May, 2014

FINAL TECHNICAL MEMORANDUM

To: Tom Moore, WESTAR
From: Till Stoeckenius
Cc: Ralph Morris, ENVIRON and Zach Adelman, University of North Carolina
Subject: Monitoring Network Assessment for the Three-States Air Quality Study

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Introduction

The University of North Carolina (UNC) at Chapel Hill Institute for Environment and ENVIRON International Corporation (ENVIRON), are performing the Three State Air Quality Study (3SAQS) through a Cooperative Ecosystems Study Unit (CESU) cooperative agreement with the National Park Service. The 3SAQS includes cooperators from U.S. Environmental Protection Agency (EPA), United States Forest Service (USFS), Bureau of Land Management (BLM), National Park Service (NPS), and the state air quality management agencies of Colorado, Utah, and Wyoming. The 3SAQS is intended to facilitate air resource analyses for federal and state agencies in the states of Wyoming, Colorado, and Utah toward improved information for the public and stakeholders in fulfilling National Environmental Policy Act (NEPA) requirements and potentially other studies. Funded by the Environmental Protection Agency (EPA), Bureau of Land Management (BLM), and the U.S. Forest Service (USFS) and with in-kind support from the National Park Service (NPS) and Colorado, Utah, and Wyoming state air agencies, the main focus of the 3SAQS is on assessing the environmental impacts of sources related to oil and gas development and production.

As part of the 3SAQS Pilot Study, air monitoring data collection was funded through 2013 at six sites: ozone monitoring at Escalante, Price and Fruitland, UT; Walden, CO and Hiawatha, WY and VOC monitoring at Wamsutter, WY (locations of these sites can be seen in Figure 6 below). In anticipation of completion of the pilot study phase, agencies involved in the 3SAQS identified the need to complete a joint, multi-agency assessment of the air monitoring network with respect to the 3SAQS objectives so as to optimize the use of available monitoring resources during the 3SAQS 2014 – 2017 main study period.

The Network Assessment was conducted by ENVIRON in close collaboration with a Network Assessment Workgroup composed of representatives from Colorado, Wyoming and Utah as well as EPA Region VIII and the federal land management agencies (BLM, NPS and FWS). A list of Workgroup members is provided in Table 1.

This memorandum provides a brief overview of the network evaluation process. Interim assessment results were presented to and discussed with the Workgroup in a series of conference calls between October 2013 and February 2014. A detailed presentation summarizing the Network Assessment objectives, scope, methodology, and results with final

recommendations was presented to the 3SAQS Steering Committee on 27 February 2014. This presentation is provided in Appendix A. Other detailed data and results from the assessment are included as additional appendices to this memo. Together, this memo and accompanying appendices document the data sources, analysis methods and results of the assessment.

Table 1. Network Assessment Workgroup members.

Agency	Member(s)
Colorado Dept. of Health and Environment (CDPHE)	Gordon Pierce Greg Harshfield Kevin Briggs
U.S. Environmental Protection Agency (EPA)	Gail Tonnesen Rebecca Matichuk Vanessa Hinkle
National Park Service (NPS)	Mike George Barkley Sive Mike Barna
Bureau of Land Management, Colorado	Chad Meister
Bureau of Land Management, Wyoming	Charis Tuers
Bureau of Land Management, Utah	Leonard Herr Collin Schwartz
Utah Division of Air Quality (UDAQ)	Patrick Barickman Bo Call
Wyoming Dept. of Environmental Quality (WYDEQ)	Cara Keslar
U.S. Forest Service (USFS)	Debbie Miller John Korfmacher

Scope and Objectives

The 3SAQS Monitoring Network Assessment was designed to guide the effective use of limited air monitoring funds to support the 3SAQS during the 2014 – 2017 study period. Preliminary discussions with the Network Assessment Workgroup indicated that the assessment should focus on monitoring in rural or semi-rural areas in the Intermountain West portion of the 3-state region away from the major population centers (the Front Range communities in Colorado and the Wasatch front communities in Utah) and that the primary focus should be on ozone while recognizing that adequate monitoring of ozone precursors and particulate matter (PM) is also important. With these considerations in mind, the Workgroup identified the following key monitoring objectives:

- Provide adequate spatial coverage of study area,
- Monitor locations with O_3 close to or above National Ambient Air Quality Standards (NAAQS),
- Monitor locations downwind of existing or planned future development areas,
- Monitor Air Quality Related Values impacts on Class I and sensitive Class II areas,
- Characterize background O_3, and

- Provide data, including O_3, PM and precursor measurements, to support model performance evaluation.

The Network Assessment was designed to determine the adequacy of the existing network with respect to these objectives and to determine the optimal network configuration going forward for achieving these objectives within the available resources. The Network Assessment was thus designed to provide a set of recommendations for how best to:

- Utilize the available 3SAQS monitoring budget,
- Optimize collaborative operational efforts among 3-State cooperating agencies, and
- Implement the 3-State agencies' individual commitments to monitoring operations.

Approach

Data Gathering

Working in collaboration with the Network Assessment Workgroup, ENVIRON gathered information on current monitor locations, equipment, and recent air quality observations together with spatial information on emissions, future oil and gas developments, population, mean transport winds and geography (terrain, nonattainment area, Class I area and tribal land boundaries). We created a series of map overlays with these spatial data; these maps are included as GIS shapefiles in Appendices B and C. We also mapped 2008 annual 4th highest daily maximum 8-hour ozone concentrations extracted from CAMx photochemical model simulations conducted as part of the WRAP WestJump project (ENVIRON, 2013). Shapefiles of post processed model results were provided by Adelman, 2013 and are provided in Appendix D. These data were combined into a series of map overlays and analyzed as described below to evaluate the adequacy of the existing network along with locations where additional monitoring data would be most helpful in achieving the objectives identified above. Resulting map overlays were used in a series of analyses as described in the following sections.

Evaluation of Existing Monitoring Network

Using data obtained from EPA and other federal agencies, a spreadsheet database of all existing ozone and PM monitoring sites including site identifier, location, responsible agency(s), equipment type(s), monitoring period of record and other information was constructed. Database entries were reviewed by members of the Workgroup and revised as needed to accurately reflect the current network status. The resulting database is provided in Appendix E.

Area Served Analysis

In keeping with EPA guideline procedures for network assessments (EPA, 2007), an "Area Served" analysis was conducted by first drawing Thiessen polygons based on current monitoring site locations. Thiessen polygons, which are defined by the locus of points lying equidistant between each neighboring pair of monitoring sites, provide a first approximation to the area served by each monitor, irrespective of typical transport wind directions. Results from the Thiessen polygon analysis were then refined to account for blocking of low-level winds by

major terrain features (as generally approximated by areas above 8,000 ft [2,400 m] elevation). This process is illustrated in Figure 1.

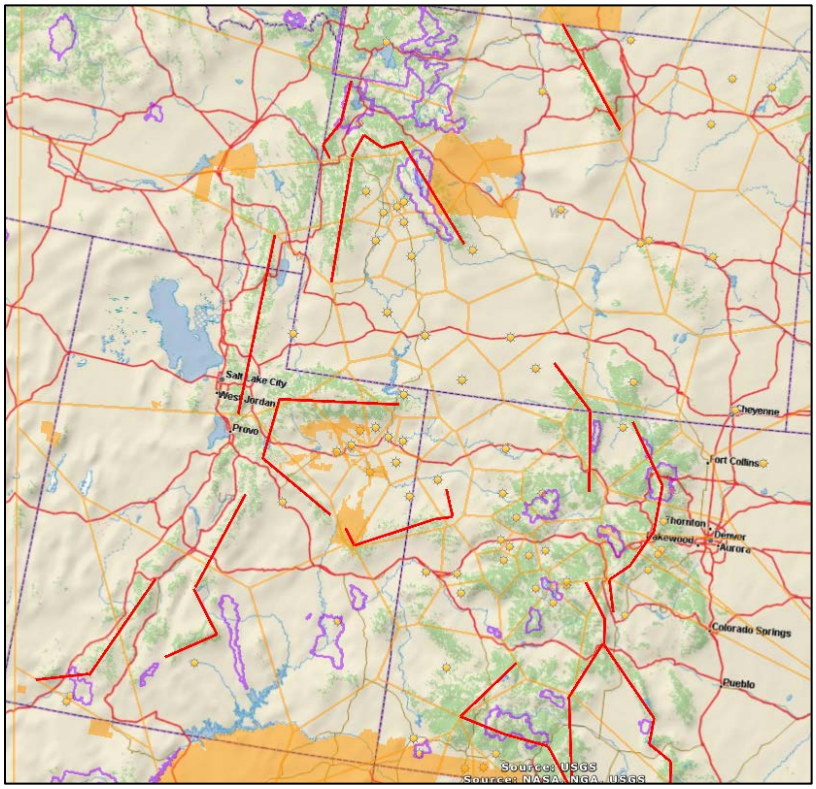

Fig. 1. Existing ozone monitors (yellow dots), Thiessen polygons (orange polygons) and major terrain blocks (thick red line segments); background map shows tribal lands (orange shaded areas), Class I areas (purple outlines), forested areas (pale green), cities and highway network (thin red lines).

Additional information applicable to understanding the general area represented by each existing monitoring site was obtained via an examination of inter-site correlations in daily maximum 8-hour average ozone concentrations (Dmax8HrO3) provided by Debra Miller of the USFS (Miller, 2013). Correlations were initially based on the actual Dmax8HrO3 between all possible pairs of sites. Correlations between the mostly rural sites included in the analysis were found to be fairly high (r^2 generally above 0.5), even for site pairs separated by many hundreds of kilometers, reflecting the strong seasonal and large-scale transport factors responsible for most of the temporal variability at these sites which occurs on timescales of several weeks or longer. These long period, large scale variations tend to mask correlations at shorter timescales associated with localized episodes during which concentrations in some locations have been observed to approach or exceed the 0.75 ppb NAAQS. In an attempt to better capture spatial correlations of these significant shorter timescale features, we also calculated correlations in departures of Dmax8HrO3 from the centered running 30-day mean:

$$\Delta\text{Dmax8HrO3}_i = \text{Dmax8HrO3} - \sum_k \text{Dmax8HrO3}_k/30$$

Where $\Delta Dmax8HrO3_i$ is the departure from the 30-day mean for day *i* and the summation index *k* runs from *i*-15 to *i*+14. Pearson product-moment and Kendall tau rank correlation coefficients were computed for both Dmax8HrO3 and ΔDmax8HrO3 based on data from 2007 – 2012. Results of the inter-site correlation analysis (see Appendix F) were used to help evaluate potential gaps in the monitoring network as described below and also to determine if data from certain pairs of sites were closely correlated and thus largely redundant.

Emissions Source Assessment

Gridded emissions for 2008 (4 km horizontal resolution) were extracted from the WRAP WestJump modeling files by (Adelman, 2013) and map overlays of annual emissions of criteria pollutants by source category prepared. Source categories and pollutants are listed in Table 2. These maps identify locations of key emission sources by source category and pollutant. An example for upstream oil and gas sector NOx emissions (including area and point sources) is shown in Figure 2. Shapefiles for additional maps are provided in Appendix C.

Table 2. Source categories and pollutants used for emission maps

Source Category	File Name (see Appendix C)
Upstream Oil & Gas (from WRAP Phase 3 study)	WRAP_P3
Upstream Oil & Gas (basins not included in WRAP Phase 3)	nonWRAP
Major Point Sources based on CEM data	CEM_Point
Other Point Sources	PTNCEM
Aircraft, Locomotive, Marine	ALM
Other non-road sources	NonroadMobile
Residential Wood Combustion	ResWoodCombustion
On-Road Mobile	OnroadMobile
Other Area Sources	NonpointArea

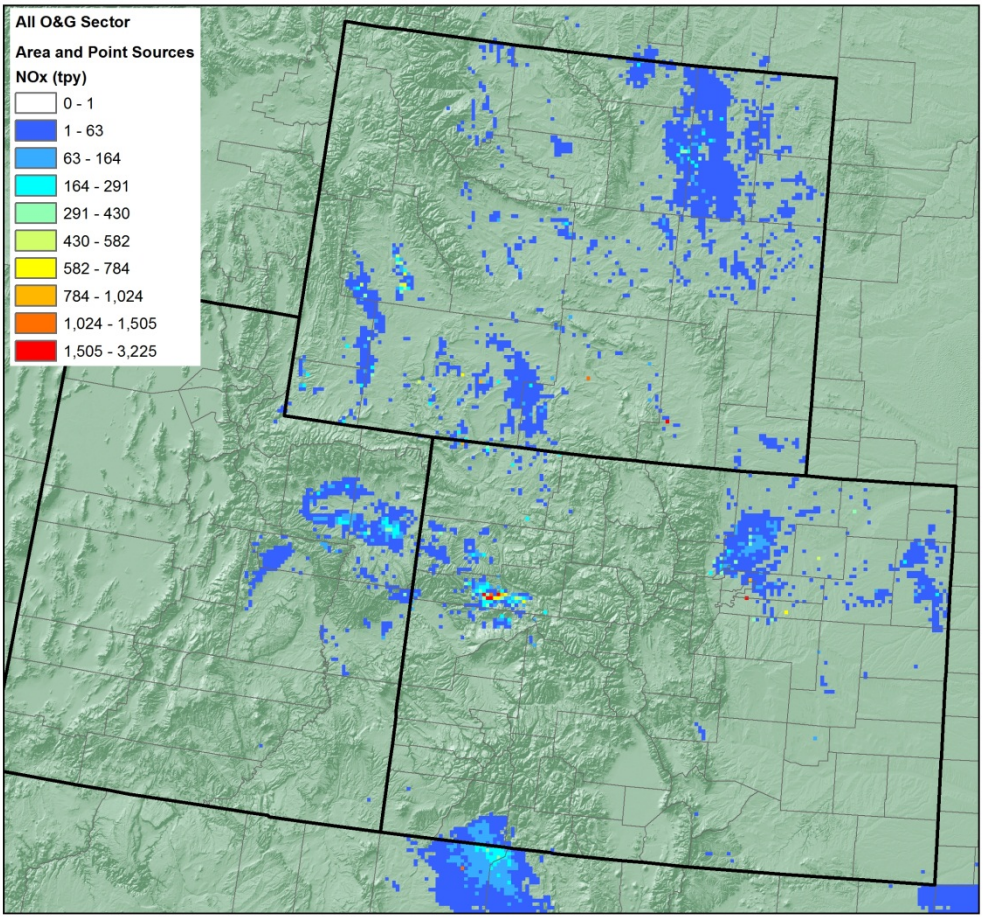

Fig. 2. Upstream oil and gas NOx emissions (area and point sources).

Areas with potential future emissions were identified by surveying Workgroup members for public information on planned new developments. Results of this survey were used to map locations of potential future oil and gas development in the 3-state region which were then compared with locations of current and potential future monitoring sites (see map overlays in Appendix B).

Air Quality Representativeness Analysis

Locations of particular concern from a monitoring network design perspective include areas where concentrations have historically approached or exceeded the levels of ambient standards. Most recently available annual 4th highest daily maximum 8-hour ozone concentrations for each site in the monitoring site database were mapped to identify such locations. An attempt was made to estimate a recent design value at all sites, even those which were recently closed or had large amounts of missing data. Results were stored in the monitoring site database and mapped as shown in Figure 3, which shows locations where ozone concentrations approaching or exceeding 75 ppb have been observed in recent years.

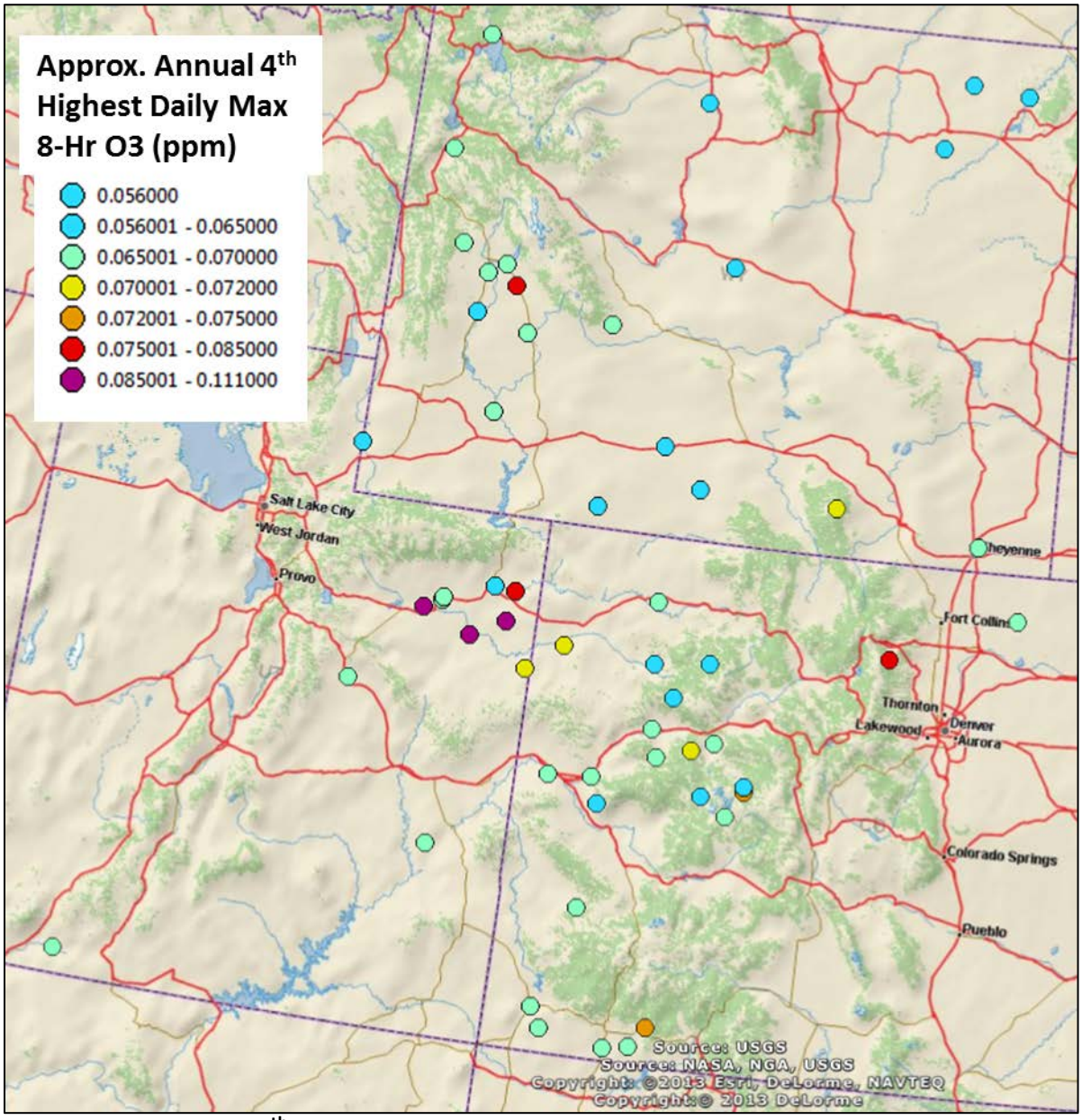

Fig. 3. Recent annual 4th highest daily maximum 8-hour ozone concentrations at existing monitoring sites.

Population Served Analysis

Although the major population centers along the Front Range and the Wasatch Front were not included in the Network Assessment, several smaller communities are located within the study area and monitoring of population exposures is one objective of the monitoring network. Population by zip code was extracted from the 2010 US Census data and mapped as shown in Figure 4; maps of the exterior boundaries of urban areas as defined by the US Census Bureau were also created (see Appendix B). These results were examined to understand the relationship of monitor locations to population centers although population exposure monitoring was not a major focus of the network evaluation.

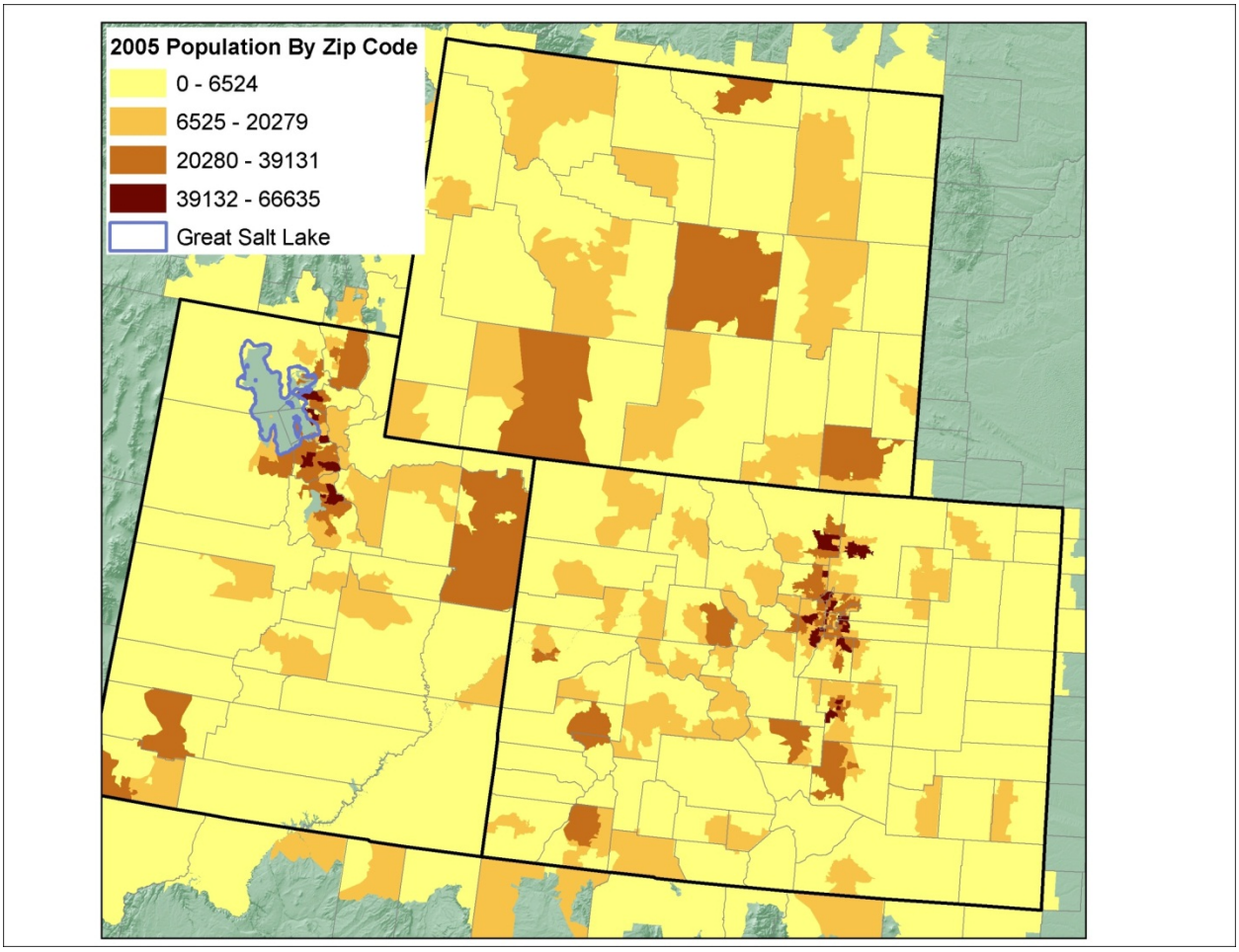

Fig. 4. Population by zip code (2010 US Census).

Identification of Potentially Underserved Areas

Based on results from the analyses described above, a set of 13 "potentially underserved areas" (UAs) was identified as suggested by the green filled polygons in Figure 5. Each UA represents an area within which the existing network was judged to be insufficient to achieve the network objectives. Note that the UA polygon boundaries in Figure 5 are only intended as visual clues suggestive of the general region comprising the potentially underserved area and are not drawn to any exact specifications. Essentially, the UA represents a potentially significant "gap" in the existing network. The relative importance of each UA was then evaluated by listing positive and negative attributes with respect to the value of adding monitoring resources within the UA and the UA's were ranked into "low", "medium" and "high" priority bins. UA evaluation results are summarized in Table 2; the list of positive and negative attributes, additional comments from the Workgroup and the assigned priority bin for each UA are included in Appendix G.

Table 2. Summary of UA evaluation results.

Area	Assessment Summary	Recommended Rank
UA13: Roan Plateau	Downwind of O&G developments and far from Rangely; USFS suggests Douglas Pass site	3
UA5: Dinosaur East Side	Downwind of O&G developments, cross-border transport; high values at surrounding sites	3
UA12: Kremmling Area	Mostly high elevation; downwind of White River O&G development; low elevation areas not well represented by current network; potential USFS Holy Cross site in southern end and DRI Storm Peak in northern end	2-3
UA3: Medicine Bow – Saratoga	Potentially downwind of large O&G development but WestJump predicts low anthropogenic impact; may be manageable by USFS	2
UA9: Dove Creek North Side	May be reasonably well represented by existing sites but there is potential for future development in the area (Mancos and Paradox)	2
UA2: East-Central WY	Considered **high** priority by WY DEQ and WY BLM due to future development plans; considered low priority by other agencies; mobile monitors in place 2013 – 2014 and likely to continue	3
UA4: Central West WY	Some on-going development to the south but otherwise of lower interest; issues regarding jurisdictions on tribal lands require resolution; considered medium priority by WY DEQ	1-2
UA6(Caineville-Hanksville), UA7(Green River-Westwater), UA8(Blanding Area)	Long way from any existing assets; UDAQ suggests existing sites are reasonably representative of UA6, UA7 and UA8	1
UA10(Delta-Montrose), UA11(Black Canyon of the Gunnison)	Minimal evidence of ozone greater than background; Near otherwise unmonitored Class I areas (Black Canyon of the Gunnison and West Elk); Easy access via US-50	1
UA1: Saguache-Monte Vista-Alamosa	Low priority based on ENVIRON analysis and other comments received;	1

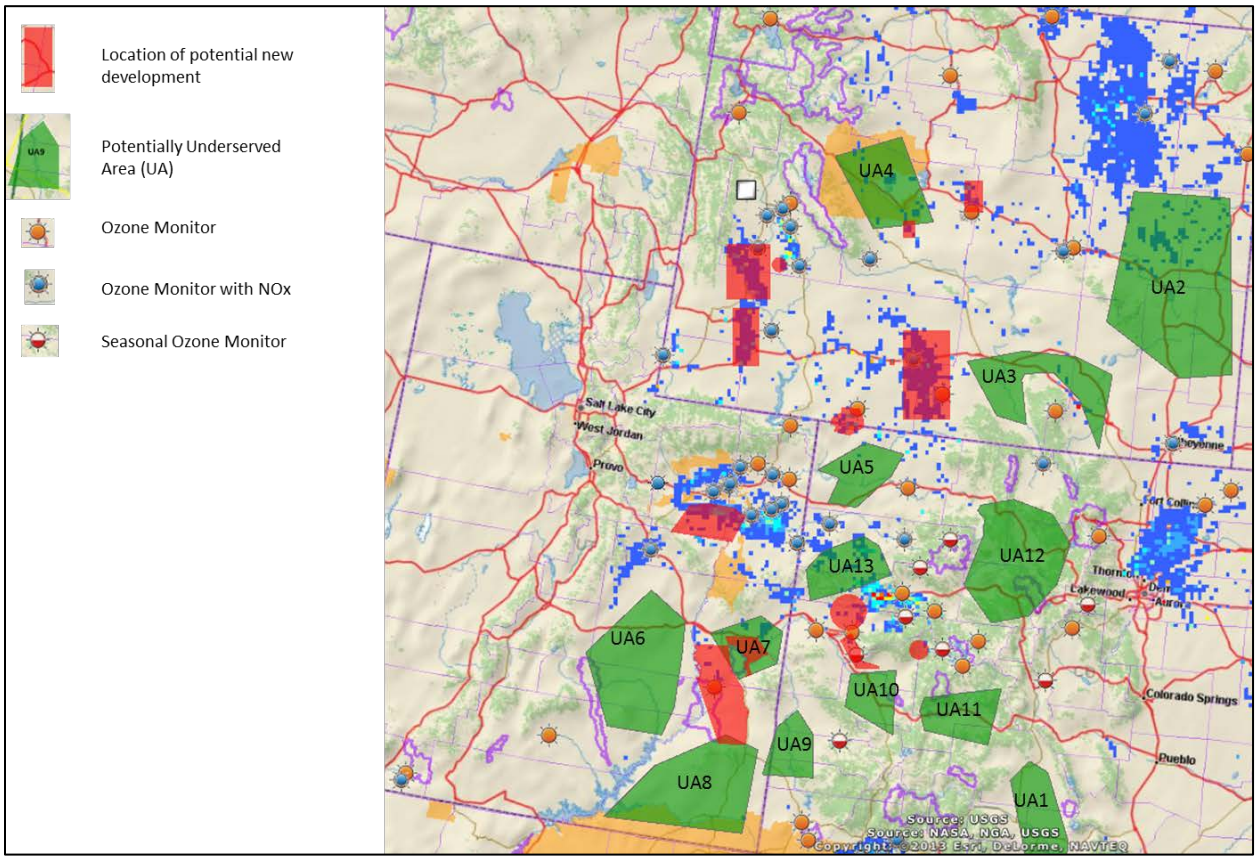

Fig. 5. Potentially Underserved Areas with existing ozone monitoring network and areas of potential future development.

Development of Final Recommendations

Using results from the analyses described in the previous section, ENVIRON and the Network Assessment Workgroup developed final recommendations for changes to the 3SAQS monitoring network by first classifying existing monitoring sites into two groups:

1. "Permanent" sites, most of which have a long monitoring record and which will remain in place for the foreseeable future because they have demonstrated value in fulfilling the network objectives or are needed to fulfill existing obligations and have firm, on-going funding commitments.
2. All other sites ("non-permanent" sites), including sites where additional monitoring may not be warranted based on the record of observations collected thus far or for other reasons as well as sites with demonstrated value but for which continued funding during the 2014 – 2017 3SAQS is uncertain.

Sites falling in the second category were further evaluated, together with results of the UA analysis described above, to arrive at a final set of recommendations for changes to the network. This included evaluation of the pros and cons of establishing new sites in one or more

of the UAs, including evaluation of practical difficulties likely to be encountered given the remote locations represented by many of the UAs as well as cost savings from closing any existing sites and potential cost savings of moving equipment from a site designated for closure to a new site. Several guiding factors were taken into consideration when formulating the recommendations:

- Maintain existing sites through end of 2014 whenever possible to avoid disruptions in current monitoring records;
- Include at least basic meteorological monitoring at all new sites (to the extent possible);
- There is no requirement implied in these recommendations that states designate any particular monitors belonging to the permanent network - sites can be designated as Special Purpose sites for an indefinite period;
- It is recognized that states can decide to close or move sites during the '14-'17 timeframe, but are asked to consult with 3SAQS cooperators prior to doing so.

Recommendations for network reconfiguration are shown in Figure 6. Most existing sites (blue stars) were recommended to be retained and are expected to continue operating using existing state and federal funding. Some existing sites recommended for continued operation (marked by orange bull's-eyes) were identified as requiring additional funding to stay open, including Escalante, Price and Fruitland in Utah; Lay Peak in Colorado and Murphy Ridge and Hiawatha in Wyoming.[1] A number of additional existing sites (marked by red diamonds) were recommended for potential closure to save resources unless other funding becomes available - most but not all of these are seasonal sites operated by the USFS. Finally, establishment of new monitors was recommended at five locations shown by the yellow pushpins in Figure 6: Paradox, Douglas Pass, and Dinosaur East in Colorado and Medicine Bow in Wyoming. Detailed justifications for and discussion of these recommendations are provided in Appendices A and G.

[1] After completion of this analysis, the state of Wyoming determined that they would be able to fund continued operation of the Hiawatha monitor as well as VOC monitoring at Wamsutter.

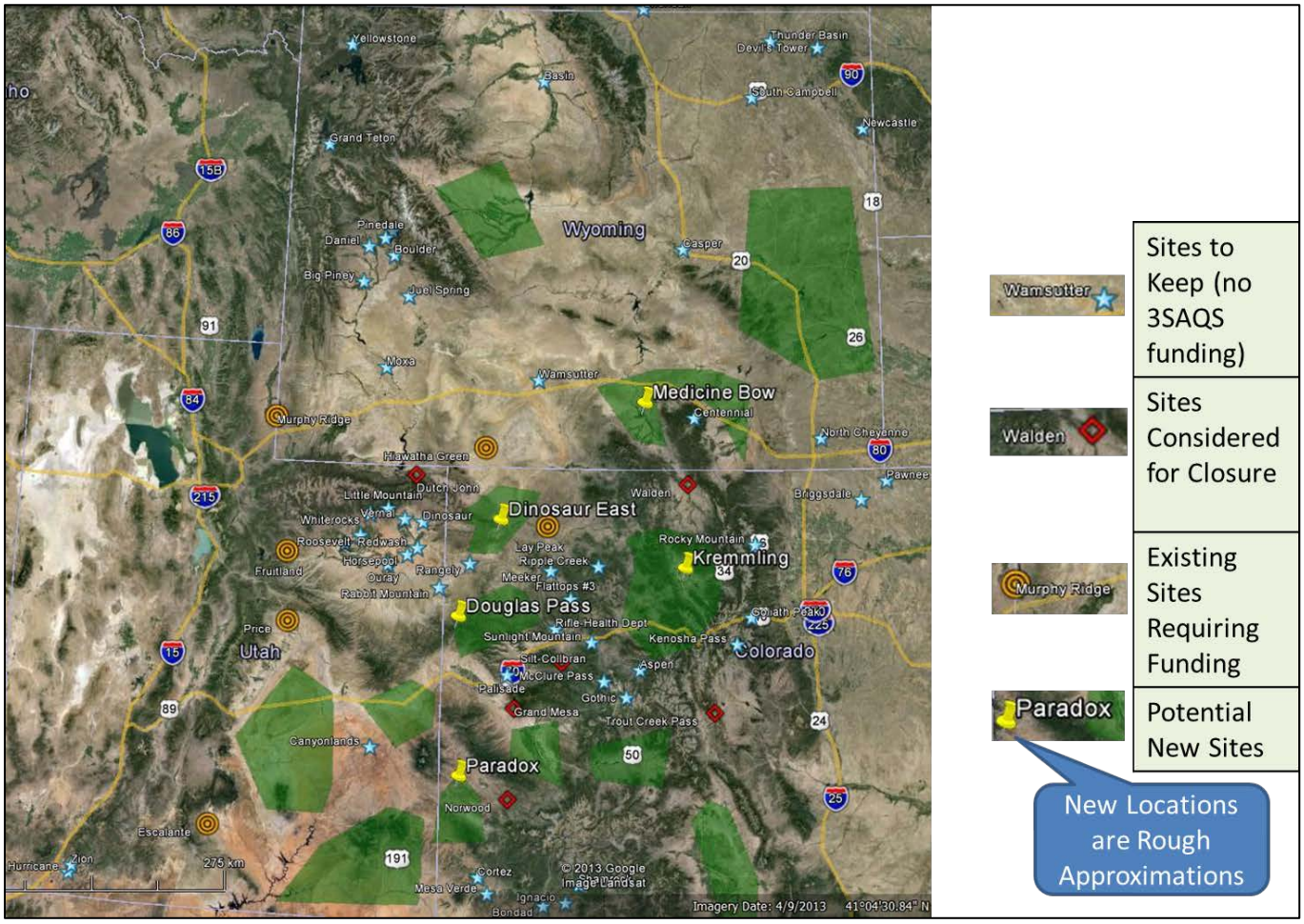

Fig. 6. Final network reconfiguration recommendations and associated funding sources.

Cost Analysis

A detailed analysis was conducted to determine the costs associated with each of the recommended network changes described in the preceding section, taking into account availability of equipment and trained site operators, data handling, quality control and quality assurance requirements and availability of in-kind contributions. Resulting estimated costs were then compared with the 3SAQS monitoring budget and adjustments made as needed to reconcile any mismatch. A spreadsheet with results of the costing analysis is included in Appendix H.

During evaluation of the costs of the recommended network changes, it was decided to continue monitoring at all currently operating sites through 2014 and implement the recommended site changes in 2015. The final recommended network configuration for 2015 – 2017 is shown in Figure 7. Included in this figure are several sites marked by orange triangles (Storm Peak, Deadman Pass and Holly Cross) which are not part of the 3SAQS study but which are expected to become operational during this time period. Sites marked by blue squares, which include both several existing and new sites, are recommended for partial funding out of

the 3SAQS budget with the remaining funding needed to operate these sites being provided by significant in-kind contributions that have been committed by BLM, USFS, NPS and each of the states as detailed in Appendix H.

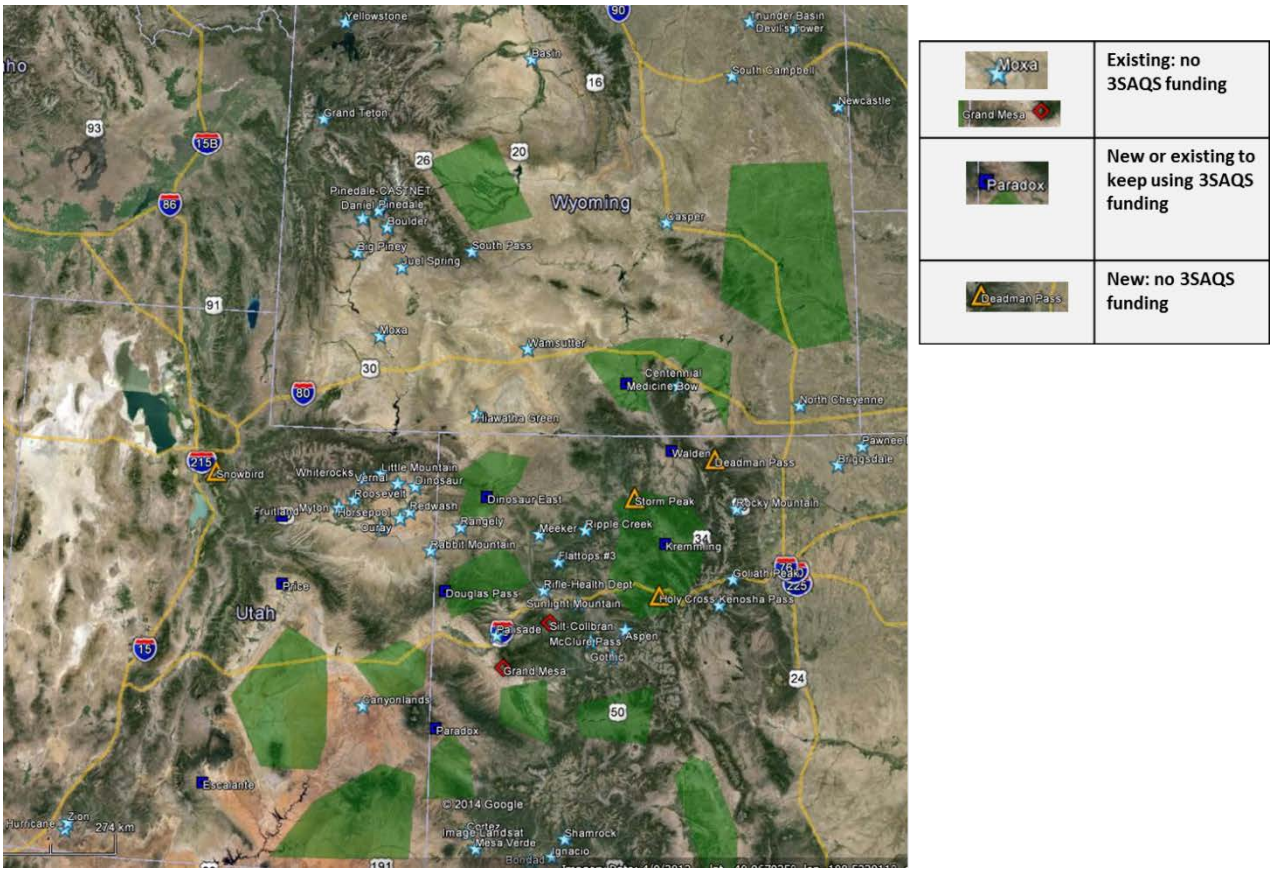

Fig. 7. Final recommended network configuration for 2015 – 2017.

Summary

Continued air quality monitoring is needed to support the 3SAQS during the 2014 – 2017 study period. To determine the most effective use of limited available monitoring resources, an assessment of the existing monitoring network, including monitoring funded under the 3SAQS pilot study, was undertaken. The network assessment focused on the generally rural intermountain region within the three state domain away from the major population centers (the Wasatch Front on the west and the Front Range communities on the east). ENVIRON, working together with UNC and a Network Assessment Workgroup composed of representatives from each participating state air agency, EPA and the federal land management agencies, gathered data from existing monitoring sites, the geography and climatology of the region, emissions, air quality model simulations, and potential future development areas. Using these data, ENVIRON undertook a series of analyses designed to identify, evaluate and prioritize potential gaps or redundancies in the monitoring network, perform a cost analysis,

and develop a set of recommendations for using available 3SAQS funding to support modifications to the network to better achieve the 3SAQS study objectives. Final recommendations were presented to the 3SAQS Steering Committee. This memorandum, together with the referenced appendices, documents the scope, objectives, data sources, analysis methods and results of the assessment.

References

Adelman, Z., 2013. Personal communication, Zac Adelman, University of North Carolina.

ENVIRON, 2013. *Western Regional Air Partnership (WRAP) West-wide Jump-start Air Quality Modeling Study (WestJumpAQMS), Final Report*. ENVIRON Int. Corp., Alpine Geophysics LLC, and University of North Carolina, September (http://www.wrapair2.org/westjumpaqms.aspx#).

EPA, 2007. *Ambient Air Monitoring Network Assessment Guidance*. EPA-454/D-07-001, U.S. Environmental Protection Agency, Research Triangle Park, NC, February.

Miller, D. 2013. Personal communication, Debra Miller, U.S. Forest Service.

Appendices

Appendix A: Network Assessment methodology, results and final recommendations: presentation to the 3SAQS Steering Committee, 27 February 2014.

Appendix B: Geographic data in ESRI Shapefile format (terrain, political boundaries, population, areas of potential future development, seasonal mean boundary layer winds).

Appendix C: Emissions data from 2008 WRAP WestJump study in ESRI Shapefile format.

Appendix D: CAMx model results for 2008 base case runs from WRAP WestJump study in ESRI Shapefile format.

Appendix E: Ozone and PM monitoring site information database.

Appendix F: 8-hour daily maximum ozone inter-site correlations for all site pairs.

Appendix G: Table of pros and cons of adding new monitoring sites in each potentially underserved area (UA) and recommended priority ranking of each UA.

Appendix H: Monitoring cost analysis results.