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March 1, 2016

VIA ELECTRONIC FILING

Ms. Mary Dyas, Compliance Project Manager
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

Re: Sonoran Energy Project, Petition to Amend (02-AFC-1C)
Project Owner's Comments on Staff's Preliminary Staff Assessment

Dear Ms. Dyas:

On February 1, 2016, the California Energy Commission ("Commission") Staff published the Preliminary Staff Assessment ("PSA") for the Sonoran Energy Project ("SEP" or the "Project"). Herein please find Project Owner AltaGas Sonoran Energy Inc.'s ("Project Owner") comments on specific sections of the PSA.[1] At this time, Project Owner has no comments on those sections of the PSA that are not identified herein. The comments below are organized as follows: Soil & Water Resources, followed by Traffic and Transportation and Visual Resources. Additional comments on remaining sections of the PSA are presented in the order in which they appear in the PSA. Lastly, for certain items discussed at the February 24, 2016 Staff PSA Workshop Project Owner will be filing responses to questions and additional information in a separate filing subsequent to the filing of these comments (*e.g.*, related to water conservation measures, groundwater levels, one-line diagram, TRANS-9, etc.). Project Owner anticipates docketing such additional information in mid-March, 2016.

[1] Project Owner's proposed edits to Conditions of Certification set forth herein are identified as **bold underlined** or ~~strikethrough~~ text.

Alaska California Idaho
Minnesota Oregon Utah Washington
and Washington, D.C.

I. SOIL & WATER RESOURCES[2]

The PSA's conclusions regarding water use are not supported. As discussed more fully below, there is no legal basis for new analysis of SEP's water use, and the PSA mischaracterizes the applicable laws, ordinance, regulations and standards ("LORS"). Furthermore, the evidence supports that there is sufficient water available to supply SEP, and the PSA fails to fully analyze the impacts of staff's proposed dry-cooling mitigation. Moreover, the Project Owner's proposed voluntary water conservation program is adequate. Accordingly, as supported by the analysis below, the PSA's proposed Revised Conditions of Certification (Soil&Water-7 and Soil&Water-10) is unwarranted, and should be deleted.[3]

A. SEP's Proposed Water Use Complies with LORS

The PSA concludes that SEP's groundwater demand may result in significant impacts to the Palo Verde Mesa groundwater basin and the Colorado River. (PSA, p. 4.9-1.) This conclusion is not supported by the evidence. As set forth in detail in Project Owner's January 28, 2016, Supplemental Water Resources filing (TN# 210068) and discussed further herein, there is adequate groundwater supply available for SEP. As an initial matter, however, this conclusion ignores the applicable legal framework, and the PSA mischaracterizes the applicable LORS relating to water supply.

It is undisputed that the Project is licensed to use up to 2,800 acre-feet per year ("AFY") of water from the Palo Verde Mesa groundwater basin. This is the baseline against which the PTA must be evaluated. The PTA does not propose to change the quantity or source of water used for the Project and, therefore, there is no modification proposed that may have impacts on the environment or on the Project's ability to comply with LORS. (20 Cal. Code Regs., § 1769(a)(1).) Because SEP does not propose any changes to water use, this water use was

[2] On January 28, 2016, Project Owner docketed a 67-page Water Resources Supplemental Filing, in support of the pending PTA. (TN# 210068.) Project Owner incorporates the entirety of that document and the arguments contained therein into these comments on the PSA.

[3] As illustrated in Table 1 (PSA, pg. 4.9-3), SOIL&WATER-7 seeks to reduce the SEP's licensed water use from 2,800 acre-feet per year ("AFY") to 280 AFY, which is a mere 10 percent of the amount licensed in 2012. SOIL&WATER-10 similarly seeks to limit annual use to "one-tenth the licensed water use limit…"

previously found by the Commission not to result in potentially significant impacts on water supply, and the Project Owner is not proposing any changes to the previously approved water use, there is no legal basis for evaluating mitigation for or alternatives to water use. (*See* 20 Cal. Code Regs., § 1741(b)(1); *see also* CEQA Guidelines, § 15126.6.)[4]

The PSA also suggests that "environmental conditions" warrant new analysis of water supply. (PSA, p. 4.9-1.) This is not a legal basis on which to conduct additional environmental review. (CEQA Guidelines, § 15162.) Additionally, the PSA fails to identify specific changes to the environmental conditions in the Project area that could result in new significant environmental effects and there is no evidence of such changes. Indeed, the evidence is to the contrary - groundwater levels in the Palo Verde Mesa groundwater basin have been rising since the mid-1980s. (TN# 210068)

The PSA suggests that there are new LORS required to be considered. (PSA, pp. 4.9-5 to 4.9-6.) This is incorrect. Water Code sections 10910-10915, governing water supply assessments and cited in the PSA, was adopted in 2003, prior to the 2005 Final Decision and well before the 2012 Amendment. Executive Orders No. B-28-14 and No. 29-15 are not LORS governing water use for power plants. Finally, as discussed in greater detail below, the Sustainable Groundwater Management Act does not impose requirements on the groundwater basin at issue here. (See Part I.A.4, below.)

The PSA contains many comments about legal requirements for water use being "reasonable," (or "unreasonable"), "sustainable" and "reliable." (*See*, *e.g.*, PSA, pp. 4.9-1, 4.9-2, 4.9-5, 4.9-8, 4.9-10, 4.9-13, 4.9-17 and 4.9-18.) Staff's characterization and application of these legal requirements is inaccurate.

1. SEP's Licensed Water Use Is Consistent With California Constitution Article X, Section 2

Article X, Section 2 states in pertinent part that water resources are to be used for "beneficial use to the fullest extent of which they are capable," which is "primarily thought to refer to the

[4] At the PSA Workshop on February 24, 2016, Staff agreed that the baseline for environmental review is 2,800 AFY.

method, manner, or means of use."[5] This constitutional mandate does *not* exclude use of groundwater resources for industrial purposes such as for the SEP. In fact, absent alternative available water supplies, such as recycled or brackish water, the "method, manner, or means of use" of groundwater for the SEP – power generation for public consumption – is consistent with the mandate of Article X, Section 2 to utilize water for beneficial use to the fullest extent.

2. The Licensed Amount of 2,800 AFY Is "Reasonable Use" For The SEP.

Use of groundwater for industrial power generation purposes is not an unreasonable use, particularly where an alternative suitable water supply is not available.[6] Water Code section 13550 states specifically that use of potable water for industrial uses is *not* a waste where recycled water supplies are not available. Even if recycled water supplies were available for SEP (which is not the case), Water Code section 13550 also requires consideration of whether recycled water could be furnished "at a reasonable cost to the user" such that the State Water Resources Control Board "shall find that the cost of supplying the treated recycled water is comparable to, or less than, the cost of supplying potable domestic water."[7]

There is no recycled water supply available for the SEP, which is in a rural, desert environment located miles away from urbanized areas that do not have recycled water infrastructure. Accordingly, use of groundwater such as that from the Palo Verde Mesa groundwater basin is appropriate and reasonable – even necessary – as a matter of law for the SEP to operate.

Also, "reasonable" water use does *not* require the water user to use water in accordance with any particular scientific methods or technology and, therefore, the conditions in the PSA seeking to require dry cooling are not supported by law.[8]

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[5] California Constitution, Article X, Section 2; Scott S. Slater, *California Water Law and Policy* (2012) § 1.13, p. 1-23. *See also, City of Lodi v. East Bay Municipal Utility District* (1936) 7 Cal.2d 321, 341.

[6] Water Code § 13350.

[7] Water Code § 13350(a)(2).

[8] Scott S. Slater, *California Water Law and Policy* (2012) § 12.02, p. 12-8, citing to, *Erickson v. Queen Valley Rancho Co.* (1971) 22 Cal.App.3d 578, 585.

Contrary to implications from the PSA's general and vague references to the Governor's Executive Orders (Nos. B-28-14 and 29-15) calling for efficient use of water, those Orders do not state that groundwater for industrial uses is not efficient, or "reasonable." California legal authority actually demonstrates a presumption of reasonable use "based on the underlying belief that economic considerations would prevent a water user from wasting water."[9]

Ultimately, the Project Owner would be subject to "reasonable and beneficial" use requirements set forth by the California Constitution and related legal authorities while operating the SEP. As a matter of law, the SEP's licensed amount for 2,800 AFY does not violate California law.

3. California Code of Regulations, Title 23 Specifically Enumerates Industrial Use (e.g., power plant operations) As A "Beneficial Use"

Section 659 of the California Code of Regulations states: "Beneficial use of water includes those uses defined in this subarticle." Section 665 of the California Code of Regulations states that industrial use "means the use of water for the purposes, not more specifically defined herein, of commerce, trade or industry."[10] As such, use of groundwater for power generation is a beneficial use of water as a matter of law.

4. The Sustainable Groundwater Management Act Does Not Mandatorily Apply to the Palo Verde Mesa Groundwater Basin

Historically in California, "percolating groundwater" was not subject to a statewide regulatory program until 2015, when the Sustainable Groundwater Management Act ("SGMA") came into effect. California law presumes that groundwater is percolating.[11] With the California Department of Water Resources ("DWR") having determined a number of groundwater basins are in critical condition of "overdraft," SGMA identifies 43 groundwater basins as high priority

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[9] *Id.* at p. 12-9, citing to, *Tulare Irr. Dist. V. Lindsay-Strathmore Irr. Dist.* (1935) 3 Cal.2d 489, 547-548.

[10] *See also,* Water Code § 1058.

[11] *Los Angeles v. Pomeroy* (1899) 124 Cal. 597, 628, 633-34.

and 84 as medium priority.[12] Overdraft means that the amount of groundwater pumped from a basin exceeds the amount of water recharging the basin. These 127 basins account for approximately 96 percent of the groundwater used in the state.[13] Outside of these 127 basins are groundwater basins that are *not* subject to mandatory regulation by SGMA, which for clarity, DWR has characterized as "low" and "very low" priority (*see,* fn. 13).

Attempting to support reducing the SEP's licensed water amount, the PSA states "the Governor signed the SGMA laws, which are intended to help better manage groundwater basin balances" and in the next sentence concludes that the "SEP would put the Palo Verde Mesa into [sic] even further into an unsustainable condition."[14] The PSA is wrong.

The Palo Verde Mesa groundwater basin in which the SEP is located is *not* among the 127 basins for which SGMA requires management. In other words, the State of California through DWR – with all of its protective measures for sustainability through SGMA and otherwise – has determined the SEP's basin is *not* at risk of short water supply (or "overdraft") requiring SGMA's management requirements. Similarly the groundwater basins immediately adjacent to the Palo Verde Mesa groundwater basin are also characterized as "low" or "very low" priority, thus demonstrating further that the PSA incorrectly relies on SGMA *and* that sufficient water supplies do exist for the SEP. SGMA is mandatory for groundwater basins identified by the DWR as high priority and medium priority, but is voluntary for low-priority groundwater basins. The Palo Verde Mesa, Chuckwalla Valley, and Palo Verde Valley groundwater basins are all identified as low-priority groundwater basins. There is no evidence to support the PSA's claim that the measures required by SGMA are applicable to the water licensed for use by the Project.

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[12] There are four priority levels: high, medium, low, and very low pursuant to Water Code § 10722.4. For DWR's characterizations of groundwater basins throughout the state, *see* http://www.water.ca.gov/groundwater/sgm/SGM_BasinPriority.cfm.

[13] http://www.water.ca.gov/groundwater/sgm/SGM_BasinPriority.cfm.

[14] PSA, p. 4.9-17.

5. The PSA Incorrectly Treats The "Proposed" Accounting Surface Rule as a Valid, Existing Rule

In addition, the PSA incorrectly concludes that a *proposed* rule for Colorado River water should be treated as an *existing* rule, which is wholly contrary to fundamental jurisprudence. For the PSA to acknowledge that the "status of the [proposed] rulemaking has not changed" yet conclude that "new restrictions" might occur in the future and therefore should be assumed to apply now is entirely speculative and would violate legal authorities regarding, among other things, due process.[15] It is not appropriate to speculate about what laws and regulations may apply to any activity in the future, and the CEC does not have authority to impose requirements on SEP based on potential future laws and regulations that may or may not be adopted and become effective.

Accordingly, for the reasons stated above and in Part I.C, supra, and based upon the analysis of EnviroLogic Resources' report docketed on January 28, 2016 (TN# 210068), sufficient water supplies do in fact exist for the SEP and the PSA's conclusion as a matter of the law that the *proposed* Colorado River rule bears any weight for the SEP's water resource use and needs is simply incorrect.

6. Staff Seeks to Unlawfully Adjudicate Project Owner's Water Right

Project Owner has an overlying water right by owning land that lies over a groundwater supply. The PSA does not acknowledge this right, and its proposed reduction of licensed water use would infringe the Project Owner's water right. California water rights are considered and treated under the law as real property rights.[16] When groundwater is the water supply source, a landowner's water right generally is an "overlying right," which, "analogous to that of a riparian owner in a surface stream," is "the right of the owner of the land to take water from the ground underneath for use on his land within the basin or watershed; the right is based on ownership of

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[15] To be enforceable as a matter of due process under the state Constitution (Article 1) and federal Constitution (Fifth and Fourteenth Amendments), a rule must be sufficiently clear and, fundamentally, must be duly adopted by an entity with the power to create the rule or obligations. *See, e.g., Coates v. Cincinnati* (1971) 402 U.S. 611; *William & Mary Law Review*, Vol. 54:987, p. 988.

[16] *Copeland v. Fairview Land & Water Co.* (1913) 165 Cal. 148, 154; *Stanislaus Water Co. v. Bachman* (1908) 152 Cal. 716, 725.

the land and is appurtenant thereto."[17] Overlying right holders enjoy a correlative share to the water, generally meaning that the overliers equally share the water.[18] The California Supreme Court established in 1903 the doctrine of reasonable use, which "limits the right of others to such amount of water as may be necessary for some useful purpose in connection with the land."[19]

As such, the Project Owner has an overlying water right that cannot be unilaterally adjusted as the PSA seeks to do, by requiring dry cooling or by any other means. The PSA's attempt to reduce water use to 1/10, or any other reduction from the currently licensed amount of 2,800 AFY[20] would limit the SEP's Project Owner from exercising its right to reasonable and beneficial use of water for SEP operations, which could arise to an unlawful "taking" under the federal and state constitutions.

B. SEP's Proposed Water Use Is Consistent with State Water Policy

The use of groundwater at SEP is allowed under various state policies, including State Water Resources Control Board ("SWRCB") Resolution Nos. 75-58 and the Commission's Integrated Energy Policy Report ("IEPR") (2003). SWRCB Resolution 75-58 and the 2003 IEPR both

[17] *City of Pasadena v. City of Alhambra* (1949) 33 Cal.2d 908, 925.

[18] *Katz v. Walkinshaw* (1903) 141 Cal. 116, 134-137.

[19] *Katz, supra,* 141 Cal. at 134.

[20] The CEC lacks jurisdiction and authority to adjudicate or otherwise limit Project Owner's water right, evident at least in part by the lack of any explicit authority delegated by the Legislature to the CEC and the State Water Resources Control Board ("State Water Board") having jurisdiction and authority to adjudicate surface water rights, not groundwater rights, evident by Water Code § 1200 (and the State Water Board's website stating such: http://www.waterboards.ca.gov/waterrights/board_info/water_rights_process.shtml#rights.) Also, clear decisional authorities by the judicial branch including the California Supreme Court prohibits even a court from determining a water right based on notions of equity or what it thinks "should" be the right. *See, e.g.*, *City of Barstow v. Mojave Water Agency* (2000) 23 Cal.4th 1224, 1240 ["Overlying rights are special rights to use groundwater under the owner's property." And, "absent the party's consent, a physical solution may not adversely affect that party's existing water rights." (*Id.* at pp. 1243-1244, 1250-1251.) This overlying right includes the landowners' "present and prospective reasonable and beneficial use upon the land." (*Id.* at p. 1240.) *See also, City of Santa Maria v. Adam* (2012) 211 Cal.App.4th 1090.

prohibit the use of fresh inland waters for power plant cooling unless "use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound." (Res. 75-58 at p. 4; 2003 IEPR at p. 40[21] (emphasis added).) The 2003 IEPR then notes that the Energy Commission will approve the use of fresh inland water for cooling purposes only where alternative water supply sources are shown to be "environmentally undesirable" and "economically unsound." (*Id*.)

While both Project Owner and Staff agree that Policy 75-58 applies to the use of fresh water for power plants in California, Project Owner disagrees that this Policy is applicable to the water supply for SEP. Policy 75-58 defines "fresh inland waters" as "inland waters which are suitable for use as a source of domestic, municipal, or agricultural water supply **and which provide habitat for fish and wildlife.**" (Emphasis added.) Because the groundwater beneath the SEP site does not provide habitat for fish and wildlife, Policy 75-58 does not apply.[22]

Staff argues that since the 2005 Commission Decision, Staff "form[ed] the belief that the water quality constituent threshold of 1,000 mg/L total dissolved solids (TDS) discussed in the 2005 Decision is not intended to apply to groundwater," referencing a Staff reply brief as support for its argument:[23]

> "The Water Board Letter supports consideration of site specific factors and further indicates that while the 1,000 mg/L TDS standard may be one of the factors that apply to a determination about the suitability of surface water use, it does not apply to groundwater use." (Genesis 2010)

(PSA, p. 4.9-9.) Staff then argues that their "consultation" with the State Board provides additional perspective on the SEP's proposed use of groundwater, by stating that the Water

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[21] The 2003 IEPR requires that the "use of other water supply sources and other methods of cooling would be environmentally undesirable or economically unsound."

[22] This Commission has previously recognized that the reach of SWRCB 75-58 does not extend to underground water sources. The Commission in the Elk Hills decision (99-AFC-1 at page 253) quotes the Policy 75-58 definition of "fresh inland waters" in reaching this conclusion.

[23] Reliance on a brief filed by Staff in an unrelated CEC proceeding does not constitute evidence in support of Staff's position regarding SEP.

Board Letter "states the 1,000 mg/L TDS standard should not apply to groundwater." [24] Based on Staff's skewed interpretation of the 2010 Water Board Letter, Staff then errantly concludes that the groundwater beneath the SEP site is a "high quality water" and that SEP's use of such water is contrary to State Water Policy. (PSA, p. 4.9-18.) Staff fails to acknowledge what the January 2010 State Board letter **actually** says:

> More specifically, your questions relate to Resolution 75-58's definitions of "brackish waters" and "fresh inland waters" and Resolution 88-63's treatment of "sources of drinking water." "Brackish waters" is defined by Resolution 75-58 as "waters with a salinity range of 1,000 to 30,000 mg/l and a chloride range of 250 to 12,000 mg/l." (State Water Board Resolution 75-58, p. 2.) "Fresh inland waters" is defined by Resolution 75-58 as "those inland waters which are suitable for use as a source of domestic, municipal, or agricultural water supply and which provide habitat for fish and wildlife." (*Ibid*.) **As a general matter, that means "fresh inland waters" for purposes of Resolution 75-58 does not extend to groundwater, which typically does not provide fish and wildlife habitat.** On the other hand, State Water Board Resolution 88-63 generally provides that all surface waters and ground waters with a TDS of 3,000 mg/L or less shall be considered to be suitable for municipal or domestic water supply.
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> The Commission's primary issue revolves around whether brackish water with a TDS of between 1,000 and 3,000 mg/L should be considered to be fresh inland waters in the context of Resolution 75-58's Principle No. 2. The answer is typically yes for surface waters and **no for ground waters**. Due to the State Water Board's subsequent adoption of Resolution 88-63, which establishes the threshold of 3,000 mg/L for suitability, or potential suitability, for domestic or municipal water supply, surface waters that support fish and

[24] Moreover, Staff fails to acknowledge the amendment to the 2005 license that Staff analyzed in March 2012. During the processing of that amendment, Staff did not revisit or reanalyze the Project's water use except to acknowledge that the 3,300 AFY evaluated previously would not be required for the amended Project and that the Project only required 2,800 AFY. At no time during the 2012 amendment proceeding did Staff argue that the 2010 State Board letter demonstrates that the 1,000 mg/L level does not apply to groundwater, or that the currently licensed water use should be re-assessed in view of the 2010 State Board letter.

> wildlife habitat and have a concentration of 3,000 mg/L or less should be considered to be "fresh inland waters" for the purposes of Resolution 75-58's Principle No. 2. As a result, such waters should only be used for these renewable energy projects upon a demonstration that the use of other water supplies or methods of cooling would be "environmentally undesirable" or "economically unsound." **With respect to ground waters, they would not be considered "fresh inland waters" because they do not provide habitat for fish and wildlife. (Emphasis added.)**

(Letter from Dorothy Rice, SWRCB to Melissa Jones, CEC dated January 20, 2010 (attached to Applicant Genesis Solar, LLC's Reply Brief in Support of Committee Scoping Order, Docket No. 09-AFC-8), Attachment A hereto.) Contrary to Staff's assertion in the PSA, the information provided in the 2010 Water Board Letter is not new information or a new interpretation of a then 35-year old Policy. Rather, the information provided in the 2010 Water Board Letter reiterates the language contained in the Policy itself. [25] This letter supports the conclusion that Policy 75-58 does not apply to groundwater and, therefore, does not apply to SEP.

Despite the inapplicability of this policy to groundwater, because the Commission has used SWRCB 75-58 in the past as guidance in determining the appropriateness of a particular water supply, Project Owner nonetheless explains below how the proposed water supply for the SEP is consistent with State Water Policy. Assuming, *arguendo*, that Policy 75-58 applies to groundwater, when reviewing the principles set forth in Policy 75-58, groundwater at the SEP site squarely fits into the third most highly desirable category, "brackish water from natural sources or irrigation return flows." [26] In fact, the 2005 Decision describes the groundwater used by SEP as degraded irrigation return flows:

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[25] Project Owner agrees with Staff and the Water Board that Resolution 88-63 generally provides that all surface waters and groundwaters with a TDS of 3,000 mg/L or less shall be considered to be suitable for municipal or domestic water supply. In fact, the Colorado River Basin Plan confirms that the groundwater beneath the SEP site is suitable for municipal supply. (*See* Table 2-5, Colorado Hydrologic Unit (715.00), at http://www.swrcb.ca.gov/coloradoriver/publications_forms/publications/docs/rb7-plan.pdf.) However, such a conclusion is not sufficient to conclude that these waters are "fresh inland waters."

[26] Principle 1 prioritizes the types of water allowed for use in powerplant cooling as follows: (1) wastewater being discharged to the ocean; (2) ocean water; (3) brackish water from natural sources or irrigation return flow; (4) inland wastewaters of low TDS; and (5) other inland waters.

> in this case the groundwater has been recovered from water previously used for irrigation. With virtual certainty, the water that will recharge the aquifer in response to project pumping will be water dedicated initially to agricultural use. We are aware that some of the recharge water will be operational spillage; but this PVID water is effectively being used twice. Initially, it is dedicated to agricultural use, a significant segment of California's economy. Then it is recovered and stored in an aquifer as degraded groundwater to be used again for electricity production, also a significant and necessary segment of California's economy and welfare.

(See 2005 Final Decision at p. 254 (TN# 36138); see also TN# 210068 Project Owner's Supplemental Water Resources Filing.)

Moreover, as previously noted, the groundwater beneath the SEP site meets the definition of "brackish", with TDS levels above 1,000 mg/l and chloride concentration above 250 mg/l.[27] (PTA, Table 2-2, pp. 2-3 - 2-4, p. 3-158 (TN# 205652).) Policy 75-58 specifically provides that "the application of the term "brackish" to a water is not intended to imply that such water is no longer suitable for industrial or agricultural purposes." Further, principle 3 of Policy 75-58 states that "in considering issuance of a permit or license to appropriate water for power plant cooling, the Board will consider the reasonableness of the proposed water use when compared with other present and future needs for the water source and when viewed in the context of alternative water sources that could be used for the purpose." As noted, SEP's water use is consistent with Principle 3 because the water supply is degraded irrigation return flow. (2005 Final Decision at p. 254 (TN# 36138).) Further, SEP's proposed water conservation program is consistent with Principle 3 in that it helps prevent high-quality Colorado River water from being degraded by seeping into the groundwater in approximately 4.75 miles of unlined canals.[28]

[27]Policy 75-58 defines "brackish waters" as "all waters with a salinity range of 1,000 to 30,000 mg/l and a chloride concentration range of 250 to 12,000 mg/l."

[28] The same set of facts support conformance with California Constitution, Article X, section 2, and the California Water Code, which require that waters of the State be put to beneficial and reasonable use. [*See* Part I.A.1, *infra*]

In addition to the foregoing information, and again assuming *arguendo*, that Policy 75-58 applies, a discussion of whether an alternative water supply or alternate cooling methods are "environmentally undesirable" or "economically unsound" is also required. (2003 IEPR at p. 41; Policy 75-58 at p. 4, Principle 2.) As previously discussed, no other water supplies are available or contemplated for the Project. (See TN# 206606, pp. 7-2 - 7-3.) Thus, only an evaluation of whether alternate cooling methods are environmentally undesirable or economically unsound is required. Although Staff recommends dry cooling for SEP, Staff glosses over the adverse environmental impacts associated with dry cooling <u>at the SEP site</u> as well as the fact that dry cooling at the SEP site is economically unsound.

The Energy Commission interprets "environmentally undesirable" to mean the same as having a "significant adverse environmental impact." Staff acknowledges that there may be environmental impacts associated with dry cooling, but simply states that "the potential thermal plume, visual and noise impacts" will be discussed in those respective sections of the PSA.[29] As Project Owner noted in its January 2016 Water Resources Supplement (TN# 210068), dry cooling at the SEP site would have significant adverse environmental impacts on land use (aviation/airport), traffic and transportation (aviation/airport), visual resources, and noise as it would create substantially worse noise, visual, and thermal plume impacts than the proposed wet cooled SEP. (See below, Section I.E.) Adverse impacts related to air quality and greenhouse gases are also discussed below in Part VI, *infra*.

Staff also asserts that dry cooling is feasible "in a hot climate where water is scarce" (PSA at p. 4.9-11) by referencing two Texas projects that utilize dry cooling and a third project proposed in Pennsylvania that just received an air permit. (PSA, pp. 4.9-11, 4.9-12.) Staff fails to take into consideration the data Project Owner provided in response to Data Request 21 that demonstrates how the Texas locations are not comparable to the SEP site from a meteorological perspective. (See TN# 206606.)

[29] The only section of the PSA that actually "analyzes" the environmental impacts of dry cooling (and does not push that analysis off for inclusion solely in the Final Staff Assessment) is the Traffic and Transportation section, which states that Staff's preliminary analysis of the ACC shows the ACC's critical thermal plume velocity of 4.3 m/s is predicted to occur up to 1,500 feet AGL- far higher than the thermal plume associated with the proposed, wet cooled SEP. The Traffic and Transportation section then notes that additional analysis will be contained in the FSA.

The comparison of ambient temperature and humidity data for Blythe and the Texas project locations that was provided in Data Response 21 has been updated below to include the Pennsylvania project referred to by Staff (Moxie Freedom Generation Plant in Salem Township, PA). As shown in the table below, the temperatures and relative humidities at the Pennsylvania location are also significantly different than those at Blythe, with much lower ambient temperatures and higher relative humidities than the SEP location. Because dry cooling systems operate with the ambient dry bulb temperature as the theoretical minimum attainable temperature, there are significant efficiency penalties associated with dry cooling when temperatures are high and relative humidities are low. As a result, the loss in capacity that would result from the use of dry cooling instead of wet cooling at the Sonoran Energy Project would be significantly higher than the loss in capacity experienced by the Texas and Pennsylvania projects.

Comparison of Meteorological Conditions at Power Plant Sites

Statistic	Temperature, deg F				Corresponding Humidity, %			
	Blythe	Granbury	Wharton	Salem	Blythe	Granbury	Wharton	Salem
Average	74.5	69.9	66.4	49.9	31.0	72.9	62.9	67.8
99%	109.8	93.8	101.2	85.9	12.9	42.0	28.0	46.4
Maximum	122.7	107.0	109.8	105.9	7.0	18.0	22.0	36.0

Met data for Granbury (Wolf Hollow plant location) from Dallas-Fort Worth International Airport.
Met data for Wharton (Colorado Bend plant location) from William Hobby Airport (Houston).
Met data for Salem (Moxie Freedom plant location) from Wilkes-Barre Airport (PA).
Texas location weather statistics are 30 year averages for the period 1985 through 2014.
PA location weather statistics are 43-year averages for the period 1973 through 2015.

The evidence in the record also demonstrates that dry cooling at the SEP site is also economically unsound. The Energy Commission interprets "economically unsound" to mean the same as "economically or otherwise infeasible." "Feasible" is defined under CEQA and in the CEC Siting Regulations as being "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social and technological factors." (14 Cal. Code Regs., § 15364; 20 Cal. Code Regs., § 1702(f); *see* 2003 IEPR at 40.) While dry cooling is technologically feasible, it will reduce SEP's operational efficiency and will significantly increase both capital and operational costs of SEP. (*See* TN# 210068; *see also* TN#s 206606 (Project Owner's Responses to Staff's Data Requests, Set One;

208219 (Project Owner's Revised Response to DR43.) Thus, it is not capable of being accomplished in a successful manner. (See also, Part I.E, *infra* (re cost of dry-cooling).)

Based on the foregoing, and contrary to the assertions in the PSA, use of groundwater at SEP is consistent with State Water Policy.

C. Staff's "Water Supply Assessment" is Fundamentally Flawed

The PSA acknowledges that the purpose of a water supply assessment is to inform decision-makers about water availability "for projects that substantially increase the potable water demand on a local system." (PSA, p. 4.9-13.) As discussed above, the amended SEP does not propose to increase water use as compared to the existing licensed use and, therefore, a water supply assessment is not required for the PTA. Moreover, the PSA continues to ignore that the BEP II license was amended in 2012 and, therefore, inappropriately concludes that the 2005 Final Decision needs to be updated to include a water supply assessment. (PSA, p. 4.9-14.) In fact, the appropriate baseline for water use is the 2012 decision on the amendment to BEP II. Even if a water supply assessment were required for the amended SEP, the PSA's conclusions regarding water supply availability are not supported.

Notwithstanding the absent regulatory need for a WSA, the Project Owner's Groundwater Availability Report[30] (TN # 210068) clearly demonstrates that adequate water is available to serve the Project without adverse impacts. The CEC refers to a water budget prepared in 2013 for the Blythe Mesa Solar Project, licensed by the BLM in 2015. Such representation of groundwater availability is, at best, an incomplete picture of groundwater conditions in the Palo Verde Mesa groundwater basin, and more accurately may be described as misleading as to how much water is actually available, including from the SEP.

First, Staff underestimates recharge from runoff. The area where precipitation occurs extends beyond the Palo Verde Mesa groundwater basin boundaries and amounts to about 165,000 acres upgradient from the SEP site. The Blythe Mesa Solar Project water budget is based on a basin size of 130 square miles, only about 83,200 acres, the area where recharge occurs is underestimated by half. An infiltration rate of 5 percent is more likely than the 1 percent

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[30] When reviewing the PSA and drafting these comments, it was discovered that a numerator and denominator were reversed in one calculation in the Groundwater Availability Report. This calculation error resulted in an underestimation of recharge on the mesa. An updated Report will be docketed to reflect this correction.

estimated in the WSA. For example, AECOM 2010 and AECOM 2011 use 5 percent for a recharge rate. At this 5 percent rate, the recharge from precipitation amounts to approximately 2,500 AFY versus the 242 AFY presented in Soil & Water Resources Table 4.

Second, in the Blythe Mesa Solar Project water budget relied on by Staff irrigation return flows are estimated to be only 1.8 percent of an estimated 3,911 AFY of irrigation water applied. However, AECOM 2010 estimates return flows of 1.3 AFY for each acre of irrigated land. The 3,911 AFY of irrigation is roughly equivalent to 870 acres of irrigated land at an application rate of 4.5 acre-feet per acre per year. A reasonable estimate of acreage under irrigation is 1,500 acres based on a review of aerial photographs. The return flows calculated on the basis of the AECOM 2010 estimated rate results in more than an order of magnitude difference between what is presented by the CEC Staff and return flow calculations by Project Owner's consultants (72 AFY vs. 2000 AFY).

Third, underflow from adjoining basins also is significantly underestimated as presented in the PSA. As set forth in the Groundwater Availability Report, dated January 27, 2016, (TN# 210068), Darcy's Law calculations indicate approximately 12,600 AFY flows beneath the SEP site within the area of the potential cone of depression of the proposed new (but currently licensed) wells. In addition, water levels in the Palo Verde Mesa groundwater basin have been rising since the mid-1980s, and demonstrated via on-site monitoring wells to have risen on the SEP site over the last decade, indicating an increase of groundwater in storage – despite the operation of BEP1. Clearly, the projected deficits presented in Soil & Water Resources Table 4 are not real, BEP I has been pumping for almost 13 years and theoretically would contribute to a projected deficit, yet available data contradict that conclusion. Staff's underlying assumptions related to interbasin flow are likely incorrect as well. The McCoy Wash portion of the Palo Verde Mesa groundwater basin is not a closed basin . Inflows from upper Chuckwalla Valley groundwater basin, Rice Valley groundwater basin, and Palo Verde Valley groundwater basin, and flows through fractured mountain ranges resulting in mountain front recharge (Wilson and Guan, 2004) to the alluvial basin, all contribute to groundwater flow.

Staff's conclusion that there are not sufficient water supplies to serve the Project during normal, dry, and multiple dry-year scenarios is not supported. The statement that the Palo Verde Mesa groundwater basin does not have sufficient storage is also incorrect. According to the California DWR (2004), the basin has approximately 6.84 million acre-feet of groundwater in storage. CEC Staff inferences that pumping groundwater at the SEP site would result in a gradual lowering of the water table have been proven wrong using site-specific and basin-wide data – the water table has risen 3-5 feet over the last decade despite pumping at the adjacent BEP I.

D. Staff's Assumptions Regarding Connectivity to the Colorado River are Not Supported by Evidence

The PSA generally discusses connectivity between groundwater pumping in the Palo Verde Mesa groundwater basin and the Colorado River. This issue was addressed in detail in the 2005 Decision. In summary, in that decision the Commission determined that Palo Verde Mesa groundwater and the Colorado River are legally distinct, and project groundwater pumping would not cause a significant project or cumulative impact. The Commission stated: "With the measurement methods employed in the River, the recharge water volume is not only insignificant, it is undetectable by measurement, even though it is actually happening according to the physical laws of hydrologic recharge." (See 2005 Final Decision at p. 254 (TN# 36138).)

The issue is perhaps best described in the Groundwater Availability Report (TN# 210068) describing groundwater conditions in the Project area, which was filed just before PSA publication. The boundary between the Palo Verde Mesa groundwater basin and the Palo Verde Valley groundwater basin is generally the boundary of the current Colorado River floodplain. However, this is a topographic boundary and not a hydrologic boundary. Groundwater is not precluded from moving between basins by a low permeability zone or similar boundary condition.

Groundwater has moved between these two basins, in both directions, since time immemorial. However, the normal flow condition is for groundwater to flow from the upland areas toward the river. The attached figure shows groundwater level contours presented in the water supply assessment for the Blythe Mesa Solar Project. (See Attachment B hereto.) Superimposed on the figure are flowlines showing direction of groundwater flow. The flow direction along the boundary of the two basins is largely parallel until the point where groundwater from the Chuckwalla groundwater basin enters the Palo Verde Mesa groundwater basin. Groundwater then flows from the Palo Verde Mesa groundwater basin to the Palo Verde Valley groundwater basin. While there is certainly contribution to the groundwater flow in the Palo Verde Mesa groundwater basin from underflow from the Palo Verde Valley groundwater basin at the north end of the study area, the flow directions indicated by the contours suggest the norm is flow parallel to basin boundaries.

As discussed in Part I.A.5 above, the proposed Accounting Surface Rule is considered by CEC Staff to be potentially applicable to the SEP. The proposed rule described static water table elevations that define whether the rule would apply at a particular location. Wells with a static water table elevation lower than the accounting surface elevation at that location in the proposed rule are considered to potentially draw water from the Colorado River. If the static water table in the well is higher than the proposed rule elevation at that location, the well is not considered to be drawing on Colorado River water for recharge. The static water elevation in the BEP I production and onsite monitoring wells, and the new (currently licensed) SEP wells, are higher elevation than the proposed rule elevation and, as such, are not considered to draw water from the Colorado River.

E. Staff Has Failed to Fully Analyze the Impacts of Proposed Dry Cooling "Mitigation" As Required By Law

CEQA requires evaluation of the environmental impacts of a proposed mitigation measure. (14 Cal. Code Regs., § 15126.4(a)(1)(D) ("If a mitigation measure would cause one or more significant effects in addition to those that would be caused by the project as proposed, the effects of the mitigation measure shall be discussed but in less detail than the significant effects of the project as proposed."); see also, *Save our Peninsula Comm. v. Monterey Cty. Bd. of Supervisors* (2001) 87 Cal.App.4th 99, 130 ("An EIR is required to discuss the impacts of mitigation measures."); *Sacramento Old City Assn. v. City Council* (1991) 229 Cal.App.3d 1011, 1040 ("Even assuming the parking reduction [mitigation] measures adopted by the City Council are supported by substantial evidence showing a reduction of parking problems to insignificance, the possible adverse effects of some of the mitigation measures . . . should have been considered in the EIR.").)

The PSA fails to fully disclose and evaluate the adverse environmental impacts of proposed dry cooling mitigation (Soil&Water-7 and Soil&Water-10), which include at least increased air emissions, more severe thermal plumes, electrical capacity losses and visual impacts. (*See e.g.*, Parts II, III, VI, XIV; *see also* TN# 210068.) Moreover, the PSA completely fails to consider the feasibility of dry-cooling, as required by law. (Pub. Resources Code, § 21080(a)(3) ("Specific economic, legal, social, technological, or other considerations, including considerations for the provision of employment opportunities for highly trained workers, make infeasible the mitigation measures or the alternatives identified in the environmental impact report.").)

Project Owner has submitted information on the cost of dry-cooling, as compared to the proposed wet cooled project. (TN#210068.) Staff suggests that the cost of offsetting the SEP's water use must be taken into consideration when comparing cost of dry-cooling with cost of wet cooling, speculating about the cost to mitigate the water use. (PSA, p. 4.9-11.) Staff has selectively included the cost of offsetting water use to artificially inflate the cost of wet-cooling. Staff fails to consider other costs associated with dry-cooling, which include the costs to replace lost electrical capacity and energy losses that result from dry-cooling and cost of mitigating or offsetting increased air emissions resulting from dry-cooling. If staff intends to attempt to capture all potential costs of dry-cooling versus wet-cooling, these capacity and energy losses and increased emissions must also be accounted for. Staff's speculation about the comparative costs is, therefore, incomplete and misleading.

F. Canal Lining is an Appropriate Measure to Address Staff's Concerns Regarding SEP's Water Use

As noted above, no mitigation is required for SEP's proposed water use because SEP does not result in a significant unmitigated adverse impact. The Commission acknowledged this in the 2005 Final Decision and nothing has changed. (2005 Final Decision, p. 272.) To address Staff's concerns, the Project Owner nonetheless proposes a voluntary water conservation program. The PSA suggests that the Project Owner's proposal to offset water use with canal lining is inconsistent with the intent of the 2005 Final Decision. (PSA, pp. 4.9-12 – 4.9-13.) Staff takes out of context the 2005 Final Decision reference to "window-dressing". (*Ibid.*) In fact, the 2005 Final Decision makes clear that the Commission was concerned that the fallowing offset program could encourage increased irrigation, thereby undermining the goal of the fallowing program. (2005 Final Decision, p. 272.) The 2005 Final Decision did not consider alternative conservation programs and did not opine about the adequacy of conservation and efficiency measures such as canal lining.

On February 23, 2016, the Project Owner filed a Technical Memo (TN# 210520) describing a voluntary canal lining program to reduce water conveyance losses in the PVID systemin an amount equal to the Project's currently licensed water use of 2,800 AFY. Under the program, the Project Owner would line nine segments of the PVID canal system totaling 25,110 feet (4.76 miles) for a total water use efficiency improvement of 2,813 AFY. The cost estimate of the canal lining program is approximately $6.2 million, based on the concept design (a Class 4 cost estimate). PVID is also recommending that the Project Owner consider an additional component of the water conservation plan to further enhance PVID's water use efficiency: the addition of a Caterpillar long-reach excavator that would allow for additional drain cleaning, which would further reduce water losses.

Canal lining is a water-use efficiency measure that represents a reduction in the quantity of water diverted from the Colorado River (or an increase in water returned to the Colorado River at the Palo Verde Outfall). Although canal seepage can recharge groundwater levels, high groundwater levels can adversely affect agricultural productivity in the Palo Verde Valley. In addition, it is far better to simply keep the water in the Colorado River through reductions in diversions (or increases in direct return flows) than to rely on an indirect pathway of canal seepage. Because canal lining would enhance overall water use efficiency in the greater Blythe region, it truly and appropriately addresses the Project's currently licensed water use.

Additional information regarding the proposed voluntary canal lining program will be provided in a subsequent filing, which will also address questions posed by Staff during the February 24, 2016 PSA Workshop.

G. Additional Comments on the Soil & Water Section of the PSA

In addition to the above comments, Project Owner has the following specific comments on the proposed conditions in Certification in the PSA.

The Project Owner proposes the following revisions to Condition Soil&Water-4 to reflect the proposed disposal of SEP wastewater to the Blythe Energy Project's evaporation ponds.

~~ZERO LIQUID~~WASTEWATER DISCHARGE SYSTEM
SOIL&WATER-4: The project shall ~~operate with a Zero Liquid Discharge (ZLD)~~ wastewater **to the Blythe Energy Project's two evaporation ponds**~~ treatment system~~. A liquid wastewater discharge **to**~~either~~ the on~~-or off~~-site **evaporation ponds** is prohibited, with the exception of the temporary discharge of wastewater ~~to evaporation ponds~~ permitted by the RWQCB via the issuance of Waste Discharge Requirements during periods of ~~ZLD~~ **the Blythe Energy Project's evaporation pond**~~ system~~ outages. ~~The design shall include a schematic, narrative of operation, maintenance schedules, on-site salt cake or slurry storage facilities, containment measures and influent water quality. The design information shall also include characterization of the residual cake solid or slurry waste to be produced by the ZLD system that adequately describes the physical and chemical properties for consideration of appropriate storage, transportation, and disposal.~~ The project owner shall provide annual reporting of the functionality of the ~~ZLD~~ **wastewater disposal** system and document any problems to the CPM.

> **Verification:** Sixty (60) days prior to the start of construction~~ of the Zero Liquid Discharge (ZLD) system~~, the project owner shall submit to the CPM the final design of the **wastewater disposal** system for approval. In the annual compliance report, the project owner shall submit a status report on operation of the **~~ZLD~~wastewater disposal** system, including disruptions, maintenance, volumes of interim wastewater streams stored on site, volumes of ~~residual cake~~ solids or slurry generated and the landfills used for disposal.

The Project Owner proposes the following revisions to Condition of Certification Soil & Water-7 to be consistent with the Water Conservation Plan.

SOIL&WATER-7: No later than 6 months after the beginning of site mobilization, the project owner shall provide a Water Conservation Offset Plan (WCOP) ~~for review and comment by the Natural Resources Conservation Service (NRCS), US Bureau of Reclamation (USBR), Colorado River Board (CRB), and the Palo Verde Irrigation District (PVID), and~~ for review and approval by the CPM. The CPM-approved WCOP shall remain in effect for the life of the project~~, unless superseded by a USBR-approved WCOP following assertion of federal jurisdiction over project groundwater pumping~~. The Final WCOP shall include ~~the following:~~ **estimates of canal seepage, areas of proposed canal lining, and estimated seepage reduction (water conservation) achieved from lining each canal segment.**

~~a) Best Management Practices (BMPs) to prevent significant impacts resulting from soil erosion of the fallowed lands for all soil types.~~

~~b) Tabulation and corresponding maps of lands and the acreages proposed for fallowing and documentation to verify that they have been irrigated during at least 3 of the 5 most recent years.~~

~~c) An estimate of the water required and the methods planned to measure water use as needed to prevent soil erosion of fallowed agricultural lands, i.e., water used by a cover crop, etc., and the proposed means to include such use in the accounting method of actual water conserved.~~

Verification: No later than 6 months after the beginning of site mobilization, the project owner shall submit a WCOP ~~to NRCS, USBR, CRB and~~ PVID for review and comment, and to the CPM for review and approval. In the **first** annual compliance report, the project owner shall submit its annual accounting under the WCOP demonstrating the actual conservation of Colorado River water equivalent to SEP's annual water use~~, and that erosion impacts from fallowed/retired land remain less than significant~~.

S&W-10- As noted above, Project Owner rejects Staff's proposed changes to Soil & Water-10 and requests that the Condition remain as licensed in 2012.

II. TRAFFIC & TRANSPORTATION

A. Staff's Conclusions Regarding the Significance of the SEP Cooling Tower Plume are Unsupported by the Evidence

1. Staff's Conclusions Rely on Outdated Data

Staff relies on guidance issued by the Australian Government Civil Aviation Safety Authority (CASA) in 2004[31] to set a significance threshold of 4.3 meters per second for thermal plumes. However, that guidance is outdated, and it is being misapplied.

The 2004 CASA guidance indicated that "exhaust plumes with a vertical gust in excess of the 4.3 metres [sic] per second (m/s) threshold may cause damage to an aircraft airframe, or upset an aircraft when flying at low levels." However, according to a report prepared by the Airport Cooperative Research Program (ACRP), CASA was unable to verify the source of this threshold.[32]

The 2004 CASA guidance also states, "Since plume rise and lateral dispersion are highly dependent on crosswind and the temperature differential between the plume and ambient air, this assessment requires the use of site specific metrological [sic] data throughout the full height of the plume."[33] However, the plume rise calculation technique (the Spillane method) currently used by Staff does not use site-specific meteorological data; rather, it evaluates only a worst-case condition for plumes occurring during calm wind conditions. Therefore, the plume rise assessment performed by Staff using the Spillane method is inconsistent with the 2004 CASA guidance and the 4.3 m/s vertical velocity is not being applied in accordance with the guidance.

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[31] Australian Government Civil Aviation Safety Authority (CASA) Advisory Circular AC 139-05(0), June 2004.

[32] DeVita, P., Email to Anna Henry, CASA Airspace Specialist, Harris Miller & Hanson Inc., June 5, 2013. From Transportation Research Board, Airport Cooperative Research Program (ACRP) Report 108, 2014, p. 55.

[33] CASA 2004, p. 4 (emphasis added).

The CASA guidance was revised in 2012[34] to include a new critical plume velocity criterion of 10.6 m/s, along with a revised plume assessment methodology and new mitigation options if the plume assessment shows a potential hazard to aircraft. The new 10.6 m/s criterion is based on Airservices Australia's "Manual of Aviation Meteorology"[35] which defines severe turbulence as vertical wind gusts in excess of 10.6 m/s, which may cause a momentary "loss of control." If Staff wishes to rely on CASA guidance for determining the significance of plume velocities, the current threshold velocity of 10.6 m/s should be used instead of relying exclusively on the outdated and unsubstantiated 4.3 m/s threshold.

If a CASA evaluation determines that plume rise has the potential for significant impact, the 2012 CASA guidance provides mitigation options for plume rise impacts, such as inserting a symbol and height on aviation charts to make pilots aware of the plume rise, designating a "danger area" on aviation charts to alert pilots to the potential plume hazard, or designating a "restricted area" on aviation charts to alert pilots not to fly over the area.[36] In fact, the VFR map for the Blythe Airport already includes markings notifying pilots of the presence of a power plant and a notice to "avoid direct overflight of power plant."[37] Thus, even if an assessment were to show that the potential plume impacts associated with SEP were significant, appropriate mitigation measures have already been implemented for the adjacent Blythe Energy Project (BEP) and are also available for SEP.

With respect to guidance in the U.S., the ACRP guidebook[38] recommends that a plume assessment

[34] Australian Government Civil Aviation Safety Authority (CASA), Advisory Circular (AC) 139-5(1), November 2012. "Plume Rise Assessments". The June 2004 advisory circular is no longer referenced on the CASA website.

[35] Airservices Australia, "The Manual of Aviation Meteorology," 2003.

[36] CASA 2012, p. 5.

[37] http://vfrmap.com/?type=vfrc&lat=33.619&lon=-114.717&zoom=10

[38] Transportation Research Board, Airport Cooperative Research Program (ACRP) Report 108, "Guidebook for Energy Facilities Compatibility with Airports and Airspace," 2014, p. 56.

> "… should evaluate the height at which the plume velocity from the exhaust stack reaches the average vertical velocity criterion of 4.3 m/s along with the new critical plume velocity criterion of 10.6 m/s. To put these two thresholds into some perspective, the 4.3 m/s is equivalent to the wind blowing at 9.61 mph (or 8.4 knots) and the 10.6 m/s threshold is equivalent to a wind blowing at 23.7 mph (or 20.6 knots). Using the Beaufort Wind Scale,[39] ***the 4.3 m/s is characterized under the Beaufort scale as a gentle breeze described as leaves and small twigs constantly moving.*** The 10.6 m/s is characterized as a fresh breeze described where small trees in leaf begin to sway." [emphasis added]

A "gentle breeze" is clearly not a significant impact or even a potentially significant impact that requires mitigation.

The ACRP guidebook for energy facilities' compatibility goes on to state, "[t]he 4.3 m/s is not a standard, but rather a trigger for further plume assessment in order to evaluate the potential hazard to aircraft operations."[40] Staff, however, misapplies the 4.3 m/s threshold as an absolute standard that determines significance, contrary to aircraft safety expert guidance.

2. Staff Should Also Consider Frequency with which Worst-Case Meteorological Conditions Occur in Determining Significance of Thermal Plumes

As discussed above, the Spillane method of calculating thermal plume velocity used by Staff evaluates only a worst-case condition for plumes occurring during calm wind, cold temperature conditions.

> Thermal buoyancy is greatest for the cooling towers when the temperatures are cold and relative humidities are high as this causes the highest differential between exhaust temperature and ambient temperature… Wind causes increased mixing which limits both the initial vertical plume height potential due to its initial momentum and the effect of the thermal buoyancy. It is under calm

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[39] U.S. National Oceanic and Atmospheric Administration (NOAA), "Beaufort Wind Scale": http://www.spc.noaa.gov/faq/tornado/beaufort.html.

[40] ACRP 2014, p. 55.

> conditions that plume maintain their coherence and will maintain the highest velocity potential.[41]

Therefore, to fully evaluate the potential significance of thermal plumes from the Project, it is also important to consider the frequency with which these worst-case ambient conditions occur. The following table summarizes wind speed and ambient temperature statistics for Blythe Airport for a 7-year period, 1989 through 1995.

Summary of Ambient Temperatures and Wind Speeds, Blythe Airport 1989-1995

Wind Speed (m/s)	All Ambient Temperatures				Ambient Temperature ≤70°F				Ambient Temperature ≤39°F			
	All Hours		Between 9 am and 6 pm		All Hours		Between 9 am and 6 pm		All Hours		Between 9 am and 6 pm	
	No. of Hours	% of Hours	No. of Hours	% of Hours	No. of Hours	% of Hours	No. of Hours	% of Hours	No. of Hours	% of Hours	No. of Hours	% of Hours
Calm	7,286	11.9%	2,231	3.6%	4,478	7.3%	1,034	1.7%	179	0.3%	1	0.002%
<= 1.0 m/s	7,379	12.0%	2,257	3.7%	4,527	7.4%	1,044	1.7%	185	0.3%	1	0.002%
<= 2.1 m/s	16,170	26.4%	4,873	7.9%	9,532	15.5%	2,111	3.4%	376	0.6%	1	0.002%
<= 2.6 m/s	25,708	41.9%	7,559	12.3%	14,443	23.5%	2,952	4.8%	537	0.9%	1	0.002%
> 2.6 m/s	32,199	52.5%	14,196	23.1%	11,614	18.9%	3,281	5.3%	286	0.5%	9	0.015%
Missing WS	3,437	5.6%	1,249	2.0%	1,088	1.8%	264	0.4%	31	0.1%	1	0.002%
Total	61,344	100%	23,004	38%	27,145	44%	6,497	11%	854	1%	11	0.02%

The table includes "[c]onditions conducive to creating the most significant plume turbulence; calm wind speed conditions (<2 knots or 1meter per second [m/s]) when the ambient temperature is below 70F."[42] The table also shows the frequency with which these conditions occur when the ambient temperature is 39 degrees or below, which is the temperature at which the worst-case thermal plume velocity analysis has been evaluated. The table shows that these conditions occur during approximately 7 percent of hours per year (based on 7 years of historical data), while calm winds and temperatures at or below 39°F (reflecting the worst-case thermal plume velocity modeling conditions) occur less than 1 percent of hours per year. Staff has further indicated in testimony on thermal plumes in the Blythe area that the time period of most concern is 9 am to 6

[41] Blythe Energy Project Phase II (BEP II), Final Staff Assessment (FSA), April 2005, p. 4.10-38.

[42] BEP II FSA 2005, p. 4.10-37.

pm.[43] These frequencies are further reduced to 3 percent of hours per year and 0.002 percent of hours per year, respectively, during this time period of most concern.

This is consistent with Staff's testimony in the BEP II case, where they found that "[t]he conditions conducive for turbulence and plume occurrence overlap and both occur almost exclusively from October through May and with the vast majority occurring during the overnight and morning hours (10 pm to 10 am),"[44] the conditions under which worst-case thermal plumes are expected to occur are rarely experienced during the 9 am to 6 pm time period of most concern.

3. Staff's Conclusions Are Not Consistent with FAA Guidance

The Federal Aviation Administration ("FAA"), not the CEC or CASA, is the agency with jurisdiction over airport safety in California. The FAA has issued new technical guidance on evaluating the potential impact of thermal plumes on airport operations.[45] Staff's application of the 2004 CASA significance threshold to the results of plume modeling based on the Spillane method considering only calm wind conditions is inconsistent with the FAA's finding that "…the plume size and severity of impact on flight can vary greatly depending on several factors at a site such as… [l]ocal winds, ambient temperatures, stratification of the atmosphere at the plume site."[46] While the FAA guidance recommends that "[a]irport sponsors and land use planning and permitting agencies around airports are encouraged to evaluate and take into account potential flight impacts from existing and planned development that produce plumes…"[47], this guidance does not include any thresholds of significance or determinations regarding unacceptable impacts of thermal plumes. The FAA expects to issue an updated Advisory Circular to include guidance on airport compatible land use issues, including

[43] Staff Assessment and Draft Environmental Impact Statement for the Blythe Solar Power Project, March 2010, p. C.10-42. (TN# 55836).

[44] BEP II FSA 2005, p. 4.10-37.

[45] Federal Aviation Administration Memorandum, "Technical Guidance and Assessment Tool for Evaluation of Thermal Exhaust Plume Impact on Airport Operations," September 24, 2015; p. 2

[46] FAA 2015, p. 2.

[47] FAA 2015, p. 2.

evaluation of thermal exhaust plumes, in Fiscal Year 2016.[48] Meanwhile, the FAA guidance notes that the Aeronautical Information Manual has been updated to instruct pilots to avoid flight in the vicinity of exhaust plumes.[49]

To aid in performing the recommended reviews, the FAA has sponsored the development of a new model, the MITRE Exhaust-Plume-Analyzer, which takes into account local meteorological conditions. The FAA guidance indicates that "[t]he MITRE Exhaust-Plume-Analyzer can be an effective tool to assess the impact exhaust plumes may impose on flight operations at an existing or proposed site in the vicinity of an airport."[50]

The MITRE Plume Hazard Model incorporates the Spillane methodology as well as vertical acceleration (gust) and roll modeling.[51] The model evaluates plume behavior under all wind conditions, not just calm conditions, and evaluates the probability of severe turbulence and upset.[52] Although no threshold of significance has been established for the results of the MITRE model, the MITRE model output includes data relating the plume velocity at various elevations to "…the TLS (Target Level of Safety) of 1.0×10^{-7} that was considered the acceptable level of risk based on the 2006 FAA Safety Risk Analysis."[53]

The MITRE model currently provides only two-dimensional graphical output, and the ability to customize the assessments is very limited.[54] The model is also limited in that it can assess only a single plume or multiple identical plumes (such as from a cooling tower), so it cannot be used to evaluate cumulative impacts from multiple plume sources.

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48 FAA 2015, p. 2.

49 FAA, "Change 1 to Aeronautical Information Manual (AIM), effective 7/24/14," Section 7-5-15: "Avoid Flight in the Vicinity of Exhaust Plumes (Smoke Stacks and Cooling Towers)."

50 FAA 2015, p. 2.

51 MITRE, Exhaust Plume Analyzer User Guide, October 2014, p. 11.

52 MITRE 2014, p. 12.

53 ACRP 2014, p. 56.

54 Personal communication between Sierra Research and Ryan W. Huleatt of MITRE, October 2015.

4. Staff's Assertion that the SEP Modeling Shows a Higher Velocity Plume than the Previously Modeled BEP II Plume is Not Correct

In the PSA, Staff compares the results of the cooling tower thermal plume modeling submitted by the Applicant for SEP with the modeling results for the BEP II cooling tower. In the Traffic and Transportation section of the PSA, Staff states,

> Staff's plume modeling conducted for BEP II estimated that plumes from the cooling tower and turbines with sufficient velocity to cause turbulence (4.3 m/s) would easily exceed 500 feet above the ground. For SEP, the project owner has estimated under worst-case conditions that the thermal plumes emitted from the gas turbine and the cooling tower will exceed the critical velocity of 4.3 m/s at elevations up to 800 feet and 1,088 feet above the ground, respectively.[55]

Staff goes on to say that they would be conducting their own plume velocity analysis for the Project as proposed and for the Staff-proposed ACC. However, the Executive Summary makes no reference to the need for additional analysis and concludes,

> …the project owner's thermal plume modeling results … predict higher velocity plumes from the SEP compared to the BEP II.[56]…

In the Land Use section, Staff repeats this unfounded conclusion, stating,

> The results of the project owner's thermal plume analysis predict higher velocity plumes for the SEP than the plumes analyzed under the 2005 Decision.[57]

These conclusions are not valid because they are not based on comparable modeling results. In addition, the results of the thermal plume modeling performed by Staff for the original design as

[55] Sonoran Energy Project – Petition to Amend – Preliminary Staff Assessment (PSA), Section 4.10 (Traffic & Transportation), p. 4.10-7. (TN #210090)

[56] PSA p. 2-11.

[57] PSA p. 4.5-1.

part of the BEP II proceeding do not demonstrate that the BEP II cooling tower plumes had lower velocity than the SEP cooling tower plumes.

In the SEP PTA, the Project Owner used the Spillane methodology to determine that under calm wind, cold ambient conditions, the combined cooling tower plume height would exceed 4.3 m/s up to a height of 1,046 feet above stack top (1,088 feet above ground).[58] (This analysis was performed to be consistent with prior staff analyses, and not because the Project Owner believes that the 4.3 m/s criterion is appropriate.) In contrast, Staff's evaluation of cooling tower exhaust plume turbulence in the BEP II FSA (2005) used the SCREEN3, SACTI and CSVP models. Staff's evaluation in the BEP II FSA concluded that "the plume will rise well over 500 feet above ground, which would indicate the plume velocity would likely still be quite high at 500 feet above ground… it is expected that the plume average velocity at 500 feet would be greater than 4.3 m/s (846 fpm) under the proper ambient conditions."[59] This analysis in the BEP II FSA indicates only that the velocity will exceed 4.3 m/s at 500 feet above the ground; it does not indicate at what elevation the thermal plume velocity would fall below the inappropriate 4.3 m/s criterion.

Further, the Staff did not evaluate potential thermal plume impacts from the amended BEP II project design that was approved in 2012, despite the fact that the modification included an increase in the size of the cooling tower.[60] In fact, the analysis of the BEP II cooling tower thermal plume velocity for the most recently approved project design using the Spillane methodology, included as Attachment C hereto, shows that the velocity of the combined thermal plume from the BEP II cooling tower would have exceeded 4.3 m/s up to approximately 1,131 feet AGL, higher than the 1,088 feet AGL height for the SEP cooling tower plume. Therefore, the conclusion that the SEP cooling tower plumes would have higher velocities than the BEP II plumes is simply incorrect and should not be relied upon by Staff to draw conclusions regarding significance. To the contrary, impacts of the SEP cooling tower thermal plumes would be less than or equivalent to what is currently licensed.

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[58] Blythe Energy Project Phase II – Petition to Amend (PTA), Appendix 3.11A, August 2015.

[59] BEP II, FSA, 2005, p. 4.10-41.

[60] Staff Analysis, Blythe Energy Project Phase II Petition to Amend, March 2012, p. 1 ("…[i] Increase in size of cooling tower by 1,020 square feet to improve the efficiency and performance of the plant at higher temperatures)."

B. Use of Dry Cooling at SEP Expected to Have Higher Thermal Plume Impacts Than the Proposed Wet Cooling System

As discussed above (Section I.E), the PSA fails to properly evaluate the impacts of the proposed dry-cooling mitigation.

As discussed in Data Response 22,[61] the Project Owner has not performed a detailed thermal plume velocity analysis for a dry cooled alternative at the SEP because such an analysis would require a fully designed dry cooling system. The thermal plume characteristics are extremely sensitive to the input values used in the Spillane Approach that reflects the CEC Staff's current plume velocity analysis procedure.[62] The Spillane Approach calculations require detailed information regarding exhaust temperature and velocity. However, these parameters are inversely related (higher fan velocity will result in lower exhaust temperature and vice versa), and fan velocity also determines the noise level of the ACC. Without final decisions regarding such design parameters, any detailed thermal plume velocity analysis would be speculative and would not necessarily be representative of actual ACC performance.

However, based on the results of previous studies of ACCs and ACC alternatives in the Project area, thermal plume impacts from an ACC at the SEP site likely would be more significant than thermal plumes from the mechanical draft wet cooling tower that has been proposed for the Project. In the PSA, Staff state that a preliminary analysis of thermal plume impacts from dry cooling at SEP show "the ACC critical plume velocity of 4.3 meters per second (m/s) is predicted to occur up to 1,500 feet AGL."[63] This is over 350 feet <u>higher</u> than the height of the critical plume velocity for the SEP wet cooling tower. Further, based on a Staff-conducted Exhaust Plume Turbulence analysis for the Blythe II project, the Blythe II Final Decision concluded that the use of dry cooling for the proposed BEP II would have significant impacts on aircraft safety at the proposed site, based on the following findings:

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[61] AltaGas Sonoran Energy Inc., "Data Responses, Set 1," dated November 12, 2015. (TN# 206606).

[62] See also Appendix 3.11A (Thermal Plume Analysis) to the PTA.

[63] PSA Section 4.10 (Traffic & Transportation), p. 4.10-7.

1. Dry cooling thermal plumes would have the potential to cause significant turbulence over a much wider range of ambient conditions and number of hours annually than the wet cooling tower thermal plumes.

2. Dry cooling thermal plumes would be more resistant to the effects of wind than wet cooling tower thermal plumes.

3. Dry cooling thermal plumes would cause air turbulence at low altitudes.

4. Turbulence caused by the dry cooling thermal plumes would likely be worse than that caused by the wet cooling tower during warmer ambient temperatures and during periods with higher wind speeds. [64]

CEC Staff evaluated thermal plume impacts from ACCs proposed for the Blythe Solar Power Project (2009-AFC-06) and found the following:

> The air-cooled condensers would produce thermal plumes, resulting in updrafts of varying velocities, depending on weather conditions and the level of load at the power plant. Updraft velocities would be highest when winds are calm and during full load operating conditions. Because the air vented from the air-cooled condensers would contain negligible moisture and the ambient air is usually dry, water vapor would not routinely form in and around the plumes. Thus, they would usually be invisible to pilots.[65]

In the PSA, Staff also indicated that "[t]hermal plume impacts could potentially be increased due to the proposed change in [cooling] technology for the SEP"[66] and "Staff is proposing the SEP use dry cooling instead of a wet cooling tower for the SEP. Dry cooling would emit invisible thermal plumes rather than visible water vapor. A preliminary analysis for dry cooling was

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[64] Final Decision at p. 263. (TN# 36138.)

[65] Blythe Solar Power Project (Docket No. 09-AFC-6): Supplemental Staff Assessment Part 2: Aviation Assessment, July 2010, p. 22. (TN# 57532.)

[66] PSA, Section 4.5 (Land Use), p. 4.5-13.

conducted by staff that shows a significant increase in plume velocity as compared to a wet cooling tower."[67]

The concern regarding thermal plume visibility has also been highlighted by the Transportation Research Board[68] in a report regarding impacts of energy technologies on aviation:

> Thermal plumes are created by power plants using dry cooling systems releasing hot air that rises at a measurable rate and causes air turbulence. Unlike a vapor plume, that turbulence cannot be perceived by a pilot, which increases the potential risk to aviators. [p. 4]
>
> It is possible that aircraft are less affected by vapor plumes (than thermal plumes) because they are a recurring feature that can be seen allowing pilots to make adjustments as needed. [p. 18] [69]

Based on evaluations of thermal plume impacts conducted by CEC Staff and aviation safety experts, the implementation of a dry cooling system at SEP is likely to result in increased hazards to aircraft due to increased frequency and severity of turbulence, and to the lack of a visible vapor plume that would alert pilots to the potential for turbulence. (See also, Letter from Edward Cooper, Director Riverside County Airport Land Use Commission to Jim Adams, CEC (Feb. 10, 2016) (TN# 210490).)

C. Existing Condition TRANS-9 Is Not Feasible

The current Project license includes condition TRANS-9, which requires action by others (i.e., *not* the Project Owner) to modify the airport's Automated Surface Observing System ("ASOS"),

[67] PSA, Section 4.10 (Traffic & Transportation), p. 4.10-1 (emphasis added).

[68] Transportation Research Board, Airport Cooperative Research Program (ACRP) Synthesis 28: Investigating Safety Impacts of Energy Technologies on Airports and Aviation. 2011.

[69] Although this remark was made in the chapter that addresses solar project impacts, the chapter on traditional power plants observes, "Thermal plume turbulence for traditional power plants is generally the same as that described in the Thermal Plume Turbulence section in chapter three for concentrated solar power projects. The dry-cooling system, typically an air-cooled condenser, is the same structure regardless of how the power plant generates steam that requires cooling." (*Id*. at p. 27.)

change traffic patterns, and redesignate runways. These requirements cannot be implemented by the Project Owner and, for this and other reasons, Trans-9 requires revision. In particular, changes to the VFR traffic pattern and redesignation of the primary runway would require actions by the Airport and FAA; both have already indicated that they would not support these changes at this airport.

1. ASOS

TRANS -9 requires that "[a] remark [be] placed on the Airport's Automated Surface Observation System (ASOS), or equivalent broadcast, advising pilots to avoid low altitude direct overflight of the power plant". However, the ASOS program is a joint weather reporting system operated by the National Weather Service in cooperation with the FAA and the Department of Defense. The ASOS is designed to measure current weather conditions and transmit those data via radio and telephone. There is no information available that indicates the technical capability exists to add data to that broadcast. (ASOS Users Guide, Attachment D hereto.) Thus, it is inappropriate to impose this requirement on SEP.

2. Changes to VFR Traffic Pattern

TRANS-9 also requires that "[t]he VFR traffic pattern to runway 26 [be] changed from left-hand turns to right-hand turns." This would change the direction of turns for aircraft while in the pattern from left to right. However, the FAA has established left turn traffic patterns as the norm in the United States. In fact, at uncontrolled airports such as Blythe Airport ("BLH"), the FAA states that left traffic patterns should be established except where obstacles, terrain, and noise sensitive areas dictate otherwise. (FAA AC 90-66A, Attachment E hereto.)

The major rationale for the FAA's position is the fact that the pilot normally sits on the left side of the aircraft and the pilot is able to more clearly see the airspace that he/she is turning into. In addition the pilot can more easily see the runway and other ground based objects. This is particularly important when trying to avoid overflight of a specific area.

The movement of the existing traffic pattern to the north also would place it directly over the existing north/south runway. This is a less desirable location due to the proximity to aircraft electing to use the north/south runway, specifically runway 35. FAA, therefore, is unlikely to authorize the change in traffic pattern and this requirement is likely infeasible.

3. Redesignation of the Primary Runway

Finally, TRANS-9 requires that "[a] runway, other than runway 26, [be] designated as the primary calm wind runway." Runways at airports are normally designed to align with the prevailing wind conditions at the specific airport location. The design of the primary runway is intended to accommodate the most prevalent annual average wind conditions. In most cases the longest and best equipped runway from a navigational/lighting perspective accommodates this standard. This is the case at Blythe airport. Runway 26 is 6543 feet long and 150 feet wide while runway 35 is shorter and narrower (5800 feet long and 100 feet wide). Runway 26 also has approximately two times the weight bearing capacity of runway 35. The two instrument approach procedures into Blythe airport which specify a runway (RNAV/GPS RWY26 and VOR/DME RWY 26, Attachments F and G hereto) use runway 26. Although both runways have 4 box VASI (Visual Approach Slope Indicator) lights installed, it is unlikely the airport or the FAA would endorse a change to the current designated primary runway based on the other superior attributes of runway 26. Therefore, this requirement is infeasible.

In addition to the foregoing, the 2005 Decision contains language regarding TRANS-9 being "subject to" and "requir[ing] FAA approval." (2005 Decision at pp. 126, 189-90.) Since FAA approval is required, the Commission expressly stated that the Commission shall retain jurisdiction to impose or, as appropriate, seek the FAA's imposition of alternate or additional measures if circumstances warrant." (*Id*. at p. 190.) The Commission clearly intended that TRANS-9 could be revised in the event that FAA approval was not obtained and/or if the FAA recommended alternate measures be implemented. As acknowledged by Staff, it is unlikely that the FAA or the Airport will approve implementation of TRANS-9 as currently written.[70]

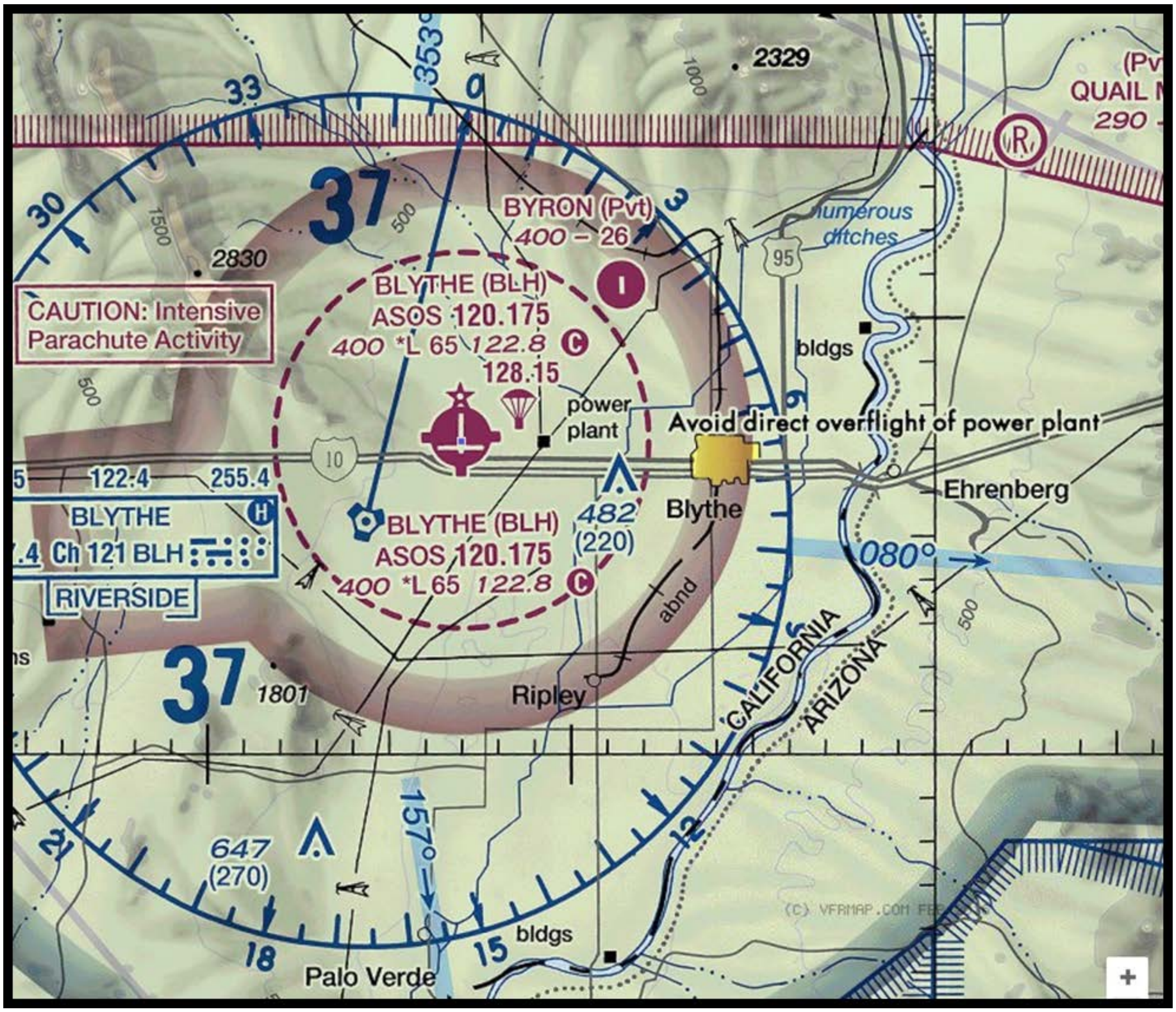
4. Existing Plume-Related Safety Measures at BLH

a. VFR Sectional Chart Markings and Other FAA Information

Aviation safety in the vicinity of the current generating facility adjacent to the proposed site is provided by the FAA and the airport in a manner consistent with the methods used nationwide to identify potential flight risks to pilots. Specifically, the Visual Flight Rules

[70] Traffic and Transportation – Record of Conversation re Blythe Airport and TRANS-9, p. 2. (TN #207014)

(VFR) charts contain information on parachute drop areas/activity, bird concentrations, power plants and transmission lines among many others. The current VFR Sectional chart for Blythe airport shown below (AirNav.com 2/24/2016) provides information regarding the existing BEP facility. Specifically, the location of the BEP facility is identified with the notation “power plant,” and an additional notation states “Avoid direct overflight of power plant.”



In addition, the directory information published by various entities on the features and services at Blythe Airport contain a similar advisory, shown as “Additional Remarks” below.. These publications are widely available both on-line and in written form[71] and are the method employed by the FAA to designate information critical to VFR flight.

Additional Remarks

- ACFT OVER 12500 LBS AVOID HOUSING AREA 1.5 NM SW BLO 2000' FINAL APCH RWY 35 BE ESTABD 2 NM FM TOUCHDOWN.
- DEP FM RY 17 MAKE CLIMBING LEFT TURN SOON AS SAFETY PERMITS. USE WIDE TFC PATTERN FOR RYS 26 & 35.
- POWER PLANT 1 MILE EAST OF ARPT PRODUCING THERMAL PLUMES; AVOID LOW ALTITUDE DIRECT OVERFLIGHT OF THE POWER PLANT.
- PAJA. PRCHT TRNG HIGH AND LOW LVLS ALL HRS NE QUAD OF ARPT

Since the current notification methods provide a high level of awareness to pilots as to the location of the existing power plant and a resultant safe flying environment at Blythe airport, it is recommended that the same methods be employed to assure aviation safety for the SEP.

b. Lighting

The lighting of the power plant structures is appropriate if such lighting does not potentially cause confusion on the part of pilots. For example, the lighted structure is normally the tallest, most significant obstruction in a given area, For this reason, lighting a shorter structure (such as a cooling tower) could be dangerously misleading to pilots unfamiliar with the airport. Lighting the stack is already required by existing Condition TRANS-8.

To the extent that the FAA, Blythe Airport, Riverside County ALUC, and CEC Staff believe additional measures would be appropriate, the Project Owner looks forward to constructive discussions regarding additional appropriate and feasible measures.

III. VISUAL RESOURCES

As discussed above (Section I.E), the PSA fails to properly evaluate the impacts of the proposed dry-cooling mitigation.

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[71] For example, see http://www.airnav.com/airport/kblh.

The Project Owner discussed the potential for significant visual impacts from an ACC in the January 28, 2016 supplemental filing. (TN# 210068.) In the Visual Resources section (4.12) of the PSA, Staff acknowledges that the potential visual impacts of dry cooling technology have not been assessed, and indicates that these impacts will be evaluated as part of the Final Staff Assessment. A meaningful assessment of potential visual impacts of dry cooling at SEP must consider not only the likely design of an ACC but also where the ACC would be located. Staff suggests that an ACC "would most likely be located just north of the proposed power block location."[72] In general, the ACC would need to be located as close as possible to the steam turbine because of the size of the ducting required to connect the steam turbine exhaust and the cooling structure. However, locating the ACC to the north of the current power block location would situate it away from the steam turbine, and would cause the ACC to encroach on Airport Land Use Zone C and move the ACC closer to the centerline of runway 26. To accommodate an ACC at SEP, the power block would have be shifted south, closer to Hobsonway, and the ACC would be located southwest of the power block. This design change would require the ACC to be located where it would be visible from Hobsonway and I-10 (Key Observation Point 1), rather than being located behind the power block where it would be less noticeable.

As noted in the PSA, Staff acknowledges that SEP's major structures would be taller but fewer than those of BEPII, resulting in an overall smaller project profile and footprint. The addition of an ACC, with substantially larger dimensions than the proposed wet cooling tower, will significantly alter Staff's assessment of the visual impacts at Key Observation Point (KOP) 1 and possibly at KOP 2 and KOP 3 as well.

In addition to the above comments, Project Owner has the following comments on the Visual Resources section of the PSA.

- Page 4.12-9, Cumulative Impacts, 2nd full paragraph – This paragraph identifies a reasonably foreseeable cumulative project as the Irish Energy Project. Because the Irish Energy Project has not been publicly announced, and design of the project is not yet complete it is not reasonably foreseeable; therefore, cumulative impacts associated with this project are speculative. If the Irish Energy Project begins the licensing process, cumulative impacts for that Project plus any other reasonably foreseeable projects, including the SEP, will be analyzed. Since impacts are only cumulative significant if both SEP and IEP are constructed, it only makes sense to consider those impacts during the

[72] FSA, p. 4.12-9

licensing of IEP, should such a license application be filed. As such, the Irish Energy Project should be removed from the SEP cumulative impact analysis due to the circular logic.

IV. EXECUTIVE SUMMARY

Project Owner is concerned that various "summary" paragraphs in the Executive Summary do not match the respective environmental assessment discussions contained the PSA and provide an incorrect "roadmap" of what is in the PSA. In addition to the foregoing, Project Owner has the following comments on the Executive Summary section of the PSA.

- Pages 2-2 through 2-14 – This section summarizes staff's position and analyses regarding the proposed water supply and mitigation plan, wastewater disposal, the status of the Section 106 Memorandum of Understating, and cooling system, among other things. Please revise this section as appropriate based on the Project Owner's PSA comments set forth herein.

- Page 2-14, Transmission System Engineering – This section concludes that Staff is unable to determine if the Project would comply with LORS because the System Impact Study (SIS) has yet to be completed. In reality, the existing Conditions TSE-1 through TSE-8 will ensure that SEP will be constructed (through review of proposed designs and inspections of constructed facilities by the CPM-appointed Chief Building Official) and operated consistent with applicable LORS without the need for the SIS results. Finally, Western Area Power Administration indicates that the SIS will be released by mid-March 2016.

V. PROJECT DESCRIPTION

Project Owner has the following comments on the Project Description section of the PSA.

- Page 3-5, Water Supply, Treatment, and Wastewater Discharge, 3rd paragraph – As discussed during the February 4, 2016 PSA Workshop. Project Owner proposes to dispose of process wastewater to the existing Blythe Energy Project's evaporation ponds and only rely on the SEP evaporation ponds as contemplated in existing condition BIO-12 for emergency purposes only. Additional information related to SEP's wastewater discharge will be docketed in a forthcoming filing. Please update this paragraph with the new proposed process wastewater disposal approach.

VI. AIR QUALITY

Project Owner has the following comments on the Air Quality section of the PSA.

A. Changes and Corrections to the Air Quality Section

1. Comments on the Staff's Air Quality Analysis

In Air Quality Table 5, Staff shows NOx emissions during commissioning activities as 625 lb/hr and 70 tons/yr. The Project Owner notes that the maximum NOx emission rates during commissioning of the SEP were revised in the December 17, 2015, submittal[73] to 550 lb/hr and 66 tons/yr; Air Quality Table 5 should be updated to reflect the Project Owner's current proposed emission rates.

On page 4.1-9, Staff states, "It is assumed that both CTGs could startup simultaneously." Since there is only one CTG in the revised SEP plant design, this statement is no longer relevant and should be deleted.

In Staff's discussion of secondary pollutant impacts on p. 4.1-14, Staff inadvertently omitted the number "5" from the recommended ammonia slip limit.

2. Comments on Conditions of Certification/Verification Conditions

Several of the Verification conditions refer to "each combustion turbine, "each duct burner system," "each selective catalytic reduction system," "each oxidation catalyst system," "each cooling tower," and "either turbine." To avoid confusion, we request that the Staff correct these references to reflect the current plant design of a single combustion turbine and duct burner and single cooling tower.

AQ-2, Verification: Please correct the reference to the applicable NSPS from Subpart GG to Subpart KKKK.

AQ-6: Please correct the CO emissions limit during cold starts to 136 pounds per hour.

[73] "Project Owner's Additional Responses to Staff's Data Requests 2 and 4," TN# 207068, December 17, 2015. Attachment DR4-R2.

AQ-6. Emissions of CO and NOx from this equipment, including the duct burner, may exceed the limits contained in Condition 4 during startup and shutdown periods as follows:

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b. During a cold startup emissions shall not exceed the following, verified by CEMS:

i. NOx – 187.5 lb

ii. CO – ~~134.0~~ **136.0** lb

***

AQ-11: Please correct the condition as follows:

AQ-11. Emissions of NOx, CO, CO2, oxygen and ammonia slip shall be monitored using a Continuous Emissions Monitoring System (CEMS). Turbine fuel consumption shall be monitored using a continuous monitoring system. Stack gas flow rate shall be monitored using ~~**either**~~ a Continuous Emission Rate Monitoring System (CERMS).

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AQ-17: Please revise the condition to be consistent with the MDAQMD's current proposed conditions:

AQ-17. The o/o must surrender to the District sufficient valid Emission Reduction Credits for this equipment before the start of construction of any part of the project for which this equipment is intended to be used. In accordance with Regulation XIII the operator shall obtain 85.6 tons of NO_x and 23.3 tons of VOC offsets. **NOx ERCs may be used to meet the VOC offset obligation at a ratio of 1:1**.

AQ-21a: As part of the revised one-hour NO_2 modeling assessment provided in the December 17, 2015 submittal, the maximum hourly NOx emission rate during commissioning was reduced from 625 pounds per hour to 550 pounds per hour and the maximum daily NOx emissions during the commissioning period were revised accordingly. These emission rates have been corrected in the MDAQMD's current proposed conditions. Please revise the hourly and daily NOx limits in Condition AQ-21 to reflect these new, lower limits as follows:

AQ-21. During the commissioning period, the emission rates from the gas turbine system shall not exceed any of the following limits:

a. NOx (as NO2) – ~~625~~ **550** lb/hr and ~~15,610~~ **13,750** lb/day;

***

AQ-25 and -26, Verification: The Verification conditions refer to a "supplemental health risk assessment" that must be submitted to the District and the CPM within 45 days of the initial compliance test. The project owner requests that this requirement be deleted, as no justification has been provided for requiring any additional analysis of health risks from the project beyond the information already provided.

> **Verification:** The results of the initial compliance test (see **AQ-24**) ~~and a supplemental health risk analysis~~ shall be submitted to the District and the CPM within forty-five (45) days after testing.

AQ-50, Verification: The Verification condition for this condition applicable to the auxiliary boiler refers to the cooling tower. Please correct the reference as shown below.

> **Verification:** The project owner shall provide to the District and CPM, 30 days prior to installation of **the auxiliary boiler** ~~each cooling tower~~, manufacturer and design data. A summary of significant operation and maintenance events for **the auxiliary boiler** ~~each cooling tower~~ shall be included in the Quarterly Operational Reports (**AQ-SC7**).

AQ-52, Verification: The Verification condition requires the submittal of auxiliary boiler specifications at least 30 days prior to purchase to demonstrate that the auxiliary boiler meets the NSPS emission limit requirements at the time of engine [sic] purchase. While this condition is appropriate for a stationary engine, it is not appropriate for a small natural gas-fired boiler. Please revise the Verification condition as shown below:

> **Verification:** The project owner shall ~~submit auxiliary boiler specifications at least 30 days prior to purchasing auxiliary boiler for review and approval demonstrating that the auxiliary boiler meets NSPS emission limit requirements at the time of engine purchase.~~ **provide to the District and CPM, 30 days prior to installation of the auxiliary boiler, manufacturer and design data. A summary of significant operation and maintenance events for the auxiliary boiler shall be included in the Quarterly Operational Reports (AQ-SC7).**

AQ-53 and AQ-43: Please correct the hourly SOx (as SO_2) emission limits in both conditions to 0.09 lb/hr. The 0.05 lb/hr values shown are based on the annual average sulfur content of 0.25 gr/100 scf, while these short-term limits should instead be based on the 24-hour average fuel sulfur content of 0.5 gr/100 scf. These corrections have been made in the MDAQMD's current proposed permit conditions.

B. Dry Cooling at the SEP Site Would Result in Greater Air and Greenhouse Gas Impacts from the Project

As noted above (Section I.E), the PSA fails to properly evaluate the impacts of the proposed dry-cooling mitigation in the area of Air Quality and Greenhouse Gas emissions.

1. Emissions will Increase as a Result of the Reduction in Plant Efficiency

The use of dry cooling at SEP has the potential to increase air emissions and greenhouse gas impacts from the Project as a result of the reduction in gas turbine efficiency. These impacts were discussed in the Best Available Control Technology analysis included in Appendix 3.1D to the PTA and in the Project Owner's January 28, 2016, Water Resources Supplemental Filing (TN #210068):

> Dry Cooling – In evaluating once-through cooling replacement technologies, USEPA determined that dry cooling costs are sufficient to pose a barrier to entry to the marketplace for some projected new facilities. Additionally, dry cooling was determined to have a detrimental effect on electricity production by reducing energy efficiency of steam turbines, also known as the "energy penalty." The energy penalty results from the power producer utilizing more energy than would otherwise be required with recirculating wet cooling to produce the same amount of power. Dry cooling produces increased parasitic loads from larger recirculation pumps and fans required by dry cooling. Additionally, because the degree of cooling of the water affects the efficiency of the steam turbine, dry cooling can result in raising the overall heat rate of the power plant by increasing the backpressure to the steam turbine. These effects are discussed in further detail in Chapter 3 of the Technical Development Document for the 2001 NPDES Regulation. As a result of the analysis for the NPDES rule, USEPA concluded that energy penalties associated with dry cooling tower systems pose a significant feasibility problem in some climates. It follows that the energy penalty would be the highest in climates that exhibit (1) high ambient (dry bulb) temperatures, and (2) low relative humidity. As the ambient temperature increases, the convection rate between the hot water and the hot ambient air decreases in a dry cooling tower. Also, as relative humidity decreases, the rate of evaporation (which is responsible for 80 percent of the cooling) increases in a wet cooling tower. The opportunity cost of not using the most efficient cooling technology in a particular climate adds to the energy penalty. For the SEP project, it is noted that the energy

> penalty would be highest at the time of peak demand, i.e., summer heat episodes when the plant would theoretically be operating at its peak load.
>
> ***
>
> Because of energy penalties, power plants using dry cooling burn more fuel and produce more air emissions per kilowatt-hour of energy produced.

The use of dry cooling will increase the plant net heat rate by up to 7 percent, depending upon ambient conditions, meaning that the gas turbine would need to consume up to 7 percent more fuel to achieve the same performance (in terms of net power output to the grid). This would in turn increase emissions of all pollutants, including greenhouse gases, by up to 7 percent during plant operation. Although the increases would be offset to some extent by the elimination of direct PM emissions from the wet cooling tower, the use of dry cooling still would be expected to result in a net increase in PM10 precursor emissions, as discussed further in Section B.1.c below.

Revised Plant Performance Summary

Ambient Condition (Case #)	39 deg (Case 20758)	74 deg (Case 20761)	74 deg (Case 20762)	110 deg (Case 20764)	110 deg (Case 20765)	122 deg (Case 19950)
Gross Output (kW)	543,923	525,291	496,258	526,546	497,325	514,585
Est Plant Aux Power (kW)	17,406	15,759	14,143	15,796	14,174	15,438
Additional Loss from ACC (kW)	7,537	7,134	7,000	24,900	23,861	36,418
Adjusted Net Output (kW)	518,981	502,398	475,115	485,850	459,290	462,729
Fuel Input Gas Turbine, MMBtu/hr (HHV)	3,161.8	3,034.7	3,034.7	3,055.4	3,055.4	2,990.9
Fuel Input Gas Turbine, MMBtu/hr (LHV)	2,853.6	2,738.9	2,738.9	2,757.6	2,757.6	2,699.4
Fuel Input Duct Burner, MMBtu/hr (HHV)	221.6	221.6	0	221.6	0.0	221.6
Fuel Input Duct Burner, MMBtu/hr (LHV)	200.0	200.0	0.0	200.0	0.0	200.0
Rev Plant Net Heat Rate, Btu/kWh (HHV)	6,519.3	6,481.5	6,387.3	6,744.9	6,652.4	6,942.5
Rev Plant Net Heat Rate, Btu/kWh (LHV)	5,883.8	5,849.7	5,764.7	6,087.5	6,004.0	6,265.9
Original Plant Net Heat Rate, Btu/kWh (LHV)	5,799.7	5,767.9	5,681.0	5,790.7	5,707.6	5,808.7
Rev Plant Thermal Efficiency, % (LHV)	58.0%	58.3%	59.2%	56.0%	56.8%	54.5%
Original Plant Thermal Efficiency, % (LHV)	58.8%	59.2%	60.1%	58.9%	59.8%	58.7%
Increase in Plant Net Heat Rate	1.4%	1.4%	1.5%	4.9%	4.9%	7.3%
Reduction in Thermal Efficiency, %	-1.4%	-1.4%	-1.5%	-4.9%	-4.9%	-7.3%

(blue) from the plant performance summary
(yellow) from the SEP dry cooling study
(green) SEP calculations

2. Emissions in the Region Will Increase As a Result of the Reduction in Plant Output

The use of dry cooling will also result in approximately a 7 percent reduction in electrical output during hot weather conditions, when electrical power is most in demand.[74] This will require the dispatch of other plants with even higher emissions.[75]

As discussed in Section 3.16.2 of the PTA and in the Project Owner's January 28, 2016, Water Resources Supplemental Filing,

> Because electricity generation and demand must be in balance at all times, the energy provided by a new generating resource must simultaneously displace the same amount of energy from an existing resource. The electricity from the new generating resource will only be dispatched if it were less expensive to operate, which will occur when the new generating resource is more efficient than the existing resource. By definition, then, the new resource will produce fewer GHG emissions than the resource it is replacing.

In the PSA, Staff concurs with this finding:

> When dispatched, SEP would displace less efficient (and thus higher GHG-emitting) generation. Because the project's GHG emissions per megawatt-hour (MWh) would be lower than those of other power plants that the project would displace, the addition of SEP would contribute to a reduction of California and overall Western Electricity Coordinating Council system GHG emissions and GHG emission rate average.[76]

The reduction in net power output from SEP due to the increase in the auxiliary power requirements of the dry cooling system would need to be obtained from another generating resource that is by definition less efficient and will therefore have higher emissions. Table 3.1-45

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[74] PTA Section 3.16.4.1.

[75] PTA Appendix 3.1D, p. 3.1D-23.

[76] PSA Air Quality Appendix AIR-1, p. 4.1-60.

of the PTA compared the thermal efficiency of many of the natural gas-fired combined cycle projects built in California over the past 15 years and demonstrated that the proposed SEP has the best thermal efficiency of any of the listed projects. Therefore, any reduction in generating capacity from SEP that would occur as a result of an air cooled condenser (ACC)/dry cooling performance penalty would need to be made up from less thermally-efficient facilities that would emit more GHG emissions than SEP. It is also likely that the firming capacity that will be provided by SEP as a result of its Rapid Response characteristics (i.e., starting up and reaching full gas turbine load within 30 minutes; ramp rate of 50 MW/minute) could not be provided by existing combined cycle plants and would need to come from simple cycle gas turbines, which are even less thermally efficient, and therefore with higher emissions, than the combined cycle turbines listed in the table.

3. Estimates of the Increases in Emissions Resulting from the Use of Dry Cooling at SEP

As discussed in Sections a and b above, there are two ways that an ACC would result in increased emissions over the wet-cooled design: the higher heat rate means higher emissions during all plant operations, and the loss in output means that the unavailable megawatts would have to be made up somewhere else. Using the revised plant performance summary shown above and the 2013 temperatures at Blythe Airport, the Project Owner projects an overall 2.5 percent increase in heat rate for the plant due to the use of an ACC. In addition, the Project Owner projects a loss of approximately 68,000 MWh/yr as a result of the reduction in net plant output. The resulting increases in emissions are summarized in the table below.

	Increases in Annual Emissions Due to Change to Dry Cooling, tpy							
	NOx	SOx	CO	VOC	PM10	Ozone precursors	PM10/PM2.5 precursors	CO2e
SEP with wet cooling	85.6	8.8	78.0	24.2	40.1	109.8	158.7	1,481,963
SEP with dry cooling	87.2	9.0	79.0	24.7	33.0	111.8	153.9	1,518,669
Change in emissions	1.6	0.2	1.0	0.5	-7.1	2.1	-4.8	36,706
Additional emissions due to reduced SEP output	2.6	0.2	2.5	0.7	1.6	3.3	5.1	16,820
Overall change in emissions	4.2	0.4	3.5	1.2	-5.5	5.4	0.3	53,526

The 2.5 percent increase in heat rate was assumed to result in a 2.5 percent increase in annual NOx, SOx, CO and VOC emissions during all base load and duct-fired operation, and in total

annual GHG emissions. No change in PM_{10}[77] emissions from the gas turbine or in the emissions of other criteria pollutants during startup or shutdown was assumed.

The 68,000 MWh in lost output that would no longer be available from SEP was assumed to come from the CPV Sentinel peaking plant near Palm Springs. Sentinel is a new and efficient gas-fired peaking plant that is likely to be a comparable source of replacement generation for SEP, given its proximity to the proposed plant site and performance characteristics (fast start, fast ramp rate) that are similar to those to be provided by Sonoran. This is a conservative assumption because replacement generation from another gas-fired power plant would be less efficient and would result in higher emissions. Emission rates for the Sentinel gas turbines were taken from that plant's air permit. The calculation does not include emissions from any additional startups that might occur at the Sentinel facility.

These calculations show that a change to wet cooling would result in increases in all directly-emitted pollutants except PM_{10}. They also show that in spite of the elimination of up to 7.1 tons of directly-emitted PM_{10} from the cooling tower, there would also be an overall net increase in emissions of PM_{10} and $PM_{2.5}$ precursors.

VII. BIOLOGICAL RESOURCES

Project Owner has the following comments on the Biological Resources section of the PSA.

- Page 4.2-1, Summary of Conclusions - As discussed at the February 24, 2016 PSA Workshop, Project Owner is no longer proposing to discharge process wastewater to the onsite evaporation ponds except in the cases of cooling system initial commissioning, maintenance, planned or forced outages or emergency, consistent with Condition BIO-12. Instead SEP wastewater will be directed to the Blythe Energy Project's two evaporation ponds, which are currently in use and have bird deterrents in place. As noted above, additional information and details regarding SEP's wastewater discharge will be docketed in a subsequent filing.

[77] All PM_{10} emissions from the gas turbine/HRSG and cooling tower are assumed to be smaller than 2.5 microns, so references to PM_{10} are equally applicable to $PM_{2.5}$.

- Page 4.2-2, Introduction, 2nd paragraph – As noted above, the SEP evaporation ponds will be operated consistent with Condition BIO-12. Therefore no new significant impacts to biological resources are expected.

- Page 4.2-4, Evaporation Ponds – As noted above, the SEP evaporation ponds will be operated consistent with Condition BIO-12. Therefore no new significant impacts to biological resources are expected.

- Page 4.2-8, Cumulative Impacts – The cumulative impacts include avian collisions with transmission lines and mortality due to potentially toxic wastewater present in the evaporation ponds associated with the cumulative sources. Staff concludes that SEP's use of a zero-liquid discharge system (ZLD) will mitigate SEP's contribution to the cumulative biological impacts associated with the current baseline conditions. The Project Owner contends that directing SEP's process wastewater to the existing Blythe Energy Project's evaporation ponds also mitigates SEP's contribution to the cumulative biological impacts.

- Page 4.2-8, Conclusions and Recommendations - As noted above, the SEP evaporation ponds will be operated consistent with Condition BIO-12. No new significant impacts to biological resources are expected and the Conclusions and Recommendations section should be revised to reflect change in the SEP design.

- Lastly, as discussed throughout these comments and throughout the project record dry cooling has not been determined to be economically feasible for SEP and may result in increased traffic and transportation impacts to the nearby Blythe airport. (See Part II, supra).

Biological Resources Conditions of Certification ("COCs")

Project Owner requests that the following clarifications regarding Staff's proposed COCs be addressed and/or explained. The edits provided by Staff are included from the PSA and the Project Owner includes proposed changes in bold, underlined italics and bold, strikethrough text.

BIOLOGICAL RESOURCES MITIGATION IMPLEMENTATION AND MONITORING PLAN (BRMIMP)

BIO-5 The project owner shall submit two copies of the proposed BRMIMP to the CPM (for review and approval) and to ~~CDFG~~ **CDFW** and USFWS (for review and comment) and shall implement the measures identified in the approved BRMIMP.

The final BRMIMP shall identify:

1. All biological resources mitigation, monitoring, and compliance measures proposed and agreed to by the project owner;
2. All biological resources Conditions of Certification identified in the Commission's Final Decision;
3. All biological resource mitigation, monitoring and compliance measures required in federal agency terms and conditions, such as those provided in the USFWS Biological Opinion;
4. All biological resources mitigation, monitoring and compliance measures required in other state agency terms and conditions, such as those provided in the ~~CDFG Incidental Take Permit and Streambed Alteration Agreement and~~ Regional Water Quality Control Board permit;
5. All biological resources mitigation, monitoring and compliance measures required in local agency permits, such as site grading and landscaping requirements;
6. All sensitive biological resources to be impacted, avoided, or mitigated by project construction, operation and closure;
7. All required mitigation measures for each sensitive biological resource;
8. Required habitat compensation strategy, including provisions for acquisition, enhancement, and management for any temporary and permanent loss of sensitive biological resources, ***as applicable***;
9. A detailed description of measures that shall be taken to avoid or mitigate temporary disturbances from construction activities;
10. All locations on a map, at an approved scale, of sensitive biological resource areas subject to disturbance and areas requiring temporary protection and avoidance during construction if construction will disturb lands outside of the existing permanent fence;

11. If construction will disturb lands outside of the existing permanent fence, then supply aerial photographs, at an approved scale, of all areas to be disturbed during project construction activities - one set prior to any site or related facilities mobilization disturbance and one set subsequent to completion of project construction. Include planned timing of aerial photography and a description of why times were chosen;
12. Duration for each type of monitoring and a description of monitoring methodologies and frequency;
13. Performance standards to be used to help decide if/when proposed mitigation is or is not successful;
14. All performance standards and remedial measures to be implemented if performance standards are not met;
15. A process for proposing plan modifications to the CPM and appropriate agencies for review and approval; and
16. A copy of all biological resources permits obtained.

Verification: The project owner shall provide the specified document at least 30 days prior to start of any site (or related facilities) mobilization. The CPM, in consultation with the ~~CDFG~~ **CDFW**, Western Area Power Administration, the USFWS and any other appropriate agencies, will determine the BRMIMP's acceptability within 45 days of receipt.

The project owner shall notify the CPM no less than five (5) working days before implementing any modifications to the approved BRMIMP to obtain CPM approval. Any changes to the approved BRMIMP must also be approved by the CPM in consultation with ~~CDFG~~ **CDFW**, Western Area Power Administration, the USFWS and appropriate agencies to ensure no conflicts exist.

Within thirty (30) days after completion of project construction, the project owner shall provide to the CPM, for review and approval, a written report identifying which items of the BRMIMP have been completed, a summary of all modifications to mitigation measures made during the project's site mobilization, ground disturbance, grading, and construction phases, and which mitigation and monitoring items are still outstanding.

Project Owner requests clarification within BIO-5's verification. As it is currently written, the BRMIMP must be submitted at least 30 days prior to the start of mobilization; however, comments on the BRMIMP from the CPM, in consultation with the CDFW, Western Area Power Administration, the USFWS and any other appropriate agencies are due within 45 days of receiving the document. The Project Owner requests that mobilization be permitted 30 days after submitting the BRMIMP and any comments be addressed as they are received.

CONSTRUCTION MITIGATION MANAGEMENT TO AVOID HARASSMENT OR HARM

BIO-6 The project owner shall manage their construction site, and related facilities, in a manner to avoid or minimize impacts to the local biological resources. Measures to be implemented are:

1. Install a temporarily fence and provide wildlife escape ramps for construction areas that contain steep walled holes or trenches if located outside of an approved, permanent exclusionary fence. The fence around the 66-acre site is an approved, permanent exclusionary fence. The temporary fence shall be hardware cloth or similar materials that are approved by USFWS and ~~CDFG~~ **CDFW**;
2. Ensure all food-related trash is disposed of in closed containers and removed at least once a week.
3. Prohibit feeding of wildlife by staff or contractors;
4. Prohibit non-security related firearms or weapons from being brought to the site;
5. Prohibit pets from being brought to the site;
6. Report all inadvertent deaths of **~~sensitive~~** ***special-status*** species to the appropriate project representative. Injured ***special-status*** animals shall be reported to ~~CDFG~~ **CDFW and the CPM,** and the project owner shall follow instructions that are provided by ~~CDFG~~ **CDFW**. ~~.~~ All incidences of wildlife injury or mortality resulting from project-related vehicle traffic on roads used to access the project shall be reported in the MCR;
7. Minimize use of rodenticides and herbicides in the project area;
8. Cover selected electrical equipment with the potential to electrocute wildlife within the substation with appropriate UV resistant material;
9. Shield lighting to prevent off-site impacts and when night-time construction is approved by the CPM, and then limit its use during nighttime construction to

only what is necessary to complete the approved work or when worker safety is an issue of concern;

10. Design and install power lines following Avian Power Line Interaction Committee’s guidelines;
11. Follow the ~~July 1999~~ **December 2009** (or most current) desert tortoise handling procedures whenever a desert tortoise is encountered; and
12. Post speed limits for construction-related traffic ~~**on Riverside Avenue**~~ ***in applicable areas*** and take actions against repeat offenders.

Verification: All mitigation measures and their implementation methods shall be included in the BRMIMP.

Project Owner requests that #6 of BIO-6 be edited to clarify that special-status wildlife species injuries will be reported to the applicable agencies. First, the term “sensitive” is a specific designation and “special-status” is more appropriate because it encompasses all wildlife designations, including (but not limited to) listed or proposed for listing under the State and/or Federal Endangered Species Acts, Species of Special Concern (SSC), and taxa designated as a special-status, sensitive, or declining species by other state or federal agencies, or a non-governmental organization (NGO). Secondly, reporting injuries of common wildlife species, could be cumbersome and overload the wildlife agencies. All wildlife injuries and mortalities will be included in the Monthly Compliance Reports. In addition, #12 should be changed to reflect all applicable traffic areas.

~~**Fence Monitoring**~~

~~**BIO-8** The project owner shall conduct maintenance monitoring of the wildlife exclusion fencing on a monthly basis and complete repairs within one week of a problem being identified. Temporary fencing must be installed at any gaps if it shall remain open overnight.~~

~~**Verification:** The project owner shall submit records of all monitoring dates, identify the locations that required repair, and any corrective actions taken in the MCR and Annual Compliance Report.~~

Regarding BIO-8, the COC has been included twice and the Project Owner requests that the extra BIO-8 be removed from Staff’s Assessment.

BIO-9 The Designated Biologist or Biological Monitor shall be contacted if ***special-status*** wildlife is found within the fenceline during construction and if it does not leave voluntarily without physical contact or harassment within 24 hours of being found. Actions to prevent physical harm to any wildlife from construction equipment shall immediately be taken by on-site staff. The local office of the California Department of Fish and ~~Game~~ **Wildlife and the CPM** shall be contacted if ~~**sensitive**~~ ***special-status*** wildlife is found within the fenceline during operations.

Verification: For any wildlife found within the fenceline during construction a report shall be completed by the Designated Biologist and submitted with the MCR. For any wildlife found within the fenceline during operations, a report shall be completed by the plant manager and submitted with the Annual Compliance Report.

Project Owner requests that BIO-9 be edited to clarify special-status wildlife species will be reported to the applicable agencies. First, the term "special-status" is more appropriate. Secondly, reporting common wildlife species could be cumbersome and overload the wildlife agencies. All wildlife injuries and mortalities will be included in the Monthly Compliance Reports.

BURROWING OWL SURVEYS AND COMPENSATION FOR IMPACTS

BIO-10 The project owner shall conduct a pre-construction survey(ies) for burrowing owl activities to assess owl presence and need for further mitigation. The Designated Biologist or Biological Monitor(s) shall monitor active burrows throughout construction to identify additional losses from nest abandonment. The project owner shall protect lands and enhance or install burrows to compensate for impacts to active burrows at the site, along related facilities, or within 150 feet of these features. The project owner shall protect lands to compensate for permanent losses of potential upland foraging habitat. Based on the burrowing owl survey results, the following three actions shall be taken by the project owner to offset impacts during construction:

1. Where a burrowing owl is sighted:
    a. If paired owls are present in areas scheduled for disturbance or degradation (e.g., grading) or within 150 feet of a permanent project feature, and nesting is not occurring, owls are to be removed per ~~CDFG~~ **CDFW**-approved passive relocation. Passive relocation is only acceptable typically from September 1 to January 31, to avoid disruption of breeding activities. The specific dates for

acceptable passive relocation are dependent on the end of burrowing owl nesting season during that calendar year.

b. If paired owls are present within 150 feet of a temporary project disturbance (e.g., transmission line stringing), active burrows shall be monitored by the Designated Biologist or Biological Monitor(s) throughout construction to identify additional losses from nest abandonment and/or loss of reproductive effort (e.g., killing of young).

c. If paired owls are nesting in areas scheduled for disturbance or degradation, nest(s) shall be avoided from February 1 through August 31 by a minimum of a 250-foot buffer or until fledging has occurred. The specific dates for acceptable passive relocation are dependent on the end of burrowing owl nesting season during that calendar year. Following fledging, owls may be passively relocated.

2. Based on the actions taken during construction, the project owner shall provide a land protection and monitoring proposal for CPM approval, and to the ~~CDFG~~ **CDFW** for review 60 days prior to commercial operation. The land protection shall be based on the following premises:

a. To offset the loss of active foraging and burrow habitat, the project owner shall provide 6.5 acres of protected lands within the Palo Verde Valley for each pair of owls or unpaired resident bird that was passively relocated or for which project-related disturbance caused nest abandonment and/or loss of reproductive effort (e.g., killing of young). Protection of additional habitat acreage per pair or unpaired resident bird may be applicable in some instances (such as for gross negligence on the part of the project owner or a contractor).

b. To offset the permanent loss of potential foraging and burrow habitat, the project owner must provide 0.5 acre of land within the Palo Verde Valley for every acre of suitable habitat they permanently converted to an unsuitable use (e.g., ponds or buildings) that was within 300 feet of a burrowing owl pair or unpaired resident.

c. The project owner's protected lands shall be within 1,800 feet***, or the nearest available parcel if no property can be acquired within 1,800 feet,*** of occupied burrowing owl habitat.

d. For each occupied burrow destroyed during construction, existing unsuitable burrows on the protected lands shall be enhanced (e.g., cleared of debris or enlarged) or new burrows installed at a ratio of 2:1.

e. The project owner must provide funding for long-term management and monitoring of protected lands based on the Center for Natural Lands Management Property Analysis Record, or similar cost analysis program***, as applicable***.

Verification: The project owner shall survey for burrowing owl activities to assess owl presence and need for further mitigation 30 days prior to site mobilization.

If construction is delayed or suspended for more than 30 days after the survey, the area shall be resurveyed.

Surveys shall be completed for occupied burrows at the fenced parcel and for a 500-foot buffer around these features (where possible and appropriate based on habitat). All occupied burrows shall be mapped on an aerial photo.

At least 15 days prior to the expected start of any project-related ground disturbance activities, or restart of activities, the project owner shall provide the burrowing owl survey results and mapping to the CPM, Western Area Power Administration, and ~~CDFG~~ **CDFW**.

Within 30 days prior to the start of commercial operation, the project owner shall submit to the CPM two copies of the relevant legal paperwork that protects lands in perpetuity (e.g., a conservation easement as filed with the Riverside County Assessor), and any related documents that discuss the types of habitat protected on the parcel.

If a private mitigation bank is used, the project owner shall provide a letter from the approved land management organization stating the amount of funds received, the amount of acres purchased in long-term management, and their location.

Project Owner requests that the above clarifications be added to BIO-10, particularly in the event that protected land is not available within 1,800 feet of occupied burrowing owl habitat.

VIII. CULTURAL RESOURCES

In the PSA, Staff indicates that "it is not certain if AltaGas was required to, or indeed accepted a contractual obligation to interests in the terms of the MOA as stipulated in **CUL-8**." (PSA at p. 4.3-3.) Similarly, later in the section Staff states that "it is indeterminate to staff … if the MOA obligations were transferred from Caithness to AltaGas as specified in [CUL-8]." (PSA at p. 4.3-10; *see also* PSA at p. 2-7.) As set forth previously in the compliance docket for the Project and again below, no action (transfer or acceptance) was required because AltaGas Sonoran is not a "successor in interest" to Caithness Blythe II, LLC.

As set forth in AltaGas Sonoran Energy Inc.'s Notice of Name Change or, in the Alternative, Petition to Change Ownership of the Blythe Energy Project, Phase II (TN# 202303), on April 29, 2014, AltaGas Power Holdings (U.S.) Inc., a Delaware corporation ("APHUS"), acquired 100 percent of the equity interests in the owner of the Project, Caithness Blythe II, LLC, a Delaware limited liability company. Following the closing of the acquisition, Caithness Blythe II, LLC was converted from a Delaware limited liability company to a Delaware corporation pursuant to Delaware law and the company's name was changed to AltaGas Sonoran Energy Inc.

Under Delaware law, for all purposes, the converted entity (AltaGas Sonoran Energy Inc.) is deemed to be the same entity as the converting limited liability company (Caithness Blythe II, LLC) and the conversion constitutes a continuation of the existence of the limited liability company in the form of such other entity or business form. (*See* Del. Code, § 18-216(c).) Similarly, California statute provides that an entity that converts into another entity pursuant to the California corporate conversion statute is for all purposes the same entity that existed before the conversion. (*See* Cal. Corp. Code, § 1158(a).) Thus, the Project's direct owner is now AltaGas Sonoran Energy Inc.

Because both California and Delaware law deems a converted entity to be the same as the entity being converted, the conversion of Caithness Blythe II, LLC to AltaGas Sonoran Energy Inc. <u>should not have required</u> a Petition to Change Ownership with the California Energy Commission pursuant to Title 20, California Code of Regulations, section 1769(b). However, because Title 20, California Code of Regulations, section 1769(b) does not expressly address the requirements in the event of a conversion of entity type and name change of a direct project owner, AltaGas Sonoran filed a Notice of Name Change or, in the Alternative, Petition to Change Ownership in case CEC Staff determined such entity conversion and name change required compliance with Section 1769(b). (*See* Notice of Receipt, TN# 202354.)

The Commission approved the "change" on June 18, 2014. (Order No. 14-0618-1(f), TN# 202592.) Regardless of how the CEC Staff treated the information (especially in light of the fact that the CEC regulations are silent regarding a conversion of entity type and name change of a direct project owner), the fact remains that California and Delaware law deems the converted entity (AltaGas Sonoran Energy Inc.) to be the same entity as the converting limited liability company (Caithness Blythe II, LLC).

Based on the foregoing, no "change" in ownership of the facility occurred as part of the transaction. APHUS acquired 100 percent of the equity interests in Caithness Blythe II, LLC, and, following the closing of the acquisition, converted Caithness Blythe II, LLC from a Delaware limited liability company to a Delaware corporation pursuant to Delaware law and then changed the company's name AltaGas Sonoran Energy Inc.

Thus, AltaGas Sonoran is a party to the MOA and, if it is determined to be in effect, is bound by its terms. AltaGas Sonoran also acknowledges and agrees to the terms of CUL-8, which prohibits AltaGas Sonoran from conducting any activities within the fenced portion of CA-RIV-6370H or removing any portion of the fence without approval of the CPM.

Cultural Resources Conditions of Certification

Project Owner proposes the following change to COC CUL-1 in order to allow for the expedited approval of a CRS or alternate(s) previously approved by the Commission Staff on another siting case.

> **CUL-1** Prior to the start of ground disturbance, the project owner shall obtain the services of a Cultural Resources Specialist (CRS), and one or more alternates, if alternates are needed, to manage all monitoring, mitigation and curation activities. The CRS may elect to obtain the services of Cultural Resource Monitors (CRMs) and other technical specialists, if needed, to assist in monitoring, mitigation and curation activities. The project owner shall ensure that the CRS evaluates any cultural resources that are newly discovered or that may be affected in an unanticipated manner for eligibility to the California Register of Historic Resources (CRHR) and NRHP. No ground disturbance shall occur prior to CPM approval of the CRS, unless specifically approved by the CPM.

CULTURAL RESOURCES SPECIALIST

For CRS and alternate(s) previously approved by the Commission, the project owner shall submittal resumes showing the CRS and alternate(s) applicable Commission projects previously supported. For CRS and alternate(s) not previously approved by the Commission, ~~T~~the resume for the CRS and alternate(s) shall include information demonstrating that the minimum qualifications specified in the U.S. Secretary of Interior Guidelines, as published in the Code of Federal Regulations, 36 CFR Part 61 are met. In addition, the CRS shall have the following qualifications:

IX. HAZARDOUS MATERIALS MANAGEMENT

Project Owner's only comment on this section is to update the Staff that Project Owner docketed a revised Offsite Consequence Analysis on February 2, 2016. (TN# 210131.)

X. LAND USE

Project Owner has the following comments on the Land Use section of the PSA:

- Page 4.5-1, Summary of Conclusions, 3rd bullet – The PSA states "The project could result in more severe land use impacts from the thermal plumes, which could affect aircraft safety and result in the project's incompatibility with the nearby Blythe Airport and the Riverside County ALUCP." The PSA notes, however, that the Riverside County ALUCP does not list thermal plumes as a hazard or otherwise address thermal plumes. (PSA, p. 4.5-9.) Accordingly, thermal plumes cannot be the basis for a conclusion that SEP is inconsistent with the Riverside County ALUCP. In this same bullet, the PSA states "The results of the project owner's thermal plume analysis predict higher velocity plumes for the SEP than the plumes analyzed under the 2005 Decision." This conclusion is not valid because it is not based on comparable modeling results (see the Project Owner's comments on Traffic and Transportation).

- Page 4.5-1, Summary of Conclusions, 4th bullet – As noted in the Project Owner's comments on the Project Description, the SEP operational process wastewater will now be disposed of in the Blythe Energy Project's existing evaporation ponds. As such, the new land use impacts noted in the 4th bullet will no longer occur. Therefore, please remove this bullet text in the FSA.

- Page 4.5-2, Summary of Conclusions, 2nd full paragraph, Recommendation by Soil and Water Resources staff for SEP to be dry cooled – The PSA has not demonstrated that dry cooling is economically feasible at SEP. Staff further states that the Project Owner would need to spend less money for mitigation with dry cooling. Economic trade-offs have been considered, and wet cooling is still preferred. Furthermore, the potential impacts of dry cooling at SEP on visual resources and traffic and transportation will result in significant, new, unmitigated impacts not considered in the PSA.

- Page 4.5-5, Laws, Ordinances, Regulations and Standards, Land Use Table 1, Blythe Airport Land Use Compatibility Plan – The consistency determination notes that "The SEP's plumes could potentially pose a more severe hazard to aircraft than the BEP II's plumes." This conclusion is not valid because it is not based on comparable modeling results (see the Project Owners comments on Traffic and Transportation). Additionally, the conclusion that SEP's plumes could create incompatibility with the Riverside County ALUCP is incorrect because the ALUCP does not identify thermal plumes as a hazard. Furthermore, the Project Owner does not believe all of the measures in Condition TRANS-9 are warranted or necessary to mitigate impacts to aviation safety (please see the Project Owners comments on Traffic and Transportation). In addition, the Project Owner has no control over the FAA and therefore is not able to implement the conditions of TRANS-9. As noted in the Project Owner's comments on the Project Description, the SEP operational process wastewater will now be disposed of in the Blythe Energy Project's existing evaporation ponds. As such, the new land use impacts noted in the table are no longer expected. Please remove them in the FSA.

- Page 4.5-7, Compliance with Zoning Regulations, 3rd paragraph, the Commission staff has not demonstrated that dry cooling is economically feasible for the SEP. As such, this discussion should either be revised to assume the use of degraded groundwater as proposed by the Project Owner or the Commission staff should conduct an economic feasibility analysis for the use of dry cooling at SEP.

- Page 4.5-8, Compliance with 2004 Blythe Airport Land Use Compatibility Plan, 2nd paragraph – This paragraph indicates that the 161-kilovolt (kV) transmission line located in Compatibility Zone C will exceed 70 feet in height and as such constitutes a "Major Land Use Action" for which the Airport Land Use Commission requests an advisory review. As noted in the SEP PTA Land Use section, the 161-kV gen-tie located within

Zone C will not exceed 70 feet in height.[78] As such, the 161-kV gen tie is not a "Major Land Use Action" and does not require an advisory review.

- Page 4.5-9, Compliance with 2004 Blythe Airport Land Use Compatibility Plan, 1st full and 2nd paragraphs – As noted above, the SEP wastewater will be directed to the Blythe Energy Project's evaporation ponds, allowing SEP to comply with Condition BIO-12.

- Page 4.5-9, Compliance with 2004 Blythe Airport Land Use Compatibility Plan, 3rd paragraph – Thermal plumes do not create inconsistency with the Riverside County ALUCP. Additionally, the issue of thermal plumes is addressed in the Project Owner's Traffic and Transportation comments below.

- Page 4.5-10, Water Conservation Offset Program Participation, 3rd paragraph – The Project Owner is proposing a water offset program that does not include fallowing agricultural land, but by lining Palo Verde Irrigation District (PVID) supply canals. As stated above, an economic feasibility analysis of dry cooling has not been performed by Commission Staff and the Project Owner's analysis indicates that the proposed voluntary water offset program results in a lower overall costs with a higher energy efficiency for SEP. Additionally, since the water offset program does not rely on fallowing agricultural land, Conditions LAND-3 and LAND-6 are no longer necessary and can be deleted.

- Page 4.5-12, Cumulative Analysis – The Project Owner's water offset program does not rely on fallowing agricultural land, therefore no cumulative impact to agricultural land would occur. Additionally, Blythe Energy Project is a baseline condition and does not contribute to the cumulative impacts of the SEP. Cumulative impacts to agricultural lands from SEP cannot occur when agricultural lands are not being affected by SEP. Furthermore, the Project Owner's comments on the PSA Traffic and Transportation analysis shows that Condition TRANS-9 are not require to mitigate potential aviation impacts from SEP.

- Page 4.5-12, Conclusions and Recommendations – Please incorporate the above comments into the Conclusions and Recommendations.

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[78] SEP PTA, page 3-95, 2nd full paragraph, last sentence.

- Page 4.5-14, Proposed Conditions of Certification – Conditions LAND-3 and LAND-6 are no longer necessary and can be deleted.

XI. TRANSMISSION LINE SAFETY AND NUISANCE

Project Owner has the following comments on the Transmission Line Safety and Nuisance section of the PSA.

- Page 4.11-2, Environmental Impact Analysis, 2nd paragraph – This section notes that proposed SEP transmission support towers will be 85 to 110 feet above ground level. This reference was associated with the proposed 230-kV alternative interconnection that was removed from the SEP project description. The 161-kV gen tie support tower designs will be less than 70 feet above ground level.

XII. WASTE MANAGEMENT

Project Owner has the following comments on the Waste Management section of the PSA.

- Page 4.13-5, Operational Waste, 1st full paragraph – The SEP wastewater will be sent to the existing Blythe Energy Project's evaporation ponds. As such, no ZLD system will be employed at SEP. Wastes will be generated by the SEP water treatment system, which will be analyzed to determine if they need to be managed and disposed as non-hazardous or hazardous wastes, consistent with the intent of Condition WASTE-7.

Waste Management Conditions of Certification

Based on the above comment, Project Owner proposes the following changes to Condition WASTE-7.

> **WASTE-7** The project owner shall determine if the water treatment~~ZLD~~ generated wastes are hazardous or non-hazardous pursuant to Chapter 12, section 66262.11 of Title 22 of the California Code of Regulations. The wastes shall be managed as designated wastes if the wastes are classified as non-hazardous, unless determined otherwise.
>
> **Verification:** The project owner shall notify the CPM via the annual compliance report regarding the classification of the wastes and the treatment/disposal methods utilized.

XIII. ENGINEERING ASSESSMENT

A. Power Plant Efficiency

As noted above, staff has failed to analyze the impacts to power plant efficiency that result from the proposed dry-cooling mitigation. As set forth in Parts I.B and VI.B herein, dry-cooling has the potential to significantly impact power plant efficiency.

B. Transmission System Engineering

On page 5.5-3, Switchyard and Interconnection Facilities, 3rd paragraph – the 161-kV gen tie is 1,320 feet long, not 1,132 feet as noted in this paragraph.

XIV. ALTERNATIVES

Project Owner concurs with the conclusion in the Alternatives section of the PSA that:

- The changes in the Petition to Amend (PTA) would not create new significant environmental effects or substantial increases in the severity of previously identified significant effects;
- The PTA does not propose substantial changes which would require major revisions of the Alternatives analysis in the 2005 Commission Decision; and
- The circumstances under which the amended SEP would be undertaken would not require major revisions of the Alternatives analysis in the 2005 Commission Decision.

(PSA, p. 6-8.) In particular, changes in the PTA do not create new significant impacts on water resources, the PTA does not propose substantial changes to water use, and the circumstances under which the amended SEP would be undertaken, including availability of water, do not require revisions to the Alternatives analysis in the 2005 Commission Decision.

The Alternatives section acknowledges that Water Resources staff has suggested the amended SEP be modified to incorporate dry cooling, but the Alternatives section does not discuss dry cooling as an alternative design. (PSA, p. 6-3.) As an initial matter, there is no new information that would change the conclusion in the 2005 Final Decision, which states, "given that wet cooling does not create significant impacts, we conclude that hybrid cooling would likely be better than dry cooling, but not a reasonable alternative to wet cooling" (Final Decision, p. 283, *emphasis added*.) In fact, the Alternatives section confirms that "the circumstances under which the amended SEP would be undertaken would not require major revisions of the Alternatives analysis in the 2005 Commission Decision." (PSA at pp. 6-8.) Project Owner's comments on the amended SEP's lack of significant impacts to water resources are addressed above.

Even assuming it is appropriate to consider dry cooling for the amended SEP, however, the record supports the conclusions in the 2005 Final Decision that dry cooling is not feasible at the SEP site. Significantly, the PSA does not include any new information or analysis of the increased environmental impacts and negative impacts on project efficiency that the 2005 Final Decision concludes would result from dry cooling. In finding that no new analysis of Alternatives is required as compared to the 2005 Final Decision, the PSA acknowledges that the following conclusions in the 2005 Final Decision remain valid:

> [T]he Commission finds that dry cooling in the hot desert does not have the flexible cooling capacity to reliably operate the project as an intermediate load following facility as presently needed by the electricity marketplace. Electricity output and efficiency would be reduced. Additionally, dry cooling costs significantly more than wet cooling and produces more hazardous thermal plumes in this Blythe Airport environment. Lastly, dry cooling towers would be substantially more massive, creating more visual impact. Again, given that wet cooling does not create significant impacts, we conclude that hybrid cooling would likely be better than dry cooling, but not a reasonable alternative to wet cooling. Thus, the Commission finds that dry cooling and hybrid cooling are not preferable to the proposed wet cooling.

(2005 Final Decision, p. 283.) Project Owner has submitted evidence supporting the continued validity of these conclusions. (*See, e.g.,*TN#s 206187, 206451, 206606, 208219, 210068.) Accordingly, the Commission's 2005 conclusion that dry cooling and hybrid cooling are not preferable to the proposed wet cooling remain valid.

Project Owner appreciates the opportunity to comment on the PSA and looks forward to further discussions with Staff and appropriate agencies regarding outstanding issues, particularly with respect to water use and aviation, in advance of the Staff's publication of the Final Staff Assessment.

Very truly yours,

Melissa A. Foster

MAF:jmw

State Water Resources Control Board

Executive Office

Linda S. Adams
Secretary for Environmental Protection

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Arnold Schwarzenegger
Governor

January 20, 2010

Ms. Melissa Jones
Executive Director
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814-5512

Dear Ms. Jones:

STATE POLICIES FOR WATER QUALITY CONTROL AND THEIR APPLICABILITY TO POWER PLANT LICENSING

Thank you for your letter of November 23, 2009, in which you seek the State Water Resources Control Board's (State Water Board) assistance with applications for renewable energy projects currently pending before the California Energy Commission (Commission). As these projects would develop new sources of renewable energy and qualify for federal financial assistance, the Governor's Office and the Commission have placed a high priority on their timely review. To that end, I will ensure that State Water Board management staff is available to consult with Commission staff on water supply issues for these projects as needed.

State Water Board management staff will also coordinate with the management staff at the affected regional water quality control boards (regional water boards) on water quality issues to help ensure that the affected regional water boards continue to timely process the applicants' reports of waste discharge. In addition, my staff is available to discuss other methods for streamlining the Commission's review of these projects, including ensuring consistent approaches for regional water boards' adoption of waste discharge requirements, assessing appropriate waste discharge fees for regional water board oversight activities, and coordinating monitoring, inspection, and enforcement activities.

You have asked whether State Water Board policies support the use of supply water with a total dissolved solids (TDS) range of 1,000 to 3,000 mg/l for these projects, and, if so, which factors should be considered by the Commission in determining whether the use of such waters should be allowed for each project. State policy for water quality control does allow, under some circumstances, the use of supply water with TDS ranging from 1,000 to 3,000 mg/l to supply renewable energy projects. As discussed in greater detail below, the State Water Board's policies and state law identify multiple factors that should be considered when evaluating alternate sources of supply water for these projects.

Your questions relate to the interaction between certain provisions of State Water Board Resolution 75-58 ("Water Quality Control Policy on the Use and Disposal of Inland Waters Used for Powerplant Cooling") and State Water Board Resolution 88-63 ("Sources of Drinking

Water"). As official state policies for water quality control, State Water Board Resolutions 75-58 and 88-63 are binding on all state agencies unless the Legislature provides otherwise. (Wat. Code, § 13146.)

When it adopted State Water Board Resolution 75-58 in 1975, the State Water Board recognized that new power plants were being considered for non-coastal sites, and expressed a concern about the limited availability of inland waters for powerplant cooling. The board stated that Resolution 75-58's purpose is to "provide consistent statewide water quality principles and guidance for adoption of waste discharge requirements, and implementation actions for powerplants which depend upon inland waters for cooling." (State Water Board Resolution 75-58, p.1.) Further, the board anticipated that the policy "should be particularly useful in guiding planning of new power generating facilities so as to protect beneficial uses of the State's water resources and to keep the consumptive use of freshwater for powerplant cooling to that minimally essential for the welfare of the citizens of the State." (*Ibid.*)

The provisions in Resolution 75-58 that are most relevant to your questions about sources of water for the pending renewable energy projects are the following three "Principles:"

> 1. It is the Board's position that from a water quantity and quality standpoint the source of powerplant cooling water should come from the following sources in this order of priority depending on site specifics such as environmental, technical and economic feasibility consideration: (1) wastewater being discharged to the ocean, (2) ocean, (3) brackish water from natural sources or irrigation return flow, (4) inland wastewaters of low TDS, and (5) other inland waters.
>
> 2. Where the Board has jurisdiction, use of fresh inland waters for powerplant cooling will be approved by the Board only when it is demonstrated that the use of other water supply sources or other methods of cooling would be environmentally undesirable or economically unsound.
>
> 7. The State Board encourages water supply agencies and power generating utilities and agencies to study the feasibility of using wastewater for powerplant cooling. The State Board encourages the use of wastewater for powerplant cooling where it is appropriate. Furthermore, Section 25601(d) of the Warren-Alquist Energy Resources Conservation and Development Act directs the Commission to study, "expanded use of wastewater as cooling water and other advances in powerplant cooling" and Section 462 of the Waste Water Reuse Law directs the Department of Water Resources to "...conduct studies and investigations on the availability and quality of waste water and uses of reclaimed waste water for beneficial purposes including, but not limited to... and cooling for thermal electric powerplants."

(State Water Board Resolution 75-58, pp. 4-5.)

In State Water Board Resolution 88-63, the board determined that, with specified categorical exceptions, "[a]ll surface and ground waters of the State are considered to be suitable, or potentially suitable, for municipal or domestic water supply . . . ." (State Water Board Resolution 88-63, p. 1.) The relevant categorical exceptions is where the water has TDS exceeding 3,000 mg/L and the water is not reasonably expected by regional boards to supply a public water system. (*Ibid.*)

More specifically, your questions relate to Resolution 75-58's definitions of "brackish waters" and "fresh inland waters" and Resolution 88-63's treatment of "sources of drinking water." "Brackish waters" is defined by Resolution 75-58 as "waters with a salinity range of 1,000 to 30,000 mg/L and a chloride range of 250 to 12,000 mg/l." (State Water Board Resolution 75-58, p. 2.) "Fresh inland waters" is defined by Resolution 75-58 as "those inland waters which are suitable for use as a source of domestic, municipal, or agricultural water supply and which provide habitat for fish and wildlife." (*Ibid.*) As a general matter, that means "fresh inland waters" for purposes of Resolution 75-58 does not extend to groundwater, which typically does not provide fish or wildlife habitat. On the other hand, State Water Board Resolution 88-63 generally provides that all surface waters and ground waters with a TDS of 3,000 mg/L or less shall be considered to be suitable for municipal or domestic water supply.

The Commission's primary issue revolves around whether brackish waters with a TDS of between 1,000 and 3,000 mg/L should be considered to be fresh inland waters in the context of Resolution 75-58's Principle No. 2. The answer is typically yes for surface waters and no for ground waters. Due to the State Water Board's subsequent adoption of Resolution 88-63, which establishes the threshold of 3,000 mg/L TDS for suitability, or potential suitability, for domestic or municipal water supply, surface waters that support fish and wildlife habitat and have TDS concentrations of 3,000 mg/L or less should be considered to be "fresh inland waters" for the purposes of Resolution 75-58's Principle No. 2. As a result, such waters should only be used for these renewable energy projects upon a demonstration that the use of other water supplies or other methods of cooling would be "environmentally undesirable" or "economically unsound." With respect to ground waters, they would not be considered "fresh inland waters" because they do not provide habitat for fish and wildlife.

Neither "environmentally undesirable" nor "economically unsound" is defined in Resolution 75-58. It appears that the State Water Board has not had occasion to formally interpret or apply either phrase since it adopted Resolution 75-58. If recycled water is available, and its use would not cause greater significant adverse effects on the environment than the use of fresh inland waters would cause, then it is unlikely that the State Water Board would find that the use of the recycled water is "environmentally undesirable." Water Code section 13550, which was enacted in 1977, helps to inform how the phrase "economically unsound" should be applied. Section 13550 contains a legislative declaration that the use of potable[1] domestic water for nonpotable uses, including industrial use, is a waste or unreasonable use of the water if the State Water Board determines that, among other things, recycled water of an adequate quality is available at a cost that is comparable to, or less than, the cost of supplying the potable water. Therefore, if recycled water is available for these projects at roughly the same or lower cost, then the use of fresh inland waters should clearly be considered to be "economically unsound."

In its 2003 Integrated Energy Policy Report, the Commission stated that it interprets "economically unsound" in this context as "economically or otherwise infeasible." To the extent

[1] "Potable water" in Water Code section 13550 refers to both surface water and ground water.

that the Commission determines that it is appropriate to require project applicants to incur substantially increased, but economically feasible, costs in order to use recycled water in lieu of fresh inland waters, such a result would not be compelled by the terms of Water Code section 13550. As the State Water Board has not yet defined "economically unsound," it is not possible to determine whether such a result would be required by Principle No. 2 of Resolution 75-58. Nonetheless, it would be consistent with Principle No. 7 of Resolution 75-58, which encourages the use of recycled water for powerplant cooling.

As you point out, Principle No. 1 of Resolution 75-58 lists brackish water as generally a higher priority for powerplant cooling than inland wastewaters of low TDS and other inland waters. This priority scheme is, however, explicitly dependent on site-specific considerations, including environmental considerations. One of the underlying bases for Resolution 75-58 is that "[t]he loss of inland waters through evaporation in powerplant cooling facilities may be considered an unreasonable use of inland waters when general shortages occur." (State Water Board Resolution 75-58, p. 3, Basis 4.) Thus, in a water short area with available recycled water, site-specific environmental considerations may dictate that the use of recycled water should take precedence over the use of brackish water.

Finally, the State Water Board understands that the Commission and other state and federal agencies are working on a longer-term plan for future renewable energy projects. The State Water Board would welcome the opportunity to assist with such a planning effort by identifying the existing and anticipated future sources of recycled water that may be available for future energy projects. Such a mapping approach may be used by the Commission and potential project applicants in siting future power plants in closer proximity to such sources of recycled water, thereby minimizing additional demands on the state's limited potable water supplies.

I hope that this answers the questions you have posed. Please do not hesitate to contact Jonathan Bishop, State Water Board Chief Deputy Director, at (916) 341-5820 to discuss these or any other issues.

Sincerely,

Dorothy Rice

Dorothy Rice
Executive Director

ATTACHMENT B

Explanation

- Project Location
- Groundwater Basins
- 2000 Groundwater Elevation Contour
- Groundwater Flowpaths

GCS WGS 1984
Datum of 1984
Prepared March 1, 2016

Sources: NAIP 2012 aerial imagery (map.dfg.ca.gov WMS Image Server), California Groundwater Basins 2015 (www.water.ca.gov shapefile), 2000 Groundwater Elevations (AECOM, 2010)

This map was prepared for the purpose of identifying the location of general site features and water resources only and is not intended to provide a legal description or location of property ownership lines.

EnviroLogic Resources, Inc.
ENVIRONMENTAL • WATER RESOURCES SCIENTISTS

GROUNDWATER FLOW

Sonoran Energy Project
Blythe, California

ATTACHMENT C

Attachment C

Project Owner's Assessment of Thermal Plume Impacts for BEP II Cooling Tower Design Approved by the CEC in 2012

BEP II Cooling Tower
Predicted Calm Wind Plume Velocities

Stack Parameters and Ambient Conditions	
Ambient Temperature (F)	39
Ambient Temperature (K)	277.04
Stack Height (m)	15.24
Stack Diameter (m)	9.14
Stack Velocity (m/s)	9.56
Exhaust Temperature (K)	299.26
Calculations	
Zv Virtual source Height (m)	2.16
F^0 initial stack buoyancy (m^4/s^3)	145.42
$(V^*a)_0$	42.05
Plume height at critical CEC vertical velocity of 4.3 m/s (calculated by solving cubic equation)	
Individual Plumes	
Height above ground (ft)	280
Height above stacktop (ft)	230
Combined Plumes	
Height above ground (ft)	1,131
Height above stacktop (ft)	1,081

BEP II Cooling Tower
Predicted Calm Wind Plume Velocities

Ht above AGL (ft)	Individual Plumes		
	Height above stacktop (m)	Height above stacktop (ft)	Plume Velocity, m/s
125	22.9	75	N/A
130	24.4	80	N/A
140	27.4	90	N/A
150	30.5	100	N/A
160	33.5	110	N/A
197	44.8	147	N/A
200	45.7	150	N/A
250	61.0	200	4.62
280	70.1	230	4.30
400	106.7	350	3.57
500	137.2	450	3.23
600	167.6	550	3.00
700	198.1	650	2.82
800	228.6	750	2.68
950	274.3	900	2.52
1,000	289.6	950	2.47
1,131	329.5	1,081	2.36
1,200	350.5	1,150	2.31
1,400	411.5	1,350	2.19
1,600	472.4	1,550	2.09
1,800	533.4	1,750	2.00
2,000	594.4	1,950	1.93
2,200	655.3	2,150	1.87
2,400	716.3	2,350	1.82
2,600	777.2	2,550	1.77
2,800	838.2	2,750	1.72
3,000	899.2	2,950	1.68

BEP II Cooling Tower
Predicted Calm Wind Plume Velocities

Ht above AGL (ft)	Individual Plumes		
	Height above stacktop (m)	Height above stacktop (ft)	Plume Top-hat Radius (m)
125	22.9	75	3.31
130	24.4	80	3.56
140	27.4	90	4.04
150	30.5	100	4.53
160	33.5	110	5.02
197	44.8	147	6.83
200	45.7	150	6.97
250	61.0	200	9.41
280	70.1	230	10.88
400	106.7	350	16.72
500	137.2	450	21.60
600	167.6	550	26.48
700	198.1	650	31.35
800	228.6	750	36.23
950	274.3	900	43.55
1,000	289.6	950	45.98
1,131	329.5	1,081	52.37
1,200	350.5	1,150	55.74
1,400	411.5	1,350	65.49
1,600	472.4	1,550	75.24
1,800	533.4	1,750	85.00
2,000	594.4	1,950	94.75
2,200	655.3	2,150	104.51
2,400	716.3	2,350	114.26
2,600	777.2	2,550	124.01
2,800	838.2	2,750	133.77
3,000	899.2	2,950	143.52

BEP II Cooling Tower
Predicted Calm Wind Plume Velocities

Distance between stacks (m): 14.63
No. of stacks: 11
N^0.25 approximation for merged stacks

Combined Plume			
Ht above AGL (ft)	Height above stacktop (m)	Height above stacktop (ft)	Plume Velocity, m/s
125	22.9	75	Not Merge
130	24.4	80	Not Merge
140	27.4	90	Not Merge
150	30.5	100	Not Merge
160	33.5	110	Not Merge
197	44.8	147	Not Merge
200	45.7	150	Not Merge
250	61.0	200	Not Merge
280	70.1	230	Not Merge
400	106.7	350	6.50
500	137.2	450	5.88
600	167.6	550	5.46
700	198.1	650	5.14
800	228.6	750	4.88
950	274.3	900	4.58
1,000	289.6	950	4.50
1,131	329.5	1,081	4.30
1,200	350.5	1,150	4.21
1,400	411.5	1,350	3.99
1,600	472.4	1,550	3.80
1,800	533.4	1,750	3.65
2,000	594.4	1,950	3.52
2,200	655.3	2,150	3.41
2,400	716.3	2,350	3.31
2,600	777.2	2,550	3.22
2,800	838.2	2,750	3.14
3,000	899.2	2,950	3.06

Automated Surface Observing System

(ASOS)

User's Guide

National Oceanic and Atmospheric Administration
Department of Defense
Federal Aviation Administration
United States Navy

March 1998

Foreward

The 1990s have witnessed a carefully planned and executed modernization of the nation's weather services. The Automated Surface Observing System (ASOS) is the first system to be operationally deployed as part of theis modernization. ASOS is therefore in the forefront of system deployments and associated service improvements that will require most of this decade to complete. In this sense, ASOS is the harbinger of 21st century weather services.

In the end state, ASOS will be operational at about 1,000 airports across the United States. This system is the primary surface weather observing system in the United States, which supports the essential aviation observation programs of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD).

The implementation of ASOS brings with it many opportunities and challenges. The opportunities include the unprecedented availability of timely, continuous and objective observations from many more locations. The challenges generally related to institutional learning needed to fully understand and adjust operation to take the greatest advantage of this new technological resource. The potential applications of the ASOS data go beyond that of providing basic weather information for aviation and forecasting; ASOS also will provide enhanced support to vital national programs such as public safety, hydrology, climatology, agriculture, and environmental protection, just to name a few. The *ASOS User's Guide* is intended as basic reference and introduction to ASOS for a broad range of users.

As of this writing (March 1998), there are about 500 commissioned ASOS's nationwide. An additional 500 are coming on-line in the next few years. This deployment fulfills the commitment of the Government made over a decade ago to provide the nation a highly cost-effective, capable and reliable automated weather observing system for safe, efficient aviation operations and other applications. This achievement is made possible by the dedicated effort of many people throughout the government and private industry working together as a team to conceive, plan, develop, test and evaluate, implement, commission, monitor, maintain and operate a system.

This *ASOS User's Guide* is gratefully dedicated to all who have worked so hard to make ASOS a reality. Special thanks are extended to Dr. Jim Bradley for mentoring this program from the very beginning. Finally I wish to thank Dave Mannarano for coordinating the writing and production of this *ASOS User's Guide*.

Vickie L. Nadolski

Vickie L. Nadolski
ASOS Program Manager

Executive Summary

Since the last Automated Surface Observing System (ASOS) User's Guide was published in June 1992, numerous changes have occurred. These changes have, to the maximum practical extent, been incorporated into this updated version of the ASOS User's Guide. These changes include the transition of observing code format from the Surface Aviation Observation (SAO) code to the Aviation Routine Weather Report (METAR) code in 1996; the implementation of new software loads into ASOS up to and including software Version 2.6; the incorporation of various sensor enhancements and improvements, including modification to the Heated Tipping Bucket precipitation accumulation gauge, the hygrothermometer, and anemometer; and incorporation of the Freezing Rain and Lightning Sensors into the ASOS sensor suite. Additional product improvement efforts are underway to further expand and improve the capabilities of ASOS. These efforts are also described in the ASOS User's Guide.

As of this writing (March 1998), there are about 500 commissioned ASOS's nationwide. An additional 400 + are coming on-line in the next few years. This deployment fulfills the commitment the Government made over a decade ago to provide the nation a highly cost-effective, capable and reliable automated weather observing system for safe, efficient aviation operations and other applications. This achievement is made possible by the dedicated efforts of many people throughout the government and private industry working together as a team to conceive, plan, develop, test and evaluate, implement, commission, monitor, maintain and operate the system.

This ASOS User's Guide is gratefully dedicated to all who have worked so hard to make ASOS a reality. Special thanks are extended to Dr. Jim Bradley for mentoring this program from the very beginning. Finally I wish to thank Dave Mannarano for coordinating the writing and production of this ASOS User's Guide.

Vickie L. Nadolski
ASOS Program Manager

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CHAPTER ONE

1.0 Introduction

Since the first aircraft took flight, weather observations have been essential for safe aviation operations. Over the years, the National Airspace System (NAS) has expanded to thousands of flights and millions of passenger and cargo miles a day. Paralleling this expansion has been the demand for increased weather observations. In recent years the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD) have collectively expended over 1,000 staff-years annually to create and disseminate manual weather observations. This expanding demand on human resources spurred the development of automated sensors and reporting systems to provide surface weather observations.

With the advent of new reliable and sophisticated sensors and computer technology in the 1970s, it became increasingly practical to automate many observing functions. This potential came to fruition with development and testing of the Automated Surface Observing System (ASOS) in the 1980s, and its deployment and implementation in the 1990s. By the turn of the century, over 900 airports will have ASOS.

The primary function of the ASOS is to provide minute-by-minute observations and generate the basic Aviation Routine Weather Report (METAR) and Aviation Selected Special Weather (SPECI) report. This information is essential for safe and efficient aviation operations, and is used by the public to plan day-to-day activities. ASOS also provides valuable information for the hydrometeorologic, climatologic, and meteorologic research communities.

1.1 Purpose and Scope

The purpose of the *ASOS User's Guide* is to familiarize users with the unique characteristics of ASOS data, how to interpret it, and optimize its use. The primary audience for the *ASOS User's Guide* includes pilots, air traffic controllers, meteorologists, hydrologists, climatologists, and other users of surface weather observations. It is assumed that readers are familiar with the current Federal Meteorological Handbook Number 1 (FMH-1), which describes the observing practices, coding, and reporting standards for surface weather observations.

This *User's Guide* provides information applicable to all ASOS units, whether they are sponsored by the NWS, FAA, or DOD. The *Guide* covers all essential aspects of system operation, including data acquisition, processing, and report formatting and dissemination. This *Guide* is by no means exhaustive and additional information is referenced.

The *ASOS User's Guide* is organized into four topical areas. Each topical area includes one or more chapters. The information within these topical areas flows from a general introduction to specific core detail and finally to a conclusion or summary.

The first topical area provides a general overview (Chapters 1-2). The second topical area discusses the automation of the objective weather elements (Chapter 3) and automation of the subjective weather elements (Chapter 4). These chapters describe the sensor operation principles, the algorithms, and the strengths and limitations of ASOS in reporting each element. The next topical area provides specific examples and explanations of ASOS output (Chapters 5-6). Finally Chapter 7 provides a look to the future and a conclusion. Appendices provide additional detail. This includes examples of ASOS video screens, performance specifications, and a quick reference guide to the content of the ASOS generated METAR/SPECI reports.

1.2 Background

The earliest fielded automated systems, the Automated Meteorological Observing System (AMOS) and the Remote Automated Meteorological Observing System (RAMOS), were deployed in the 1960s and 1970s. These systems reported only the objective elements of ambient and dew point temperature, wind (speed and direction), and pressure.

The more complex, spatially observed elements of sky condition and visibility had to await advances in sensor technology and improvements in computer processing. These goals were initially achieved by developing and fielding the Automated Observation (AUTOB) in the early 1970s. It was only when these more subjective elements could be automated that the opportunity arose to develop a fully automated observation system. The first such system was developed during the joint FAA-NWS Aviation Automated Weather Observing System (AV-AWOS) experiments performed between 1973 and 1978. In the 1980s, further advances in technology finally permitted the NWS, FAA, and DOD to develop a practical, fully automated observing system for nationwide use.

1.3 Total Surface Observation Concept

ASOS provides the basic surface weather observation at many airports. At selected airports, an observer may add information to the ASOS observation. These additions are considered important for safe and efficient operations in the airport/terminal area and provide backup observations for those elements that ASOS normally reports.

Although ASOS is the primary source of surface observational data in the United States, other surface observing networks, distinct from ASOS, provide supplementary data for forecasting and other specific interests. These networks include severe weather spotter networks, hydrological reporting networks, synoptic and climatological observing networks, and cooperative observing networks. Data from these sources are not derived from ASOS and are not provided as part of the ASOS observation. This information is included in separate data sets or products. Examples of this information are severe weather reports (tornado/funnel cloud sightings, etc.), snow depth, water equivalent of snow on the ground, and middle and high cloud information (height, amount, and type).

In the modernized weather service, new and improved technologies such as satellite, Doppler Weather Surveillance Radar (WSR-88D), and lightning detection networks provide valuable weather information separate from data reported by the ASOS. By integrating these data, meteorologists can now obtain a more accurate and complete depiction of the weather than what can be obtained only from a single source.

1.4 Quality Control

The automation of surface observations reduces or eliminates direct human involvement in acquiring (sensing, collecting), processing (assessing, formatting, documenting), and disseminating (transmission, display, broadcast) surface observations. Even though the ASOS is highly automated and reliable, effective Quality Control (QC) of ASOS products is critical for ensuring the high level of trust in the automated output (Figure 1).

There are three cascading levels of quality control for ASOS. Each level focuses on a different temporal and spatial scale.

- Level 1 is performed on-site, in real-time before an observations is transmitted.
- Level 2 is performed at a Weather Forecast Office (WFO) for a designated area, about the size of a state, usually within 2 hours after the scheduled observation transmission time.
- Level 3 is performed centrally on all ASOS METARs nationwide, usually about 2 hours after the scheduled transmission time.

Level 1—At the Site

Built into each ASOS are automated self-diagnostics and QC algorithms. These QC algorithms operate on raw sensor data; they prevent questionable data from being included in the One-Minute-Observation (OMO) or the transmitted METAR/SPECI. When the ASOS detects either a qualifying degree of system degradation, component failure, or data error, the relevant data are excluded from report processing and a Maintenance Check Indicator ($) is appended to the METAR/SPECI report. If sufficient raw data are not available for report processing, the element is not included in the OMO or METAR/SPECI report. The $ is used to indicate that maintenance may be needed but does not necessarily mean that the data are erroneous. On-site observers may also augment and/or backup the ASOS METAR/SPECI data at selected locations. These observers provide an immediate data check and often catch problems before the observation is transmitted.

Level 2—Area

WFO personnel routinely monitor and assess the availability and meteorological quality of long-line transmitted METARs and SPECIs from all ASOS locations in their county warning area (CWA). This quality control usually occurs within 1- 2 hours after the data are transmitted. If data are suspect, the WFO staff investigates the problem, informs points of contact (either the on-site observer, maintenance technician, or associated FAA Flight Service Station) and coordinates corrective action to ensure that a quality observation is provided, or suspends the questionable observation pending resolution of a problem. The goal at the area level is to correct a problem or prevent any additional erroneous data from being transmitted. When a system problem is detected, a maintenance technician is notified. Maintenance technicians are based at selected NWS offices and service all NWS and FAA ASOS's within their area of responsibility. The Navy and Air Force perform maintenance on their own ASOSs.

Level 3—National

National QC operations are centered at the ASOS Operations and Monitoring Center (AOMC). It is staffed 24-hours a day and provides an 800 phone-in number for trouble calls. AOMC technicians routinely monitor the long-line transmitted ASOS hourly METAR. To help with this monitoring, two types of automated messages are routinely provided to the AOMC. These messages identify: (1) those METAR/SPECI reports with a $ appended and (2) those METAR not received within the standard Time-Of-Transmission window. These messages are provided by the NWS Telecommunication Gateway (NWSTG), which is collocated with the AOMC in the NWS Systems Operations Center (SOC).

When a problem is encountered, AOMC technicians open a trouble report, alert the responsible ASOS Electronic Technician and/or NWS office to take appropriate action, and monitor progress toward resolution. The AOMC may also coordinate with the appropriate FAA Weather Message Switching Center Replacement (WMSCR) facility to resolve FAA National Airspace Data Interchange Network (NADIN) communications problems that affect long-line transmission of ASOS reports. AOMC QC action is usually initiated after hourly METAR data are missing for 2 hours.

The AOMC performs other vital functions, such as downloading critical operational information to the ASOS, keeping accurate clock synchronization, and maintaining data for system reinitialization, such as field elevation, magnetic declination, phone numbers, etc.

The goal at the national level is to maintain uniform system integrity and prevent problems in data from continuing for extended periods of time.

Automated QC messages are generated at the National Center For Environmental Prediction (NCEP) hourly and made available to WFOs. These messages identify horizontally inconsistent and possibly unrepresentative observations through comparison of selected elements in the hourly METAR with a corresponding computer-generated Optimal Interpolation (OI) analysis field. The evaluated elements are:

- Wind direction and speed
- Potential temperature (used as a surrogate for ambient temperature)
- Dewpoint temperature
- Sea-level pressure.

Those METAR elements that differ from the corresponding OI value by more than the allowable criteria are flagged as suspect and included in the NCEP CQ message. Other automated QC monitoring programs are operational at the local WFO and alert the staff when data elements or whole observations are missing, usually within 1 hour.

The National Climatic Data Center (NCDC) performs additional quality control prior to archive.

1.5 General Conventions

The time convention used in this document to describe the valid times and schedules used by ASOS is:

DD:HH:MM:SS

Where:
DD = Date; $01 \leq DD \leq 31$

HH = Hour (24-hour clock); $00 \leq HH \leq 23$

MM = Minute; $00 \leq MM \leq 59$

SS = Second; $00 \leq SS \leq 59$

H+MM = Minutes past the current hour.
M+SS = Seconds past the current minute.

For example, a time period from 56 minutes past the previous hour to 50 minutes past the current hour would be referenced as: "-H+56 to H+50."

The times specified in this document are in either Local Standard Time (LST) or Universal Coordinated Time (UTC), alternately referred to as Zulu Time (Z).

In the descriptions of the algorithms, if less than 75 percent of the maximum amount of data used in the computation of any parameter is available, the parameter is not reported. Unless otherwise noted, all midpoint fractional values are rounded *down* to the nearest appropriate value. All other values are rounded in accordance with normal rounding procedures.

Figure 1. ASOS Quality Control Concept

CHAPTER TWO

2.0 System Description

The ASOS performs all the basic observing functions, including the acquisition, processing, distribution, transmission, and documentation of data.

2.1 System Components

The ASOS consists of three main components. The first two components are at all ASOS locations; the third component is found only at airports at which observer augmentation/backup support is provided.

- Sensor group(s), consisting of individual weather sensors and a Data Collection Package (DCP)
- The Acquisition Control Unit (ACU)
- The Operator Interface Device (OID)

2.1.1 ASOS Sensor Groups

The ASOS sensors continuously sample and measure the ambient environment, derive raw sensor data and make them available to the collocated DCP. These raw sensor data include visibility extinction coefficients, ceilometer cloud hits, freezing precipitation resonant frequencies and other sensor data. These data are processed as preliminary input into the observation algorithms. The ASOS consists of the following basic complement of sensors[1] :

- Ceilometer, Cloud Height Indicator [CHI] Sensor (one to three sensors per site)
- Visibility Sensor (one to three sensors per site)
- Precipitation Identification (PI) Sensor
- Freezing Rain (ZR) Sensor (not planned to be included where ZR potential is nil)
- Lightning Sensor (only at selected sites)
- Pressure Sensors (two sensors at small airports; three sensors at larger airports)
- Ambient/Dew Point Temperature Sensor
- Anemometer (wind direction and speed sensor)
- Precipitation Accumulation Sensor (Heated Tipping Bucket [HTB] Gauge)

Sensors are sited in accordance with guidance stated in the Federal Standards for Siting Meteorological Sensors at Airports (FCM-S4-1987), published by the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM). At virtually all locations, the pressure sensors are located indoors within the ACU.

The field complement of ASOS sensors are typically located near the Touchdown Zone (TDZ) of the primary designated instrument runway. If the TDZ site was found unacceptable, the Center Field (CF) location is the most likely alternate location. The field sensor array is referred to as the "ASOS Combined Sensor Group." At larger airports or airports where the operational need is justified, additional sensors may be strategically located at an other location to provide additional weather information ("Meteorological Discontinuity Sensor Group") or backup sensor capabilities ("Backup Sensor Group"). These additional sensor groups generally consist of a ceilometer, a visibility sensor, and a collocated DCP[2] . Figure 2 shows a typical ASOS Combined Sensor Group. Figure 3 shows an optional ASOS "Meteorological Discontinuity" or "Backup" Sensor Group.

A DCP is located with each sensor group. It continually gathers and processes raw data from the adjacent sensors (e.g., voltages, extinction coefficients, data counts) and conditions these data before transmission to the ACU. Data conditioning may include such processes as sampling, formatting, and scaling.

2.1.2 Acquisition Control Unit

The ACU, which is the central processing unit for the ASOS, is usually located inside a climate controlled structure, such as an observing office or control tower building. It ingests data from the DCP(s) and pressure sensors, and is capable of accepting information from the FAA New Generation Runway Visual Range (NGRVR) system.

The ACU performs final processing, formatting, quality control, storage and retrieval of the data, and makes ASOS data available to users through various outlets. A brief description of the various ASOS data outlets and data

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[1]Other sensors are under development and may be added at a later time.

[2]At the Hub airports, the PI sensor will be included in the Touchdown Sensor Group if it is located at the TDZ of the primary instrument runway.

Figure 2. ASOS Combined Sensor Group

Figure 3. Additional Sensor Group

Figure 4. Availability of ASOS Data

types is summarized in Figure 4. Additional details and examples may be found in Chapters 6 and 7.

2.1.3 Operator Interface Device

The Operator Interface Device (OID) is the primary means through which an on-site observer enters back-up or augmentation observations into the ASOS METAR/ SPECI report. It consists of a keyboard, and video screen interfaced directly with the ACU either through hardwire or telephone line. Various OID screen displays are available; see Appendix A for examples.

2.2 ASOS Data Outlets

The ASOS Peripheral Data Outlets include:

- The ASOS Operator Interface Device (OID) and remote dial-in user interactive video screen displays. Examples of various OID video screen displays are shown in Appendix A
- On-site video display screens. These include the Video Display Unit (VDU) screens, and user-provided video monitors
- On-site printer hard copy (at OID equipped locations), when required
- Long-line dissemination of coded messages through NWS and FAA communications networks. Long-line networks are described in Section 6.3
- Computer-generated voice (available through FAA radio broadcast to pilots, and general aviation dial-in telephone lines). Examples of computer-generated voice messages are given in Section 6.4

2.3 ASOS Data Types

The various ASOS data types available through these outlets include:

- One-Minute Observation (OMO) data (content same as METAR/SPECI data)
- Aviation Routine Weather Reports (METAR) and Aviation Selected Special Weather Reports (SPECI). At staffed locations, SPECI messages for tornadic or volcanic activity are manually composed and disseminated through ASOS when these conditions are observed (described in Section 5.3)
- Auxiliary data display (described in Section 5.4)
- Standard Hydrometeorological Exchange Format (SHEF) messages (described in Section 5.5)
- Maintenance Data (raw sensor data, system diagnostics, system status) (examples given in Appendix A)
- Daily and Monthly Summary messages (described in Section 5.6)

2.4 METAR Elements

The ASOS will automatically report the following surface weather elements in the METAR:

- Wind: Direction (tens of degrees - true), Speed (knots), and Character (gusts)
- Visibility up to and including 10 statute miles
- Runway Visual Range (RVR) at selected sites
- Basic Present Weather Information (type and intensity): Rain, Snow, Freezing Rain, Squalls
- Obstructions: Fog, Mist, Haze, and Freezing Fog
- Sky Condition: Cloud Height and Amount (CLR, FEW, SCT, BKN, OVC)[3] up to 12,000 feet above ground level
- Ambient Temperature, Dew Point Temperature (degrees Celsius)
- Pressure: Altimeter Setting in inches of mercury (Hg), and Sea-level Pressure (SLP) in Hectopascals (hPa)[4] in Remarks
- Automated, Manual, and Plain Language Remarks (depending on service level) including: Volcanic Eruption (plain language), Tornadic Activity (plain language), Wind Shift, Tower Visibility, Beginning and Ending of Precipitation, Virga (plain language), Significant Cloud Types (plain language), SLP, and Other Significant (Plain Language) Information
- Additive and Automated Maintenance Data including: 3, 6, 24-hour Precipitation Amount, Hourly Temperature and Dew Point, 6-hour Maximum and Minimum Temperatures, 3-hour Pressure Tendency, various sensor status indicators, and maintenance check indicator ($).

The ASOS Capability to report these elements is summarized in Appendix B. The content of the ASOS METAR/ SPECI is described in the following chapters and is summarized in Appendix C. In the future, ASOS may also provide additional information on snowfall, hail, drizzle, and sunshine duration (see Chapter 7 for further details).

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[3]In the METAR code cloud amounts are depicted as either Clear (CLR), Few (FEW), Scattered (SCT), Broken (BKN), or Overcast (OVC)

[4]A Hectopascal (hPa) value is equivalent to a millibar (mb), i.e., 1012 hPa = 1012 mb.

2.5 Automated METAR vs. Manual METAR

In form, the unattended ASOS METAR and the attended ASOS (Observer oversight) METAR look very much alike. For example, under the same circumstances, the ASOS would report:

KDEN 281950Z AUTO 11006KT 6SM HZ SCT080 15/12 A3013 RMK AO2 SLP123

while the observer who is editing the ASOS might report:

KDEN 281950Z 11006KT 5SM HZ SCT080 BKN140 15/12 A3013 RMK AO2 FEW ACC W SLP123

Notice that both METARs contain the station ID, observation type, time, wind, visibility, obstructions, sky condition, ambient temperature, dew point temperature, altimeter setting, and sea-level pressure (in remarks).

The automated observation indicates the station type as “AUTO” which signifies an unattended observation (i.e., Observer not logged onto ASOS for back-up or augmentation), and identifies the system as one capable of reporting present weather (AO2).

The second observation indicates that the Observer logged onto the system (AUTO is missing). The Observer augmented sky condition for clouds above 12,000 feet and added information in the Remarks section about cloud type and location which ASOS cannot provide. This is just one example. Other detailed examples are given in Chapter 5.

To fully appreciate these examples, the *ASOS User’s Guide* first examines each of the weather elements reported by the ASOS and compares the manual and automated observations in terms of sensors used, the observing procedures employed, and reporting capabilities. Automated observing concepts are also discussed for greater clarity and understanding. The specific chapter-by chapter breakdown is as follows:

- **Chapter 3** discusses the more objective and directly measured (i.e., non-visual) elements such as ambient temperature, dew point temperature, wind, pressure, and precipitation accumulation.

- **Chapter 4** discusses the more subjective, and to some extent, indirectly measured (i.e., visual) elements of sky condition, visibility, present weather (phenomena and obstructions).

- **Chapter 5** provides examples of ASOS weather reports, messages, and summaries.

- **Chapter 6** discusses the outlets through which the ASOS data are available.

- **Chapter 7** describes those elements not currently provided by ASOS, future product improvement plans, and alternate means through which these data are now available or may be available in the future.

CHAPTER THREE

3.0 Automating the Objective Weather Elements

The "objective" weather elements are defined as ambient and dew point temperature, wind, pressure, and precipitation accumulation. These elements are classified as "objective" because they are more simply and directly measured and are easier to automate than other elements. This chapter describes how ASOS reports objective elements.

3.1 Ambient and Dew Point Temperature

Ambient and dew point temperature reports are among the most widely disseminated of all the weather elements in the surface observation. Because of keen public interest, nearly all radio and most television stations report temperature and humidity at least once an hour. Ambient and dew point temperature are vital in determining aircraft performance and loading characteristics and are critical for accurate weather forecasts. To meet these needs, ASOS provides a 5-minute average ambient air and dew point temperature every minute.

3.1.1 Ambient/Dew Point Temperature Sensor

Both the manual and automated temperature sensors directly measure the ambient dry-bulb and the dew point temperatures. The hygrothermometer used in the ASOS is a modern version of the fully automated "HO-83" hygrothermometer, first used operationally in 1985. This instrument uses a platinum wire Resistive Temperature Device (RTD) to measure ambient temperature and a chilled mirror to determine dew point temperature.

The RTD operates on the principle that electric resistance in a wire varies with temperature. This RTD is located in the stream of aspirated air entering the sensing unit and assumes the ambient air temperature.

To determine dew point temperature, a mirror is cooled by a thermoelectric or Peltier cooler until dew or frost begins to condense on the mirror surface. The body of the mirror contains a platinum wire RTD, similar to that used for ambient temperature. This RTD assumes the mirror's temperature, which is held at the dew point temperature.

Figure 5. ASOS Hygrothermometer

When this condition occurs, the mirror's surface is in vapor pressure equilibrium with the surrounding air (i.e., has reached the saturation vapor pressure). The temperature required to maintain this equilibrium is, by definition, the dew point temperature.

Optical techniques are used to detect the presence of surface condensation. Within the hygrothermometer, a beam of light from a small Light Emitting Diode (LED) is directed at the surface of the mirror at a 45 degree angle. Two photo-resistors are mounted to receive the reflected light. The "direct" sensor is placed at the reflection angle and receives a high degree of light when the mirror is clear. The indirect sensor is placed to receive light scattered when the mirror is clouded with visible condensation, (i.e., dew or frost formation).

In normal operation, a feedback loop controls an electric heat pump running through a cooling-heating cycle, which cools the mirror until dew or frost is formed; it then heats the mirror until the condensate (dew or frost) is evaporated or sublimed. This cycle nominally takes about 1 minute to complete.

As the mirror's cloudiness increases, the "direct" sensor receives less light and the "indirect" sensor receives more light. When the ratio of indirect to direct light reaches an adaptive criterion value, the mirror is considered to be at the dew point temperature. The adaptive criterion value (ratio of indirect to direct light) is adjusted once a day to compensate for residual contamination on the mirror due to dust and other airborne particulates.

Table 1. Temperature Sensor—Range, Accuracy Resolution

Parameter	Range	RMSE	Max Error	Resolution
Ambient	**-80°F to -58°F**	**1.8°F**	**± 3.6°F**	**0.1°F**
Temperature	-58°F to +122°F	0.9°F	± 1.8°F	
	+122°F to +130°F	1.8°F	± 3.6°F	
Dew Point	-80°F to -0.4°F	3.1°F to 7.9°F	4.5°F to 13.9°F	0.1°F
Temperature	-0.4°F to +32°F	2.0°F to 7.9°F	3.4°F to 13.9°F	
	+32°F to +86°F	1.1°F to 4.7°F	2.0°F to 7.9°F	

Since a clean mirror needs relatively less indirect light to determine when dew has formed than a dirty mirror, the mirror is heated once a day to recalibrate the reference reflection expected from a dry mirror. This procedure compensates for a possible dirty or contaminated mirror and redefines adaptive criterion value used to determine when dew or frost has occurred. This once per day recalibration nominally takes about 15 minutes.

The ASOS hygrothermometer meets all NWS specifications for measuring range, accuracy, and resolution. The specifications for accuracy are given in Root Mean Square Error (RMSE) and Maximum (MAX) Error. Specifications are listed in Table 1.

The RMSE for Dew Point Temperature is given as a range of values and is dependent on the Ambient Temperature minus the Dew Point Temperature value (i.e., Dew Point Depression [DD]). The low end of the RMSE and MAX Error range is for a DD of 0°F; the high end of the Error range is for a DD of 63°F.

3.1.2 Ambient Temperature/Dew Point Temperature Algorithm

Both ambient temperature and dew point temperature are considered conservative elements (i.e., continuous in space, and slowly and smoothly changing in time). Based on this characteristic, time-averaging over a short period is the preferred method of measurement.

The ASOS hygrothermometer continually measures the ambient temperature and dew point temperature and provides sample values approximately six times per minute. Processing algorithms in the hygrothermometer use these samples to determine a 1-minute average temperature and dew point valid for a 60-second period ending at M+00. These data are passed to the ACU for further processing.

Once each minute the ACU calculates the 5-minute average ambient temperature and dew point temperature from the 1-minute average observations (provided at least 4 valid 1-minute averages are available). These 5-minute averages are rounded to the nearest degree Fahrenheit, converted to the nearest 0.1 degree Celsius, and reported once each minute as the 5-minute average ambient and dew point temperatures. All mid-point temperature values are rounded *up* (e.g., +3.5°F rounds up to +4.0°F; -3.5°F rounds up to -3.0°F; while -3.6 °F rounds to -4.0 °F).

The ACU performs all temperature averaging functions. It also performs a number of data quality tests on the ambient and dew point temperatures, including upper and lower limit checks, a rate of change check, and a cross comparison. The current 1-minute ambient and dew point temperature are compared against these limits. The upper and lower limits are +130°F to -80°F for ambient temperature and +86°F to -80°F for dew point temperature.

If the current 1-minute ambient or dew point temperature differs from the last respective, non-missing, 1-minute reading in the previous 2 minutes by more than 10°F, it is marked as "missing." The current 1-minute ambient temperature is also compared against the current 1-minute dew point temperature to ensure the dew point is not higher. If the dew point temperature exceeds the ambient temperature by 2°F or less, the dew point temperature is set equal to the ambient temperature. If the dew point temperature exceeds the ambient temperature by more than 2°F, the 1-minute dew point temperature is set to "missing."

If, within the past 5 minutes, there are at least four valid (i.e., non-missing) 1-minute ambient and dew point temperatures, the respective 5-minute averages are computed and reported in degrees Celsius in the OMO and METAR. If there are less than four valid 1-minute average ambient or dew point temperatures within the past 5 minutes, ASOS does not compute the current 5-minute average for ambient or dew point temperature. When this occurs, ASOS uses the most recent 5-minute average value calculated within the past 15 minutes.

If the ASOS has not recorded a valid 5-minute average ambient or dew point temperature within the past 15-minutes, no ambient or dew point temperature is reported and the sensor failure notation is entered into the ASOS system maintenance log (SYSLOG). This 15-minute "hold-off" allows the daily 15-minute calibration heat cycle to occur without adverse affect. The current 1-minute average ambient temperature and the 5-minute average ambient temperature are updated once each minute and stored in memory for 12 hours. These stored data are used in further computation:

- Once each minute, ASOS uses the running 5-minute average ambient temperature to update the hourly maximum and minimum ambient temperatures. At the end of the hour (H+59), the cumulative maximum and minimum ambient temperatures for the hour and the minute(s) they occurred are stored in memory for 24 hours.

- At synoptic hour (00, 06, 12, and 18 UTC) reporting times, the current 6-hour maximum and minimum ambient temperatures are computed from the hourly maximum and minimum ambient temperatures in tenths of degrees Celsius, and included as remarks ("$1s_nT_xT_xT_x$" for maximum temperature, and "$2s_nT_nT_nT_n$"for minimum temperature) in the current synoptic hourly METAR.

- The current 12-hour average ambient temperature is also computed once each minute from the current and previous 12-hour reported 5-minute average temperature (this value is used for calculating current sea-level pressure).

- Once each hour (at the hourly METAR report time) the current hourly ambient temperature and dew point temperature are reported in the METAR Remarks section, to the nearest tenth of a degree Celsius, in the form "$Ts_nT'T'T's_nT'_dT'_dT'_d$."

- Once each minute, ASOS computes the highest and lowest ambient temperatures, so far for the current calendar day, in tenths of degrees Celsius. The calendar day maximum and minimum ambient temperatures are reported in the midnight, LST hourly METAR remarks ($4s_nT_xT_xT_x s_nT_nT_nT_n$), and are stored in memory for 31 days as part of the Daily Summary Product. The "midnight, LST hourly METAR" is usually transmitted before 23:59 LST. Therefore, there may occasionally be a discrepancy between the maximum and minimum temperatures reported in the "4" group and the daily maximum and minimum temperatures reported in the ASOS Daily Summary Message (DSM) which runs from 00:00 to 23:59 LST (see Section 5.6 for details).

- Once each day (at 23:59 LST), the highest and lowest ambient temperatures for the current month, along with the date(s) of occurrence, are computed and stored in memory until the end of the following month. On the first day of the following month, ASOS outputs the Monthly Maximum Temperature and date(s) of occurrence, plus the Monthly Minimum Temperature and date(s) of occurrence[7] .

Additional temperature parameters are derived from the Calendar Day and Monthly Maximum and Minimum Temperature data. These data may be reported in the daily and/or monthly summary messages, as appropriate.

The daily data include: calendar day average ambient temperature, the latest daytime maximum temperature (LDT), the latest nighttime minimum temperature (LNT), departure of calendar day average ambient temperature from normal, and heating degree days (HDD) or cooling degree days (CDD).

The monthly data include: average monthly temperature, average monthly maximum and minimum temperature, number of days maximum temperature exceeded a set maximum temperature threshold (90°F in the 48 contiguous United States and Hawaii, and 70°F in Alaska), number of days maximum temperature $\leq$ 32°F, number of days minimum temperature $\leq$ 32°F, number of days minimum temperature $\leq$ 0°F, monthly heating degree days, and monthly cooling degree days.

Relative humidity is calculated using the 5-minute average ambient (dry-bulb) temperature and dew point temperature. The 5-minute average temperature is also used to process other algorithms, specifically sky condition (obscuration determination), present weather (freezing rain determination, and snow - rain discrimination), obscurations (freezing fog, fog, mist, haze discrimination), and pressure (sea-level pressure, pressure altitude, and density altitude calculation).

3.1.3 Ambient Temperature/ Dew Point Temperature Strengths and Limitations

Although the methodology of determining the ambient temperature and dew point temperature is not new, substantial improvements have been achieved by ASOS in measuring temperature and dew point by increasing the

[7]These data are contained in the Monthly Summary message issued by ASOS.

sensor aspiration and siting the sensors away from buildings and heat islands. Furthermore, ASOS's continuous monitoring, self-diagnostics, and application of quality control algorithms ensure that any ambient temperature/dew point temperature degradation trend is reported before sensor performance falls below performance standards.

At times, however, the reported dew point temperature may become stuck at around zero degrees Celsius. At other times, it may not be representative because of excessive mirror contamination due to dust or other atmospheric aerosols. An aggressive preventative maintenance program is conducted that includes periodic cleaning of the mirror surface. Furthermore, a planned product improvement effort is underway to find a more reliable alternative for measuring Dew Point temperature (see Section 7.2.2 for details).

3.2 Wind

The rotating cup anemometer and the simple wind vane are the principal indicators of wind speed and direction. Until the mid 1940s, the electrical contacting anemometer was the standard wind measuring instrument. Since then, the "F420" series of instruments have become the standard for wind measurement in the U.S. A basic system of this series consists of a cup-driven Direct Current (DC) generator with an output calibrated in knots and a vane coupled to an indicator by means of a DC synchro-system. The ASOS uses a modern automated version of the F420, in which electro-magnetic signals generated by the rotating cup and wind vane are directly converted into reportable values by ASOS.

Before ASOS, airport wind sensors were generally exposed 20 feet above ground level. With modern, high-performance aircraft, this standard no longer applies. Now, current federal standards for siting meteorological equipment specify (with some variance permitted) a height of 10 meters (32.8 feet). Typical ASOS wind sensor heights are 33 feet or 27 feet, depending on local site-specific restrictions or requirements. Figure 6 shows the ASOS anemometer. The ASOS will report the following wind related parameters.

Wind Direction: ASOS reports a 2-minute average of 5-second average wind directions once a minute (i.e., 24 samples each minute) for distribution through the OMO and computer-generated voice messages. The current 2-minute average wind direction is updated on selected OID screen displays once every minute and included in the transmitted METAR/SPECI messages. The direction from which the wind is blowing is reported to the nearest 10 degree increment (e.g., 274 degrees is reported as 270 degrees). Wind direction is reported relative to *true north* in the METAR/SPECI message, in the daily/monthly summaries, and on all video displays. Wind direction is reported relative to *magnetic north* in the computer-generated voice messages, and on the OID "AUX" data display screen. See section 3.2.2.1 for details.

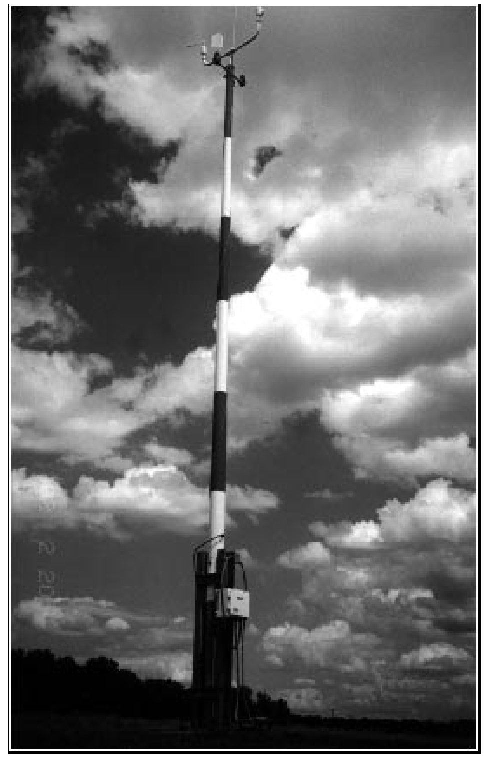


Figure 6. ASOS Anemometer

Wind Speed: A 2-minute average is updated once every 5 seconds and is reported once every minute in the OMO and computer-generated voice messages, and included in the METAR/SPECI message and various OID screen displays. See Section 3.2.2.1 for details.

Wind Gust: This is a basic component of wind character and is updated every 5 seconds. It is appended to and reported with the basic wind observation only when appropriate conditions for reporting wind gust exist (see definition in Section 3.2.2.2). Wind gust information is included in the current OMO, computer-generated voice messages, the METAR/SPECI, and OID displays.

Wind Shift: This remark is reported in the OMO and the METAR/SPECI when appropriate. See Section 3.2.2.2a for details.

Variable Wind Direction: This data element is reported in the OMO and the METAR/SPECI when appropriate. See Section 3.2.2.2b for details.

Table 2. Wind Sensor—Range, Accuracy, Resolution

Parameter	Range	Accuracy	Resolution
Wind Speed	0 to 125 knots	± 2 knots - or - 5% (whichever is greater)	1 knot
Wind Direction	0 to 359 degrees	± 5 degrees when wind speed is ≥ 5 knots	nearest degree

Squall: Although squall is a basic component of wind character and, under appropriate conditions is updated every 5 seconds, it is reported in the *present weather* section of the METAR/SPECI observation; direction and speed values are indicated in the wind group. See Section 3.2.2.2c for details.

Peak Wind: This remark is reported in the scheduled hourly METAR, as appropriate. It is the greatest 5-second average wind exceeding 25 knots which has been observed since the previously scheduled hourly METAR.

Daily Peak Wind: This value is reported in the Daily Summary message (see Section 5.6.1). It is the greatest 5-second average wind speed observed (converted to miles per hour) during the 24-hour calendar day beginning at 5-seconds past midnight, Local Standard Time (LST), (00:00:05 LST) and ending at midnight (00:00:00 LST) the next day.

Fastest 2-Minute Wind: This value is reported in the Daily Summary message. It is the fastest 2-minute average wind speed (in miles per hour) observed over the 24-hour calendar day.

3.2.1 Wind Sensor

The ASOS wind sensor (Figure 6) employs a "light chopper," electro-optical method to determine wind speed and convert it to appropriate electro-magnetic signals. Wind sensor measurements conform to the Range, Accuracy, Resolution specifications described in Table 2. In addition, the sensor's starting threshold for response to wind direction and wind speed is 2 knots. Winds measured at 2-knots or less are reported as calm.

3.2.2 Wind Algorithm

The basic method of observing wind direction and speed is to take a fixed point, time averaged measurement. The ASOS algorithm uses a 2-minute period to obtain the current average wind direction and speed. In both cases, ASOS obtains the wind character (i.e., gusts and present weather squalls) and the peak wind by comparing the difference between the average wind speed with the maximum "instantaneous" wind speed observed over a specified time interval. When this difference exceeds a prescribed value, the appropriate additional wind information is included in the observation. The ASOS wind shift remark is determined from the difference between the current 10-minute average (of 2-minute average winds) and the 10-minute average (of 2-minute average winds) from 15 minutes ago, provided the intervening 2-minute average wind speeds are greater than 9 knots. Within ASOS, all average wind directions and speeds are rounded up to the nearest degree and knot, respectively.

3.2.2.1 Wind Direction and Speed

In the past, observers monitored an analog or digital wind dial over a short period to determine the average wind direction and speed for the observation. Most sites also had a wind recorder device to provide a continuous documented record of measured wind direction and speed. The observer often used this device to determine the maximum instantaneous wind speed over the 10-minute period before completing the observation. The observer used visual/mental averaging and ultimate human judgement to create an observation of wind. This method was not always consistent from site to site or from one observer to another.

ASOS continuously and objectively measures wind direction and speed once every second, far more frequently, consistently, and accurately than an observer could. Every

ASOS processes data identically, which provides site-to-site consistency unknown in past records. Five-second wind direction and wind speed averages are computed from the 1-second measurements. These 5-second averages are rounded to the nearest degree and nearest knot and are retained for 2 minutes. These five-second averages are the fundamental units used to compute reportable wind values and are, in effect, the ASOS equivalent to the manual "instantaneous" wind observation.

Every 5 seconds a running 2-minute average wind (direction and speed) is computed and used to further compute wind character. If the computed 2-minute average wind speed is 2 knots or less, the 2-minute average wind direction and speed is reported as "calm" (00000KT).

Once each minute the current 2-minute average wind is stored in memory for 12 hours and made available for reporting in the OMO, the computer generated voice messages (i.e., the ground-to-air radio and telephone dial-in message), the METAR/SPECI reports, and OID displays.

3.2.2.2 Wind Character

Wind Character information is added to the METAR after the Wind Direction and Speed data when the variability in the steady state wind exceeds threshold criteria. Wind Character components include Wind Gusts and Variable Wind. Although Wind Squalls are reported as a Present Weather phenomena in METAR, they are also discussed here for comparison and contrast.

Both the manual procedure and the ASOS algorithm determine Wind Character by examining the maximum "instantaneous" wind speed over the 10-minute period immediately preceding the observation. The manual procedure requires a visual examination and interpretation of the dial readings or recorder to determine "instantaneous" wind speed. The ASOS algorithm, by contrast, relies on objective 5-second averages of 1-second wind measurements.

3.2.2.2a Gusts

In the **manual procedure**, a gust is reported when an observer sees rapid fluctuations in sensor wind speed indications with a variation of 10 knots or more between peaks and lulls during the 10-minutes before the observation. The reported gust is taken from the maximum "instantaneous" wind speed observed during this period. The average 2-minute wind is used to report wind direction and wind speed. Conceivably, an average 2-minute wind speed as low as 3 knots (observed in the last minute) may be reported with a gust of 10 knots (observed in the last 10 minutes). Observations of 5 knots with gusts of 10 to 15 knots, however, are the more common minimum values reported.

The **ASOS algorithm** also relies on a 10-minute observation period to determine gusts, but uses it in a different way. Once every 5 seconds, the ASOS computes the greatest 5-second average wind speed (and corresponding direction) during the past minute, and once each minute stores this information in memory for 12 hours.

Once every 5 seconds the ASOS computes the current 2-minute average wind speed and compares it with the greatest 5-second average wind speed during the past minute. If the current 2-minute average wind speed is equal to or greater than 9 knots and the greatest 5-second average wind speed (during the past minute) exceeds the current 2-minute average speed by 5-knots or more, then the greatest 5-second average speed observed during the past minute is stored in memory as a gust for 10 minutes.

Once every 5 seconds, the ASOS compares the highest gust stored in memory for the past 10 minutes with the current 2-minute average wind speed. If the difference between the two is 3 knots or more, the current reported wind speed is greater than 2 knots, and the highest gust exceeds the minimum 5-second wind speed in the past 10 minutes by 10 knots or more, then the highest gust stored in memory is designated as the reportable gust. This value is appended to the current wind direction and speed reported in the OMO, computer-generated voice messages, and the METAR/SPECI reports. The minimum gust speed reported by ASOS is 14 knots. Wind speeds from 3 knots and 11 knots may be reported with gusts to 14 knots. For example, a 2-minute average wind of 240 degrees at 10 knots with gusts to 20 knots is reported as: "24010G20KT."

3.2.2.2b Variable Wind

Both the manual procedure and the ASOS algorithm use the same definition for determining a variable wind but use different methods for reporting it. In both cases, a variable wind is reported when the wind direction varies by 60 degrees or more during the 2-minute evaluation period before the observation. If the 2-minute wind speed is 6 knots or less, than a variable wind direction indicator (VRB) is included in the basic wind group; if the 2-minute wind speed is greater than 6 knots, then a variable wind direction group is appended to the basic wind group in the body of the METAR/SPECI report.

The basis for the manual determination of a variable wind is simply a visual interpretation of the wind instrument reading during the 2-minute evaluation period. The ASOS algorithm by contrast compares the range of 5-second average wind directions during the past 2 minutes (24 samples).

In either case, if the current 2-minute average wind speed is 6 knots or less, the wind direction and speed is reported as “VRBff,” where “ff” is the current 2-minute average wind speed in knots. For example, a variable wind at 3 knots is encoded as “VRB03.”

If the current 2-minute average wind speed is greater than 6 knots, then the current wind direction and speed are placed in the body of the report and followed by a variability indicator in the form “$d_nd_nd_nVd_xd_xd_x$,” where $d_nd_nd_n$ is the minimum, and $d_xd_xd_x$ is the maximum variable wind direction during the past 2-minutes. For example, a current 2-minute wind of 270 degrees at 10 knots that varies from 240 degrees to 300 degrees is coded as: 27010 240V300.

3.2.2.2c Squalls

In the **manual procedure**, observers report a squall when wind speed suddenly increases by at least 16 knots and speed is sustained at 22 knots or more for at least 1 minute. Observers manually determine a squall by visually examining the indicated or recorded “instantaneous” wind speed. The reported squall value is taken from the maximum “instantaneous” wind speed sustained for at least 1 minute. Although squalls are measured as a parameter of wind, they are reported as an element in the present weather field of the METAR/SPECI report.

ASOS algorithm by contrast, computes a potential squall value once every 5 seconds. If the current 2-minute wind speed (measured every five seconds) is greater than or equal to 22 knots and exceeds the 2-minute average wind speed computed two minutes ago by 16-knots or more, then the highest 5-second average wind speed during the last 2-minutes is stored in memory as a squall for 10 minutes. Only the current squall or non-squall default value is stored in memory. The stored squall value is reported as “SQ” in the present weather field if the current 2-minute average wind speed is greater than 2 knots, and if the squall value exceeds the current 2-minute average wind speed by more than 3 knots.

According to this algorithm, a squall may continue to be reported by the ASOS for up to 10 minutes after the squall is written to memory, provided the above minimum wind-speed, squall reporting conditions are met. The minimum wind speed - squall combination reported by ASOS is a wind speed of 3 knots, with a squall of 22 knots.

3.2.2.3 Wind Remarks

The ASOS will include Wind Shift and Peak Wind remarks in the METAR/SPECI reports when appropriate.

3.2.2.3a Wind Shift

Both the manual procedure and the ASOS algorithm use the same definition of a wind shift as described in the FMH-1: “A wind shift is indicated by a change in wind direction of 45 degrees or more in less than 15 minutes with sustained winds of 10 knots or more throughout the wind shift.”

The observer relies on his alertness and a visual estimate of the 2-minute average wind to determine the onset of a wind shift. A Frontal Passage (FROPA) remark may be appended to the wind shift remark when the wind shift is associated with a frontal passage. This determination of course is based on human judgement.

The ASOS, on the other hand, determines a wind shift by first making sure that minimum wind speed and direction change criteria are met. These checks are made to ensure that light, variable winds are not erroneously reported as a wind shift.

The wind *speed* criterion requires that all 2-minute average wind speeds computed each minute over the past 15 minutes are greater than 9 knots. If this criterion is met, then the current 10-minute average wind *direction* derived from ten one-minute-observations is compared to a similar 10-minute average wind direction from 15 minutes ago. If the wind directions differ by 45 degrees or more, then a wind shift is encoded.

The wind shift remark generated by the ASOS in the METAR report is: “WSHFT hhmm,” where “hhmm” is the Universal Coordinated Time (UTC) of when the shift began (15 minutes ago). Once the wind shift remark is reported, it will continue to be included in all subsequent reports (including long-line dissemination of ASOS generated SPECI) through the next scheduled hourly METAR. The ASOS, of course, is unaware of distant phenomena and synoptic scale weather patterns and consequently cannot confidently determine if a frontal passage (FROPA) remark should be appended to the wind shift remark. Therefore, FROPA is not reported by ASOS. At attended sites however, this remark may be added by the Observer in accordance with agency reporting policy.

3.2.2.3b Peak Wind

The Peak Wind, by definition, is the highest instantaneous wind speed observed or recorded since the last scheduled hourly observation (METAR). The Peak Wind direction, speed and time of occurrence are reported in METAR remarks as: "PK WND dddff(f)/(hh)mm," where ddd = direction (true) in tens of degrees, ff(f) = wind speed in knots, and (hh)mm = (hour) minutes past current hour of most recent occurrence of the reported peak wind. The "hh" indicator is included only when the peak wind occurred in the previous hour since the last METAR.

The manual procedure requires a Peak Wind to be reported when the maximum *instantaneous* wind speed since the last METAR exceeds 25 knots.

In ASOS, the Peak Wind is determined from the highest observed 5-second average wind speed which exceeds 25 knots since the last generated METAR, whether transmitted or not (FIBI).

3.2.3 Wind Strengths and Limitations

The major strength of the ASOS in reporting winds is the consistency of measurements. While Observers rely on perception and human judgement to interpret wind instruments, automated systems rely on digital second-by-second measurements that are processed identically from time-to-time and place-to-place.

One limitation in the automated observation is a lag in reporting wind shifts (in METAR remarks). The wind shift algorithm cannot rely on external clues used by the observer (like thunder or snow showers) for early collateral assurance of a wind shift - frontal passage occurrence. It must therefore wait the full 15-minutes required in the definition of wind shift before outputting a remark. Although highly unlikely, a wind shift and variable wind remark may both be generated and included on the same METAR under conditions of light and variable winds which just barely meet the wind shift reporting criteria, or when a FROPA has occurred in the preceding 10-15 minutes. To be more responsive to operational needs, the wind reporting algorithm has been tuned to prevent excessive, frequent reporting of a wind shift once a report is issued and when a variable wind condition exists.

3.3 Pressure

Atmospheric pressure is the most important surface weather element for aircraft operations since it provides the means of establishing the height of an aircraft above the ground. It is the only element that cannot be directly observed or qualitatively sensed by the observer or pilot. As a result, pressure has always been carefully measured and the operational sensor routinely compared to some reference standard.

All the currently computed pressure elements will continue to be reported by the ASOS with the same or higher level of precision as the human report. The pressure parameters available from ASOS are:

- Sensor Pressure
- Altimeter Setting
- Pressure Remarks
- Sea-Level Pressure
- Density Altitude
- Pressure Altitude
- Pressure Change/Tendency
- Station Pressure

Because accurate pressure is critical, three separate and independent pressure sensors are used at towered airport locations. At other locations, two pressure sensors are used. The ASOS algorithm compares the pressure sensors' readings and issues a pressure report only when there is acceptable agreement between at least two sensors.

3.3.1 Pressure Sensor

The ASOS pressure measurement instrument consists of redundant digital pressure transducers, which use capacitive sensors, one side of which is permanently evacuated to a vacuum to make it a barometric pressure sensor. Advanced microcomputer electronics and sophisticated firmware provide reliable performance. The barometers are located on a tray at the bottom of the ACU and are exposed to the ambient air pressure. In cases when the ACU is installed in pressurized buildings, this exposure is through a port connected to an outside static pressure vent. Figure 7 shows the pressure sensors in the ACU. The specified operational characteristics for these sensors are:

- Range: 16.9 - 31.5 inches of mercury
- Accuracy: ± 0.02 inches of mercury
- Resolution: 0.003 inches of mercury (measurement); 0.005 inches of mercury (reporting)

3.3.2 Pressure Algorithm

A sophisticated algorithm routinely computes and updates the pressure report for each pressure sensor once a minute from readings obtained every 10 seconds from each

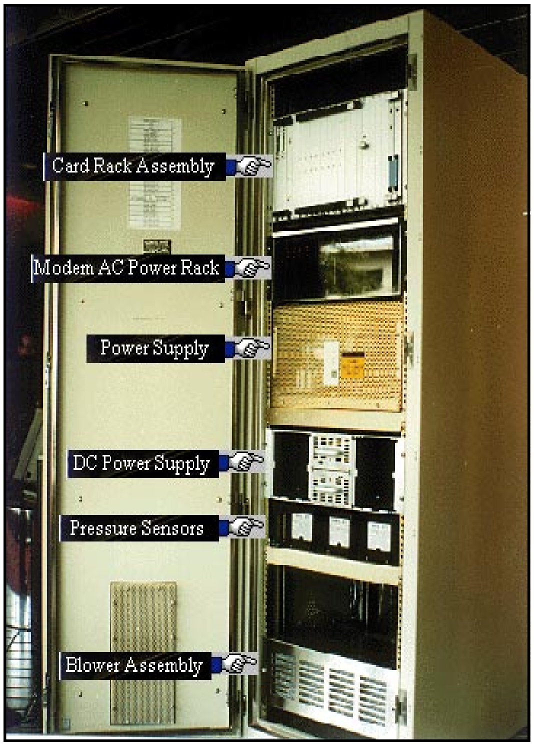


Figure 7. ASOS Pressure Sensor

sensor. If one or more of the 6 pressure readings obtained from each sensor in the past minute is missing, then the 1-minute pressure value for that sensor is marked as "missing" and the sensor is logged as "inoperative." The current 1-minute pressure values from each sensor are then compared against each other and absolute differences computed. The lowest 1-minute sensor pressure value obtained from a pair of sensors, whose pressure difference is 0.04 inch or less, is the designated ASOS pressure to be reported at the end of the minute. This pressure value is then used to compute an altimeter setting and other derived pressure values.

A sensor whose 1-minute sensor value differs by more than 0.04 inch from another operational sensor is automatically logged as "inoperative" and the sensor pressure value set to "missing." This will cause a maintenance check indicator to be appended to all subsequent ASOS METAR/SPECI reports until the sensor is returned to an "operational" status. Once a pressure sensor is logged as inoperative, it can only be returned to an "operational" status by a maintenance technician. If one of the sensors (at two-sensor locations), or if two of the sensors (at three-sensor locations) are logged as "inoperative," then the designated ASOS pressure elements are all omitted in the METAR/SPECI reports.

3.3.3 Pressure Strengths and Limitations

The pressure sensors are the most reliable and accurate sensor in ASOS. The only limitation (if one can call it that) is that pressure remarks will be reported more often in ASOS METAR messages than in manual METAR messages simply because of the continuous weather watch which ASOS provides.

3.4 Precipitation Accumulation

Accurate liquid-equivalent precipitation accumulation measurements are essential for hydrological, flood forecasting, and agriculture applications. For aviation purposes, freezing or frozen precipitation accumulation measurements provide a quantitative dimension to the qualitative detection and reporting of freezing or frozen precipitation by other ASOS sensors.

Basic manual measurements of precipitation accumulation in the U.S. have traditionally relied on the Standard 8-inch Gauge. This consists of an 8-inch cylinder with an inverted funnel orifice leading to a graduated inner cylinder at the base of the funnel neck. The inner cylinder is used to measure liquid precipitation accumulation. When freezing or frozen precipitation is expected or is occurring, the funnel and inner cylinder are removed. Frozen precipitation captured in the outer cylinder are periodically melted indoors to measure the liquid-equivalent of frozen precipitation (LEFP).

In the early development of an automated precipitation accumulation gauge, it was recognized that automated measurement of liquid and LEFP each presented a unique challenge, so, a separate specification was written for each type of precipitation. The automated Heated Tipping Bucket (HTB) technology from the 1970s was adopted and modified to meet these needs. Over the years, many improvements were made and incorporated into ASOS. Early versions of the heated gauge applied excessive heat creating excessive evaporation and the under-reporting of the liquid-equivalent mass.

The current version of the HTB gauge applies less heat over a longer heating cycle, thus yielding a more accurate mass measurement of frozen precipitation. Changes in the tipping bucket inner design also have improved overall performance in liquid precipitation events. These improvements have resulted in the ASOS HTB becoming a very capable liquid precipitation accumulation gauge in all but the most extreme heavy rainfall events. However, some deficiencies still remain in its ability to fully measure precipitation accumulation during the cold-season LEFP events. Consequently, the ASOS HTB is primarily used to measure liquid accumulation. Alternative solutions are being pursued to provide LEFP information. These solutions include: (1) Provision of separate LEFP reports through existing manual supplementary observing networks from event-driven Supplementary Data Observations and schedule-driven Supplementary Climate Data reports, and (2) Development of a follow-on All-Weather Precipitation Accumulation Gauge for ASOS (see Section 7.2.4).

3.4.1 Heated Tipping Bucket (HTB) Precipitation Gauge

The ASOS HTB shown in Figure 8 consists of 6 main components:

Figure 8. ASOS Heated Tipping Bucket

- A wind shield that surrounds the HTB and protects it against blowing snow from falling into the HTB collector funnel (the wind shield is installed on the ASOS HTB in climates where the snowfall is $\geq$ 20% of the annual precipitation accumulation)
- A 12-inch diameter collector funnel
- A pivoting dual chamber tipping bucket. This bucket tips when one chamber is filled with 0.01 inch of liquid precipitation, thus emptying the contents into a drain pan and exposing the other chamber to the precipitation gathered by the collector funnel
- An electronic switch which counts the number of tips per minute
- A drain pan and a drain tube
- Heating elements to prevent freeze-up during cold weather.

The HTB has 2 heating elements. One heating element is wrapped around the underside of the collector funnel, and the other around the drain tube. Each heater is separately thermostatically controlled to maintain a temperature of 40°F. A master thermostat regulates electric power to both heating elements. Power is turned on when the temperature falls below 40°F and is turned off when the temperature falls below -20°F. Power is not turned on again until the temperature rises above -12°F. Power is turned off when the temperature is at or above 40°F.

The HTB has a precipitation accumulation range of 0 to 10.00 inches per hour, a resolution of 0.01 inch (i.e., one tip) and an accuracy of ± 0.02 inch or 4% of the hourly total (whichever is greater).

3.4.2 Precipitation Accumulation Algorithm

The precipitation accumulation algorithm obtains precipitation accumulation data from the HTB precipitation gauge once each minute. These data are valid for discrete 60-second periods ending at M+00. The ASOS algorithm corrects the tipping bucket measurement, particularly during periods of high rainfall rates. Each minute the measured rainfall is adjusted using the following equation:

$$\mathbf{C = A\,(1 + .60A)}$$

In this equation, C = the calculated rainfall amount and A = the measured amount from the tipping bucket. All calculations are performed internally using floating point until rounded for final output each minute.

If a 1-minute precipitation accumulation output is missing and the precipitation identifier sensor (discussed in Section 4.3) is either inoperative or concurrently reports precipitation, then the associated METAR precipitation remarks/messages will either be omitted (Prrrr remark is deleted), or contain a "/ " (e.g., 6////, 7////). Furthermore, when the precipitation accumulation sensor is inoperative, a "PNO" remark will be appended to the METAR to indicate that precipitation accumulation information is not available. In SHEF, missing precipitation accumulation data will be reported as "M" in place of the missing value. When available, the output data are used each minute by the algorithm to compile a variety of cumulative precipitation remarks/messages. These include:

METAR hourly message, "Prrrr" remark: In this message "rrrr" is the liquid equivalent of all precipitation (in hundredths of an inch) which has occurred since computation of the Prrrr remark for the last scheduled hourly

METAR message. The “rrrr” is the sum of all 1-minute precipitation accumulations calculated during this period. If any of the required constituent 1-minute precipitation accumulation calculations are missing, the remark is omitted and “PNO” is appended to the remarks section. If no precipitation has occurred since the last scheduled hourly METAR, the Prrrr remark will not be reported. If only a trace of precipitation has occurred, the Prrrr remark will report “P0000.”

METAR 3- and 6-hourly report, “6RRRR” precipitation accumulation remark: “RRRR” is the amount of precipitation, in hundredths of an inch, which has accumulated in the past 3- or 6-hours. Three-hourly amounts are reported in the 03, 09, 15, and 21 UTC METAR reports. Six-hourly amounts are reported in the 00, 06, 12, and 18 UTC METAR reports.

If any of the constituent hourly Prrrr remarks are missing, the 6RRRR remark is encoded as 6////.

METAR 24-Hour “7RRRR” precipitation accumulation remark: “RRRR” in this message is the amount of liquid equivalent in hundredths of an inch accumulated over the last 24-hours. This remark is reported with the 1200 UTC METAR provided there has been at least 0.01 inch of precipitation in the past 24-hours (i.e., since the last 1200 UTC METAR). The precipitation accumulation reported in the 7RRRR remarks is compiled from the hourly precipitation computations. If any hourly amount is missing during the 24-hour period, the 7RRRR remark is encoded as 7////.

SHEF 15-Minute Precipitation Criteria message: These messages are generated when the current 15-minute period accumulation exceeds the locally established precipitation accumulation onset threshold and will cease when the accumulation for the current interval falls below the termination threshold. The precipitation accumulations for the four most recent discrete 15-minute periods (ending at H+00, H+15, H+30 and H+45) are chronologically listed in these messages.

These messages are issued in “.E” SHEF message format, and are initially disseminated through the NWS or the FAA communications networks to the NWS Telecommunications Gateway (NWSTG) and the System Monitoring and Coordination Center (SMCC) where they are made available for redistribution to NWS offices and compilation on the daily Service Records Retention System (SRRS) tape for the National Climatic Data Center (NCDC). These messages are identified within the NWS by their RR6 AFOS/AWIPS header: “CCCRR6XXX,” where “CCC” is the originating AFOS node, “RR6” is the designation for SHEF 15-minute messages originating from ASOS and “XXX” is the ASOS location identifier (see Section 5.5.1 for details).

All SHEF data from FAA sites are contained in a “collective” (a group of individual messages bundled together) and are identified by the collective header “NMCRR7NKA.” The precipitation accumulation for each 15-minute period is derived from the sum of the 1-minute precipitation accumulation calculations within each discrete 15-minute period. If any of the constituent 1-minute precipitation accumulation calculations are missing, the value encoded in the SHEF 15-minute precipitation criteria message for the entire 15-minute period is “M.”

SHEF Hourly Routine Precipitation message: The precipitation accumulation period for this message is 60 minutes. The end time (in minutes past the hour) is set at H+00. These messages are issued once an hour at the time specified to support calibration of the precipitation processing at the designated WSR-88D Radar Product Generator.

These SHEF messages contain an hourly precipitation accumulation. They are issued in “.A” SHEF message format and are made available and distributed in the same manner as the SHEF 15-Minute Precipitation Criteria messages. The messages are identified within the NWS by their RR7 AFOS/AWIPS header: “CCCRR7XXX.” All SHEF data from FAA sites are contained in a collective and are identified by the collective header “NMCRR7NKA.” These messages are further distinguished from the 15-Minute Precipitation Criteria messages by message type identification within the body of the message (see Section 5.5.2 for further details).

The SHEF Hourly Routine Precipitation accumulation is derived from the sum of the 1-minute precipitation accumulation calculations during the latest discrete 60-minute period. If any of the constituent 1-minute precipitation accumulation calculations are missing, the SHEF Hourly Precipitation message will report the precipitation accumulation as “PPH M” (see Section 5.5.2).

Daily and Monthly cumulative precipitation totals: These precipitation totals are summed each minute and included along with other data in the Daily Summary and Monthly Summary Products/messages.

The information in the Daily Summary is valid for the 24-hour period beginning at 00:00 LST and ending at 23:59 LST. This message is issued on the following calendar day at programmable transmission times (see Section 5.6 for further details).

The Monthly Summary message is valid for the calendar month. This message is issued on the first day of the following month at a time specified by the system manager. The Monthly Summary message contains the amount(s) and date(s) of the maximum 24-hour precipitation accumulation during the calendar month; the number of calendar days with precipitation equal to or greater than 0.01, 0.10, 0.50 and 1.00 inches respectively; and departure of monthly cumulative precipitation totals from normal. Other parameters are also included in the Daily and Monthly Summary messages. See Sections 5.6.1 and 5.6.2 for further details.

3.4.3 Precipitation Accumulation Strengths and Limitations

There are well known problems (referenced in Section 3.4) associated with a HTB precipitation gauge. A major problem occurs during high rainfall rate events when the tipping bucket cannot keep up with the water flow and under-reports the accumulation. The ASOS software corrects for the HTB bias to under report precipitation accumulation during most heavy rainfall events (greater than 1.80 inch per hour); however, during extremely heavy rainfall events (greater than 10 inches per hour), the HTB may still under-report the total rainfall accumulation.

During freezing conditions, the application of heat to melt snow and prevent gauge icing also induces evaporation or sublimation, especially during light freezing rain or snow events at temperatures near 32°F. This results in a tendency to under-report freezing or frozen precipitation accumulation.

The tendency to under-report accumulation during freezing rain or snow events is moderated by using a less intense heat source to melt the frozen precipitation from the tipping bucket at a slower rate. The slower heating rate however, can sometimes allow unmelted snow to bridge over the heated funnel surface and form a snow cap over the orifice opening which prevents any further accretion into the gauge.

At some time after the precipitation event ends, under bright sunshine and/or warming ambient temperature, the snow cap melts and falls into the gauge. This causes a delayed accumulation to be registered and falsely reported at a time when no precipitation is occurring. “False tips” may also be caused by dew, frost, or heavy fog.

CHAPTER FOUR

4.0 Automating the Subjective Weather Elements

While automating most objective weather elements is fairly straightforward, there are numerous complexities in automating subjective visual elements such as sky condition, visibility, and present weather. The major problem is how to objectively quantify subjective human judgement.

With subjective elements, observers traditionally read instruments and watch weather conditions in their area at a fixed time to produce a "snap-shot" observation—a method called spatial averaging. To create a similar observation, automated systems repetitively sample conditions in a relatively small volume of air and then average these data over a set time period—a technique called time averaging. Technological advances have made it possible for modern observations to progress from the periodic, subjective, spatial averaging methodology of the observer to an objective, nearly continuous, temporal averaging method of automated observing systems.

The rules for observing sky condition (clouds), visibility, present weather, and obscurations were designed for observers and are still defined for subjective use; however, the FMH-1 now includes expanded rules for automated techniques. Because of the complexity of the subjective weather elements, separate sections are devoted to sky condition, visibility, and present weather. Each section discusses the differences between manual and automated rules and techniques.

4.1 Automating Sky Condition

Observers have used rotating beam ceilometers (RBC) and the newer laser beam ceilometers (LBC) for years to measure the height of clouds. Visual estimates were still needed to determine the amount of clouds. The challenge of automating the data from such sensors was not only to process the height accurately, but also to provide a representative description of the amount of cloud coverage. Because the atmosphere is normally in motion, it was found that processing the ceilometer signal through a sophisticated algorithm over a 30-minute time period provided an optimally representative and responsive observation similar to that depicted by an observer. To be sensitive to the latest changes in sky conditions, the most recent 10 minutes of the data are processed twice (double-weighted). To be most responsive to operational needs, the

Figure 9. Laser Beam Ceilometer

ASOS ceilometer is located near the touchdown zone of the primary instrument runway at most airports. At large airports, a secondary Cloud Height Indicator (CHI) may be located elsewhere on the airport to provide additional information when there is a meteorological discontinuity. At small airports the ceilometer may be collocated with other sensors near a center-field location or touchdown zone, depending on local siting requirements.

4.1.1 Cloud Height Indicator Sensor

The ASOS uses a laser beam ceilometer with a vertical measuring range of 12,600 feet and reporting range of 12,000 feet (Figure 9). The ASOS cloud sensor, or CHI, is a vertically pointed laser transmitter and receiver. Its operation is similar to radar in that the time interval between pulse transmission and reflected reception from a cloud base is used to determine the cloud height. Sophisticated time-averaging algorithms in the ACU are also used to interpret "cloud hit" information from the CHI and determine cloud height and amount.

The CHI consists of a gallium arsenide laser beam ceilometer operating in the near Infrared (IR) portion of the electro-magnetic spectrum at a wavelength of about a 0.9 microns. The instrument employs Light Detection and Ranging (LIDAR) principles and computer algorithms to provide cloud coverage and height information. The noise inherent in the return signal varies with ambient temperature. To optimize the laser's signal-to-noise performance, the CHI's pulse frequency varies with the ambient temperature. The frequency range is 620 Hertz (Hz) to 1,120 Hz with a nominal pulse frequency of 770 Hz at room temperature (68 ºF). The frequency is also modulated by the age of the equipment to maintain a constant power output. The width of the beam is confined to a divergence of ± 2.5 milliradians (mrad) so that at 12,000 feet the beam's sample area is a circle with a diameter of 60 feet.

The CHI reports will contain only opaque clouds. Moisture layers, or thin clouds detected by the CHI and considered too thin to be a cloud, will be reported as a restriction to vertical visibility or simply not reported. The reporting of vertical visibility is dependent on the thickness and density of the moisture layer. To correctly classify these signals received by the ceilometer, sensor software processes the data into three categories: "no hit," "cloud hit," and "unknown hit."

The signal signature of a cloud return or "cloud hit" is characterized by a rapid increase in backscatter when the beam passes from the clear air beneath the cloud into the moist conditions within the cloud. Figure 10 is an example of a "cloud hit" at 4,500 feet. At the end of each 12-second sampling, the CHI produces a detailed, high-resolution back-scatter profile from which a unique determination of the cloud base can be made. The cloud base "hits" (or returns) from each pulse are assigned to one of the 252 50-foot vertical data bins within the 12,600 foot measurement range. This results in a vertical resolution of 50 feet!

Not all signal returns exhibit the sharp signature pattern of a "cloud hit," (as shown in Figure 10). Those signals without sharp returns are classified as "unknown hits." A return from deep fog where the scatter return pattern extends from the surface to around 600 feet is shown in Figure 11. These "unknown hits" are primarily caused by precipitation and fog that mask the base of the clouds. This broadened moisture field returns laser back scatter signals from various heights within the moisture field. Because these signals cannot be processed as a definite cloud return, they are processed as a vertical visibility (VV). VV is defined as the distance in feet a person can see vertically from the surface of the earth into an obscuring phenomena or indefinite ceiling.

All the values of "unknown hits" are processed and stored in height bins reserved for the VV values (separate from the "cloud hit" bins). Finally, all the returns in the VV bins are processed into a single mean height and assigned to a single bin. The VV returns are then processed by the sky condition algorithms to determine cloud cover, cloud height, or VV.

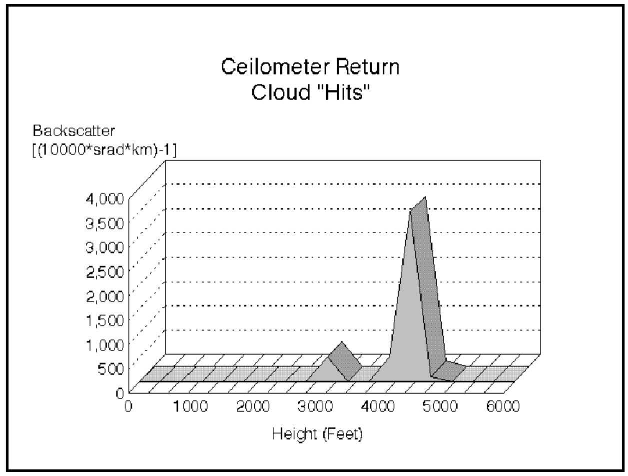


Figure 10. Example Of Cloud "Hit" At 4,500 Feet

4.1.2 Sky Condition Algorithm

Computer algorithms (organized processing steps) are used to process the signal data as described above into sky condition reports that are encoded into METAR and SPECI reports. Describing exactly how the algorithms work is quite complicated, so what follows is a simplified explanation.

Every 30 seconds a sample is compiled from the CHI's back scatter returns taken from the most recent two or three 12-second processing intervals completed within the 30-second period. Each 12-second interval processes more than 9,000 signals for back scatter returns. These data are processed to determine the height of the returns and whether the sample compiled from these returns is a "cloud hit" or an "unknown hit." Every minute, ASOS processes the most recent 30 minutes of 30-second sample data; the last 10 minutes of data are processed twice (double weighted) to be more responsive to the latest changes in sky condition. This technique provides a total of 80 samples; 40 in the

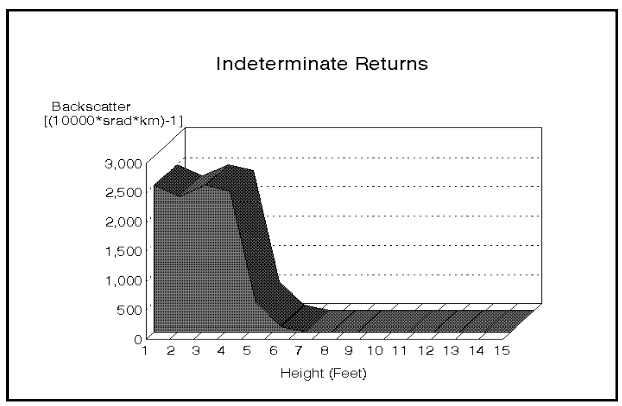


Figure 11. Example Of "Unknown Hit"

first 20 minutes and 40 in the last 10 minutes. The cloud signal hits for the latest 30 minutes are then rounded or "binned" to the nearest 100 feet for cloud heights between the surface and 5,000 feet; to the nearest 200 feet for heights between 5,000 and 10,000 feet; and to the nearest 500 feet for heights above 10,000 feet.

Each minute, if more than fives bin height values have been recorded (during the last 30 minutes), the cloud heights are clustered into layers using a least-square statistical procedure until there are only five bins remaining (each bin can have many "hits' in it). These bins, or clusters, are then ordered from lowest to highest height.

Following this clustering, ASOS determines whether the clusters can be combined into "meteorologically significant" height groups. This second clustering is done so that very close layers are not reported (e.g., BKN030 OVC032). At the end of this combining process, all cluster heights between the surface and 5,000 feet are rounded to the nearest 100 feet. Above 5,000 feet, the algorithm rounds the cluster height values to the nearest reportable value (i.e., nearest 500 ft. up to 10,000 ft. and nearest 1,000 ft. above 10,000 ft.). These bins now are called "layers" and the algorithm will select up to three of these layers to be reported in the METAR/SPECI in accordance with cloud layer reporting priority as specified in FMH-1.

Table 3. Cover ASOS Cloud Amount Report —Percent of Sky

ASOS Measured Amount in % of sky cover	Human Equivalent in oktas	ASOS Report
00 to ≤ 05	0	CLR
> 05 to ≤ 25	> 0 to 2/8	FEW
> 25 to ≤ 50	> 2/8 to ≤ 4/8	SCT
> 50 to ≤ 87	> 4/8 to < 8/8	BKN
> 87 to 100	8/8	OVC

The amount of sky cover is determined by adding the total number of hits in each layer and computing the ratio of those hits to the total possible. If there is more than one layer, the "hits" in the first layer are added to the second (and third) to obtain overall coverage. For reporting purposes, the ASOS measured cloud amount for each layer is then converted to a statistical functional equivalent of a human observation. All cloud layer heights are reported Above Ground Level (AGL) with respect to field elevation. The cloud amounts reported by ASOS are Clear (CLR) below 12,000 feet, Few (FEW), Scattered (SCT), Broken (BKN), or Overcast (OVC). Table 3 shows the relationship between the ASOS measured cloud amount, the human equivalent, and the reported category.

The sky condition algorithm also tests for total obscurations. Necessary conditions for reporting totally obscured sky include a surface visibility of one mile or less and a high percentage of "unknown hits" at or below 2,000 feet AGL. When these conditions are met, ASOS processes and formats cloud return values classified as "unknown hits" into the sky condition report as "VVaaa." VV is an obscuration; "aaa" represents the visible height in hundreds of feet an observer can see vertically into the obscuring phenomena.

Finally, when a ceiling layer (BKN or OVC) is reported below 3,000 feet AGL, an algorithm tests for conditions requiring a variable ceiling remark. If these conditions exist, ASOS places the entry of CIG minVmax (where min, max is the height in hundreds of feet of the upper and lower limits of the variability) in the remarks section.

4.1.2a Meteorological Discontinuity Sensors

A sky condition algorithm has been developed for use where cloud formation (or advection) typically occurs in (or from) a known location and results in significant concurrent differences in sky conditions over the airport. The meteorological discontinuity algorithm uses output from two CHI sensors. The primary sensor is sited near the touchdown zone of the primary instrument runway. The second CHI is typically sited 2 to 4 miles away from the primary sensor, upwind in the most likely direction of the advection, or closer to the fixed source of the unique sky condition. The second CHI serves to detect operationally significant differences in sky conditions.

Information from the meteorological discontinuity sensor is included in the ASOS METAR under appropriate conditions described below. Data from the primary and meteorological discontinuity sensors are independently processed through the single sensor algorithm and then compared. Only data from the primary sensor is used in the body of the METAR.

Table 4. Criteria For Reporting A Meteorological Discontinuity Ceiling Remark

CEILING REPORTED BY PRIMARY SENSOR	CEILING DIFFERENCE CRITERIA (Primary - Met Discontinuity)
UP TO 1,000 FEET	> 300 FEET
> 1,000 FEET UP TO 3,000 FEET	> 400 FEET
> 3,000 FEET UP TO 5,000 FEET	> 600 FEET
> 5,000 FEET UP TO 8,000 FEET	> 1,000 FEET
> 8,000 FEET	> 1,600 FEET

If the primary sensor is not operational, the sky condition is not reported, a maintenance check indicator ($) is appended to the METAR, and no further comparisons are made. If the meteorological discontinuity sensor is not operational, the remark "CHINO LOC" is added to the METAR, where LOC is the nominal location of the meteorological discontinuity sensor (e.g., CF, RWY26L), a maintenance check indicator ($) is appended to the METAR, and no further comparisons are made.

If both sensors are operational and report a ceiling, and the ceiling reported by the meteorological discontinuity sensor is lower than the ceiling reported by the primary sensor by the difference criteria listed in Table 4, then a remark "CIG VALUE LOC" is included in the METAR where VALUE is the ceiling height (in hundreds of feet) reported by the meteorological discontinuity sensor. For example, if the primary sensor reported a ceiling at 8,000 feet and the meteorological discontinuity sensor reported a ceiling at 6,500 feet on runway 26L then the remark "CIG 065 RWY26L" is reported.

4.1.2b Back-Up Sensors

At some locations, mainly major airports, a back-up CHI may be available. The back-up is generally collocated with the primary sensor suite while the meteorological discontinuity CHI is not. The back-up sensor operates continuously in stand-by mode. When a METAR/SPECI report is created, the ASOS checks for data from the primary CHI sensor. If the primary sensor is inoperative, then ASOS will interrogate the back-up sensor, process that data through single-sensor algorithms, and enter the value into the report. When the primary sensor is back in service, the back-up sensor is once again placed in stand-by mode.

4.1.3 Sky Condition Strengths and Limitations

The ASOS ceilometer is a vertically pointing laser that measures the height and infers the amount of cloud elements that pass over the sensor. It operates continually and once every minute it determines the sky condition for the most recent 30 minutes. The sensor does not measure or know what is happening along the horizon, nor does it report on clouds above 12,000 feet. The horizontal limitation can be partially overcome by using a second meteorological discontinuity CHI sensor at selected major airports where studies have shown that more than one sensor is needed. Due to the inherent motion of the atmosphere however, a single CHI is usually sufficient to report accurate cloud conditions.

A common concern is that the algorithm does not respond fast enough to changes in the sky condition. If a solid cloud deck suddenly appears, the algorithm will report a "FEW" layer within 2 minutes and a "BKN" ceiling layer within 10 minutes. One limitation however is that if the CHI becomes inoperative for three consecutive 30-second readings (1.5 minutes) or misses five or more readings in the most recent 30 minutes, it does not report sky condition. The algorithm requires a full 30-minutes of data from the CHI after restart before a valid sky condition report is once again generated.

Precipitation poses a double challenge. Because the laser can only look vertically, precipitation particles directly overhead will scatter the laser light, often leading to an increased number of "unknown" signal returns. The algorithms described above help distinguish a vertical obscuration caused by falling rain drops from the base of the cloud layer above it. Precipitation can also fall onto or collect on top of the instrument. To limit that problem, a blower is used to move air over the slanted glass cover housing of the laser lens.

Occasionally, the laser CHI can see "too many" clouds. For example, a very sensitive laser will sometimes detect invisible moist layers before they coalesce to become visible clouds. Also, occasional sharp inversions, especially in very cold winter conditions, may trigger the report of clouds. Algorithm developers will continue to work on eliminating these small but annoying traits.

There are times when the CHI may report fewer clouds than the observer. Studies have shown that up to 20 percent of the reports of "FEW" cloud events will be missed by using only one ceilometer. These events are usually widely scattered fair weather cumulus, which the ASOS may report as "CLR."

What are some of the advantages of ASOS? It will report the onset of low stratus moving over the ceilometer within 2 minutes, and the formation/dissipation of a low ceiling within 10 minutes. If a low cloud layer forms or falls below 1,000 feet AGL, or if the ceiling rises to equal or exceed 1,000 feet AGL, the ASOS will transmit a SPECI report. ASOS will continually monitor the sky condition and automatically create and issue a report with a speed and responsiveness comparable to an observer. The ceilometer does not suffer from night adaptation. Observers must wait for their eyes to adapt to the dark before being able to accurately distinguish night time sky conditions. It is difficult, even for the experienced observer, to distinguish gray on gray when lower stratus cloud layers move in under higher stratus clouds.

Finally, ASOS reports more broken cloud layers and fewer overcast layers than an observer because the ceilometer does not suffer from the "packing effect" (Figure 12). The "packing effect" is a condition where the observer tends to overestimate the cloud coverage because clouds near the horizon appear to blend together or overlap. This effect is due to the curvature of the earth and parallax view of distant objects.

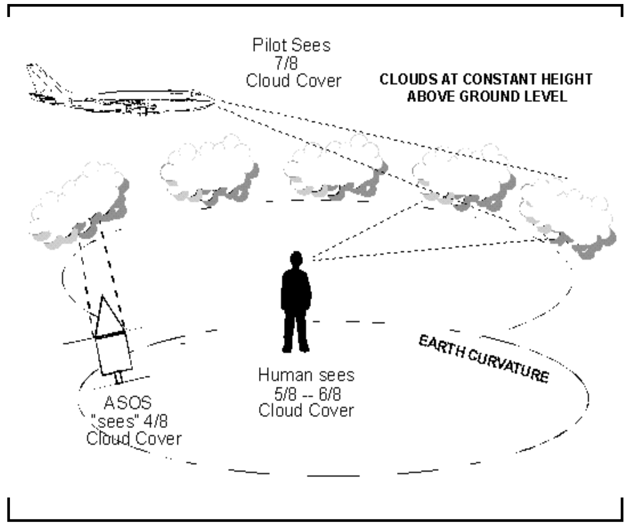


Figure 12. Example of Packing Effect

4.2 Automating Surface Visibility

Visibility remains one of the most difficult elements to automate. Sensors can successfully measure atmospheric elements relating to visibility, but it is very difficult to relate these measured elements to the characteristics of human vision. The physical limitations of the human eye and human subjectivity are greatly impacted by precipitation, day and night vision adaptation, contrast, physical obstructions, and perspective.

The value reported as the visibility may reflect only the distance an observer can see due to obstructions such as nearby buildings and trees, not how far the eye can actually see in the absence of such obstructions. It is not unusual to see differing reports of visibility observations under the same conditions because of perspective. The challenge facing observing system developers was to automate visibility reporting to accurately reflect both the meteorological and non-meteorological elements that enter into the human evaluation of visibility.

The NWS and FAA jointly developed the concept of Runway Visual Range (RVR). This concept combined visibility theory with extensive empirical testing of transmissometer measurements to represent the distance a pilot could see runway lights or objects during take off or landing. Thus, it was natural to apply this knowledge in automating the measurement of surface visibility.

The task of automating surface visibility began earnestly in the early 1970s when the FAA and NWS jointly conducted the AV-AWOS experiments. These test demonstrate the feasibility of automated surface observations. By the 1980s, the agencies were able to show that it was practical to automate surface visibility and report a value that was suitable and responsive to the needs of the aviation community. From these tests, a working group in 1981, under the auspices of the Office of the Federal Coordinator for Meteorology (OFCM), produced a set of definitions and guidance for automating sensor derived visibility.

4.2.1 Principles in Visibility Automation

In the early 1970s, NWS scientists developed the concept of Sensor Equivalent Visibility (SEV). SEV was defined as any equivalent of human visibility derived from instrument measurements. This means that visibility is not measured directly but is inferred by measuring other physical characteristics and properties of the air. These properties include the transmittance (or conversely attenuation) of light due to absorption and scattering by atmospheric contaminants such as aerosols, course particulates, and hydrometeors. Studies have shown that human visibility is closely correlated with transmittance. A sensor can measure this atmospheric capacity and quantify it through sophisticated algorithms to represent visibility. This is SEV.

Before automating visibility and applying the SEV concept, developers had to create a standard value that could be consistently reproduced in electronic sensors. The fundamental measure of atmospheric clarity, the extinction coefficient, was defined by using the Optec Transmissometer, which measures the attenuation of light by scattering and absorption in the mid-visible light wavelength of 550 nanometers (550 billionths of a meter). It was found that, in general, scattering was the primary cause of attenuation (and therefore visibility reduction). Furthermore, scatter meters were less costly to build and easier to install and maintain than transmissometers. Therefore, qualification testing focused on scatter meters with the goal that they could be used as an alternative to the Transmissometer.

A forward scatter meter was found to correlate better with Transmissometer extinction coefficients and human visibility than a back scatter meter, particularly during snow events. Later testing showed that with slight adjustments in derived visibility based on the type of weather (i.e., rain or snow) a *forward* scatter meter was fully acceptable as a visibility sensor. A visible light source was found to work best with the forward scatter meter because of better agreement with observers during small particle (e.g., haze) events.

The next step was to develop algorithms to process the sensor data into a representative visibility. This step required identifying those key elements the human eye responds to in determining visibility. During the day, the human eye relies on variations in contrast between the visibility target and its background when viewing through fog, mist, haze, rain, or snow. At night, the human eye uses a distant unfocused light to determine visibility. The illuminance threshold, like contrast threshold, assumes that the average observer can see a light source of two mile-candle illuminance.

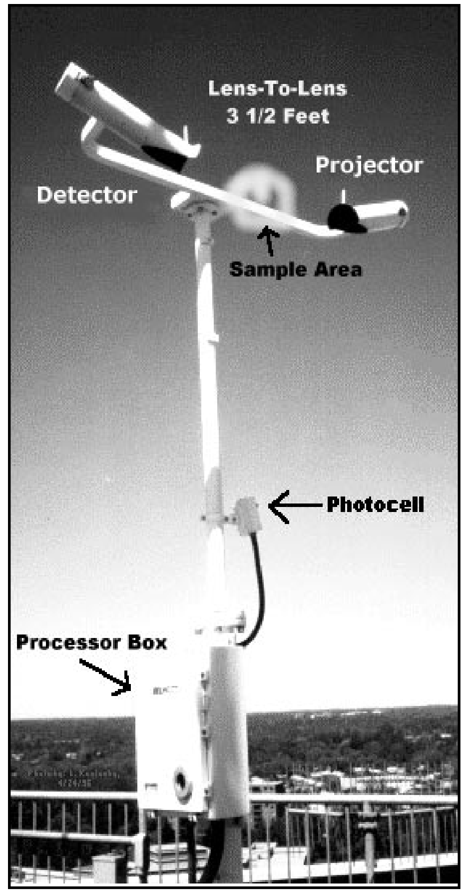


Figure 13. Forward Scatter Visibility Sensor

A photocell on the visibility sensor turns on at dawn or off at dusk at a light level between 0.5 and 3 foot candles (deep twilight). This function determines whether the sensor uses the day or night equation to calculate visibility. For a given extinction coefficient, the day calculation will provide a visibility from 1/2 to 1/3 of that derived by the night equation. Therefore, an abrupt change in visibility may be reported after sunrise or sunset if there is a significant obstruction.

SEV and the prevailing visibility (PV) of the observer are based on different concepts. The SEV in ASOS is derived by frequently measuring the forward scatter characteristics of a small atmospheric sample (0.75 cubic feet) near the sensor and processing these data for 10 minutes. PV, as determined by the observer, relies on visual interpretation of current conditions in a full 360 degree circle around the observation point. This is not done continuously, but only during hourly observation time and when significant weather changes are occurring and noted. SEV and the human-derived prevailing visibility agree most consistently when the weather is homogeneous over a large area; however, testing has shown that there is also strong agreement between human and automated visibilities, even during periods when weather conditions are quite variable.

The AV-AWOS experiments in 1979 showed that the values obtained from three visibility sensors (in a 3-mile triangular arrangement) were, in most cases, in close agreement. Further testing supported the premise that only one sensor, located in a representative area, could be used to describe the visibility for an airport area. It was still recognized that sites plagued by advection fog or other visibility discontinuities would require additional sensors. Every airport required a site survey to properly locate the visibility sensor and identify locations that might need additional sensors.

The location of the visibility sensor(s) was critical. The small sampling volume of the sensor dictated that the sensor be located as near to the area of concern as possible. As a result, most primary visibility sensors were placed near the touchdown zone (TDZ) of the primary instrument runway. The actual siting of the sensors had to meet, as closely as possible, the requirements established by the Federal Standard for Siting Meteorological Sensors at Airports, and the clearance requirements of the FAA. This included consideration of local sources of visibility reduction (e.g., plowed fields, snow blowing operations, and smokestacks), the proper sensor height (at least 10 feet), and adequate obstacle clearances.

4.2.2 Forward Scatter Sensor

The ASOS visibility sensor (Figure 13) operates on a forward scatter principle in which light from a pulsed Xenon flash lamp in the blue portion of the visible spectrum is transmitted twice a second in a cone-shaped beam over a range of angles. The projector and detector are protected with a lens hood and canted down at 15 degrees from the horizon to prevent snow blockage.

The detector "looks" north to minimize sun glare, particularly from low sun angles near sunrise or sunset. To optimally balance the detection efficiency and differentiation ability of the sensor under varying conditions, a nominal 45 degree horizontal incident angle is set between the projector beam and the detector field-of-view within the sampling volume. This is achieved by offsetting the projector about 45 degrees to the left (i.e., northwest) of the detector. As a result, the projector beam does not directly

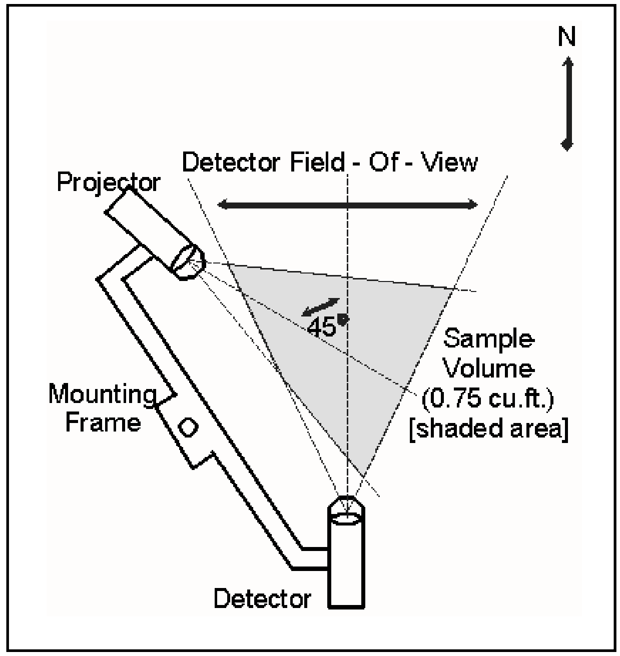


Figure 14. Visibility Sensor—Top View

impinge on the detector lens. Only that portion of the beam that is scattered forward by the intervening medium in the sampling volume is received by the detector (see Figure 14). The sensor sampling volume is 0.75 cubic feet and the sensor response time is 20 seconds. A measurement sample is taken every 30 seconds. Visibility sensor measurement accuracy is specified in reference to comparison with two NWS visibility standards and is summarized in Table 5. In this regard, the forward scatter sensor has shown excellent performance when compared with the "Optec" Transmissometer standards.

Visibility in METAR is reported in statute miles (SM). The reportable increments are: M1/4SM, (less than 1/4SM), 1/4SM, 1/2SM, 3/4SM, 1SM, 1 1/4SM, 1 1/2SM, 1 3/4SM, 2SM, 2 1/2SM, 3SM, 4SM, 5SM, 6SM, 7SM, 8SM, 9SM and 10SM. Note that visibilities between zero and less than 1/4 mile are reported as M1/4SM[8]. Measured visibilities exactly half way between reportable values are rounded down. Visibilities of 10 miles or greater are reported as "10SM."

4.2.3 Visibility Algorithm

The ASOS visibility algorithm samples sensor data every minute, obtaining a 1-minute average extinction coefficient and day/night indication. The algorithm calculates a 1-minute average visibility every minute and stores the value for 10 minutes. Finally, ASOS computes a running 10-minute **harmonic** mean once per minute from the stored data to provide the latest visibility.

[8] Manual observations of 0, 1/16, and 1/8SM may be augmented.

Table 5. Visibility Sensor—Accuracy in Statute Miles
(As compared to NWS Standard Transmissometer)

ASOS Visibility Measurements	at least 80% of data within these limits.	at least 98% of data within these limits	all data within these limits
0 thru 1 ¼	± ¼	± ½	± 1
1 ½ thru 1 ¾	+ ¼, - ½	+ ½, - ¾	± 1
2 thru 2 ½	± ½	± 1	± 1
3 thru 3 ½	+ ½, - 1	+ 2 RI*/ - 1	+ 2 RI*/ -1
4 thru 10	± 1 RI*	± 2 RI*	± 2 RI*

*RI + Reportable Increment

A harmonic mean is used in the final computation rather than an arithmetic mean because it is more responsive to rapidly decreasing visibility conditions and will generally yield a lower value than the arithmetic mean. This result is preferable because it provides an earlier warning of deteriorating conditions. Conversely, when visibilities are rising rapidly, the harmonic mean will be slower than the arithmetic mean in reporting the improving visibility. This conservative bias is intended to provide an additional margin of aviation safety. A 10-minute computation and a harmonic averaging technique was chosen to strike an optimal balance. A longer averaging period tends to dampen short-term non-homogeneous fluctuations while harmonic averaging may respond conservatively to rapidly changing conditions. The harmonic mean is computed from the formula:

$$\bar{\mathbf{V}} = \mathbf{n / (1/V_1 + 1/V_2 + ...+ 1/V_n)}$$

Where $\bar{\mathbf{V}}$ is the harmonic mean, n = 10, and V_1, V_2,... V_n, are the individual 1-minute values.

The difference between the harmonic mean and the arithmetic mean can be seen when a fog bank moves in and suddenly drops the visibility from 10 miles to 1/4 mile. Initially there are 10, 1-minute values of visibility equal to 10 miles and both the arithmetic and harmonic mean are reporting 10 mile visibility. In the first minute, there are nine values of 10 miles and one value of 1/4 mile used to compute the current visibility. The arithmetic mean yields 9.025 miles while the harmonic mean yields 2.041 miles. In the second minute, there are now eight values of 10 miles and two values of 1/4 mile used to compute current visibility. In this case, the arithmetic mean is 8.050 miles and the harmonic mean is 1.136 miles.

The value obtained from this computation is then rounded down to the nearest reportable visibility value. This visibility is stored in memory for 31 days as part of the METAR/SPECI reports and made available for distribution. The raw extinction coefficient and day/ night settings are stored for 12 hours in the engineering data for maintenance technician monitoring purposes. Eight one-minute data samples in the last 10 minutes are required to form a report. If less than 8 of the current 10, 1-minute visibility values are available in memory, the 1-minute visibility is not reported by ASOS.

The newest visibility value is checked against the visibility reported in the last METAR or SPECI report to determine if it has passed any specified visibility thresholds. If so, ASOS creates a SPECI report. The algorithm also checks for variable visibility. If requirements for variable visibility are met, ASOS generates an appropriate automated remark.

At airport locations with control towers, the ASOS provides the ability to enter tower visibility. If tower visibility is less than 4 statute miles and is also less than the reported surface visibility, then tower visibility is entered in the body of the report and surface visibility is entered in remarks. If, on the other hand, the surface visibility is less than the tower visibility, then surface visibility is entered in the body of the report and tower visibility is entered in remarks.

4.2.3a Meteorological Discontinuity Visibility Sensor

At some airports a second visibility sensor is placed where unique weather, not necessarily representative of the entire airport, may impact flight operations for a portion of the airport or a particular runway. The secondary meteorological discontinuity visibility sensor may be used to provide an early alert of deteriorating conditions, such as fog rolling in off a nearby bay or river. Whereas the primary visibility sensor is sited near the touch-down zone of the primary instrument runway, the second (meteorological discontinuity) visibility sensor is sited about 2-4 miles away in the most likely location for a meteorological discontinuity.

The data from the primary and meteorological discontinuity sensors are independently processed through the single sensor algorithm and then compared. Only data from the primary sensor is used in the body of the METAR.

If the primary visibility sensor is not operational, the visibility is not reported, a maintenance check indicator ($) is appended to the METAR, and no further comparisons are made. If the meteorological discontinuity visibility sensor is not operational, the remark "VISNO LOC" is added to the METAR, where LOC is the nominal location of the meteorological discontinuity visibility sensor (e.g., CF, RWY26L), a maintenance check indicator ($) is appended to the METAR, and no further comparisons made.

If both sensors are operational, a meteorological discontinuity visibility remark is reported when the visibility measured by the meteorological discontinuity sensor is less than 3 miles and is also less than the visibility measured by the primary visibility sensor by one-half mile or more. When these conditions are met, a remark in the form "VIS VALUE LOC" is added to the METAR, where VALUE is the visibility reported by the meteorological discontinuity sensor and LOC is the nominal location of the meteorological discontinuity sensor. For example, a meteorological discontinuity visibility value of 1SM on runway 26L is reported as: VIS 1 RWY26L.

4.2.3b Back-Up Visibility Sensor

A back-up visibility sensor is available at selected major airports where a requirement has been established. It is located within 2 statute miles of the primary visibility sensor and operates continually in "sleep mode," i.e., measurements are taken, stored internally in ASOS, but not included in the METAR report until activated by failure of the primary sensor. The ASOS algorithms process the primary and back-up sensor data separately and determine when data from the back-up sensor are substituted in the observation. When the primary sensor is restored the back-up sensor returns to "back-up" status.

4.2.4 Visibility Strengths and Limitations

One of the main advantages of the visibility sensor is its location at the touchdown zone of the primary instrument runway where it provides a precise visibility value appropriate for that location. Another strength of the sensor is consistency of observations. Under the same weather conditions, an ASOS visibility reported at one site will be identical to the visibility reported at another site because both ASOSs use identical sensors and algorithms. Variations introduced by human observers from such limitations as perspective, sun angle, day and night differences, and poor locations are eliminated.

During certain daylight hours the human eye can readily be affected by light back-scattered toward the observer. This may occur around sunrise or sunset when sunshine is pouring into a low cloud deck or a local weather obstruction, (such as mist, snow, rain, or haze) from behind the observer. In this situation, the bright sky and the back-scattered light can overwhelm the human eye causing the observer to report a lower visibility than ASOS. This back-scattering of light from the sun and sky into the observer's vision by particulates in the air is called "airlight."

Visibility restrictions under back-scatter conditions are considerably less common than under forward-scatter conditions. Under airlight conditions, a direct 180 degree back-scatter reflection is required for reduced human visibility. Visibilities in other directions are not as restricted. Consequently, airlight visibilities are not representative of the entire viewing area. Under forward-scatter conditions, however, ASOS uses a wider 0-45 degree scattering angle range to obtain a more representative measurement of conditions.

The major disadvantage of an automated forward scatter sensor is the small sampling volume (0.75 cubic feet) which can give undue weight to small scale differences in the atmosphere. Even broadening the sample by including all the sensor measurements over a 10 minute period (20 samples) may not provide enough data to create a visibility report that represents the entire airport area. For instance, if patches of fog (BCFG) or shallow fog (MIFG) form, or a fog bank moves over one end of the runway, ASOS may not "see" it if the sensor is not in the right location. Initial site surveys were conducted at each airport to determine proper placement of the primary visibility sensor. Follow-on studies are conducted to decide if additional sensors are needed.

4.3 Automating Present Weather and Obscurations

As noted earlier, the algorithms developed for automated reporting of visibility and sky condition required a new perspective. By contrast, the automated detection and reporting of present weather and obstructions required whole new observing technologies and techniques. Present weather and obstructions arguably are the most complex and difficult elements to automate due to their variety of composition and appearance. Once the first generation of present weather sensors was developed, the reporting algorithms were refined to give a present weather report similar to the human report. Improvements in sensor capability and algorithm sophistication have resulted in the current generation of highly-capable, automated, present weather and obstruction reporting technology.

The ASOS employs a variety of sensors to correctly report present weather and obscurations. A new lightning sensor has recently been added to the ASOS sensor suite at a limited number of sites, which provides information on thunderstorms. The precipitation identification (PI) sensor discriminates between rain and snow; a freezing rain sensor detects ice accretion caused by freezing precipitation; and the visibility sensor and hygrothermometer provide data for algorithms that further refine the reports of present weather and infer the existence and type of obscuration.

4.3.1 Single Site Lightning Sensor

Where required, the ASOS uses the Global Atmospherics Inc. (GAI) Model 924 single site lightning sensor as a source for reporting a thunderstorm (see Figure 15.Lightning Sensor). The ASOS Lightning Sensor (ALS) is installed at selected Service-Level “D” ASOS sites that do not have the FAA Automated Lightning Detection And Reporting System (ALDARS). The ALDARS is another source of lightning information provided through the National Lightning Detection Network described in Section 4.3.3. The ALS sensor is a single-point omnidirectional system that requires two criteria before reporting a thunderstorm: an optical flash and an electrical field change (radio signal), which occur within milliseconds of each other. The requirement for simultaneous optical and radio signals virtually eliminates the possibility of a false alarm from errant light sources.

The sensor can detect cloud-to-ground and cloud-to-cloud strikes. All strikes are counted, but only the cloud-to-ground strikes are used to generate an estimate of the range. Cloud-to-ground strikes are grouped into three range bins: 0 to 5 miles, 5 to 10 miles, and 10 to 30 miles. Because the cloud-to-cloud detection is less efficient than cloud-to-ground detection, the ASOS considers cloud-to-cloud strikes to be within 5 miles.

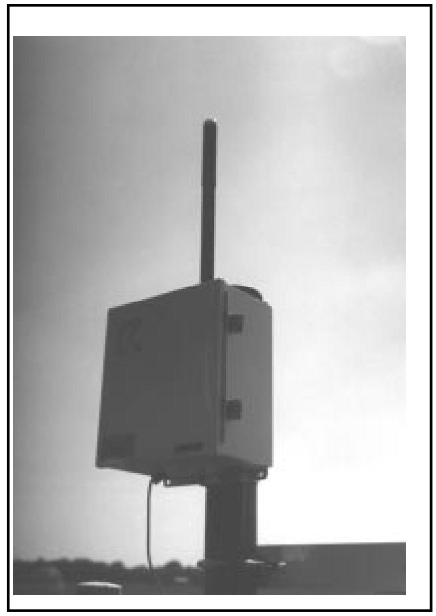


Figure 15: Lightning Sensor

A cloud-to-ground strike is made up of one or more individual *flashes*. Within one flash, numerous discharges can occur; these individual discharges are called *strokes*. The sensor groups all strokes occurring within 1 second of each other into a single flash. The range of a cloud-to-ground strike is determined by the range of the closest stroke within a flash.

The sensor automatically “ages” each lightning strike for 15 minutes. Because a thunderstorm is defined to be in progress for 15 minutes after the last lightning or thunder occurs, the sensor continues to report each strike in the appropriate bin for 15 minutes after it is first detected. A thunderstorm is determined to end when no strikes are detected within the last 15 minutes.

4.3.2 Single Site Lightning Sensor Algorithm

ASOS polls and processes data from the single site lightning sensor once a minute. The raw sensor data can be viewed through Direct Command Mode using a “THUNDER” command. To determine the starting and stopping times of a thunderstorm, ASOS examines data in the 0-5 and 5-10 mile cloud-to-ground range bins and in the cloud-to-cloud bin. For the single site lightning sensor, ASOS does not use data in the 10-to-30 mile range bin.

A thunderstorm is declared to start when the *sum* of strikes in the three bins (0-5, 5-10, and cloud-to-cloud) is equal to, or greater than, two. To minimize the possibility of a false alarm, the ASOS algorithm requires two strikes to start a thunderstorm; false alarms are more likely with a single-stroke starting algorithm. ASOS declares a thunderstorm to end when the last strike is "aged" out of the three bins and the sum of the strikes in the three bins falls to zero.

There are two possible thunderstorm reports: "TS" when strikes are occurring within 5 miles, and "VCTS" when strikes are occurring outside 5 miles but within 10 miles. ASOS transmits a SPECI report at the start and end of any thunderstorm condition.

To begin a "TS" report, the two-or-more strike condition must occur in one of the following formats:

- 0-5 bin only
- cloud-to-cloud bin only
- 0-5 and 5-10 bins
- 0-5 and cloud-to-cloud bins
- cloud-to-cloud and 5-10 bins
- 0-5, 5-10, and cloud-to-cloud bins

A "VCTS" report is transmitted when the strikes occur only in the 5-10 mile bin. If a thunderstorm begins as a "VCTS" report, and a single strike is detected in either the 0-5 or the cloud-to-cloud bin, the report is changed to "TS." Similarly, a "TS" report will be changed to "VCTS" when the only strikes detected are occurring in the 5-10 mile bin.

4.3.3 Automated Lightning Detection And Reporting System

A potential alternative source of lightning information is the National Lightning Detection Network (NLDN) operated by GAI. It consists of approximately 100 lightning direction finder sensors located throughout the Continental U.S. (CONUS). The sensors record the parameters of each cloud-to-ground lightning strike with precise time and location. All strike reports are sent by satellite to the GAI processing center at Tucson, AZ, where a computer processing algorithm compares strike reports from multiple sensors, computes each strike location, and provides this information to the FAA communications network within seconds of the strike.

The FAA has constructed a processing architecture called Automated Lightning Detection and Reporting Systems (ALDARS) at each of the 20 Air Route Traffic Control Centers (ARTCCs) in the CONUS. There is no NLDN lightning coverage in Alaska or Hawaii. The AWOS Data Acquisition System (ADAS) at each ARTCC filters NLDN data for its particular ARTCC coverage area and identifies strikes within 30NM of any Airport Reference Point (ARP) within the ARTCC coverage area. A strike is placed in one of three range bins: within 5NM of ASOS (at the airport), 5-10NM of ASOS (vicinity of the airport), and 10-30NM (distant from ASOS). These data are sent to the ASOS by the ADAS where they are processed and treated by ASOS as any other sensor derived data, and are included in the transmitted ASOS reports when appropriate. At sites that may concurrently receive ALS and NLDN-ALDARS information, the ALS data will take precedence for processing and reporting by ASOS. Current plans, however, call for no sites to have both ALS and ALDARS data.

4.3.4 ASOS Lightning Sensor Strengths and Limitations

- The ALS occasionally reports valid lightning within 10 miles when thunder cannot be heard by an observer. An extensive field evaluation in the summer of 1997 indicated that the sensor can report 15-20% *more* valid thunderstorm minutes than an observer, primarily because an observer's ability to hear thunder at most airports is restricted.

- Due to the two-part criterion (optical and radio) for identifying lightning strikes, the sensor has an inherently low false alarm rate. The 1997 field evaluation indicated a false alarm rate of 0.0039 (i.e., about 0.4 percent of ASOS thunderstorm minutes may be false).

- The ranging estimates provided by the sensor have significant uncertainty and can contribute to reporting thunderstorms when cells are beyond 10 miles. A very strong lightning strike at 15-20 miles can be erroneously placed in the 5-10 mile bin by the ASOS sensor.

- The 1997 field evaluation identified cloud-to-cloud strikes detected at ranges near 30 miles. The cloud-to-cloud bin was retained in the ASOS algorithm because of the importance of cloud-to-cloud lightning in identifying thunderstorms. A significant number of thunderstorms contain primarily cloud-to-cloud lightning and if it were eliminated from the reporting algorithm, there would be a risk of failing to report thunderstorms.

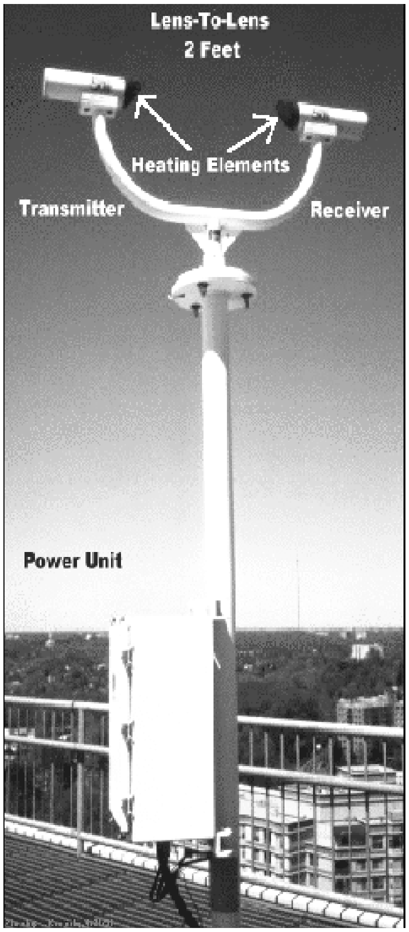


Figure 16. The Precipitation Identification Sensor

4.3.5 Precipitation Identification Sensor

The Precipitation Identification sensor (PI), better known as a Light Emitting Diode Weather Identifier (LEDWI), differentiates rain from snow and determines the intensity of the precipitation.

The LEDWI contains a coherent light transmitter (i.e., there is a continuous relationship among the various phases of the light waves within the beam) and a photo diode receiver. The transmitter and receiver are mounted on a cross-arm 10 feet above the ground or base of the platform. They are equipped with heated lens hoods, face directly at each other, are separated by a distance of 2 feet and are oriented in a north-south direction with the receiver looking north. (See Figure 16 for a view of the LEDWI.)

The transmitter generates a coherent Infrared (IRED) light beam, 50 millimeters in diameter, aimed directly at the receiver. The receiver lens is masked with a narrow 1 millimeter horizontal slit aperture through which the transmitter light beam passes before it is focused by the lens and impinges on the photo diode. The narrow aperture makes the receiver more sensitive to beam fluctuations caused by particles down to the size of a small raindrop (0.04 inch diameter).

Because the slit is much wider than its height, the receiver is more sensitive to beam fluctuations induced by the vertical velocity component of particles passing through the beam than the horizontal component. Built-in sensor algorithms minimize the possibility of any false identification caused by greater sensitivity.

As a particle of rain or snow passes through the coherent light beam, the particle creates a shadow that modulates the light, which then passes through the receiver's horizontal slit aperture as a partially coherent (intermittently disrupted), colliminated (parallel to the slit) beam. The shadow varies depending on the size and speed of descent of the particle as it falls across the receiver.

When many particles fall through the beam, a scintillation pattern is created. The fluctuating beam pattern is sensed by a photo diode and amplified, creating a jumble of frequencies containing information on the size and speed of the falling particles. A spectral analysis reveals how much energy or power is contained in the various frequency bands. For example, a predominance of power in low frequencies from 75 to 250 Hz indicates snow. When energy is predominantly in a band from 1000 to 4000 Hz, the precipitant is almost certainly rain. The LEDWI registers rain and snow mixed as a "smearing" of the spectral power, which is usually reported by ASOS as unknown precipitation (UP). This analysis is the basis of the discrimination algorithm, which differentiates rain from snow.

When the precipitation is not mixed, (i.e., pure rain or pure snow) the LEDWI can determine the intensity of the precipitation. The intensity is determined by the power of the signal return in the rain (1-4 kHz) or snow (75-250 Hz) portion of the power spectrum. The power return of rain is derived from the size and fall velocity of the particles whose size distribution, correlates well with liquid water content. It is possible to accurately determine the rain intensity through an empirical relationship (the Marshall-Palmer distribution), which can distinguish light (up to 0.10 inch per hour), moderate (0.11-0.30 inch per hour), or heavy (greater than 0.30 inch per hour) intensities for rain.

In the case of snow, it is again the size and fall velocity of the snowflakes that determines their size distribution. This correlates well with rate of snow accumulation. Unlike rain however, the density of snow can vary significantly depending on whether the snow is "wet" or "dry," and so the liquid content cannot be accurately determined.

The LEDWI report of intensity is well correlated with the rate of snow accumulation but is not directly related to the visibility reduction due to snow, which observers use to differentiate between light, moderate, and heavy snow. ASOS processing algorithms use the visibility sensor data to modify the LEDWI snow intensity report so that moderate snow is not reported when the visibility is greater than 1/2 mile and heavy snow is not reported when the visibility is greater than 1/4 mile.

The LEDWI has an "adaptive baseline," which adjusts the power spectrum threshold to reduce reports of false precipitation. For instance, wind turbulence and thermals (e.g., the shimmer seen across an open field on a sunny day) can induce scintillations that are near the frequencies characteristic of snow. Therefore, ASOS sets the threshold for snow detection above the spectral power induced by turbulence.

This "adaptive baseline" can pose a problem when snow increases so slowly that the baseline rises without snow being detected. When this occurs, only a sudden increase in snow may trigger the sensor to report snow. A similar condition may occur when the LEDWI is turned on (say after a power failure) and precipitation is falling. The initial adaptive baseline may be set much too high to detect precipitation correctly and will not be reset to a representative threshold until the precipitation ends.

Rain detection is generally not a problem. Occasionally, if the rain is preceded by a gradually increasing drizzle, the rain channel adaptive baseline threshold may rise to a point where light rain is not sensed. As a general rule, rain lighter than 0.01 inches per hour will not be detected.

4.3.6 PI Algorithm

Every minute, the PI algorithm requests the PI sensor data, stores the data in memory for 12 hours, and examines the latest 10 minutes of data stored in memory. If three or more samples are missing, the algorithm sets the sensor status to "inoperative" and reports "missing" for that minute. If the 10-minute memory buffer contains less than two sensor samples of precipitation, the precipitation report terminates.

If, however, two or more samples in the latest 10 minutes indicate precipitation, the algorithm then determines the type and intensity to report. In general, to report anything other than "Unknown Precipitation" (UP), two of the samples are required to be the same type. If there is a tie between two types of precipitation (e.g., two rain samples and two snow samples) snow is reported. This determination is based on the hierarchal scheme for reporting present weather: liquid (-RA, RA, +RA), freezing (-FZRA, FZRA), and frozen (-SN, SN, +SN) in ascending order.

ASOS reports only one precipitation type at a time. For instance, if both freezing rain and snow are detected, snow is reported. Additional precipitation elements may be added to the report by observers. The PI algorithm performs a temperature check on the PI sensor output. If -SN, SN, or +SN is reported, and the temperature is > 38 F, then the PI sensor output is set to "No Precipitation" (NP). The PI algorithm also formats and reports precipitation beginning and ending remarks just as the observer does.

Once the precipitation type is determined from the last 10 minutes of data, then the 1-minute samples from the past 5 minutes are used to compute intensity. Precipitation intensity is determined from the highest common intensity derived from three or more samples. Common intensities for heavy precipitation are light, moderate and heavy; for moderate precipitation, common intensities are light and moderate. For example, if rain is the determined precipitation type, and there are three moderate rain and one light rain detected in the past 5 minutes, then ASOS reports moderate rain in the METAR/ SPECI report. Likewise, if snow is the determined type and there are one light, two moderate, and one heavy snow in the past 5 minutes, then moderate snow is reported.

As a third example, if the most recent 5 minutes of sensor data contains one report of light rain, and two reports of moderate rain, then light rain is reported by ASOS. If, on the other hand, there are less than three common intensities of the reported precipitation type, then ASOS reports the lightest intensity. For example, if rain is the determined type, and there are only one moderate rain and one heavy rain reported by the sensor, then the precipitation intensity is set to moderate rain (RA) in the ASOS METAR/SPECI report. If snow is the determined precipitation type and there are only one moderate and one heavy snow, then ASOS reports moderate snow.

The ASOS PI algorithm formats and reports precipitation beginning and ending remarks just as the observer does. The PI sensor output is further compared with the freezing rain sensor output to ultimately determine the precipitation reports and remarks (see description of the freezing rain algorithm for further details).

Under blowing snow conditions, particularly where snow is blown to a height of 10 feet or more, the PI sensor (LEDWI) can mistakenly interpret the scintillations from blowing snow rising up and/or settling through the sensor's IRED beam as rain, and occasionally as snow, depending on the vertical velocity of the snow particles.

At higher wind speeds (10 knots or greater), the upward vertical velocity of the snow particles usually is sufficient to be incorrectly interpreted as rain. The ASOS blowing snow algorithm interrogates the LEDWI and other ASOS sensors for concurrent blowing snow conditions and rain reported by the LEDWI. When this “error” is detected, ASOS replaces the false LEDWI rain report with a correct blowing snow report in the ASOS METAR/SPECI present weather field. This change is made by evaluating sky condition and 15-minute average data for ambient temperature and wind. A 15-minute average is used to reduce the risk of the output oscillating from one present weather report “solution” to another. ASOS evaluates all LEDWI reports of rain with an ambient temperature of 32 ^{o}F or less. Under these conditions, either blowing snow (BLSN) or unknown precipitation (UP), is reported in the present weather field. When all data are available, ASOS reports blowing snow when:

- Visibility is less than 7 statute miles
- Ambient temperature is 14 ^{o}F or less
- Sky cover is less than overcast or the ceiling height is greater than 10,000 feet
- Wind speed is greater than 22 knots,

If these conditions are not met, ASOS reports UP.

4.3.7 PI Strengths and Limitations

Because of its continuous monitoring capability, the ASOS PI sensor often detects and reports the beginning and end of rain or snow before an observer. In addition, because of its sensitivity, the PI sensor can detect light precipitation even at times when it cannot distinguish between rain and snow (as the observer can). In these situations, the ASOS may report too many “UPs.” Earlier updates to the sensor and the algorithm minimized generation of excessive remarks (e.g., UPB04E07R AB07E14UPB14, etc).

Because drizzle particles are small and fall slower than raindrops, their power spectrum is weak and smeared; therefore, drizzle is often not detected. On occasion, however, it may elevate either the high or low frequency channel of the PI sensor sufficiently to be reported as rain or snow. When light drizzle is falling, the PI sensor may, on occasion, interpret the scintillation pattern created by these suspended water droplets as light snow when the temperature is $\leq$ 38 F. Product improvement efforts are aimed at reliably detecting and correctly reporting drizzle (see Section 7.2.5).

Ice pellets (PL) and rain have a similar size and fall velocity. Consequently, ice pellets will force an output from the PI sensor of either UP, -RA, RA, or +RA (depending on intensity of the ice pellets). The PI sensor will more likely interpret this as rain and output -RA, RA, or +RA rather than UP. The ASOS processing algorithm will, in turn, also report either -RA, RA, or +RA, as output by the PI sensor.

ASOS may report other types of frozen precipitation as rain or snow, depending on the scintillation pattern caused by their size and fall velocity. For example, snow grains are larger than drizzle and fall slower so they are sometimes reported as snow. Snow pellets also fall slower than raindrops and will therefore be reported as snow. Hailstones are larger than raindrops and fall faster, and therefore will be reported as rain.

In mixed precipitation conditions, such as snow and ice pellets, the PI sensor likely interprets the ice pellets as rain (see above). The snow, however, has a higher reporting precedence and thus snow will be reported by the processing algorithm. A mixture of snow grains and drizzle may also be reported as snow. In cases where snow grains are mixed with freezing drizzle, ASOS will either report snow or no precipitation.

Sometimes the LEDWI may sense non-atmospheric phenomena. For example, insects flying in the receiver field of view can cause it to report precipitation. Spiders that run threads between the cross arms can trigger a false precipitation report when the wind moves the threads up and down. Even sun glint, particularly on a bright day when there are snow crystals (diamond dust) floating in the air, can trigger false precipitation indications.

Strong winds during snow and blowing snow occasionally pack the receiver or projector heads of the LEDWI with snow. A total blockage of the lens will cause a loss of any detected signal creating an error condition. A partial blockage may contaminate the measurement and lead to inaccurate reports of precipitation type or intensity. An intensive ongoing effort is underway to eliminate the problem and prevent lens blockage.

4.3.8 Freezing Rain Sensor

The ASOS Freezing Rain (FZRA) Sensor is based on technology initially developed to detect icing on aircraft in flight. The sensing device consists of a small cylindrical probe that is electrically stimulated to vibrate at its resonant frequency. A feedback coil is used to measure the vibration frequency, which is proportional to the mass of the probe. Figure 17 shows the design of this “magnetostrictive oscillator” (i.e., Freezing Rain Sensor). Magnetostriction is a property of certain metals in which

Figure 17. Freezing Rain Sensor

a change in the (axial) dimension of a body caused a change in magnetization. It is used in the ASOS sensor to drive the probe at a natural resonant frequency of 40kHz. The axial vibration is of such low amplitude that it cannot be seen or felt. The probe is orientated vertically to provide optimal uniform exposure to freezing precipitation regardless of wind direction. This position also prevents birds from alighting.

When ice freezes on the probe, the combined mass increases and the resonant vibration frequency decreases. There is a well defined relationship between the measured frequency and the ice accretion on the probe. The freezing rain instrument is sensitive enough to measure accumulation rates as low as 0.01 of an inch per hour. The freezing rain sensor continuously monitors the resonant frequency of the vibrating probe, obtains a sample once a second, and once each minute averages the results to update the probe's current resonant frequency. When excessive freezing rain accumulates, (i.e., equal to or greater than 0.08 inch) the sensor goes into a heating cycle to melt the freezing rain from the probe and return it to the base resonating frequency. This process normally takes two to three minutes. During this time, the sensor status is set to "deice" and the output is not updated.

4.3.9 FZRA Algorithm

Once each minute, the freezing rain algorithm accesses the current 5-minute average ambient temperature and the current frequency output from the freezing rain sensor and stores this data in memory for 12 hours. Data from the last 15 minutes are used to compute the current 1 minute freezing rain report. If three or more freezing rain sensor outputs in the last 15 minutes are missing, the sensor status is set to "inoperative," and the freezing rain report is set to "missing." The current minute's frequency output is converted to an ice accretion thickness using the following equation:

Zt = (40,000 - Fn) * 0.000152

Where **Zt** is the current ice accretion thickness in inches and **Fn** is the current sensor frequency.

Each minute the Freezing Rain sensor outputs a report. The Freezing Rain report is set to "FRZA" under the following combined conditions:

- If the current ice accretion exceeds 0.005 inch,
- If the current ice accretion exceeds the minimum accretion since the sensor was last declared operational or during the past 15 minutes, whichever is less, by 0.002 inch
- If the current five-minute ambient temperature is less than 37^{o}F.

Otherwise, the freezing rain report is set to indicate a lack of freezing precipitation for the current minute. The freezing rain report for each minute is saved for 15 minutes. Finally, the freezing rain report is checked against the present weather report from the previous minute and special alert criteria for the beginning and ending of freezing precipitation, or changes in intensity, and if necessary a SPECI will be generated.

Table 6 shows the reporting scheme for the ASOS Present Weather Report. The reporting scheme follows the familiar hierarchy of LIQUID-FREEZING-FROZEN, in ascending order of priority. Only the highest priority precipitation phenomena observed will be reported at any one time (i.e., ASOS does not report mixed or multiple precipitation types). For example, if the freezing rain sensor indicates "-FZRA" and the precipitation identifier reports "UP", then the ASOS will report "-FZRA."

The previous minutes' present weather reports are further examined to determine which present weather remarks need to be generated and appended to the METAR report. This includes precipitation beginning and ending times in minutes past the current hour (e.g., FZRAB05E21). Once freezing rain has been sensed and the ambient air temperature is 36^{o}F or below, it will be encoded in subsequent METAR reports for 15-minutes after it is no longer sensed.

4.3.10 FZRA Strengths and Limitations

The major strength of the freezing rain sensor is its sensitivity and continuous monitoring, usually allowing it to detect freezing precipitation conditions before an observer, especially at night. Working in conjunction with other sensors, mixed precipitation events can be better defined. For example, under conditions of mixed precipitation, such as ice pellets (PL) and freezing rain (FZRA), the PI sensor will output UP, -RA, RA, or +RA (for the PL), and the FZRA sensor will output FZRA. In any event, the ASOS processing algorithms will finally interpret and correctly report this condition as -FZRA or FZRA (see Table 7).

Table 6. Present Weather Reporting Hierarchy

Freezing Rain Sensor Report	Precipitation Identification Sensor Report	ASOS Present Weather Report
FZRA	No Precip.	NP
FZRA	Missing	NP
FZRA	UP	- FZRA
FZRA	- RA	- FZRA
FZRA	RA	FZRA
FZRA	+RA	FZRA
FZRA	- SN	- SN
FZRA	SN	SN
FZRA	+SN	+SN

At temperatures near freezing, snow can become attached to the probe firmly enough to cause a frequency shift that could be misinterpreted as freezing rain. This problem of differentiating snow from freezing precipitation is overcome by checking the output of the PI sensor to determine if it is raining or snowing when the freezing rain sensor has a frequency shift. If the PI sensor indicates rain, then the report will be freezing rain. If the PI sensor indicates snow, then snow will be reported in the body of the METAR message.

4.3.11 Obscuration Algorithm

Obstructions are not directly measured by ASOS, but rather inferred from the measurement of visibility, temperature, dew point, and present weather (precipitation). ASOS reports only four obstructions: fog (FG), mist (BR), freezing fog (FZFG) and haze (HZ). Other obscurations, such as dust, smoke, and blowing sand are not automatically reported by ASOS, but may be augmented by the observer in accordance with agency policy.

The obscuration algorithm checks the reported visibility once each minute. When the surface visibility drops below 7 statute miles, the algorithm obtains the current dew point depression (DD) to distinguish between FG, BR, and HZ. If the DD is less than or equal to 4^0F (~2^0 C), then FG or BR will be reported (Table 8). Visibility will then be used to further differentiate between FG and BR. If the visibility is less than 7 miles and down to 5/8ths of a mile, BR is reported. If the visibility is less than 5/8ths of a mile, FG is reported. If the ambient temperature is also below freezing, freezing fog (FZFG) is reported. When precipitation is reported, FG or BR may also be reported when the preceeding conditions are met. When the DD is greater than 4^0F (~2^0 C) and no precipitation is reported by the PI and freezing rain sensors, then HZ is reported as the obscuration; however, when precipitation is reported HZ is not reported.

Table 7. ASOS Report of Freezing/Frozen Phenomena

Type of Weather Occurrence	ASOS Present Weather Report
Ice Pellets (PL)	-RA, RA, or +RA
Ice Pellets and Snow (SN)	-SN, SN, or +SN
Ice Pellets and Freezing Rain	-FZRA, or FZRA
Ice Crystals	No Precipitation
Hail (GR)	+RA
Snow Grains (SG)	-SN, SN, or +SN
Snow Pellets (GS)	-SN, SN, or +SN

In the event the DD is missing (i.e., temperature and/or dew point is missing) the obscuration algorithm relies solely on visibility to discriminate between FG, BR and HZ. If the reported visibility is less than 7 miles and equal to or greater than 4 miles, HZ is reported. If the visibility is less than 4 miles and down to 5/8ths of a mile, then BR is reported as the obscuration. If visibility is less than 5/8ths of a mile, FG is reported. When present weather is also reported, FG or BR is appended to the present weather re-

Table 8. ASOS Report of Present Weather

°F			VIS	PRESENT WEATHER	
T	T_d	DD		PRECIPITATION	OBSCURATION
28	20	8	3	NONE	HZ
28	27	1	1/4	SN	SN FZFG
28	22	6	5	NONE	HZ
38	37	1	1/2	NONE	FG
38	34	4	5/8	NONE	BR
40	M	M	4	NONE	HZ

port. If reported visibility is equal to or greater than 4 miles but less than 7 miles, and no present weather is reported, then HZ is reported as the obscuration.

4.3.12 Obscuration Algorithm Strengths and Limitations

One obvious characteristic of the obscuration algorithm is that FG or BR cannot be reported, even if it is the only obstruction to vision, when the DD is greater than 4°F or when DD is missing and visibility is 4 miles or more. In these situations, if FG or BR is actually occurring, then HZ is incorrectly reported when the visibility is less than 7 miles. The ASOS, of course, cannot report obscuration remarks for distant phenomena such as "FG BANK NE-SE." The ASOS, on the other hand, will provide more timely reporting of the formation and dissipation of obscuring phenomena due to its continuous monitoring capability.

CHAPTER FIVE

5.0 Explanations/Examples of ASOS Observations

ASOS provides six basic types of data:

- 5-Second Wind Update
- The OMO Data
- The METAR / SPECI Messages
- Auxiliary Data
- The SHEF Messages
- The Daily and Monthly Summary
- Products/Messages

5.1 5-Second Wind Updates

The current 2-minute average wind is computed once every 5 seconds and automatically updated on FAA provided ASOS Controller Equipment (ACE) video displays at selected sites. A list of the 24 most recent 5-second average wind values used to compute the current 2-minute average wind is also available on the OID screen. (See Appendix A for example of 5-second average wind).

5.2 One-Minute Observations

Once each minute, ASOS performs internal diagnostic and QC checks on sensor data and then updates the One Minute Observation (OMO). The OMO is encoded in METAR format and includes all basic weather parameters found in the body of the METAR plus selected automated remarks. The OMO also accepts manually entered remarks (via OID keyboard entry), such as variable visibility and tower visibility. The basic difference between the OMO and the METAR/SPECI is that the OMO is generally not transmitted long-line beyond the local FAA or NWS communications network node (see bullet 3 below). OMO information is collected during the 60-second period ending at M+00 and made available to users each minute at M+23 (23 seconds past the current minute) through the following media:

- **OID, VDU, and authorized dial-in user computer display screens.** Various screen displays of OMO data are available. See Appendix A for examples, and the *ASOS Software User's Manual* (SUM) for details.

- **Computer-generated voice messages of the current OMO (or METAR / SPECI).** These messages are sent to pilots (generally within 50 miles of an airport) through the ASOS Ground-To-Air VHF radio or navigation aid. They are also made available to the aviation community through telephone number provided for dial-in.

- **Long-Line Dissemination:** OMO data will **not** be sent over long-line until both the modernization of the FAA and the NWS communications networks is complete (see Figures 18 and 19). At that time, FAA ADAS and NWS AWIPS communications nodes will collect OMO data from local ASOS locations. These data will be made available to FAA and NWS users in METAR format. Future communication links will allow each NWS WFO to access the OMO data from selected ASOS locations every 5-minutes when operating in the "warning" mode, or every 15-minutes when operating in the "alert" mode.

5.3 ASOS Aviation Routine Weather Reports

All ASOS locations prepare and disseminate Aviation Routine Weather Reports in METAR / SPECI code format. Although ASOS is designed to operate completely unattended, it can also function in an attended mode with an observer augmenting data and providing backup support if needed. In either case, the ASOS report is identified by the "AO2" designator near the beginning of the remarks (RMK) section of the report. This indicates that the ASOS report is an Automated Observation–Type 2, with the added capability to report present weather phenomena (e.g., RA, SN, FZRA). When operating in the unattended mode, an "AUTO" report modifier is inserted near the beginning of the report after the Date-Time group.

When operating in the attended mode, the AUTO designator does not appear. The absence of the AUTO designator indicates that an observer and/or an air traffic controller is signed-on to the OID and is capable of providing backup or augmentation support if necessary. Only one observer is permitted to sign-on the ASOS at a time. Remote (off-site) observer sign-on is not permitted. If the observer corrects the ASOS METAR/SPECI report, the "COR" indicator appears as the report modifier after the Date-Time group. When the observer and the air traffic controller are both signed-off the ASOS, the AUTO report modifier is restored to the METAR/SPECI report.

When an aircraft mishap occurs, the on-site observer can (and should) initiate a local special observation. In this event, the remark "(ACFT MSHP)" is appended to the local SPECI report, which is sent to the ASOS printer and stored in memory for 31 days. The long-line version of the SPECI report is sent without the (ACFT MSHP) indicator.

All ASOS reports that are transmitted through the NWS long-line communications network are captured at the NWS Systems Monitoring and Coordination Center (SMCC) and compiled with other transmitted data into a daily Selective Records Retention System (SRRS) tape. This tape is sent to the National Climatic Data Center (NCDC) once a day for archiving and inclusion in various climatic summaries. NCDC also directly downloads data from selected sites for special climatological processing.

5.3.1 Backup and Augmentation

"Backup" is observer editing of the ASOS report for missing , clearly erroneous, or temporarily unrepresentative elements that ASOS should report correctly, or transmission of an entire report when total ASOS equipment failure has occurred. This activity may include use of alternative data sources and transmission medium. Only data elements normally generated by ASOS are added to the ASOS observation through backup. Backup may be applied to the ASOS-generated METAR/SPECI reports or to daily and monthly summary products. For example, backup could occur if the ASOS Hygrothermometer becomes inoperative and the temperature/dew point data are omitted in the METAR. To backup the ASOS observation, an observer using alternate source(s) of information manually edits temperature/dew point data into the ASOS observation in place of the missing data (See Example 1 in Section 5.3.4). This complete observation is then transmitted as the METAR report.

Augmentation is the process of manually adding information to an ASOS METAR/SPECI report or Daily Summary Message / Monthly Summary Message (DSM / MSM) product that is beyond the capability of ASOS to provide on its own. This task is performed before transmission. FAA/NWS policy permits augmentation at designated locations where qualified staff are available.

Edited and augmented data are processed by the ASOS when computing the daily and monthly summary products. For example, if the operator edits a temperature in a METAR report, that edited temperature value would automatically be used to compute the daily and monthly summary temperature information for the site. The extent of backup and augmentation provided at each location is dependent on the national and regional policies of the host agency. Each agency provides observer support in coordination with interagency NWS/FAA and aviation industry agreement on the service level assigned to each location.

5.3.2 Missing vs. Non-Event Data

Generally, if less than 75 percent of the data required for the computation of any weather element for the METAR/SPECI report are available, then ASOS simply does not report that element. For example, if three 1-minute visibility values are missing in the past 10 minutes, then the current 1-minute visibility will be missing. One notable exception to the 75 percent rule is that precipitation accumulation requires nearly 100 percent of the 1-minute data samples during the accumulation period. For example, if just one 1-minute precipitation accumulation value is missing in the past hour, then the current hourly precipitation accumulation report will be missing.

When a schedule-driven or event-driven data element is missing in the *body* of the METAR/SPECI report, the corresponding group and the preceding space for that data element are omitted from the report. Trailing elements in the report shift to fill in the blank space left by the omitted data.

Schedule-driven elements should always appear in the METAR/SPECI report: Wind, Visibility, Sky Condition, Ambient and Dew Point Temperature, and Altimeter. It is readily apparent from the compressed form of the report when these elements are missing. For event-driven (i.e., criteria triggered) elements such as runway visual range, present weather and obstructions, it is not always clear from the report that their omission is due to missing data or simply because the event has not occurred.

To clearly show when event-driven elements are missing, a sensor status indicator is added to the remarks section when ASOS cannot report the element. A sensor status indicator is also added to the remarks section when event-driven meteorological discontinuity sensor data for secondary visibility and/or sky condition are not available. Additionally, a sensor status indicator is included in the remarks section when the event-driven hourly precipitation accumulation remark is not available. Finally, although Sea-Level Pressure (SLP) information is included in both the METAR and SPECI reports from ASOS, a sensor status indicator for missing SLP is only added to the METAR report when SLP information is not available. The sensor status indicators are:

- RVRNO—Runway Visual Range Information Not Available
- FZNO—Freezing Rain Sensor Information Not Available
- PWINO—Present Weather Identifier Information Not Available
- TSNO—Thunderstorm Information Not Available
- PNO—Precipitation Accumulation Gauge Information Not Available
- SLPNO—Sea Level Pressure Information Not Available
- CHINO LOC—Cloud Height Indicator Information at Meteorological Discontinuity Location Not Available (e.g., CHINO E)
- VISNO LOC—Visibility Sensor Information at Meteorological Discontinuity Location Not Available (e.g., VISNO RWY06)

In general, when data for an automated remark are not available the remark is omitted from the METAR/SPECI report. A notable exception is when more than a trace of precipitation has occurred but accumulation data for the period is incomplete (i.e., some data are missing and therefore the amount is undetermined). In this case, the 3/6 hourly and 24 hourly precipitation accumulations are coded as 6//// and 7////, respectively.

5.3.3 Estimated Data

The *Federal Standard Algorithms for Automated Weather Observing Systems Used for Aviation Purposes* (November 1988), does not allow an automated system to use algorithms to generate estimated data for a METAR/SPECI report. Because ASOS conforms to the federal standard, estimated automated data is not included in any ASOS generated METAR/SPECI report. Estimated data however, may be manually included in the ASOS METAR/SPECI report through backup when the automated data are missing or deemed inaccurate. The METAR/SPECI report does not indicate whether a data element has been estimated.

5.3.4 Examples of METAR/SPECI Reports

The examples in this section conform to the FMH-1, Federal Meteorological Handbook No. 1, Surface Weather Observations and Reports (December 1995). See Appendix C for a quick reference guide for the ASOS-generated METAR/SPECI reports.

Example 1: Missing Data

METAR KSP1 021156Z AUTO A3029 RMK AO2 SLPNO 6//// 7//// 51018 PWINO FZRANO TSNO RVRNO PNO $

At this automated site where observer oversight is not available, the word "AUTO" is encoded after the date/time group. In the remarks section, the "AO2" indicates that this is an automated system with a precipitation discriminator. In other words, this site can report the occurrence of precipitation in the present weather field. In this METAR report, the only element reported is the altimeter (A3029). If an element is missing, METAR code does not permit an "M" to be encoded. Missing elements are simply not encoded. The only exceptions to this rule are found in the remarks section. When sea-level pressure is missing, "SLPNO" (sea-level pressure not available) is encoded. When precipitation accumulation amounts are not available, the 3- or 6-hourly and 24-hourly precipitation additive data groups, i.e., 6RRRR and 7RRRR, will appear as "6////" and "7////." METAR code does allow for sensor status indicators to be encoded at the end of the report. Since this site is in need of maintenance, a maintenance indicator ($) is placed at the end of the report.

Example 2: Full Report

METAR KMTJ 031153Z AUTO 36003KT 3SM -SN BR BKN009 BKN016 OVC070 00/M01 A3008 RMK AO2 SNB1057 CIG 006V010 SLP166 P0000 60000 70002 T00001006 10017 20000 51005 FZRANO TSNO

This 1200 UTC report is from a fully operational automated site without observer oversight. Because the site does not have a freezing rain sensor installed and does not have the capability to automatically report thunderstorms, FZRANO and TSNO are encoded in the remarks section. The obscuration mist (BR) has been encoded since the surface visibility is less than 7SM, but greater than or equal to 5/8SM, and the dew point depression is less than or equal to 4^{o}F. ASOS automatically provided all of the encoded data including the begin time for the snow (SNB1057), the variable ceiling height remark (CIG 006V010), and the sea-level pressure value (SLP166).

Example 3: Surface Visibility vs. Tower Visibility

SPECI KDEN 060409Z 03008KT 2 1/2SM BR OVC003 M06/M07 A3012 RMK AO2 TWR VIS 3 VIS 1 1/4V5

This SPECI report is from a site with observer oversight; note that the AUTO indicator after the date-time group is omitted. In this report both the surface, sensor derived visibility and the tower, human derived visibility are included. When the tower visibility is less than 4SM, the lower of the two visibility values is encoded in the body of the report and the other is included in the remarks section. In this case, the surface visibility is lower and therefore encoded in the body, while the tower visibility is found in the remarks section of the report. The tower visibility is manually entered into the ASOS report through the OID. The variable visibility remark (VIS 1 1/4V5) is automatically provided by ASOS and refers to the surface visibility.

Example 4: Meteorological Discontinuity Sensor Data

a: METAR KBOS 291856Z 03006KT 1 3/4SM BR FEW001 SCT019 BKN023 12/10 A2961 RMK AO2 SFC VIS 3 CIG 018 E SLP028 T01170100 $

The tower visibility is 1 3/4SM and the surface (sensor) visibility is 3SM. In this case, the tower visibility is encoded in the body of the report and surface visibility is placed in remarks (SFC VIS 3). A meteorological discontinuity sensor grouping (ceilometer and visibility sensor) is located east of the primary ASOS sensor suite. A ceiling height of 1,800 feet is being reported east of the primary sensors (CIG 018 E). If the meteorological discontinuity ceilometer was not operational, then the remark "CHINO E" would have been encoded.

b: SPECI KBOS 291710Z 06004KT 1 1/2SM BR OVC001 09/08 A2970 RMK AO2 SFC VIS 1 3/4 VIS 1/2 E $

A visibility remark (VIS ½ E) has been encoded for the meteorological discontinuity sensor installed east of the primary sensors. If this visibility sensor were not operational, then the remark "VISNO E" would have been encoded.

c: METAR KBOS 292256Z 04004KT 1 1/2SM RA BR BKN011 BKN050 OVC060 11/11 A2956 RMK AO2 SFC VIS 3 TSB29E50 SLP008 VIS W-N 1 3/4 TS DSPTD P0016 T01110106 $

In the remarks section, the observer has augmented a sector visibility (VIS W-N 1 3/4). ASOS does not now automatically report a sector visibility.

Example 5: Obstructions

a. SPECI KATY 080515Z AUTO 00000KT 1/4SM **FZFG** VV001 M23/M25 A3036 RMK AO2 FZRANO TSNO PNO

b. METAR KATY 080553Z AUTO 00000KT 1/4SM **HZ** VV001 M23/M26 A3036 RMK AO2 SLP326 6//// **T12331261** 11139 21239 410671239 58007 FZRANO TSNO PNO

c. METAR KATY 080653Z AUTO 00000KT 2 1/2SM **BR** OVC001 M23/M26 A3037 RMK AO2 SLP329 **T12331256** FZRANO TSNO PNO

ASOS can automatically report the obscurations of fog (FG), freezing fog (FZFG), mist (BR), haze (HZ), and blowing snow (BLSN). Reporting these phenomena is based on surface (sensor) visibility, temperature, dew point depression, and the occurrence of precipitation. If there is precipitation, ASOS does not automatically report HZ or BLSN; however, it may report FG, FZFG, or BR during precipitation.

Looking at the three reports above, the obscuration changes from FZFG to HZ and then to BR. In the first report, the surface visibility is less than 5/8SM, the temperature is below 0ºC, and the dew point depression is less than 4ºF. Therefore FZFG is encoded. FZFG would also have been encoded if precipitation were occurring. In the second report, the dew point depression changes to 5ºF (ambient temperature = -23.3ºC and dew point temperature = -26.1ºC) and the obscuration changes to HZ. If precipitation were occurring, HZ would not have been encoded. In the third report, the surface visibility increases to 2 1/2SM and dew point depression changes to 4ºF (ambient temperature = -23.3ºC and dew point temperature = -25.6ºC). Therefore, BR is encoded as the obscuration. Note that no distinction is made between BR and freezing mist, as is done with FG and FZFG. Mist is reported as BR regardless of the temperature.

Example 6: Obstructions vs Visibility

a. SPECI KSP1 311245Z 31007KT 1/2SM BR 26/25 A3003 RMK AO2 SFC VIS 3 $

b. SPECI KSP1 311247Z 31007KT 1/2SM FG 26/25 A3004 RMK AO2 TWR VIS 3 $

In the first report of this example, the tower visibility is 1/2SM and the surface (sensor) visibility is 3SM. Determining surface obscuration is based on surface visibility, not tower visibility. In this case, note that BR is encoded as an obscuration. In the second report, we changed the surface visibility to 1/2SM and the tower visibility to 3SM. The obscuration correctly changed from BR to FG.

Since surface observations are taken at the surface, obcuration entries should accurately report conditions at the surface, not at the height of the tower cab. Both reports are correct as encoded.

Example 7: Obstructions vs. Surface Visibility

a. SPECI KSP1 041606Z 03013G22KT **2 1/2SM BR** CLR 23/21 A3005 RMK AO2 **TWR VIS 10** $

b. SPECI KSP1 041608Z 36011G18KT **2 1/2SM** CLR 23/21 A3004 RMK AO2 **SFC VIS 10** $

Because ASOS provides reports of surface conditions, algorithms that automatically encode obscurations, as well as the intensity of snow, use the surface (sensor) visibility as input. In the first report, the surface visibility is 2 1/2SM and the tower visibility is 10SM. In this case, ASOS automatically encoded mist (BR) as the obscuration. In the second report, the visibilities were changed to 10SM at the surface and 2 1/2SM from the tower cab. Since the surface visibility is now 10SM, ASOS does not encode an obscuration since it is not occurring at the surface. Both reports are correct as encoded.

Example 8: Variable Wind

a. METAR KSP1 301756Z AUTO **33007KT 290V360** 10SM FEW049 19/M01 A2981 RMK AO2 SLP229 T01941006 10200 20122 58017 PWINO TSNO $

b. METAR KSP1 301856Z AUTO **VRB06G15KT** 10SM SCT050 19/M01 A2978 RMK AO2 SLP220 T01941011 PWINO TSNO $

c. SPECI KORE 291712Z AUTO **33003KT** 6SM HZ SCT014 BKN038 BKN049 11/07 A2965 RMK AO2 TSNO

Variable wind direction encoding is based on the observed sustained wind speed. When the wind has a sustained speed of greater than 6 knots, the variability of the wind's direction is encoded in the body of the report. (See the first report in this example.) When the sustained wind speed is 6 knots or less, a variable wind has an encoded direction of "VRB." As is shown in the second report of this example, the sustained wind speed is 6 knots but the wind is gusting to 15 knots. (Gusts are reported for a minimum of 10 minutes after they are first observed.) The direction is still encoded as "VRB." In the third report the winds are not variable and the actual direction is encoded.

Example 9: Surface Visibility and RVR, Plus Remarks

METAR KSP1 041156Z 05024G33KT 020V080 M1/4SM **R04/2800V5000FT** +SN FZFG VV002 M02/M02 A2953 RMK FUNNEL CLOUD B06 FUNNEL CLOUD E10 AO2 PK WND 04036/1135 **SFC VIS 1/4** SNB07 PRESFR SLP096 SNINCR 2/12 4/012 6//// 7//// T10201020 10167 21022 58199 PNO $

At selected sites, Runway Visual Range (RVR) is encoded when conditions warrant. As shown above, RVR is encoded immediately after the visibility in the body of the report. RVR is encoded whenever surface visibility is one statute mile (1SM) or less, and/or if the minimum RVR value is less than or equal to 6,000 feet. In this case, surface visibility is 1/4SM (see remarks section).

This example also illustrates the order of remarks in an ASOS report. After the "RMK" (remarks) contraction, the following order is used:

1. Tornadic remarks: e.g., FUNNEL CLOUD B06 FUNNEL CLOUD E10
2. "AO2" indicator
3. Automated remarks: e.g., PK WND 04036/1135 SFC VIS 1/4 SNB07 PRESFR SLP096
4. Manual remarks: e.g., SNINCR 2/12 4/012
5. Additive data: 6//// 7//// T10201020 10167 21022 58199
6. Sensor status indicators: e.g., PNO
7. Maintenance check indicator: $

Example 10: Surface Visibility and RVR

a. SPECI KSP1 041202Z 35008KT M1/4SM BR CLR 18/18 RMK A02 **SFC VIS 2** SNE02 PNO $

b. SPECI KSPI 041205Z 35008KT 340V070 **1/4SM** FG CLR 18/18 RMK A02 TWR VIS 2 SNE02 RVRNO PNO $

If for any reason the RVR should not be available from a site designated to report RVR, the remark RVRNO is encoded when the surface visibility is 1 statute mile or less. In the first report above, the surface visibility is 2SM. In the second report, the surface visibility reduces to 1/4SM and the RVRNO remark is encoded.

Example 11: Corrected Report

a. METAR KSP1 081153Z 22006KT 9SM FEW250 M10/M13 A3015 RMK AO2 SLP259 T11001128 11094 21133 58006 **4/002**

b. METAR KSP1 081153Z **COR** 22006KT 9SM FEW250 M10/M13 A3015 RMK AO2 SLP259 **4/002** T11001128 11094 21133 58006

This example illustrates the ASOS correction feature. Anyone signed-on as an observer can generate a corrected report. This feature allows the observer to enter data any place in the report. The observer is completely responsible for data quality and proper encoding practices. ASOS does not do any error checking in the correction feature. In the first report, the observer added the "4/sss" (snow depth on ground) group, however, it was not encoded in the proper order of entry. Using the ASOS correction feature allows the observer to correct data. In the second example a corrected report was issued with the "4/sss" group encoded in the proper location, between the "SLP259" and

"T11001128" group. Future enhancement to the ASOS QC algorithms will include format error checking when manual entries are made.

Example 12: Augmentation For Severe Present Weather

SPECI KSP1 241321Z 04008KT 7SM **+FC** -TSRA FEW035 BKN070 OVC090 31/20 A2964 RMK **TORNADO B14 NE** AO2 TSB21RAB21 P0000 $

This SPECI was generated to report the beginning of a thunderstorm (TS), which began at 1321Z. Note that a tornado (+FC) also is occurring and began at 1314Z. The observer added the +FC indicator in the body of the report and the direction (northeast - NE) from the station where the tornado was located when it began.

Example 13: Augmentation For Volcanic Eruption:

SPECI KSP1 241258Z 01007KT 300V040 3/4SM **VA** FEW050 BKN070 OVC095 10/M03 A2963 RMK AO2 VIS 1/4V5 **MT AUGUSTINE VOLCANO 70 MILES SW ERUPTED 241255 LARGE ASH CLOUD EXTENDING TO APRX 30000 FEET MOVING NE** RVRNO $

When a volcanic eruption is first noted, a SPECI report is generated. Because there was volcanic ash (VA) at the site, the observer augmented the SPECI to report this obscuration. More information about the eruption was entered by the observer in the remarks section (shown in bold print).

5.4 Auxiliary Data

Auxiliary data consists of:

- Relative Humidity
- Sea-Level Pressure
- Station Pressure
- Density Altitude
- Pressure Altitude
- Magnetic Wind

These data are available on the VDU, user-provided video monitor screens and selected OID screens; they are updated every minute. The auxiliary data are generally derived from other processed sensor data by the weather reporting algorithms, and, therefore, cannot be edited directly, but may be altered indirectly by editing of the component parameters through the OID. Examples of auxiliary data displays are shown in Appendix A.

5.5 Standard Hydrometeorological Exchange Format (SHEF) Messages

In addition to METAR messages (which may contain precipitation accumulation remarks such as Prrrr, 6RRR/, and 7RRRR), ASOS also generates two distinct SHEF message types.

One type of message is in ".E" SHEF message format. This message is generated when precipitation accumulation onset criteria are exceeded and is discontinued when precipitation accumulation falls below the termination criteria. This type of message is referred to as the "SHEF 15-minute Precipitation Criteria Message." This message contains a chronological listing of precipitation accumulation during the four most recent 15-minute reporting time periods. The 15-minute Precipitation Criteria Message is issued at either H+00, H+15, H+30, or H+45.

The second type of SHEF message is in ".A" SHEF format and is routinely generated at a fixed time each hour (H+00). This message is referred to as the "SHEF Hourly Routine Precipitation Message" and contains precipitation accumulation information for a 60-minute time interval ending at a fixed time each hour.

The onset and termination criteria for the SHEF 15-minute Precipitation Criteria Message and the end time for the SHEF Hourly Routine Precipitation Message are set during system acceptance. They may be subsequently changed only by an authorized ASOS system manager. SHEF messages are stored in ASOS memory for a minimum of 3 days plus so far for the current day. SHEF messages are available from all NWS and FAA ASOS locations.

All SHEF messages originating from NWS ASOS locations and transmitted on the NWS AFOS network are identified by the generic message header: "CCCNNNXXX," where NNN = RR6 (for the SHEF 15-minute Precipitation Criteria Message), or RR7 (for the SHEF Hourly Routine Precipitation Message). For NWS ASOS locations, CCC is the Station Identifier (SID) for the primary responsible WSFO/WFO, and XXX is the ASOS location's SID. SHEF messages originating from NWS ASOS locations are transmitted individually.

Those SHEF messages originating from FAA ASOS locations are captured at the FAA WMSC (WMSCR in the future) and passed across Gateway to the NWS as collectives. These collectives are identified by the AFOS PIL header: "NMCRR7NKA." Collectives contain both types of SHEF messages (RR6, RR7) from commissioned and pre-commissioned FAA ASOS locations.

Example I. SHEF 15-Minute Precipitation Criteria Message

MESSAGE NUMBER	TIME	ONSET CRITERIA	TERMINATION CRITERIA	PCPN VALUE
	1200 UTC	0.50 inch	0.25 inch	0.00 inch
	1215 UTC	0.50 inch	0.25 inch	0.25 inch
	1230 UTC	0.50 inch	0.25 inch	M
RR6 SHEF MSG #1	1245 UTC	0.50 inch	0.25 inch	0.75 inch
RR6 SHEF MSG #2	1300 UTC	0.50 inch	0.25 inch	0.25 inch
	1315 UTC	0.50 inch	0.25 inch	0.20 inch

SHEF MSG #1:

```
    TOPRR6TOP
    TTAA00 KTOP 201245
.E TOP 1020 DH1200/PPC/DIN15/0.00/0.25/M/0.75: C = 0.50/.25
```

SHEF MSG #2:

```
    TOPRR6TOP
    TTAA00 KTOP 201300
    .E TOP 1020 DH1215/PPC/DIN15/0.25/M/0.75/0.25: C = 0.50/.25
```

Legend for Example I. (See SHEF Message #1)

.E TOP:	.E format message from Topeka, KS (TOP).
1020:	Month (October) and day (20) for first observation in time series (current year assumed).
DH1200:	Hour and minute UTC time stamp of first data value in time series. Example given here is 12:00 UTC.
PPC:	Precipitation, Actual Increment (PP); Fifteen minute increment (C).
DIN15:	DI = Data Interval; N15 = Fifteen Minutes.
/0.00/ /0.25/ /M/ /0.75:	Incremental precipitation (in inches) for first, second, third and fourth 15-minute periods of time series. Missing data are replaced with "M." The first value (0.00 inches) is valid for 12:00 UTC. The last value (0.75) is valid for 12:45 UTC.
C = n.nn/.tt	SHEF 15-minute onset threshold criteria/termination threshold criteria. In this example: n.nn = 0.50 inches, and .tt = .25 inches.

Distinctions between different SHEF message formats are also made in the body of the individual messages. See SHEF Version 1.1 issued by the NWS Office of Hydrology, 31 January 1985 for further details.

5.5.1 SHEF 15-Minute Precipitation Criteria Message

The messages in Example I are identified by the “RR6” in the AFOS header, the “.E” message type designator and the “DIN15” 15-minute time interval indicator in the body of the message.

In Example I, MSG #1 was issued at 12:45 UTC because during the current 15-minute period (12:31 - 12:45 UTC) the precipitation accumulation first exceeded the 15-minute precipitation accumulation onset criteria of 0.50 inch. The three previous 15-minute time periods are also included in MSG#1 and listed in chronological order (even though precipitation accumulation during those time periods did not exceed the onset threshold criteria).

MSG #2 was issued at 13:00 UTC because precipitation accumulation during the immediately preceding 15-minute period (ending at 12:45 UTC) exceeded the onset threshold criteria and the precipitation accumulation during the current 15-minute period (12:46 - 13:00 UTC) is still equal to or greater than the termination criteria of 0.25 inch. 15-Minute Precipitation Criteria Messages cease to be issued when the discrete 15-minute precipitation acccumulation falls below the termination threshold criteria. If precipitation accumulation is missing during any minute within a discrete 15-period, then the value reported for that 15-minute period is “M.”

5.5.2 SHEF Hourly Routine Precipitation Message

The messages in Example II are identified by the “RR7” in the AFOS header, and the “.A” SHEF format designator in the body of the message. In example II the end time of the SHEF Hourly Routine Precipitation Message is set at H+00. Thus, all precipitation accumulation reports in example II are for the 60-minute period from H+01 to H+00. A SHEF Hourly Routine Precipitation Message is issued routinely every hour, regardless of whether or not there was precipitation during the hour.

SHEF MSG #3 is valid at 1400 UTC. This 60-minute period includes the 0.20 inch precipitation accumulation which occurred during the 15-minute period ending at 1315 UTC. Note that the detection threshold specified for the ASOS HTB is 0.01 inch per hour, and the precipitation rate accuracy is the larger of 10 percent or 0.01 inches per hour.

SHEF MSG #4 shows a large 60-minute accumulation of 1.35 inches ending at 1500 UTC.

SHEF MSG #5 valid at 1600 UTC is a typical example of a 60-minute reporting period with no measurable precipitation.

SHEF MSG #6 valid at 1700 UTC is a typical example of a 60-minute reporting period where some of the 1-minute data were missing. If precipitation accumulation is missing during any minute within the discrete 60-minute period, then the value reported in the SHEF Hourly Routine Precipitation message after “PPH” is “M.”

5.6 Daily and Monthly Summaries

All ASOS locations are capable of generating and transmitting daily and monthly weather summaries, however, only selected NWS ASOS locations transmit these data long-line. These summaries are valid for the calendar day, or the calendar month, ending at 23:59 LST. The daily summaries are normally transmitted early on the following day at a programmable transmission time specified by the system manager. Backup transmission times are generally 1 and 2 hours after the initial scheduled transmission time. The monthly summaries are normally transmitted early on the first day of the new month at programmable transmission times. Backup transmission times are generally 1 and 2 hours after the initial scheduled transmission time. The ASOS generated daily and monthly summaries replace the “F-6” data previously provided from staffed locations.

Daily and monthly summaries are stored in ASOS memory for 10 days after transmission. The content and format of the daily and monthly summary messages is only briefly summarized here.

5.6.1 Daily Summary Message

The Daily Summary Message (DSM) contains data to complete the Preliminary Local Climatic Data (PLCD) record for each specified location. These data are valid for the previous day and include:

Example II. SHEF Hourly Routine Precipitation Message

MESSAGE NUMBER	TIME	PCPN VALUE
RR7 SHEF MSG #3	1400 UTC	0.20 inch
RR7 SHEF MSG #4	1500 UTC	1.35 inch
RR7 SHEF MSG #5	1600 UTC	0.00 inch
RR7 SHEF MSG #6	1700 UTC	Missing

SHEF MSG #3:

```
TOPRR7TOP
TTAA00 KTOP 201400
.A TOP 1020 DH1400/PPH 0.20
```

SHEF MSG #4:

```
TOPRR7TOP
TTAA00 KTOP 201500
.A TOP 1020 DH1500/PPH 1.35
```

SHEF MSG #5:

```
TOPRR7TOP
TTAA00 KTOP 201600
.A TOP 1020 DH1600/PPH 0.00
```

SHEF MSG #6:

```
TOPRR7TOP
TTAA00 KTOP 201700
. A TOP 1020 DH1700/PPH M
```

Legend for Example II. (See SHEF MSG #3)

.A TOP:	".A" format message from Topeka, KS (TOP).
1020:	Month (October), and day (20) of observation (current year assumed).
DH1400:	Observation time in UTC. Example given here is for MSG # 3 (14:00 UTC).
PPH:	Precipitation, Actual Increment (PP); Hourly increment (H).
0.20 (a.aa):	Incremental precipitation is in hundredths of an inch. In the example given here, precipitation accumulation for the current hour in MSG # 3 (ending at 14:00 UTC) is 0.20 inch

- Daily (00:00 to 23:59 LST) Maximum/ Minimum Temperatures and Times of Occurrence
- Daytime (0700 to 1900 LST) Maximum Temperature and Time of Occurrence
- Nighttime (1900 to 0800 LST) Minimum Temperature and Time of Occurrence
- Daily Minimum Sea-Level Pressure
- Daily Total Precipitation Accumulation (Liquid Equivalent)
- Hourly Precipitation Amounts (H+00 to H+59)
- Daily Average 2-Minute Wind Speed
- Fastest 2-Minute Wind Direction, Speed (MPH) and Time of Occurrence
- Daily Peak Wind Direction and Speed (MPH) and Time of Occurrence
- Weather Occurrence Symbols
- Minutes of Sunshine and Percentage of Sunshine **(When Available)**
- Daily Total Snowfall, Ice Pellets Accumulation **(When Available)**
- Depth of Snow, Ice and/or Ice Pellets on the Ground (In Whole Inches) at a Designated Observation Time **(When Available)**
- Average Daylight Sky Cover (Sunrise to Sunset) **(When Available)**
- Average Daily Sky Cover **(When Available)**
- Remarks for Estimated Data

5.6.2 Monthly Summary Message

The Monthly Summary Message (MSM) contains data necessary to complete the monthly Preliminary Local Climatic Data (PLCD) record for each specified location. These data are valid for the previous calendar month and include:

- Monthly Maximum Temperature and Date of Occurrence
- Monthly Minimum Temperature and Date of Occurrence
- Average Daily Maximum Temperature
- Average Daily Minimum Temperature
- Average Monthly Temperature
- Number of Days with Maximum Temperature of 32° F and Below
- Number of Days with Maximum Temperature of 90°F and Above (Use 70° F in NWS Alaska Region)
- Number of Days with Minimum Temperature of 32° F and Below.
- Number of Days with Minimum Temperature of 0° F and Below.
- Monthly Heating Degree Days
- Monthly Cooling Degree Days
- Monthly Mean Station Pressure
- Monthly Mean Sea-Level Pressure
- Monthly Maximum Sea-Level Pressure and Date and Time of Occurrence
- Monthly Minimum Sea-Level Pressure (Nearest 0.01 Inch Hg) and Date and Time of Occurrence
- Monthly Total Precipitation (Water Equivalent)
- Number of Days with Precipitation Greater Than or equal to 0.01, 0.10, 0.50, and 1.00 inch
- Greatest 24-Hour Precipitation (Water Equivalent) and Date(s) of Occurrence
- Short Duration Precipitation (5, 10, 15, 20, 30, 45, 60, 80, 100, 120, 150, 180 min) including Date of Occurrence and Time when period ended
- Monthly Total Hours of Sunshine Observed **(When Available)**
- Monthly Percentage of Total Sunshine Observed **(When Available)**
- Greatest 24-Hour Snowfall and Date(s) of Occurrence **(When Available)**
- Greatest Depth Of Snow on Ground and Date(s) of Occurrence **(When Available)**
- Number of Clear, Partly Cloudy, and Cloudy Days during Month **(When Available)**
- Remarks For Estimated Data

5.7 ASOS High-Resolution Sensor Data

High-resolution sensor data from the ASOS 12-hour archive file are available for review at the ASOS OID or to authorized remote users. These data have not undergone final quality control checks. They are primarily intended for maintenance troubleshooting purposes and should not be used as valid meteorological data without extensive evaluation. The high-resolution data which are available for review are summarized in Table 9. Examples of ASOS 1-Minute Sensor Data are shown in Appendix A.

Table 9. ASOS High-Resolution Data

- 30-Second Cloud Height Reading (Ceilometer Data)
- 1-Minute Average Visibility Extinction Coefficient
- 1-Minute Photometer Reading
- 1-Minute Average Ambient Temperature
- 1-Minute Average Dew Point Temperature
- 2-Minute Average Wind Speed and Direction (Every Minute)
- Maximum 5-Second Average Wind Speed and Direction For Each Minute
- 1-Minute Precipitation Identification Sensor Data
- 1-Minute Lightning Data *
- 1-Minute Precipitation Amount
- 15-Minute Incremental Precipitation Amount Stored Every 15 Minutes
- 1-Minute Sunshine Data *
- 1-Minute Frozen Precipitation Water Equivalent *
- 1-Minute Snow Depth *
- 1-Minute Freezing Rain Occurrence
- 1-Minute Average Pressure For Each Pressure Cell

* When Sensors Become Available

CHAPTER SIX

6.0 ASOS Data Outlets

ASOS data are provided through multiple data outlets. There are five basic types of ASOS data outlets. The basic ASOS data outlets are described below along with a brief description of the types of data available through each of these outlets. The basic ASOS data outlets are:

- On-Site and Remote OID Video Screen Displays, and Remote User Interactive Video Screen Displays
- On-Site, Non-Interactive Screen Displays
- On-Site Printer Hard copy
- Long-Line Coded Messages
- Computer-Generated Voice Messages

6.1 Interactive Video Screen Displays

At staffed ASOS locations, up to two Operator Interface Devices (OID) can be provided. The OID consists of a monitor and keyboard and provides interactive access to ASOS data through the ACU. A primary OID is located at the designated primary observer location. At airports with air traffic control towers, an OID is also provided which may be designated either the primary or secondary OID, depending upon primary observer location. On-site users may "sign-on" to the ASOS OID in any one of four access levels with the proper password. Those four levels include:

- Observer Level
- Air Traffic Control (Tower) Level
- Technician Level
- System Manager Level

OID users in both the Observer Level and the Air Traffic Control Level can be signed on to the ASOS simultaneously, however no two users can be signed on in the Observer Level at the same time. Remote OID users and remote interactive computer users may only sign on as:

- Unsigned User
- Technician
- System Manager

Up to 8 on-site OID/remote OID users may be signed-on at one time, however, only one on-site OID user at a time may be signed-on in the (primary) Observer Level or Air Traffic Control (ATC) Level. It is not possible to remotely sign-on in the Observer level or ATC level. This prevents remote editing or augmenting of the ASOS data. The various types of data available in these sign-on levels are listed in Figure 4, and shown in Appendix A, ASOS Video Displays.

6.2 Non-Interactive Screen Displays

On-site displays, other than the OID, include the FAA ACE Video Display (VD) and the Video Display Unit (VDU). The VD is intended for Air Traffic Controller use. The VDU (up to 4 per airport) is intended for observer use at the primary observation location. Other users, such as fixed base operators, may interface with the ASOS by providing their own off-the-shelf, non-interactive video monitors. Up to 50 such monitors can be interfaced with ASOS at a single airport. The data which may be displayed on these monitors is identical to the data displayed on the VDU. See Appendix I for examples of the FAA VD and VDU screens.

The FAA VD includes the 5-second wind update of the current 2-minute average wind (magnetic), the current 1-minute update of the altimeter setting, the last transmitted METAR, and the density altitude at the time of the last transmitted METAR. This data is automatically updated by the ASOS.

The VDU displays the most current OMO data, the last transmitted METAR, and auxiliary data such as Relative Humidity, Sea-Level Pressure, Density Altitude, Pressure Altitude, and wind (direction given in both magnetic and true degrees). Most auxiliary data are refreshed automatically once every minute (see Section 5.4 for details). The data available on the user provided monitor is identical with that provided on the VDU. No user interaction with ASOS is permitted with the FAA VD, VDU, or user provided monitor.

6.3 ASOS Printer

One printer may be provided at the primary OID equipped location. The following data are automatically printed:

- All transmitted METARs

- The OMO generated just before and after the OID edit function has been accessed
- Equipment failures
- Daily and monthly summaries (after computed)

In addition, any data displayed on the primary OID screen may be printed upon command.

6.4 Long-Line Dissemination

The ASOS coded messages are transmitted nationwide through NWS and FAA communication networks (see Figures 18 and 19).

Initially, the FAA will provide OMO data for local use only; no networking of these data is possible. Additionally, all ASOS METAR messages are available to users on both the FAA and NWS networks. Exchange of ASOS METAR messages between the FAA and NWS communications networks occurs through the NWS Telecommunication Gateway (NWSTG). ASOS METAR messages, SHEF data, and Daily Summary and Monthly Summary Messages from both FAA and NWS locations are additionally available to other users through the NWSTG.

In the final network configuration, OMO data from all ASOS locations will be made available to users upon request. OMO data from specified ASOS locations will be provided to the NWS Weather Forecast Offices (WFO), upon request, once every 5 minutes when the WFO is operating in the "warning" mode, or once every 15 minutes when the WFO is operating in the "alert" mode.

6.5 Computer-Generated Voice Messages

ASOS computer-generated voice messages include those which are broadcast directly to pilots through the ASOS ground-to-air radio, and those which are made available to the general aviation public through FAA sponsored telephone dial-in access. The information contained in the ground-to-air radio message and the telephone dial-in message are identical. ASOS computer-generated voice observations are spoken at the rate of 100 words per-minute.

The content of the computer-generated voice message is either the current OMO or the current METAR, depending on location. At unstaffed locations, the OMO is used; at FAA towered locations the OMO or METAR may be used at the discretion of the air traffic controller. The content of the computer-generated voice includes the following:

- Location identification
- Type of observing station (automated), but not type of observation (i.e., METAR or SPECI)
- The valid time of the observation
- The individual reported weather elements normally included in the METAR (except sea-level pressure). One major difference from the METAR however, is that wind direction in the voice message is given in reference to *magnetic* direction instead of true direction
- Selected automated remarks and manual OID keyboard entered remarks

After the altimeter setting information is given, the word "remarks" is spoken to indicate that additional information follows. This additional information may be ASOS generated and/or manually entered. The ASOS is capable of selecting appropriate words from the approved ASOS voice vocabulary (see Appendix D) and producing computer-generated voice remarks for:

- Variable visibility (e.g., "visibility two miles variable three miles")
- Pressure (e.g., when density altitude is $\geq$ 1,000 feet an automated remark is generated; "Density altitude two thousand five hundred")
- Lightning (e.g., "Lightning Distant Northeast")

Manually generated remarks are appended to the computer-generated voice remarks through the OID keyboard. For example, manual entry remarks through the OID keyboard may include tower-visibility.

At towered airports, the air traffic controller has the option of selecting for the broadcast weather message either METARs (scheduled or unscheduled) or OMOs. At non-towered locations, the broadcast weather message defaults to the OMO.

Each computer-generated voice message begins with an identification of the location, the phrase "AUTOMATED WEATHER OBSERVATION" and the UTC (ZULU) time of the observation.

To clarify and distinguish the different data elements in the computer-generated voice message a verbal identifier (prefix) accompanies each weather element (e.g., "temperature four dew point three"). Weather elements missing in the METAR or OMO alpha-numeric message are enunciated as "missing" in the corresponding computer-gener-

Figure 18. ASOS Network Data Flow—Initial Configuration (1997)

Figure 19. ASOS Network Data Flow—Final Configuration

ated voice message (e.g., "sky condition missing,"; "visibility missing").

Example 1

If the airport's specific location is included in the airport's name, the airport's name is announced.

"BREMERTON NATIONAL AIRPORT, AUTOMATED WEATHER OBSERVATION, ONE FOUR FIVE SIX ZULU, ..."

"RAVENSWORTH JACKSON COUNTY AIRPORT, AUTOMATED WEATHER OBSERVATION, ONE FOUR FIVE SIX ZULU, ..."

Example 2

If the airport's specific location is not included in the airport's name, the location name is first announced, and then the airport name is given.

"SAULT STE MARIE, CHIPPEWA COUNTY INTERNATIONAL AIRPORT, AUTOMATED WEATHER OBSERVATION, ONE FOUR FIVE SIX ZULU, ..."

"SANDUSKY, COWLEY FIELD, AUTOMATED WEATHER OBSERVATION, ONE FOUR FIVE SIX ZULU, ..."

Example 3

During the nationwide implementation of the ASOS, each location will operate in test mode for approximately 30-60 days before commissioning. A longer period of test broadcasts may occur at selected locations. During this test period, computer-generated voice messages will have the word "TEST" in the message following the word "OBSERVATION" to indicate that the observation is not official.

"BREMERTON NATIONAL AIRPORT AUTOMATED WEATHER OBSERVATION **TEST** ONE FOUR FIVE SIX ZULU, ..."

Example 4

The phrase "TEMPORARILY INACTIVE" is added to the message after the word "OBSERVATION" to indicate that the system is inoperative.

"BREMERTON NATIONAL AIRPORT, AUTOMATED WEATHER OBSERVATION, TEMPORARILY INACTIVE, ONE FOUR FIVE SIX ZULU, ..."

Example 5

In this example, a "clear below 12,000 feet" observation is given. Notice that the number "9" is pronounced NINER. The magnetic declination at MHK is 7^{o}E. The true wind direction reported in the METAR (280 degrees) is reported as 270 degrees magnetic (rounded to the nearest 10 degrees) in the computer-generated voice message.

METAR KMHK 010355Z AUTO 28008KT 10SM CLR 20/13 A2988 RMK AO2 SLP929 T02000130

"MANHATTAN MUNICIPAL AIRPORT, AUTOMATED WEATHER OBSERVATION, ZERO THREE FIVE FIVE ZULU, WIND TWO SEVEN ZERO AT ZERO EIGHT, VISIBILITY ONE ZERO, SKY CONDITION CLEAR, TEMPERATURE TWO ZERO CELSIUS, DEW POINT ONE THREE CELSIUS, ALTIMETER TWO NINER EIGHT EIGHT"

Example 6

In this example, a manual lower tower visibility is given. The measured true wind direction is 164 degrees (rounded to 160 for reporting in the METAR). The measured magnetic wind direction is 157 degrees (rounded to 160 degrees for reporting in the computer-generated voice message). Although magnetic declination at MHK is 7^{o}E, note that both the true and magnetic wind directions are reported as 160 degrees in this example.

SPECI KMHK AUTO 090735Z 16005KT 1SM -RA BR OVC050 20/20 A2992 RMK AO2 SFC VIS 3 P0001

"MANHATTAN MUNICIPAL AIRPORT, AUTOMATED WEATHER OBSERVATION, ZERO SEVEN THREE FIVE ZULU, WIND ONE SIX ZERO AT ZERO FIVE, VISIBILITY ONE, LIGHT RAIN MIST, SKY CONDITION OVERCAST FIVE THOUSAND, TEMPERATURE TWO ZERO CELSIUS, DEW POINT TWO ZERO CELSIUS, ALTIMETER TWO NINER NINER TWO, REMARKS SURFACE VISIBILITY THREE"

Example 7

ASOS does not report a cloud height of zero, but is capable of reporting a vertical visibility with an obscuration. Observed visibilities of zero, 1/16 or 1/8 mile are all reported as "less than one quarter" mile by ASOS but may be manually augmented. The pressure sensors are inoperative and therefore the altimeter is missing (note the "$" maintenance flag in the METAR message). The magnetic declination at ABI is 8°E. With a calm wind however, both the true wind direction in the METAR (00000) and the magnetic wind direction in the computer-generated message are reported as "calm."

SPECI KABI 121255Z AUTO 0000KT M1/4SM FG VV001 16/16 RMK AO2 $

"ABILENE MUNICIPAL AIRPORT, AUTOMATED WEATHER OBSERVATION, ONE TWO FIVE FIVE ZULU, WIND CALM, VISIBILITY LESS THAN ONE QUARTER, FOG, VERTICAL VISIBILITY ONE HUNDRED FEET, TEMPERATURE ONE SIX CELSIUS, DEW POINT ONE SIX CELSIUS, ALTIMETER MISSING"

Example 8

In this example, variable visibility is automatically included as a remark. The magnetic declination at BUF is 8°W. The computed true wind direction (rounded to the nearest degree) is 237 degrees, and the computed magnetic wind direction (also rounded to the nearest degree) is 245 degrees. For reporting purposes, wind directions are rounded down to the nearest 10 degrees. Thus the true direction reported in the METAR is given as 240 degrees while the magnetic direction reported in the computer-generated voice message is also given as 240 degrees.

SPECI KBUF 111541 AUTO 24010 11/2SM -SN SCT010 OVC018 M02/M03 A2955 RMK AO2 VIS 1V2

"GREATER BUFFALO AIRPORT, AUTOMATED WEATHER OBSERVATION, ONE FIVE FOUR ONE ZULU, WIND TWO FOUR ZERO AT ONE ZERO, VISIBILITY ONE AND ONE HALF, LIGHT SNOW, SKY CONDITION SCATTERED AT ONE THOUSAND OVERCAST AT ONE THOUSAND EIGHT HUNDRED, TEMPERATURE MINUS ZERO TWO, DEW POINT MINUS ZERO THREE, ALTIMETER TWO NINER FIVE FIVE, REMARKS VISIBILITY ONE VARIABLE TWO"

CHAPTER SEVEN

7.0 Introduction

This chapter lists elements ASOS does not now provide and describes plans for product improvement.

7.1 Data Not Provided by ASOS

The elements not currently sensed or reported by ASOS are listed in Table 10. Other complementary technology or supplementary observing networks will report these weather conditions. Some additional data may be added to the ASOS report through augmentation. Data from separate observing networks or from remote sensing technologies such as WSR-88D, GOES, and LDS can be used to complement the sensor observation provided by ASOS.

The operational implementation of ASOS is clearly a major technological achievement in automation of surface observations. As with any new sophisticated technology, continuous development and product improvement are essential to keep pace with an ever changing world. The ASOS product improvement program is an on-going effort to enhance existing capabilities and develop new sensors and/or algorithms for reporting hail, snowfall, liquid equivalent of frozen precipitation, and snow accumulation. Work continues on incorporating independent ALS and NLDN-ALDARS data into the ASOS to provide real-time information on thunderstorm location.

Table 10. Weather Elements Not Reported by ASOS

- Tornado, funnel cloud, waterspout [b]
- Hail [abc]
- Ice crystals [a]
  [Snow grains, Ice Pellets, Snow pellets] [abc]
- Drizzle, freezing drizzle [abc]
- Volcanic ash [b]
- Blowing obstructions (sand, dust, spray) [abc]
- Smoke [b]
- Snow fall (accumulation rate) and snow depth (6-hourly) [abc]
- Hourly snow increase (SNINCR) remarks [abc]
- Liquid Equivalent of Frozen Precipitation [abc]
- Water equivalent of snow on the ground [ac]
- Clouds above 12,000 feet [abcd]
- Operationally significant clouds above 12,000 feet in mountainous areas [b]
- Virga [b]
- Distant precipitation in mountainous areas and distant clouds obscuring mountains [b]
- Operationally significant local variations in visibility [b]
- Minutes of sunshine [c]

a = Provided by supplementary observing networks
b = May be provided by manual augmentation
c = May be provided by future ASOS sensors/algorithms
d = Provided by complementary technologies (Satellite Cloud Product, ALDARS, etc.)

7.2 Planned Product Improvement

The development and fielding of the ASOS network represents a large initial commitment of time and tax dollars. The goal of ASOS planned product improvements is to ensure the most cost-effective benefits to the nation well into the next century, to prevent premature system obsolescence and the need for a costly full system replacement, and to more adequately meet changing user requirements and decrease maintenance demands. To meet this goal, the NWS has initiated a long-term product improvement program.

The objectives of this multi-year program are to refine and improve the ASOS baseline suite, while taking advantage of future scientific and technical breakthroughs in sensors and algorithms which will enhance and expand the baseline capabilities. The current ASOS baseline includes reports for the following elements: Wind, Visibility, Present Weather/Obscurations, Ambient Temperature/Dew Point Temperature, Altimeter Setting (Pressure), and Liquid Precipitation Accumulation.

Typically, several years of test and evaluation activities are required before a new sensor is ready for implementation. The process begins by first defining the operational and performance requirements that a potential sensor must meet, defining the specification, and then selecting a number of vendors from which to procure suitable prototypes. These prototypes are generally tested and evaluated over at least a two year period in selected environments to ensure that the sensors are subjected to a full spectrum of weather conditions.

An iterative process of refining the hardware and software capabilities occurs during this period. Evaluation results and requests for specific changes are continuously sent to the vendors. As potential technology improvements become available, they are incorporated into the prototype sensors for further testing.

The most promising prototype sensors, usually from one vendor, are then integrated into the operational ASOS sensor suite and tested at approximately 20 sites for another year or two. This procedure enables test and evaluation to occur in a more realistic setting and under more varied weather conditions. It also helps to ensure that the hard ware/software components of the new sensor are compatible with those of the existing ASOS sensor suite.

The iterative process of sensor refinement continues as the vendor receives evaluation data and requests for changes. At this stage, the evaluation process includes feedback from potential users, made possible by the more operational setting. After evaluation and filtering of user feedback comments, recommendations for improvement are forwarded to the vendor. Again, as sensor improvements become available, they are incorporated into the prototype sensors for further testing. Upon successful completion of this process, a new sensor/capability is added to the ASOS nationwide network. The following sections describe specific product improvement activities.

7.2.1 Ice-Free Wind Sensor

The current ASOS wind sensor uses the traditional cup and vane design that occasionally experiences freeze-up in icing conditions. To minimize these occurrences, the ASOS Program Office is testing a variety of replacement wind sensors with respect to the ability to continue operation under adverse winter conditions such as freezing rain, freezing drizzle, and snow. First-year testing started during the fall of 1995 with ice-free wind sensors from four vendors. Second-year testing (field, chamber, and wind tunnel) started in December 1996 and is ongoing as of this writing.

7.2.2 Dew Point Sensor

The current ASOS dew point sensor exhibits several problems, including corrosion and calibration problems, resulting in inaccurate and unreliable performance of the sensor. Consequently, ASOS technicians make more frequent periodic maintenance trips than the ASOS specified 90-day preventive maintenance interval. Several modifications have been made, and continue to be made, to the existing dew point sensor. One improvement is the replacement of the silver coated mirror with a gold coated mirror. This increases the mirror's reflectivity and the sensor's ability to compensate for mirror contamination over a longer period of time before maintenance is needed. An effort is now underway to completely replace the chilled mirror dew point sensor with an alternative technology.

An alternative vendor/technology search was conducted in Spring 1996 and revealed five potential alternative sensor technologies:

- Chilled surface-capacitive
- Infrared hygrometer
- Hygro-mechanical arch
- Lithium chloride
- Thin-film capacitive

Based on analysis of the competing technologies, the thin-film capacitive technology was selected for testing. Initial testing began at four test locations in 1997.

7.2.3 Ceilometer/Sky Condition

The ASOS specification requires the ceilometer to report cloud heights up to 12,000 feet. Under most circumstances, the sky condition algorithm processes the cloud height information properly. The resultant sky condition report is fairly representative of the actual sky condition near the airport. However, the algorithm can be improved to enhance reporting of cloud bases and vertical visibility during fog, virga, and precipitation events. Algorithm improvements are also needed to reduce the false reporting of lower mid-level moisture layers as clouds.

The ASOS Program can and will make some of the proposed algorithm enhancements using the current ceilometer. Laser beam ceilometer technology employed in the current model has advanced in recent years to provide improved cloud base detection. In addition, new generation cloud height sensors (e.g., 25,000 foot ceilometers) may provide more reliable information in the lower atmosphere during adverse weather conditions. Initial testing of the 25,000 foot ceilometers from three vendors started in August 1996.

7.2.4 All-Weather Precipitation Accumulation Gauge

The current ASOS Heated Tipping Bucket gauge is strictly a liquid precipitation accumulation sensor. A Frozen Precipitation Water Equivalent Sensor was a planned addition to ASOS. Numerous attempts were made to design a suitable frozen precipitation water equivalent sensor. These sensors typically consisted of a collection bucket mounted on a load cell. The basic problem was that the load cell exhibited too much hysteresis with temperature. In June 1996, the NWS Offices of Hydrology and Meteorology finalized a requirement for an “all-weather” gauge that will measure both liquid and frozen precipitation water equivalent. Initial testing of all-weather precipitation accumulation gauges (AWPAG) from two vendors started in January 1997. The AWPAG requirement was modified in Spring 1997 based on initial test results. Follow-on testing is planned for 1998.

7.2.5 Enhanced Precipitation Identification

The current precipitation identification sensor does not consistently detect and report light precipitation (< 0.01 inch/hour), ice pellets, or hail. The current precipitation identification sensor was designed to meet a requirement to detect precipitation that falls at a rate $\geq$0.01 inch/hour. ASOS’s existing precipitation identification sensor can detect rain or snow; however, the sensor identifies ice pellets and hail as rain, or undetermined precipitation (UP). Field reports have identified a resurgent need for the detection and identification of drizzle or very light precipitation (< 0.01 inch/hour), ice pellets, and hail. Finally, although the first generation algorithms for blowing snow are now part of ASOS, further development and refinement is being pursued. Initial sensor testing from two vendors started during 1995-1996 winter. A single vendor’s technology was tested during 1997.

7.2.6 Sunshine

The ASOS specification has a requirement for a sunshine sensor. Test and evaluation of candidate sensors began in 1992. The sunshine sensors from test vendors were tested and evaluated. All candidates’ sensors were compared with two reference sensors, the Foster-Foskett and the Eppley pyrheliometer. Test results revealed that one vendor was clearly superior in meeting the ASOS specification. In 1995, the Office of Meteorology redefined the ASOS specification for the sunshine sensor. Sunshine sensors from the leading vendor were installed at four test sites in early 1996. A one-two year demonstration began at eight other sites in Summer 1997.

7.2.7 Schedule

The earliest product improvement sensor forecasted to reach production is the sunshine sensor. It is expected to be fielded as early as FY 1999. Limited production and field implementation of other sensors/algorithms is estimated to start in the year 2000 and be completed by 2007.

7.3 Summary

The characteristics of the ASOS include:

- Continuous Operation; Reports Updated Every Minute
- Fast Response to Changing Conditions
- Consistency of Observations
- Designed for Aviation Operational Use
- Critical Sensors Normally Located Near TDZ
- Visibility Determinations to 10 Miles
- Cloud Height Determination Up to 12,000 Feet
- Present Weather Sensors Included
- Multiple Sensors Where Needed

Among the basic strengths of the ASOS observation is the ability to measure critical weather parameters (such as sky condition and visibility) where they are needed most —at the touchdown zone(s). Other parameters may be measured at a representative location, usually near the center of the airport. ASOS data are updated once each minute and transmitted directly to the air traffic controller. ASOS generated METAR messages, SHEF messages, and daily and monthly summary products are routinely made available for nationwide dissemination. The ASOS is capable of performing all the basic observing functions and operating fully unattended, thus freeing observing personnel for other demanding duties.

ASOS data may be accessed through a variety of media never before available from a surface observing site. Various local on-site video screen displays are available on the OID (proper access code/password may be required), and VDU. Remote monitor hook-up can be made available to airlines and other external users on the airport. Authorized remote users (with modem-equipped computers and the proper access code/password) may also acquire a wide variety of OID screen displays through the ASOS remote user dial-in port. Computer-generated voice messages are made available to local aviation users through ground-to-air broadcast and a dial-in telephone number provided at each ASOS location. Long-line users are provided with routine access to ASOS generated METAR and SHEF messages, and daily and monthly summary data. The wealth of high-quality ASOS data now available to users provides new resources and exciting opportunities in meeting future needs for environmental data.

ASOS DATA TYPE	ASOS DATA OUTLET											
	OID/REMOTE USER INTERACTIVE SCREENS					ON-SITE SCREEN	ON-SITE PRINTER	LONG-LINE			COMPUTER GENERA VOICE	
	OBSVR LEVEL (1)	ATC LEVEL (1)	MAINT LEVEL	SYS MGR LEVEL	UN-SIGNED USER LEVEL	VDU	(STAFFED SITES)	NWS AFOS	NWS AWIPS	FAA NADIN	GROUND-TO-AIR RADIO	TELEPH DIAL-IN
OMO DATA	◆	◆	◆	◆	◆		◆		◆ [2]	◆ [2]	◆ [3]	◆
METAR DATA	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆ [3]	◆
AUXILIARY DATA	◆	◆	◆	◆	◆	◆	◆					
SHEF DATA	◆		◆	◆	◆		◆	◆	◆	◆ [4]		
MAINTENANCE DATA	◆		◆	◆	◆		◆					
DAILY SUMMARY DATA	◆		◆	◆	◆		◆	◆	◆			
MONTHLY SUMMARY DATA	◆		◆	◆	◆		◆	◆	◆			

◆ Data type available through data outlet

1 This level not available remotely
2 Selected OMO data provided once every 5 or 15 minutes upon request
3 Either OMO or last transmitted METAR/SPECI - Not both
4 Available through FAA ADAS interface

Figure 4. Availability of ASOS Data

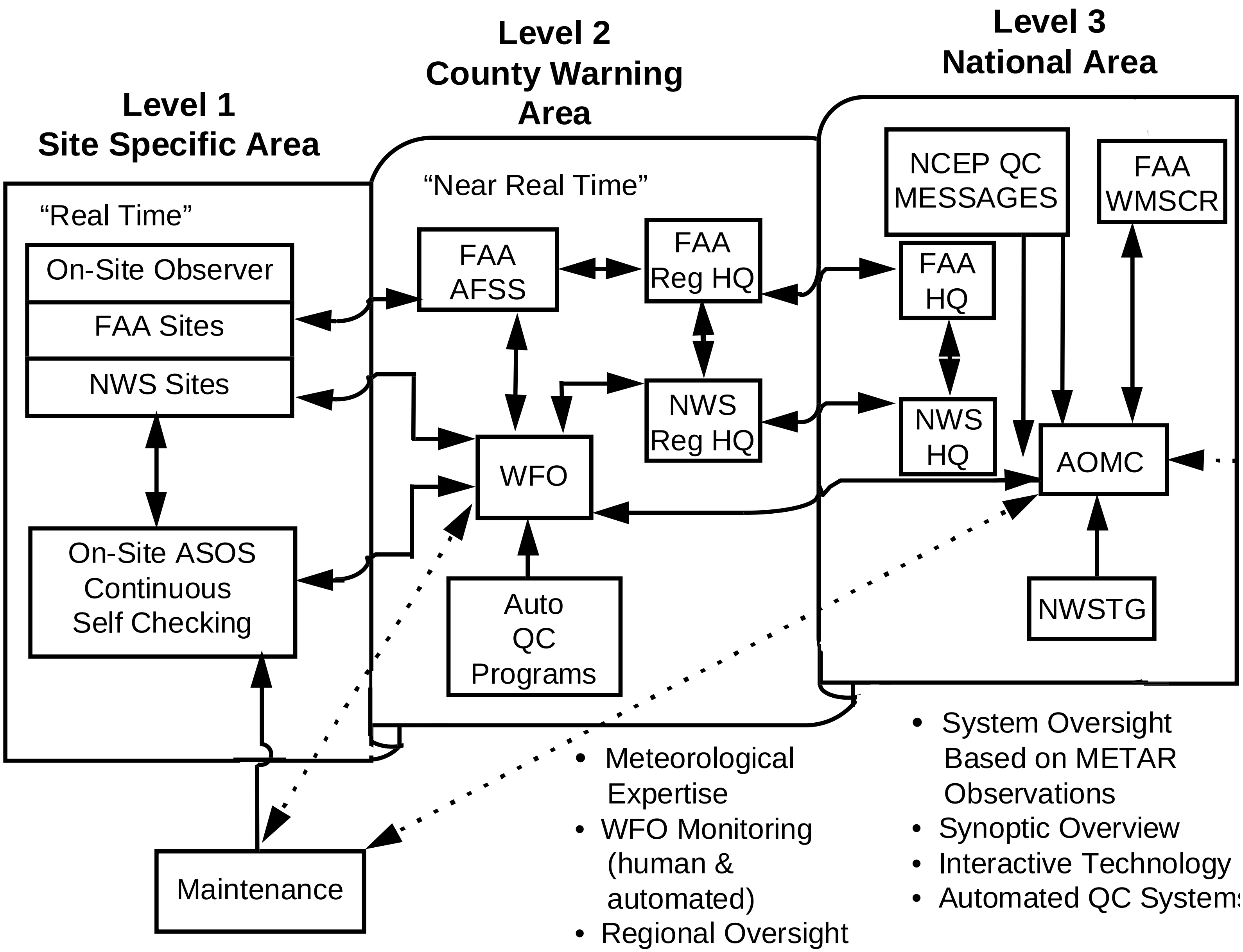
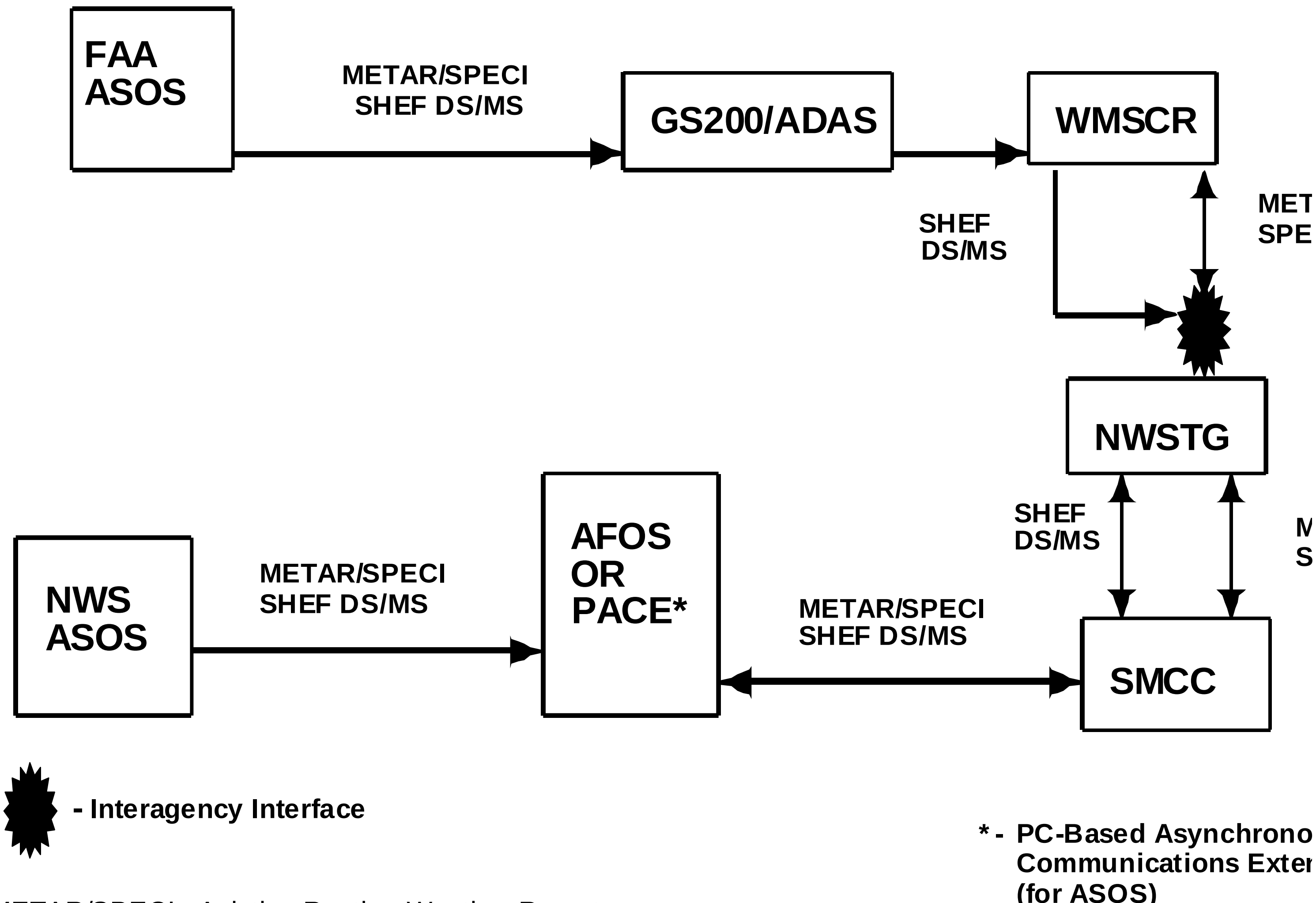
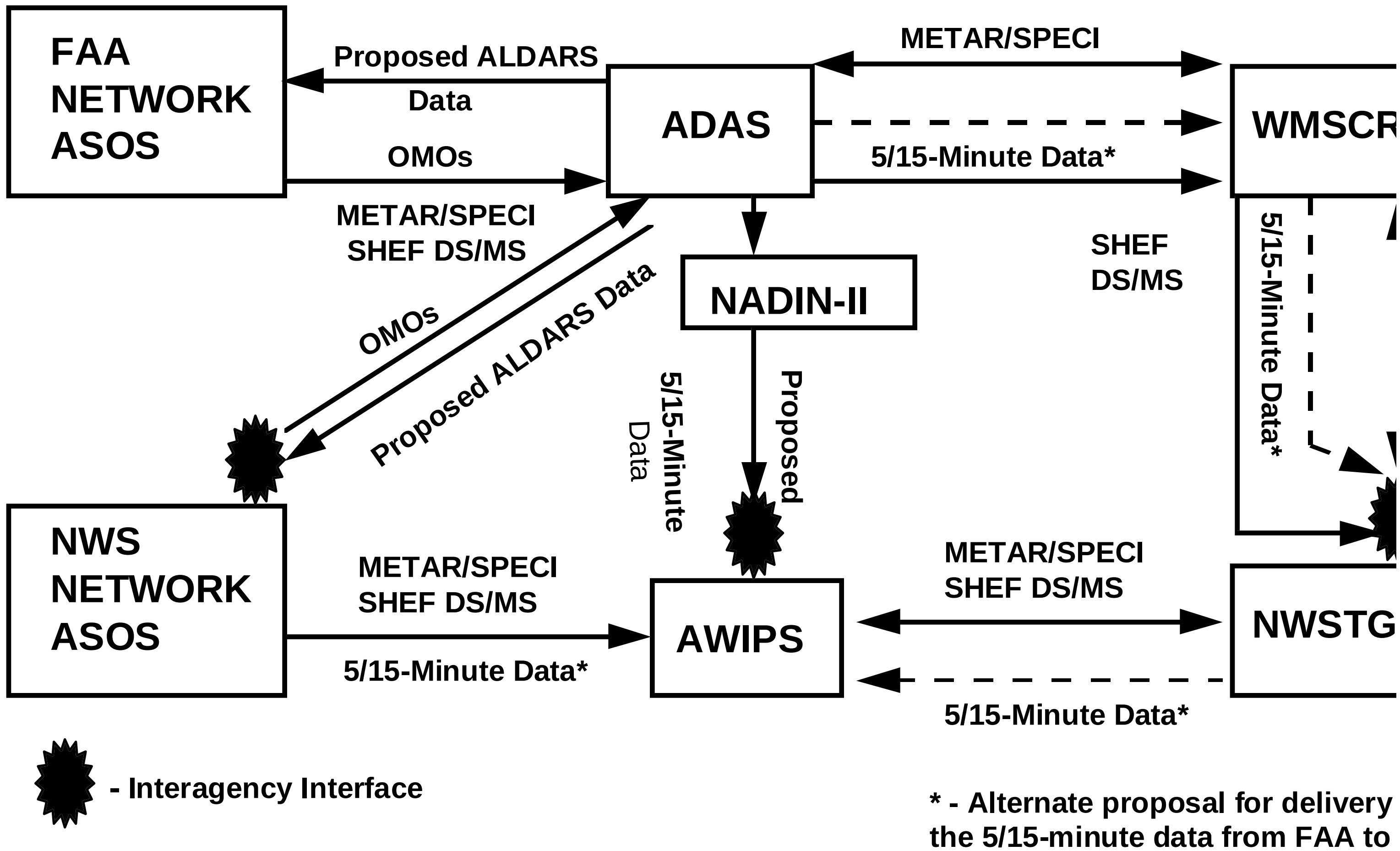


Figure 1. ASOS Quality Control Concept



METAR/SPECI - Aviation Routine Weather Report
SHEF - Standard Hydrometeorological Exchange Format Reports
NWSTG - National Weather Service Telecommunications Gateway
ADAS - AWOS/ASOS Data Acquisition System
WMSC - Weather Message Switching Center

Figure 18. ASOS Network Data Flow——Initial Configuration (1997)



METAR/SPECI - Aviation Routine Weather Report
SHEF - Standard Hydrometeorological Exchange Format Reports
OMOs - One Minute Observations
DS/MS - Daily Summary/Monthly Summary Messages
WMSCR - Weather Message Switching Center Replacement
ALDARS - Automated Lightning Detection and Reporting System

Figure 19. ASOS Network Data Flow—Final Configuration

Meteorological Discontinuity/Backup Sensor Group

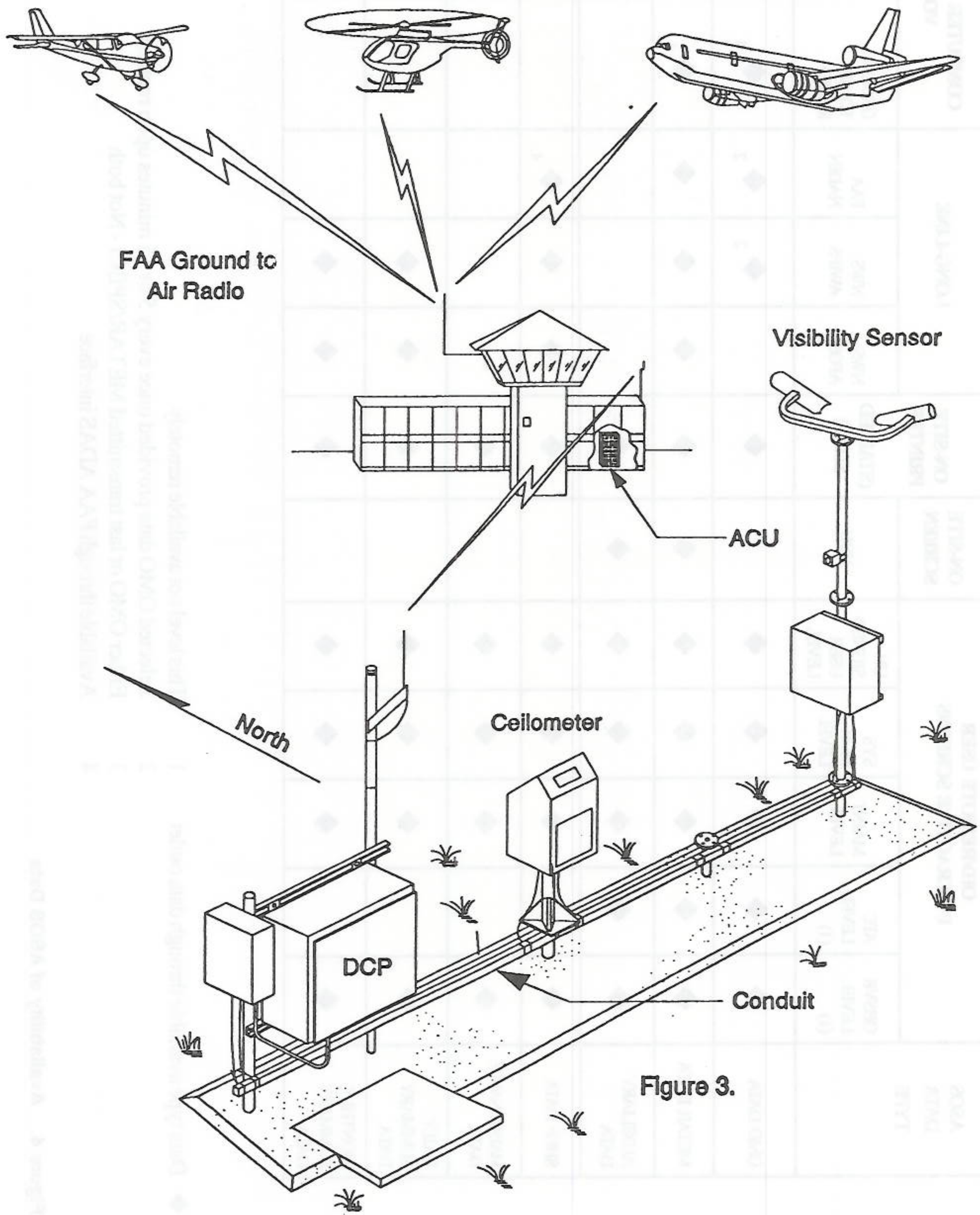


Figure 3.

Combined Sensor Group

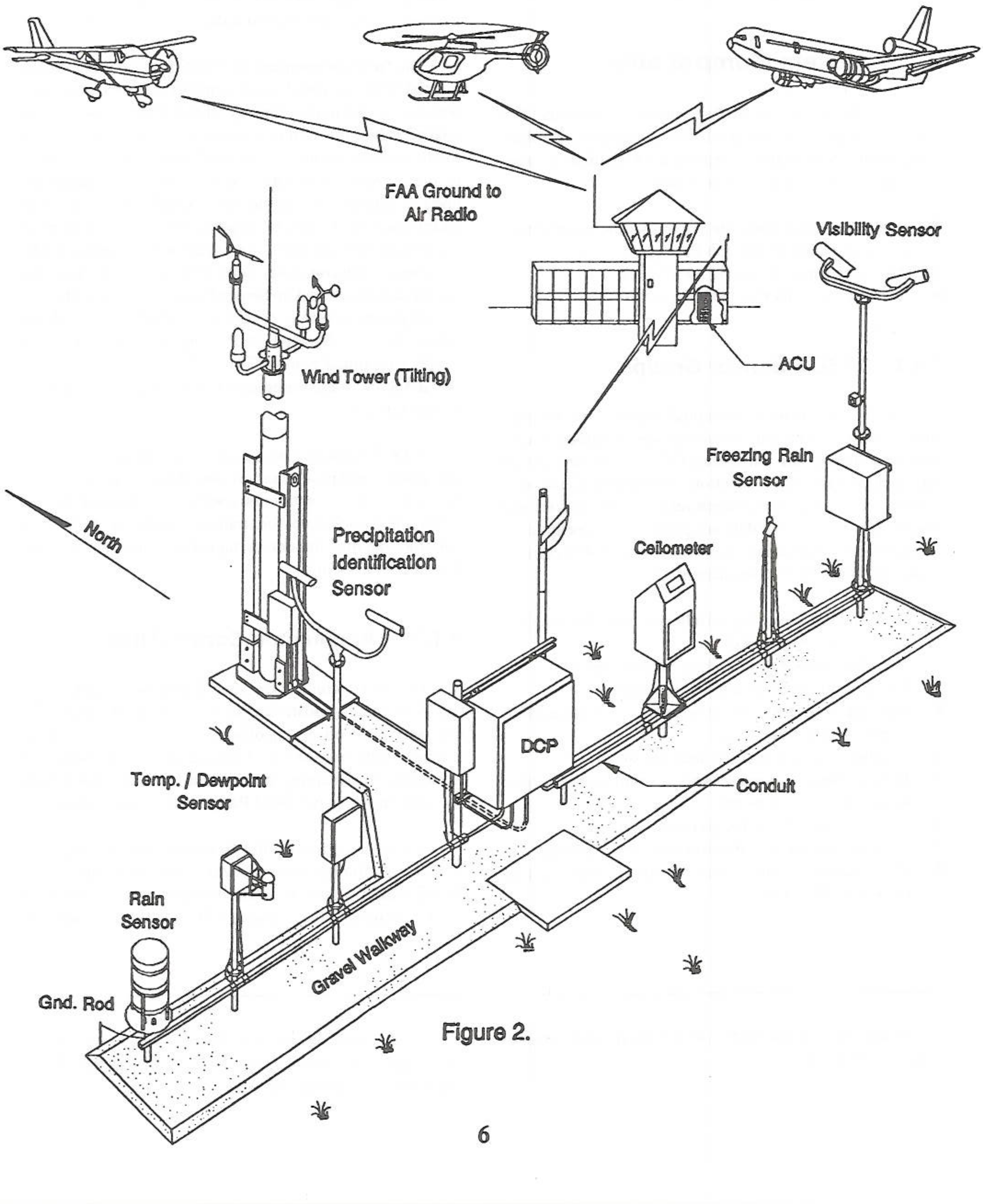


Figure 2.

U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: RECOMMENDED STANDARD TRAFFIC PATTERNS AND PRACTICES FOR AERONAUTICAL OPERATIONS AT AIRPORTS WITHOUT OPERATING CONTROL TOWERS

Date: 8/26/93
Initiated by: ATP-230
AC No. 90-66A

1. PURPOSE.

This advisory circular (AC) calls attention to regulatory requirements and recommended procedures for aeronautical operations at airports without operating control towers. It recommends traffic patterns and operational procedures for aircraft, lighter than air, glider, parachute, rotorcraft, and ultralight vehicle operations where such use is not in conflict with existing procedures in effect at those airports.

2. CANCELLATION.

AC 90-66, Recommended Standard Traffic Patterns for Airplane Operations at Uncontrolled Airports, dated February 27, 1975, is cancelled.

3. PRINCIPAL CHANGES.

This AC has been updated to reflect current procedures at airports without operating control towers. Principal changes include: adding on "Other Traffic Pattern" section, amending appendix charts to remain consistent with the Airman's Information Manual (AIM), expanding the "Related Reading Material" section from "airplane" to "aeronautical" operations, adding definition and references to Common Traffic Advisory Frequency (CTAF), acknowledging straight-in approaches are not prohibited but may be operationally advantageous, and adding a paragraph on wake turbulence.

4. DEFINITIONS.

a. Airports Without Operating Control Towers. Airports without control towers or an airport with a control tower which is not operating. These airports are commonly referred to as non-towered, uncontrolled, or part-time towered airports.

b. Common Traffic Advisory Frequency (CTAF). A frequency designed for the purpose of carrying out airport advisory practices while operating to or from an airport without an operating control tower. The CTAF may be a UNICOM, MULTICOM, flight service station, or tower frequency and is identified in appropriate aeronautical publications.

5. RELATED READING MATERIAL.

a. Airport/Facility Directory (AFD).

b. Airman's Information Manual (AIM).

c. Fly Neighborly Guide, Helicopter Association International.

d. Aviation USA, Aircraft Owners and Pilots Association (AOPA).

e. State aviation publications.

f. Various pilot guides.

g. Pilot Operations at Nontowered Airports, AOPA Air Safety Foundation pamphlet.

h. Guidelines for the Operation of Ultralight Vehicles at Existing Airports, United States Ultralight Association.

i. Facts for Pilots, United States Parachute Association.

j. The latest addition of the following AC's also contain information applicable to operations at airports without operating control towers:

(1) AC 90-23, Aircraft Wake Turbulence.

(2) AC 90-42, Traffic Advisory Practices at Airports Without Operating Control Towers.

(3) AC 90-48, Pilot's Role in Collision Avoidance.

(4) AC 91-32, Safety In and Around Helicopters.

(5) AC 103-6, Ultralight Vehicle Operations-Airports, Air Traffic Control, and Weather.

(6) AC 105-2, Sport Parachute Jumping.

6. BACKGROUND AND SCOPE.

a. Regulatory provisions relating to traffic patterns are found in Parts 91, 93, and 97 of the Federal Aviation Regulations (FAR). The airport traffic patterns contained in Part 93 relate primarily to those airports where there is a need for unique traffic pattern procedures not provided for in Part 91. Part 97 addresses instrument approach procedures. At airports without operating control towers, Part 91 requires only that pilots of airplanes approaching to land make all turns to the left unless light signals or visual markings indicate that turns should be made to the right.

b. The Federal Aviation Administration (FAA) believes that observance of a standard traffic pattern and the use of CTAF procedures as detailed in AC 90-42 will improve the safety and efficiency of aeronautical operations at airports without operating control towers.

7. GENERAL OPERATING PRACTICES.

a. Use of standard traffic patterns for all aircraft and CTAF procedures by radio-equipped aircraft are recommended at all airports without operating control towers. However, it is recognized that other traffic patterns may already be in common use at some airports or that special circumstances or conditions exist that may prevent use of the standard traffic pattern.

b. The use of any traffic pattern procedure does not alter the responsibility of each pilot to see and avoid other aircraft. Pilots are encouraged to participate in "Operation Lights On," which is a voluntary pilot safety program described in the AIM designed to enhance the "see-and-avoid" requirement.

c. As part of the preflight familiarization with all available information concerning a flight, each pilot should review all appropriate publications (AFD, AIM, Notices to Airmen (NOTAM), etc.), for pertinent information on current traffic patterns at the departure and arrival airports.

d. It is recommended that pilots utilize visual indicators, such as the segmented circle, wind direction indicator, landing direction indicator, and traffic pattern indicators which provide traffic pattern information.

e. The FAA encourages pilots to use the standard traffic pattern. However, for those pilots who choose to execute a straight-in approach, maneuvering for and execution of the approach should be completed so as not to disrupt the flow of arriving and departing traffic. Therefore, pilots operating in the traffic pattern should be alert at all times to aircraft executing straight-in approaches.

f. Pilots who wish to conduct instrument approaches should be particularly alert for other aircraft in the pattern so as to avoid interrupting the flow of traffic. Position reports on the CTAF should include distance and direction from the airport, as well as the pilot's intentions upon completion of the approach.

g. Pilots of inbound nonradio-equipped aircraft should determine the runway in use prior to entering the traffic pattern by observing the landing direction indicator or by other means. Pilots should be aware that procedures at airports without operating control towers generally do not require the use of two-way radios; therefore, pilots should be especially vigilant for other aircraft while operating in the traffic pattern.

h. Wake turbulence is generated by all aircraft. Therefore, pilots should expect to encounter turbulence while operating in a traffic pattern and in proximity to other aircraft. Aircraft components and equipment can be damaged by wake turbulence. In flight, avoid the area below and behind the aircraft generating turbulence especially at low altitude where even a momentary wake encounter can be hazardous. All operators should be aware of the potential adverse effects that their wake, rotor or propeller turbulence has on light aircraft and ultralight vehicles.

8. RECOMMENDED STANDARD TRAFFIC PATTERN.

Airport owners and operators, in coordination with the FAA, are responsible for establishing traffic patterns. However, the FAA encourages airport owners and operators to establish traffic patterns as recommended in this AC. Further, left traffic patterns should be established except where obstacles, terrain, and noise-sensitive areas dictate otherwise. Appendix 1 contains diagrams for recommended standard traffic patterns.

a. Prior to entering the traffic pattern at an airport without an operating control tower, aircraft should avoid the flow of traffic until established on the entry leg. For example, wind and landing direction indicators can be checked while at an altitude above the traffic pattern. When the proper traffic pattern direction has been determined, the pilot should then proceed to a point well clear of the pattern before descending to the pattern altitude.

b. Arriving aircraft should be at the appropriate traffic pattern altitude before entering the traffic pattern. Entry to the downwind leg should be at a 45-degree angle abeam the midpoint of the runway.

c. It is recommended that airplanes observe a 1000-foot above ground level (AGL) traffic pattern altitude. Large and turbine-powered airplanes should enter the traffic pattern at an altitude of 1,500 feet AGL or 500 feet above the established pattern altitude. A pilot may vary the size of the traffic pattern depending on the aircraft's performance characteristics.

d. The traffic pattern altitude should be maintained until the aircraft is at least abeam the approach end of the landing runway on the downwind leg.

e. The base leg turn should commence when the aircraft is at a point approximately 45 degrees relative bearing from the runway threshold.

f. Landing and takeoff should be accomplished on the operating runway most nearly aligned into the wind. However, if a secondary runway is used, pilots using the secondary runway should avoid the flow of traffic to the runway most nearly aligned into the wind.

g. Airplanes on takeoff should continue straight ahead until beyond the departure end of the runway. Aircraft executing a go-around maneuver should continue straight ahead, beyond the departure end of the runway, with the pilot maintaining awareness of other traffic so as not to conflict with those established in the pattern. In cases where a go-around was caused by an aircraft on the runway, maneuvering parallel to the runway may be required to maintain visual contact with the conflicting aircraft.

h. Airplanes remaining in the traffic pattern should not commence a turn to the crosswind leg until beyond the departure end of the runway and within 300 feet below traffic pattern altitude, with the pilot ensuring that the turn to downwind leg will be made at the traffic pattern altitude.

i. When departing the traffic pattern, airplanes should continue straight out or exit with a 45-degree left turn (right turn for right traffic pattern) beyond the departure end of the runway after reaching pattern altitude. Pilots need to be aware of any traffic entering the traffic pattern prior to commencing a turn.

j. Airplanes should not be operated in the traffic pattern at an indicated airspeed of more than 200 knots (230 mph).

k. Throughout the traffic pattern, right-of-way rules apply as stated in FAR Part 91.113. Any aircraft in distress has the right-of-way over all other aircraft. In addition, when converging aircraft are of different categories, a balloon has the right-of-way over any other category of aircraft; a glider has the right-of-way over an airship, airplane, or rotorcraft; and an airship has the right-of-way over an airplane or rotorcraft.

9. OTHER TRAFFIC PATTERNS.

Airport operators routinely establish local procedures for the operation of gliders, parachutists, lighter than air aircraft, helicopters, and ultralight vehicles. Appendices 2 and 3 illustrate these operations as they relate to recommended standard traffic patterns.

a. Rotorcraft.

(1) In the case of a helicopter approaching to land, the pilot must avoid the flow of fixed-wing aircraft and land on a marked helipad or suitable clear area. Pilots should be aware that at some airports, the only suitable landing area is the runway.

(2) All pilots should be aware that rotorcraft may fly slower and approach at steeper angles than airplanes. Air taxi is the preferred method for helicopter ground movements which enables the pilot to proceed at an optimum airspeed, minimize downwash effect, and conserve fuel. However, flight over aircraft, vehicles, and personnel should be avoided.

(3) In the case of a gyrocopter approaching to land, the pilot should avoid the flow of fixed-wing aircraft until turning final for the active runway.

(4) A helicopter operating in the traffic pattern may fly a pattern similar to the airplane pattern at a lower altitude (500 AGL) and closer to the airport. This pattern may be on the opposite side of the runway with turns in the opposite direction if local policy permits.

(5) Both classes of rotorcraft can be expected to practice power-off landing (autorotation) which will involve a very steep angle of approach and high rate of descent (1,500-2,000 feet/minute).

b. Gliders.

(1) A glider, including the tow aircraft during towing operations, has the right-of-way over powered aircraft.

(2) If the same runway is used by both airplanes and gliders, the glider traffic pattern will be inside the pattern of engine driven aircraft. If a "Glider Operating Area" is established to one side of a powered-aircraft runway, the glider pattern will normally be on the side of the airport closest to the "Glider Operating Area." This will allow gliders to fly the same direction traffic pattern as powered aircraft in one wind condition and necessitate a separate opposing direction traffic

pattern in the opposite wind condition. (See examples in Appendix 2, Glider Operations).

(3) Typically, glider traffic patterns have entry points (initial points) from 600 to 1,000 feet AGL.

c. Ultralight Vehicles.

(1) In accordance with FAR Part 103, ultralight vehicles are required to yield the right–of–way to all aircraft.

(2) Ultralight vehicles should fly the rectangular pattern as described in Appendix 2. Pattern altitude should be 500 feet below and inside the standard pattern altitude established for the airport. An ultralight pattern with its own dedicated landing area will typically have a lower traffic pattern parallel to the standard pattern with turns in the opposite direction.

(3) All pilots should be aware that ultralights will fly significantly slower than airplanes. In addition, ultralights may also exhibit very steep takeoff and approach angles. Turns may be executed near the end of the runway in order to clear the area expediently.

d. Lighter Than Air Aircraft.

(1) A balloon has the right–of–way over any other category of aircraft and does not follow a standard traffic pattern.

(2) Due to limited maneuverability, airships do not normally fly a standard traffic pattern. However, if a standard traffic pattern is flown, it will be at an airspeed below most other aircraft.

e. Parachute Operations.

(1) All activities are normally conducted under a NOTAM noting the location, altitudes, and time or duration of jump operations. The Airport/Facility Directory lists airports where permanent drop zones are located.

(2) Jumpers normally exit the aircraft either above, or well upwind of, the airport and at altitudes well above traffic pattern altitude. Parachutes are normally deployed between 2,000 feet and 5,000 feet AGL and can be expected to be below 3,000 feet AGL within 2 miles of the airport.

(3) Pilots of jump aircraft are required by Part 105 to establish two–way radio communications with the air traffic control facility or Flight Service Station which has jurisdiction over the affected airspace prior to jump operations for the purpose of receiving information in the aircraft about known air traffic in the vicinity. In addition, when jump aircraft are operating at or in the vicinity of an airport, pilots are also encouraged to provide advisory information on the CTAF, i.e., "Chambersburg traffic, jumpers away over Chambersburg.

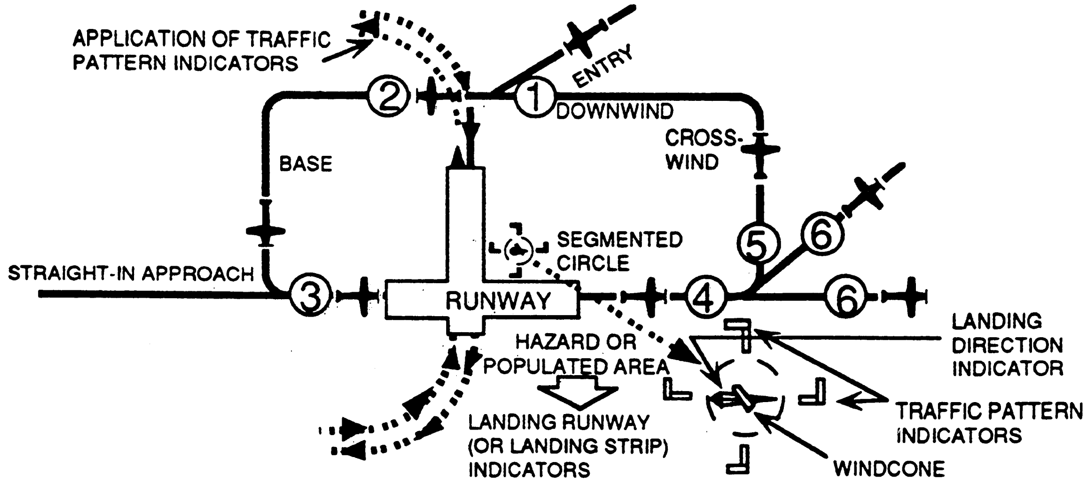
(4) When a drop zone has been established on an airport, parachutists are expected to land within the drop zone. At airports that have not established drop zones, parachutists should avoid landing on runways, taxiways, aprons, and their associated safety areas. Pilots and parachutists should both be aware of the limited flight performance of parachutes and take steps to avoid any potential conflicts between aircraft and parachute operations.

(5) Appendix 3 diagrams operations conducted by parachutists.

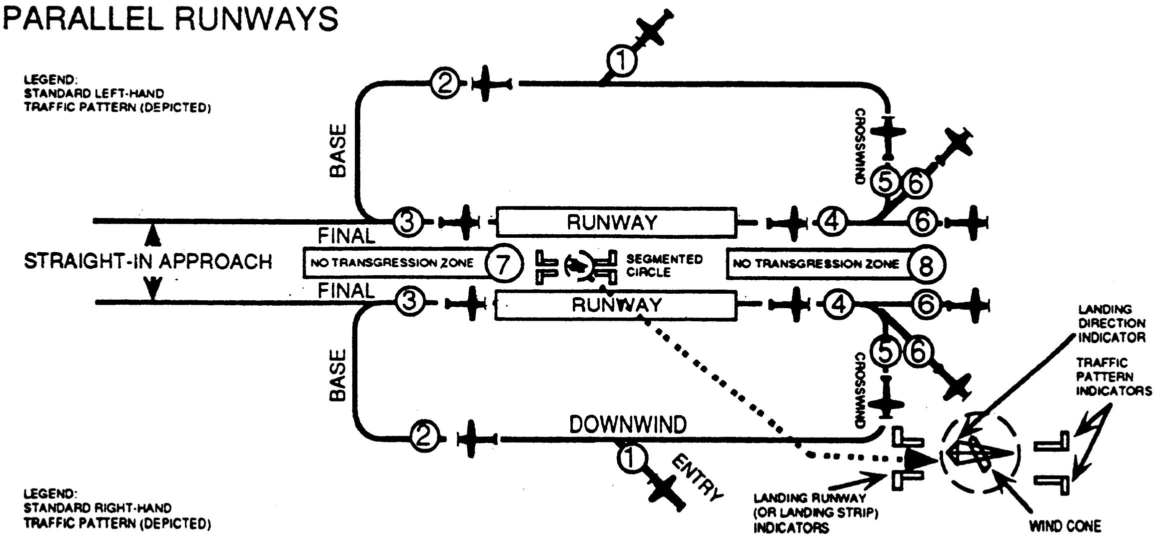
Harold W. Becker
Acting Director, Air Traffic
Rules and Procedures Service

AIRPORT OPERATIONS

SINGLE RUNWAY

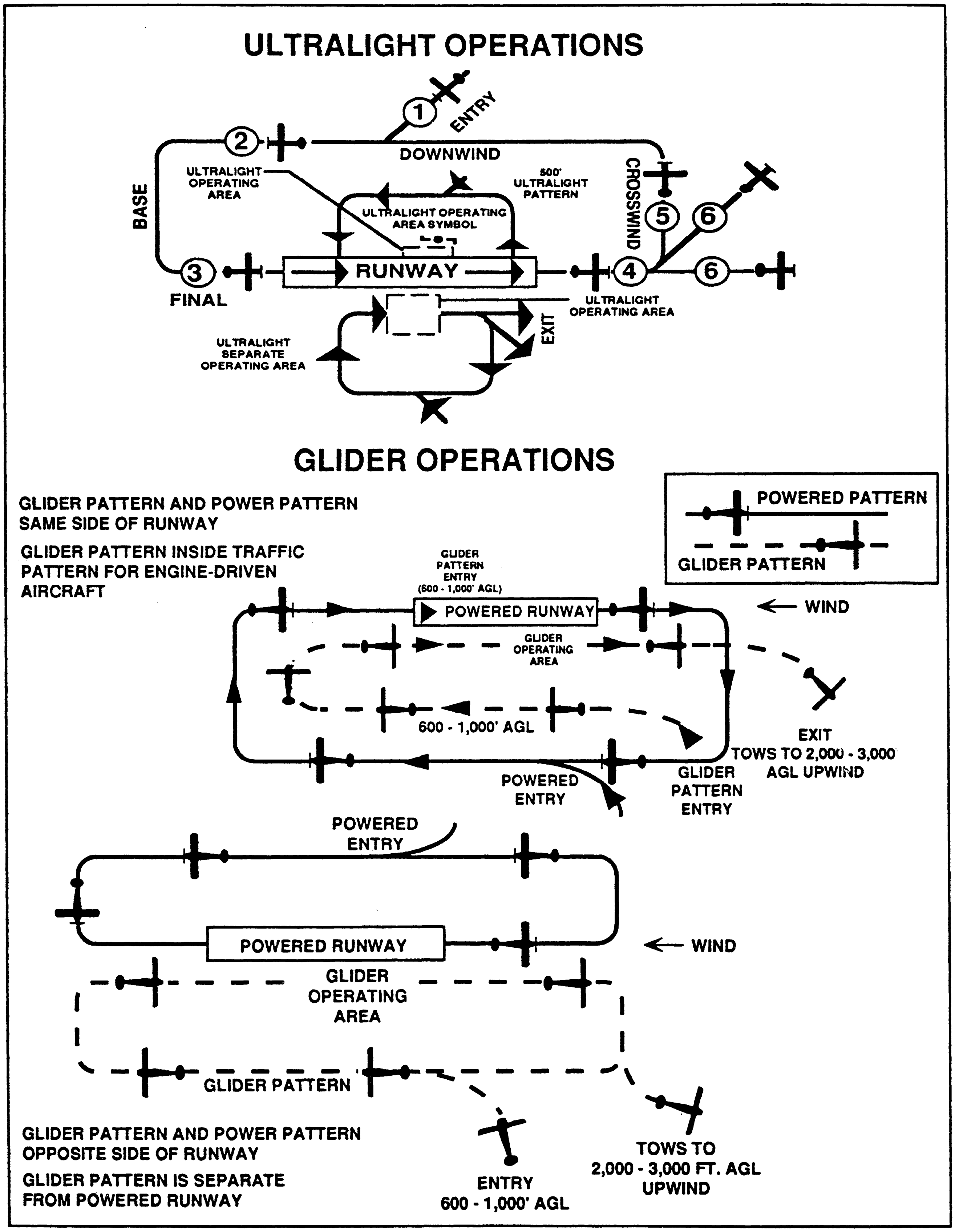


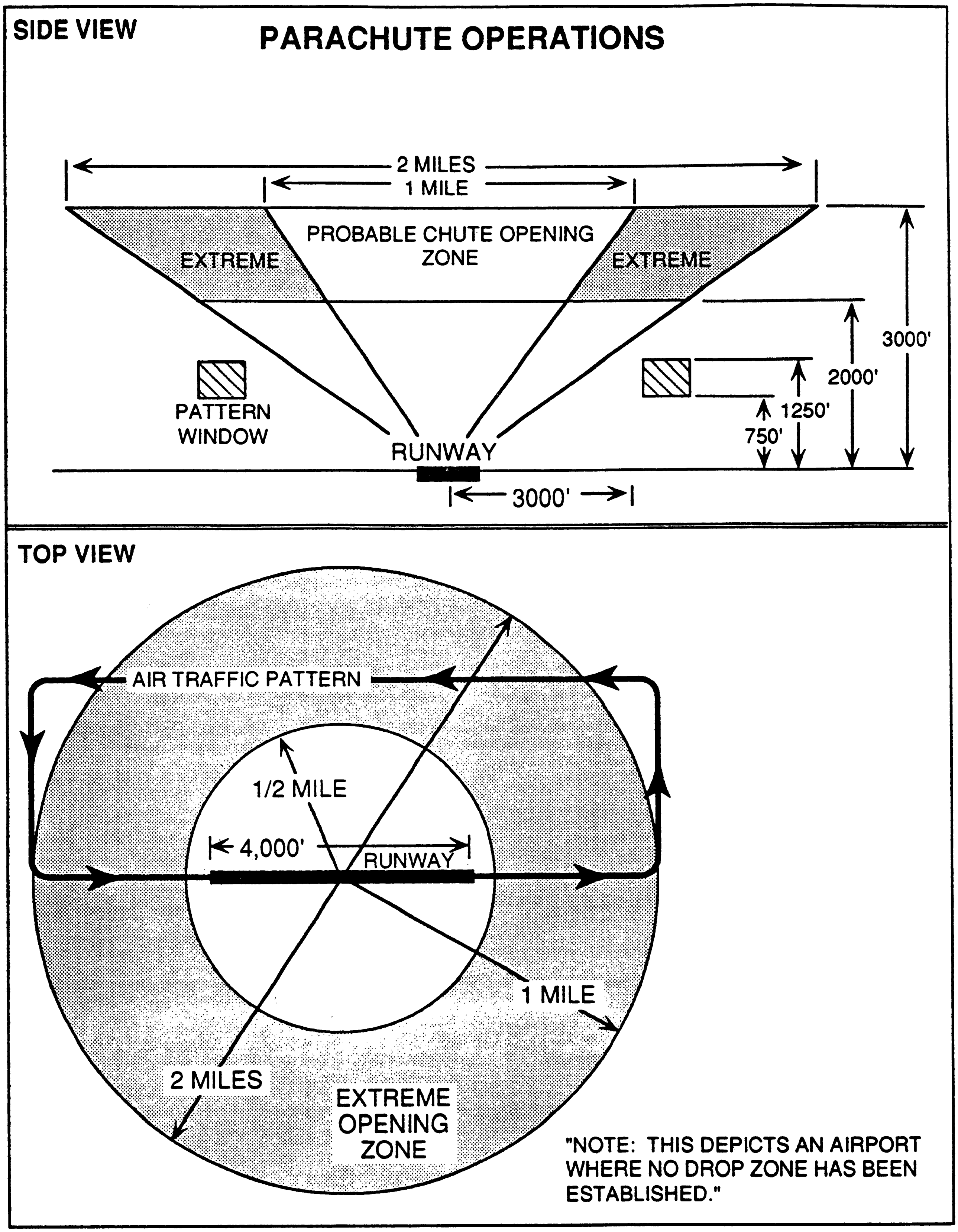
PARALLEL RUNWAYS



KEY

1. Enter pattern in level flight, abeam the midpoint of the runway, at pattern altitude. (1000' AGL is recommended pattern altitude unless established otherwise).
2. Maintain pattern altitude until abeam approach end of the landing runway, or downwind leg.
3. Complete turn to final at least 1/4 mile from the runway.
4. Continue straight ahead until beyond departure end of runway.
5. If remaining in the traffic pattern, commence turn to crosswind leg beyond the departure end of the runway, within 300 feet of pattern altitude.
6. If departing the traffic pattern, continue straight out, or exit with a 45º left turn beyond the departure end of the runway, after reaching pattern altitude.
7. Do not overshoot final or continue on a track which will penetrate the final approach of the parallel runway.
8. Do not continue on a track which will penetrate the departure path of the parallel runway.


ULTRALIGHT OPERATIONS
1
ENTRY
2
DOWNWIND
BASE
ULTRALIGHT OPERATING AREA
500' ULTRALIGHT PATTERN
CROSSWIND
ULTRALIGHT OPERATING AREA SYMBOL
5
6
3
RUNWAY
4
6
FINAL
ULTRALIGHT OPERATING AREA
EXIT
ULTRALIGHT SEPARATE OPERATING AREA
GLIDER OPERATIONS
GLIDER PATTERN AND POWER PATTERN SAME SIDE OF RUNWAY
GLIDER PATTERN INSIDE TRAFFIC PATTERN FOR ENGINE-DRIVEN AIRCRAFT
POWERED PATTERN
GLIDER PATTERN
GLIDER PATTERN ENTRY (600 - 1,000' AGL)
POWERED RUNWAY
WIND
GLIDER OPERATING AREA
600 - 1,000' AGL
EXIT
TOWS TO 2,000 - 3,000' AGL UPWIND
POWERED ENTRY
GLIDER PATTERN ENTRY
POWERED ENTRY
POWERED RUNWAY
WIND
GLIDER OPERATING AREA
GLIDER PATTERN
GLIDER PATTERN AND POWER PATTERN OPPOSITE SIDE OF RUNWAY
GLIDER PATTERN IS SEPARATE FROM POWERED RUNWAY
ENTRY 600 - 1,000' AGL
TOWS TO 2,000 - 3,000 FT. AGL UPWIND



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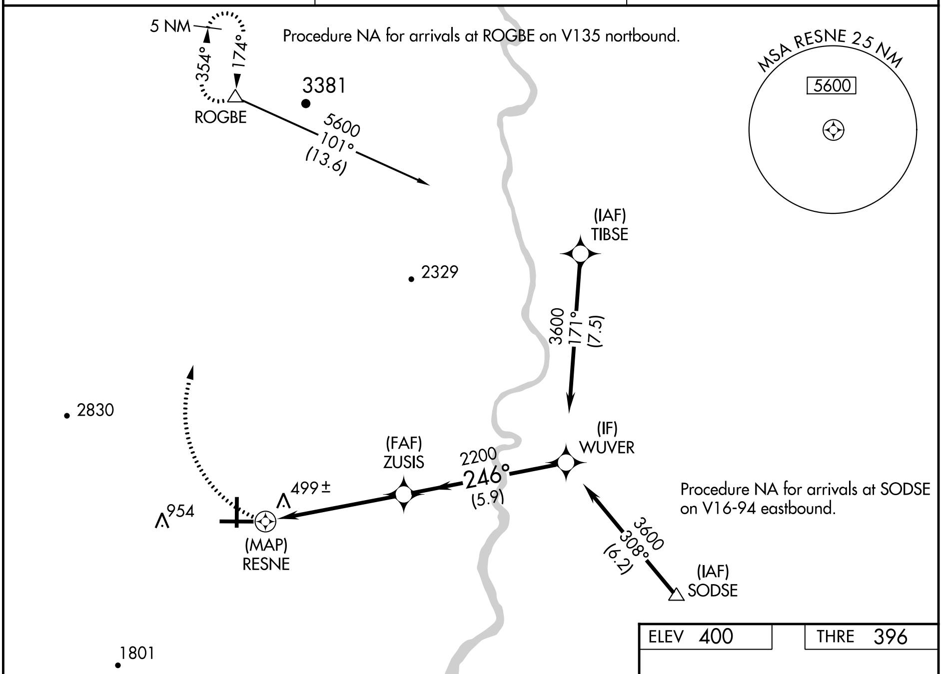
RNAV (GPS) RWY 26
BLYTHE (BLH)

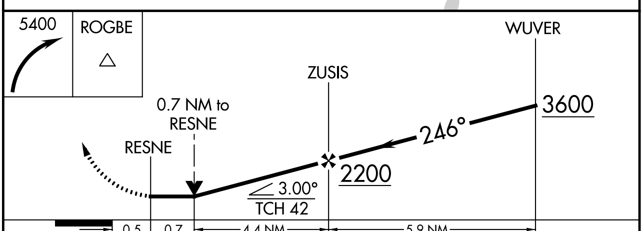
WAAS	APP CRS	
CH **45626** **W26A**	**246°**	Rwy ldg **6543** THRE **396** Apt Elev **400**

▼ **Missed approach requires a minimum climb of 375 feet per NM to 3500.
Ⓐ *Missed approach requires a minimum climb of 345 feet per NM to 3500.
When local altimeter setting not received, procedure NA.
DME/DME RNP-0.3 NA. Visibility reduction by helicopters NA.

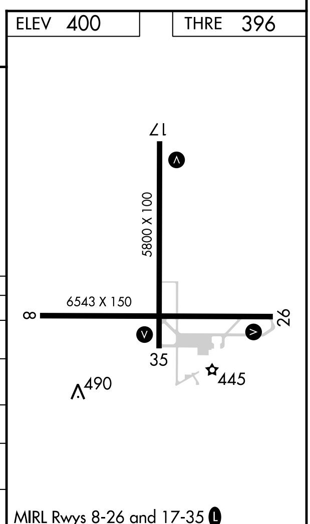
MISSED APPROACH: Climbing right turn to 5400 direct ROGBE and hold, continue climb-in-hold to 5400.

ASOS	LOS ANGELES CENTER	UNICOM
120.175	**128.15 285.6**	**122.8** (CTAF) Ⓛ





CATEGORY	A	B	C	D
*LP MDA	800-1 404 (400-1)		800-1⅛ 404 (400-1⅛)	
LP MDA	1940-1¼ 1544 (1600-1¼)	1940-1½ 1544 (1600-1½)	1940-3 1544 (1600-3)	
**LNAV MDA	800-1 404 (400-1)		800-1⅛ 404 (400-1⅛)	
LNAV MDA	2060-1¼ 1664 (1700-1¼)	2060-1½ 1664 (1700-1½)	2060-3 1664 (1700-3)	
CIRCLING	2060-1¼ 1660 (1700-1¼)	2060-1½ 1660 (1700-1½)	2060-3 1660 (1700-3)	



SW-3, 04 FEB 2016 to 03 MAR 2016

SW-3, 04 FEB 2016 to 03 MAR 2016

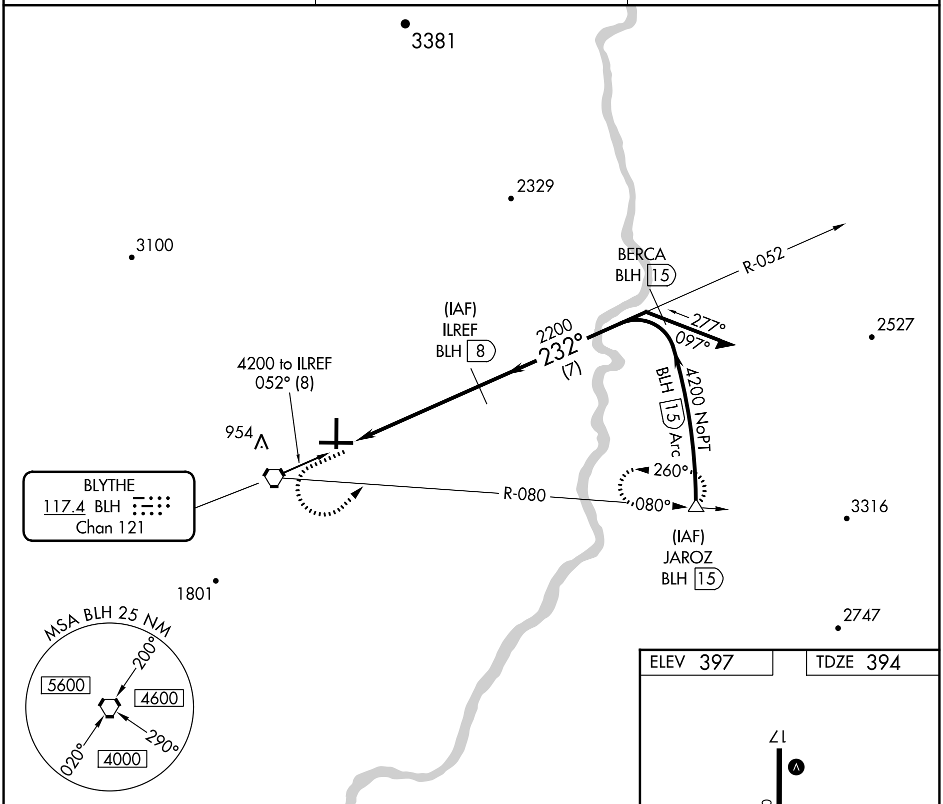
ATTACHMENT G

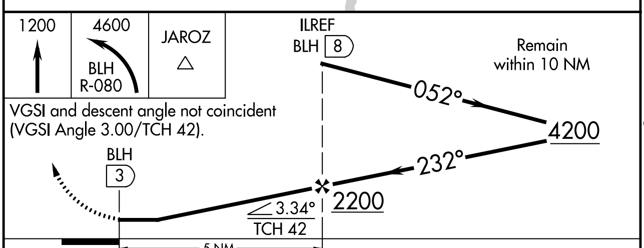
VOR/DME RWY 26
BLYTHE (BLH)

VORTAC BLH	APP CRS	Rwy ldg	6543
117.4 Chan **121**	**232°**	TDZE	**394**
		Apt Elev	**397**

MISSED APPROACH: Climb to 1200 then climbing left turn to 4600 via BLH VORTAC R-080 to JAROZ/15 DME and hold.

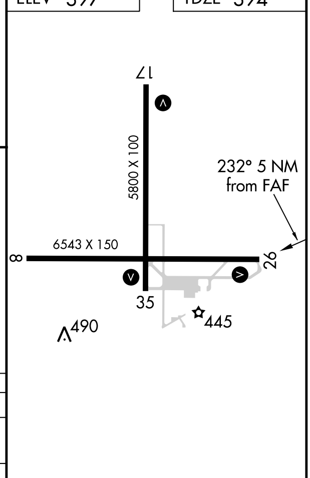
ASOS	LOS ANGELES CENTER	UNICOM
120.175	**128.15 285.6**	**122.8** (CTAF) L





CATEGORY	A	B	C	D
S-26	760-1 366 (400-1)			760-1¼ 366 (400-1¼)
CIRCLING	840-1 443 (500-1)	860-1 463 (500-1)	960-1½ 563 (600-1½)	1260-2¾ 863 (900-2¾)

ELEV 397 TDZE 394



MIRL Rwys 8-26 and 17-35 L

SW-3, 04 FEB 2016 to 03 MAR 2016