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To: Oregon Energy Facility Siting Council

From: Sarah Esterson, Senior Siting Analyst

Date: October 18, 2018

Subject: Agenda Item B (Action Item) - Golden Hills Wind Project – Supplemental Staff Report for Council Review of Request for Contested Case on Proposed Order on Request for Amendment 5 for the October 25-26, 2018 EFSC Meeting

Attachments: Attachment 1: Request for Contested Case (Ms. Gilbert/Friends of Grande Ronde Valley)
Attachment 2: Comments on Draft Proposed Order (Ms. Gilbert/Friends of Grande Ronde Valley)

Introduction

In preparation for the October 25-26, 2018 Energy Facility Siting Council (Council) meeting, the Oregon Department of Energy (Department) provided a staff report to Council on October 12, 2018 for Agenda Item B, Council Review of the Proposed Order on the Golden Hills Wind Project Request for Amendment 5 of the Site Certificate (proposed order). Agenda Item B includes two potential Council decisions: the first decision is whether to grant or deny a contested case proceeding on the proposed order; and if a contested case proceeding is not granted, the second decision is whether to approve, amend or deny the proposed order. The deadline for submittal of contested case requests occurred on the same date the staff report was provided to Council. Therefore, a supplemental staff report is provided to support Council's review of requests for contested case received by the deadline.

Council Scope of Review on Contested Case Proceeding Requests for Site Certificate Amendments

One request for a contested case proceeding on the proposed order was timely filed with the Department by the October 12, 2018 deadline. The request was received from Ms. Irene Gilbert, as an individual and on behalf of Friends of the Grande Ronde Valley (FGRV). The following evaluation presents the Department's recommendations to Council on: 1) whether the request satisfies the requirements for requesting a contested case proceeding; 2) whether the issues were properly raised on the record of the draft proposed order public hearing; and 3) whether each of the issues identified in the request justifies a contested case proceeding.

Evaluation of Request for Contested Case

Individuals eligible to participate in a contested case proceeding must submit to the Department a request, by a specified deadline, that contains responses to the information requirements of OAR 345-027-0071(6)(a) – (j).

Evaluation of Whether Issue Was Properly Raised

Pursuant to OAR 345-027-0071(5), in order to be eligible to request a contested case proceeding on the proposed order, a person must have properly raised the issue. To properly raise an issue, the person must have:

(1) Commented either in writing or in person on the record of the draft proposed order public hearing, from July 13 through August 23, 2018;
(2) Raised the issue with sufficient specificity to afford the Council an adequate opportunity to respond; and,
(3) Raised an issue that is within the jurisdiction of the Council.

For reference, the Department provides additional description for the Council's review of the eligibility requirements listed above.

Sufficient Specificity

For an issue to have been raised with sufficient specificity, the individual must have presented facts on the record of the draft proposed order public hearing that support the individual's position on the issue (OAR 345-027-0067(3)(e)(F)). It is not sufficient for an individual to refer to one of Council's standards and make generalized assertions that a standard has not been met.

Jurisdiction

An issue is outside of Council jurisdiction if it has no authority to render a decision on the issue. In general, Council has jurisdiction to determine whether the facility, with proposed changes, meets a Council standard and all other applicable state statutes and rules.

Evaluation of Whether Request Raises Significant Issue of Law or Fact

OAR 345-027-0071(9) contains the standard of review for contested case requests for site certificate amendments. It states:

> "To determine that an issue justifies a contested case proceeding, the Council must find that the request raises a significant issue of fact or law that may affect the Council's determination that the facility, with the change proposed by the amendment, meets the applicable laws and standards included in chapter 345 divisions 22, 23 and 24."

Therefore, simply raising a significant issue of law or fact is not sufficient to justify a contested case. The significant issue of law or fact must have some connection to the Council's determination whether the facility, which in this case is the Golden Hills Wind Project, with proposed changes, meets applicable laws and Council standards.

OAR 345-027-0071(10) gives the Council three options for action on a contested case request:

> **Option 1**: Under OAR 345-027-0071(10)(a), if the Council finds that an issue justifies a contested case under the criteria quoted above, the Council can decide to conduct a contested case proceeding. The contested case proceeding would be limited to the issues that the Council found sufficient to justify the proceeding.
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> **Option 2:** Under OAR 345-027-0071(10)(b), if the Council finds that the request identifies one or more properly raised issues that an amendment to the proposed order, including modification to conditions, would settle in a manner satisfactory to the Council, the Council may deny the request as to those issues and direct the Department to amend the proposed order and send a notice of the amended proposed order to the persons described in OAR 345-027-0071(4).
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> **Option 3:** Under OAR 345-027-0071(10)(c), if the Council finds that an issue does not justify a contested case under the criteria quoted above, the Council can deny the contested case request. The Council would issue a written order specifying the basis for the decision. The Council would then have the further option to adopt, modify or reject the proposed order on the amendment request.

Department Evaluation of Request for Contested Case

Ms. Gilbert/FGRV provided written comments and oral testimony on August 23, 2018 on the record of the draft proposed order. In these comments, Ms. Gilbert/FGRV raised 9 issues. In her request for a contested case proceeding (request) received on October 12, 2018, provided as Attachment 1, she includes 6 issues which she represents to be of the 9 issues raised in her August 23, 2018 comments, provided as Attachment 2. Based on review, the Department recommends Council consider the request filed to satisfy the informational requirements of OAR 345-027-0071(6). To the extent that the request modifies issues from those raised on the record of the draft proposed order, and when the modification is not related to a material change presented in the proposed order, the Department recommends Council not allow or consider such changes. Pursuant to OAR 345-027-0071(5), if the action recommended in the proposed order differs materially from the draft proposed order, including any recommended conditions of approval, persons eligible to request a contested case may raise new issues within the jurisdiction of the Council that are related to such differences.

To the extent that the request provides additional documentation in support of issues, the Department recommends Council not allow or consider such information. Information intended to be considered in support of comments and issues should be provided on the record of the draft proposed order public hearing. The record of the draft proposed order closed on August 23, 2018 and a request to extend the comment period was not received.

The analysis presented below includes the Department's evaluation of whether the issue was properly raised and whether the issue justifies a contested case.

Irene Gilbert Issue 1

> "*The developer must be required to do pre-construction documentation of wells on non-participating landowner's property adjacent to the wind development. The wells need to be monitored during construction and operation of the wind development to assure the development has not resulted in changes including reduced capacity, sedimentation or toxic substances in the water in the area of the wind development."**
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> **Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.*

<u>Recommendation: Council find core issue was properly raised on the record; modifications included in the request for Issue 1 should not be considered</u>

After reviewing Ms. Gilbert's written and oral comments, the Department agrees that Ms. Gilbert's Issue 1 was provided in a comment on the record of the draft proposed order (Comment 1). Ms. Gilbert's Comment 1 identified ORS 469.501(g) and (k) and the Public Services standard

(OAR 345-022-0110) and expressed a concern related to potential drinking water impacts from groundwater contamination from operational vibration from wind turbines. Therefore, the Department recommends Council find that because the issue was raised on the record of the draft proposed order with sufficient specificity and is within Council's jurisdiction, Issue 1 was properly raised.

In her request for Issue 1, in response to the OAR 345-027-0071(6)(d) requirement to provide a statement describing why Council should determine that the issue justifies a contested case, Ms. Gilbert modifies the issue as raised on the record of the draft proposed order and refers to and provides four additional documents. Modifications include referencing additional standards for which the issue applies (Structural Standard, and Soil Protection standard), and incorporates into the issue a concern of potential impacts to public water wells and soils from wind turbine size and weight; and a potential concern to groundwater from the facility's well. As noted above, the Department recommends Council not allow the request to modify the issue, unless based on a material change presented in the proposed order, or introduce new substantive information not previously provided on the record of the draft proposed order, as the appropriate opportunity for introduction of new information occurs during a comment period.

Recommendation: Council find that Issue 1 does not raise a significant issue of fact or law that may affect the Council's determination

In Issue 1 of the request, as raised in Comment 1 on the record of the draft proposed order, Ms. Gilbert expressed a concern of potential water quality impacts to adjacent non-participating landowner wells from operational vibration from wind turbines. Based on the potential impacts, and in order to find compliance with ORS 469.501(g) and (k) and the Public Services standard, Ms. Gilbert requested that Council require the certificate holder to conduct a pre-construction inventory of adjacent non-participating landowner wells, including well depth and quality, and then to conduct water quality testing and monitoring of identified wells during both construction and operation to assure adjacent non-participating landowners wells are not impacted by wind turbine construction and operation and contain safe drinking water.

This issue, as raised in Comment 1 on record of the draft proposed order, is addressed in Section III.M. Public Services of the proposed order, which Ms. Gilbert acknowledges in her request. In this section, the Department provides two recommendations for Council.

First, the Department recommends that Council consider the information relied upon in support of concerns related to groundwater impacts from wind turbine vibration to be editorial, specifically related to a wind project in Ontario, Canada; and, therefore, not representative of factual information relevant to the facility or the amendment request.[1] However, as noted in the

[1] In her August 23, 2018 comments on the record of the draft proposed order, Ms. Gilbert relies upon the following media sources to support concerns regarding potential impacts to groundwater from wind turbine vibration:

proposed order, the Department considers the information cited from the Wind Energy Siting Handbook, American Wind Energy Association, describing potential water quality impacts from aquifer collapse and compaction from construction-related blasting and contamination from blasting material type, such as perchlorate, to be reasonably factual. Therefore, the Department evaluated the sufficiency of previously imposed conditions to reduce potential groundwater impacts from blasting, which the certificate holder is authorized. Council previously imposed conditions under the Structural Standard, specifically Condition PRE-SS-02 (V.A.4) requiring the certificate holder to design, engineer and construct the facility to avoid dangers to human safety presented by non-seismic hazards (e.g. landslides, erosion, flooding and settlement). If the certificate holder utilizes blasting as a construction technique, compliance with Condition PRE-SS-02 (V.A.4) and PRE-SS-01 (V.A.1), as described in Section III.C. Structural Standard of the proposed order, would minimize the likelihood of potential groundwater impacts by minimizing potential subsurface risks such as aquifer collapse.

Second, the Department recommends Council find that the Public Services standard applies to potentially significant adverse impacts to public and private providers of water service, and not individual private water wells. Therefore, the Department recommends in the proposed order that Council find documenting adjacent non-participating landowner wells and ongoing testing and monitoring of such wells is not related to the Council's Public Services standard and not needed, given the previously imposed conditions under the Structural Standard.

In her request, Ms. Gilbert acknowledges the evaluation of her comments in the proposed order but argues that private water wells should be considered under the Public Services standard because the "provider of water is a private entity which would be the company who drilled the well and the landowner who paid for it." Further, she argues that the conditions referenced by the Department do not address all of her comments, specifically risk of groundwater contamination from wind turbine vibration. As noted above, the information previously provided by Ms. Gilbert related to potential groundwater contamination from operational wind turbine vibration was considered editorial in nature and specific to a facility in Canada, and therefore considered not factual or relevant to the facility or the amendment request. Further, the Public Services standard applies to public and private providers of a service – intended to apply to services provided to members of a community, and not to an individual citizens' privately owned commodity.

For the reasons described above, the Department recommends that the Council find that Ms. Gilbert's Issue 1 does not raise a significant issue of fact or law that may affect the Council's determination that the facility, as amended, meets an applicable standard.

"Turbines Have Negative Impact on our Drinking Water," March 27, 2018, obtained from http://glbr-sos.org; and "Wind turbines impact on groundwater to be discussed - Public Meeting planned August 10, 2016" obtained from www.wind-watch.org

Irene Gilbert Issue 2

> *"The Oregon Department of Energy and Energy Facility Siting Council failed to meet the requiremernts [sic] of OAR 345-022-0000 requiring that the evidence on the record proide [sic] a preponderance of evidence that the site complies with ORS 469.300 - 469.570 and 459.590 to 469.619 and standards adopted by the council. The communications from the tribes raise legitimate issues which result in questions regarding whether or not the development meets the above requirements. Not only were those issues not addressed by the council, but the council failed to respond to requests for information which would have resulted in a showing that the facility failed to meet standards for public safety, wildlife protections, and the provision of public services. The record currently does not show a preponderance of evidence to support the decisions that were made. On the contrary, the record shows that there are questions regarding all the issues I have requested contested cases on."**

> ***Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.***

<u>Recommendation: Council find Issue 2 was not properly raised on the record of the draft proposed order</u>

After reviewing Ms. Gilbert's written and oral comments, the Department disagrees that Ms. Gilbert's Issue 2 was provided in a comment on the record of the draft proposed order (Comment 9), as referenced in her request. Therefore, the Department recommends Council find that because the issue was not raised on the record of the draft proposed order, Issue 2 was not properly raised.

- On the record of the draft proposed order public hearing, Ms. Gilbert's oral testimony and written comments (Comment 9) expressed concern that the comment received from the Confederated Tribes of Warm Springs Reservation of Oregon (CTWS) suggests that government to government consultation is needed and had not been completed.
- In her request for a contested case proceeding, Ms. Gilbert's Issue 2 identifies Council's General Standard of Review (OAR 345-022-0000), ORS 469.300 – 469.570 and 459.590 – 469.619 and argues generally that, based upon comments received from CTWS and Confederated Tribes of Umatilla Indian Reservation (CTUIR) on the record of the draft proposed order, that there is not a preponderance of evidence on the record to meet standards for public safety, wildlife protections and provisions of public services.

The differences between Issue 2 as presented in the request and Comment 9 as provided on the record of the draft proposed order public hearing include Ms. Gilbert's reference to Council's General Standard of Review (OAR 345-022-0000) and ORS 469.300 – 469.570 and 459.590 – 469.619; and, incorporation into the issue a perceived lack of response to questions provided in

CTUIR's comments to support a statement that there is not a preponderance of evidence on the record to meet standards for public safety, wildlife protections and provisions of public services. The Department recommends Council not consider changes to the issue, as represented in Comment 9 on the record of the draft proposed order, in its evaluation of Issue 2.

This issue, as raised in Comment 9 on record of the draft proposed order, was addressed in Section III.K. Historic, Cultural and Archeological Resources of the proposed order, which Ms. Gilbert acknowledges. In the proposed order, the Department describes that CTWS commented on the proposed increase in temporary access road and crane path width and its potential impacts to historic properties and stated that if there are any changes to the site boundary, then additional identification, evaluation, and protection of historic properties or cultural resources may be necessary, including review of RFA5 under Section 106 of the National Historic Preservation Act (NHPA) (referred to as "government to government consultation").

In the proposed order, the Department noted that the amendment request under review does not includes changes to the site boundary and that the Section 106 NHPA (government to government consultation) does not apply to Council review of proposed and amended energy facilities because it is triggered by a federal nexus – a federal action. If the federal Section 106 NHPA applies, the certificate holder must comply with such requirements independent of and outside the Council review process. Council considers potential historic, cultural and archaeological impacts of facilities pursuant to state law and Council rules. Previous historic, cultural and archaeological resource surveys for the ASC and subsequent amendments did not identify Tribal resources within the site boundary, and the proposed changes in temporary access road and crane path width would not result in changes to the previously approved site boundary.

For the reasons described above, the Department recommends that the Council find that Ms. Gilbert's Issue 2 was not properly raised.

Irene Gilbert Issue 3

> "*The development poses a risk to private and commercial aircraft as it exceeds the 500 foot no fly zone.*"
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> **Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.*

<u>Recommendation: Council find core issue was properly raised on the record; modifications included in the request for Issue 3 should not be considered</u>

After reviewing Ms. Gilbert's written and oral comments, the Department agrees that Ms. Gilbert's Issue 3 was provided in a comment on the record of the draft proposed order (Comment 3). Ms. Gilbert's comment did not identify a standard, but expressed a concern related to

potential safety risks to aircraft operators from the increase in total turbine height, as proposed in Request for Amendment 5. Therefore, the Department recommends Council find that because the issue was raised on the record of the draft proposed order with sufficient specificity and is within Council's jurisdiction, Issue 3 was properly raised.

In her request for Issue 3, in response to the OAR 345-027-0071(6)(d) requirement to provide a statement describing why Council should determine that the issue justifies a contested case, Ms. Gilbert modifies the issue as raised on the record of the draft proposed order and refers to comments and a recommended condition amendment received on the record of the draft proposed order from the Oregon Department of Aviation (Aviation). The Department did not make material changes in the proposed order in response to Aviation's comments; therefore, the Department recommends Council not consider the above referenced changes to Issue 3.

Recommendation: Council find that Issue 3 does not raise a significant issue of fact or law that may affect the Council's determination.

This issue, as raised in Comment 3 on the record of the draft proposed order, was addressed in Section III.P.1 Public Health and Safety for Wind Energy Facilities of the proposed order. In her request, Ms. Gilbert does not address the evaluation of Comment 3 as presented in the proposed order, but expresses a belief that the "Determination of No Hazard" 7460-1 process (or airspace study) required for each wind turbine is not, but should be, a pre-construction requirement. As described in the proposed order, prior to construction of any wind turbine, a Determination of No Hazard from Federal Aviation Administration (FAA) and Aviation is required. As described in the proposed order, the certificate acknowledges that if a wind turbine is disallowed by FAA or Aviation following review of the airspace study, wind turbines would not be constructed in those identified locations.

For the reasons described above, the Department recommends Council find that Ms. Gilbert's Issue 3 does not raise a significant issue of fact or law that may affect the Council's determination that the facility, with proposed changes, satisfies the requirements of the Public Health and Safety for Wind Energy Facilities standard.

Irene Gilbert Issue 4

> *"The setbacks from roads and structures are not adequate to provide for the health and safety of the public as required by OAR 345-024-0010 and Land Use OAR 345-022-0030."*
>
> **Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.*

Recommendation: Council find Issue 4 was properly raised on the record; modifications included in the request should not be considered

After reviewing Ms. Gilbert's written and oral comments, the Department agrees that Ms. Gilbert's Issue 4 was provided in a comment on the record of the draft proposed order (Comment 4). Ms. Gilbert's comment identified the Public Health and Safety Standard for Wind Energy Facilities (OAR 345-024-0010), expressed a concern related to potential public health and safety risks from turbine blade or ice throw, and requested Council impose a 1,000-foot setback from wind turbines to roads and structures. Therefore, the Department recommends Council find that because the issue was raised on the record of the draft proposed order with sufficient specificity and is within Council's jurisdiction, Issue 4 was properly raised.

In her request for Issue 4, in response to the OAR 345-027-0071(6)(d) requirement to provide a statement describing why Council should determine that the issue justifies a contested case, Ms. Gilbert modifies the issue as raised on the record of the draft proposed order by relating the issue to compliance with the Council's Land Use standard (OAR 345-022-0030), raising issue with Condition PRE-LU-03 (IV.D.4), referring to and providing additional documentation in support of the issue, and recommending a new setback condition based on 1.5 times the total turbine tower height. As previously noted, the Department recommends Council not allow modification of the issue or consider new substantive information not previously provided on the record of the draft proposed order, as the appropriate opportunity for introduction of new information occurs during a comment period.

Recommendation: Council find that Issue 4 does not raise a significant issue of fact or law that may affect the Council's determination

This issue, as raised in Comment 4 on the record of the draft proposed order, requested a 1,000-foot setback from the proposed larger wind turbines to roads and structures based on a referenced study. The Department reviewed the study and affirms that it is from a reputable online database of peer-reviewed, scientific articles. In her request, Ms. Gilbert does not address the evaluation of Comment 4 as presented in the proposed order, but expresses a continued belief that setback distances from wind turbines to roads and structures are not sufficient to provide adequate protection of public health and safety.

As addressed in Section III.P.1 Public Health and Safety for Wind Energy Facilities of the proposed order, the Department considers the recommended 1,000-foot setback to be arbitrary as it is, based on review of the referenced study, a value between those resulting from outputs of modeled throw distances from wind turbines with significant variability ranging of 2 and 20 MW and normal operating blade-tip speeds of 70 meters/second.

In response to Ms. Gilbert's Comment 4 in the proposed order, the Department clarifies that OAR 345-024-0010(2) requires the Council to find that the certificate holder can design, construct and

operate the facility to preclude structural failure of the tower or blades that could endanger public safety. In other words, the Council must evaluate if the certificate holder has demonstrated that it has the ability to preclude a structural failure in the first place through design, construction and operation of the turbines. OAR 345-024-0010(2) does not establish a minimum setback requirement nor require that a certificate holder demonstrate an *elimination* of all public health and safety risk from unanticipated catastrophic failure *[Emphasis added].* Instead, it requires that the certificate holder design, construct and operate the facility to avoid such a failure, to have adequate mechanisms in place to warn of an impending failure, and to minimize the consequences of such failure.

In the proposed order, the Department presents the certificate holder's representations that the probability of catastrophic blade failure is extremely low due to IEC 61400 design standards; extreme loading and fatigue testing during manufacturing; and, compliance with previously imposed site certificate conditions. Council previously imposed Condition PRE-PH-01 (IV.I.2) and PRO-PH-01 (IV.I.4) requiring wind turbines to be equipped with self-monitoring devices and vibration sensing equipment; and, that the certificate holder conduct regular wind turbine inspection and maintenance activities during operations. Vibration-sensing equipment would detect vibration caused by aerodynamic or structural flaws and would trigger equipment shutdown in order to prevent tower or blade failure. Additionally, Council previously imposed Condition PRO-PH-01 (IV.I.4) requiring that, prior to operation, the certificate holder submit to the Department materials related to its operational safety-monitoring program; and, during operations, conduct regular turbine and turbine tower component inspections and maintenance.

In the proposed order, the Department amended Condition PRO-PH-01 (IV.I.4) to provide the Department an opportunity to review wind turbine tower and blade inspection and repair and maintenance activities, and evaluate causal factors in the event of tower or blade failure during operations. If the causal analysis identifies that tower or blade failure was preventable by the certificate holder, the Department maintains authority to issue citation of corrective actions or violation of the site certificate. The amended condition, as presented in the proposed order, is provided below (underline text represents material changes from the draft proposed order to proposed order, in response to Ms. Gilbert's comment on the record of the draft proposed order):

Amended Condition PRO-PH-01: Prior to operation, the certificate holder shall:

a) S~~s~~ubmit to the Department materials or other documentation demonstrating the facility's operational safety-monitoring program and cause analysis program, for review and approval. The program shall, at a minimum, include requirements for regular turbine blade and turbine tower component inspections and maintenance, based on wind turbine manufacturer recommended frequency.

b) The certificate holder shall document inspection and maintenance activities including but not limited to date, turbine number, inspection type (regular or other), turbine tower and blade condition, maintenance requirements (i.e. equipment used, component repair or replacement description, impacted area location and size), and wind turbine operating

status. This information shall be submitted to the Department pursuant to OAR 345-026-0080 in the facility's annual compliance report.

c) In the event of blade or tower failure, the certificate holder shall report the incident to the Department within 72 hours, in accordance with OAR 345-026-0170(1), and shall, within 90-days of blade or tower failure event, submit a cause analysis to the Department for its compliance evaluation.
[Final Order on ASC, Condition IV.I.4; Final Order on AMD4; AMD5]

Moreover, Council previously imposed Condition GEN-PH-01 (IV.I.8) establishing minimum setback distances from public road rights-of-way (minimum right-of-way width of 60-feet) and from the nearest boundary of the certificate holder's lease area, which based on total wind turbine blade-tip height equates to a distance of 715 feet; and, establishes a setback distance of 1,320 feet from the nearest residence. The 1,320 foot setback distance from wind turbines to residences, as required per Condition GEN-PH-01(b) (IV.I.8), provides a greater setback distance than is requested by Ms. Gilbert. While the existing setback to roads is less than that requested by Ms. Gilbert, the Department considers that the existing and recommended amended condition are sufficient to minimize the risk of potential catastrophic tower and blade failure and does not consider the referenced study to represent a new impact specific to the facility, with proposed changes, that warrants differing setbacks.

For the reasons described above, the Department recommends Council find that Ms. Gilbert's Issue 4 does not raise a significant issue of fact or law that may affect the Council's determination that the facility, with proposed changes, satisfies the requirements of the Public Health and Safety for Wind Energy Facilities standard.

Irene Gilbert Contested Case Issue 5

"The survey areas are not adequate to include all impacts."

**Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.*

Recommendation: Council find Issue 5 was properly raised on the record

After reviewing Ms. Gilbert's written and oral comments, the Department agrees that Ms. Gilbert's Issue 5 was provided in a comment on the record of the draft proposed order (Comment 6). Ms. Gilbert's comment identified the Council's Fish and Wildlife Habitat and Threatened and Endangered Species standards and expressed a concern related to the adequacy of pre-construction survey areas to inform the extent of potential impacts to habitat, wildlife and wetlands. Therefore, the Department recommends Council find that because the issue was raised on the record of the draft proposed order with sufficient specificity and is within Council's jurisdiction, the issue was properly raised.

Recommendation: Council find that Issue 5 does not raise a significant issue of fact or law that may affect the Council's determination

This issue, as raised in Comment 6 on the record of the draft proposed order, was addressed in Section III.H. Fish and Wildlife Habitat, III.I, Threatened and Endangered Species III.Q.2. Removal-Fill of the proposed order. In her request, Ms. Gilbert does address the evaluation of Comment 6 as presented in the proposed order, but expresses a belief that pre-construction surveys, as required by previously imposed site certificate conditions, do not include sufficient setbacks nor include all areas of temporary and permanent disturbance.

As described in the proposed order, Council previously imposed Conditions PRE-DC-02 (III.C.1), PRE-TE-03 (IV.L.3), and PRE-CJ-02 (Removal Fill Condition 1) requiring that, prior to construction, the certificate holder conduct field-based surveys, according to protocols reviewed and approved by the Department in consultation with ODFW, to confirm habitat and presence of threatened or endangered species, and a wetland delineation survey, respectively. The area to be included in these pre-construction surveys, as referenced by the conditions, includes *all areas temporarily and permanently affected by construction and operation of facility components. [Emphasis added]*. The existing conditions require the certificate holder to obtain approval of the habitat and threatened and endangered species survey protocols prior to completing the surveys, but reference a protocol provided in the ASC Exhibit P which previously established survey area buffers extending 750-feet from 500-feet (or 1,250-ft) of wind turbines and existing roads, and buffers extending 750-feet from new roads.

The assessment of appropriate survey buffers, and evaluation of potential changes to the previously established buffers, will be evaluated prior to construction and confirmed by the Department and ODFW. It is not clear whether Ms. Gilbert expressly has concerns regarding the adequacy of the above-referenced conditions; however, because the pre-construction survey areas for habitat, threatened and endangered species, and wetlands must include all areas to be temporarily and permanently affected by facility components, and habitat and species survey buffer areas will be reviewed and established based on ODFW recommendations, the Department recommends that the Council find that Ms. Gilbert's Issue 5 does not raise a significant issue of fact or law that may affect the Council's determination that the facility, as amended, meets an applicable standard.

Irene Gilbert Contested Case Issue 6

> *"Impacts to birds and bats must continue to be monitored through the duration of the life of this project."*
>
> **Additional discussion was included with this issue in the request, which is not included for brevity. See Attachment 1 of this Supplemental Staff Report for the complete request.*

Recommendation: Council find Issue 6 was properly raised on the record, modifications in the request should not be considered

After reviewing Ms. Gilbert's written and oral comments, the Department agrees that Ms. Gilbert's Issue 6 was provided in a comment on the record of the draft proposed order (Comment 7). Ms. Gilbert's comment expressed a concern related to potential impacts to bird and bat species from the increase in rotor swept area from the proposed larger wind turbines, and requested, under ORS 469.507, that the certificate holder be required to conduct wildlife surveys and fatality monitoring for the life of the facility. Therefore, the Department recommends Council find that because the issue was raised on the record of the draft proposed order with sufficient specificity and is within Council's jurisdiction, the issue was properly raised.

In her request for Issue 6, in response to the OAR 345-027-0071(6)(d) requirement to provide a statement describing why Council should determine that the issue justifies a contested case, Ms. Gilbert modifies the issue as raised on the record of the draft proposed order by referencing the Council's Fish and Wildlife Habitat standard (OAR 345-022-0060), Threatened and Endangered Species standard (OAR 345-022-0070), and Cumulative Effects for Wind Energy Facilities standard (OAR 345-024-0015). As previously noted, the Department recommends Council not allow the request to modify the issue as raised on the record of the draft proposed order.

Recommendation: Council find that Issue 6 does not raise a significant issue of fact or law that may affect the Council's determination

This issue, as raised in Comment 7 on the record of the draft proposed order, was addressed in Section III.H. Fish and Wildlife Habitat of the proposed order. In her request, Ms. Gilbert does not address the evaluation of her comment within the proposed order. In the proposed order, it is described that the changes proposed in RFA5, specifically the proposed larger wind turbines, may pose additional avian collision risk due to the larger rotor-swept area from the longer turbine blades and taller hub height. Council previously imposed Condition OPR-FW-05 (IV.M.11) requiring the certificate holder to, during operations, implement a Wildlife Monitoring and Mitigation Plan (WMMP).

Consistent with Ms. Gilbert's comments, the WMMP includes short-term and long-term surveys to evaluate wildlife impacts. Specifically, the WMMP requires that the certificate holder conduct raptor nest surveys for 5-year intervals for the life of the facility. The WMMP also requires that the certificate holder conduct a short-term post-construction bird and bat fatality monitoring study (including 16 surveys per year, for two years) and an avian use and behavior study, both of which will provide important data that can be used in adaptive management. Results of the bird and bat fatality monitoring study would be compared against the WMMP's thresholds of concern for bird and bat species that, if exceeded, would require the certificate holder to implement additional mitigation if determined appropriate. The Department recommended in the draft proposed order that Council amend the draft WMMP to clarify that if any mitigation is required for a threshold of exceedance, that the mitigation be approved through amendment of the WMMP by Council. Additional mitigation could include long-term fatality monitoring studies, as Ms. Gilbert requests, or other mitigation as deemed appropriate, through Council review, as sufficiently benefiting the affected species.

As described in the proposed order, ORS 469.507 requires the establishment of programs for monitoring the environmental and ecological effects of the construction and operation of an energy facility. The statute, however, does not identify or require specific monitoring programs, nor establish a specific duration for which monitoring programs be implemented. The Council has implemented the statutory requirements of ORS 469.507 in part through OAR Chapter 345 Division 26 rules. OAR Chapter 345 Division 26 rules establish requirements for a certificate holder to develop and implement a plan for complying with each site certificate condition; and, establish reporting and incident notification requirements for certificate holders. Condition OPR-FW-05 (IV.M.11) was imposed to ensure compliance with OAR Chapter 345 Division 26 rule.

Based on the above-described analysis, the Department recommends that the Council find that Ms. Gilbert's Issue 6 does not raise a significant issue of fact or law that may affect the Council's determination that the facility, as amended, meets an applicable standard.

Attachment 1: Request for Contested Case
(Ms. Gilbert/Friends of Grande Ronde Valley)

ESTERSON Sarah * ODOE

From: ott.irene@frontier.com
Sent: Friday, October 12, 2018 3:51 PM
To: ESTERSON Sarah * ODOE
Cc: CORNETT Todd * ODOE; BENNER Janine * ODOE; Albert J. Farmer
Subject: CONTESTED CASE REGARDING GOLDEN HILLS AMENDMENT REQUEST 5
Attachments: golden contested case request amendment five.docx; golden contested case request amendment five adendum.docx

Sarah:
I hope you are in receipt of my request for contested cases on several issues related to the above amendment. I sent material by hard copy due to concerns that I did not have access to a scanner to include attachments.]

I am also sending this to assure that you receive my written comments and an addendum to provide additional support for my requests.

To: Sarah Esterson, Senior Siting Analyst
From: Irene Gilbert, Legal Research Analyst
Friends of the Grande Ronde Valley
2310 Adams Ave.
La Grande, Oregon 97850

October 10, 2018

Contested Case Request regarding Golden Hills Wind Project, Amendment 5

Contrary to the recommendations from the Oregon Department of Energy and subsequent approval of a site certificate, I continue to be confident that the site certificate does not meet council standards. I am requesting contested cases on several issues.

Introductory Statement:
Due to the fact that changes have occurred through four previous amendments, the impact of this amendment are of far greater concern than the developer has indicated. In fact, the currently proposed development in no way reflects the originally sited development. This amendment continues to reference that original site certificate and it's conditions in spite of the major differences that exist. This is problematic for multiple reasons including:

- The original Site Certificate and supporting information is nearly 10 years old and some of the information is even older.
- There have been multiple amendment requests that have occurred between the original site certificate and Amendment 5. This has resulted in approval of what have been treated as insignificant changes that cumulatively have resulted in a major change in the development.
- The reliance upon site certificate conditions that were developed for the original site certificate, and have continued to be used has resulted in a site certificate that fails to provide for the protection of the public, resources or wildlife. For example:
    - Originally the development was to include up to 420 foot turbines, now they are being planned for 650 feet.
    - Originally roads were to be 20 feet wide, now they may be up to 100 feet wide.
    - Originally there was a limit on the weight of the turbines, now that is to be exceeded.
    - Originally, the ground clearance under the turbine blades was to be 65 feet, now it is only planned for 45 feet.

FOLLOWING ARE THE RESPONSES RELATED TO THE OREGON DEPARTMENT OF ENERGY AND ENERGY FACILITY SITING DIVISION EXPANDED REQUIREMENTS BEYOND WHAT IS REQUIRED BY THE MODEL RULES AND WHICH CLEARLY SHOW AN INTENT TO EXCLUDE THE PUBLIC FROM BEING ABLE TO HAVE ACCESS TO A CONTESTED CASE IF THEY DISAGREE WITH DECISIONS OF THE OREGON DEPARTMENT OF ENERGY AND ENERGY FACILITY SITING COUNCIL AS THEY ARE LISTED IN OAR 345-027-0071. I am including my responses for both myself as an individual as well as the representative of the Friends of the Grande Ronde Valley under each section of this rule where the item is generic in nature and the response applies to all the contested case requests Additional information, where needed, is included in the body of my statement of

why the issue needs to be heard.

OAR 345-027-0071(6)(a)
Irene Gilbert
2310 Adams Ave.
La Grande, Oregon 97850
ott.irene@frontier.com

These contested case issues are being requested on behalf of myself as an individual and also as the person representing the Friends of the Grande Ronde Valley.

OAR 345-027-0071(6)(b)

Issues (Additional information is included in the extended comments regarding each request:
1. Due to the potential for damage to the water table from the weight and vibration of these wind turbines, the developer needs to provide pre-construction surveys of water depth and quality and monitor post construction impacts.
2. The Oregon Department of Energy failed to make a legitimate effort to obtain and respond to concerns of the tribes, who are the "experts" in these areas related to this development which has resulted in a failure of the application to show a preponderance of evidence that site certificate standards are met.
3. The Site Certificate needs to require documentation prior to the start of construction which includes the following information from the Oregon Department of Aviation in addition to showing that they notified them of the development: hazards identified and mitigation of impacts to aircraft safety.
4. Turbine setbacks from public roads and property adjacent to the development are not adequate to protect the public from ice throw or flying objects.
5. Survey areas do not include all areas of direct and indirect impacts due to excluding crane paths, new and significantly changed roads and roads connecting turbine strings.
6. Bird and bat fatality surveys and monitoring must be required through the life of the project.
.

OAR 345-027-0071(6)(c)
I raised all these issues in my verbal comments before the council on August 23, 2018 at the public hearing on this amendment. They were also all raised in my written comments dated August 23, 2018 as follows:
Issue One was Issue One in my written comments.
Issue Two was Issue Nine in my written comments.
Issue Three was issue Three in my written comments.
Issue Four was Issue Four in my written comments.
Issue Five was issue Six in my written comments.
Issue Six was issue seven in my written comments.

OAR 345-027-0071(6)(d)
Responses to this question are included in the narratives following this section.

OAR 345-027-0071(6)(e), OAR345-027-0071(6)(i)
Impacts to FGRV and it's members:
-- I have had delegated to me responsibility for representing the FGRV who have an interest in stopping negative impacts that this industrial wind development will have on the natural resources and quality of life for members and the public. I am qualified to represent this non-profit and it's members due to the fact that I have been attending the Energy Facility Siting Committees meetings for over 8 years, studying issues related to energy development, participating on citizen advisory groups related to the siting of energy developments, attending Public Utility Commission Meetings, testifying regarding bills, etc. Interests of members of the FGRV extends to assuring that site certificates are not allowed which may set a precident for future developments with similar unacceptable impacts on the resources and people of the state including FGRV members. Many members are concerned regarding the incongruence of the landscapes when natural resources are overshaddowed by monster metal wind turbines. Many members travel and spend time in the area of the proposed development. They state concern regarding the impacts this development will have in establishing Oregon as open to being a "test site" for untested new wind turbine designs with a lack of data regarding how these turbines will impact resources. Consistently members have voiced concern regarding the changes in the quality of life and environmental damages which will preclude their children and grandchildren from having the opportunities to have access to a similar quality of resources, wildlife and viewscapes that are currently available to them. There are developers with wind monitors already in place planning to build wind developments that will include issues raised in these contested case requests. The outcome of failing to challenge the decisions will mean that the unacceptable decisions on this development will establish precidents that people do not feel they can live with.
Noone else can represent the interests of this group as I am designated as the Legal Research Analyst for the orgnization and this job is included in my job duties. In addition, I am the only one with my level of knowledge and experience in these areas in our organization.

OAR 345-027-0071(6)(e), OAR 345-027-0071(6)(h)
Impacts to me personally:
--I travel the road through Moro several times a year. I was raised in Wheeler County, Oregon and the counties surrounding our home including Sherman County. I have strong ties to the area. My brother's ashes were scattered in Wheeler Coounty and I am committed to protecting eastern Oregon from industrial developments which will preclude my grandchildren from experiencing the unspoiled nature of our family history as it has existed during the many decades my family has spent time there. We lived in Wheeler County for years and afterward we hunted, fished, camped, and visited old friends for years. I continue to have friends from my childhood there. This development will do irreparable damage to the traditions and value of the land to future generations of Oregonians and to me personally. It is important to me to protect the resources and social value this area provides including it's wildlife, physical resources, opportunities for quiet relaxation, and isolation. I find it personally exceedingly depressing to go to a place I value such as this, where I have a history, and find it covered with wind turbines.
In addition, my two step daughters are Chickasaw Indian. They strongly relate to and value their Indian heritage They believe their Indian identity is being destroyed through damages inflict on the land of their ancestors and specifically, the damages this development will add to

the previous devastation. I am personally impacted by actions to disregard and avoid concerns of the tribes due to the fact that are committed to protecting the rights and history of the tribes and I am committed to protecting my history and access to an unspoileld landscape. I am not aware of anyone else who commented on the same issues, or anyone who has requested a contested case on these issues. My step-daughter provided a statement of her tribal affiliation - Attached

OAR 345-027-0071(6)(f)
I will not be using an attorney at this point in the process, however, may engage one in the future.

OAR 345-027-0071(6)(g)
I am asking to participate as a full party both as an individual and as the representative of the Friends of the Grande Ronde Valley.

CONTESTED CASE ISSUES AND JUSTIFICATION
ORS 469.300(26) defines a site certificate thusly, "means the binding agreement between the state of Oregon and the applicant authorizing the applicat to construct and operate a facility on an approved site incorporating all conditons imposed by the coucil on the applicant." This statute forms the basis for all the contested case requests that follow. The site certificate either is in conflict with the statute, contains information that is not accurate or does not contain information needed to assure the applicant will meet the requirements of the Oregon Revised Statutes and/or the Oregon Administrative Rules.

CONTESTED CASE REQUEST NUMBER ONE

1. *The developer must be required to do pre-construction documentation of wells on non-participating landowner's property adjacent to the wind development. The wells need to be monitored during construction and operation of the wind development to assure the development has not resulted in changes including reduced capacity, sedimentation or toxic substances in the water in the area of the wind development.*

ORS 469.501(g) is regarding authorizing standards which provide "Protection of public health and safety, including necesary safety devices and procedures." Conditions need to be included in the site certificate that provide for procedures that will assure a safe water supply to residents near this development. While the applicant cannot be denied a site certificate based upon impacts to the water supply, the Oregon Department of Energy and Energy Facility Siting Council have been made aware of the concerns of the public as well as state agencies related to this issue. A failure to provide appropriate monitoring would consititute an abuse of power in the event this development is approved absent monitoring of it's impacts. A site certificate condition or conditions is needed to address these legitimate concerns. Also, *OAR 345-022-0110(1) states that there needs to be a determination that the construction and operation of the development is not likely to result in significant impacts to the ability of public or private providers of water.* In this case, the provider of water is a private entity which would be the company who drilled the well and the landowner who paid for it, or bought the property with the well on it. Therefore, OAR 345-022-0110(l) applies.
There are no developments in Oregon or the United States which exceed 600 feet in height and

there are indications that the weight and vibrations caused by wind developments may be impacting the water table and wells. As a result, the Oregon Department of Energy and Energy Facility Siting Council cannot make a determination that the construction and operation of the development is not likely to result in significant impacts to water. Mitigation of the potential for impacts needs to occur through testing and monitoring of wells to assure safe drinking water is available to non-participant owners of property adjacent to the development. It also appears that developments which negatively impact wells would be out of compliance with the Ground Water Act.

--It has been documented that there is reason to believe that wind developments can affect wells.

--The site certificate process is to include conditions to provide for the safety and health of the public who may be negatively impacted by the development. The references are from multiple locations, multiple sources and multiple years. They provide adequate documentation that it is prudent to monitor impacts of this development due to the fact that it far exceeds the weight and resulting impacts on the transfer of water beneath the ground than any previous development.

-Documents attached to my original comments show impacts which may occur and which have been identified for multiple years. They include, the following which are not being provided in hard copy with this contested case request, but are to be included as resources:
"Wind Energy Impacts on Groundwater Resources" from the Wind Energy Siting Handbook, American Wind Energy Association.
"Wind turbines impact on groundwater to be discussed", Public Meeting planned August 10, 2016.
"Turbines have Negative Impact on our Drinking Water", published by GLBR SOS on March 27, 2018.

Additional documentation which is being provided in this request for a contested case include the following: (Please note that these documents should not be required in a request for a contested case, however, the Oregon Department of Energy and Energy Facility Siting Council have been requiring an unreasonable amount of supporting evidence that should not be required prior prior to being allowed the actual contested case). Due to that, the following additional documentation is being attached to this request, or in the case of very large documents, I am attaching excerpts from the document:

1. "Groundwater Level Declines in the Columbia River Basalt Group and their Relationship to Mechanisms for Groundwater Recharge: A Conceptual Groundwater System Model, Columbia Basin Ground Water Managmeent Are of Adams, Franklin, Grant, and Lincoln Counties," June 2009, authored by John Porcello, Terry Tolan, and Kevin Lindsey, GSI Water Solutions, Inc., Kennewick, Washington. This paper outlines and references multiple studies showing the critical nature of the ground water changes occurring in the Columbia River Basalt Group. This is the groundwater system that will be impacted should the Golden Hills project be built. Given the critical state of this groundwater system and the number of wells and agricultural activities dependent upon ground water, the issue of ground water impacts needs to be monitored to determine if this wind development is adding to the critical impacts occurring. Not only is this important for the currently proposed project, but the data is needed should the Oregon Department of Energy and Energy Facility Siting Council decide to approve additional wind developments utilizing untested wind generators such as those proposed by this developer.

2. Memorandum dated March 15, 2018 from Justin Iverson and Brenda Batem,a to the Water Resources Commission which includes documentation of the critical nature of ground water resources in the Columbia Basin.
3. "Wind Farms and Groundwater impacts: A Practice Guide to EIA and Planning Considerations" authored by the Nothern Ireland Environment Agency. This document provides a table indicating some of the potential ground water impacts from wind developments.
4. "Turbines south of SH72 will impact watershed" Hopkins resident, North Country Now, February 12 , 2018. This article, combined with previously submitted, while not scientifically based, indicates the fact that the impacts of wind developments on water supply is of a public concern.

Given the critical nature of impacts to the groundwater in the columbia basin, the cumulative impacts of weight, vibration, constructions and operation activities, decommissioning and the plans to have an on-site well capacity of under 5,000 gallons per day pose a potential significant impact on ground water. Above information more than supports the need for monitoring ground water impacts of this development prior to and during the operation of the wind development. A site certificate condition should be included requiring a pre-construction survey of well depth and quality prior to the construction and periodic checks of any changes during the life of the development. Safe water is a Public Health and Safety issue as noted in OAR 345-024-0010)
This request for a contested case is related to the next one involving the failure of the Oregon Department of Energy to respond to requests for information from the Colnfederated Tribes of the Umatilla since the information requested would have been included in this request if it had been provided.

CONTESTED CASE ISSUE TWO

The Oregon Department of Energy and Energy Facility Siting Council failed to meet the requiremernts of OAR 345-022-0000 requiring that the evidence on the record proide a preponderance of evidence that the site complies with ORS 469.300 - 469.570 and 459.590 to 469.619 and standards adopted by the council. The communications from the tribes raise legitimate issues which result in questions regarding whether or not the development meets the above requirements. Not only were those issues not addressed by the council, but the council failed to respond to requests for information which would have resulted in a showing that the facility failed to meet standards for public safety, wildlife protections, and the provision of public services. The record currently does not show a preponderance of evidence to support the decisions that were made. On the contrary, the record shows that there are questions regarding all the issues I have requested contested cases on. The
failure of the Oregon Department of Energy and Energy Facility Siting Coincil to make a legitimate effort to obtain input from the tribes regarding Amendment when it is clear that the tribes had serious concerns regarding whether or not the development met those standards appears to be a purposeful effort to avoid requiring the developer to take actions to assure compliance with the standards. The comments received from the tribes as interpreted by ODOE indicate that those contacted did not object to the development. That is not accurate. The response from a member of the Confederated Tribes of the Warm Springs stated that they had no objection, however it was necessary to contact the Tribal Council in order to obtain the

input from the tribe. They clearly stated that they were not speaking for the tribe, and that the Department of Energy needed to contact the Tribal Council as the appropriate government to government group to speak. That has not been done. Prior to issuing a site certificate, the Oregon Department of Energy and Energy Facility Siting Council need to take the action necessary and required as opposed to referencing only part of the statement that was received and treating that statement taken ot of context as meeting the requirement that they request input from impacted tribes as the group with expertise in this area.

A second memorandum dated August 17, 2018 came from the Confederated Tribes of the Umatilla Indian Reservation. That letter also was not taken seriously, and comments were not addressed, nor requested actions taken. That letter stated concern with the lack of adequate standards for the control of weeds and vegetation standards at other wind generation sites in NE Oregon. The request indicated a need to assure an adequate process that would be in effect for the life of the project. Instead of ignoring the request, the Oregon Department of Energy should have added the tribes as one of the groups to be involved in the development of the weed management plan referenced in PRE-SP-0l (Condition IV.E.4, Amended in Final Order on AMD3, AMD4).

They also indicated concern regarding the lack of completion of an analysis of the cumulative impacts of all wind power generation in the Columbia Basin. This request was not complied with nor responded to.

The responce to the ODOE from the Confederated Tribes of the Umatilla included a request for specific additional information so that the "impacts of the larger turbines proposed in this amendment may be assessed". The requests included:

"I. How different are the operating and performance characteristics of the larger turbines (e.g. how much more power will each turbine produce, what is the difference in the angular velocity of the blade tips, difference in maximyum wind rating, etc.)? Please be as specific as possible.

2. How different are the construction requirements (volume of ground displaced, anchor depth, etc.)?

3. What is the total mass of a larger turbine and how much greater is it than a smaller turbine?

4. What forces are exerted on the ground by the larger wind turbines during 1)stagnant wind conditions and 2) high wind events (wind velocity equal to tyurbine maximum wind rating)?"

The referenced memo was dated August 17, 2018. The Oregon Department of Energy ignored the requests, closed the comment period on August 23, 2018, approved the Draft Site Certificate on August 24, 2018. This action denied the Confederated tribes of the Umatilla any opportunity to make comments regarding the change in size of these wind turbines, and denied them access to a contested case.

In addition, the failure to provide the information denied me the opportunity to use the specific weight and impact changes between the previously approved and currently approved turbines in drafting my contested case request regarding the fact that these turbines will exert more force than those previously approved on the soils and combined with the impacts of vibration from the wind turbines, may damage ground water paths and result in negatively impacting the water table and wells in the Columbia Basin. My family, which includes two individuals who are documented as tribal members, share the concerns of the tribes related to the damaging impacts that are occurring as a result of wind and solar developments and Golden Hills proposed plans to construct turbines of a size not previously used . Allowing these turbines

absent an evaluation of potential impacts based upon data which has not been provided poses a threat to the land and water resources protected by treaty rights. No standards impacted by the size and weight of the turbines can show a "preponderance of evidence" absent the information that was requested but not provided to the tribes. My family is deeply offended by the lack of respect demonstrated by the failure to responses to comments and questions from the tribes. A failure to allow a contested case hearing will add to the disrespect shown to date. The Oregon Department of Energy and Energy Facility Siting Council should provide the information requested, reopen the comment period for this development, and address issues brought forward regarding the impacts these turbines may have or allow contested cases to be held to resolve the issues.

CONTESTED CASE ISSUE THREE

The development poses a risk to private and commercial aircraft as it exceeds the 500 foot no fly zone. It also poses a risk to Wasco Airport as indicated in previous comments submitted by the public. The developer needs to obtain documentation that the development will not increase the risk to airplanes flying in the area prior to the start of construction. Small planes are required to stay above 500 feet to avoid hazards. In this case, the developer is planning to construct turbines that will exceed the level at which planes, regardless of the types of navigational equipment they are using, or not using, and regardless of whether they are flying in daylight or darkness can expect there to be no objects that would result in a collision.
This contested case request is based upon the failure of the Site Certificate to address the requirements of OAR 345-024-0010 requiring the protection of the public health and safety. The site certificate only indicates one condition related to the hazard posed by wind turbines exceding 500 feet and imposing beyond the No Fly Zone. Condition PRE-PH-03 (Finals Order on ASC, Condition IV.I.7) requiring the developer to submit the "Notice of Proposed Construction" to the department, the FAA and the Oregon Department of Aviation prior to beginning construction. The response to that that submission is not required prior to the construction of the development.
The Oregon Department of Aviation responded in writing on August 20, 2018 indicating the need to change this site condition to require the developer to also provide a copy of the response from ODA prior to the construction commencing and include any proposed mitigation options related to any affirmative hazard determination. The letter makes specific reference to the fact that the prior approval related to a different turbine than the ones that would be approved by this amendment. They also reference ORS 836.530 as the controlling statute and OAR 738-070-0110(l)(a) as the administrative rule being applied. The Oregon Department of Energy and Energy Facility Siting Council do not have the authority to override state statute in their decisions. The Oregon Department of Aviation also commented that the Wasco state Airport is under Federal grant assurances and obligations which require them to assure that Hazards will be Removed and Mitigated to protect instrument and visual operations to the airport and to prevent the establishment or creation of future airport hazards. The federal grant also requires a restriction on land in the immediate vicinity to activities and purposes compatible with normal airport operations. Flights into or out of the Wasco state Airport will cause risk to me and all other citizens in the event that the above requirements are not included in the site certificate. In addition, the status and expertise of the Oregon Department of Aviation in determining hazards and appropriate mitigation of those hazards at this airport

exceed the expertise of the Oregon Department of Energy and the Energy Facility Siting Counsil members expertise. Given the "life or death" nature of this hazard, the recommendations should be implemented. This request for a contested case is based upon the failure of the ODOE and EFSC to honor these requests in order to protect the safety and health of Oregon citizens.

CONTESTED CASE ISSUE FOUR

The setbacks from roads and structures are not adequate to provide for the health and safety of the public as required by OAR 345-024-0010 and Land Use OAR 345-022-0030. The risk from detached objects or ice being thrown from the turbines is real, and weather conditions in the winter in the area of the proposed development frequently result in icey conditions as evidenced by weather warnings related to highway hazards as well as the applicant's description of the site included in their Amendment Application. In addition, you will find attached a copy of "Analysis of throw distances of detached objects from horizontal-axis wind turbines" by Sarthatlak, Hamid; and Sorensen, Jens. This scientific paper published in **Fluid Mechanics, Department of Wind Energy;** Technical University of Denmark, Lygby, Denmark and also **Wind Energy,** 2016, (location found at bottom of article attached) gives a very thorough analysis of the aerodynamics of objects flying from wind turbines. Ice throw is identified as moving a distance of 100 to 600 meters(1968 feet). Since this is the most likely object to be thrown, a distance in the middle range of the distances reported, or 1,000 feet would be reasonable to reduce and mitigate the potential of harming people or animals. Given the reduced number of turbines at this location, this is a reasonable request to provide for the health and safety of the public.

I am requesting a contested case on this issue due to the failure of the Fifth Amended Site Certificate to provide protection to the public from objects thrown from the proposed wind turbines, whether they be parts coming off the turbine or ice being thrown from the turbines. The prior submitted references clearly indicate that the setbacks are not adequate, however, due to the extreme requirements that requestors provide information that normally would not be needed until an actual contested case occurs, I submit the following additional documents related to this issue:

"Maintenance concern flagged over newer windfarms" by David McPhee, September 26, 2018. The impacts that maintenance can have over the need for setbacks is supported by the loss of a turbine blade from one of the wind towers located at the Stateline Wind Project this year. The attached document shows the entire blade came off the turbine. This occurred as the blade hit the tower which indicates that it was in the downward position resulting in a minimum distance of movement from the turbine compared to what would be predictable had the blade dislodged in either an upright position, or in the "Wind Energy, 2016; 19:151-166 published by John Wiley and Sons, Ltd., Page 165 attached, the maximum distance for a full blade throw in the event the turbine tip speed is 70 m/s which equals 156 MPH, is 2,296 feet. The proposed turbine will have a tip speed greater than this, and the distances of throw could be anywhere up to the 2,296 feet. A prudent person would understand the need to establish setbacks which would address as much of this distance as is possible.

The occurrance of ice throw is related to winter storms. In the Energy Facility Siting Council discussions regarding this recommendation, the incidence of storms resulting in ice build up were minimized. Attached exerpt from the State of Oregon, "Emergency Management Plan,

February 2012" indicates that this is a real hazard, and not an occurrance that would have to result from some freak occurance requiring a special aligning of the stars combine with an individual who is the most unlucky person in the world as was implied by a council member. The Fifth Amended Site Certificate, Item PRE-LU-03 (Final Order on ASC, Condition IV.D.4; Amended Final Order on AMD4.) states that the site certificate holder shall not locate any aboveground structure including wind turbines within 50 feet of any external property right of way of any arterial or major collector road. This condition should specifically exclude wind turbines. The minimum setback from roads or property lines needs to be either the Manufacturers recommended setbacks or 1.5 times the total height of the wind turbine, measured to the property line or the edge of the road right of way unless a greater distance is required to provide for public safety.

CONTESTED CASE ISSUE NUMBER FIVE
The survey areas are not adequate to include all impacts.
The relevant statute and rules are ORS 469.507 and OAR 345-022-0060 Particularly troubling is the limitation to just the footprint of laydown areas, new substations and mitigation areas and existing roads. I can also find no indication that surveys will be performed on the transmission lines connecting this development to the grid, or the connecting corridors between turbine strings. The survey boundaries need to be at least as wide as the required setbacks for protection of wildlife at the site and must include all land, such as wetland being impacted by the development action either permanently or temporarily as well as direct and indirect impacts to wildlife. OAR 345-022-060, OAR 345-022-070 and OAR 345-021-0010 all require the information regarding impacts which extend beyond the bases of structures or the actual road beds and to include the area of indirect impacts. Currently surveys are being allowed which include the siting corridors for the turbine strings, but fail to include the siting corridors for the crane paths, new roads and those with major changes (given that the new site certificate allows roads up to 100 feet wide, this is no small issue). The limited area of the surveys mean that multiple indirect impacts will be ignored. For example, construction of a road or changing an existing 20 foot road to 100 feet will have significant impacts beyond the actual road bed to wildlife. Wetland impacts will also exend beyond the road bed. All surveys need to include all areas of construction impacts and include setbacks from those construction activities that will allow for identification of resources protected by standards.

CONTESTED CASE ISSUE NUMBER SIX *Impacts to birds and bats must continue to be monitored through the duration of the life of this project.* Rules relating to this issue are:
ORS469.507 and OAR 345-022-0060 and OAR 345-022-0070
You cannot know what the impacts are absent data regarding those impacts. This is the first time a turbine of this size has been allowed in Oregon, thus there is very little information available which documents the impacts that they will have. The applicant has provided documentation that states that there are differing projections regarding wildlife impacts of these new turbines. It is unavoidable that this development will have direct impacts on birds and bats including threatened and endangered species. Oregon resources are being exposed to what amounts to an experiment by allowing the development of turbines of this height and weight. There is no time when the need for OAR 469.507 which requires the monitoring of environmental and ecological effects of construction and operation of energy facilities will be more apparent. The wildlife surveys and fatality monitoring needs to continue through the life

of the project. The developer would lead you to believe that increasing the circumfrence of the turbin blades is a small change in impacts. This is simply not accurate. It is not a simple 1:1 increase. For example, the original site certificate for this development was for turbine blades that were to span approximately 355 feet. This amendment calls for blades that will span approximately 605 feet. The area that blades 355 feet across covers would be 2.27 acres. Increasing the span of the blades to 605 feet means the plades will cover an area of 6.60 acres. Increasing the diameter of the blades by 250 feet results in the area of the rotor sweep being nearly 3 times as large. For the impacts to birds and bats to be similar or less thans the originally proposed turbines, this development would have to reduce the number of turbines to 1/3 the original number. This alone should result in a denial of this amendment request as the wildlife impacts are unsustainable given the fact that turbines do not discriminate regarding the status of birds and bats that are Threatened or Endangered. The current site certificate requires one wildlife survey prior to the start of construction, and a minimum of one following construction with the possibility of a second. The fatality study also can be limited to one survey. The above statutes and rules require monitoring through the life of the project for compliance with the rules. This contested case is necessary to require the site certificate include repeated surveys and fatality monitoring every five years for the life of the project. This should be occurring with all developments, but is critical for one such as this where there is absolutely no objective evidence regarding the cumulatibe impacts this development will have over time on Oregon wildlife resources.

Please provide the language of my requests for contested cases on the above issues in their entirety in any reference to decisions regarding the contested case requests I am making. Comments that are paraphrased or taken out of context often do not reflect the same message as peoples words and they can fail to communicate important information.

Irene Gilbert, Legal Research Analyst
Friends of the Grande Ronde Valley
2310 Adams Ave.
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Contested Case Request regarding Golden Hills Wind Project, Amendment 5 Addendum

*Received from Ms. Gilbert in email on October 10, 2018

To: Sarah Esterson, Senior Siting Analyst October 10, 2018
From: Irene Gilbert, Legal Research Analyst
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Contested Case Request regarding Golden Hills Wind Project, Amendment 5 Adendum

This document is to be included with the hard copy you should have received today. Due to the number of attachments and the fact that my scanner was not working, I sent the information I had completed by overnight carrier. This additional information forms the entire document regarding my requested case requests: also as the person representing the Friends of the Grande Ronde Valley.

Issues (Additional information regarding contested case issues:

1. Due to the potential for damage to the water table from the weight and vibration of these wind turbines, the developer needs to provide pre-construction surveys of water depth and quality and monitor post construction impacts.

In the justification for ignoring my suggestion during the comment period, the Oregon Department of Energy indicated they had previously required a general requirement that would minimize the potential for aquafer collapse due to blasting. These site certificate conditions do not address all my concerns.

The greatest risk will be the vibration combined with the weight of the planned turbines. The compressive forces these wind generators will be exerting on the soil and rock structure below them will be significant enough to break down the routes that ground water flows and impacts can be expected to increase over time.

The dismissal of the concerns by stating that the Oregon Department of Energy and Energy Facility Siting Council rules do not require consideration of impacts to private wells as stated on Page 75 of the Proposed Order is offensive at best and also ignores the groundwater system in the Columbia Basin. I have provided documents showing that the flow of ground water in the Columbia Basin is complex and interconnected. By all rights,you should be requiring monitoring for an extended area, and certainly at a minimum, it is likely that any negative impacts will extend to the Town of Morro and any others in proximity to the wind development which rely upon wells to provide water to the citizens and which will be at risk due to the gargantuan size and weight of these towers. These impacts need to be addressed under several rules and statutes: 1. The Public Services Standard due to impacts to wells, both public and private. 2. The Structural Standard OAR 345-022-0020 Structural Standard which requires " (c) The applicant, through appropriate site-specific study, has adequately characterized the potential geological and soils hazards of the site and its vicinity that could, in the absence of a seismic event, adversely affect, or be aggrivated by, the construction and operation of the proposed facility, and (d) The applicant can design, engineer and constryct the facility to avoid dangers to human safety presented by the hazards identified in subsection (c)."
I read this to mean that absent ongoing monitoring to assure the development does not result in well contamination or loss, , the developer would be required to have an engineer model the potential impacts of each turbine given the soil and geological makeup of each site and model the impacts of the vibration in combination with the weight of each turbine. 3. OAR 345-022-0022 Soil Protection standard

which requires the Council to find that the design, construction and operation of the facility, taking into account mitigation, are not likely to result in a significant adverse impact to soils including, but not limited to, erosion and chemical factors such as salt deposition from cooling towers, land applicant of liquid effluent and chemical spills. If you read the attachments I provided regarding studies of the Columbia Basin ground water, you will find that the creation of fizures can mean that one layer of water which is poluted can move into another level causing it to become unsafe. Also, any polutants on the soil surface can access the water table through the ground impacts of the turbine bases.. 4. ORS 469.500 specifically mentions "Protection of public health and safety, including necessatry safety devices and procedures and the ability of the local communities to provide water.
There is no requirement in the site certificate that would address how turbines of the size and weight of those proposed would impact the soils and groundwater in the area of the turbines given the intertaction of soil, underlying rock structures, water movewment with the weight and vibration that will occur when the turbine blades are actively moving..

ADDITIONAL INFORMATION REGARDING THE FAILURE TO ADDRESS TRIBAL REQUESTS
The Oregon Department of Energy failed to make a legitimate effort to obtain and respond to concerns of the tribes, who are the "experts" in treaty rights, wildlife and historical issues. The failure to use these resources amounts to a failure to show with a preponderance of evisdence that this development meets the site certificate standards. The fact that the tribes requested specific information as a result of their concerns indicates that there are serious questions regarding whether or not the application for this amendment should be approved. Certainly, there is a lack of information which would allow an evaluation of multiple standards including the Public Service Standard, Safety and Health, Habitat Impacts and more.

The Oregon Department of energy responded to this comment by saying that they were not required to address concerns of the tribes. They also stated that the tribes would have to identify specifically what resource might be damaged. See Page 64 of the Proposed Order on Request for Amendment 5. In addition, this page fails to reflect the requests from the tribes which were ignored. These requests would have lead to specific recommendations based upon the information provided if it had been provided.

My step daughter and I find it unbelievable that the Oregon Department of Energy does not find it necessary to address issues of the tribes because they do not believe there is a specific rule requiring them to do so.

ADDITIONAL INFORMATION REGARDING TO INADEQUATE SETBACKS
The site certificate should at a minimum follow the recommended setback obtained from the turbine manufacturer, if any are provided. If not, the setbacks need to be a minimum of 1 1/2 times the total height of the turbine, which is the standard given by at least one turbine manufacturer as previously documented.

ADDITIONAL INFORMATION REGARDING THE FAILURE TO REQUIRE SURVEYS TO IDENTIFY ALL IMPACTS, DIRECT AND INDIRECT OF THE DEVELOPMENT
The survey areas are not adequate to include all impacts.
The relevant statute and rules are ORS 469.507 and OAR 345-022-0060 Particularly troubling is the limitation to just the footprint of laydown areas, new substations and mitigation areas and existing roads. The minimum survey area for all facility components needs to be the setbacks required for

turbine developments in locations where there raptor nests, and all other setbacks for wildlife, noise, wetlands, turbines, etc.

ADDITIONAL INFORMATION REGARDING FAILURE TO PROVIDE NECESSARY MONITORING OF WILDLIFE IMPACTS

CONTESTED CASE ISSUE *Impacts to birds and bats must continue to be monitored through the duration of the life of this project.* Rules relating to this issue are:
ORS469.507 and OAR 345-022-0060 and OAR 345-022-0070
My original comments regarding this issue which continue to be relevant should have resulted in a change in the site certificates to require monitoring of impacts for the life of the project. When the developer states that there is a lack of data regarding the wildlife impacts which was stated during the determination of the legitimacy of my request, and the Oregon Department of Energy and Energy Facility Siting Council refuse to adhere to the statute and rule requiring monitoring of impacts for the life of the project, it smacks of an abuse of power. Absent a method of monitoring what impacts will be, the site certificate amendment needs to be denied as no decision can currently be made regarding how extensive the damages will be. The current site certificate requiring one pre-construction and one post-construction survey avoids the requirement to determine cumulative impacts of the development as required by OAR 345-024-0015. This requirement is the only method that can document that any mitigation proposed is effective, or if the increased turbine size, area of rotor sweep and larger height and reduction of ground clearance is causing unsustainable damages to wildlife. Absent documentation of the impacts, the site certificatre amendment cannot be approved as there is no documentation regarding the cumulative impacts this development will have.

Please provide the language of this additional information in support of my requests for contested cases in their entirety including the previously submitted comments.

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Cover Sheet added by the Oregon Department of Energy (Department)

Notes to Council:

- The following information was included in the Request for Contested Case Proceeding on Proposed Order on Golden Hills Wind Project Request for Amendment 5 (request)
- As noted in the Supplemental Staff Report, the Department recommends that unless the Council elects to reopen the record of the draft proposed order, that the contents of the attached information not be considered in the Council's evaluation of issues raised in the request

GROUNDWATER LEVEL DECLINES IN THE COLUMBIA RIVER BASALT GROUP AND THEIR RELATIONSHIP TO MECHANISMS FOR GROUNDWATER RECHARGE: A CONCEPTUAL GROUNDWATER SYSTEM MODEL, COLUMBIA BASIN GROUND WATER MANAGEMENT AREA OF ADAMS, FRANKLIN, GRANT, AND LINCOLN COUNTIES

JUNE 2009

PREPARED BY
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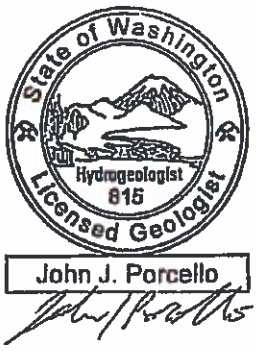

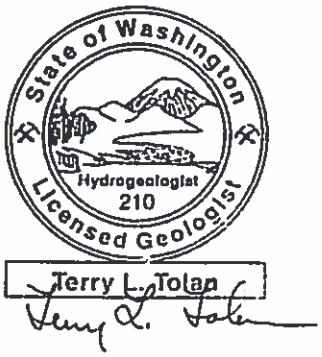

EXECUTIVE SUMMARY

The Columbia River Basalt Group (CRBG) hosts a regional aquifer system that is the primary, and in many cases the only, water supply for numerous communities, small water systems, individual homes, industry, and agriculture in east-central Washington. In this central portion of the semi-arid Columbia Plateau, primarily in Adams County and southern Lincoln County, the CRBG aquifer system has experienced significant water level declines and does not appear to receive significant, if any, natural recharge. The occurrence of groundwater declines within the CRBG aquifer system is a significant concern to water resources managers in the region.

The Columbia Basin Ground Water Management Area (GWMA) has conducted a Subsurface Geologic Mapping and Hydrogeologic Assessment project to complete subsurface geologic mapping in Lincoln County and develop a conceptual model of the groundwater flow system. The conceptual model evaluates several key aspects of the regional groundwater resources, including the potential for natural recharge to be occurring from the Lake Roosevelt Pool and from other nearby surface water bodies; the age of CRBG groundwater and the potential for modern recharge to be occurring naturally; and the degree of interconnection between the different parts of the CRBG aquifer system, both horizontally and vertically. The conceptual model is thus a working description of how water recharges the CRBG aquifers, how groundwater moves through these aquifers, and how groundwater discharges from these aquifers. While the focus of the conceptual model is on understanding conditions in the areas of the historically steepest water level declines (in the Odessa Groundwater Management Subarea), the conceptual model is a regional-scale framework for describing groundwater conditions in and beyond this area. The local and regional scales of the conceptual model provide a comprehensive analysis of the mechanisms and locations for groundwater recharge and discharge to be occurring under natural conditions, as well as providing a framework for evaluating future groundwater management strategies, such as artificial recharge.

This project and numerous previous studies have found that the CRBG aquifer system resides in sediments that lie on top of the CRBG basalt flows, and also in thin interflow zones that are situated between layers of dense, massive, low-permeability basalt flows. Within the CRBG, groundwater is present primarily in thin, discrete zones that are hydraulically separate from each other in most areas, except near recharge areas on the periphery of GWMA. Many such water-bearing interflow zones exist in the CRBG, but their compartmentalized nature results in little direct connection between individual zones. Connection occurs primarily where uncased (open-borehole) water supply wells artificially cross-connect multiple zones. This artificial cross-connection has been prevalent in Lincoln and Adams Counties for many years and has been noted by this project and previous studies to have resulted in passive downward drainage of groundwater from relatively shallow basalt zones to deeper zones over long periods of time. This phenomenon and the continuation of pumping and well deepening practices during the past 2 to 3 decades are the principal causes of the significant declines in groundwater yields and groundwater levels in these two counties.

The occurrence and movement of groundwater in the CRBG is governed by 1) its geologic features (lithology, folding, faulting, the areal extent of individual interflow zones [including lateral pinchouts], the presence of buried structures [granitic bedrock or vertical basalt dikes], and the presence of erosional features [coulees]); and 2) its exposure to surface water sources (lakes, rivers, streams, canals, irrigation). The recent subsurface geologic mapping conducted for this project shows that with the exception of areas along the Snake River in eastern Franklin County, the deep (Grande Ronde Basalt) aquifers have little exposure at the ground surface and thus receive very little recharge that flows into the interior of GWMA. This finding is consistent with the results of geochemical and age dating studies, which indicate that groundwater in the Grande Ronde Basalt is pre-Holocene in age (i.e., greater than 10,000 years old). Shallower water-bearing zones (in the Wanapum Basalt) receive some recharge from precipitation runoff in the floors of coulees; however, because of groundwater pumping and the prevalence of uncased boreholes that drain water into deeper zones, streamflows and groundwater elevations in the Wanapum Basalt have not recovered to pre-development conditions.

For both the shallow (Wanapum Basalt) and deep (Grande Ronde Basalt) aquifers, the recent subsurface geologic mapping work indicates that the Lake Roosevelt pool and other reaches of the Columbia River and the Spokane River do not recharge any of the basalt aquifers in GWMA. Additionally, subsurface inflow of groundwater into GWMA from adjoining areas appears to occur only along the Adams/Whitman county line. However, this inflow may be limited in magnitude, particularly in the Grande Ronde Basalt, as indicated by geologic evidence (the suspected presence of a buried dike system along the Cow Creek drainage, and buried structures in Whitman County and southern Spokane County) and geochemical analyses of groundwater samples. Consequently, the subsurface geologic mapping, the long-term record of groundwater elevation trends in GWMA, and the geochemical and age-dating studies together indicate that in Adams County and southern Lincoln County, the existing groundwater supplies in the Grande Ronde Basalt are ultimately not reliable or sustainable in the long-term under current water management programs. Deepening wells is only a temporary solution to mitigating declining groundwater levels and well yields; the recent increase in pumping from the Grande Ronde Basalt is tapping ancient sources of water that receive little if any recharge near groundwater pumping centers or at the margins of GWMA. While the long-term outlook for Grande Ronde Basalt water supplies in this portion of GWMA is not promising, restoration of historical groundwater supplies in the Wanapum Basalt via artificial recharge may be possible in this same area because of the prevalence of Wanapum Basalt exposures in coulee floors and the northern channeled scablands of northern Lincoln County.

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INTRODUCTION

The Columbia Basin Ground Water Management Area (GWMA) of Adams, Franklin, Grant, and Lincoln Counties encompasses approximately 8,300 square miles in south-central Washington (see Figure 1 and Plate 1). This report is one in a series of four reports prepared by GWMA in 2009 that presents the results of a comprehensive study of the portion of the Columbia Basin groundwater system underlying GWMA. The study, which is called the Subsurface Geologic Mapping and Hydrogeologic Assessment Project, was funded by the Washington State Legislature for the 2007-2009 biennium and builds on previous studies of the regional groundwater systems that lie in the four-county GWMA area. The Subsurface Geologic Mapping and Hydrogeologic Assessment Project was conducted for the purpose of developing a framework for understanding and describing groundwater occurrence and flow, groundwater quality, and the relationship between groundwater and surface water within GWMA. Specific objectives for the study were to: 1) refine and upgrade the GWMA geologic database and geographic information system (GIS), 2) complete the subsurface mapping project (primarily in Lincoln County), and 3) use the data from this study to test and refine one or more conceptual models of the groundwater flow system and the relationship between groundwater and surface water.

This and previous studies for GWMA have been conducted because of concerns about the continued decline of groundwater levels in the basalt aquifers that lie beneath portions of GWMA. In particular, GWMA stakeholders have recognized the need for study efforts that focus on identifying the aquifers contributing groundwater to production wells, the extent of those aquifers, and the recharge sources (if any) for these aquifers. Productive aquifers are found in the Columbia River Basalt Group (CRBG) in three formations (from youngest to oldest, the Saddle Mountains Basalt, Wanapum Basalt, and Grande Ronde Basalt), as well as in interstratified sediments (Ellensburg Formation) that are present in some areas. In the CRBG, productive aquifers are present in thin, discrete zones that are separated by thick sequences of dense, massive basalt rock that yields negligible amounts of water, if any.

The legislative directive that accompanied the 2007-2009 biennium funding requested that the study address the following issues:

1. The potential recharge, or lack of recharge, of the GWMA CRBG aquifers by the Lake Roosevelt pool
2. The potential for recharge of the GWMA CRBG aquifers by other surface water bodies found around the edge of the GWMA
3. The age of CRBG aquifer groundwater and the potential for modern recharge of the basalt aquifers
4. The degree of interconnection between the different parts of the CRBG aquifer system, both horizontally and vertically

5. A review of GWMA's conceptual model of how water recharges the CRBG aquifers, how groundwater moves through these aquifers, and how groundwater discharges from these aquifers

Understanding these questions, as we now do, provides GWMA stakeholders with a powerful tool box to use in monitoring the different portions of the groundwater system; devising strategies to mitigate against further groundwater level decline and the associated reductions in groundwater supplies; and building groundwater models which can be used to study the impacts of different actions, including artificial recharge.

The focus of this report is the Odessa Groundwater Management Subarea (herein referred to as the Odessa Subarea) and nearby areas to the north (Plate 1). This focused study area encompasses the portions of Lincoln, Adams, and Franklin counties that lie east of the East Low Canal, which conveys agricultural irrigation water from Lake Roosevelt to the Columbia Basin Irrigation Project (CBIP). Groundwater declines are largely concentrated in the Odessa Subarea because groundwater pumping is the sole source of water in this area; CBIP water is not available in the eastern portion of GWMA for irrigation use. This report focuses on describing the degree of horizontal and vertical interconnections between the various CRBG aquifers that are present in the Odessa Subarea, and the locations and relative significance of recharge sources to the various CRBG flows. The interpretations and findings on this subject have been derived in part from examining the temporal trends in water levels that have been measured during the past three to four decades in production wells and in non-pumping observation wells. However, the interpretations and findings in this report are also heavily derived from the subsurface geologic mapping work and the resulting improvements in the geologic conceptual model of GWMA that have also occurred under this study.

This report is the fourth in a series of reports documenting the Subsurface Geologic Mapping and Hydrogeologic Assessment Project. The four project reports are as follows:

- GWMA, 2009a, A summary of Columbia River Basalt Group geology and its influence on the hydrogeology of the Columbia River Basalt aquifer system, Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., June 2009.
- GWMA, 2009b, Geologic framework of selected sedimentary and Columbia River Basalt Group units in the Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington, Edition 3: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., and the Franklin County Conservation District, June 2009.
- GWMA, 2009c, Groundwater geochemistry of the Columbia River Basalt Group aquifer system – Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by S.S. Papadopoulos and Associates, Inc., and GSI Water Solutions, Inc., June 2009.

- GWMA, 2009d, Groundwater level declines in the Columbia River Basalt Group and their relationship to mechanisms for groundwater recharge: A conceptual groundwater system model for the Columbia Basin Ground Water Management Area of Adams, Franklin, Grant, and Lincoln Counties, Washington: Consultant report prepared for Columbia Basin GWMA, prepared by GSI Water Solutions, Inc., June 2009.

The primary objective of this report (GWMA, 2009d) is to document new and previous geologic analyses and interpretations, groundwater level records, and geochemical analyses for the purpose of improving the understanding of groundwater occurrence and movement, groundwater recharge and discharge, and the degree and locations of hydraulic interconnection (particularly vertical connection) between the different groundwater-bearing zones that lie at multiple depths throughout the CRBG. A particular focus of this report is to describe the mechanisms by which recharge occurs to shallow and deep water-bearing zones alike, both currently and historically. A secondary objective of this report, and its companion reports (GWMA, 2009a, 2009b, 2009c), is to create an updated conceptual hydrogeologic model that 1) can provide insights as to the long-term reliability of groundwater supplies, particularly in the Odessa Subarea; and 2) facilitate future evaluations of various water management strategies, including artificial recharge projects.

To meet these objectives, the remainder of this report summarizes the nature of the current groundwater availability concerns, and then describes the historical studies of the aquifer system and the declining groundwater levels. The report then discusses the salient geologic features that have a direct controlling effect on the occurrence and movement of groundwater in the basalt aquifers, including discussions of how those features facilitate or impede groundwater recharge and groundwater movement. This understanding of the geologic system is then used to interpret the available water level and geochemical data, with an emphasis on identifying the nature and relative significance of current and historic recharge to the various basalt aquifers that are present beneath GWMA. The report concludes with a summary of the principal observations and conclusions from this evaluation, including interpretations about groundwater recharge that have been newly developed under the Subsurface Geologic Mapping and Hydrogeologic Assessment project. These descriptions thus constitute a conceptual model of the hydrogeology of the CRBG aquifer system. The conceptual model is largely descriptive and qualitative in nature and provides a working framework for future monitoring and management of the regional groundwater resource, including the formulation, analysis, and implementation of resources management strategies.

NATURE OF THE PROBLEM

Groundwater is an important source of water to meet agricultural, industrial, and municipal water demands in GWMA, and groundwater is the only source of water supply in the eastern portion of GWMA. The Subsurface Geologic Mapping and Hydrogeologic Assessment project was funded by the Legislature during the 2007-2009 biennium

because of growing concerns by GWMA and local groundwater users about continued declines in groundwater levels in the Odessa Subarea and the corresponding implications of these declines for the long-term sustainability of deep aquifer production wells and groundwater supplies.

Little was written about the hydrogeology of the area encompassed by GWMA prior to 1968. A statewide study of the occurrence of flowing artesian wells noted the occurrence of two wells in eastern GWMA with discharges of 300 gallons per minute (gpm) or greater (Molenaar, 1961). The study identified a 300-gpm flowing artesian well in the southeastern corner of Adams County near the Palouse River and the mouth of Cow Creek (in Township 15N, Range 37E, Section 34C1 [T15N, R37E, 34C1], owned by the Oregon-Washington Railroad and Navigation Co., and measured in December 1949). The study identified a 570-gpm flowing artesian well about 5 to 6 miles north of the Town of Odessa in Lincoln County (T22N, R33E, Section 4F1, owned by L.J. Bonney and measured in September 1956).

The first publication from the scientific and regulatory community to comprehensively identify and discuss the occurrence of groundwater level declines in the eastern portion of GWMA was conducted by the state's former Department of Water Resources and was published as Washington Water Supply Bulletin (WSB) 31 (Garrett, 1968). As described in WSB-31, settlement began in the Odessa area in the 1880s, accompanied by the development of dry-land wheat farming. During the early 1960s, wheat growers found that markedly greater crop yields could be obtained by applying supplemental water through the use of sprinkler irrigation systems. In much of Lincoln and Adams Counties, landowners east of the Columbia Basin Irrigation Project (CBIP) service area turned to groundwater from the regional CRBG aquifer system for their source of irrigation water. WSB-31 noted that many of these early wells were being drilled to depths of 1,000 feet or more, though some wells also obtained large amounts of water from shallow alluvial deposits lying in the floors of local coulee systems. WSB-31 identified rapid rates of groundwater usage in the early 1960s, including a doubling of the annual groundwater pumping volume from 1963 to 1965 within this study area, which occupies southwest Lincoln County and northwest Adams County. This and surrounding areas were designated by the State of Washington as the Odessa Groundwater Management Subarea. Implementation rules for the Odessa Subarea were developed by the Washington Department of Ecology (Ecology) in 1973, in the form of Washington Administrative Code (WAC) Chapters 173-128A and 173-130A. In particular, WAC 173-30A specified that aquifers in the Odessa Subarea could not decline more than an average of 30 feet every 3 years before regulatory action would be taken.

Records maintained by Ecology show that the number of water wells drilled or deepened in an individual year increased gradually from the 1960s through the early 1970s, increased dramatically in the mid-1970s (when Ecology revoked a 1968 ban on groundwater withdrawals and started issuing new water right permits), and has also increased over time since the mid-1980s (Figure 2). In Lincoln County, the annual number of installations and deepenings for water supply wells (both small- and large-capacity) has increased each year since 1990.

The study by Garrett (1968) was the first of several studies by the former state DWR and by other agencies that documented the continuing lowering of regional groundwater levels east of the CBIP service area. Garrett measured as much as 20 feet of lowering during the one-year period from late 1964 through December 1965. He also noted that comparatively shallow domestic wells had seen water level declines of 1 to 2 feet at locations that were as much as several miles away from centers of heavy pumping by deep wells. The next study of the area (Luzier and Burt, 1974; WSB-33) noted that pumping in the Odessa Subarea increased from 16,000 acre-feet (af) in 1963 (from 85 wells) to about 74,000 af in 1968 (from 169 wells), with groundwater levels declining at rates of 2 feet per year to more than 10 feet per year between 1965 and 1968. Luzier and Burt (1974) predicted continued declines at rates of between 8 and 18 feet per year in the Odessa Subarea if annual pumping were to be maintained at 1967 rates. Later, a U.S. Geological Survey (USGS) study (Cline and Collins, 1992) noted that in 1984, 75 percent of the groundwater pumping in the State of Washington occurred in the four counties that today comprise the Columbia Basin GWMA. In addition to the historical record of increased pumping and continued lowering of groundwater levels, local landowners also have reported that streamflows began decreasing in certain drainages in northern Lincoln County (particularly Sinking Creek and Lake Creek) after regional groundwater development began for agricultural irrigation purposes (Wildrick, 1982; Wildrick, 1991).

PREVIOUS STUDIES OF GROUNDWATER LEVEL DECLINES AND CRBG HYDROGEOLOGY

A large number of hydrogeologic studies of the CRBG have been conducted over the past 50 years. Some studies have been regional in nature, covering large areas in Washington and Oregon where the CRBG is present. Others have been focused on conditions in local groundwater basins within the CRBG, such as the Quincy, Pasco, and Walla Walla Basins. Some studies have focused on gathering pumping and water level data, while others have focused on interpreting geologic and hydrologic data for the purpose of characterizing hydrogeologic conditions, including the occurrence of groundwater, the degree of vertical hydraulic interconnection between CRBG water-bearing zones, and the locations and magnitude of groundwater recharge and groundwater discharge from various water-bearing zones in the CRBG. This section surveys key literature references that have preceded, and been utilized during, the Subsurface Geologic Mapping and Hydrogeologic Assessment project.

The first regional-scale study of CRBG groundwater was performed by Newcomb (1959), who published his own observations on groundwater occurrence in the CRBG in Washington and Oregon. This publication examined several important aspects of CRBG hydrogeology, including descriptions of the presence and absence of groundwater in various zones; the mechanisms by which water moves in and between basalt flows; tectonic (structural) controls on groundwater occurrence, movement, and recharge; and the state of development and water quality at the time. His publication built on periodic local basin studies conducted during the prior 60 years, including studies by Russell in southeastern Washington (1897), Smith in Yakima County (1901), Calkins in east-central Washington (1905), Schwennesen and Meinzer in the Quincy Basin (1919), Newcomb in

the Walla Walla River Basin (1951), Brown near Pilot Rock, Oregon (1955), Hart and Newcomb in the Tualatin Valley of Oregon (1956), and Hogenson in the Umatilla Basin of Oregon (1957). In his discussion of groundwater occurrence, Newcomb (1959) noted that groundwater is present in separate, compartmentalized zones in the CRBG, with little vertical connection between any two water-bearing zones that are separated by an individual basalt flow:

> "The completely massive lava flow and the flow whose center part is massive do not commonly allow water to pass across them readily in a vertical direction. These tight strata of massive rock commonly form tabular separation between the water-bearing zones. This type of separation of the water-bearing zones is demonstrated by the perched position of some of the groundwater in surficial deposits like the Palouse Formation, and by the "Layered" occurrence of seeps and springs in canyons or hillsides. Water can pass vertically through the cubically fractured "brickbat" type of flow; this is especially evident near the surface, in wells and excavations. Apparently the joints and other fractures, which are partly open in most flows at and near the surface, are at least partly closed deep underground.
>
> The water-bearing zones are commonly identified in wells as more easily drilled parts of the basalt sequence. Changes in the static water levels, as different aquifers are penetrated during the drilling of wells, are further evidence of the tabular separation of the permeable zones in the basalt." [pg 6]

Newcomb (1959) noted that changes in water levels of as much as 100 feet were being commonly observed when drilling over a depth interval of just a few feet. These changes occurred when drilling through the bottom of a massive basalt flow and into the underlying interflow zone. Newcomb noted that in some cases the water level rose, sometimes to artesian conditions. He concluded that the increases in the static water level indicated that the massive basalt flow interiors were acting as confining layers for groundwater in the underlying interflow zone. Newcomb stated that the occurrence of confining conditions is in part "an expression of the resistance to percolation" into a given water-bearing zone from overlying or underlying water-bearing zones.

In his 1959 publication, Newcomb also noted that long fracture zones transecting the basalt section could be acting as effective groundwater barriers because of slippage, shearing, and the resulting formation of clayey gouge along fault planes. Newcomb concluded that "the fundamental pattern of aquifers in the Columbia River basalt is that of separate tabular zones, each of which is interrupted in many places but nevertheless is of rather widespread lateral extent." [pg 7] Soon after this publication, the USGS published a more detailed study of the influence of subsurface structures on groundwater movement in basalt (Newcomb, 1961). This study noted that high-yielding basalt wells were being found in structurally down-warped portions of the CRBG, including at Walla Walla, Cold Creek, and Ephrata in central and eastern Washington. Newcomb (1961) observed that these wells were situated on the upgradient side of fault zones, and he concluded that the faults were acting as barriers and subsequently creating "reservoirs" of

groundwater that were supporting groundwater pumping from high-yielding wells. While this study did not examine conditions within the Odessa Subarea, because of the lack of deep irrigation wells at the time, it was the first study to observe that geologic structures can influence groundwater occurrence significantly at both the local and regional scale.

Six years after publication of the first focused study of the Odessa Subarea (Garrett, 1968, WSB-31), two subsequent studies were conducted cooperatively by the State and the USGS to update the status of groundwater level conditions and further examine the hydrogeologic mechanisms controlling groundwater yields and water level trends in the region (Luzier et al., 1968, WSB-36; Luzier and Burt, 1974, WSB-33). Key topics and findings discussed in these studies, particularly in WSB-33, were as follows:

- The studies concluded that the major CRBG aquifers in east-central Washington, including in the Odessa-Lind area, are present in the interflow zones and that groundwater in these aquifers is normally confined by dense basalt of low permeability. The study authors also noted that the direction of groundwater movement (generally from the northeast to the southwest) coincides with, and is controlled by, the regional dip of the basalt flows.
- The study authors prepared groundwater contour maps for shallow and deeper basalt aquifer zones, from which they identified the presence of localized areas where the horizontal hydraulic gradient is steep, with flatter gradients immediately upgradient to the east (see Figures 3, 4, and 5). Referring to similar studies elsewhere in the CRBG by Newcomb (1961, 1969), Luzier and Burt (1974) concluded that buried, subsurface structural features likely exist at the location of the steep gradient, and that such structures, while not identifiable from drilling or borehole geophysical logs, are acting as "groundwater dams" that limit the amount of groundwater that can continue moving to the west, as reflected by marked changes in the hydraulic gradient over short distances. They estimated that a groundwater dam, or series of dams, was present along a northwest-southeast trending line just east of the East Low Canal. After mapping the amount of groundwater level declines and the amount of pumping in both the shallow and deeper zones throughout the Odessa-Lind area, Luzier and Burt (1974) found that the measured annual rate of water level decline in the deep zones from 1965 through 1969 closely coincided with the rate predicted from theoretical calculations that assume a groundwater dam is present just east of the canal.
- Luzier and Burt (1974) also noted that many anecdotal reports in the Odessa-Lind area, along with data from a number of borehole geophysical logs, showed the occurrence of downward cascading groundwater in wells that were open (uncased) through multiple basalt layers. Luzier and Burt (1974) concluded that while some natural connection may exist vertically between various aquifer zones in the CRBG, the amount of natural vertical connection is insignificant compared with the artificial vertical connection created by the presence of uncased boreholes. They referred to this artificial vertical connection as a "short circuit" between aquifer zones and also noted that downward drainage via uncased wells continues from shallow zones regardless of whether or not a well is actively

pumping at any given time. In their conclusions, Luzier and Burt (1974) stated that "the short-circuiting effect of deep wells is the rule rather than the exception" [pg 50]. Additionally, from an examination of hydrographs in wells constructed only in the shallow zones, Luzier and Burt (1974) observed that the large number of open boreholes and "short circuits" was causing steady declines in shallow zone groundwater levels, and that this could create "acute" problems for shallow domestic and stock wells, many of which they noted had already gone dry. Luzier and Burt (1974) also expressed concern about the potential for reduced streamflows; they noted that data from a stream gage on Crab Creek (at Irby) was suggesting that such depletion might have already begun at that time.

- Luzier and Burt (1974) also predicted that the continuation and expansion of pumping in the Odessa-Lind area would likely cause declines in groundwater levels nearby, including in the Canniwai Creek drainage and near the towns of Wilbur and Ritzville. They concluded that groundwater withdrawals in the Odessa-Lind area at that time were already outpacing the rate of natural recharge, and that the initially high yields of the basalt aquifers was fostering over-development and depletion of the regional CRBG groundwater resource in the area. Their report expressed concern that communities, irrigators, and industries were becoming committed to, and dependent on, the CRBG groundwater resource and would eventually feel the long-term effects of overpumping.

Brown (1978, 1979, and 1980) reviewed geophysical logs and water level data from a State network of observation wells and concluded that the CRBG groundwater flow system could be conceptualized as essentially a two-layer groundwater flow system, rather than several separate confined aquifer systems. Brown (1978) stated that along the southwest side of the Odessa-Lind area, he could not find evidence of the groundwater dams described by Luzier and Burt (1974) because he found it possible to correlate basalt flows on each side of the location where the dams were thought to be present (Brown, 1978, page 31). However, he acknowledged that there was good hydrologic evidence of the presence of the dams, despite the difficulty obtaining direct geologic evidence. Brown (1978) also stated that correlation of basalt flows over large areas was only possible in the deepest basalt flows, and not in shallower flows, which he concluded must have significant vertical hydraulic interconnection because of their discontinuous nature horizontally. He concluded that the controlling factors for groundwater occurrence and movement therefore "may not be wholly stratigraphic." (Brown, 1980, page 17.) Yet he also stated that the study left no doubt that understanding basalt stratigraphy is necessary in order to understand basalt hydrology. In the third report, Brown (1980) called for further research, including packer tests, geochemical analysis, and age dating, to better understand the controlling factors. These research activities were later conducted in the Pasco Basin at the Hanford Site, as part of hydrogeologic characterization studies for the proposed Basalt Waste Isolation Project (BWIP) (Gephart et al., 1979; Myers and Price, 1979, 1981; Price, 1982; Graham et al., 1984; USDOE, 1988) as well as later research efforts at Hanford (Spane and Webber, 1995; Newcomer et al., 2002; Reidel et al., 2002). The findings of those studies are discussed below in the section of this report titled "Geologic Controls on Groundwater Occurrence and Movement".

The next set of studies in the eastern half of GWMA was conducted by Ecology in the Sinking Creek watershed of northern Lincoln County, beginning in the early 1980s. The study, which initially produced four reports (Wildrick, 1982, 1985, 1990, and 1991), examined potential causes for decreased streamflows in Sinking Creek, focusing in particular on whether CRBG groundwater pumping was responsible for the decreases. After reviews by Ralston (1991a, b), Ecology conducted a more detailed study of possible pumping effects on spring flows feeding the creek (Covert, 1995). Together, these studies identified an apparent response of spring flows and spring water levels to local and regional-scale pumping from deep CRBG aquifer zones. One of the larger springs (Baring Spring) showed apparent flow variations in response to groundwater pumping with a lag of three to four days (Covert, 1995). This included recovery when pumping temporarily stops in the mid-summer during the first wheat harvest of the year, when little if any rainfall is occurring (Covert, 1995, page 10). However, despite this apparent response, long-term monitoring in the Sinking Creek watershed showed no further declines in groundwater levels in the uppermost basalt even though declines continued over time in deeper basalt zones (Wildrick, 1990; Ralston, 1991a). Additionally, Ralston (1991b) expressed a belief that wells distant from this area (for example, near the Town of Wilbur) could potentially be contributing as much to the changes in water levels and spring flows in the Sinking Creek area as the wells close to Sinking Creek.

Cline (1984) conducted an update of pumping volumes and groundwater level declines through 1981. This study evaluated an area roughly four times larger than the area studied by Luzier et al. (1968). Cline concluded that the lack of complete water level recovery in many areas after the irrigation season was an indication that pumping was already exceeding the amount of recharge occurring to the CRBG basalt aquifers. He noted that groundwater levels were declining at a faster rate during the period 1977-1978 than 10 years earlier. He also noted that in some locations, groundwater that had once been in the uppermost aquifers had drained away, as evidenced by the drying up of domestic and stock wells that tapped only these aquifers. While Cline's analysis was largely focused on quantifying trends in groundwater levels and groundwater pumping volumes, he made two observations that are relevant to understanding the degree of vertical interconnection between different water-bearing zones in the CRBG:

- Cline pointed out a particularly striking example of how deepening a production well can cause a significant change in its static water level as it is penetrated into deeper water-bearing zones in the CRBG. His example was a well in eastern Grant County (T21N, R30E, 3E1) that was deepened from a depth of 451 feet to a depth of 651 feet in 1965, and which subsequently experienced an instantaneous decline in the static water level of approximately 150 feet (see Figure 6).
- Cline also studied the water level data from the installation of nested observation wells installed by the State and the USGS.
    - For the Odessa observation well (T20N, R33E, 16E1-E6), the static water level was at a depth of about 140 feet in the open borehole prior to construction of each individual piezometer. This water level was the

composite of the various water levels from each contributing water-bearing zone over the 750-foot thickness of the open hole. Cline noted that once the five individual piezometers were constructed, the water levels in four of the piezometers were markedly different, while the water level in the fifth piezometer appeared to be similar to that of the open borehole (see Figure 7).

- At the Basalt Explorer observation well, Cline noted that the piezometers initially showed static water levels that were similar to the water level previously observed in the open borehole. He attributed this similarity to a lack of nearby pumping from each zone being monitored. However, as shown in Figure 8, a steady decline in the borehole water level was observed for 8 years prior to installation of the piezometer network, and this trend continued during the early to mid 1970s in one of the three piezometers, but not in the other two.

From 1982 through the 1990s, under its Regional Aquifer-System Analyses (RASA) program, the USGS estimated groundwater recharge rates and conducted modeling work and other studies to understand the hydrology and water budget for the Columbia Plateau (Bauer and Vaccaro, 1990; Hansen et al., 1994; Vaccaro, 1999; Bauer and Hansen, 2000).

- One of the first publications containing a water budget analysis under this study was by Bauer and Vaccaro (1990), who estimated the average annual groundwater recharge rates for each of 53 subareas within the Columbia Plateau using a deep-percolation computer model. This model estimated deep percolation (groundwater recharge) rates under predevelopment and current land-use conditions. In Lincoln and Adams Counties, their analysis of five separate areas indicated that average annual recharge in eastern GWMA is less than 2 inches and could be as low as 0.13 inches under undeveloped conditions. The study concluded that irrigation had increased deep percolation by 1.1 to 1.6 inches in two areas and may have slightly decreased deep percolation in the other three areas (by 0.06 to 0.33 inches).
- Hansen et al. (1994), Vaccaro (1999), and Bauer and Hansen (2000) presented the final RASA project findings of regional hydrologic conditions in the Columbia Plateau, including the results of numerical model simulations of pre-development conditions and conditions that might occur if the pumping pattern from 1983 through 1985 were to continue into the foreseeable future, with and without expansion of the CBIP. Of particular relevance to the current study of the hydrogeologic system in GWMA were the following observations and conclusions presented in these two reports:
    - Bauer and Hansen (2000) estimated that recharge on non-irrigated lands is zero in low-elevation portions of the Columbia Plateau that receive less than 8 inches of precipitation annually. On irrigated lands, Bauer and Hansen (2000) estimated that annual irrigation recharge to groundwater during the mid-1980s was on the order of 10 inches per year in areas

irrigated with surface water, and 1.5 to 2 inches per year in areas irrigated with groundwater. This difference is likely attributable to the different irrigation practices in use at that time (flood irrigation within the CBIP service area and center-pivot irrigation elsewhere in the groundwater-dependent areas). Much of the CBIP service area has since switched to pivot irrigation, which means current recharge rates are likely lower at this time than at the time of the RASA study.

- The RASA study concluded that the upper portion of the Grande Ronde Basalt is present beneath the Spokane River at the Lincoln/Spokane county line. However, the study noted the occurrence of a groundwater divide south of the river and concluded that any groundwater in the Grande Ronde Basalt just south of the river was moving northwards to the river, rather than moving south from the river into GWMA (Lane and Whiteman, 1989; Bauer and Hansen, 2000).
- The model simulated that as of 1985, the effect of groundwater development (compared with pre-development conditions) had been to decrease groundwater discharges to upper Crab Creek by about 38 cubic feet per second (cfs) while almost doubling the amount of groundwater discharge to lower Crab Creek (from 76 cfs under pre-development conditions to 145 cfs in 1985; Bauer and Hansen, 2000).
- For two of the three CRBG formations (Saddle Mountains Basalt and Wanapum Basalt), the USGS designed the model by lumping all of the individual flows and members of a given CRBG formation into a single hydrostratigraphic unit for simulation purposes. For the deepest CRBG formation (the Grande Ronde Basalt), the model used a similar lumping process, but simulated the Grande Ronde as two systems (shallow and deep). While this "lumping" approach was helpful for simplifying the natural system in a manner that made computer simulations feasible, given the computing power available at that time (the mid-1990s), it resulted in a model design that simulated uniform geologic conditions and hydraulic properties through the full thickness of an individual formation (hundreds, or even a few thousands, of feet) at any given location. As a result, the entire thickness of the CRBG, which is estimated to be as much as 2 miles in southwestern GWMA, was represented with only four model layers, even though it is comprised of more than 300 distinct basalt flows and interflow zones (Tolan et al., 1989).
- The model simulated moderate to significant vertical interconnection between CRBG formations, including an inherent assumption that deeper portions of the CRBG are discharging groundwater to the Columbia River at the center of the basin, where the CRBG is thickest. However, this assumption contradicts the findings of studies conducted at the Hanford Site (USDOE, 1988), which suggest that any such upwards movement of groundwater must be occurring very slowly, as discussed later in this report.

- Over the entire simulation area, the model estimated that the volume of water moving vertically into and out of the upper Grande Ronde Basalt is equivalent to 62 percent of the total recharge to this formation. In the Wanapum Basalt, the model estimated that the total water volume moving vertically to or from adjoining formations is equivalent to 126 percent of its total recharge.
- The use of thick model layers and the assumed strong interconnection to surface water discharge zones (particularly the Columbia River) appeared to cause difficulties calibrating the model. During the process of calibrating the vertical connection between individual basalt layers and between the basalt and surface water bodies, the authors reported considerable difficulty in obtaining reasonable estimates for this connection while also retaining the ability to reproduce field-measured vertical gradients and groundwater elevations (Bauer and Hansen, 2000).
- Another apparent cause of model calibration difficulties was the use of a time-averaged (or "steady-state") approach to running the groundwater model. This approach assumes that groundwater discharge is balanced by groundwater recharge throughout the entire simulation area and in all model layers. While the authors ran the model in a manner that sought to recognize the observed changes in groundwater storage during their calibration period (spring 1983 to spring 1985), they nevertheless encountered calibration difficulties in the Odessa Subarea. In particular, the initial model runs estimated that some portions of the Wanapum Basalt that were still under development were supposedly dewatered by the early 1980s. To correct this problem, the authors concluded that it was necessary to increase the amount of recharge to the Wanapum Basalt beyond the initial estimates reported by Bauer and Vaccaro (1990). Bauer and Hansen (2000) attributed this increased recharge volume to the surface water that is present at times in the coulees crossing this area. However, it is possible that the model's assumption of equal groundwater recharge and discharge rates, which is an inherent assumption in any steady-state model run, was creating an artificial need for more simulated recharge to balance out the simulated pumping rates and storage changes, which were based on historical pumping and water level records.
- Among its many uses, the model was used to estimate the amount of further water level decline that might occur in the Wanapum Basalt under the continuation of the water management practices occurring in 1985, with no expansion of the CBIP. The model estimated that the Wanapum Basalt would become dewatered in localized areas in southern Lincoln County and western Adams County. The model also predicted that large areas in the Columbia Plateau, including some areas in eastern GWMA, would see no more than 10 feet of additional water level decline. Like the model calibration runs, this simulation assumed that the CRBG groundwater system would eventually reach a steady-state condition, in which total groundwater discharge within the model area is the same

magnitude as groundwater recharge. This simulation therefore assumed that sufficient groundwater recharge would occur on a regional scale to eventually balance the 1983-1985 volume and spatial distribution of pumping, even if this pumping were to continue indefinitely into the future.

In summary, the earliest historical studies of the hydrogeologic system in GWMA and surrounding areas concluded that the CRBG groundwater system is significantly compartmentalized, except where wells artificially cross-connect two or more water-bearing interflow zones. This early view of the hydrogeologic system was derived primarily from inspections of geologic logs and construction diagrams for production wells, and from water level data collected in the 1970s during and immediately after construction of multi-level piezometers for the State observation well network. More recently, numerical models of groundwater recharge and groundwater flow have been developed. These tools have been regional and sub-regional in scale and subsequently have "lumped" many individual CRBG flows into single layers for the purposes of simulating horizontal and vertical groundwater flow in the CRBG, as well as the connection of the CRBG to surface water. This more recent approach to representing the CRBG groundwater system is at odds with the findings from most early studies, as well as local knowledge regarding well and aquifer system responses to well deepenings and continued pumping from the CRBG, particularly in the eastern portion of GWMA. The nature of the vertical interconnection and lateral controls on groundwater occurrence and movement are fundamental to the description and management of CRBG groundwater, especially in the context of understanding its connection to surface water and the mechanisms by which artificial recharge projects could conceivably be conducted in the future. While the purpose of this report is to present and discuss the available water level data in GWMA, and in particular the Odessa Subarea, as well as the interpretations about groundwater conditions that can be derived from those data, such discussions first require a fundamental review of the current scientific understanding of the types of geologic features that control groundwater occurrence and movement, including groundwater recharge and discharge. This topic is discussed in the next section of this report.

GEOLOGIC CONTROLS ON GROUNDWATER OCCURRENCE AND MOVEMENT

As discussed previously, the Subsurface Geologic Mapping and Hydrogeologic Assessment project, of which this report is a part, has been funded by the Legislature for the purpose of describing the dynamic relationship between groundwater and surface water inside GWMA. Evaluating groundwater level trends and connection between aquifers is a key component of this study, and includes significant reliance on the newly-acquired subsurface geologic mapping conducted in Lincoln County under this project. Details regarding the subsurface geologic mapping work conducted under the current study are contained in the companion documents to this report that present the geologic framework within GWMA (GWMA, 2009a, 2009b). The geologic framework has been developed by combining new subsurface mapping work, conducted under the Subsurface

Tertiary sediments, as the geochemical signatures cannot be explained solely by considering the geochemical reactions that occur between basalt and groundwater. Based on this and other information, USDOE (1988; p 3.9-173) concluded that "the concept that significant, areally distributed, vertical groundwater flow through cooling and tectonic fractures is a general phenomenon in the central Columbia Plateau probably is incorrect based on hydrochemical data." The study report concluded that faults or fracture zones are more likely to be the primary conduits for vertical movement of groundwater.

While USDOE (1988) did not estimate the rates of groundwater exchange between the Grande Ronde Basalt and the overlying Wanapum Basalt, it is possible to estimate the general range of time frames over which such exchanges might occur in the Hanford Site area. USDOE (1988) reported that the magnitude of the upward vertical gradients in the Wanapum Basalt and Grande Ronde Basalt are approximately 10^{-3} feet per foot beneath the Hanford Site. Given the range of vertical hydraulic conductivity values estimated at the Hanford Site (1×10^{-9} to 3×10^{-3} feet per day [USDOE, 1988]), the equivalent depth (or volume per unit area) of water moving upwards from the Grande Ronde Basalt to the Wanapum Basalt is likely on the order of 1×10^{-12} to 3×10^{-6} feet of water each day in this general area. This in turn suggests that under the conditions observed at the Hanford Site, a hypothetical 1-foot high column of water would take between 1,000 years and 3 billion years to migrate vertically out of a basalt interflow zone in the Grande Ronde Basalt. This calculation indicates that any upwards movement of groundwater from the Grande Ronde Basalt to the overlying Wanapum Basalt near the Columbia River probably occurs extremely slowly. This finding in turn is consistent with the understanding that limited recharge is occurring regionally to the Grande Ronde Basalt, except possibly along the Snake River in eastern Franklin County.

PRINCIPAL OBSERVATIONS AND CONCLUSIONS

Long-term water level records for CRBG wells in GWMA indicate that groundwater levels in shallow and deep CRBG water-bearing zones have declined markedly in Adams County and much of Lincoln County since the onset of groundwater development for irrigation purposes in the 1960s. The data indicate that groundwater levels in this part of GWMA are continuing to decline as time goes on, particularly in the deepest water-bearing zones that have been tapped for groundwater development (in the upper and lower Grande Ronde Basalt).

The data and interpretations provided by past and present geologic studies, hydrologic evaluations, groundwater level analyses, and water quality (geochemical, age-dating and isotopic) studies, collectively provide a consistent understanding of the geologic framework of the Columbia Plateau and the behavior of the many CRBG aquifers that comprise the local basalt groundwater resource inside GWMA. The groundwater recharge and flow system in the CRBG aquifers underlying the GWMA is characterized by a series of separate, water-bearing layers found in interflow zones at the tops and bottoms of individual basalt flows. These interflow zone layers, or aquifers, are separated by the dense, solid, unfractured basalt rock that forms the bulk of the basalt

section in the Columbia Basin. The aquifers in the interflow zones can receive recharge where they are at and near the ground surface, in direct hydrologic connection with surface water and high precipitation areas. An interflow zone can also receive recharge if its outer margin is buried, in which case the lateral "pinching out" of the interflow zone allows upgradient groundwater in adjoining interflow zones to subsequently recharge the pinched-out zone at its margin. Groundwater in the interflow zones moves more-or-less parallel to stratification along the tops and bottoms of the individual dense basalt flows. The water table elevation in a given interflow zone is dictated by the vertical positions (elevations) of the interflow zone and the elevation of the recharge area for the interflow zone. The horizontal hydraulic gradient is dictated by the slope (dip) of the top of the underlying dense basalt flow. In the central portion of the study area (away from its margins), vertical movement of groundwater through the dense basalt flow interiors is extremely small in magnitude, occurring primarily in coulees and artificially through wells that are constructed as uncased boreholes open to multiple interflow zones.

In the Columbia Basin, the CRBG groundwater system is compartmentalized not only vertically, but also laterally. Folds and faults commonly act to restrict lateral groundwater movement and can almost act as barriers to lateral groundwater flow, especially in the interior of the basin. An example of this is a monoclinal flexure zone that was first inferred by Luzier and Burt (1974) and has now been identified by the Subsurface Geologic Mapping and Aquifer Assessment Project (see Plate 2). This monoclinal flexure zone coincides with the occurrence of significant groundwater declines (east of the flexure) with areas where lesser declines have occurred to the west. Other examples of features that can restrict lateral groundwater movement include a suspected dike system along Cow Creek in eastern Adams County and a dike system that has been mapped near the City of Cheney, just east of GWMA.

Generally speaking, the Wanapum Basalt and the Grande Ronde Basalt have some important differences in their water-bearing capability, the age of their waters, their ability to receive recharge from surface water sources, and thereby their ability to sustain groundwater pumping on a long-term basis. Specifically:

1. In eastern GWMA, the Wanapum Basalt has notably lower water-yielding capability, and therefore a lower apparent permeability, than the Grande Ronde Basalt. This is indicated by the large number of production well deepenings in the area, as well as by data from specific capacity tests conducted in the State observation well network. Water level data from the State observation well network also show that the initial declines in Wanapum Basalt groundwater levels in eastern GWMA have largely stabilized during the past 3 or more decades, whereas groundwater levels in the Grande Ronde Basalt are continuing to decline markedly in this same area.
2. From the perspective of water supply development and sustainability, the Wanapum Basalt and the Grande Ronde Basalt have virtually no interconnection in the interior of GWMA, other than through uncased boreholes. At the State observation wells, trends in water levels over time are distinctly different in the Wanapum Basalt members than in the Grande Ronde Basalt. Water levels in the

Wanapum Basalt have generally shown only minor fluctuations from year to year since the early 1970s, with little if any long-term changes occurring as groundwater pumping has shifted into the Grande Ronde Basalt during the past few decades. Compared with the Wanapum Basalt, the Grande Ronde Basalt shows much deeper water levels with distinct declining trends in recent years. If the Grande Ronde Basalt members were highly interconnected with the various members of the Wanapum Basalt, then the trends and water levels would be similar. Yet this is not the case, which means that the Wanapum Basalt is not significantly recharging the Grande Ronde Basalt, except where uncased boreholes create artificial cross-connections. This finding is consistent with data from the Hanford Site (USDOE, 1988), which is located in an inferred regional discharge zone for Wanapum Basalt and Grande Ronde Basalt groundwater. The Hanford Site data suggest that it would take between 1,000 and 3 billion years for a hypothetical 1-foot water column to migrate upwards out of the Grande Ronde Basalt, given the typical values for the vertical hydraulic gradient and vertical hydraulic conductivity of the basalt flow interiors. The data at Hanford and in GWMA are consistent in that they provide substantial evidence that natural vertical connection between the Wanapum Basalt and the Grande Ronde Basalt is minimal in the inferred regional groundwater discharge area at and near Hanford and also in the interior of the Columbia Basin.

3. Natural interconnection may exist at the outer margins of the Wanapum Basalt, where in some locations the underlying Grande Ronde Basalt may extend a limited distance outward from the margin of the Wanapum Basalt, closer to potential recharge sources. However, any such areas where a natural interconnection exists are far from the areas where the largest water level declines have occurred (in the Odessa Subarea). Additionally, the subsurface geologic mapping conducted under this study has demonstrated that the Wanapum Basalt and Grande Ronde Basalt aquifers are not recharged by the Columbia and Spokane Rivers. Furthermore, statistical analyses of the geochemical data for the Grande Ronde Basalt indicate that the water types are as highly evolved near the eastern margin of GWMA as in the interior of the Odessa Subarea, which suggests that any recharge to the Grande Ronde Basalt from the east and north is extremely limited in magnitude.

4. The Wanapum Basalt tends to have younger groundwater than the Grande Ronde Basalt. Groundwater in Wanapum Basalt members is recharged by 1) streamflows in coulees, primarily in eastern GWMA where the Wanapum Basalt is exposed in the coulee floors, and 2) and by canal systems that penetrate into the Wanapum Basalt in certain areas in the central and western portions of GWMA (for example, near Moses Lake and Royal City). The geologic, water level, and age-dating studies together indicate that modern artificial recharge is occurring to the Wanapum Basalt via artificial and natural pathways. Because of the significant exposures of shallow (Wanapum) basalt in the coulee floors of northern and eastern GWMA, additional artificial recharge in the coulee floors would likely increase groundwater elevations in the Wanapum Basalt.

5. As first discussed by Luzier and Burt (1974), uncased wells are a significant cause of historical groundwater levels declines in the Wanapum Basalt members, because the non-pumping water levels in these members are much higher than groundwater levels in the underlying Grande Ronde Basalt, which is the target of many irrigation and other production wells in GWMA. As a result, drainage of groundwater from the shallow zones via uncased boreholes is a passive process, occurring whether or not the well is actively pumping from its deep target water-bearing zone in the Grande Ronde Basalt.

6. Variations in rainfall do not explain the historical declines in groundwater levels and, where observed (i.e., Sinking Creek and Crab Creek), the historically observed declines in streamflows. The past 40 to 50 years of groundwater development have not been accompanied by predominantly drier-than-normal conditions.

7. Groundwater in the Grande Ronde Basalt, both in areas of significant declines and other areas, is very old and may be receiving little natural recharge under present conditions, except possibly in Franklin County where the Grande Ronde Basalt appears to be in connection with the Snake River. In the Odessa Subarea, radiocarbon and stable isotope data, and the absence of detectable tritium and CFCs, indicate that groundwater produced from deep irrigation wells completed in lower Grande Ronde Basalt members is pre-Holocene (more than 10,000 years old), indicating that it recharged the Grande Ronde Basalt prior to the late-Pleistocene Missoula Floods. Studies of the cooling joints that are present in the basalt flow interiors have concluded that water can move through these joints soon after emplacement of the basalt, but that the joints seal up over time as a result of this movement. Consequently, it is possible that many centuries, or thousands of years, have passed since appreciable recharge occurred to the Grande Ronde Basalt. This means that prior to groundwater development, the water-bearing zones in the Grande Ronde Basalt essentially constituted a subsurface "reservoir" with little to no significant inflows or outflows (i.e., ambient predevelopment groundwater recharge and groundwater discharge rates were extremely small in magnitude). With the onset of groundwater development, the water level data indicate that significant discharges of groundwater by pumping activities have not been balanced by groundwater recharge, particularly in the Odessa Subarea. This observation, the radiocarbon dating, and the cooling joint studies together indicate that the post-development groundwater budget in Adams, Grant, and Lincoln counties can be described as "discharge via pumping is approximately equal to the change in groundwater storage, with little or no subsequent recharge of the aquifer system".

8. Deepening wells is only a temporary solution to mitigating declining groundwater levels and well yields. In past years, the increase in the number of wells being deepened into the Grande Ronde Basalt likely caused an increase in the volume of water draining out of the Wanapum Basalt in some areas. Additionally, the increase in pumping from the Grande Ronde Basalt, is tapping ancient sources of water that receive little if any recharge near groundwater pumping centers or even at the margins of GWMA.

9. Items 1 through 8, taken together, indicate that while the existing groundwater supplies in the Grande Ronde Basalt may remain viable for continued use in the near future, these supplies are not reliable or sustainable in the long-term under current water management programs, particularly in the portions of Adams County and southern Lincoln County that lie east of the flexure zone and west of the Cow Creek drainage. While the long-term outlook for Grande Ronde Basalt groundwater supplies in this portion of GWMA is not promising, increasing the groundwater levels in the Wanapum Basalt via artificial recharge may be possible in this same area because of the prevalence of Wanapum Basalt exposures in coulee floors and the northern channeled scablands of northern Lincoln County.

These findings are based on the data and interpretations provided by past and present studies of the geologic characteristics, groundwater level trends, and groundwater ages inside GWMA. The confidence in these findings has been substantially increased by the recent completion of subsurface geologic mapping in northern Lincoln County, and also by the consistency of these findings with many of the previous hydrogeologic studies conducted in the Columbia Basin. The findings in this report thus constitute a hydrogeologic conceptual model for the CRBG aquifer system, which provides a working framework for future monitoring and management of the regional groundwater resource, including the formulation, analysis, and implementation of resources management strategies.

ACKNOWLEDGEMENTS

The authors would first like to thank Paul Stoker, the Executive Director of the Columbia Basin GWMA, for his tireless support and encouragement throughout the various GWMA projects where the ideas described here have been refined, polished, and debated. On the GWMA project team we want to thank Walt Burt, Dimitri Vlassapoulos, Mike Riley, Vern John, Steve Reidel, Jon Travis, Jesse Manley, Susan Loper, and Adrienne Lindsey, all of whom contributed in no small way to the ultimate completion of this report. We would also like to thank the well owners and drillers who live and work in GWMA and provided us with invaluable information and insights into how these aquifers work. Finally, thanks to the hydrogeologists who provided us with thoughtful reviews on various editions of this paper, Jim Anderson, Vern Johnson, Steve Reidel, and Kayti Didrickson. The work done for the preparation of this report was funded by an appropriation from the Washington Legislature to the GWMA by way of the Department of Ecology.

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MEMORANDUM

TO: Water Resources Commission

FROM: Justin Iverson, Groundwater Manager JI
Brenda Bateman, Technical Services Division Administrator BB

SUBJECT: Agenda Item A, March 15, 2018
Water Resources Commission Meeting

Review of Conditions in Critical Groundwater Areas

I. Introduction

There are seven critical groundwater areas in Oregon, which require periodic review of conditions to evaluate the effectiveness of the designation in achieving reasonably stable groundwater levels. This is an informational overview for Commission discussion.

II. Background

A critical groundwater area (CGWA) may be designated to address groundwater supply, quality, or thermal issues. A designation under ORS 537.730-740 allows the Commission to take a number of corrective actions necessary to address groundwater issues, which may include reducing groundwater pumping under existing permitted or certificated rights. Oregon currently has seven existing critical groundwater areas shown in Attachment 1, which were designated because of water supply issues. Table 1 on the next page summarizes Oregon's seven critical groundwater areas.

All seven critical groundwater areas in Oregon were designated by order of the State Engineer or Water Resources Director pursuant to the 1955 statute. Current statutes, codified in 1991, allow critical groundwater areas to be established by rule.

New groundwater uses in an area may also be managed by withdrawal (ORS 536.410) or classification (ORS 536.340). Groundwater areas designated under these administrative controls (see Attachment 1) are not addressed in this report.

Recommended Action 1.A. of the 2017 Integrated Water Resources Strategy (IWRS), calls for conducting additional groundwater investigations, including "evaluating groundwater administrative areas." The IWRS notes that evaluations could include a review of: water-level trends, boundary accuracy, and whether designated areas are meeting the goals of groundwater stabilization, groundwater recovery, and protection of existing water users. This report focuses on water-level trends only.

Table 1: Summary of Critical Groundwater Areas in Oregon

Restricted Area & Effective Date	Affected Aquifer or Formation	Allowable Uses	Other Limitations	Affected Area	Affected County	Source
Cow Valley Nov. 12, 1959	Alluvial aquifer and underlying volcanic rocks and sediments	Exempt uses only		33 sq. mi.	Malheur	Special Order Vol.10 Pg 216
The Dalles Dec. 11, 1959	Columbia River Basalt	Exempt uses only		21 sq. mi.	Wasco	Special Order Vol.10 Pg 247
Cooper - Bull Mtn May. 17, 1974	Columbia River Basalt	Exempt uses only	Domestic exemption on parcels larger than 10 acres	41 sq. mi.	Washington	Special Order Vol.24 Pg 370
Ordnance Basalt April 2, 1976	Columbia River Basalt	Exempt uses only		175 sq. mi.	Morrow Umatilla	Special Order Vol.27 Pg 40
Ordnance Gravel April 2, 1976	Alluvial aquifer	Exempt uses only		82 sq. mi.	Morrow Umatilla	Special Order Vol.27 Pg 40
Butter Creek Jan. 27, 1986	Columbia River Basalt	Exempt uses only	Annual Allocation to "Sustainable Annual Yield"	274 sq. mi.	Morrow Umatilla	Special Order Vol.40 Pg 1
Stage Gulch May 15, 1991	Columbia River Basalt	Exempt uses only	Annual Allocation to "Sustainable Annual Yield"	183 sq. mi.	Umatilla	Special Order Vol.45 Pg 278

III. Discussion

Water Rights Largely Remain Valid

In all seven critical groundwater areas (CGWAs), the number of valid groundwater rights remains near the same level that resulted in the original supply concerns. Many of these rights are not fully exercised for voluntary reasons, which may include changes in land use, implementation of conservation measures, or development of new supplies. Some junior rights in the Butter Creek and Stage Gulch CGWAs are not exercised by reason of critical area control, and some municipal rights in the Cooper-Bull Mountain area were reduced by the special order. While pumping has generally declined since critical area designation, the underlying water rights are largely still valid and potential remains for them to be exercised directly or by transfer in the future.

Water Level Responses Vary After CGWA Designation

The Cow Valley CGWA (Attachment 2) in the Malheur Basin was the first CGWA designated in the state. Groundwater levels in this CGWA recovered between about 1980s and early 1990s, but have declined since that time. In 2015, the Department received a complaint from two permit-exempt groundwater users in Cow Valley, citing groundwater declines forcing them to lower pumps in some wells. Exempt use wells within Cow Valley are junior to all certificated uses and are completed to comparatively shallow depths. Given these facts, exempt well users may need to deepen wells that do not fully penetrate the Cow Valley aquifer system to maintain their junior permit-exempt groundwater use.

Groundwater levels in two of the oldest CGWAs (The Dalles, Attachment 3; and Cooper-Bull Mtn., Attachment 4) have recovered in response to reduced pumping. In Cooper-Bull Mtn., three aquifer storage and recovery (ASR) projects have also supported water level recovery. Similarly, groundwater levels in the Ordnance Gravel CGWA (Attachment 5) have stabilized with the implementation of the County Line aquifer recharge (AR) project.

However, groundwater level declines have generally continued, albeit generally at a slower rate, in the three Columbia River Basalt critical groundwater areas in the Umatilla Basin (Ordnance Basalt, Attachment 6; Butter Creek, Attachment 7; and Stage Gulch, Attachment 8). Annual groundwater pumping is a fraction of that permitted under the existing water rights for these areas, controlled by an annual allocation process defined in the Umatilla Basin Rules (OAR 690-507). Considerable staff effort is expended each year on the groundwater allocation process for the Butter Creek and Stage Gulch critical areas. Two irrigators have developed agricultural ASR projects in the Butter Creek CGWA to support operation of their farms, while others have investigated the potential for an ASR project and found it to be infeasible.

IV. Summary

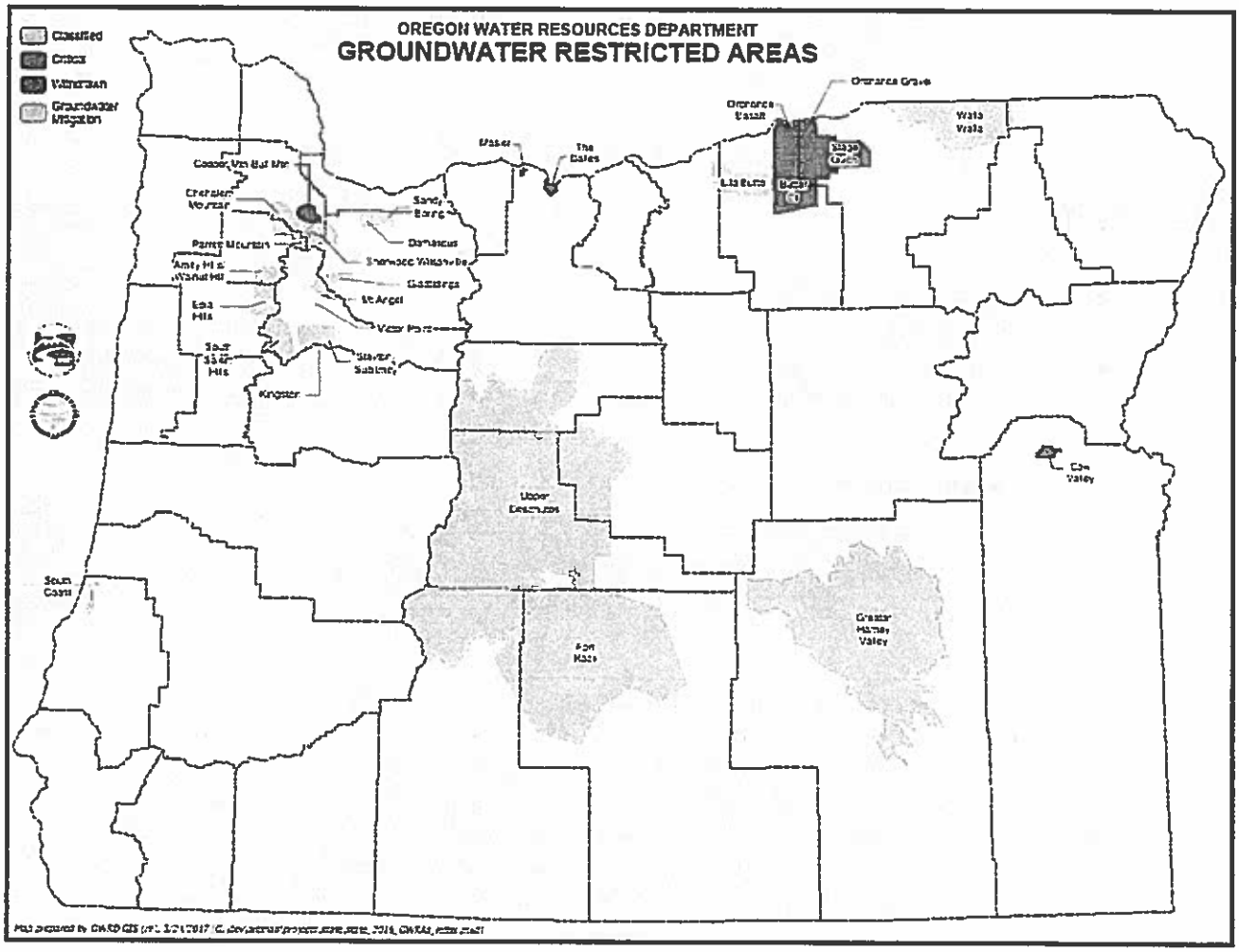
Critical groundwater area provisions for maintaining or achieving reasonably stable groundwater levels have been more effective in some areas than others. In some areas, reductions in groundwater use coupled with artificial groundwater recharge have led to water level recovery or stabilization. In other areas, declines continue in spite of pumping curtailments. Given this, existing CGWA controls should be maintained, and controls in areas where groundwater levels continue to decline should be re-evaluated as resources allow.

Attachments:

1. Map of Groundwater Restricted Areas in Oregon
2. Cow Valley Critical Groundwater Area Summary, Map, and Hydrograph
3. The Dalles Critical Groundwater Area Summary, Map, and Hydrograph
4. Cooper-Bull Mtn. Critical Groundwater Area Summary, Map, and Hydrograph
5. Ordnance Basalt Critical Groundwater Area Summary, Map, and Hydrograph
6. Ordnance Gravel Critical Groundwater Area Summary, Map, and Hydrographs
7. Butter Creek Critical Groundwater Area Summary, Map, and Hydrographs
8. Stage Gulch Critical Groundwater Area Summary, Map, and Hydrographs

Justin Iverson, Groundwater Manager
503-986-0933

Map of Groundwater Restricted Areas in Oregon (CGWAs indicated in red)



Ordnance Basalt Critical Groundwater Area, Morrow and Umatilla Counties

Control Instrument: Order of the Director dated April 2, 1976 (Vol. 27, pg. 40)

Reasons for Critical Groundwater Area Declaration: Groundwater level declines in Columbia River Basalt Group aquifers

Area: 175 sq miles
Controlled Aquifer: Columbia River Basalt Group (CRBG) Aquifers

Summary of Original Critical Area Control by Order of the Director:

- Basalt (shallow and deep) aquifers are closed to further appropriation
- Irrigation season is defined
- Totalizing meters and record of withdrawal from each non-exempt well is required
- State engineer makes an annual evaluation of water levels and use to determine the effectiveness of the control provisions to maintain reasonably stable groundwater levels

Current Administration of Area:

- No new permits are issued
- Department staff monitor groundwater levels and use annually

Description:

The Ordnance Basalt Critical Groundwater Area is roughly centered on the former Umatilla Ordnance Depot, located west of the Umatilla River near Hermiston and south of the Columbia River. The Columbia River Basalt Group (CRBG) is a series of lava flows with a composite thickness greater than 10,000 feet in the Columbia Plateau. Each flow is characterized by a series of internal features, which generally include a thin rubble zone at the contact between flows and a thick, dense, low porosity and low permeability interior zone. In some cases, sedimentary layers were deposited during the time between basalt flow emplacements. A flow top, sedimentary interbed (if present) and flow bottom are collectively referred to as an "interflow zone." Most water occurs in interflow zones under confining conditions at the contacts between lava flows. CRBG flow features result in a series of stacked, thin aquifers that are confined by dense flow interiors. The low permeability of the basalt flow interiors usually results in little connection between the stacked, tabular aquifers. Each aquifer within the basalts has a unique water level head. Two aquifers within the CRBG were identified in the Critical Area order, a "shallow" zone located less than 400 feet below the surface and a "deep" zone located between 400 and 900 feet below land surface.

Basalt groundwater development began in the 1940s and increased into the 1970s. Groundwater levels declined at a rate of 3 to 4 feet per year during this period. Deep basalt groundwater levels are currently declining at a lesser rate (Figure 9). This is likely due to usage reductions over time and leakage from the upper aquifers through improperly constructed wells. Total decline in the deep basalt aquifer exceeds 150 feet. Wells completed only into the shallow basalt show relatively stable long-term water levels (Figure 10), with a total decline of less than 20 feet.

The basalt aquifers in this CGWA are closed to further permitted appropriation. OWRD staff measure groundwater levels and annual use each February, when irrigation pumps are idle. Water levels in the shallow basalt aquifer are reasonably stable, although they have not recovered to historic levels. Water levels in the deep basalt aquifer continue to decline approximately two feet per year. Commingling wells, which are open to both the shallow and the deep basalt aquifers, continue to make accurate groundwater level data collection difficult. Commingling wells should be repaired or replaced with wells that meet current well construction standards. In recent years, many of the wells in the critical area have converted use from irrigation to confined animal feeding operations, transitioning from seasonal to year-round use. Although this does not represent an increase in annual volumetric use, it does mean that many of the wells are pumping during February data collection efforts. This complicates assessment of year-to-year water level changes at many of the CGWA observation wells. Dedicated water level monitoring wells are needed in both the shallow and the deep basalt aquifers to assess the stability of the resource into the future.

Ordnance Gravel Critical Groundwater Area, Morrow and Umatilla Counties

Control Instrument: Order of the Director dated April 2, 1976 (Vol. 27, pg. 40)

Reasons for Critical Groundwater Area Declaration: Groundwater level declines in sedimentary aquifer

Area: 82 sq miles

Controlled Aquifer: Shallow sand and gravel aquifer

Summary of Original Critical Area Control by Order of the Director:

- Gravel aquifer is closed to further appropriation
- Annual appropriation (use) within the Lost Lake-Depot subarea is limited to 9,000 acre-feet
- Totalizing meters and record of withdrawal from each non-exempt well is required
- State engineer makes an annual evaluation of groundwater levels and use to determine the effectiveness of control provisions to maintain reasonably stable groundwater levels

Current Administration of Area:

- No new permits are issued
- Department staff monitor groundwater levels and use annually
- Department staff track 9,000 acre-foot limit and artificial groundwater recharge and recovery in the Lost Lake-Depot subarea

Description:

The Ordnance Gravel Critical Groundwater Area is located west of the Umatilla River near Hermiston. The broad plain of the CGWA is characterized by sediments ranging up to approximately 200 feet thick that overly the Columbia River Basalt Group. The erosional topography of the underlying basalt controls the geometry of the bottom of the sedimentary aquifer. The thickest accumulation of saturated coarse sands and gravels lies in an east-west oriented trough near the center of the CGWA. The sediments thin and become finer-grained toward the margins of the CGWA.

Significant groundwater development of the Ordnance Gravel aqufier began in the 1950s and increased through 1970. Groundwater levels declined during this period (Figure 11). There are two areas of intense groundwater development: the Lost Lake-Depot subarea and the Westland Road subarea. The Order curtailed use under groundwater rights in the Lost Lake-Depot subarea to a total of 9,000 acre-feet per year, and prevented new permitted allocation in the remainder of the CGWA. Coincident with the Critical Groundwater Area Order being issued, an artificial groundwater recharge project was implemented. This project continues through the present, diverting winter water from the Umatilla River and allowing it to recharge the aquifer through leaky canals. Artificial groundwater recharge causes an increase in seasonal water levels in nearby wells (Figure 12). Lost Lake-Depot subarea groundwater right holders use this artificially stored water to make up for curtailment implemented by the CGWA order.

OWRD staff measure groundwater levels and annual use each February, when irrigation pumps are idle. In recent years, several dedicated observation wells have been drilled in the

gravel aquifer, which has greatly improved OWRD's ability to assess the condition of the resource and the feasibility of new artificial groundwater recharge proposals. Under the current artificial recharge and groundwater pumping regime, water levels in the Ordnance Gravel aquifer are relatively stable.

Butter Creek Critical Groundwater Area, Morrow and Umatilla Counties

Control Instrument: Order of the Director dated January 27, 1986 (Vol. 24, pg 1) (for declaration of the critical groundwater area); OAR 690-507-0610 to -0700 (in 1990, 1992, and 1999 for designating subareas and determination and distribution of sustainable annual yield)

Reasons for Critical Groundwater Area Declaration: Groundwater level declines in basalt aquifers

Area: ~274 sq miles

Controlled Aquifer: CRB aquifers

Summary of Original Critical Area Control by Order of the Director:

By Order:

- Appropriation limited to exempt uses and existing authorizations
- Pending applications were rejected
- Creates six subareas for management purposes
- Establishes total annual withdrawal for four subareas
- Except for exempt uses, provides for use on the basis of relative priority
- Establishes a system to request and be authorized to pump an annual volume
- Requires totalizing meters for all non-exempt use withdrawals

By Rule:

- Establishes an irrigation season from March 15th to November 1st
- Requires functioning access ports on wells
- Requires a totalizing flowmeter on authorized wells
- Requires water user to keep a monthly water use record and report readings by December 1st each year
- Causes water users to perform certain actions when flowmeters break
- Causes water users to notify OWRD of well or pump work
- Sets an initial sustainable annual yield (SAY) for each subarea and creates a method to revise those values
- Creates a method to distribute the SAY amongst users
- Defines reasonably stable water level
- Allows changes in SAY in order to achieve reasonably stable water levels
- Notes a rulemaking process to change subarea boundaries

Current Administration of Area:

- OWRD tracks pumpage and water levels in Critical Area wells
- OWRD receives, compiles, and analyzes annual allocation requests from water users
- Based on SAYs, requests, and other factors, OWRD determines annual allocations for each water right in the Critical Area.

Description:

The Butter Creek CGWA is located within the Umatilla Basin in north-central Oregon. The area is bordered on the west by the Ordnance Basalt Critical Groundwater Area and the Ella Butte Groundwater Limited Area and on the east by the Stage Gulch Critical Groundwater Area. Portions of the cities of Hermiston and Umatilla are included within the boundaries. The area is entirely underlain by a thick sequence of numerous basalt lava flows of the Columbia River Basalt group, which is also the most important groundwater reservoir in the area.

Irrigation from groundwater sources in the Umatilla Basin, primarily the basalt groundwater reservoir, increased rapidly in the late 1960s through the late 1970s. Several factors combined to encourage the rapid development of the basalt groundwater reservoir. These included more efficient hard-rock drilling methods, the large production of water available from typical deep basalt wells, new irrigation techniques, favorable crop prices, and the availability of relatively inexpensive electrical power. In the Butter Creek area, the peak in the development occurred in the middle to late 1960s. Regional investigations indicated that for the period from 1965 to 1980 water levels declined 100 feet or more in much of the Butter Creek area.

Water levels continued to decline during the period 1980 to 1990, despite reduced pumpage documented in the area during that same period. Figure 13 shows the groundwater level decline that occurred between 1972 and 1986 due to unsustainable groundwater extraction from the aquifer, and the reduction in decline rate after implementation of the CGWA. Although the rates of decline in the deep basalt groundwater reservoir have slowed in some areas, total declines are at historically low levels in all subareas, and several areas continue to experience declines at rates similar to the pre-1986 rates (Figure 14).

Stage Gulch Critical Groundwater Area, Umatilla County

Control Instrument: Order of the Director dated 5/15/1991, (for declaration of the critical groundwater area); OAR 690-507-0750 to -0840 (in 1991 for designating subareas and determination/distribution of sustainable annual yield)

Reasons for Critical Area Declaration: Excessively declining water levels in basalt aquifers indicating an overdrawn groundwater supply

Area: 183 sq miles

Controlled Aquifer: Upper and deep basalt groundwater reservoirs

Summary of Original Critical Area Control by Order of the Director:

- Creates the critical groundwater area for the upper and deep basalt groundwater reservoirs that underlie the area
- Limits the appropriation (use) to exempt uses and existing authorizations
- Indicates that no new permits will be issued
- Indicates that pending application is rejected
- Creates eight subareas for management purposes
- Limits the extent of deepening of certain wells
- Establishes an irrigation season from March 1st to November 30th but includes an exception method for a longer season
- Requires functioning access ports on wells
- Requires a totalizing flowmeter on authorized wells
- Requires water users to keep a weekly use record and report readings by December 1st each year
- Causes water users to perform certain actions when flowmeters break
- Requires water users to notify WRD of well or pump work
- Sets an initial Sustainable Annual Yield (SAY) for seven of the eight subareas and establishes a method to revise those values
- Limits water use to the SAY and establishes a method to distribute the SAY amongst users
- Defines reasonably stable water level

Current Administration of Area:

- OWRD tracks pumpage and water levels in the area
- OWRD receives, compiles, and analyzes requests annually from users for an allocation
- Based on the SAY, requests, and other factors, OWRD determines annual allocations for each water right in the area

Process of Periodic Review:

- OAR 690-507-0820 requires the department to determine whether a reasonably stable water level was achieved in each subarea in 1995 and every five years thereafter
- Allows for changes in SAY to achieve reasonably stable water levels
- Allows for modifications of subarea boundaries

- Allows for review of SAY and subarea boundaries at times other than the five year required review
- Requires a rulemaking hearing for changes to SAY or subarea boundaries
- Allows individual water users within the CGWA to petition the Department to modify SAY or subarea boundaries

Description:

The Stage Gulch CGWA is located within the Umatilla Basin in north-central Oregon. The area abuts the eastern boundary of the Butter Creek Critical Groundwater Area. The cities of Echo, Stanfield, and most of Hermiston are included within the boundaries. The area is entirely underlain by a thick sequence of numerous basalt lava flows of the Columbia River Basalt group, which is also the most important groundwater reservoir in the area.

Irrigation from groundwater sources in the Umatilla Basin, primarily from the basalt groundwater reservoir, increased rapidly in the late 1960s through the late 1970s. Several factors combined to encourage the rapid development of the basalt groundwater reservoir. These included more efficient hard-rock drilling methods, the large production of water available from typical deep basalt wells, new irrigation techniques, favorable crop prices, and the availability of relatively inexpensive electrical power. In the Stage Gulch area, the peak in the development occurred in the middle to late 1970s. Regional investigations indicated that for the period 1965 to 1980 water levels declined 50 feet or more in much of the Stage Gulch area.

Water levels continued to decline during the period 1980 to 1990, despite reduced pumpage documented in the area during that same period. Figure 15 shows the groundwater level decline that occurred between 1974 and 1991 due to unsustainable groundwater extraction from the aquifer, and the reduction in decline rate after implementation of the CGWA. Although the rates of decline in the deep basalt groundwater reservoir have slowed in some areas, total declines are at historically low levels in all subareas, and several areas continue to experience declines at rates similar to the pre-1991 rates (Figure 16).

Oregon Administrative Rule 690-507-0780 outlines the duties of the water users in the Stage Gulch Critical Groundwater Area. The rules require that each authorized well have an access port with a minimum diameter of ¾ inch (690-507-0780(2)(a)), which allows the determination of the water level at any time. The rules also allow for installation of an airline in addition to the access port (690-507-0780 2b). As of 2016, the majority of authorized wells in the Critical Area do not have the required access port, however many do have airlines that allow determination of water levels. At least one quarter of the authorized wells in the Critical Area have no means of determining water level at any time.

The rules also require a totalizing flowmeter be installed and maintained on each well authorized for 10 or more acres. The specifications for required flowmeters are outlined in 690-507-0785. The majority of the authorized wells do have flowmeters installed; however, many of these do not meet the required specifications. Specifically, it is common for flowmeters to roll over during the course of an irrigation season (690-507-0785(1)(e)), which causes difficulty in accurately assessing the total amount of water pumped during the year from each well.

posted: August 26, 2017 • Environment, Northern Ireland, Photos

Wind farms and groundwater impacts: A practice guide to EIA and Planning considerations

Author: Northern Ireland Environment Agency

What impact can a wind farm have on groundwater?

The development of a wind farm has the potential to impact on groundwater quality, groundwater quantity and/or the established groundwater flow regime. Figure 1 shows the scale and extent of the foundation of a single wind turbine which could potentially impact on the aquatic environment. Changes to the local water environment can affect receptors such as wells/boreholes, springs, wetlands and waterways, and can also have implications for groundwater dependent ecology and/or land stability.

Figure 1: Construction of the foundation of a single wind turbine.

The key impacts to groundwater that can result from the construction, operational and decommissioning stages of wind farms are summarised in Table 1 below.

Table 1: Potential impacts on groundwater from wind farms

	Construction Phase	Operational Phase	Decommissioning Phase
Groundwater Flow Regime	Earthworks and site drainage: • Reduction in water table if dewatering is required for turbine foundation construction or borrow pits; • Changes to groundwater	Physical presence of turbines and tracks: • Possible changes to groundwater distribution; • Reduction in groundwater storage. Reduction of forestry in	Physical presence of former turbines and tracks: • Possible changes to groundwater distribution; • Reduction in groundwater storage.

	distribution and flow.	site area: • Changes to infiltration and surface runoff patterns, thereby influencing groundwater flow and distribution.	
Groundwater Quality	Earthworks: • Disturbance of contaminated soil and subsequent groundwater pollution. Materials Management: • Pollution from spills or leaks of fuel, oil and building materials.	Materials Management: • Pollution from spills or leaks of fuel or oil.	Use of vehicles and machinery to remove infrastructure: • Pollution from spills or leaks of fuel or oil.

Download original document: "Wind farms and groundwater impacts"

Some possibly related stories:

- Direct and rebuttal testimony of Pamela Dodds
- 'Wind Farms' — Some Deep Ecology Considerations
- Wind Farms Provide Negligible Useful Electricity
- Investigating the impacts of windfarm development on peatlands in England
- Decommissioning Estimate for the Green River Wind Farm Phase I
- Assessing and Mitigating Noise Impacts

filed: February 13, 2018 • Letters, New York

Turbines south of SH 72 will impact watershed

Credit: Opinion: Turbines south of SH 72 will impact watershed, says Hopkinton resident | North Country Now | February 12, 2018 | northcountrynow.com ~~

There is a big difference between south and north of 72.,.it is called the "Watershed"

In case some don't realize who live in Hopkinton and the surrounding towns, most of our water supply can be traced back to the Watershed south of 72.

What happens when extensive blasting and driving is done for the 20 or more steel pilings needed to support each massive 500-600 foot industrial wind tower? It disrupts the water flow deep in the bedrock. Yes, they need to drive each and every steel piling up to 50 ft. deep. This means waterways are polluted, totally rerouted, or dried up entirely.

All of us in Hopkinton have either dug or drilled wells. Perhaps you think you are safe because you live no where near a proposed tower site and you imagine it will have little, if any, impact on your day-to-day life. Well, think again. No doubt your water supply can be traced back to the same place mine does. How will you feel if one day you turn on your tap and only brown undrinkable water pours out or none at all? Can you afford to drill a new well and maybe still not find clean water?

Who will be responsible for the multitude who will lose their only source of the vital necessity of clean water?

Has the Hopkinton Town Board even considered the massive expense and calculated the cost to supply clean water to each and every taxpayer's home who will possibly lose this vital necessity?

Latest News
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Maine:
Company revives wind farm plan that state wildlife officials had opposed
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Proposed Cork wind farm to 'muddy' water supply
Australia:
Gippsland wind farm adversely affecting residents, independent report says
Indiana, Letters:
Locals cite turbine health concerns
Opinions, U.S.:
With PTC deadlines looming, could

They have to take this as a serious and very possible reality and what of the town's liability, after all, they have been made aware that the Watershed is south of 72, by even some on the Wind Advisory board they appointed.

How much will it ultimately cost each of us taxpayers? What about those of us who live out-of-town too far from the main roadway to have town water lines?

We have rights to maintain what we already have...clean water.

Why would our elected town officials even consider allowing these wind towers to play Russian roulette with a vital and necessary part of all of our lives!

Just plain and simple – say no to South of 72.

Stick with the wise decisions you originally made to follow the advice of the wind advisory board. Stick with your original statement that Hopkinton and Parishville were sister towns that were working closely together to have coordinating wind laws, to protect all of their residents. Parishville wisely chose to pass a resolution that protected all their people.

If the town can't afford a new lawn mower, let's have a community-wide fundraiser!

(We don't need outsiders slithering into our town seducing individuals with futile promises of wealth.)

We have Survived & Thrived for over 200 years! And we will continue to grow and thrive!

Sherry Blum

Hopkinton

Source: Opinion: Turbines south of SH 72 will impact watershed, says Hopkinton resident | North Country Now | February 12, 2018 | northcountrynow.com

Wind Catcher cancellation be part of a trend?
Massachusetts: **Yarmouth again balks at Vineyar Wind pact**
Letters, New York: **Wind company towers come down in Parishville, Hopkinton; community remains cautious until all leases canceled**
Michigan: **Legal problems surface with Huron's master plan**
Rhode Island: **Governor's push for clean energy moves forward on eve of primary election**
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Ohio, Opinions: **Don't make next generation pay for our mistakes**
Australia, Letters: **We're deep in the wind wow-zone, but hold on a s**
South Dakota: **Appeal filed against approval of Dakota Range Wind project**

Maintenance concern flagged over newer windfarms

Written by **David McPhee** - 26/09/2018 10:32 am

Newer windfarms require more than double the amount of maintenance than older ones, according to an independent inspection firm.

Windfarms under five years of age require on average seven repairs per turbine in contrast to those older than that period only needing 2.2 repairs.

A report by UK blade repair firm Altitec claims that new projects are likely to "require more active monitoring and maintenance", despite operators expecting to prioritise older developments.

Altitec say that the emergence of larger capacity turbine models has led to an increase in blade spans resulting in unforseen operation and maintenance (O&M) challenges.

Tom Dyffort, managing director, Altitec Group, said: "We recommend that all wind farms undergo regular blade inspections, no matter their age, to ensure they continue to perform at their optimal levels and that energy production remains as high as possible.

"But our records indicate that, during the first five years of a wind farm's operational lifetime, O&M managers may be more prone to overlooking the need for blade maintenance.

"Ultimately, this will only result in more serious faults developing, more repairs being required and longer periods of turbine downtime."

The turbine repair firm say that external repairs account for the vast majority of work required on wind turbines, adding that structures become"damaged and distorted due to the mechanical stresses placed upon them as the blades flex and twist under loading".

Russia's Energy Minister on Iran

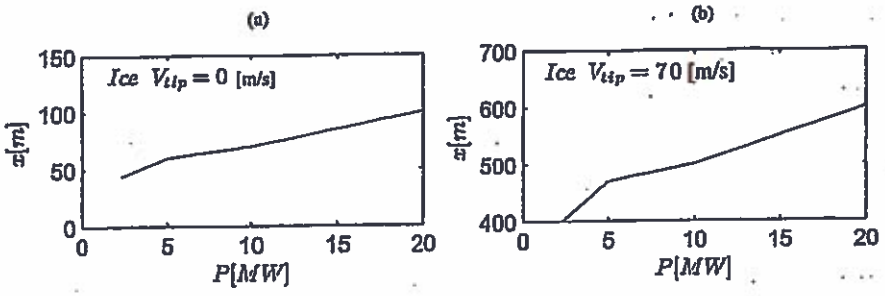

Figure 19. Maximum throw distances obtained for the ice throw in (a) standstill operation, i.e., $V_{tip} = 0$ m/s and (b) normal operating condition, i.e., $V_{tip} = 70$ m/s as a function of turbines power.

figures, the horizontal axis shows the turbine capacity and the vertical axis represents the maximum throw distance. It can be concluded that, in general, the tip speed has a large impact on the throw distances. From Figure 18(a), the turbine size does not affect the throw distances drastically for the lower tip speeds, whereas throw distances at high tip speeds experience a significant growth with increasing turbine size. Figure 18(b), on the other hand, shows that the effect of turbine size on the throw distance for the shell parts is almost negligible.

4. CONCLUDING REMARKS

Trajectory analysis of detached parts of blades and ice fragments thrown from horizontal-axis wind turbines was studied extensively using Newton's and Euler's equations of motion and rotation, employing a blade element approach for the aerodynamics. Full-blade and blade-shell analyses were performed for turbines running under different tip velocities. Turbine upscaling laws were derived, and simulations of throw distances were performed for four different turbine sizes, ranging from existing 2.3 MW machines to future 20 MW turbines.

In some cases, erratic behavior was observed in the computations, where a small change in one parameter could influence throw distance drastically. The behavior was believed to depend highly on the initial conditions. A likely explanation is that a small change in positioning and velocity components in some cases alters the distribution of forces on the detached objects and causes significant changes in the trajectory.

Maximum throw distances obtained at different tip speeds and detachment sizes were analyzed, and it was shown that the tip speed plays the most important role in the throw distance. From the full-blade throw analysis, it was shown that, when released at extreme tip speeds, throw distance picks up more rapidly with the tip speed rather than throw at lower tip speeds (looking at the absolute throw distances). The considered [thrown] full-blade pieces reached approximately 700, 900 and 2000 m at tip speeds of 70, 100 and 150 m/s, respectively. For the blade shell, throw distances were found to be approximately constant as turbine size escalates, and of the same order of magnitude as in the full-blade throw. Throw calculations were also obtained at the tip speeds of $V_{tip} = 0$ and $V_{tip} = 70$ m/s for ice pieces of three different aspect ratios and it was seen that the maximum throw distances scaled almost linearly with the turbine size irrespective of the tip speed. The ice-throw distances reached about 100 and 600 m in standstill $V_{tip} = 0$ m/s and normal operating conditions $V_{tip} = 70$ m/s, respectively. The throw distances presented by this study were obtained with respect to a set of initial parameters without taking into account their probabilities of occurrence. The authors are extending the current study to include the risk levels associated with each of the cases.

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WINTER STORMS CHAPTER

Winter storms are among nature's most impressive spectacles. Their combination of heavy snow, ice accumulation, and extreme cold can totally disrupt modern civilization, closing down roads and airports, creating power outages, and downing telephone lines. Winter storms remind us how vulnerable we are to nature's awesome powers.

For the most part, the wind aspects of winter storms are covered in the windstorms chapter of this plan. Heavy precipitation aspects associated with winter storms in some parts of the state, which sometimes lead to flooding, are covered in the flood chapter of this plan. The winter storms chapter instead generally addresses snow and ice hazards, and extreme cold.

Hazard Analysis/Characterization

Recipe for a Winter Storm

Snowstorms need two ingredients: cold air and moisture. Rarely do the two ingredients occur at the same time over western Oregon, except in the higher elevations of the Coast Range and especially in the Cascades. But snowstorms do occur over eastern Oregon regularly during December through February. Cold arctic air sinks south along the Columbia River basin, filling the valleys with cold air. Storms moving across the area drop precipitation, and if conditions are right, snow will occur.

Figure WS-1: Troutdale area – December 1996 (photo courtesy of the National Weather Service)

However, it is not that easy a recipe for western Oregon. Cold air rarely moves west of the Cascades Range. The Cascades act as a natural barrier, damming cold air east of the range. The major spigot is the Columbia River Gorge, which funnels cold air into the Portland area. Cold air then begins deepening in the Columbia River Gorge, eventually becoming deep enough to sink southward into the

Willamette Valley. If the cold air east of the Cascades is deep, it will spill through the gaps of the Cascades and flow into western valleys via the many river drainage areas along the western slope. Cold air in western Oregon is now in place. Now, the mechanism is to get a storm to move near or over the cold air, which will use the cold air and produce freezing rain, sleet and/or snow. Sometimes, copious amounts of snow are produced. Nearly every year, minor snowfalls of up to six inches occur in the western interior valleys. However, it is a rare occurrence for snowfalls of over a foot in accumulation.[1]

Snow is relatively rare along the coast in Oregon. There is, however, a noticeable relationship between latitude and snowfall. Appendix WS-1 shows average annual snowfall at various Oregon stations. Notice, in particular, Crater Lake, one of the snowiest measurement stations in the United States, which once reported nearly 900 inches of snow in one season.[2]

Ice storms and freezing rain can cause severe problems when they occur. The most common freezing rain events occur in the proximity of the Columbia Gorge. The Gorge is the most significant east-west air passage through the Cascades. In winter, cold air from the interior commonly flows westward through the Gorge, bringing very cold air to the Portland area. Rain arriving from the west falls on frozen streets, cars, and other sub-freezing surfaces, creating severe problems. As one moves away from the Gorge, temperatures moderate as the marine influence becomes greater and cold interior air mixes with milder west-side air. Thus freezing rain is often confined to areas in the immediate vicinity of the Gorge: Corbett, Troutdale, perhaps as far west as Portland Airport. Downtown Portland and the western and southern suburbs often escape with no ice accumulation.[3]

History of Winter Storms in Oregon

A list of Oregon's most significant ice storms may be found in Appendix WS-2. The following are Oregon's most notable snowstorms, according to the National Weather Service:

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[1] National Weather Service – Portland, Oregon Forecast Office, *Historical Storms and Data—Oregon's Notable Historical Snowstorms,* March 20, 2003

[2] Oregon Climate Service, The Climate of Oregon, From Rain Forest to Desert, Corvallis, Oregon 1999

[3] From *The Oregon Weather Book, A State of Extremes*, George Taylor and Raymond Hatton, OSU Press, 1999

Subject: RE: Copy of information regarding the blade drop reported at the Aug. 24, 2018 Energy Facility Siting Council Meeting

From: CORNETT Todd * ODOE (Todd.Cornett@oregon.gov)

To: ott.irene@frontier.com;

Cc: Janine.Benner@oregon.gov;

Date: Monday, September 10, 2018 7:47 AM

Irene,

Below is the email that Duane sent to Council members.

Todd

Greetings Council Members and Chair Beyeler,

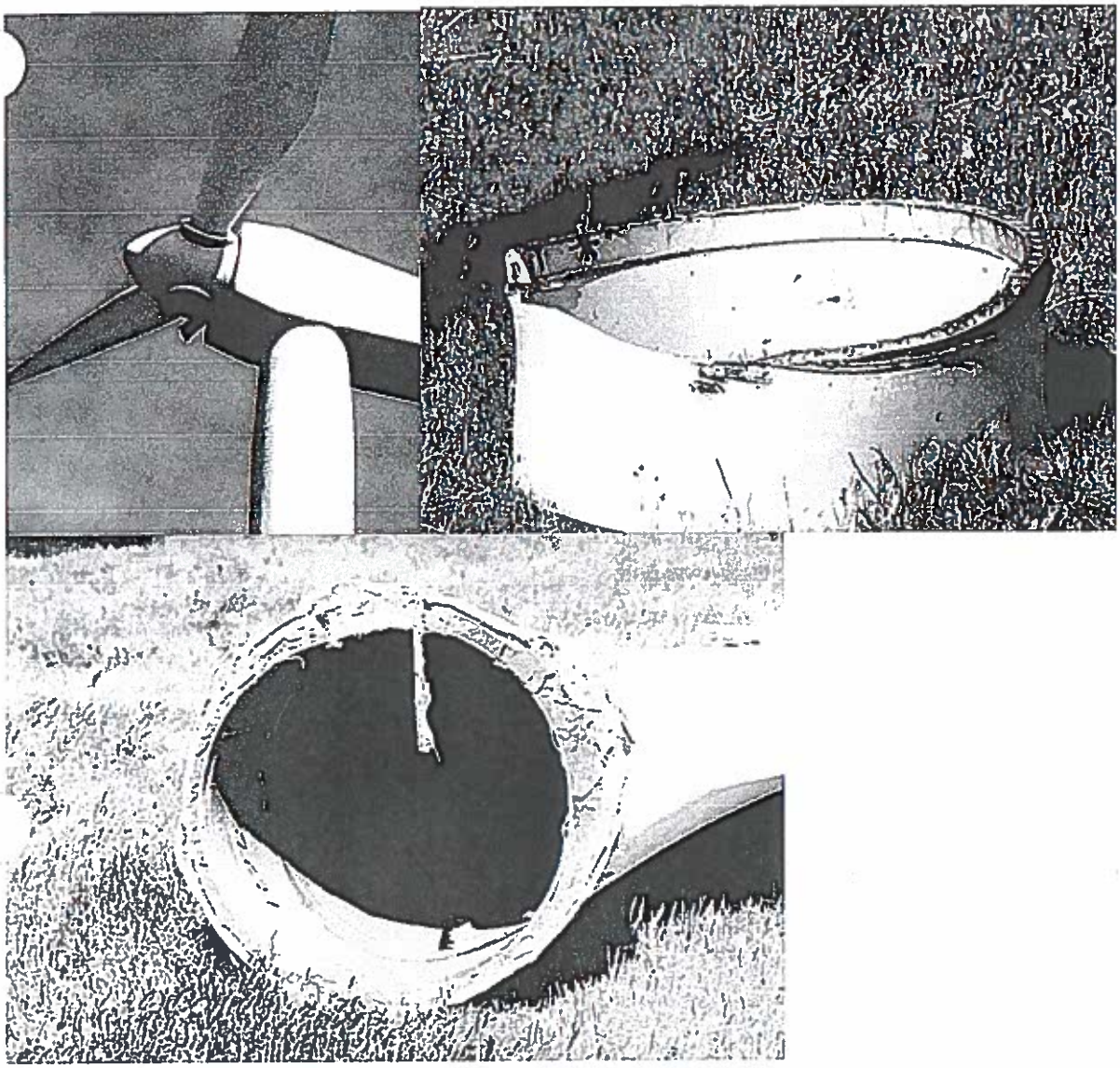
This e-mail is regarding the Councils request for additional information pertaining the Blade loss at Tower BGC-13 @ Stateline Wind Project.

The requested was initiated from the past EFSC meeting dated August 24, 2018.

The below explanation of the Turbine blade loss was provided from the Stateline Wind Project, Wind Manager. (Michael Odman)

"The failure of the blade was associated with a crack that propagated around the bolt holes in the aluminum root of the blade. The blade then began to tear off at the root while it was producing and then hit the tower as it rotated, causing it to completely liberate. It hit the ground approx. 50' from the tower and then slid around 75' to 100' feet from the tower in the field at the end of the row. The root insert itself came loose from the blade and was lying between the tower and blade itself

Here are a few pictures. Let me know if you need any further information."



Please don't hit "Reply All", to this message as it may constitute a quorum.

If you have further questions, please send your questions directly to my e-mail.

Thank you,

uane Kilsdonk

Compliance Officer

Oregon Department of Energy
550 Capitol St N.E., 1st Floor

To: Oregon Department of Energy

From: Adrienne Wilson

Subject: Golden Hills Wind Farm

Irene Gilbert is my step mother. I have discussed with her in detail my concerns about the way the tribe issues seem to be ignored when it comes to the decisions about modern day energy developments. I am a Chickasaw/Choctaw Indian. My concerns are very serious in nature about the destruction of our land rights to this great nation. Modern developments make me fearful of the future in terms of preservation of our precious natural resources.

I am hopeful that my stepmother can obtain a contested case and require the state to address tribal issues related to the Golden Hills Wind Farm destruction of my heritage.

Sincerely,
Adrienne Wilson
Adrienne WILSON
Phone: 503-984-6148

Attachment 2: Comments on Draft Proposed Order
(Ms. Gilbert/Friends of Grande Ronde Valley)

To: Sarah Esterson, Senior Siting Analyst
From: Irene Gilbert, Legal Research Analyst
Friends of the Grande Ronde Valley
2310 Adams Ave.
La Grande, Oregon 97850

August 23, 2018

Comment regarding Golden Hills Wind Project, Amendment 5

This request should not be processed as an amended site certificate.

- Original Site Certificate is nearly 10 years old and some of the information is even older.
- The Amendment changes along with prior amendments have resulted in a development which is entirely different than the originally sited development and yet there are multiple references to prior decisions and use of site certificate conditions that were implemented as a result of needs identified for the prior development.
    - Originally the development was to include 420 foot turbines, now they are being planned for 650 feet.
    - Originally roads were to be 20 feet wide, now they may be up to 100 feet wide.
    - Originally there was a limit on the weight of the turbines, now that is to be exceeded.
- ODOE should not be using the amendment process to make major changes in a site certificate such as this, and the information and process should be the same as a new site certificate, as this is a completely different development than the one originally sited.
- ODOE should not be making a pre-determination that certain sections of the rules are not applicable. This change provides for a review of all eligibility factors, and the Department may not make a predetermination that portions of the rules do not apply. The changes to the amendment rules already limit the rules that can be contested beyond what many of us believe is legal, and this issue is currently being included in the appeal of these rules which is before the Oregon Court of Appeals. Further restrictions absent a change in the statutes appears to be nothing more than a power play on the part of the Department of Energy. For example, the increased weight of these turbines will necessitate heavier cranes and equipment which will increase soil compaction. Comments related to an issue such as that would be appropriate and should be considered.

I am making the following comments regarding changes and concerns with the current analysis of the Amendment Request Number 5:

1. *Per OAR 345-022-0030(3), the facility must comply with local government's acknowledged comprehensive plan and land use ordinances that are in effect on the date the applicant submits the application.* The site certificate needs to include the requirement in Sherman County Ordinance #39-2007 requiring wind energy facilities be located at least one mile from

incorporated cities. The prior exclusion of this requirement is no longer valid for the following reasons:

-- A judge absent any formal court decision is not authorized to make legal determinations as was done in this case.

-- The statute regarding a "goalpost law" no longer exist and has been deleated from the statutes.

-- It is clear from reading the court decisions when this law was in effect that it was intended to preclude counties from changing the land use laws after an application had been filed. It did not apply when future changes occurred as apparently was believed by those referencing this law.

--Land Use Plans are to be reviewed based upon the language effective the date the application is filed.

A condition needs to be included in the site certificate indicating the prior decision to exempt this development from the local rule no longer applies.

2. *The developer must be required to do pre-construction documentation of wells on non-participating landowner's property adjacent to the wind development. The wells need to be monitored during construction and operation of the wind development to assure the development has not resulted in changes including reduced capacity, sedimentation or toxic substances in the water in the area of the wind development and monitor wells during construction and operation.*

ORS 469.501(g) and (k)relate to the need to provide safe water. Also, OAR 345-022-0110(1) states that there needs to be a determination that the construction and operation of the development is not likely to result in significant impacts to water.

There are no developments in Oregon which exceed 600 feet and very few in the United States and there are indications that the weight and vibrations caused by wind developments may impact wells. As a result, the Oregon Department of Energy and Energy Facility Siting Council cannot make a determination that the construction and operation of the development is not likely to result in significant impacts to water. Mitigation of the potential for impacts needs to occur through testing and monitoring of wells to assure safe drinking water is available to non-participant owners of property adjacent to the development. It also appears that developments which negatively impact wells would be out of compliance with the Ground Water Act.

--It has been documented that there is reason to believe that wind developments can affect wells.

--The site certificate process is to include conditions to provide for the safety and health of the public who may be negatively impacted by the development. The references are from multiple locations, multiple sources and multiple years. They provide adequate documentation that it is prudent to monitor impacts of this development due to the fact that it far exceeds the weight and resulting impacts on the transfer of water beneath the ground than any previous development.

Document attached shows impacts which may occur and which have been identified for multiple years:

"Wind Energy Impacts on Groundwater Resources" from the Wind Energy Siting Handbook, American Wind Energy Association.

"Wind turbines impact on groundwater to be discussed", Public Meeting planned August 10,

2016.
"Turbines have Negative Impact on our Drinking Water", published by GLBR SOS on March 27, 2018.

3. *The development poses a risk to private and commercial aircraft as it exceeds the 500 foot no fly zone.* It also poses a risk to Wasco Airport as indicated in previous comments submitted by the public. The developer needs to obtain documentation that the development will not increase the risk to airplanes flying in the area prior to the start of construction. Small planes are required to stay above 500 feet to avoid hazards. In this case, the developer is planning to construct turbines that will exceed the level at which planes, regardless of the types of navigational equipment they are using, or not using, and regardless of whether they are flying in daylight or darkness can expect there to be no objects that would result in a collision.

4. *The setbacks from roads and structures are not adequate to provide for the health and safety of the public as required by OAR 345-024-0010.* The risk from detached objects or ice being thrown from the turbines is real, and weather conditions in the winter in the area of the proposed development frequently result in icey conditions as evidenced by weather warnings related to highway hazards as well as the applicant's description of the site included in their Amendment Application. In addition, you will find attached a copy of "Analysis of throw distances of detached objects from horizontal-axis wind turbines" by Sarthatlak, Hamid; and Sorensen, Jens. This scientific paper published in **Fluid Mechanics, Department of Wind Energy;** Technical University of Denmark, Lygby, Denmark and also **Wind Energy,** 2016, (location found at bottom of article attached) gives a very thorough analysis of the aerodynamics of objects flying from wind turbines. Ice throw is identified as moving a distance of 100 to 600 meters(1968 feet). Since this is the most likely object to be thrown, a distance in the middle range of the distances reported, or 1,000 feet would be reasonable to reduce and mitigate the potential of harming people or animals. Given the reduced number of turbines at this location, this is a reasonable request to provide for the health and safety of the public.

5. *Documentation regarding impacts to the Columbia River Gorge is not adequate or relevant to a determination that the currently proposed turbines will not have a significant impact on this protected site.* Comments referenced from 2007 when the proposed turbines were to be 420 feet high, not 650 feet high, have no relevance to the currently proposed turbines. The applicant's argument that because there are already some encroachments on the protected area, it is justified to add additional ones is not justified absent a full evaluation of the cumulative impacts of the existing impacts and how those will be impacted by any additional visual intrusions. OAR 345-022-0040 requires that there not be significant adverse impacts to the areas listed in this section which includes specifically the Columbia River Gorge National Scenic Area. The primary value for which this area is protected is it's views, therefore, even a minimal negative impact should not be determined to be insignificant. As the designated management groups responsible for the Gorge, the US. Forest Service and The Gorge Commission should be contacted as special advisory groups regarding whether the impacts of this change in the visibility of turbines should be considered significant. Not only will the views be impacted during the day, but the blinking lights at night also pose a negative visual feature to this protected area during the nighttime hours. I travel through this area frequently, and each time I find the impacts of the turbines immediately outside the protected area to be

incredibly offensive to my perception of a quality viewscape. I have often heard others comment with similar thoughts. The proposed turbines will be approximately 450 feet taller than the transmission lines roadways, etc. that the developer states already impact the views. I do not believe these visual impacts can be compared to that of 650 foot wind generators.

6. *The survey areas are not adequate to include all impacts.*
Particularly troubling is the limitation to just the footprint of laydown areas, new substations and mitigation areas and existing roads. I can also find no indication that surveys will be performed on the transmission lines connecting this development to the grid, or the connecting corridors between turbine strings. Construction cannot be completed in areas which are not included in surveys, so I am not sure why a developer would want to exclude these areas from surveys. The survey boundaries need to be at least as wide as the required setbacks for protection of wildlife at the site and must include all land, such as wetland being impacted by the development action either permanently or temporarily as well as direct and indirect impacts to wildlife. OAR 345-022-060, OAR 345-022-070 and OAR 345-021-0010 all require the information regarding impacts which extend beyond the bases of structures or the actual road beds and to include the area of indirect impacts.

7. *Impacts to birds and bats must continue to be monitored through the duration of the life of this project.* This is the first time a turbine of this size has been allowed in Oregon, and they are rare in the country, thus there is very little information available which documents the impacts that they will have. The applicant has provided documentation that states that there are differing projections regarding wildlife impacts of these new turbines. It is unavoidable that this development will have direct impacts on birds and bats including threatened and endangered species. Oregon resources are being exposed to what amounts to an experiment by allowing the development of turbines of this height and weight. There is no time when the need for OAR 469.507 which requires the monitoring of environmental and ecological effects of construction and operation of energy facilities will be more apparent. The wildlife surveys and fatality monitoring needs to continue through the life of the project if this amendment request is approved. The developer would lead you to believe that increasing the circumfrence of the turbin blades is a small change in impacts. This is simply not accurate. It is not a simple 1:1 increase. For example, the original site certificate for this development was for turbine blades that were to span approximately 355 feet. This amendment calls for blades that will span approximately 605 feet. The area that blades 355 feet across covers would be 2.27 acres. Increasing the span of the blades to 605 feet means the plades will cover an area of 6.60 acres. Increasing the diameter of the blades by 250 feet results in the area of the rotor sweep being 3 times as large. For the impacts to birds and bats to be similar or less thans the originally proposed turbines, this development would have to reduce the number of turbines to 1/3 the original number. This alone should result in a denial of this amendment request as the wildlife impacts are unsustainable given the fact that turbines do not discriminate regarding the status of birds and bats that are Threatened or Endangered.

8. *The determination of appropriate bond amount to support restoration of the project area once the development is removed must include the cost of removal, preparation, transporting and disposal of the turbine blades, and concrete. The applicant has failed to provide this*

information which makes it impossible to make the determination required by OAR 345-022-0050 regarding the costs of decommissioning. Much of the material in turbines is not currently recyclable, and thus will no doubt be taken to a public dump. In addition, the actual weight of the supporting structures and other components will impact these costs. With the changes which mean that China will no longer take our garbage, the assessment of available locations may change, also, the cost of disposal is likely to rise significantly. The alternative of recycling the turbine blades is prohibitive in terms of cost and creates environmental hazards due to the materials in the blades that must be broken down in order to recycle them.

9. The comments from the tribes included in the agency comments state that those contacted did not object to the development. They also clearly stated that they were not speaking for the tribe, and that the Department of Energy needed to contact the Tribal Council as the appropriate government to government group to speak. That has not been done. Prior to issuing a site certificate, the Oregon Department of Energy and Energy Facility Siting Council need to take the action necessary as opposed to referencing the statement that was received as meeting the requirement that they request input from impacted tribes.

While there are multiple other concerns with the failure of this development to meet the standards in order to approve a site certificate, it is apparent from reading the draft material on the ODOE website that the decision has already been made to allow this action to occur and to determine that the multitude of impacts are all "not significant". I will not spend further time outlining issues, however, this development should not be issued an amended site certificate.

Please provide these comments in their entirety in the decision regarding this development. Comments that are paraphrased often do not reflect the same message as peoples words, and when taken out of context can fail to communicate important information as was the case with the document froms the tribes impacted by this action.

Wind Energy

WIND ENERGY
Wind Energ. 2016; **19**:151–166
Published online 19 February 2015 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/we.1828

RESEARCH ARTICLE

Analysis of throw distances of detached objects from horizontal-axis wind turbines

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ABSTRACT

This paper aims at predicting trajectories of the detached fragments from wind turbines, in order to better quantify consequences of wind turbine failures. The trajectories of thrown objects are attained using the solution to equations of motion and rotation, with the external loads and moments obtained using blade element approach. We have extended an earlier work by taking into account dynamic stall and wind variations due to shear, and investigated different scenarios of throw including throw of the entire or a part of blade, as well as throw of accumulated ice on the blade. Trajectories are simulated for modern wind turbines ranging in size from 2 to 20 MW using upscaling laws. Extensive parametric analyses are performed against initial release angle, tip speed ratio, detachment geometry, and blade pitch setting. It is found that, while at tip speeds of about 70 m/s (normal operating conditions), pieces of blade (with weights in the range of approximately 7-16 ton) would be thrown out less than 700 m for the entire range of wind turbines, and turbines operating at the extreme tip speed of 150 m/s may be subject to blade throw of up to 2 km from the turbine. For the ice throw cases, maximum distances of approximately 100 and 600 m are obtained for standstill and normal operating conditions of the wind turbine, respectively, with the ice pieces weighting from 0.4 to 6.5 kg. The simulations can be useful for revision of wind turbine setback standards, especially when combined with risk assessment studies.

KEYWORDS
wind turbine accidents; blade element theory; blade detachment; ice throw; aerodynamic model; HAWT

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Received 6 May 2014; Revised 18 December 2014; Accepted 21 December 2014

1. INTRODUCTION

The ever-growing number of wind turbines installed near inhabited areas, buildings and community facilities, such as bridges, power installations or highways, has resulted in an increasing concern by authorities to determine risk levels associated with wind turbine blade failure. From a safety point of view, the most serious failure is associated with splintering of rotor blades and detachment of debris, which could be thrown over long distances and damage people or property. Ice-throw from wind turbines installed in cold climate is also of high concern, especially for wind turbines erected near highways where the ice pieces thrown from a wind turbine may strike a passing car, which in the worst case may cause a fatal accident.

Various types of hazards regarding operation of wind turbines have recently been reported by Durstwitz and the Caithness Windfarm Information Forum.[2,3] According to a recent survey by the Caithness Windfarm Information Forum, blade failures resulting in either whole blades or pieces of blades being thrown from the turbine are the most important causes of turbine accidents.[3] A comparative graph showing the growth of wind turbine accidents over the past four decades is shown in Figure 1, where the share of blade accidents and accidents due to fire, which may eventually cause throw of fire patches, are also presented. Due to such accident data, energy authorities all over the world have tried to enforce safety distances around wind turbines and wind farms. The safety distance is a distance within which it is not allowed to build human structures such as buildings and roads. Shown in Table I is an example of the safety distance standards defined by different authorities. It can be seen from the table the values of offset safety distances fall within an extensive range of

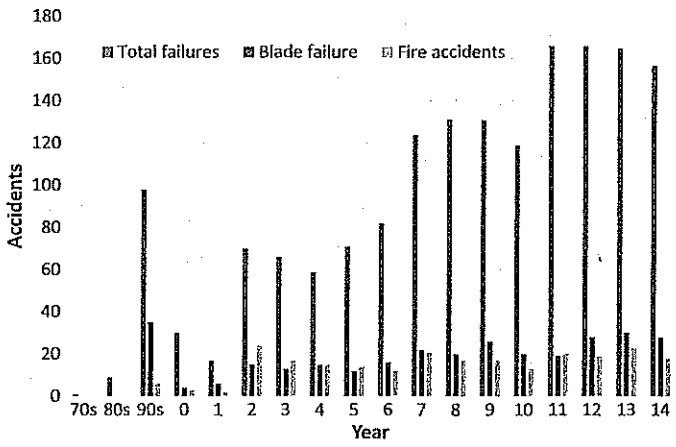

Figure 1. Comparison of wind turbine accidents and particularly blade failure data in a period from 1970s until 2014 (data taken from Caithness Windfarms[3]).

Table I. Safety distances of wind turbines from human structures as practiced in different regions of the world.[17]

Authority/source	Safety distance [m] (ft)
France	1609 (5280)
Germany	1609 (5280)
Rural Manitoba, Canada (1981)	(6500)
US National Research Council	762 (2500)
IL, USA	457 (1500)
Riverside County, CA, USA	**3218 (10560)**
MI, USA	**304 (1000)**

scales between 3.2km and 300m, and that the setback standards are not even similar in different regions of the same country. To standardize such safety guidelines, it is useful to employ mathematical models of the throw in various conditions and risk assessment tools to associate the probability of failure in each particular setting.

Motions of solid particles in fluids were first addressed analytically by Kirchhoff.[4] He showed that the equations of motion for a solid body in an ideal fluid reduce to a set of ordinary differential equations (ODE) based on Euler's equations. Further experimental investigations on falling objects revealed, despite originating from Euler's equations, various states of chaotic motion. It was also mathematically shown that Kirchhoff's equations had been prone to yield chaotic solutions [5]. Tanabe *et al.*[6] developed a set of two-dimensional equations of motion (including rotation) based on simple mechanics in which plates of zero thickness were subject to lift, friction and gravity forces. Based on those assumptions, they found five different falling patterns, ranging from a periodic movement to chaotic random motions depending on the density ratio between the solid and the surrounding fluid and on the length of the object. Pesavento and Wang[7] and Andersen *et al.*[8] performed more detailed studies to determine the motion of a falling two-dimensional elliptic object using direct numerical simulation of the Navier–Stokes equations. They took added mass and added moment of inertia into account and analyzed the transient motion and local jumps of the falling object thoroughly.

Due to complications in a real-life blade accidents (erratic motions, high Reynolds numbers, complex geometries etc.), the fundamental studies mentioned above could only partially help understanding the physics of wind turbine blade throw patterns. To cope with the wind turbine problems, simplified approaches were used. Macqueen *et al.*,[9] for instance, studied the problem of blade-throw from wind turbines, using classical ballistics and also assumption of constant lift and drag. A lift coefficient of Cl = 0.8 and a drag coefficient of Cd = 0.4 were used for the gliding simulations, with Cl = 0.0 and Cd = 1.0 for the tumbling motion. However, the probability that gliding would occur was deemed very small. Their maximum throw studies using simple ballistic analysis, that is, by neglecting aerodynamic forces, showed that in the extreme throw velocity of approximately 310m/s, the maximum throw length reaches 10km.

One of the first detailed studies on the aerodynamics of a detached wind turbine blade was performed by Sørensen[1] using a blade element approach. In this approach, the detached blade is divided into a number of sections and the aerodynamic loads are determined for each section. The total external aerodynamic load on the whole blade would then be determined as the summation of the individual forces on each section.

Wind Energ. 2016; **19**:151–166 © 2015 John Wiley & Sons, Ltd.
DOI: 10.1002/we

Recently, Rogers *et al.*[10] used a dynamic model employing quaternions instead of Euler angles and rotation vectors to form the orientation matrix and performed Monte Carlo simulations of a large set of initial conditions in order to obtain a range of the throw distances.

Ice throw has also been investigated, especially for the turbines erected in the cold climate. Seifert *et al.* measured ice-throw accidents together with a simple aerodynamic model and performed risk analysis of the ice fragments thrown from the blades.[11] Recently, a model of ice throw for a wind turbine in operation was presented by Biswas *et al.*,[12] in which calculations were carried out for ice pieces by neglecting lift and using a fixed drag coefficient of $C_d = 1.0$. It was also estimated that including the highest possible, lift increases the throw distance by approximately a factor of two.

The problem of blade/ice throw has also been investigated through the window of probabilistic methods. Such methods deal with risk levels and probabilities that a certain throw distance will occur. Such studies are typically performed together with a dynamic model for calculating the throw distances. Macqueen *et al.*,[9] Morgan,[13] Morgan and Bossanyi[14] and Rogers *et al.*[10] carried out risk analyses of ice throw to determine safety guidelines for wind developments in ice-prone areas. Sørensen[15] proposed a statistical model that determines risk levels of debris hitting people. Similarly, Carbone and Afferrante[16] performed a combined probabilistic and dynamic analyses to quantify hazards due to the blade throw.

In the present work, detailed aerodynamic analysis are performed for simulating flying debris. The cases include blade throw in which the blade together with its components is thrown, a case in which only a shell laminate is thrown and a case involving detachment of ice fragments. The governing equations of motion form a set of 18 ODEs responsible for the six degree-of-freedom motion. The resulting system of discretized equations are solved using an ordinary time integration method. Throw distances for four different turbine sizes ranging from 2.3 to 20 MW are compared, by employing simple upscaling rules. The computations are carried out for different wind and tip speeds.

2. MATHEMATICAL MODELING

The equations of motion for a detached blade include equations of translation and equations of rotation. These are obtained using Newton's second law and Euler's equations of motion, with the aerodynamic forces obtained from tabulated airfoil data. To be able to quantify the rotational motion of the detached blade, the moments of inertia around the rotation axes are calculated. This, however, cannot be calculated in a fixed coordinate system (i.e., an inertial system) since both the moments of inertia and the rotational speeds are varying and a solution would become very complicated. Instead, the equations are computed around the body-fixed principal axis, and the obtained values are subsequently transformed to the global (inertial) coordinate system to represent the absolute location and orientations. Two coordinate systems are defined here: a global coordinate system $\mathbf{x} = (x, y, z)$ with the origin on the tower basement and orthonormal right-handed unit vectors $(\vec{i}, \vec{j}, \vec{k})$, with the y-axis in the wind direction and the z-axis in the upward direction. A body-fixed coordinate system $\mathbf{b} = (x_b, y_b, z_b)$ is defined by an orthonormal right-handed unit vector $(\vec{r}_1, \vec{r}_2, \vec{r}_3)$, with the origin located at the center of gravity of the detached blade fragment and the third axis parallel to the length axis of the blade (Figure 2).

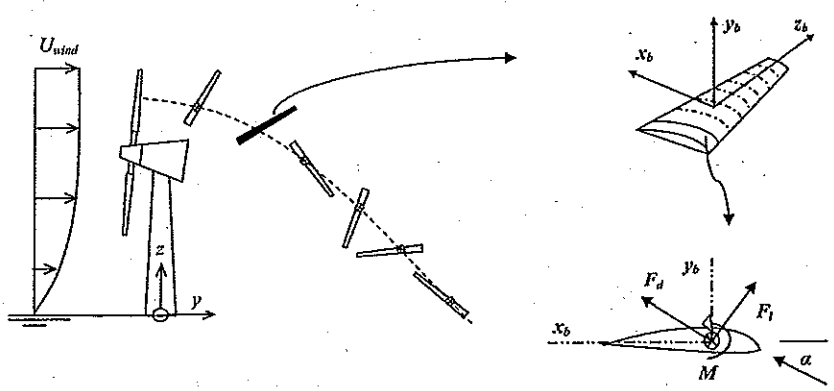

Figure 2. Sketch of the problem and definition of coordinate systems.

The orientation of the detached part is determined through a matrix $\mathbf{R}$, which gives the transformation from global coordinates to the body-fixed coordinates

$$\begin{bmatrix}\vec{r}_1\\ \vec{r}_2\\ \vec{r}_3\end{bmatrix} = [\mathbf{R}]\begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} = \begin{bmatrix}r_{11} & r_{12} & r_{13}\\ r_{21} & r_{22} & r_{23}\\ r_{31} & r_{32} & r_{33}\end{bmatrix}\begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} \quad \text{and similarly,} \quad \begin{bmatrix}\vec{i}\\ \vec{j}\\ \vec{k}\end{bmatrix} = [\mathbf{R}^{-1}]\begin{bmatrix}\vec{r}_1\\ \vec{r}_2\\ \vec{r}_3\end{bmatrix} \tag{1}$$

Equation (1) holds for transformation of any variable between the two coordinate systems. This way of defining a vectorized rotation matrix (as opposed to Euler's scalar angles) ensures uniqueness of orientation angles and avoids the problem known as gimbal lock.

The full six degree-of-freedom motion is governed by Newton's second law of motion and Euler's equations of motion:

$$m\ddot{\underline{x}}_g = \underline{F} + m\underline{g} \tag{2}$$

$$\underline{I}.\dot{\underline{\omega}}_b = \underline{\omega}_b \times (\underline{I}.\underline{\omega}_b) = \underline{M} \tag{3}$$

where m is the mass of the blade, $\underline{x}_g$ is the position vector of the center of gravity, $\underline{F}$ is the aerodynamic force acting on the center of gravity, g is the gravitational acceleration, $\underline{I}$ is the moment of inertia tensor, $\underline{\omega}$ is the angular velocity in the rotating frame of reference, $\underline{M}$ is the aerodynamic force acting along the principal axis of the moment of inertia tensor and (.) denotes differentiation with respect to time. To close the system, the following relationship between the motion of the unit vectors of the body (the blade fragment) and the angular velocity is used:

$$\dot{\underline{r}} = \underline{\omega} \times \underline{r} \tag{4}$$

where $\underline{\omega}$ is the angular velocity of the blade fragment in the inertial coordinate system, which by equation (1) is transformed into the local body-fixed coordinate system. The total set of equations are solved using a fourth-order Runge–Kutta–Nystrom or a third-order Adams–Bashforth method. For more information about the mathematical and numerical treatment of the equations, readers are referred to the early work of Sørensen.[1]

2.1. Aerodynamic modeling

For the solution of the system of ODEs, a blade element approach is employed in which each blade is divided into n sections along the span. In each section, the external forces and moments are calculated from airfoil data based on the local wind speed and relative velocities.

The three-dimensional edge effects are to some extent considered through the finite aspect ratio assumption of the blade, and the aerodynamic coefficients of lift and drag are calculated for all angles of attack based on flat-plate theory. The induced velocities are, however, neglected, and the Reynolds-number dependence of the airfoil data is disregarded. Once the aerodynamic coefficients are found, the lift, drag and moments on the blade fragment are computed as

$$L_i = \frac{1}{2}\rho v_i^2 A_i C_{Li}, \quad D_i = \frac{1}{2}\rho v_i^2 A_i C_{Di} \tag{5}$$

where L_i and D_i are lift and drag forces on the i-th section, ρ is the air density, v_i is the local relative airspeed, $A_i = c_i \Delta r_i$ is the local planform area where c_i and Δr_i are the local chord and the section lengths, and C_{Li} and C_{Di} are the sectional lift and drag coefficients at the desired angle of attack.

The static forces aerodynamic coefficients of the airfoil only depend on the angle of attack. Unsteady effects at high angles of attack are included by using the dynamic stall model of Øye.[18] In this model, the dynamic lift coefficient is obtained by interpolating between the lift coefficient of an airfoil in a fully attached flow and a lift coefficient of the airfoil when the flow around the airfoil is fully separated, i.e.,

$$C_{l,dyn} = f_s C_{l,inv}(\alpha) + (1 - f_s) C_{l,fs}(\alpha) \tag{6}$$

where $C_{l,inv}$ is the lift coefficient for a fully attached flow (i.e., inviscid flow assumption) and $C_{l,fs}$ is the lift coefficient for fully separated flow. The stall-changing rate is defined as

$$\frac{df_s}{dt} = \frac{f_s^{st} - f_s}{\tau} \tag{7}$$

where f_s is the time-dependent separation function, which can be thought of as the unsteady weighting function between the fully attached and the fully separated flow. f_s^{st} is a function of airfoil section,

$$f_s^{st}(\alpha) = \frac{C_{l,st}(\alpha) - C_{l,fs}(\alpha)}{C_{l,inv}(\alpha) - C_{l,fs}(\alpha)} \tag{8}$$

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and τ is an empirically determined time constant giving the time lag between the dynamic value of f_s and its static value. It follows from equation (7) that

$$f_s(t+\Delta t) = f_s^{st} + \left(f_s(t) - f_s^{st}\right)\exp\left(\frac{-\Delta t}{\tau}\right) \tag{9}$$

2.2. The atmospheric boundary layer effects

The inlet wind is included as a velocity profile corresponding to the Atmospheric Boundary Layer (ABL). As a result, in addition to simulating uniform inflow,[1] it is possible to simulate throw distances for blades thrown in wind fields following a power or logarithmic law, depending on the specific site information. The ABL wind profile as a function of height and atmospheric conditions reads

$$u_z = \frac{u_*}{\kappa}\left[\ln\left(\frac{z}{z_0}\right) + \psi(z, z_0, L)\right] \tag{10}$$

where u_* is the friction velocity, κ is the von Karman constant (~ 0.41), z_0 is the roughness length, ψ is a function of atmospheric stability and L is the Monin–Obukhov stability parameter (see Wyngaard[19] for more details).

If no data are available in a specific site, and neutral ABL is assumed, a power law $u(z) = u_{hub}(z/z_{hub})^{\alpha}$, $\alpha \sim 0.14$ will be used for the wind velocity at different heights having the wind velocity at hub height as an input. The power-law method is used for the parametric studies in this paper.

Using the mentioned wind profile and denoting the local position vector of a point p on the wing as $\vec{r}_{pb}$, the local relative wind velocity $\vec{u}_{pb}$, as seen by the blade fragment, is given as

$$\vec{u}_{pb} = [\mathbf{R}].(\vec{u}_{wind} - \vec{u}_g) - \vec{\omega}_b \times \vec{r}_{pb} \tag{11}$$

where the wind vector is assumed to be $\vec{u}_{wind} = (0, u_y, 0)$, neglecting the vertical and lateral components.

3. SIMULATION RESULTS

Simulations of both blade-throw and ice-throw distances are performed by solving the equations derived in the previous sections using the in-house aerodynamic code *Savbal**. The overall procedure for the solution consists of three stages, comprising coordinate transformation, aerodynamics load assessment and time integration. The initial position, orientation and velocities of the detached part are first evaluated at their local coordinates. Based on these values, an iterative procedure starts where the local velocities are evaluated, according to exerted aerodynamic loads, and integrated to give the location and orientation of the fragment in global coordinates until the fragment reaches the ground level.

For the blade-throw analysis, cases with different detached lengths and tip speeds are compared in two sub-cases: (1) the whole blade together with its sandwich structure is thrown and (2) only the shell layer of the blade is thrown. For ice-throw analysis, it turns out that the drag to mass ratio plays an important role for the magnitude of the throw distance. As a result, a few cases with different C_dA/m ratios (as discussed by Biswas *et al.*[12]) with both standstill and running turbine conditions are simulated. The analyses are performed for different wind turbine sizes.

3.1. Turbine upscaling laws

The throw distance analysis was initially performed for a 2.3 MW turbine using publicly available data. A series of empirical relations was then used to upscale the data for the larger turbines, and the analyses were performed for four different wind turbine sizes, i.e., 2.3, 5, 10 and 20 MW. The scale-up factors are first obtained for the blade length, which scales as the square root of the power ratio. Therefore, denoting the blade length, mass (applicable to both total sandwich structure and the shell laminate masses) and mass moment of inertia for the reference turbine with index a, i.e., r_a, m_a and $\mathbf{I_a}$, respectively, the corresponding values for the upscaled turbine, index b, can be obtained as

$$r_b = r_a\left(\frac{P_b}{P_a}\right)^{S_l},\quad m_b = m_a\left(\frac{r_b}{r_a}\right)^{S_m},\quad \mathbf{I}_b = \mathbf{I}_a\left(\frac{m_b}{m_a}\right)\left(\frac{r_b}{r_a}\right)^2 = \mathbf{I}_a\left(\frac{r_b}{r_a}\right)^{S_m+2} \tag{12}$$

*The computing code *Savbal* will be available upon request for further studies on this field.

Table II. Characteristics of different turbine sizes considered in the throw analyses.

Size	$L^* = \frac{L}{R}$	L (m)	m (kg)	I_X (kg·m^2)	I_Y (kg·m^2)	I_Z (kg·m^2)
2.3 MW $R = 45$ m, $H = 100$ m	1.0	45	7.3E+3	0.1E+7	0.1E+7	0.3E+04
	0.5	22.5	2.4E+3	0.1E+6	0.1E+6	0.40E+03
	0.2	10	4.1E+2	0.4E+04	0.4E+04	0.2E+02
5 MW $R = 68$ m, $H = 147$ m	1.0	66	2.6E+04	0.9E+07	0.9E+07	0.2E+05
	0.5	33	8.2E+03	0.1E+07	0.1E+07	0.3E+04
	0.2	14	1.7E+3	0.3E+05	0.3E+05	0.2E+03
10 MW $R = 93$ m, $H = 208$ m	1.0	93	8.2E+04	0.5E+08	0.5E+08	0.1E+06
	0.5	46.5	2.7E+04	0.6E+07	0.6E+07	0.2E+05
	0.2	20	5.3E+3	0.2E+06	0.2E+06	0.1E+04
20 MW $R = 132$ m, $H = 294$ m	1.0	132	2.6E+05	0.3E+09	0.3E+09	0.9E+06
	0.5	66	8.7E+04	0.4E+08	0.4E+08	0.1E+06
	0.2	29	1.6E+04	0.1E+07	0.1E+07	0.8E+04

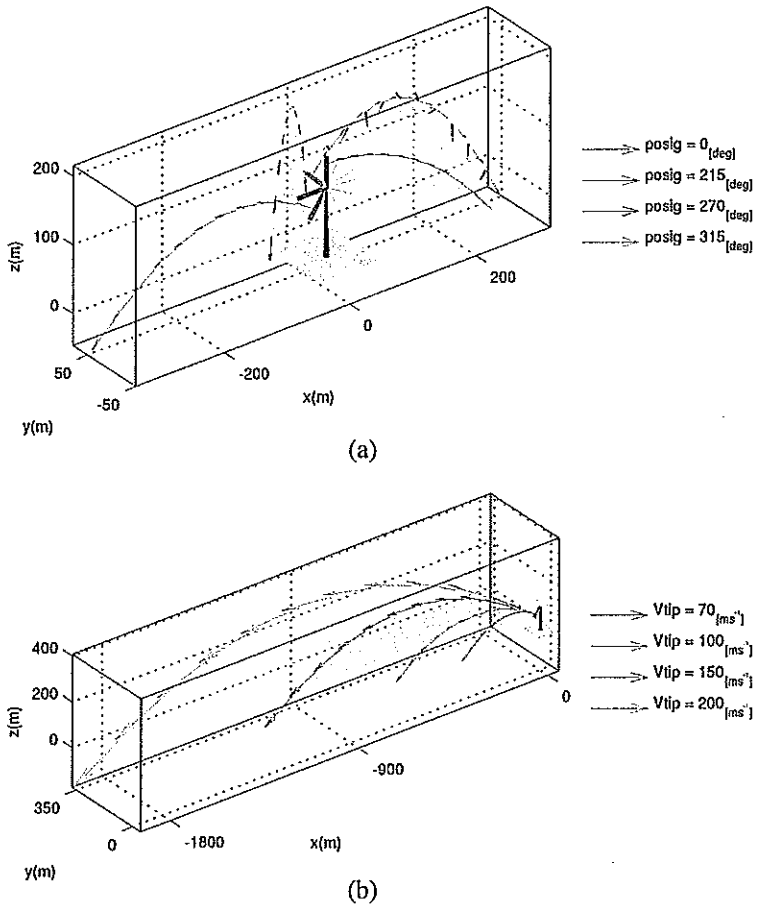

Figure 3. Schematic graphs of the throw distances for half-blade detachment changing (a) the initial release angles (upward-clockwise reference) and (b) the tip speed velocities for the 2.3 MW reference turbine.

where $\mathbf{I} = (I_x, I_y, I_z)$. In the previous relations, $S_l = 1/2$ and S_m depends on actual scaling laws when increasing the size of the rotor. From simple upscaling rules, S_m would be equal to 3 , but because of more elaborate rotor designs, this parameter is usually found to be somewhat smaller. In the present work, we employ $S_m = 2.3$ (see UpWind[20] and TPI Composites[21] for more information on turbine scaling).

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3.2. Full-blade throw analysis

In this section, the throw distance analyses are performed for four different turbine sizes based on the upscaling rules presented previously. Here, the term full blade refers to the case of blade shell including stiffening members (upper and lower shells, spar, etc.). The dimensions and other characteristics of each turbine size are reported in Table II. In accordance with the copyright policies of the turbine manufacturers, the data for the reference turbine (2.3 MW) do not correspond to an existing turbine but are chosen to mimic a real turbine.

The analysis included a parametric study, where the effects of the length of the detached parts, incoming wind speeds, blade tip speeds and wind turbine size on the blade-throw distances were investigated. The height of the tower is in all considered cases assumed to be equal to the rotor diameter. Figure 3 shows three-dimensional visualizations of the throw distances of a half-blade piece thrown of the 2.3 MW machine for different initial conditions. The small colored patches in the figure shows the instantaneous orientation of the detached part. For the sake of clarity, only some selected curves are shown in the figure. Figure 3(a) shows the effect of release angle on the throw distance, and Figure 3(b) shows the effect

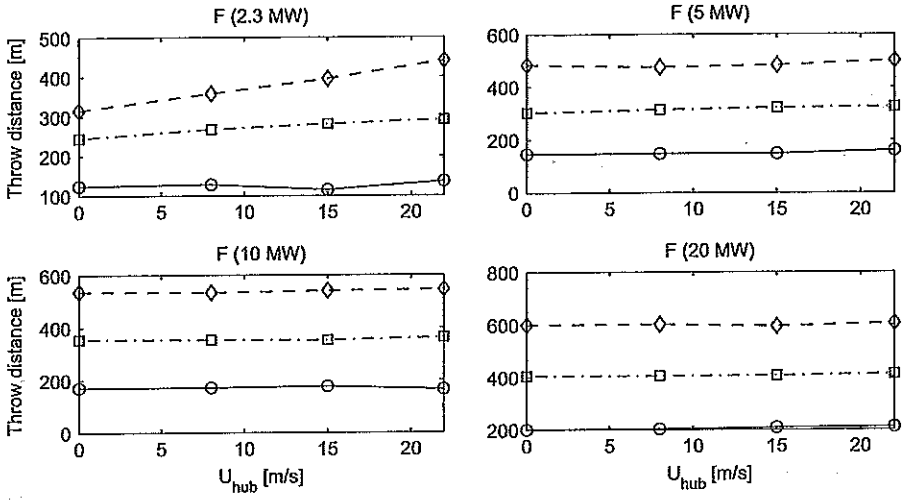

Figure 4. Throw distance calculations of full blade with three different detached lengths for 2.3, 5, 10 and 20 MW turbines at the normal operating condition of V_{tip} = 70 m/s. The horizontal axis shows the wind speed at the hub height and the vertical axis represents the throw distance. ◇ ◇ ◇: $L^* = 0.2$; □ □ □: $L^* = 0.5$; and o o o: $L^* = 1$.

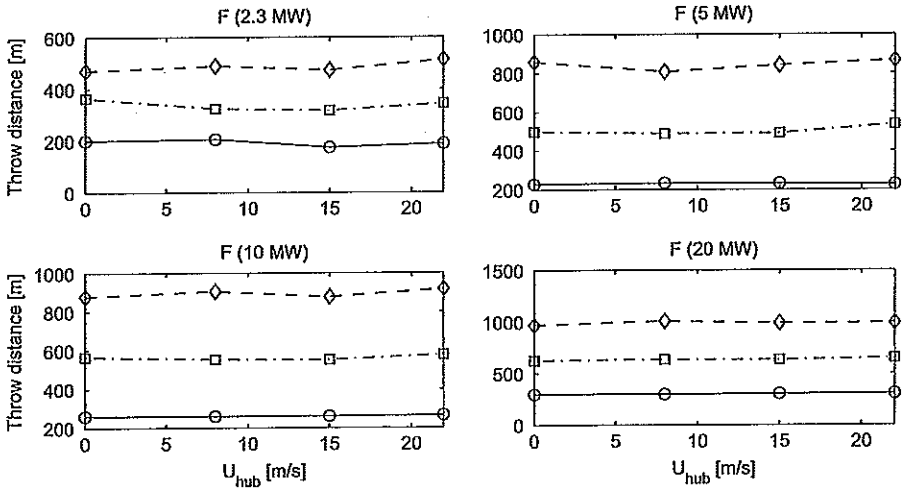

Figure 5. Throw distance calculations of full blade with three different detached lengths at a high tip speed of V_{tip} = 100 m/s. Legends are similar to those in Figure 4.

of release tip velocity. As can be seen, the release tip speed is a very important factor influencing the maximum throw distances. Normal operating conditions with $V_{tip} = 70$ m/s result in throw distances of about 500 m long, whereas a tip speed of $V_{tip} = 150$ m/s may lead to throw distances up to 2 km.

For the quantitative analysis performed in the next section, the fragments are thrown at a release angle of 45° from the horizon (225° measured upward-clockwise) in all calculations. The full-blade and blade-shell throw calculations are performed using flat-plate assumption for the aerodynamic coefficients.

Figures 4, 5 and 6 show the throw distances for three different fragments of the full blade for a combination of three blade tip speeds ($v_{tip} = 70,\ 100\ 150$ m/s) and four different incoming wind velocities (with power-law profiles) ranging between 0 and 22 m/s at hub height.

The figures are divided into three groups, the first group (Figure 4) shows the throw distances, relative to the tower position, for different incoming wind speeds (shown on the horizontal axis) and different detachment lengths at a tip speed of $V_{tip} = 70$ m/s. The detachment length L^*, shown with markers, is the length of the detached piece, measured from the blade tip and normalized by the blade length. The throw distances are calculated and plotted for the four considered wind turbine sizes ranging from 2.3 to 20 MW. As can be seen, except for the 2.3 MW machine, the effect of the incoming wind on the throw distance is almost negligible. Similarly, the effect of turbine size on the throw distance is minimal and the main

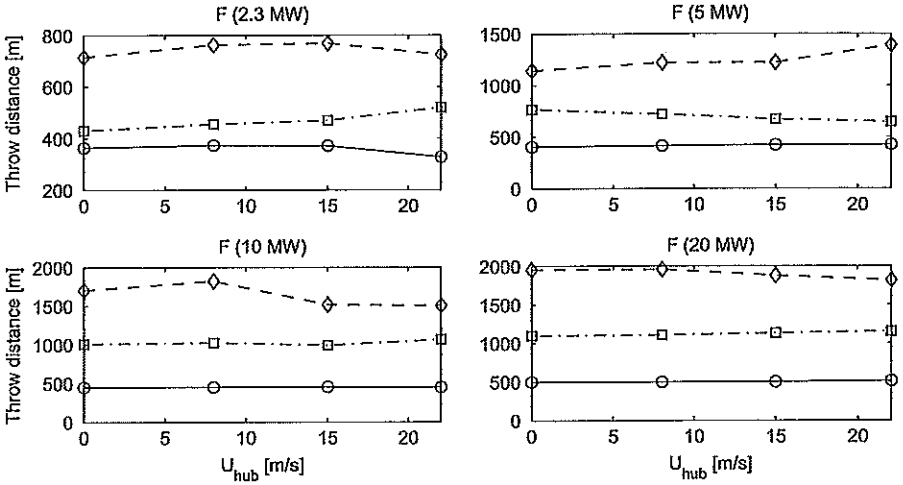

Figure 6. Throw distance calculations of full blade with three different detached lengths at an extreme tip speed of $V_{tip} = 150$ m/s. Legends are similar to those in Figure 4.

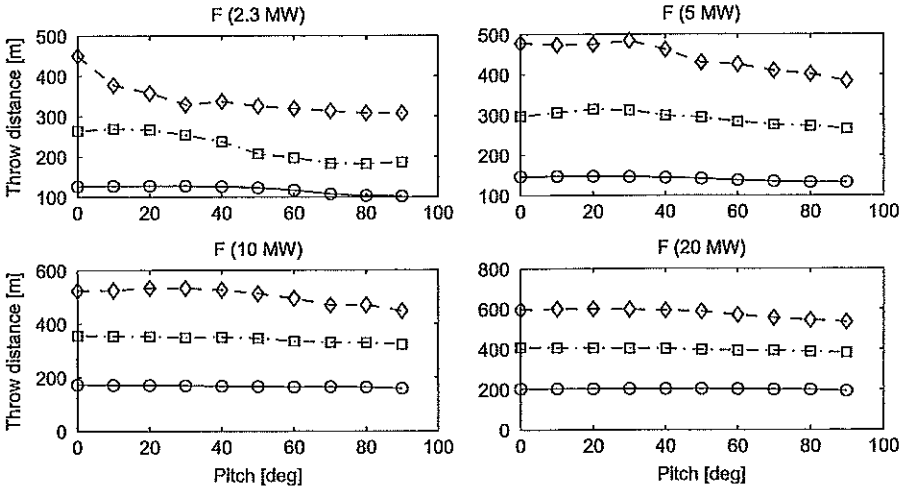

Figure 7. Sensitivity of throw distances of full blade to the initial pitch setting for 2.3, 5, 10 and 20 MW turbines operating at $V_{tip} = 70$ m/s. ◇ ◇ ◇: $L^* = 0.2$; □ □ □: $L^* = 0.5$; and o o o: $L^* = 1$.

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DOI: 10.1002/we

parameter governing the throw distance is the detachment length. The minimum throw distance is obtained for the heaviest fragment ($L^* = 0.2$) thrown from the 2.3 MW turbine, while the maximum throw distance of all cases at $V_{tip} = 70$ m/s is around 600 m for the lightest fragment ($L^* = 0.2$).

Figure 5 shows the same graphs for the higher tip speed of $V_{tip} = 100$ m/s, where the maximum throw distances for the smallest and largest turbines are about 500 and 1000 m, respectively, while the minimum throw distance is reached for a full-blade throw ($L^* = 1$) of a 2.3 MW turbine. Also, it is clear that the effect of the hub-height wind velocity is still very small. Figure 6 shows the same plots for the most extreme case considered, i.e., using a tip speed of $V_{tip} = 150$ m/s. Here, the thrown pieces reach throw distances ranging from approximately 350 m for the full-blade throw for a 2.3 MW turbine to about 2000 m for the lightest fragment thrown from the 20 MW turbine.

As can be seen from the red curve in Figure 6 for the 10 MW turbine (bottom-left), the throw distance has unexpectedly decreased when increasing the wind speed from 10 to 15 m/s. This behavior is somehow repeated to a smaller extent in other cases, especially at higher tip velocities. The unexpected results can happen because of the fact that a small change in the initial conditions can change the force/moment distributions on the fragments, thereby changing the trajectory drastically. To investigate the erratic motion further, the effect of initial pitch setting on the trajectory is analyzed in the next section.

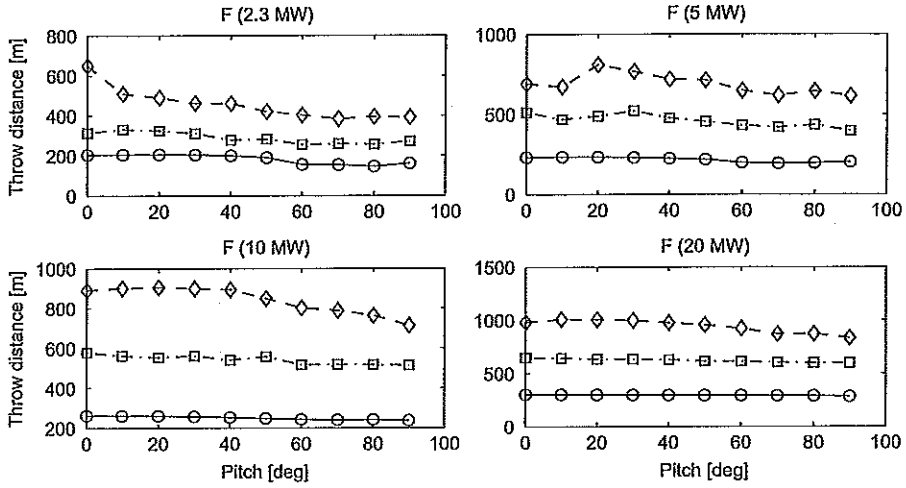

Figure 8. Sensitivity of throw distances of full blade to the initial pitch setting at $V_{tip} = 100$ m/s. Legends are similar to those in Figure 7.

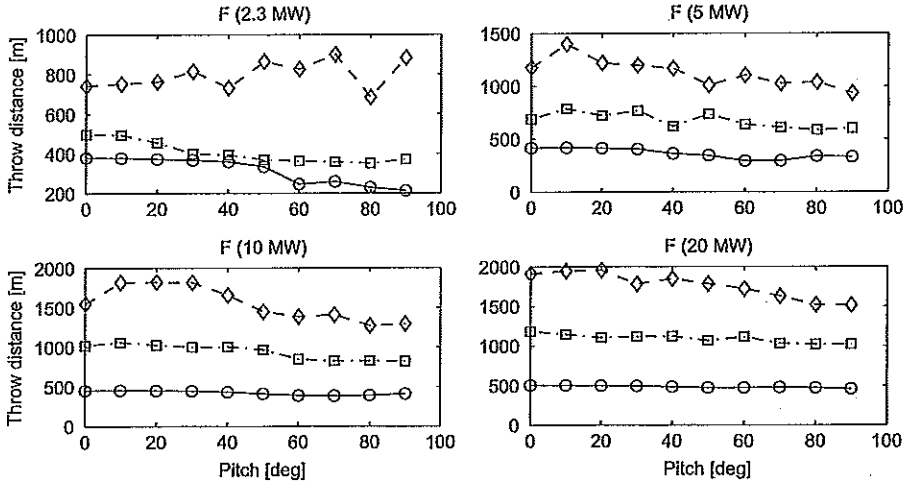

Figure 9. Sensitivity of throw distances of full blade to the initial pitch setting at $V_{tip} = 150$ m/s. Legends are similar to those in Figure 7.

3.2.1. Effect of initial pitch settings.

As explained earlier, analyses of the throw trajectories show that the throw distance for a particular wind turbine sometimes exhibits an erratic behavior going from one dominant solution to another with only a slight change in the initial conditions.

Table III. Aspect ratios, reference chord length C_{ref} and detached mass m of the blade shells ($\rho_{shell} = 1700$ kg/m^3) used for throw simulation from turbines of different sizes.

	2.3 MW		5 MW		10 MW		20 MW	
Cases – AR	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)
$AR = 1$		34		83		184		408
$AR = 5$	1	170	1.5	415	2.1	920	3	2040
$AR = 10$		340		830		1840		4080

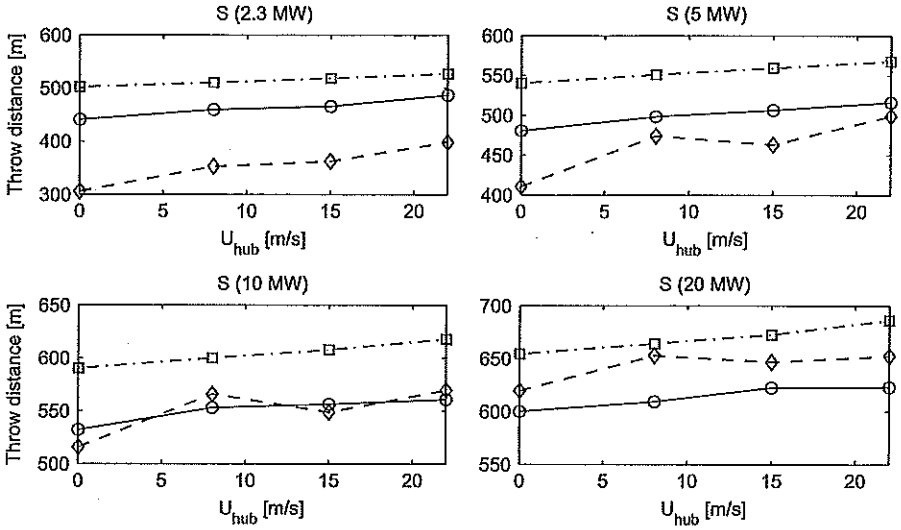

Figure 10. Throw distance calculations of blade shell with three different aspect ratios (invariant chord length for each turbine) for 2.3, 5, 10 and 20 MW turbines at a normal operating condition of $V_{tip} = 70$ m/s. ◇ ◇ ◇: $AR = 1$; □ □ □: $AR = 5$; and o o o: $AR = 10$.

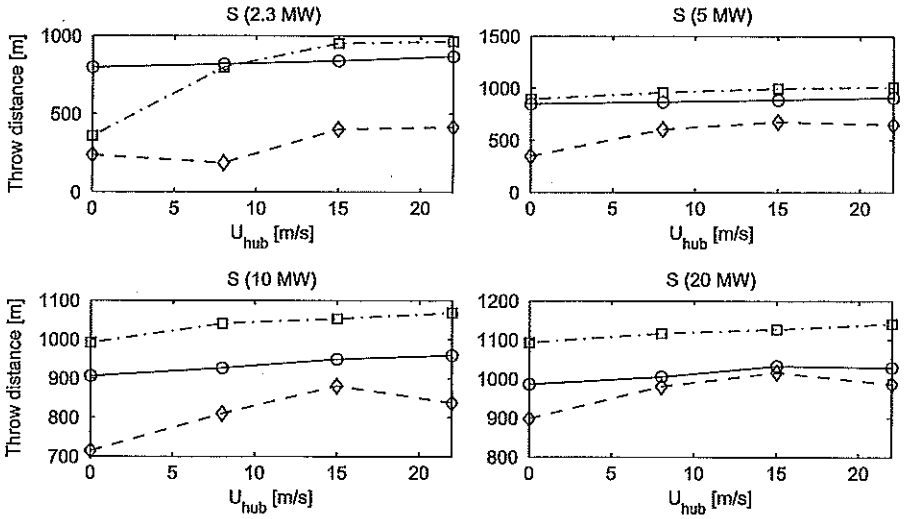

Figure 11. Throw distance calculations of blade shell at high tip speed of $V_{tip} = 100$ m/s. Legends are similar to those in Figure 10.

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To understand this behavior, a sensitivity study is performed to investigate the effects of the initial pitch settings on the trajectory. Figures 7–9 demonstrate the pitch angle dependence of the full-blade throw distances for different turbine sizes and tip speeds, where the throw distances are obtained for release pitch angles ranging from 0° to 90°. As can be seen, the pitch setting has a substantial impact especially for the lighter parts. In general, higher throw distances are achieved using fragments thrown at lower pitch angles, which are due to the reduced drag. The effect of pitch angle on the heavier pieces (green and blue curves) is, however, smaller. The reason for this is that the aerodynamics plays a less significant role for the heavy parts in the throw distance calculation and the distance is mainly governed by the inertial forces. For the extreme tip velocity, and especially for the 2.3 MW turbine, increasing the pitch angle produces erratic throw distances for the lightest fragments. The exact reason for such erratic behavior has not been yet understood, but it is most likely explained by the physics of the problem, as explained earlier.

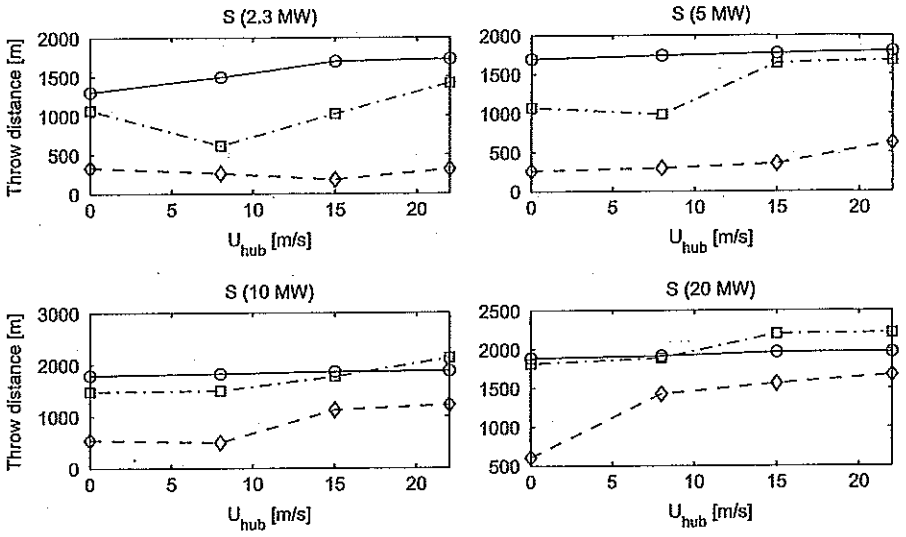

Figure 12. Throw distance calculations of blade shell at an extreme tip speed of V_{tip} = 150 m/s. Legends are similar to those in Figure 10.

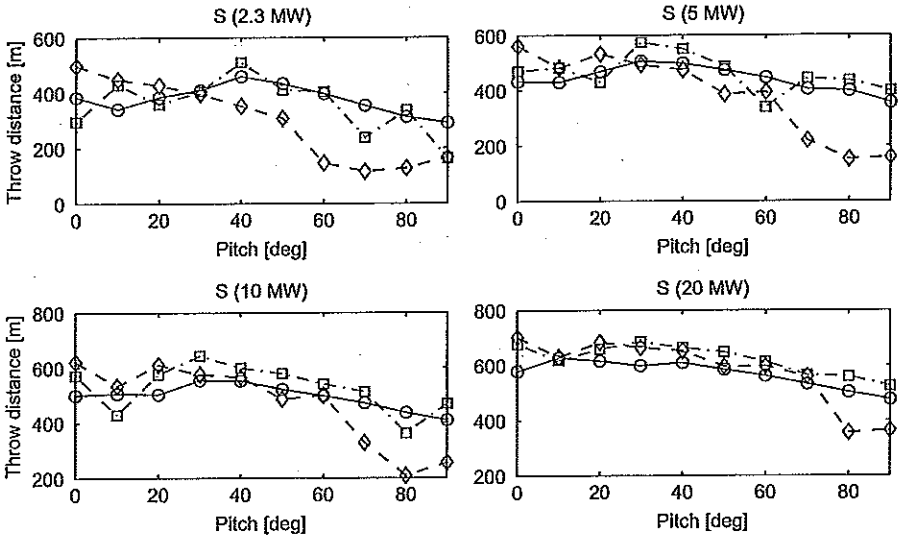

Figure 13. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 70 m/s. Legends are the same as in Figure 10.

3.3. Blade-shell throw analysis

An analysis of available data from blade failure accidents shows that depending on the manufacturing method and the structural integrity of the blade, it might first shatter into lighter parts, with the consequence that the shell layer is most likely to be thrown away. Three cases of different aspect ratios are considered for the shell throw analyses. For the reference case of 2.3 MW turbine, an average chord of 1 m and a shell thickness of 2 cm are chosen, and three aspect ratios (where AR is defined as the ratio of span to average chord) of 1, 5 and 10 are investigated. Then keeping the same AR, the analysis is repeated for each of the turbines introduced in the preceding sections. The density of the shell, consisting of fiber and glass, is assumed to be 1700 kg/m^3. Table III shows the test cases used for blade shell throw simulations.

Throw distances for the four different turbine sizes with the same working conditions as those for the full-blade case are plotted in Figures 10–12. Here, the non-dimensional length is replaced by the aspect ratio of the blade shell and three different aspect ratios are considered. As can be seen, increasing the hub-height wind speed and the turbine size generally results in larger throw distance. Nevertheless, an erratic behavior, as mentioned in the previous section, appears in the

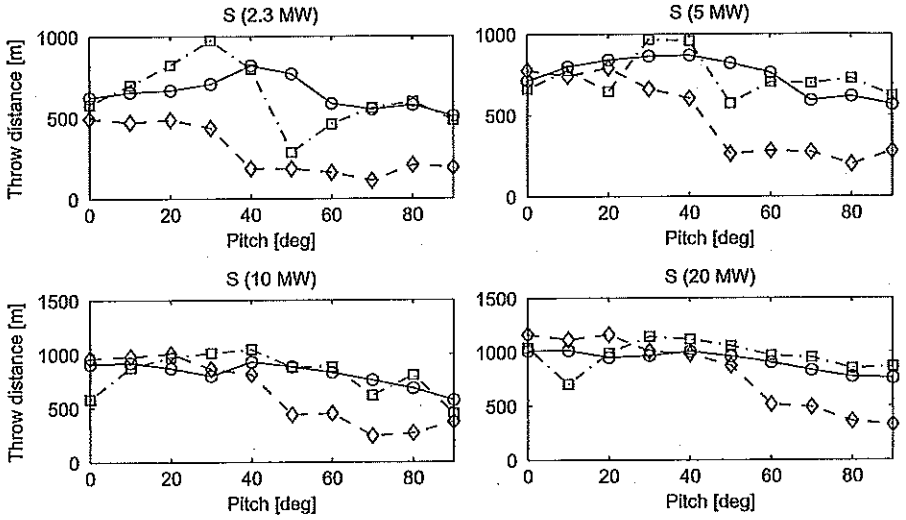

Figure 14. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 100 m/s. Legends are the same as in Figure 10.

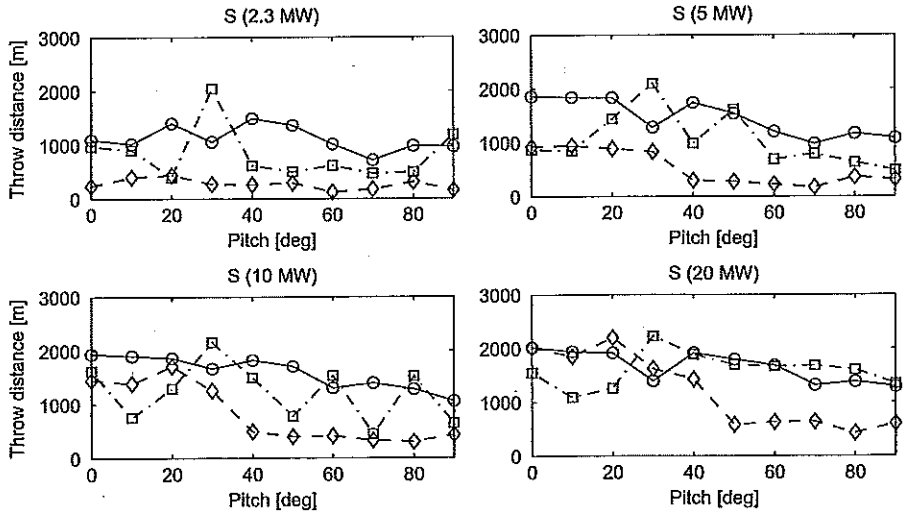

Figure 15. Sensitivity of throw distances of blade shell to the initial pitch setting at V_{tip} = 150 m/s. Legends are the same as in Figure 10.

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simulation results. By comparing the shell-throw graphs with the corresponding figures from the full-blade analysis, the throwing range of the blade shells and that of the full-blade structure are seen to be of the same order of magnitude. That is, the range is between 300 m for the 2.3 MW turbine operating at $V_{tip} = 70$ m/s and a maximum of 2200 m obtained for the 20 MW turbine in the extreme case of $V_{tip} = 150$ m/s. However, unlike the full-blade throw cases, the case with the smallest length ($AR = 1$) reaches the least throw distance, whereas for the full blade, the smallest fragment reaches the highest distance. This is most probably due to the fact that the small shell object is lighter and the corresponding inertial force is relatively small as compared with the drag forces.

As a comparison, the throw distances obtained for the ballistic motion of an equivalent particle in vacuum was also performed (results not shown), in which case there is no aerodynamic forcing on the objects. The results revealed that the ballistic throw distances are the most extreme cases in terms of throw distance.

3.3.1. Effect of initial pitch settings.

Similar to Section 3.2.1, the role of initial pitch setting on the trajectory of thrown blade-shell debris is assessed. Figures 13–15 show the pitch angle dependence of the throw distances for different turbine sizes and tip speeds for the blade-shell cases. Similar to the full-blade throw cases, the pitch setting has a substantial impact on the throw distance of thrown blade-shell structures. One major difference with the full-blade cases is, however, that the effect of the shell aspect ratios on the throw distance is much less significant and all of the cases show similar behavior with AR = 1 cases (red diamonds), predicting smaller throw distances in general.

3.4. Ice throw

For the analysis of the ice throw, the same procedure as for the blade throw is applied except that the throw analysis is not performed for the extreme tip speed conditions but only for the standstill where the tip speed is zero, and the running conditions, where the turbine is assumed to rotate in its normal operational mode at a tip speed of 70 m/s. For the icing case,

Table IV. Aspect ratios, reference chord length C_{ref} and detached mass m of the ice fragments ($\rho_{ice} = 0.7$ kg/m^3) used for throw simulation of turbines of different sizes.

	2.3 MW		5 MW		10 MW		20 MW	
Cases – AR	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)	C_{ref} (m)	m (kg)
$AR = 1$		0.18		0.43		0.97		2.16
$AR = 2$	0.1	0.36	0.15	0.87	0.2	1.95	0.3	4.33
$AR = 3$		0.54		1.31		2.94		6.49

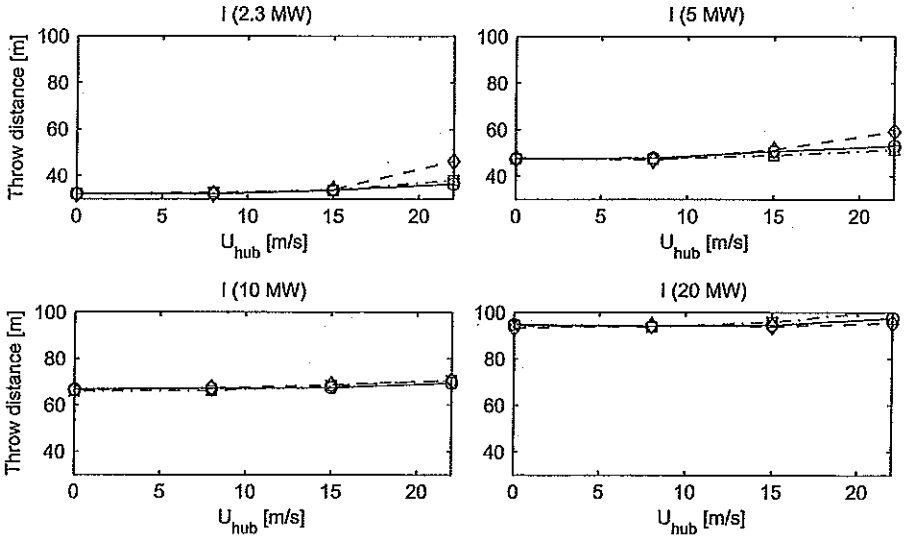

Figure 16. Throw distance calculations of ice fragments for three different aspect ratios for 2.3, 5, 10 and 20 MW turbines in standstill operation ($V_{tip} = 0$ m/s). ◇ ◇ ◇: $AR = 1$; □ □ □: $AR = 2$; and o o o: $AR = 3$.

a density of 700 kg/m^3 is used (see also Seifert *et al.*[11]). The dimensions of the tested ice fragments and corresponding turbine sizes are shown in Table IV. According to field studies performed by, e.g., Cattin *et al.*,[22] most of the ice fragments thrown away from turbine are broken into objects that typically are smaller than 1 kg. However, fragments as heavy as up to 1.8 kg have also been observed. Because the pieces are so light, the throw distance of an ice piece is mainly governed by the drag forces applied on it (which are only functions of mass–area ratio) and the incoming wind.

Similar to the previous section, studies of the effects of different parameters on throw distances are performed and plotted in Figures 16 and 17 with the graphs structured in the same way as in the previous sections.

For the simulations, no lift is considered and the drag coefficient according to the flat-plate assumption is used. Figure 16 shows that the throw distances of the standstill case range from 30 to 100 m for different turbine sizes and incoming wind speeds. For the running conditions however, the fragments can reach distances up to 600 m. It is also clear from the figure that in many cases the aspect ratio does not play a significant role in the determination of throw distances.

3.5. Maximum throw distances

This section presents a summary of the previous results in terms of maximum throw distances. The maximum throw distances are obtained from the entire set of previous simulations regardless of the size and upcoming wind speed and plotted in Figure 18 for the full-blade and blade-shell cases and in Figure 19 for the ice-throw cases, respectively. In all

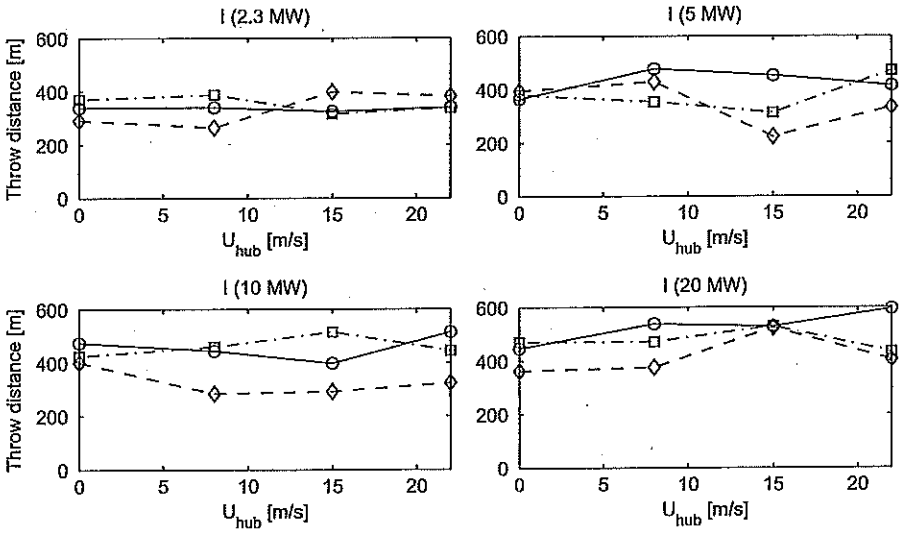

Figure 17. Throw distance calculations of ice fragments for three different aspect ratios for turbines in normal operation (V_{tip} = 70 m/s). Legends are the same as in Figure 16.

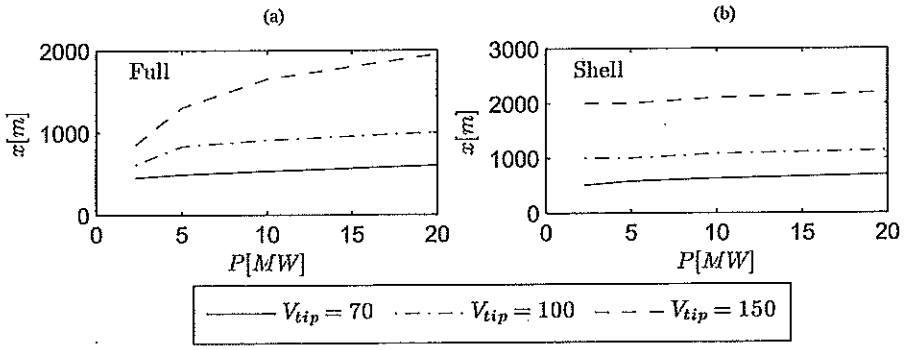

Figure 18. Maximum throw distances obtained for (a) full blade and (b) blade shell in different operating conditions. Blue line: V_{tip} = 70 m/s as a function of turbines power.

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DOI: 10.1002/we

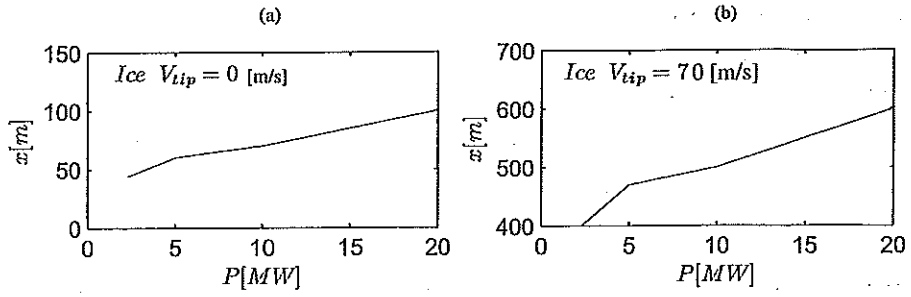

Figure 19. Maximum throw distances obtained for the ice throw in (a) standstill operation, i.e., $V_{tip} = 0$ m/s and (b) normal operating condition, i.e., $V_{tip} = 70$ m/s as a function of turbines power.

figures, the horizontal axis shows the turbine capacity and the vertical axis represents the maximum throw distance. It can be concluded that, in general, the tip speed has a large impact on the throw distances. From Figure 18(a), the turbine size does not affect the throw distances drastically for the lower tip speeds, whereas throw distances at high tip speeds experience a significant growth with increasing turbine size. Figure 18(b), on the other hand, shows that the effect of turbine size on the throw distance for the shell parts is almost negligible.

4. CONCLUDING REMARKS

Trajectory analysis of detached parts of blades and ice fragments thrown from horizontal-axis wind turbines was studied extensively using Newton's and Euler's equations of motion and rotation, employing a blade element approach for the aerodynamics. Full-blade and blade-shell analyses were performed for turbines running under different tip velocities. Turbine upscaling laws were derived, and simulations of throw distances were performed for four different turbine sizes, ranging from existing 2.3 MW machines to future 20 MW turbines.

In some cases, erratic behavior was observed in the computations, where a small change in one parameter could influence throw distance drastically. The behavior was believed to depend highly on the initial conditions. A likely explanation is that a small change in positioning and velocity components in some cases alters the distribution of forces on the detached objects and causes significant changes in the trajectory.

Maximum throw distances obtained at different tip speeds and detachment sizes were analyzed, and it was shown that the tip speed plays the most important role in the throw distance. From the full-blade throw analysis, it was shown that, when released at extreme tip speeds, throw distance picks up more rapidly with the tip speed rather than throw at lower tip speeds (looking at the absolute throw distances). The considered [thrown] full-blade pieces reached approximately 700, 900 and 2000 m at tip speeds of 70, 100 and 150 m/s, respectively. For the blade shell, throw distances were found to be approximately constant as turbine size escalates, and of the same order of magnitude as in the full-blade throw. Throw calculations were also obtained at the tip speeds of $V_{tip} = 0$ and $V_{tip} = 70$ m/s for ice pieces of three different aspect ratios and it was seen that the maximum throw distances scaled almost linearly with the turbine size irrespective of the tip speed. The ice-throw distances reached about 100 and 600 m in standstill $V_{tip} = 0$ m/s and normal operating conditions $V_{tip} = 70$ m/s, respectively. The throw distances presented by this study were obtained with respect to a set of initial parameters without taking into account their probabilities of occurrence. The authors are extending the current study to include the risk levels associated with each of the cases.

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Wind Energ. 2016; **19**:151–166 © 2015 John Wiley & Sons, Ltd.
DOI: 10.1002/we

ground water impacts

weight removed

Kirby Mountain

July 16, 2012

Wind Energy Impacts on Groundwater Resources

If a wind energy project is proposed for a site that is within a groundwater recharge area, any contaminants released at the site have the potential to be carried downward with the infiltrating stormwater, leading to contamination of the aquifer. Groundwater discharge points occur as seepage into wetlands, lakes, and streams. If a site is proposed in a groundwater discharge area, surface disturbances (such as construction or the building of stormwater retention facilities) that disrupt the local hydrology can lead to such consequences as draining the wetland or causing stream flow to become intermittent, even if the activity does not occur directly in the wetland or surface water.

During construction blasting can have an adverse impact on water supplies. Groundwater yields (including both wells and springs) are influenced by the flow of groundwater through the aquifer materials. Any disruption to these materials can potentially affect both groundwater flow and water quality. In some cases, vibrations from blasting can cause aquifer materials to collapse and compact, thereby limiting flow. In addition, bedrock fractures may be created that draw in flow from other portions of bedrock with poorer water quality, and the use of blasting agents that contain perchlorate may result in groundwater contamination.

—Wind Energy Siting Handbook, American Wind Energy Association

wind power, wind energy, wind turbines, wind farms, environment, environmentalism

Print PDF

link: July 16, 2012

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Not **30**.
Not **5**.
Average US CEO pay is
350×
av. wage worker's

Animal Agriculture
is the ***leading cause*** of:
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Deforestation
Species Loss
Water Depletion
Ocean Dead Zones

Links

VEGAN for Peace
Nonviolence begins with Our Diet

Swindle

NO BIG WIND

Petition: 2km (1¼ mi) wind turbine setback

Asthma and Herbs
Nature-Guilt
Poetry

Wind turbines + wells

Turbines Have Negative Impact on our Drinking Water

Published by **GLBR SOS** on March 27, 2018

Don't be fooled by claims that wind turbines create a reliable source of energy without impacting your drinking water. Did you know:

Established wind farms have disrupted drinking water supplies in Canada.

A group of Canadians formed Water Wells First in Ontario in February 2016 after they felt energy companies and the government were not taking seriously the effect that wind turbine construction has had on their wells. During construction, residents reported visible dirt in drinking water from wells.

Advocates said it was a temporary problem. Once construction was completed, the water would return to its former pristine state. However, nearby families have had no such luck. The turbines are operational and the well water throughout the area has a strong odor and contains visible, black sediment.

National Wind Watch
August 8, 2016
Ontario

Wind turbines impact on groundwater to be discussed

Public meeting planned Aug. 10 | By David Gough, Postmedia Network | Sunday, August 7, 2016 | www.wallaceburgcourierpress.com

A town-hall style meeting is scheduled for Aug. 10 at Country View Golf Course to discuss issues with wind turbines affecting groundwater in the former Dover Township.

The meeting is scheduled to begin at 7 p.m.

The meeting is being organized by Water Wells First, a grassroots organization that has concerns about the impact that the pile driving construction and subsequent operation of the wind turbines will have on water wells in the proposed North Kent Wind Project area.

Those concerns are due to what has happened in the former Dover Township area. A number of people have come forward and said families have suffered from turbid waters ever since a wind farm was constructed in the area a few years ago. A number of people said they have experienced the dirty well water due to the vibrations from pile driving during construction, which they say caused sediment to be disturbed and polluted their aquifer.

Water Wells First said Dover Township residents continue to have dirty water due to the ongoing operation of the turbines, which results in seismic coupling – resulting in ongoing sediment problems.

Water Wells First said it isn't just a little bit of sand in the water, as it is enough to destroy water pumps and make the water completely undrinkable.

[*rest of article available at source* [1]]

URL to article: **https://www.wind-watch.org/news/2016/08/08/wind-turbines-impact-on-groundwater-to-be-discussed/**

URLs in this post:
[1] rest of article available at source:
http://www.wallaceburgcourierpress.com/2016/08/07/wind-turbines-impact-on-groundwater-to-be-discussed

ESTERSON Sarah * ODOE

From: Christian Nauer <christian.nauer@ctwsbnr.org>
Sent: Friday, July 20, 2018 3:28 PM
To: ESTERSON Sarah * ODOE
Cc: Robert Brunoe
Subject: Re: Golden Hills Wind Project: Notice of Complete Request for Amendment 5 of the Site Certificate, Draft Proposed Order and Public Hearing - August 23, 2018 Comment Deadline

Dear Sarah,

Thank you for the opportunity to comment on the Golden Hills Wind Project: Notice of Complete Request for Amendment 5 of the Site Certificate (Sherman County).

As the technical reviewer for Section 106 of the National Historic Preservation Act (NHPA), concerns are with potential impacts to historic properties that may be located within the Area of Potential Effects (APE) for the Project. The Project APE is within the territories and areas of concern of the Confederated Tribes of the Warm Springs Reservation of Oregon (CTWSRO).

If the redesign of the Project includes any changes to the APE, then additional identification, evaluation, and protection of historic properties or cultural resources may be necessary. Please keep us in the loop on this Project.

Please keep us in the loop as these Projects develop.

Thank you again for your consideration.

Christian Nauer, MS

Archaeologist
Confederated Tribes of the Warm Springs Reservation of Oregon
Branch of Natural Resources

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Office Phone 541.553.2026
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*The Confederated Tribes of the Warm Springs Reservation of Oregon have reserved treaty rights in Ceded Lands, as well as Usual and Accustomed and Aboriginal Areas, as set forth through the Treaty with the Middle Tribes of Oregon, June 25, 1855.

*Please know that review by the Tribal Historic Preservation Office does not constitute Government-to-Government consultation. Please ensure that appropriate Government-to-Government consultation is made with the Confederated Tribes of the Warm Springs Tribal Council.

On Jul 16, 2018, at 1:51 PM, Robert Brunoe <robert.brunoe@ctwsbnr.org> wrote: