchments) model, the ABW lakes are less sensitive due to relatively deeper soils. Recommendations included conducting monitoring for 20-30 years to establish a baseline and trends and that Phase 3 lake monitoring continue until at least 2020; the ABW has been monitored for 12 years. Increasing trends of nitrate, sulfate, ammonium, and TOC (total organic carbon) in the west warrant continued monitoring, with the addition of TOC as a parameter in the Phase 3 lakes in 2008.

93. Ingersoll, George P., M. Alisa Mast, Leora Nanus, Heather H. Handran, David J. Manthorne, and Douglas M. Hultstrand. 2007. Rocky Mountain snowpack chemistry at selected sites, 2004. U.S. Geological Survey Open-File Report 2007-1045, 15 p.

94. Arnold, Jeffrey L., and Todd M. Koel. 2006. Effects of Snowmobile Emissions on the Chemistry of Snowmelt Runoff in Yellowstone National Park, Final Report. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyo., YCR-2006-1.

95. Baron, J. 2006. Hindcasting nitrogen deposition to determine an ecological critical load. Ecological Applications 16(2):433-439.

96. Corbin, Jenn**ifer, Scott Woods, and Susan O'Ney. 2006. Atmospheric effects on water** quality in high-elevation lakes of the Teton Range, Wyoming, U.S.A., in Harmon, David, ed. 2006. People, Places, and Parks: Proceedings of the 2005 George Wright Society Conference on Parks, Protected Areas, and Cultural Sites. Hancock, Michigan: The George Wright Society, p. 320-328.

97. Ingersoll, George P., M. Alisa Mast, Leora Nanus, David J. Manthorne, Heather H. Handran, Douglas M. Hultstrand, and Jesse Winterringer. 2005. Rocky Mountain

Snowpack Chemistry at Selected Sites, 2003. U.S. Geological Survey Open-File Report 2005-1332, 17 p.

98. Nanus, Leora, Donald H., Campbell, and Mark W., Williams. 2005. Sensitivity of alpine and subalpine lakes to acidification from atmospheric deposition in Grand Teton National Park and Yellowstone National Park, Wyoming. U.S. Geological Survey Scientific Investigations Report 2005–5023, 37 p.

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118.Susong, D.D., M. L. Abbott, and K. P. Krabbenhoft. 1999. Reconnaissance of mercury concentrations in snow from the Teton and Wasatch Ranges to assess the atmospheric deposition of mercury from an urban area. Eos. Transactions of the American Geophysical Union 80(46), Abstract H12b-06.

119. Turk, J.T., and D.H Campbell. 1984. Prediction of lake alkalinity in the Rocky Mountain West: in: Air Quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. U.S. Forest Service, Ogden, UT, p. 268-274.

Climate Change:

120. Fiebig, Michael. 2011. The GYA Climate Action Plan: Background and Next Steps. GYCC SOS Meeting, West Yellowstone, MT, 10 January.

The agencies of the GYCC recently complete a GYA-wide GHG Emission Reduction Climate Action Plan, which has an overall prediction of GHG emissions reduction of 21% to 36% by 2020 from the 2007 inventory year. Each park, forest, and refuge has committed to achieving a 20% reduction in GHG emissions by 2020. The project is the first of its kind to evaluate GHG emissions of the three federal agencies managing the GYA, an 18 million acre ecosystem. The first comprehensive GHG inventory was completed in April 2009, which set the stage for the creation of the ecosystem-wide GHG emissions reduction action plan. The action plan will be coming soon in document form to http://fedgycc.org/SOSGHG.htm.

121. Loosen, Anne E., and Embere Hall. 2011. Investigating American Pika Occupancy and Habitat Use in the Southern Greater Yellowstone Ecosystem, 2011 Progress Report.

In August 2008, a monitoring project on pika (Ochotona princeps) was implemented in Grand Teton and Yellowstone National Parks, in order to understand climate change impacts on pika populations. The pika is a species that resides in cold, alpine communities and consequently, is vulnerable to and incapable of thriving in warm temperatures, making it an excellent indicator of changing climate. Disappearing populations of pika have been observed in Western alpine communities due to temperature increases; there have been predictions that the pika could be one of the first mammals in the contiguous U.S. to face extinction due to climate change. This project will provide data on pika habitat use, distribution and response to various environmental conditions, as well as help facilitate resource management by understanding possible climate change conditions and associated biological impacts in the GYE. In 2010, Teton Science Schools initiated a thorough study on the distribution of American pika in the southern GYE. Please visit http://www.tetonscience.org/index.cfm?id=crc-projects-pikas for more information on this project.

122. Ashton, I. W. 2010. Observed and projected ecological response to climate change in the Rocky Mountains and Upper Columbia Basin: A synthesis of current scientific literature. Natural Resource Report NPS/ROMN/NRR—2010/220. National Park Service, Fort Collins, Colorado.

The purpose of this report is to provide increased access to regional and local information on observed and projected effects of climate change and ecosystem responses in the Rocky Mountains and Upper Columbia Basin (ROCO) in order to assist resource managers in the West with responding to ecological responses to climate change. The ROCO is defined by climate and geopolitical boundaries, and one region included in this area is the GYA. Goals of this report include highlighting common themes in climate change response and assist development of climate change impact monitoring systems (i.e. air quality, species, communities of interest, ecological processes and properties). These goals can help management and resource program actions, conservation target development, and system vulnerability identification. Certain ecosystem properties, processes, and resources have changed as a result of warming temperatures and variable precipitation and sensitive components can serve as indicators of climate change impacts. Indicators for the ROCO include freshwater resources, wildlife and plant disease, wildfire, insect invasion, alpine vegetation, phenology, butterflies, elk and birds. Understanding climate change impacts is essential for mitigation and management, especially when combined with other stressors (e.g. atmospheric pollution, land-use change, invasive species).

123. Debinski, Diane M., Hadley Wickham, Kelly Kindscher, Jennet C. Caruthers, and Matthew Germino. 2010. Montane meadow change during drought varies with background hydrologic regime and plant functional group. Ecology 91(6):1672–1681.

Climate change models often predict extreme climatic events for ecosystems, including worsening drought conditions. This study assesses the effects of drought by quantifying temporal variation in a montane meadow landscape's community composition that is characterized by a hydrological gradient. The meadows are located in two regions of the GYE (Gallatin and Teton) and were placed into six categories designating hydric to xeric (M1-M6). The report discusses several identified trends in the meadow plant communities during drought. Overall, the results showed that community change is not uniform across the landscape. Instead, it community transformation can be predicted based on functional group responses to spatial and temporal patterns of water availability, which tend to be a function of plant water use and hydrology.

124. Gray, S. T., and G. J. McCabe. 2010. A combined water balance and tree ring approach to understanding the potential hydrologic effects of climate change in the central Rocky Mountain region. Water Resour. Res., 46, W05513, doi:10.1029/2008WR007650.

This study evaluates the potential hydrologic effects of climate warming, some models suggest a temperature increase by >3°C over the next century in the central Rocky Mountains, combined with observed precipitation variation. The upper Yellowstone drainage was used as a test case and a water balance model was created to estimate river discharge from precipitation and temperature inputs. Overall, the combined tree ring and water balance scenario does not provide a precise forecast for future climate change, but does suggest that a 1°–3°C warming could adversely impact water availability in the upper Yellowstone. It also suggests that 20th century observations may portray an incomplete and optimistic idea of regional water supplies.

125. Gray, S. T, C. M. Nicholson, and M. D. Ogden. 2010. Greater Yellowstone Network: Climate of 2008. Natural Resource Report NPS/GRYN/NRR—2010/173. National Park Service, Fort Collins, Colorado.

This report discusses climate for 2008 in the GRYN and surrounding region, focusing on temperature and precipitation, with additional information on snowpack, streamflow, and drought. A series of maps illustrate climatic conditions for the GRYN and records for individual stations that depict variability at a finer scale. Compared to the reference period (1971-2000), the GRYN was slightly drier, receiving 87% of average precipitation in 2008, but was less dry than 2007. Temperatures were lower in 2008 when compared to 2007 and in January they were lower-than-average for GRTE and YELL. Snowpack was near average in the GRYN for 2008, making it one of the wettest winters in 7-9 years and high-country snowpack, unlike the past decade, persisted into early summer and therefore, caused stream discharge to be average or slightly higher in summer. Severe drought was avoided by persistent snowpack and residual moisture from May storms.

126. Greater Yellowstone Science. 2010. Monitoring Ecological Responses to Climate Change Resource Brief, Greater Yellowstone Network.

Five variables are analyzed based on climate data collected by national networks in the Greater Yellowstone I&M Network (GRYN) and Rocky Mountain I&M Network (ROMN). The GRYN, in partnership with the ROMN, determines the status and trend of temperature, precipitation, streamflow, drought, and snowpack. It has been predicted that earlier snowmelt, reduced snowpack, and summer drought will take place by the mid-21st century as a result of climate warming and precipitation variability. Reports are written on climate status annually and on trends every five years. Many ecological responses to climate change have been observed and are now monitored, including whitebark pine, amphibians, land birds, water resources, and vegetation composition and soil stability. Whitebark pine has declined drastically due to nonnative white pine blister rust and native mountain pine beetles; the heaviest infestation of mountain pine beetle on record has occurred due to a decrease in extremely cold winter temperatures. Climate change can impact amphibians by reducing available habitat, earlier breeding, distribution and abundance. Water resources may experience alteration in hydrologic regimes, water temperature (range reduction for salmonids is predicted), food webs, biodiversity, and nutrient dynamics. Landbirds are predicted to shift their range, migration and timing, and cope with reproduction interference. Altered fire regimes and invasive species will impact plant communities. Mostly all of these ecological responses have been monitored by the GRYN since about 2004 in one or all of its associated park units.

127. Greater Yellowstone Science. 2010. Climate Resource Brief, Greater Yellowstone.

2009 climate statistics reflected the region's continued recovery from the drought that began in 2008. Spring was generally 1-3 weeks earlier than average and fall started 1-3 weeks later than average, but the growing season was similar to the normal average because of cool summer temperatures. For the Yellowstone and Snake rivers, peak runoff timing was normal and total annual runoff was 119% and 132% of average, respectively. Long-term trends show an annual mean temperature increase of approximately 2.5°F from 1895-2009 at Mammoth Hot Springs. Precipitation was near normal (one of the wettest years in a decade) when compared with 1971-2000 averages. Computer-based climate models show predictions of human-caused climate change impacting drought frequency and accompanied fire frequency and severity, with less impacts on total annual precipitation in the Yellowstone area. However, precipitation will probably occur as rain rather than snow, and along with increased evaporation, this means plants will have increased water stress. Rain is rapidly lost rather than gradually released as with snowpack. A greater proportion of total annual stream discharge will be as intense spring runoff (earlier than normal) from rapid snow melt, meaning discharge could be lower during the summer and exacerbate water scarcity. Average peak runoff over the last decade has occurred 10-20 days earlier than historical averages and may move forward an additional 20 days by the end of the century. Climate zones in GRTE and YELL are also discussed in this briefing.

128. Haak, A.L., J.E. Williams, D. Isaak, A. Todd, C. Muhlfeld, J.L. Kershner, R. Gresswell, S. Hostetler, and H.M Neville. 2010. The potential influence of changing climate on the persistence of salmonids of the inland west: U.S. Geological Survey Open-File Report 2010–1236, 74 p.

Warming temperatures associated with climate change during the 20th century caused environmental trends, such as wildfire, thermal and hydrologic properties of aquatic ecosystems, that impact salmonid habitat and those trends are likely to increase into the mid-21st century. Understanding the impacts of climate change, including warmer and drier conditions, on salmonids is vital for conservation efforts and predicting where changes may occur. This study assesses the impact of climate change on the persistence of native trout and grayling in 11 western States. All of the taxa examined have some high risk in their range for the factors analyzed. For example, drought is the most persistent threat, with ≥40% of the range for seven taxa at high risk. Many of the populations examined did not meet persistence criteria, especially in the central and southern portion of the study region. Long-term persistence is impeded when condition are limited, such as when climate change stressors are combined with ecosystem stressors and have a synergistic effect. For example, more disturbed ecosystems will be more vulnerable to climate change impacts. Despite such limitations, the study results provide information on climate change effects and risks to coldwater fish, and can assist the development of conservation frameworks to increase resilience and resistance in native trout to climate change impacts.

129. Kandt, Alicen, Eliza Hotchkiss, and Mike Fiebig. 2010. Beyond the Inventory: An Interagency Collaboration to Reduce Greenhouse Gas Emissions in the Greater Yellowstone Area. Prepared under Task No. FE10.R110. Technical Report NREL/TP-7A20-49291. National Renewable Energy Laboratory, Golden, Colorado, October.

Land managers (the 10 Federal units) in the GYA have collaborated to compile GHG emissions inventories on a unit- and ecosystem-wide level, and setting mitigation goals and strategies. The report discusses this ongoing effort of cross-agency environmental emissions management in the GYA. The process is requires cross-jurisdictional land management with several agencies all working under varying mandates. This case study provides an opportunity to improve other cross-agency broad-scale management efforts that share characteristics, advantages, and limitations, which is becoming increasingly important as agencies seek common goals and strategies to tackle environmental management issues on national lands.

130. Macfarlane W.W, J. A. Logan and W.R Kern. 2010. Using the Landscape Assessment System (LAS) to Assess Mountain Pine Beetle-Caused Mortality of Whitebark Pine,

Greater Yellowstone Ecosystem, 2009: Project Report. Prepared for the Greater Yellowstone Coordinating Committee, Whitebark Pine Subcommittee, Jackson, Wyoming. 69 pages.

During the summer 2009, an aerial survey, using the Landscape Assessment System (LAS), was conducted to assess mountain pine beetle-caused mortality in the GYE whitebark pine forests. Results combining sampled and interpolated mortality values (27% by area) showed mortality of whitebark pine in the GYE at 46% (high), 36% (medium), 13% (low), and 5% (no mountain pine beetle-caused mortality). Maps and spatial data show mortality levels related to geographic location and landscape attributes. The study is anticipated to aid forest managers with preservation and restoration efforts associate with conservation plans.

131. McWethy D. B., S. T. Gray, P. E. Higuera, J. S. Littell, G. T. Pederson, A. J. Ray, and C. Whitlock. 2010. Climate and terrestrial ecosystem change in the U.S. Rocky Mountains and Upper Columbia Basin: Historical and future perspectives for natural resource management. Natural Resource Report NPS/GRYN/NRR—2010/260. National Park Service, Fort Collins, Colorado.

The purpose of this report is to provide land and natural resource managers with information on climate change and associated ecosystem responses. Understanding past climate drivers and rates and ecosystem sensitivity can help predict how ecosystems may respond in the future. Climate and vegetation history over the past 20,000 years were synthesized, which is a time span that exhibits periods of rapid climate change and ecosystem responses to long-term climate warming. The most current Global Climate Model (GCM) predictions of future change in climate variables are also reported, in order to put past conditions into context and provide future estimates. The objective was to use past data to identify climate-driven biophysical responses and possible ecosystem trajectories resultant from future climate change.

132. Rieman, Bruce E. and Daniel J. Isaak. 2010. Climate change, aquatic ecosystems, and fishes in the Rocky Mountain West: implications and alternatives for management. Gen. Tech. Rep. RMRS-GTR-250. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 46 p.

Human-caused climate change is currently altering aquatic environments throughout the Rocky Mountain West and adversely impacting populations of sensitive species. The purpose of this report is to combine literature on this topic and address the following issues: 1) the influence of changing climate and associated physical/hydrological processes on aquatic ecosystems; 2) ramifications of climate change on aquatic populations, communities, and associated conservation values; and 3) identify what can be done to mitigate climate change impacts and address the above issues. Some aquatic species may migrate to different locations or track changes and relocate, but others may be impeded by dispersal and migration barriers. Even well-studied species response to climate change can be hard to predict when considering variable interaction between biological and physical processes. Adaptation, through natural selection and plasticity, may be outpaced by climate-driven environmental changes. Proactive efforts may assist those potential adaptations, but facilitation may be required where aquatic ecosystems shift to alternative states. In the face of addressing climate change impacts to aquatic ecosystems, it is imperative to foster collaboration between disciplines, agencies, and the public.

133. Tercek, M. T. and S. T. Gray. 2010. Greater Yellowstone Network: Climate of 2009. Natural Resource Report NPS/GRYN/NRR—2010/262. National Park Service, Fort Collins, Colorado.

This report discusses climate for 2009 in the GRYN and surrounding region, focusing on temperature and precipitation, with additional information on snowpack, streamflow, and drought. A series of maps illustrate climatic conditions for the GRYN and records for individual stations that depict variability at a finer scale. Compared to the reference period (1971-2000), precipitation in 2009 was near or slightly above average in YELL and GRTE. Across the GRYN, average maximum and minimum temperature were about average to slightly below average. The snow water equivalent was near average for the year in YELL and GRTE, but snowpack was above average at some stations due to spring storms. The Bighorn Mountains showed more rapid snowmelt than normal, but was offset by above average snowpack. Total annual runoff in GRYN was 90-122% when compared to the reference period. Continued recovery from the 2008 drought took place in 2009; wet months in June and October balanced dry months in September, November, and December.

134. Yellowstone National Park. 2010. Yellowstone Resources & Issues, Chapter 8, Issues: Climate Change. Mammoth, WY/Division of Interpretation.

This document provides information on climate change globally, for the western U.S., Yellowstone, and Greater Yellowstone. In the GYE, growing season has decreased by two weeks and a longer growing season has caused willows to grow 3 times the average from 1980. Predictions for the GYE include: a decrease in alpine habitat that will impact nearly all flora and fauna, a decrease in grizzly bear alpine food sources, loss of wolverine, pika, and lynx habitat, and an increase in sagebrush-steppe conditions.

135. Gray, S., C. Nicholson, T. Dietrich, and S. Laursen. 2009. Greater Yellowstone Network: Climate of 2007. Natural Resource Technical Report NPS/GRYN/NRR–2009/076. National Park Service, Fort Collins, Colorado.

Climate of 2007 was characterized by warmer than average temperatures over the year and drier than average conditions in spring and summer, including warm nighttime temperatures in March and July. A warmer spring caused an early runoff in the GRYN and when combined with minimal snowpack, contributed to lower than average river levels from July through August. Dry-to-severe drought conditions persisted throughout the summer. Overall, climate conditions in 2007 were primarily dry and a moderate-to-severe drought that had begun in the late 1990's.

136. Heede, Richard. 2009. Jackson Hole Inventory of Greenhouse Gas Emissions in 2008. Climate Mitigation Services.

This 2008 Jackson Hole energy and emissions inventory considers the Town of Jackson, Jackson Hole, and Teton County except for areas west of Teton Pass. Tables and figures are provided for GHG emissions from various sources such as electricity (buildings), natural gas and propane (buildings), ground transportation, air travel and aviation, landfill, nitrous oxide, and HFCs and refrigerants.

137. Tucker, Julie, Dan Golub, and Anna Jones-Crabtree. 2009. Greenhouse Gas Inventory for the National Forests in the Greater Yellowstone Area.

In 2007, the USFS became the first federal land manager to join the EPA's Climate Leaders program and as a result of this affiliation, developed a GHG emissions inventory for seven pilot projects, including the National Forests in the GYA. These inventory results will be consolidated with other GYA GHG inventories developed by the NPS and FWS, by the National Renewable Energy Lab (NREL), in order to identify anthropogenic activities on all GYA federal lands. The three federal agencies will use the inventory results to set emission reduction goals collaboratively. The USFS is one action to understand and reduce its footprint and adhere to Executive Order 13423 and the 2007 Energy Independence and Security Act. This inventory estimates USFS generated GHG emissions in fiscal year 2007 on six National Forests located in the GYA, including Bridger-Teton, Beaverhead-Deerlodge, Caribou-Targhee, Custer, Gallatin, and Shoshone. Carbon sequestration and carbon sinks are not included in the inventory, only anthropogenic emissions are considered. Table 1 provides GHG emissions by forest and source category and emission source distributions are in Figure 1; GHG emissions are reported as metric tons of carbon dioxide equivalents.

138. Bailie, Alison, Stephen Roe, Holly Lindquist, and Alison Jamison. 2007. Montana Greenhouse Gas Inventory and Reference Case Projections 1990-2020. Montana Department of Environmental Quality and Center for Climate Strategies.

139. Bailie, Alison, Randy Strait, Steve Roe, Alison Jamison, and Holly Lindquist. 2007. Wyoming Greenhouse Gas Inventory and Reference Case Projections 1990-2020. Wyoming Department of Environmental Quality and Center for Climate Strategies.

140. Strait, Randy, Steve Roe, Alison Bailie, Holly Lindquist, and Alison Jamison. 2007. Idaho Greenhouse Gas Inventory and Reference Case Projections 1990-2020. Idaho Department of Environmental Quality and Center for Climate Strategies.

141. Davey, C. A., K. T. Redmond, and D. B. Simeral. 2006. Weather and Climate Inventory, National Park Service, Greater Yellowstone Network. Natural Resource Technical Report NPS/GRYN/NRTR—2006/001. National Park Service, Fort Collins, Colorado.

142. Nanus, L. and D. H. Campbell. 2003. Analysis of Air Quality Information for Vital Signs Selection in GRYN Parks: Draft Administrative Report.

143. Selkowitz, D. 2003. Compilation and Analysis of Climate Data in the Greater Yellowstone/Bighorn Canyon Area.

144. Romme, W. H., and M. G. Turner. 1992. Global climate change in the Greater Yellowstone: How will we fare in the Greenhouse Century? Yellowstone Science 1(1):2-5.

145. Romme, William H., and Monica G. Turner. 1991. Implications of Global Climate Change for Biogeographic Patterns in the Greater Yellowstone Ecosystem. Conservation Biology 5(3):373-386.

Visibility:

146. Pendery, Bruce. 2007. Evidence of Impairment of Air Quality Related Values in Bridger Wilderness Area, Wyoming.

147. Copeland, Scott. 2006. Preliminary Review of Photographs taken in 2005 from Oil & Gas Fields in Upper Green River Basin.

148. Debell, Linsey J. 2006. Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report IV, November 2006. Available Online: http://vista.cira.colostate.edu/IMPROVE/Publications/improve_reports.htm

149. Han, Ziguang, Derek C. Montague, and Jefferson R. Snyder. 2003. Airborne measurements of aerosol extinction in the lower and middle troposphere over Wyoming, USA. Atmospheric Environment 37:789-802.

150. Wyoming Department of Environmental Quality, Air Quality Division. 2003. **Wyoming's Long Term Strategy for Visibility Protection, 2003 Review Report.**

151. Gribovicz, Lee, Lincoln Sherman, Scott Cismoski and Gloria S. Mercer. 2000. Visual Air Quality in the Green River Basin, Wyoming Results From the Green River Basin Visibility Study (GRBVS).

152. Malm, William C. 2000. Spatial and Seasonal Patterns and Temporal Variability of Haze and its Constituents in the United States: Report III. Available Online: http://vista.cira.colostate.edu/IMPROVE/Publications/improve_reports.htm

153. Sisler, James F. 1996. Spatial and Seasonal Patterns and Long Term Variability of the Composition of the Haze in the United States: An Analysis of Data from the IMPROVE Network, 1996. Available Online: http://vista.cira.colostate.edu/IMPROVE/Publications/improve_reports.htm

154. Sisler, James F., Dale Huffman, and Douglas A. Latimer. 1993. Spatial and Temporal Patterns and the Chemical Composition of the Haze in the United States: An Analysis of Data from the IMPROVE Network, 1988-1991. Available Online: http://vista.cira.colostate.edu/IMPROVE/Publications/improve_reports.htm

Winter Air Quality

155. ENVIRON, T&B Systems and MSI. 2010. 2009 Upper Green River Winter Ozone Study. ENVIRON International Corp., Novato, CA, March.

This study is a follow-up to the Upper Green Winter Ozone Study (UGWOS) conducted in 2007 and 2008. It took place from mid-January through March 2009 to study ozone episode development in the UGRB and included mesonet, sodar, and permanent sampling locations. During intensive operating periods when elevated ozone conditions were forecast, routine measurements were supplemented with upper-level measurements of winds and ozone with sondes released at the Pinedale airport and non-methan organic compound sampling at three locations. The expanded network of mesonet sites in 2009, along with the additional monitoring accompanied with the Sublette County Human Health Risk Assessment study, allowed for more detailed mapping of wind patterns and ozone levels than in previous study years. Compared to 2008, the frequency and severity of elevated ozone episodes was less extensive; ozone concentrations above the NAAQS (75 ppb 8-hour avg) were seen on three days, with the highest levels at the newly deployed Mesa and Sodar monitoring sites. In 2009, the meteorological conditions associated with the ozone episodes were less extensive. Another difference from 2008 to 2009 is that a voluntary emission reduction program was introduced, which resulted in operators taking steps to reduce emissions on WDEQ issued Health Advisory days that took place on February 2 and 3.

156. MSI, ENVIRON and T&B Systems. 2010. 2010 Upper Green River Ozone Study. Meteorological Solutions Inc., Salt Lake City, UT, December.

The 2010 study took place from January 15 to March 31 2010, with a focus on spatial and temporal patterns of ozone and meteorology rather than ozone formation mechanisms as in previous years. Sample locations included permanent sites, mesonet sites, sodar, Boulder II HONO, Jonah/BAM trailer, and non-UGWOS sites. During 2010, continuous nitrous acid (HONO), a source of hydroxyl (OH) radicals key to ozone formation, measurements were collected at the Boulder station. HONO measurement results are in the findings and recommendation section (section 4.0). UGWOS 2010 data are available on the WDEQ-AQD website in an ACCESS database.

157. Ray, J. D. 2010. Winter air quality in Yellowstone National Park: 2008-2009. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2010/285. National Park Service, Denver, Colorado.

Air quality in YNP was monitored at two locations in the park as part of an adaptive management program addressing the use of over-snow winter motor vehicles and at a site near the center of West Yellowstone. Leading indicators were ambient concentrations of CO and $PM_{2.5}$ and for overall air quality and relationship to traffic, the West Entrance monitoring site is the primary indicator because of a longer record and thorough traffic counts. Old Faithful is the main destination for winter use vehicles; CO and $PM_{2.5}$ concentrations are lower at Old Faithful than at the West Entrance. The winter 2008-2009 results show that hourly and 8-hour average

CO concentrations slightly decreased at the West Entrance, but are similar at Old Faithful. Yellowstone meets NAAQS for CO and $PM_{2.5}$. However, CO is present above regional background levels (0.1-0.2 ppm) near vehicle routes, especially during winter. For $PM_{2.5}$, daily average concentrations are decreasing in YNP, but are the same or higher in the town of West Yellowstone from previous winters ($PM_{2.5}$ does not exceed NAAQS in West Yellowstone). Detailed contractor reports for the NPS winter air quality studies can be found at http://www.nature.nps.gov/air/studies/yell/yellAQwinter.cfm.

158. Stoeckenius, Till, and Lan Ma. 2010. A Conceptual Model of Winter Ozone Episodes in Southwest Wyoming. ENVIRON International Corporation, Novato, CA, January.

This report presents a conceptual model of late winter elevated ozone events in the UGRB. According to EPA ozone modeling guidance, States should develop conceptual models to describe the ozone issue. To support development of the conceptual model for ozone episodes in SW Wyoming, several analyses were conducted, largely based on data collected during the UGWOS, which was conducted during February-March 2007 and 2008. Data collection activities and summaries from UGWOS are explained in two field study reports (see ENVIRON 2008a, b). Result from this modeling study showed that the ozone episodes are characterized by conditions such as, formation of a strong surface based temperature inversion, strong albedo, transport of ozone or precursors into the UGRB from upwind areas, a diurnal recirculation pattern, and high concentrations of precursor emissions associated with tightly spaced well pads. Also, conditions such as low solar elevation angles prior to January and shorter nights and strong solar insolation after mid-March influence the timing of the ozone episodes, which are seen from late January to mid-March.

159. Bishop, Gary A., Ryan Stadtmuller, Donald H. Stedman, and John D. Ray. 2009. Portable Emission Measurements of Yellowstone Park Snowcoaches and Snowmobiles. J. Air & Waste Manage. Assoc. 59:936–942.

In-use tailpipe emissions data from snowcoaches (10) and snowmobiles (2 4-stroke) in YNP was collected by the University of Denver as part of the NPS's Temporary Winter Use Plans Environmental Assessment. Data was collected in 2006 using a portable emissions monitor. The snowcoaches had more advanced fuel management technology than previously studied, which lowered average emissions such as CO, hydrocarbons, and NO_x. A standardized route and equal passenger loading was used during data collection, but large emissions variability was still observed; snow and road conditions were suggested as the cause for variability. The study showed that computer-controlled fuel management systems on two snowmobiles increased fuel economy (25 mpg) and a major reason for observed emissions decline. Overall, the tailpipe emissions data showed that the two primary winter OSVs in YNP are very similar in per-passenger emissions.

160. Greater Yellowstone Science. 2009. Winter Air Quality Resource Brief, Yellowstone.

Visitation in the winter is lower than summer in Yellowstone, but oversnow vehicles (OSVs) produce more emissions. During the winter of 2006-2007, 46% of visitors entered by a plowed road, 33% by snowmobile, and 21% by snowcoach. For the West Entrance and Old Faithful sites, CO and PM have not exceeded federal or state ambient air quality standards. Pollutant levels have declined in recent years because snowmobiles are required to have "Best Available Technology" (BAT) and be accompanied by a licensed guide. Also, fewer snowmobiles in the park have contributed to the decline; the most recent winter use plan limited the amount of snowmobiles in Yellowstone to 540 per day to beginning in winter 2008-2009. That limit was above the daily average, but puts a cap on peak days. During winter 2007-2008, the highest CO concentration was 6.1 ppm, compared to a summer maximum of 0.8 ppm. Winter inversion layers are the main reason for the disparity between seasons, however, in the last few years PM levels have been higher in summer than winter due to wildfires. Concerns over the health of park staff are associated with air toxins in high traffic areas; a shift from 2 to 4-stroke snowmobile engines as a result of BAT reduced CO emissions, but benzene and formaldehyde are produced instead. By the winter 2011-2012, snowcoaches will be required to meet BAT. In the meantime, ongoing monitoring will help determine the successfulness of winter use plans in maintaining acceptable air quality.

161. WDEQ. 2009. State of Wyoming Technical Support Document I For Recommended 8-Hour Ozone Designation For the Upper Green River Basin, WY.

This document is a technical support document that provides a strong weight-of-evidence for the nonattainment boundary recommendation for ozone in the Upper Green River Basin (UGRB) in SW Wyoming. The ozone situations in the UGRB is very different from a majority of ozone nonattainment areas due to the fact that it is located in a rural area with a small population and the oil and gas development/production is the only industry present in the area. At the Boulder monitor, elevated ozone episodes that exceed NAAQS are associated with specific meteorological conditions, including low mixing heights, temperature inversions, and prolonged low wind speeds. Due to the importance of these meteorological conditions to the formation of ozone, it is thought that emission reductions outside of the UGRB will not result in improved ozone levels at the Boulder monitor during the episodic conditions. Please visit http://deq.state.wy.us/aqd/Ozone%20Nonattainment%20Information.asp, where important documents associated with this nonattainment recommendation document can be found. The AQD submitted a Technical Support Document (found at the above URL) to EPA in March 2009, which described the technical analysis that supports boundary selection for the nonattainment area. The AQD submitted additional documentation (found at the above URL) in May and August 2009, including a legal description of the boundary, a revised boundary figure, updated trajectory figures for pages 56 to 86 in the TSD, and a description and trajectories for the March 8-12, 2008 ozone event.

162. ENVIRON, T&B Systems and MSI. 2008b. 2008 Upper Green River Winter Ozone Study. ENVIRON International Corp., Novato, CA, October.

Uncommonly high ozone concentrations (>85 ppb 8-hour average) were observed at monitoring locations in oil and gas production regions of the Upper Green River Basin during three of the past four winters, when ozone formation is usually limited by low temperatures and low sun angles. Due to the potential regulatory implications on future oil and gas development and associated economic growth from exceeding the ozone air quality standard (75 ppb), the state of Wyoming created a program to investigate the meteorology and chemistry associated with these high ozone events. From this came the WDEQ sponsored monitoring program called the Upper Green River Winter Ozone Study (UGWOS). This report represents data collected from mid-January to March, 2008, with the main goals of understanding the processes at the root of these events and developing meteorological and air quality numerical simulations.

Results for 2008 verified several key characteristics of the winter ozone events:

- A stable vertical atmospheric column created from high pressure and a warmer upper layer of air with colder air trapped near the surface
- Clear skies and light surface winds
- A diurnal, surface wind reversal that recirculates pollutants throughout the basin
- Snow cover that limits daytime solar heating and vertical convection and approximately doubles the total UV radiation flux, a key driver of photochemical reactions
- Ozone and ozone precursors become trapped in a surface layer throughout a majority of the day

163. ENVIRON, T&B Systems and MSI. 2008a. 2007 Upper Green River Winter Ozone Study. ENVIRON International Corp., Novato, CA, April.

In 2007, AQD contracted with ENVIRON to study ozone formation in the UGRB. During the 2007 study, meteorological conditions were note adequate for ozone formation as had been the case in 2005 and 2006. But, validated data for the monitored parameters can be useful to gain a better understanding of the wintertime ozone episodes. Data (MS Access database) and the QA Plan for 2007 can be accessed at:
http://deq.state.wy.us/aqd/Upper%20Green%20Winter%20Ozone%20Study.asp.

164. Ray, J. D. 2008. Winter air quality in Yellowstone National Park: 2007—2008. Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2008/139. National Park Service, Fort Collins, Colorado.

Air quality in YNP was monitored at two locations in the park as part of an adaptive management program addressing the use of OSVs. Leading indicators were ambient concentrations of CO and $PM_{2.5}$ and for overall air quality and relationship to traffic, the West Entrance monitoring site is the primary indicator because of a longer record and thorough traffic counts. Old Faithful is the main destination for winter use vehicles; CO and $PM_{2.5}$ concentrations are lower at Old Faithful than at the West Entrance. The winter 2007-2008 results show that hourly concentrations of CO and $PM_{2.5}$ have increased slightly at the West Entrance, but are similar at Old Faithful. Yellowstone meets NAAQS for CO and $PM_{2.5}$, however, CO is present above regional background levels (0.1-0.2 ppm) near vehicle routes, especially during winter. At the monitoring locations, high uncertainty is associated with changes in winter traffic and differences measured in air quality. The daily and hourly variation in pollutant levels are a function of such variables as weather and traffic density.
A detailed contractor report can be found at http://www.nature.nps.gov/air/studies/yell/yell AQwinter.cfm

165. Shively, David D., Bruce M. C. Pape, Richard N. Mower, Yong Zhou, Rachel Russo, and Barkley C. Sive. 2008. Blowing Smoke in Yellowstone: Air Quality Impacts of Oversnow Motorized Recreation in the Park. Environmental Management 41:183-199.

Documented air quality impacts in YNP have been shown in association with snowmobile emissions, which adversely affect Park staff and resource values. High-use sites in YNP have shown localized impacts, but spatial variability of emissions and air quality needed more clarification. Ambient air was measured for 87 VOCs in YNP and West Yellowstone, Montana during winter 2002-2003 on 2 days 1 year before the implementation of a new snowmobile policy. Analyses were conducted to assess VOC sources and impacts and data was compared to similar, pristine West Coast sites. Different types of OSVs in YNP were sampled to evaluate influence on atmospheric pollutant composition; VOCs were of local origin and spatiotemporally variable. Results also showed that consistently high levels of benzene, toluene, and carbon monoxide were emitted in and around West Yellowstone as a result of elevated snowmobile traffic.

166. Bishop, Gary A., Ryan Stadtmuller, Donald H. Stedman, and John D. Ray. 2007. Portable Emission Measurements of Snowcoaches and Snowmobiles in Yellowstone National Park, Final Report, Cooperative Agreement H2350042097. Prepared for the National Park Service, Yellowstone National Park, WY.

167. Ray, J. D. 2007. Winter Air Quality in Yellowstone National Park: 2006 – 2007, Natural Resource Technical Report NPS/NRPC/ARD/NRTR--2007/065. National Park Service, Fort Collins, Colorado.

168. Ray, J. D. 2007. Winter Air Quality in Yellowstone National Park: 2005 – 2006, Air Resources Technical Report NPS/ARD—2007/D-1207, National Park Service, Denver, CO.

169. Bishop, Gary A., Daniel A. Burgard, Thomas R. Dalton, and Donald H. Stedman. 2006. In-Use Emission Measurements of Snowmobiles and Snowcoaches in Yellowstone National Park, Final Report, Cooperative Agreement H2350042097. Prepared for the National Park Service, Lakewood, CO.

170. Bishop, Gary A., Daniel A. Burgard, Thomas R. Dalton, Donald H. Stedman, and John D. Ray. 2006. Winter Motor-Vehicle Emissions in Yellowstone National Park. Environmental Science & Technology, p. 2505-2510.

171. Ray, J.D. 2005. Results from Yellowstone National Park Winter Air Quality Study 2004-2005. National Park Service, Air Resources Division.
172. Ray, J.D. 2005. Results from Yellowstone National Park Winter Air Quality Study 2003-2004. National Park Service, Air Resources Division.

173. Air Resource Specialists. 2004. Yellowstone National Park, 2004-05 Winter Use Plan, Air Quality Analysis of Snowmobile and Snowcoach Emissions. Air Resource Specialists, Fort Collins, CO.

174. Ray, J.D. 2003. Winter Air Quality Monitoring Yellowstone National Park. National Park Service, Air Resources Division, Denver, CO.

175. Sive, Barkley, et al. 2003. Spatial Variation of Volatile Organic Compounds Associated with Snowmobile Emissions in Yellowstone National Park. A Research Report Submitted to the National Park Service, United States Department of the Interior.

176. Bishop, Gary A., Jerome A. Morris, and Donald H. Stedman. 2001. Snowmobile Contributions to Mobile Source Emissions in Yellowstone National Park. Environmental Science & Technology 35(14):2874-2881.

177. National Park Service, Air Resources Division. 2000. Air Quality Concerns Related to Snowmobile Usage in National Parks. National Park Service, Denver, CO.

178. Bishop, Gary A., Donald H. Stedman, Mary Hektner, and John D. Ray. 1999. An In-Use Snowmobile Emission Survey in Yellowstone National Park. Environmental Science & Technology 33(21):3924-3926.

Oil and Gas Exploration/Energy Development

179. USDA Forest Service. 2011. Emission Reduction Techniques for Oil and Gas Activities.

This document, authored by the U.S. Forest Service, provides emission reduction and mitigation techniques that may be applied to development and production associated with oil and gas activities. The main audience intended for this document is NEPA specialists in USFS offices. However, a broad range of users are encouraged to utilize this document, such as other Federal Land Management Agencies (FLMAs), oil and gas companies, regulators, and tribal governments. These techniques are beneficial both for improvements on existing operations or for guidance on future projects and may assist in the prevention of or improvement on adverse impacts to Ambient Air Quality Standards or Air Quality Related Values.

180. USDA Forest Service. 2011. Final Supplemental Environmental Impact Statement, Oil and Gas Leasing in the Wyoming Range, January 2011. Available Online: http://www.fs.fed.us/nepa/fs-usda-pop.html?project=24734

In 2005, the Forest Service authorized the BLM to offer 35 lease parcels located in Bridger-Teton National Forest, totaling 44,720 acres, for oil and gas development in the Wyoming Range. However, the Interior Board of Land Appeals (IBLA) later found that this decision was based on deficient environmental analyses related to the potential effects of leasing and the leasing decision was suspended pending further supplemental analyses. Therefore, following the Forest Service DSEIS release in February 2010, this FSEIS was released in January 2011 to provide new information from supplemental analyses required to decide whether or not to approve leasing on these lands. The Forest Service chose Alternative 1, the No Action Alternative, not authorizing the BLM to lease the subject lands at this time.

181. Bar-Ilan, Amnon, John Grant, Rajashi Parikh, Alison K. Pollack, Doug Henderer, Daniel Pring and Kathleen Sgamma. 2010. Final Report: Development of Baseline 2006 Emissions from Oil and Gas Activity in the Wind River Basin. Prepared for Western Governors' Association. Prepared by ENVIRON International Corporation, Novato, CA.

This analysis is the result of a joint effort sponsored by IPAMS and WRAP and provides information on criteria pollutant emissions associated with oil and gas activities in the Wind River Basin, Wyoming. It is part of the development of a Phase III regional oil and gas emission inventory for the Intermountain West. A summary of total emissions in 2006 from oil and gas activities in the Wind River Basin in tons per year for NO_x, VOC, CO, SO_x, and PM was 1814, 11981, 2840, 1792, and 37, respectively. Overall, 71% of NO_x emissions were from compressor engines basin-wide and 81% of VOC emissions were from pneumatic devices, venting from well blowdowns and dehydration. Similar to other Phase III inventory findings, NO_x and VOC emissions are primarily from unpermitted sources and SO_x from permitted sources.

182. Bar-Ilan, Amnon, John Grant, Rajashi Parikh, Alison K. Pollack, Doug Henderer, Daniel Pring and Kathleen Sgamma. 2010. Final Report: Development of 2012 Oil and Gas Emissions Projections for the Wind River Basin. Prepared **for Western Governors'** Association. Prepared by ENVIRON International Corporation, Novato, CA.

This document discusses 2012 emissions projections and methodologies for oil and gas activities in the Wind River Basin, which start with the 2006 baseline oil and gas emission inventory data (see previous citation). The methodology discussion includes projected parameters, scaling factors and developing uncontrolled emissions projection parameters, and application of "on-the-books" regulation and control measures. Basin-wide total (tribal and non-tribal) emission projections for the Wind River Basin in tons per year for NO_x, VOC, CO, SO_x, and PM are 1758, 12480, 2738, 1618, and 39, respectively. When compared to 2006 baseline emissions levels, NO_x decreased by 3% and VOC increased by 4%.

183. Bar-Ilan, Amnon, John Grant, Rajashi Parikh, Alison Pollack, Ralph Morris, Doug Henderer and Kathleen Sgamma. 2010. A Comprehensive Emissions Inventory of Upstream Oil and Gas Activities in the Rocky Mountain States. EPA 19th International Emission Inventory Conference, San Antonio, TX, September 27-30, 2010.

The purpose of this project is to develop emissions inventories for upstream oil and gas exploration and development; they cover the Rocky Mountains, including New Mexico, Colorado, Utah, Wyoming, Montana, and North Dakota. This venture was co-sponsored by the Western Energy Alliance (formerly Independent Petroleum Association of Mountain States – IPAMS) and the Western Governors' Association's WRAP. The goal was to create *detailed* oil and gas emissions inventories and they are the most comprehensive ones in existence for the region. The inventories were conducted on the geological basin level and take account of all major oil and gas fields in the Intermountain West and all associated major processes and equipment from initial drilling through completion, production and processing. Survey data was collected from industry operators and permits issued by states for some sources. Criteria pollutant emissions of NO_x, VOC, CO, SO_x and PM were considered in the inventories, with a base year of 2006 and future projections for 2012. These inventories have played an important role in regulatory efforts, providing greater accuracy than previous efforts for oil and gas sector emissions characterization.

184. USDA Forest Service. 2010. Draft Environmental Impact Statement, Eagle Prospect and Noble Basin Master Development Plan Project, December 2010. Big Piney Ranger District, Bridger-Teton National Forest, Wyoming. Available Online: http://www.fs.fed.us/nepa/fs-usda-pop.html?project=14799

The U.S. Department of Agriculture-Forest Service, Bridger-Teton National Forest in cooperation with the U.S. Bureau of Land Management, High Desert District Office, State of Wyoming, prepared a Draft Environmental Impact Statement (DEIS) responding to the Plains Exploration & Production Company's (PXP) request for approval submission of a surface use plan of operations (SUPO) for a master development plan (MDP). The project would take place in the Eagle Prospect and Noble basin areas of the South Rim Unit in two phases: Phase I (Exploration by Test Wells) and Phase II (Projected Field Development). The Forest Service and BLM have been notified that PXP's proposal would include drilling approximately 136 oil and gas producing wells and 17 associated drill pads on National Forest System lands. The project would be located on land administered by the Big Piney Ranger District of the Bridger-Teton National Forest, seven miles southeast of Bondurant in Sublette County, Wyoming. This project would include refurbishment of 14.0 miles of existing NFS roads and new construction of 14.8 miles of non-system roads to access drill sites. The construction of production operation facilities and maintenance of all project components are required over the project lifetime (30+ years). Non-public access roads would be reclaimed during construction and drilling and all project components are to be reclaimed upon project completion. This DEIS assesses and explains the effects of each potential alternative established for this project, with the Forest Service having established Alternative C as their preference. Public comments were due by March 11, 2011, after a public comment period of 90 days.

185. University of Wyoming. 2009. A Spatial Measurement and Survey Approach for Improving Emission Inventory Factors and Input Data for Ozone Modeling Associated with the Pinedale Anticline Project Area. Proposal submitted by the University of Wyoming. For consideration by the Pinedale Intra-Agency Office, September.

Expanding oil and gas development in SW Wyoming has sparked concern over human exposure to VOCs, ozone and various other pollutants, specifically, wintertime ozone events in Sublette County, Wyoming. In order to develop mitigation strategies to address non-attainment episodes, a detailed understanding of the phenomenon, including the nature of the pollutants, is first required. This project proposal was submitted by the University of Wyoming to the Pinedale Intra-Agency Office to assist the WDEQ with conducting air quality measurements and analyses to assist developing emission inventory and ozone modeling data used for the Pinedale Anticline Project Area (PAPA). The approach combines a spatial network of samplers with long term monitoring downwind of the PAPA, which addresses the time-dependent spatial distribution of the pollutants and the varying spatial and temporal characteristics of the emission sources. Project objectives are as follows: conduct spatial surveys of BTEX and nitrogen oxides in and around the PAPA, assess the spatial behavior of a wide range of VOC species, and conduct continuous monitoring downwind of the PAPA.

186. Bargo, Sera, and Derek C. Montague. 2008. Assessment of Baseline Air Quality in **Wyoming's Green River Basin Prior to Accelerated Gas and Oil Well Development. 15th** Joint Conference on the Applications of Air Pollution Meteorology with the A&WMA, Session 7, All Other Aspects of Air Pollution Meteorology.

Within the last 15 years, there has been an increase in commercial activities (e.g. oil and gas development, mineral extraction) in Southwest Wyoming, a time paralleled by air quality and visibility degradation. This resulted in several air quality studies, which focused on characterizing atmospheric composition and the influence of trace constituents on visibility. The 1996 Southwest Wyoming Visibility Study (SWYVIS) characterized air quality in the UGRB using research aircrafts. Air quality modeling study outputs are being interpolated and compared with the SWYVIS flight tracks. By mapping the spatial variability of pollutant concentrations with the flight tracks, regional areas of unpolluted and impacted air quality prior to extensive natural gas well development could be determined. Air quality modeling, along with ambient air measurements and other regional air quality studies conducted concurrently with the SWYVIS, will allow the generation of a baseline in the Green River Basin. Also, the creation of a baseline dataset is further possible due to the fact that the acceleration of natural gas exploration occurred largely since the visibility studies in the region took place.

187. Bott, Kelly. 2008. Wyoming Air Quality & Natural Gas Development Map. Wyoming Department of Environmental Quality, Air Quality Division.

This map was developed by the WDEQ-AQD and shows air quality monitoring stations (WDEQ, CASTNET, IMPROVE, NADP, WARMS) and EIS development areas throughout Wyoming. It also delineates Class I areas.

188. Bureau of Land Management. 2008. Air Quality Impact Analysis Technical Support Document, Final Supplemental Environmental Impact Statement, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, WY. U.S. Department of the Interior, Bureau of Land Management, Wyoming State Office, Cheyenne, Wyoming and Pinedale Field Office, Pinedale, Wyoming, in Cooperation with State of Wyoming, Sublette County, and Sublette County Conservation District, June 2008.

This Air Quality TSD summarizes quantitative analyses of impacts to ambient air quality and AQRVs for the proposed project in the PAPA from development and production activity emissions under the various alternatives and other documented regional emissions sources. Definition of the study area was based on the project location in west-central Wyoming, which required the evaluation of project and cumulative source impacts in Wyoming and portions of Colorado, Utah, and Idaho. The analyses were carried out in the area surrounding the PAPA and the Bridger, Fitzpatrick, Gros Ventre, North Absaroka, Popo Agie, Teton, and Washakie Wilderness Areas; the Wind River Roadless Area; and the Grand Teton And Yellowstone National Parks. The impacts to ambient air quality and AQRVs (i.e. visibility, acid deposition, acidification increases to sensitive lakes) were quantified and compared to state and federal standards, thresholds, and guidance where applicable.

189. Bureau of Land Management. 2008. Record of Decision for the Final Supplemental Environmental Impact Statement, Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming. U.S. Department of the Interior, Bureau of Land Management, Cheyenne, WY, September 2008.

This document is the Record of Decision (ROD) regarding the Department of Interior's (DOI) decision on the Final SEIS, which evaluates the various oil and gas recovery options in the PAPA, for the Pinedale Anticline Oil and Gas Exploration and Development Project Area (Sublette County, Wyoming). The ROD stresses the importance of concentrated and systematic development, reducing impacts by utilizing performance based outcomes and adaptive management, and collaborative monitoring in the State.

190. Funk, Tami H., and Hilary R. Hafner. 2008. Air Monitoring Network Assessment for Southwest Wyoming, Draft Final Report, STI-908003.08-3423-DFR. Prepared for the State of Wyoming, Department of Environmental Quality, Air Quality Division, Cheyenne, Wyoming.

Southwest Wyoming (SWWY) is a region with growing energy and mineral development, which can have adverse impacts on air quality. Therefore, the WDEQ-AQD contracted with Sonoma Technology, Inc. (STI) to conduct an assessment to ensure the capability and effectiveness of the established air quality and meteorological monitoring network. Phase I and II of the study were reviewed by the External Advisory Committee (EAC), which included industry, government staff and the public, and the AQD. The assessment focused on population, geography, and emissions associated with only the SWWY study area. Recommendations and conclusions from the analyses are provided for the overall SWWY network and specific sites. For the SWWY, it is suggested that all monitoring locations collecting hourly measurements should have collocated meteorology stations, a regional site be added downwind of the oil and gas fields (between Jonah and Rock Springs), and a regional ozone monitoring site be added to the western region of the network to monitor population exposure in Kemmerer, Lyman, and/or Afton.

191. Molenar, John V., H. James Sewell, Jeffrey Collett, Cassie Archuleta, Mark Tigges, Florian M. Schwandner and Suresh Raja. 2008. NH3 Monitoring in the Upper Green River Basin, Wyoming, Extended Abstract #70.

In December 2006, Shell Exploration & Production Company initiated a long term ammonia air monitoring study at Boulder, Wyoming, in the UGRB southwest of Bridger Wilderness. Bridger Wilderness is a Class I area that may be experiencing adverse impacts to air quality and visibility from natural gas resource development. The goal of this study was to characterize the local airborne nitrogen budget, particularly concentrations of ammonia and related gases and particles, for a minimum of one year. The study spanned a 15 month period and measured ammonia and nitric acid gases, as well as ammonium, nitrate, and sulfate particles. These results show that in 2007 the UGRB ammonia concentrations were annually variable, below or near detectable limits from December through February, peaked in August at 1.55 ppbv, and had a yearly mean value of 0.24 ppbv. An ammonia weighted residence time analysis indicated that a majority of the ammonia is transported into the UGRB from agricultural and urban areas to the West and Southwest.

192. Bar-Ilan, Amnon, Ron Friesen, Alison Pollack, and Abigail Hoats. 2007. Final Report: WRAP Area Source Emissions Inventory Projections and Control Strategy Evaluation Phase II. Prepared for Western Governors' Association. Prepared by ENVIRON International Corporation, Novato, CA.

193. Russell, James, Alison Pollack, and Greg Yarwood. 2006. An Emission Inventory of Non-point Oil and Gas Emissions Sources in the Western Region. ENVIRON International Corporation, Novato, CA. 15th International Emission Inventory Conference, New Orleans, May 15-18, 2006.

194. Russell, James, and Alison Pollack. 2005. Oil and Gas Emission Inventories for the Western States. Prepared for Western Governors' Association. Prepared by ENVIRON International Corporation, Novato, CA.

195. Walker, Ronald P. 2005. Natural gas flare emission monitoring using a miniature fiber optic spectrometer. Wyoming State Geological Survey, Public Information Circular No. 43, p. 120-123.

196. National Park Service, Air Resources Division. 2004. Grand Teton NP 300km Radius.

197. National Park Service, Air Resources Division. 2004. Yellowstone NP 300km Radius.

Monitoring Databases and Programs

198. CASTNET. 2011. Clean Air Status and Trends Network. http://java.epa.gov/castnet/

The Clean Air Status and Trends Network (CASTNET) is a national air quality monitoring network that provides long-term monitoring data for rural areas in order to evaluate regional air quality trends, atmospheric deposition and fluxes, and ecological effects from pollutant emissions. Subsequently, the data is used to assess the effectiveness of air pollution control programs. Sites within the GYE are YEL408 (Yellowstone NP, Dry Chemistry) and PND165 (Pinedale, Dry Chemistry); site specific information and deposition profiles are provided. Annual CASTNET data summary reports are available for nationwide data from 2004-2008. CASTNET measurements include sulfur dioxide, particulate sulfate, particulate nitrate, nitric acid, particulate ammonium, particulate calcium, particulate sodium, particulate magnesium, particulate potassium, particulate chloride, ozone, meteorological variables and information on land use and vegetation. The primary sponsors are the EPA and NPS.

199. Gonzales-Stoller Surveillance, LLC (GSS). 2011. ESER Surveillance Database Search. http://www.stoller-eser.com/Transfer/surveillance.htm

The ESER offsite surveillance program goal is to monitor potential exposure pathways and media points that pose a risk to the public, including air. The primary focus of monitoring on and around INL is air because it is the main radionuclide transport pathway off-site. 18 ESER low volume air samplers collect information on radioactive airborne particulates at 16 locations (three at INL, seven near INL, six distant to INL). Gross alpha and gross beta analyses are conducted at these sample locations. The samples are also composited and analyzed for gamma-emitting radionuclides, charcoal filters screen for Iodine-131 by gamma spectrometry, and four sites are sampled for tritium in water vapor. Quarterly and annual surveillance reports are available on the website or by contacting the Idaho Falls Stoller office. Go to http://www.stoller-eser.com/air.htm for additional air sampling information, including sample locations, monitoring, and radionuclide fact sheets.

200. Idaho Department of Environmental Quality. 2000-2011. INL Oversight Program Air Monitoring: What Oversight Looks For in the Air We Breathe. http://www.deq.idaho.gov/inl_oversight/monitoring/air.cfm

The ID DEQ operates an air quality monitoring network as part of the INL oversight program through the Environmental Surveillance Program (ESP) to collect data on radioactive emissions from Idaho National Laboratory (INL). The INL monitoring network includes eight sample locations on and near the INL and two distant sites that utilize air samplers to collect total suspended particulate matter (TSP), gaseous radioiodine, and atmospheric water vapor to detect tritium. The ESP collects and analyzes precipitation at six monitoring locations for tritium and gamma radiation. The DEQ-INL reports an eleventh sampling station, operated by the Shoshone-Bannock Tribes at Fort Hall, as an additional background site. This site offers information on monitoring locations and access to a quarterly report archive and a library. The INL oversight program library, http://www.deq.idaho.gov/inl_oversight/library.cfm#quarterly, provides access to the data in annual reports and technical reports, including surveillance quarterly data reports.

201. Idaho Department of Environmental Quality. 2000-2011. Real-Time Air Monitoring. http://airquality.deq.idaho.gov/.

The ID DEQ assesses ambient air quality by collecting real-time data of air pollutants in order to satisfy federal regulatory requirements and understand the status of air quality in Idaho. Air quality monitoring consists of operating a monitoring network, laboratory sample analysis, and quality assurance processes. ID DEQ monitoring sites operated in the GYE are as follows: Soda Springs (SO_2), Penford – Idaho Falls ($PM_{2.5}$), Rexburg ($PM_{2.5}$), Pocatello G&G ($PM_{2.5,10}$) and Pocatello WWTP (SO_2). The data provided comes directly from air monitors for immediate public use and therefore, has not been subject to quality assurance processes and can change until it is certified as "final".

202. Montana Department of Environmental Quality. 2011. Air Quality Monitoring Sites. http://svc.mt.gov/deq/AQMonitoringSites/listDisplay.aspx

Montana DEQ's Air Quality Monitoring Program purpose is to monitor, assess and provide information on the state's ambient air quality conditions and trends and to meet requirements of the Montana and Federal Clean Air Acts. The monitoring program is a joint effort with other local air pollution agencies and industries. The data on this site provides the basis for making regulatory decisions and is available to the public and archived for future access. MT DEQ air quality monitoring locations located within the GYE include: West Yellowstone – City Center (CO and $PM_{2.5}$), West Yellowstone – Park Entrance #2 (CO and $PM_{2.5}$), Belgrade-ConAgra ($PM_{2.5}$), Belgrade-Wastewater Lagoon ($PM_{2.5}$), Bozeman – High School ($PM_{2.5}$), Billings – Coburn Road (SO_2), and Billings – St. Luke's (CO).

203. National Park Service. 2011. Access to Gaseous Pollutant and Meteorological Data. http://12.45.109.6/

Current monitoring locations located in the GYE, include the Yellowstone National Park - West Yellowstone State Site (NPS-GPMP), Yellowstone National Park - Old Faithful (NPS-GPMP), and Yellowstone National Park - Water Tank (CASTNET). This site provides data export, site specific and multi-site data products (charts, graphs, tables), reports, a current and historical monitoring map that shows general info, site specs and monitoring parameters, a summary table with site specific monitoring dates, and a monitoring history database. Annual data summaries are cited in this bibliography for the Yellowstone NP – Water Tank monitoring site (1998-2002); annual data summaries that are not site specific are available from 2003 to 2009.

204. NPElement, A Database of Lichen Elemental Concentrations in the U. S. National Parks. 2011. Version 1.0. U. S. Geological Survey. http://www.nwhc.usgs.gov/our_research/np_element.jsp

Since 1979, lichens have been sampled in U.S. National Parks for elemental analyses of tissues in order to measure levels of heavy metals, nutrients, and trace elements. Species have been sampled in Grand Teton and Yellowstone National Parks. Concentration data have been gathered and placed into an Access database containing approximately 70,330 data points and is made available on the website as a downloadable Access *.mdb file that can be queried on your personal computer and selecting specific variables. Query results can be output to user computers as Excel spreadsheet files that put the data into column format.

205. NPLichen, A Database of Lichens in the U. S. National Parks. 2011. Version 4.5. U. S. Geological Survey. http://www.nbii.gov/nplichen

This database was developed by James P. Bennett, U.S. Geological Survey and University of Wisconsin, Madison, WI and Clifford M. Wetmore, University of Minnesota, St. Paul, MN and contains approximately 29,900 records of lichen occurrences in the U.S. National Park System units. Records were obtained from scientific literature, NPS reports, and the University of Minnesota Herbarium. All lichen names in the database were standardized to Version 13 (2008) of Esslinger's Checklist of North American Lichens. Be sure to read the disclaimers before running a data query. The references and data are available for Grand Teton and Yellowstone National Park.

206. U.S. EPA. 2011. RadNet – Tracking Environmental Radiation Nationwide. http://www.epa.gov/japan2011/rert/radnet-data-map.html

RadNet is the EPA's national radiation monitoring program that offers real-time and laboratory data from both fixed and deployable monitors. RadNet monitoring locations located within the boundaries of the GYE include Idaho Falls, ID and Billings, MT; site specific data can be accessed by clicking on a monitoring location. Currently, there are no RadNet monitors in Wyoming; specifically, KYNF is working with the EPA to have a RadNet monitoring location established in Jackson, WY. However, there is a radiation monitor in Jackson that is managed by Gonzales-Stoller Surveillance, LLC (GSS), at http://www.stoller-eser.com/index2.htm.

207. Colorado State University. 2010. Views 2.0 – Visibility Information Exchange Web System. http://views.cira.colostate.edu/web/

The VIEWS database offers query, visualization, and analysis tools in order to access a variety of air quality data from several monitoring networks. Most importantly, data sets can be viewed simultaneously, which facilitates decision makers by allowing maximization of dataset analysis. The database also provides NASA satellite data, models, and emissions data.

208. National Park Service. 2010. Air Atlas. http://www.nature.nps.gov/air/maps/airatlas/index.cfm

The Air Atlas is a GIS database that provides air quality estimates from interpolated national monitoring network air pollutant data, which can be used in place of on-site monitoring, for NPS parks that are part of the Inventory & Monitoring (I&M) Program. This project is a partnership between Dr. Paul Sutton, University of Denver, and Dr. John D. Ray, National Park Service, Air Resources Division. Under the Highlights link, there is access to maps combining ozone, sulfate, nitrate, visibility, wet and dry deposition. The pollutant maps are created as 5 or 6 year climatologies in order to account for year-to-year variation and show Park Service units in order to estimate pollutant levels; summaries can be viewed for multiple maps. The focus of this database is on monitoring networks in rural areas.

209. U.S. Environmental Protection Agency. 2010. Air Emission Sources. http://www.epa.gov/air/emissions/

U.S. EPA hosts results from analysis' that track emissions and their sources for the criteria pollutants on this site. Air emissions can be viewed for each criteria pollutant, along with emissions where you live (state, county, and facility-level emission summaries), air quality trends (current and historical), and National Air Toxics Assessments (NATA). NATA is the EPA's ongoing U.S. air toxics evaluation aimed at achieving reduced emissions of toxic air pollutants.

210. U.S. Environmental Protection Agency. 2010. AirExplorer. http://www.epa.gov/airexplorer/

This site provides visualization tools for air quality analysts to generate maps, graphs, and data tables. Data is provided from the U.S. EPA Air Quality System (AQS) database.

211. U.S. Environmental Protection Agency. 2010. Western Lake Survey Data Sets. http://www.epa.gov/emap/html/data/surfwatr/data/wls.html

In fall 1985, the U.S. EPA conducted the Western Lake Survey-Phase I (WLS-I) as part of the National Surface Water Survey and National Acid Precipitation Assessment Program. The purpose of this survey was to conduct synoptic sampling for lake chemistry in the U.S. where lakes were expected to be characterized by low alkalinity.

212. USDA Forest Service. 2010. Air Resource Management Surface Water, Bulk Deposition, and Ozone Data Website. http://www.fs.fed.us/ARMdata/

Since the 1980's, the Forest Service Air Program has been inventorying and monitoring lakes and streams to perform its responsibility of protecting national forest watersheds from atmospheric deposition impacts. The main purpose it to identify watersheds that are sensitive to the effects of atmospheric deposition, such as acidic deposition and base cation depletion, long term lake chemistry trends and apply it to determining the cause (i.e. air quality, specific sources, weather, climate, land use) of changes in lake chemistry. This site also has hourly ambient ozone data with the purpose of determining ozone concentrations in the National Forests and the risk posed to sensitive vegetation and people. This information can then be used to develop land management plans, permitting, and strategies accordingly. In regards to the data, field protocols vary for older data (prior to the last five years) and a majority of the data is provisional, meaning it has not undergone first order quality assurance by the FS. The FS has confidence that the physical and chemical analyses, many of which are performed at the USFS Air Resource Management Laboratory (www.fs.fed.us/waterlab/), are of high quality, but caution is urged when drawing conclusions from the data. The ozone data have been subject to quality assurance procedures and are obtained from the EPA's CASTNET and AQS databases.

213. USDA Forest Service. 2010. US Forest Service Air Quality Image Website. http://www.fsvisimages.com/

This site offers images in and near Forest Service managed lands with the goal of protecting and improving impaired visibility and other natural resources impacted by air pollution. Real time images, archived images and historical galleries that are representative of air quality conditions are available, as well as resource links, air pollution causes and effects, and air quality monitoring information.

214. U.S. Geological Survey. 2010. Rocky Mountain Regional Snowpack Chemistry. http://co.water.usgs.gov/projects/RM_snowpack/index.html

The snowpack chemical monitoring network has been in place since 1993 and its main purpose is to determine annual concentrations and depositional amounts of nutrients and other compounds in snow from atmospheric deposition, long-term trends, and ecological impacts from atmospheric deposition. Snowpack is useful because it collects atmospheric deposition and allows for the collection of a composite sample that represents the chemistry of a majority of the annual precipitation for high elevation areas, generally greater than 1800 meters. Under the project navigation list on the studies homepage, site specific data relevant to the GYE can be accessed by selecting the Central Rockies Subregion link. All of the snowpack sites for the

Central Rockies Subregion are relevant except those located in Idaho. Graphs of chemistry concentrations and snow depth are available, as well as photos and an excel data file.

215. Western Regional Air Partnership. 2010. Emissions Data Management System (EDMS). http://www.wrapedms.org/

EDMS is an emission inventory database for the WRAP region that provides regional emissions tracking to meet SIP and TIP requirements, data utilized to address regional haze plans for the regional haze rule (RHR), and assists data collection for regional air quality analysis. Emission source categories in the EDMS include: Point or stationary sources, area/non-point sources, on road mobile sources, off or on-road mobile sources, fires, windblown dust, and biogenic sources. The information on this site is provided as a collaborative effort between WRAP Committees, Forums, and Workgroups, and State, County, EPA, and Tribal air pollution control agencies. The data may not be up-to-date or accurate due to multi-source origination and often, a lag time exists between emissions occurrence and reporting.

216. NADP. 2009. National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/

The National Atmospheric Deposition Program (NADP) has been monitoring precipitation chemistry since 1978 and is a collaborative effort between many entities, including federal, state, tribal and local governmental agencies, educational institutions, the private sector, and NGOs. This program is comprised of four main monitoring networks: the National Trends Network (NTN), Mercury Deposition Network (MDN), Atmospheric Integrated Research Monitoring Network (AIRMoN), and Atmospheric Mercury Network (AMNet). The NTN provides a long-term record of the acids, nutrients, and base cations in U.S. precipitation, MDN provides data on the geographic distributions and trends of mercury in precipitation, AIRMoN reports daily measurements of the acids, nutrients, and base cations in U.S. precipitation for studying and modeling atmospheric processes, and AMNet reports atmospheric mercury concentrations to determine mercury dry deposition.

Monitoring sites located within the GYE for the NTN include WY08 (Yellowstone National Park – Tower Falls), WY98 (Gypsum Creek), WY06 (Pinedale), WY02 (Sinks Canyon) and WY97 (South Pass City). The MDN currently collects data at WY08 and now inactive site WY07 (Yellowstone National Park – Yellowstone Lake). The NADP sites can be accessed at the above web link where available site specific data can be found, including trend plots, annual data summaries, annual data, seasonal data, monthly, data, weekly data, and daily data. There are currently no monitoring sites within the GYE for AIRMoN and AMNet. Annual data summary reports for NADP are also available from 1997-2009.

217. U.S. Environmental Protection Agency. 2009. AirData: Access to Air Pollution Data. http://www.epa.gov/oar/data/index.html

The purpose of the AirData website is to provide access to air pollution data in the United States and allows users to view reports and maps of air pollution data; the annual data summaries are developed from the EPA's AQS (Air Quality System) and NEI (National Emission Inventory) databases. The AQS database provides ambient concentrations from monitoring sites for the six criteria pollutants and HAPs and the NEI database provides annual emissions estimates from many types of sources for criteria pollutants and HAPs. All of the ambient air quality data collected by WDEQ AQD is loaded into the AQS database. Currently, data updates have been suspended while the EPA conducts an assessment of its data systems and the most recent data can be found at EPA's AirExplorer and Air Emission Sources sites.

218. National Park Service. 2006. Air Resources Information System (ARIS) http://www.nature.nps.gov/air/permits/aris/index.cfm

ARIS provides information on parks and wilderness areas managed by the NPS and FWS and the Inventory & Monitoring (I&M) networks. It identifies and provides guidance on evaluating impacts to air quality related values (AQRVs) for Class I areas. Information is maintained for 48 NPS and 12 FWS Class I areas, along with 32 Vital Signs I & M Networks, including the Greater Yellowstone Vital Signs Network (GRYN).

219. Bureau of Land Management. (n.d.) Wyoming Air Resource Monitoring System (WARMS).

The BLM-WY operates an 8-station air monitoring network that consists of several remote sites equipped to monitor meteorology, particulate, and aerosol concentrations in accordance with measurement protocols and chemical analysis procedures established by the Environmental Protection Agency (EPA) for the Clean Air Status and Trends Network (CASTNet). However, ozone is only monitored at one of the stations and it does not meet federal reference method standards. Copies of the data, quarterly reports, and site descriptions can be obtained by contacting: BLM - Wyoming State Office, Air Resource Specialist, 5353 Yellowstone Road, Cheyenne, Wyoming 82003; 307-775-6256.

220.IMPROVE. (n.d.) Interagency Monitoring of Protected Visual Environments. http://vista.cira.colostate.edu/IMPROVE/

In 1977, visual air quality legislation was added to the Clean Air Act to prevent and improve visibility impairment in Class I areas. The IMPROVE monitoring program was created in 1985 to implement this legislation by providing long term data on visibility conditions, to track changes, and determine causes of visibility degradation in National Parks and Wilderness Areas. IMPROVE monitoring locations located in the GYE include: BRID1 (Bridger Wilderness – IMPROVE Aerosol), YELL2 (Yellowstone NP 2 – IMPROVE Aerosol), and NOAB1 (North Absaroka – IMPROVE Aerosol). Inactive sites include: GRVS1 (Green River Visibility Study – IMPROVE Nephelometer) to 2000, YELL1 (Yellowstone NP - NPS FSU Aerosol) to 1987, GRTE1 (Grand Teton NP – NPS SFU Aerosol) to 1986, and LAAI1 (Lander Airport – NPS SFU Aerosol) to 1981.

221. U.S. EPA, et al. (n.d.) AIRNow. http://www.airnow.gov/

This site was developed by several partners, including the U.S. EPA, NOAA, NPS, and other tribal, state, and local agencies, in order to provide public access to national air quality information. Air Quality Index (AQI) forecasts and real-time conditions are provided for approximately 300 cities in the U.S. The data provided on this site is not fully verified and validated using quality assurance procedures as is done on the EPA Air Quality System (AQS), so the data is only utilized for reporting the AQI.

222. USDA Forest Service. (n.d.) National Lichens & Air Quality Database and Clearinghouse. http://gis.nacse.org/lichenair/index.php

This database provides information about the USFS's lichen monitoring program and access to lichen data in the National Forest system, which is imperative to federal land managers and their responsibility "to detect, map, evaluate trends, and assess the ecological impacts of air pollutants". The information available includes database queries, elemental analysis thresholds and sensitivity ratings, reports, publications, and protocols, images, educational resources, resource links, access to the Lichens and Air Quality Workgroup homepage, and USFS Air Resource Management contacts.

223. Wyoming Department of Environmental Quality. (n.d.) Wyoming Visibility Monitoring Network. http://www.wyvisnet.com/

The WDEQ's AQD Monitoring Section is responsible for the protection, preservation and improvement of Wyoming's air and helps the state maintain ambient air quality by meeting the EPA's NAAQS. The AQD accomplishes this through the operation and maintenance of ambient air quality monitors and also requires source specific ambient air quality monitoring for industrial sources. Sites located within the GYE include: Wyoming Range, Pinedale, Pinedale North, Pavilion, South Pass, Daniel South, Juel Spring, Boulder, Warbonnet, Moxa Arch, Murphy Ridge, and Wamsutter. This site allows access to real-time images and data, query validated data, data products, and quarterly and annual reports. A new feature allows users to view concentrations for air quality parameters, including 1-Hour Ozone, 8-Hour Average Ozone, 1-Hour Nitrogen Dioxide, 24-Hour Average PM_{10} and 24-Hour Average $PM_{2.5}$, on the Air Quality Data and Image Monitor Locations map for each monitoring site.

Appendix A: GYE Air Quality Contact Information

Name	Agency/Division	Title	Phone	Email
Mike Abbott	Idaho National Laboratory	Radiological and Toxic Chemical EA Contact	208-526-8596	Michael.Abbott@inl.gov
Greg Bevenger	USFS Region II Shoshone NF	Hydrologist	307-578-5163	gbevenger@fs.fed.us
Phillip Cameron	Yellowstone-Teton Clean Energy Coalition	Coordinator	307-413-1971	phil@ytcleanenergy.org
Susan Caplan	USDI BLM National Science & Technology Center	Physical Scientist: Meteorological/Air Resource Specialist	303-236-0589	Susan_Caplan@blm.gov
Scott Christensen	Greater Yellowstone Coalition	Climate Change Program Director	406-586-1593	schristensen@greateryellowstone.org
Scott Copeland	USFS Region II Shoshone NF	Visibility Data Analyst; CIRA/CSU Campus; Non-FS Contractor	307-332-9737	Copeland@cira.colostate.edu or scopeland@fs.fed.us
Michael Fiebig	USFS Region II Sustainable Operations Subcommittee	Climate Action Plan Coordinator	406-587-6755	mtfiebig@fs.fed.us
Jennifer Frazier	WDEQ Air Quality Division	Jonah Interagency Office	307-367-3991	JFrazi3@wyo.gov
Melissa Gibbs	ID DEQ	Airshed Coordinator	208-236-6160	Melissa.gibbs@deq.idaho.gov
Jill Grenon	Montana State University	Graduate Student	603-340-3527	jillgrenon@gmail.com
Melissa Hovey	BLM - WYSO	Air Resources Specialist	307-775-6099	melissa_hovey@blm.gov
George Ingersoll	USGS CR RM WRD	Snow Hydrologist	303-236-6892	gpingers@usgs.gov
Cara Keslar	WDEQ Air Quality Division	Monitoring Section Supervisor	307-777-8684	CKesla@wyo.gov
Bruce Louks	ID DEQ	Monitoring, Modeling, & Emission Inventory (MMEI) Manager	208-373-0294	bruce.louks@deq.idaho.gov
Bruce Pendery	Wyoming Outdoor Council	Staff Attorney and Program Director	435-752-2111	bruce@wyomingoutdoorcouncil.org
Ted Porwoll	USFS Region IV Bridger-Teton NF	Air Quality Technician	307-367-5722	tporwoll@fs.fed.us
Darla Potter	WDEQ-AQD	Environmental Analyst	307-777-7380	Dpotte@wyo.gov
James Powell	Keep Yellowstone Nuclear Free	Executive Director	307-699-5439	james@kynf.org

Hoby Rash	MT DEQ ARM-AMAP-Air Monitoring Section	Air Monitoring Supervisor	406-841-5260	hrash@mt.gov
John D. Ray	NPS Air Resources Division	Atmospheric Chemist; Program Manager for Gaseous Pollutant Monitoring	303-969-2820	john_d_ray@nps.gov
Larry St. Clair	Brigham Young University	Professor; Director of M.L. Bean Life Science Museum and Curator of Nonvascular Cryptogams	801-422-6211	larry_stclair@byu.edu
Mark Story	USFS Region I Gallatin NF	Hydrologist	406-587-6735	mtstory@fs.fed.us
Terry Svalberg	USFS Region IV Bridger-Teton NF	Air Quality Specialist	307-367-4326	tsvalberg@fs.fed.us
Perry Walker	Community Member	Scientist and Activist		rpwalker@wyoming.com
Brenda Younkin	Teton Science Schools	Conservation Research Center Director	307-734-3720	brenda.younkin@tetonscience.org