BEFORE THE OFFICE OF ADMINISTRATIVE HEARINGS
for the
STATE OF OREGON
OREGON WATER RESOURCES DEPARTMENT

IN THE MATTER OF: Water Right Application IS-72191 Oregon Department of Fish and Wildlife, *Applicant* Baker Valley Irrigation District, *Protestant.*	))))))))	**WRITTEN DIRECT TESTIMONY OF RYAN ANDREWS** OAH Reference No. 2021-OWRD-00089 Agency Case No.: IS-72191

I, Ryan Andrews, declare and state that the following is true and correct to the best of my personal knowledge and belief:

Foundation as an Expert Hydrologist: current and past work, expertise in the mathematics of modeling.

1. I am a Hydrologist with the Oregon Water Resources Department (OWRD, WRD, or Department). I have been a hydrologist at OWRD for over five years since January 2018. My current role is the program manager of the Surface Water Availability Program. My responsibilities are to maintain the Water Availability Reporting System (WARS) and perform hydrologic analysis regarding water availability and natural streamflow. I evaluate hydrologic data and various tools for modeling streamflow. I also provide technical assistance to other department programs through data assessment, statistical analysis, and review of technical work. One of my main responsibilities is to calculate natural streamflow to be used in evaluating applications for instream water rights.

2. My education background includes a master's degree in fisheries and wildlife from Michigan State University and a bachelor's degree in environmental biology from the University of Dayton.

Foundation to Testify to the Instream File at Issue

3. I am very familiar with the current iteration of WARS because I work with it on a daily basis. I have learned about what went in to developing various iterations of WARS by studying the

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department records from the 1990s through today that discuss the development of the program, since many of the staff involved in the development have retired.

Water Availability Generally Compared to Estimated Average Natural Streamflow

4. Estimated Average Natural Flow (EANF, ENAF, or natural streamflow) and water availability are both numbers that WRD calculates. EANF is meant to represent prehistoric streamflow and is the flow in a stream when there are no consumptive uses and there is no flow regulation by dams or reservoirs. EXHIBIT A11 at 15. From EANF I subtract existing reservoir storage, out-of-stream consumptive uses, and in-stream demands to calculate water availability. Water availability represents the amount of water available for appropriation. Water availability has no effect on my analysis of an instream application because OAR 690-077-0015(3) states "[t]he amount of appropriation for out-of-stream purposes shall not be a factor in determining the amount of an instream water right."

5. EANF is defined by OAR 690-077-0010(10) as "average natural flow estimates derived from watermaster distribution records, Department measurement records, and application of appropriate available scientific and hydrologic technology." The amount allowed for appropriation of an instream water right shall not exceed the EANF as defined by OAR 690-077-0015. The Department's standard representation of EANF as it relates to evaluating instream water rights applications is the 50% exceedance streamflow, or the streamflow that occurs at least 50% of the time. EXHIBIT A12 at 106.

Overall Approach to EANF: Gaged Data and Regression Equations

6. EANF calculations are based on measured streamflow where available (i.e., gaged watersheds) and for ungaged streams, by using statistical models called regional regression equations. EXHIBIT A13 at 15. Gaged watersheds refer to watersheds that have or had a streamgage that provides information necessary to compute the amount of water flowing in the river or stream, also known as discharge, in terms of cubic feet per second (cfs). Gaged watersheds may include a single gage at the mouth of the river or multiple gages on one or many stream reaches with varying lengths and periods of record. Streamgages provide the measured data necessary to calculate natural streamflow. It is important to note that not all measured streamflow represents natural streamflow.

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In most cases, measured streamflow needs to be naturalized to reflect natural streamflow. This is done by performing 'add-backs', which adds known consumptive uses to measured streamflows in order to calculate natural streamflow. EXHIBIT A11 at 21. Consumptive uses represent water withdrawn from a stream for beneficial use (e.g., irrigation, municipal, etc.) and is then lost to evaporation or transpiration (i.e., plant use). The amount of consumptive use for irrigation is based on the number of irrigated acres by crop type, irrigation method, and crop water requirements as estimated by Oregon State University. EXHIBIT A11 at 57. Estimates of municipal consumptive use are based on actual municipal diversions and sewage outfall data. EXHIBIT A11 at 65. Other consumptive uses, or *de minimis* uses, are comparatively small in relation to irrigation and municipal. Estimates of consumptive use for *de minimis* uses were based on studies performed by the US Geological Survey. Gaged data that has been corrected to reflect natural streamflow is then used to develop regional regression equations. EXHIBIT A11 at 41.

7. Regional regression equations are statistical models that relate natural streamflow to watershed characteristics, such as physical and climatological properties including area, precipitation, and elevation, that are known to influence hydrological properties (i.e., streamflow). The regional regression equations are similar to the following, where Q_{NSF} = natural streamflow, X_n = watershed characteristic, and β_n = regression coefficient:

$$Q_{NSF} = \exp(\beta_0)\, X_1^{\beta 1} X_2^{\beta 2} X_3^{\beta 3} \ldots$$

Regression coefficients are generated through calibration of the regression model by relating natural streamflow to watershed characteristics, such that any change in watershed characteristics or streamflow data used in developing the equation would have a resultant change in the regression coefficients and, ultimately, the estimates of natural streamflow produced by the equation.

8. Values of watershed characteristics are typically derived by Geographical Information Systems that summarize information over a delineated area that identifies the boundaries of a watershed. These characteristics are produced and published by agencies such as the US Geological Survey, the Oregon Climate Service, and the Natural Resources Conservation Service. Estimates of

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watershed characteristics are dependent upon the resolution of coverages used to extract and summarize the characteristics. Coverages refer to the data set of spatial and attribute data for geographic features. Resolution refers to the ability to recognize and distinguish features. Finer resolution coverages allow for better distinction of features and improve estimates of characteristics for watersheds.

9. In sum, for watersheds where the EANF is unknown, "an estimate of the streamflow can be made by inserting the known characteristics for the watershed into the regression equation and performing the calculations." EXHIBIT A13 at 19. In this manner, regional regression models 'interpolate' between measured streamflow locations to unmeasured locations. EXHIBIT A13 at 17.

Processing the Output of Regression Equations

10. Correction factors were (and still are) used to improve natural streamflow estimates from regional regression equations because the sum of streamflows estimated through regional regression equations for contributing areas above a gage should equal the gaged streamflow. EXHIBIT A11 at 47. WRD developed correction factors based on a comparison of modeled and measured streamflows and used this information to ensure that the sum of estimated streamflows matches actual flows. For instance, natural streamflow calculated for a gaged watershed is compared to the natural streamflows estimated through regional regression for the corresponding watershed, which may include one or many water availability basins (WABs). WABs are pre-defined areas for which estimations of water availability and natural streamflow are produced. The correction factor is calculated by dividing the actual streamflows by the corresponding sum of streamflows estimated for each WAB through regional regression. See EXHIBIT A17 at 1-2. The estimated streamflows are then multiplied by the correction factor and the corrected streamflows then sum to match the actual streamflows.

Improvements to the EANF Calculation Over Time

11. The general concept and framework for the EANF calculation has remained the same throughout each iteration of WARS. EXHIBIT A13 at 10. For this proceeding I have reviewed the Department memos and documents from the early 1990s. The 1990s is when WRD developed its Water Availability Program and associated data in response to a directive from the state legislature to

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determine water available for surface water allocations in Oregon. These documents explain how WRD worked to improve its water availability calculations over time. The documents show WRD's preliminary analyses based on the Robison method in 1991. Then in 1992 WRD began working on a new methodology referred to as "Cooper Method 1" with updated estimates of water availability. Finally, in the mid-1990s Richard Cooper made additional changes to the methodology with "Cooper Method 2." In this testimony I've noted where the memos describe the natural streamflow calculation, refinements to the input data, and how results were influenced.

12. WRD staff recognized that exceedance flows should be calculated relative to the same time period, or base period, throughout the state. The base period is a period of 30 consecutive years from which measured data is used to calculate natural streamflow. A common base period of 1958 to 1987 was adopted by WRD as the most suitable following investigations of available data. EXHIBIT A13 at 17-18. The periods of record for all gages, such as the short-record gages or out-of-phase records, that do not coincide with this base period had to be adjusted to represent the base period. EXHIBIT A13 at 18. This allowed for the inclusion of data from additional gaging stations through various iterations of the water availability estimates, even if data were collected post-1987. EXHIBIT A11 at 24.

13. The historical documents show that WRD worked to improve estimates of watershed characteristics. Richard Cooper explained that WRD's Geographic Information Services section generated the coverages to estimate the watershed characteristics and lists the watershed characteristics which include watershed area, precipitation, and monthly temperatures. EXHIBIT A13 at 22-23. An important aspect regarding the estimation of watershed characteristics is that the accuracy of the estimates is dependent upon the resolution of the coverages used to extract and summarize values for any given watershed. It was recognized in early iterations that the coverages for some were too coarse, and the coverages stopped at the state line. New coverages were obtained throughout development of WARS that resulted in better estimations of watershed characteristics, particularly for smaller watersheds. EXHIBIT A12 at 31-32. The initial version in 1991 included only four characteristics in

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the regression equations. EXHIBIT A13 at 22. Upon the incorporation of a broader set of watershed characteristics into model development, EXHIBIT A15 at 33, a statistical analysis was performed to identify the most important watershed characteristics that would optimize the regression equations. A subsequent report from 1997 indicated that the equations were revised to include seven watershed characteristics. EXHIBIT A14 at 10. The regression equations used in the current iteration of WARS rely on up to 10 characteristics depending upon the region and month that EANF is to be calculated for. EXHIBIT A11 at 46, Table 20.

14. The final version of WRD's statistical regression approach is memorialized in Cooper's 2002 publication, *Determining Surface Water Availability in Oregon*. This paper outlines the methodologies used when developing the more modern estimates of water availability as housed in the current WARS. EXHIBIT A11.

15. Collectively, these documents show the Department used an extensive process to revise its natural streamflow methodologies with final results that are well reviewed and supported. WRD staff formalized its work in reports and memos that I have studied and explained in this testimony. Extensive science, time and process was devoted to properly determine EANF.

EANF Calculations for Eastern Oregon

16. WABs are the pre-defined areas used for EANF calculations that are based on locations of streamgages, instream water rights, and the physiography of affected streams. A WAB was created to estimate natural streamflow for instream water rights application IS-72191. EXHIBIT A16 at 1.

17. The EANF in this proceeding is first provided in the technical review dated November 25, 1994. Based on the date, the methodology used to calculate the EANF is probably "Cooper Method 2." It appears the above-described steps applied to the EANF calculations in eastern Oregon. First, WRD had to make adjustments to the gaged data in eastern Oregon to account for consumptive uses above gages impacted by consumptive use. Richard Cooper explained "[i]t is unlikely that enough gages measuring natural streamflow are located in these areas to formulate good regression models." Cooper described the need to re-create natural streamflow by adding consumptive uses back to the

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measured streamflows and using that amount to formulate good regression models. As additional updates were made in the mid-1990s from "Cooper Method 1" to "Cooper Method 2", Cooper explained that streamflow measurements were, in fact, corrected to natural streamflows before estimating streamflows. EXHIBIT A14 at 4.

18. Naturalized flows from streamgage 13281500 were used in calculating natural streamflow for IS-72191. EXHIBIT A18 at 1. This gaging station measured flow on the Powder River near Haines, Oregon, downstream of what is now Phillips Lake and upstream of Thief Valley Reservoir from October 1946 to September 1953 and was used as a short-record gaging station in development of WARS. EXHIBIT 11 at 84. In order to correct streamflows estimated through regional regression equations, a correction factor was developed using information from streamgage 13289500. This gaging station measured flow near the mouth of the Powder River near Robinette, Oregon, from October 1928 to September 1932.

19. It appears based on the historical documents that WRD developed natural flow estimates for the water availability basin associated with IS-72191 using watermaster distribution records, Department measurement records, and other relevant records described above such as US Geological Survey information. Cooper indicated that streamflow measurements in eastern Oregon were corrected to natural streamflows, and this likely involved watermaster distribution records of consumptive use. Records from two gages were used in the calculation of natural streamflow for this water availability basin, and I consider the gage records to qualify as either watermaster distribution records or Department measurement records. The multi-step analysis using gaged data, statistical regression analysis, and a correction factor demonstrates the application of appropriate available scientific and hydrologic technology.

Natural Streamflow Compared to Measured Streamflow

20. In preparation for this hearing, I have read the portion of the protest stating the amount of water filed for is not in the stream during the months of June, July, August, and September. In regard to WARS, there are some important distinctions to be made between natural streamflow and

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measured streamflow. Measured streamflow can refer to gaged streamflow or individual streamflow measurements made by an individual using a current meter that measures water velocity in conjunction with stream depth and width measurements to compute discharge that are representative of a single point in time. It is important to note that natural streamflow is a concept used to establish expected streamflow conditions in the absence of human use, such as storage or consumptive use, and is calculated as the sum of gaged streamflow and consumptive use. EXHIBIT A11 at 36. Exceedance flows are calculated for both natural streamflow and measured streamflow at the same location, although in most cases they will be different, and in general, those for natural streamflow would be greater than what was measured. As mentioned previously in this testimony, there are few cases where measured streamflow would represent natural streamflow. In other words, most measured streamflow, including what is recorded by streamgages or individual streamflow measurements, is influenced by upstream use.

21. Another important distinction between natural streamflow as estimated by WARS and individual or miscellaneous streamflow measurements is that natural streamflow is calculated using data from a long period of time. This includes direct calculations using gaged streamflow as well as indirect calculations through regional regression equations. Direct estimates were developed using a tool called a flow duration curve, which shows the percent of time a specified discharge was equaled or exceeded during a given period of time. In the case of WARS, flow duration curves were calculated using mean daily flow values by month and are representative of the period of time from 1958 to 1987. EXHIBIT A11 at 23-24. For example, the 50% exceedance flow is the discharge that was equaled or exceeded 50% of the time during that period. Exceedance flows are dependent upon the time period for which they are calculated. EXHIBIT A11 at 25, Table 5. Any individual streamflow measurement that was made during that time period may have been less than that value for at least two reasons. First, the measurement would likely have been impacted by upstream use. Second, even if the system were absent of consumptive use and storage and represented natural streamflow, due to the inherent nature of how flow duration curves are derived, exceedance flows are not necessarily representative of the

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quantity of streamflow within a stream at a single point in time.

Comparison of 1994 EANF to Current Data in WARS

22. The regional regression equations used to estimate EANF for IS-72191 on the technical review are different than those currently used in WARS. See EXHIBIT A14. Additional watershed characteristics were included in the most recent iteration. EXHIBIT A11 at 46.

23. For this proceeding I compared the difference in the 1994 EANF and today's EANF from WARS.

Table 1. Difference in estimated average natural flow between values listed on the technical review for IS-72191 and those currently listed in the WARS database.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
ISWR ENAF (cfs)	163	230	393	740	1100	845	212	146	82.5	76.9	103	122
WARS (cfs)	108	158	308	702	1040	884	271	136	89.7	84.9	99.4	107
DIFFERENCE IN EANF (cfs)	-55	-72	-85	-38	-60	-39	-59	-10	7.2	8	3.6	-15

24. In some months the difference is less than 10 cfs while in others it is larger. In all months, the 1994 EANF calculations are grounded in hydrological principles and practices.

25. For this proceeding I also compared the requested instream amounts with the 1994 EANF values and today's EANF values. The requested instream amounts are well below the lowest EANF value in every month.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Requested (cfs)	25	25/30	40	40	40	40/30	25	25	25	25	25	25
Minimum EANF (cfs)	108	158	308	702	1040	845	212	136	82.5	76.9	99.4	107

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26. WRD did not propose any reductions to the instream amounts due to EANF in the 1996 PFO. If WRD reconsidered this application against its current EANF information, it would still not propose any reductions because the proposed amounts are below EANF in every month. In my professional opinion based on the methods and data available at the time, I have not found any abnormalities with the processes used to calculate EANF and the values represent the Department's best estimate of natural flow, including the months of June, July, August, and September. This concludes my testimony.

I declare under penalty of perjury that the foregoing is true and correct.

DATED this 2nd of June 2023.

Respectfully submitted,

/s/ _Ryan Andrews_____________
Ryan Andrews

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