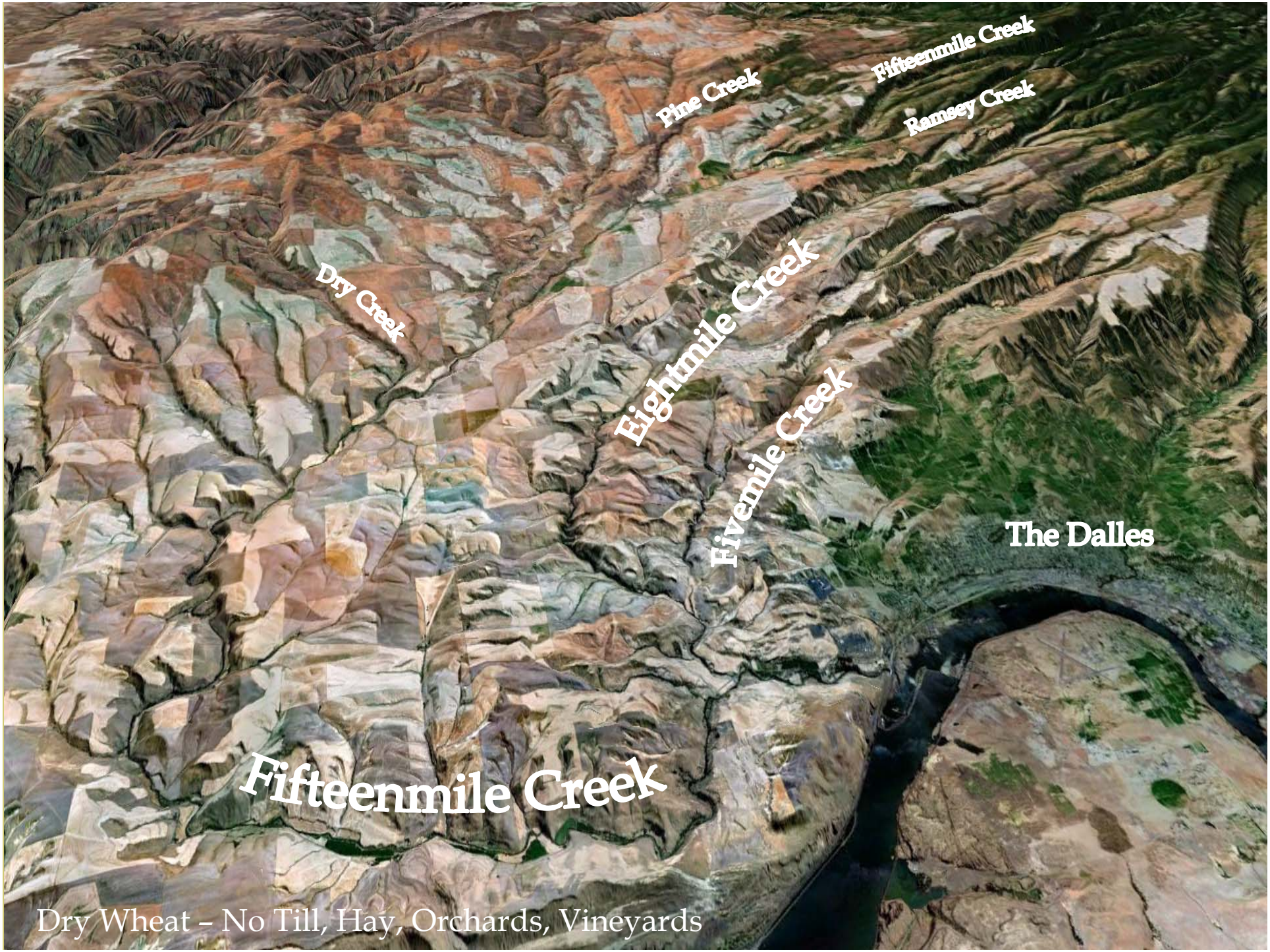
Temperature Modelling of Fifteenmile Creek

Derrek Faber – *ODFW*
Mid-C Fish Research

Presentation Outline

- Background and management concerns
- Model Development
- Implementation and Results
- Irrigator participation/ Alerts


Pine Creek
Fifteenmile Creek
Ramsey Creek
Dry Creek
Eightmile Creek
Fivemile Creek
The Dalles
Fifteenmile Creek
Dry Wheat – No Till, Hay, Orchards, Vineyards

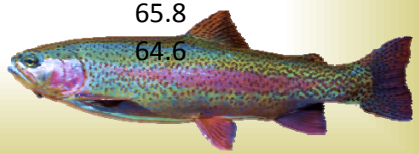
Known Exposure to Lethal Temperatures (prolonged exposure)

- Juvenile Steelhead ~72º F (23 C)
- Juvenile Coho ~76º F (25 C)
- Juvenile Chinook ~74º F (24 C)

Adult Steelhead die in temperatures 2º-4º less than juvenile steelhead.

Fifteenmile Creek Water Temperatures - 2009

Date	Eightmile Confluence	Emerson Mkt. Rd.
16-Jul-09	72.1	70.3
17-Jul-09	73.6	72.7
18-Jul-09	72.9	72.7
19-Jul-09	70.5	72.1
20-Jul-09	70.7	71.4
21-Jul-09	72.7	72.9
22-Jul-09	72.9	74.1
23-Jul-09	69.3	72.0
24-Jul-09	69.3	71.6
25-Jul-09	71.6	72.7
26-Jul-09	74.1	74.5
27-Jul-09	77.4	77.0
28-Jul-09	77.9	78.4
29-Jul-09	78.1	78.8
30-Jul-09	75.7	77.5
31-Jul-09	76.5	79.0
1-Aug-09	76.6	79.5
2-Aug-09	75.7	79.2
3-Aug-09	72.5	77.0
4-Aug-09	69.8	74.3
5-Aug-09	68.4	73.6
6-Aug-09	63.9	68.9
7-Aug-09	62.4	66.9
8-Aug-09	63.0	66.9
9-Aug-09	65.8	68.4
10-Aug-09	68.0	69.3
11-Aug-09	69.1	70.0
12-Aug-09	70.2	70.7
13-Aug-09	67.8	70.0
14-Aug-09	64.4	65.8
15-Aug-09	63.9	64.6



Motive

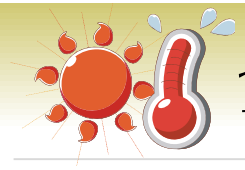
- NFMS Special Agent noticed water use during period
- Sept 2010: NMFS special agent presentation at WC
  Encouraged water conservation, stream flow monitoring
    - Warned that ESA protections still apply even during drought
    - Need to develop a contingency plan
- Fifteenmile Watershed Council sought solution
- Critical Low Flow Plan Developed (Fifteenmile Action to Stabilize Temperature, FAST)
    - Water Temperature Forecasting Model

Effects of Water Withdrawal on Water Temperature (in relation to Steelhead)

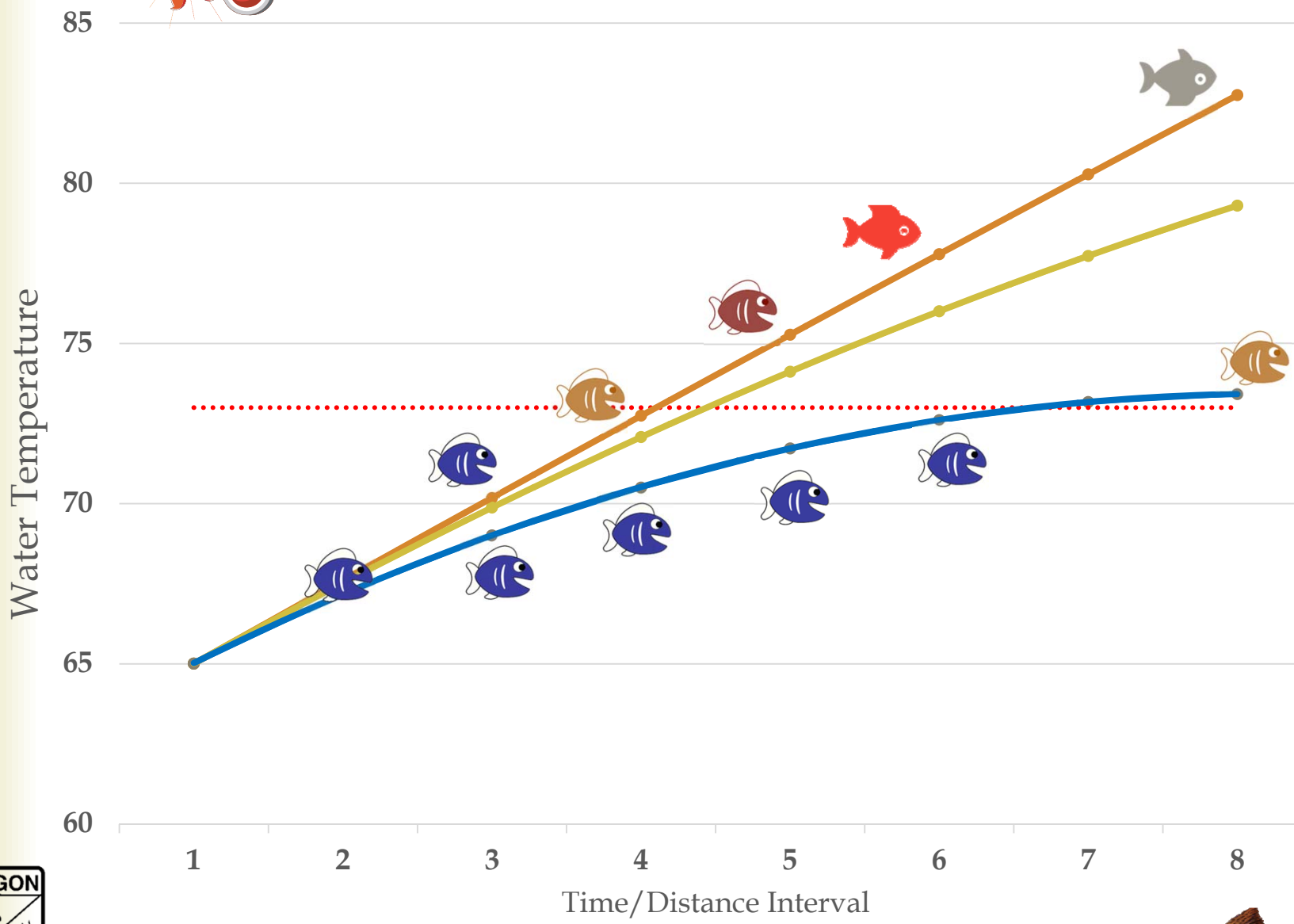
Scenario:

- 5 cfs (typical summertime flow)
- 1-mile section of Fifteenmile Creek
- 102^0 day
- Modeled using SSTEMP*

*Bartholow, J.M. 2002, SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0).



102^0



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Heat Equation:

Convection
(Flow Rate, Bed Roughness, etc.)

Radiation
(Shade, Seasonal Effects)

Conduction
(Geology, substrate, channel characteristics)

$$\Delta T = \frac{Q\ (Heat\ Energy)}{Mass\ x\ Specific\ Heat\ (water)}$$

Groundwater Volume
(Seasonal, Spatial)

Surface Water Volume
(Seasonal, Spatial)

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Available Instruments/Measurements Deployed in Fifteenmile Ck. Watershed

- Temperature Loggers
- Discharge
- IFP Net/Weather Stations
- Weather Forecast

Physical Processes := Co-correlated

→ Statistical Model

Bayesian Fixed Effect Model

$$y = X\beta + \epsilon$$

$y = known\ vector$ of observations → Water Temp

$\beta = Unknown\ Vector, Fixed\ Effects$ → Air Temp, Dew Pt., Humidity, Flow

$\epsilon = Unknown\ Vector, Random\ Errors$

X $= Known\ Design\ Matricies\ linking\ y\ \&\ \beta$ → Solved

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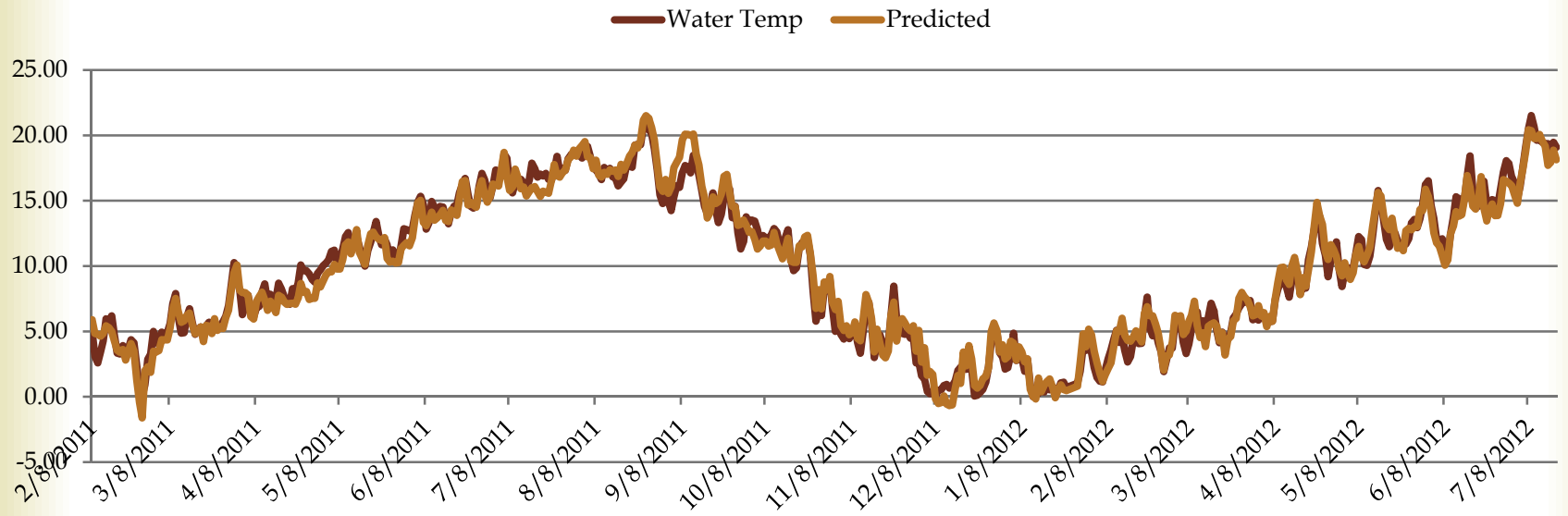
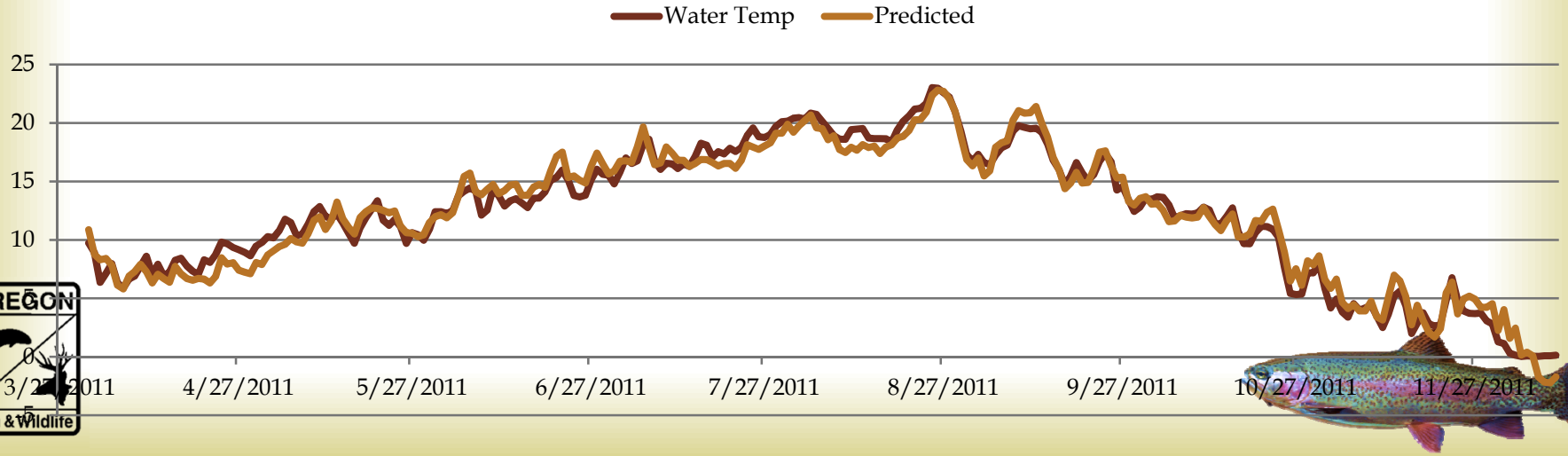
Model Performance (Back-casting):

Fifteenmile Creek at Eightmile Creek Confluence



Fifteenmile Creek at Emerson-Roberts Market Rd



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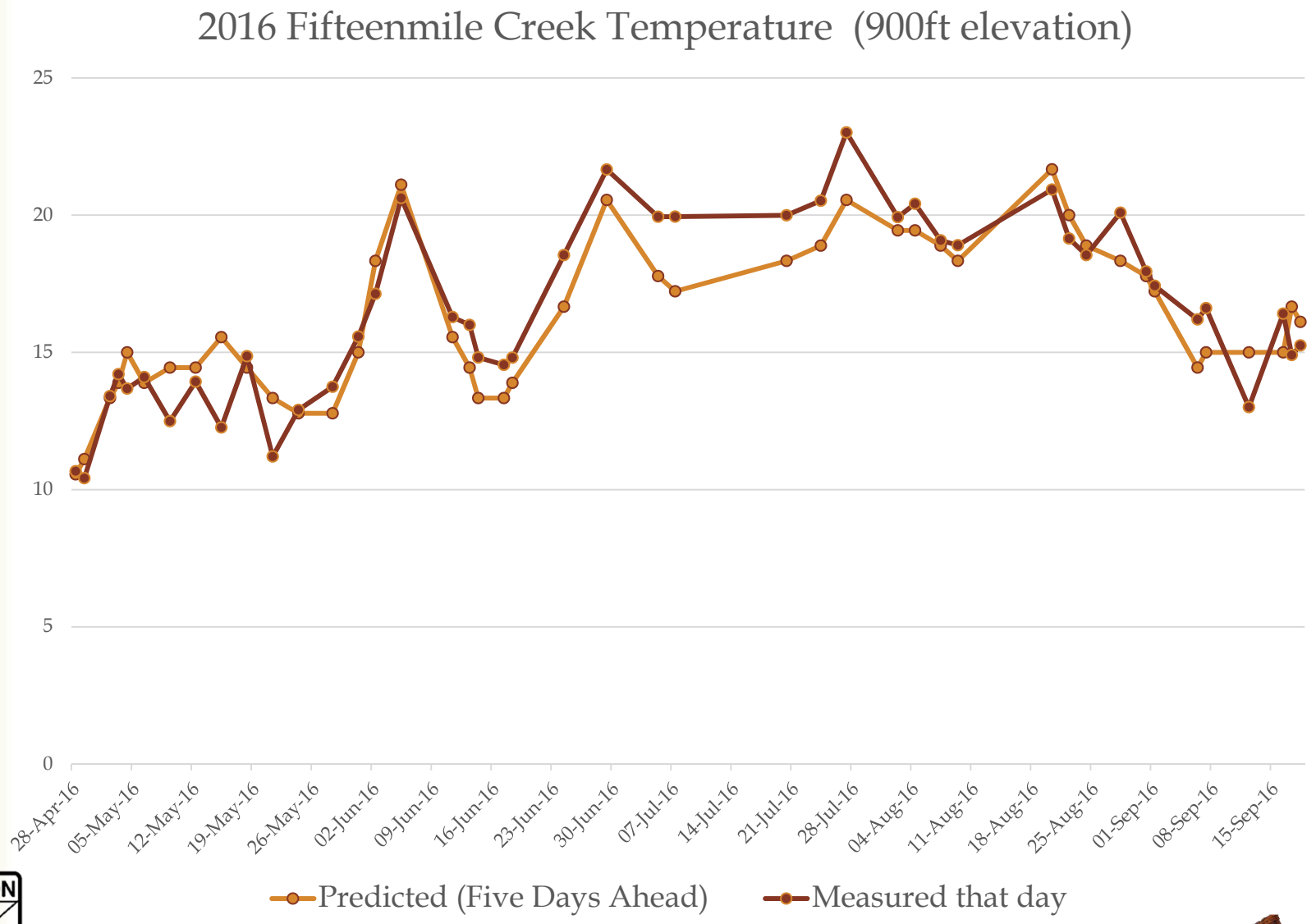
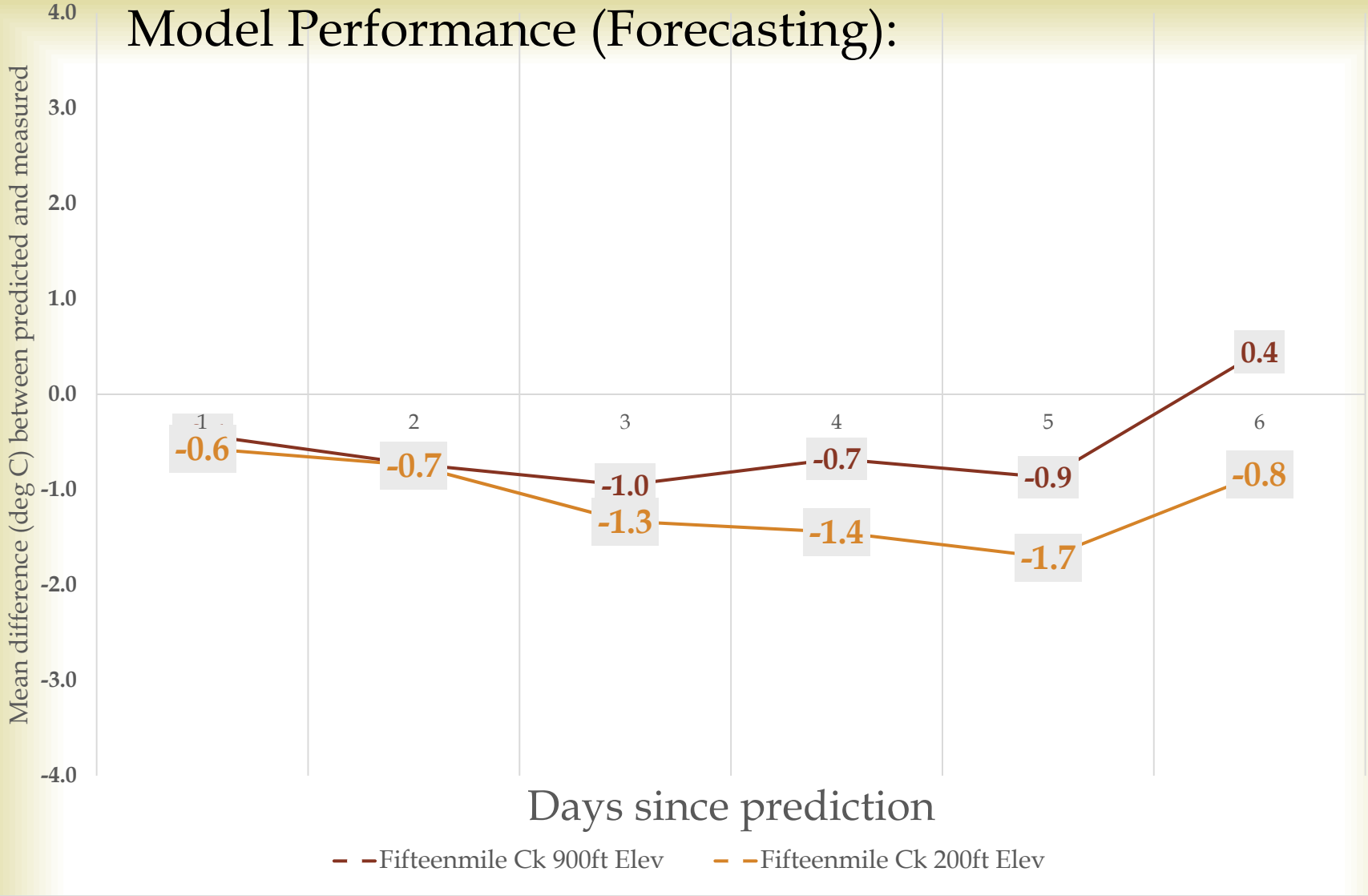
Model Performance (Forecasting):



Model Performance (Forecasting):



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FAST Program

Irrigator Participation

- Fifteenmile Water Rights (Over allocated)
- 3,450 acres with surface water rights
- Total paper rate -~47 cfs
- Instream rates senior to 1980 – 5.83 cfs

- FAST pilot year (voluntary, 2013)
- FAST – Compensation Schedule (2014-2017)

Transaction Type	Terms	Seniority	Payment
Leasing (full season and split season options available)	Required to shut off during term of lease, payment following final order from OWRD based on acre-feet approved	1856-1896 1897-1909	$73.33/acre-foot $50.00/acre-foot
FAST Option 1	Required to shut off during temperature alerts, payment at beginning of season based on acres enrolled and baseline alert days	1856-1896 1897-1909 1910-1949 1950-1959 1960-1985	$51.82/acre $44.42/acre $22.24/acre $13.88/acre $ 9.45/acre
FAST Option 2	Choose to shut off during temperature alerts, payment at end of season based on gallons curtailed (capped at payment under FAST Option 1)	Any, provided not already regulated off at time of temperature alert	Jun: $0.0004/gal Jul: $0.0003/gal Aug: $0.0003/gal Sep: $0.0003/gal

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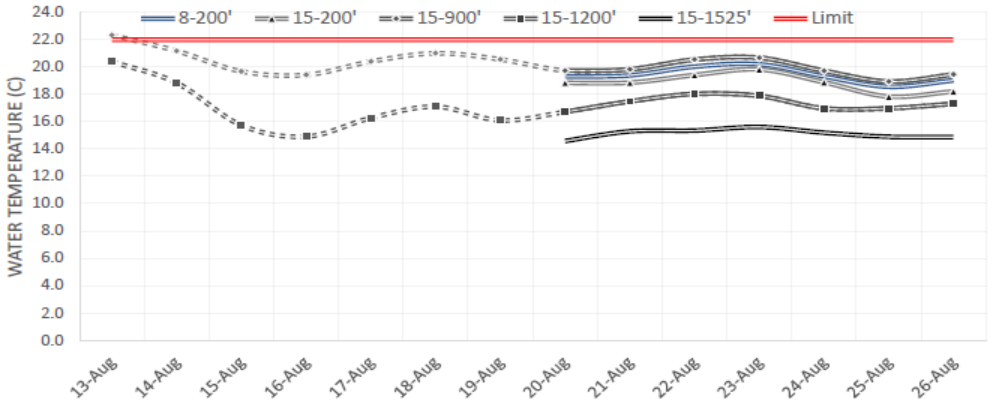
Water Temperature Below Thresholds

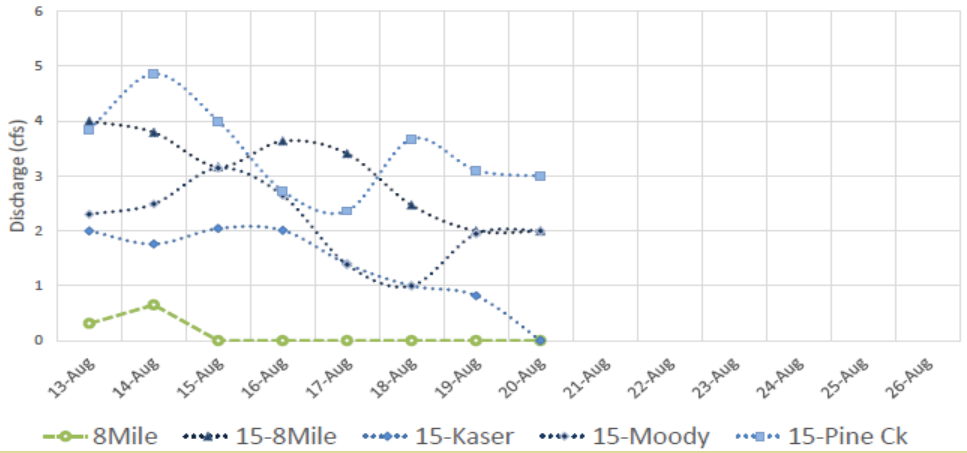
Alert issued when water temperatures exceed 71.6°F (22°C) in upper Fifteenmile Creek or 73.4°F (23°C) in lower Fifteenmile Creek, and at two sites for two or more days.

8/20/2017	Measured	Today	Water Temperature Forecast (°F)					
Elevation	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug	24-Aug	25-Aug	26-Aug
Eightmile Ck: 200 ft		67	67	68	68	67	65	66
Fifteenmile Ck: 200 ft	69	66	66	67	68	66	64	65
900 ft		68	68	69	69	67	66	67
1200 ft	61	62	63	64	64	63	63	63
1525 ft		58	60	60	60	59	59	59

MEASURED TEMP <-|-> PREDICTED TEMP



Measured Flow



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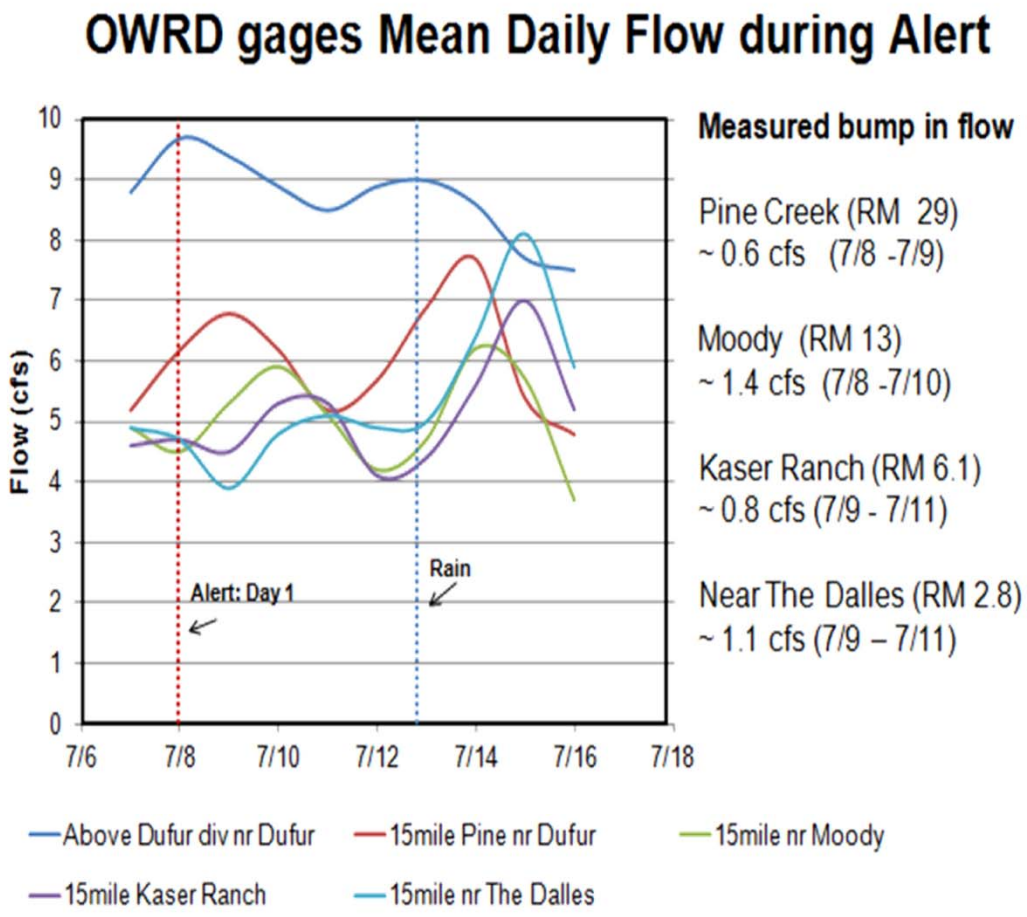
2014 Impact of curtailment on streamflow



Measured bump in flow

Pine Creek (RM 29)
~ 0.6 cfs (7/8 -7/9)

Moody (RM 13)
~ 1.4 cfs (7/8 -7/10)

Kaser Ranch (RM 6.1)
~ 0.8 cfs (7/9 - 7/11)

Near The Dalles (RM 2.8)
~ 1.1 cfs (7/9 – 7/11)

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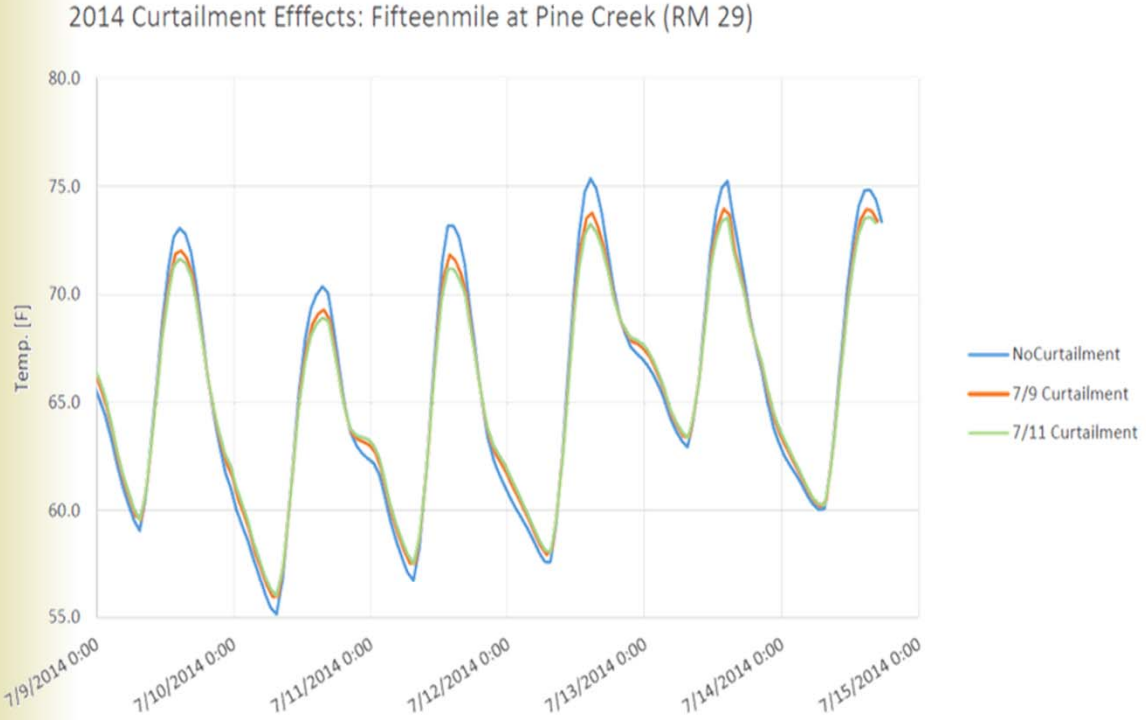
Water Temperature Modeling – 2014 FAST W3T Model by The Freshwater Trust



Date	No Curt. [F]	Curt. [F]	Diff. [F]
7/9	73.1	71.7	1.4
7/10	70.4	68.9	1.4
7/11	73.2	71.2	2.0
7/12	75.4	73.3	2.1
7/13	75.3	73.5	1.7
7/14	74.8	73.6	1.2
		Mean	1.7

RM 12.7

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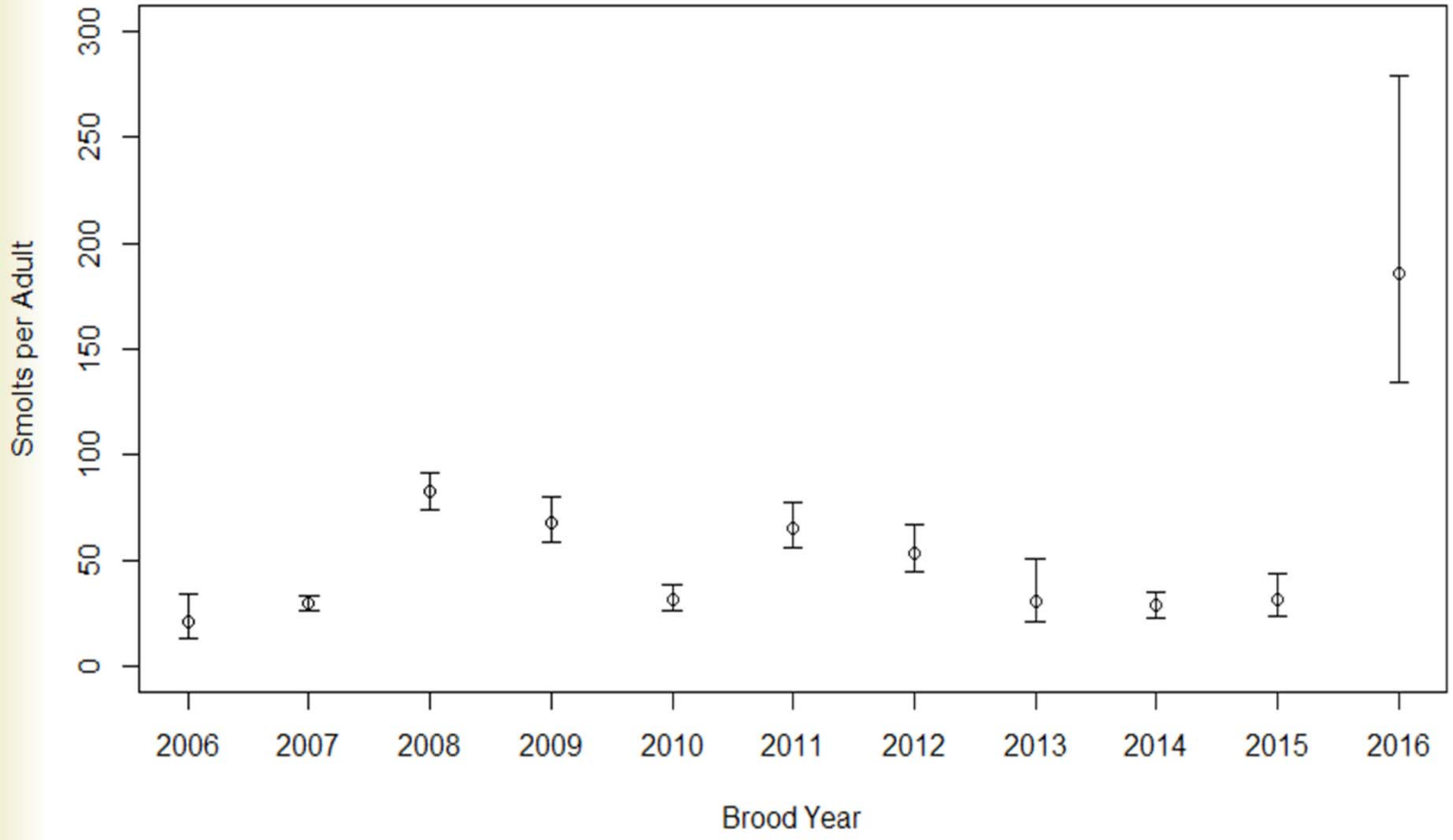
DMF1

FAST Model and Program Summary

- Model simple to deploy using available resources.
- Useful at predicting periods when water temperature is potentially lethal
- FAST Program effective at reducing water temperature during critical times
- Minimizes 'Irrigation Bottleneck'; e.g. Hastening effect of high water temperatures on fish by irrigating during high temps.

DMF1 Derrek M Faber, 4/12/2018

Fifteenmile Steelhead Smolt Production



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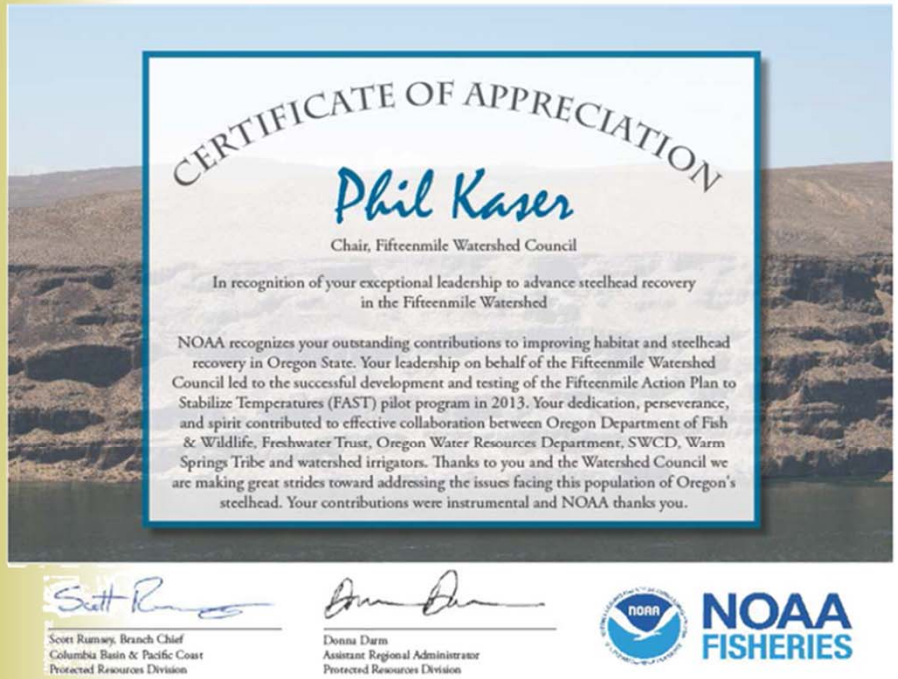
NMFS Certificate of Appreciation



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Fifteenmile Action to Stabilize Temperatures (FAST)

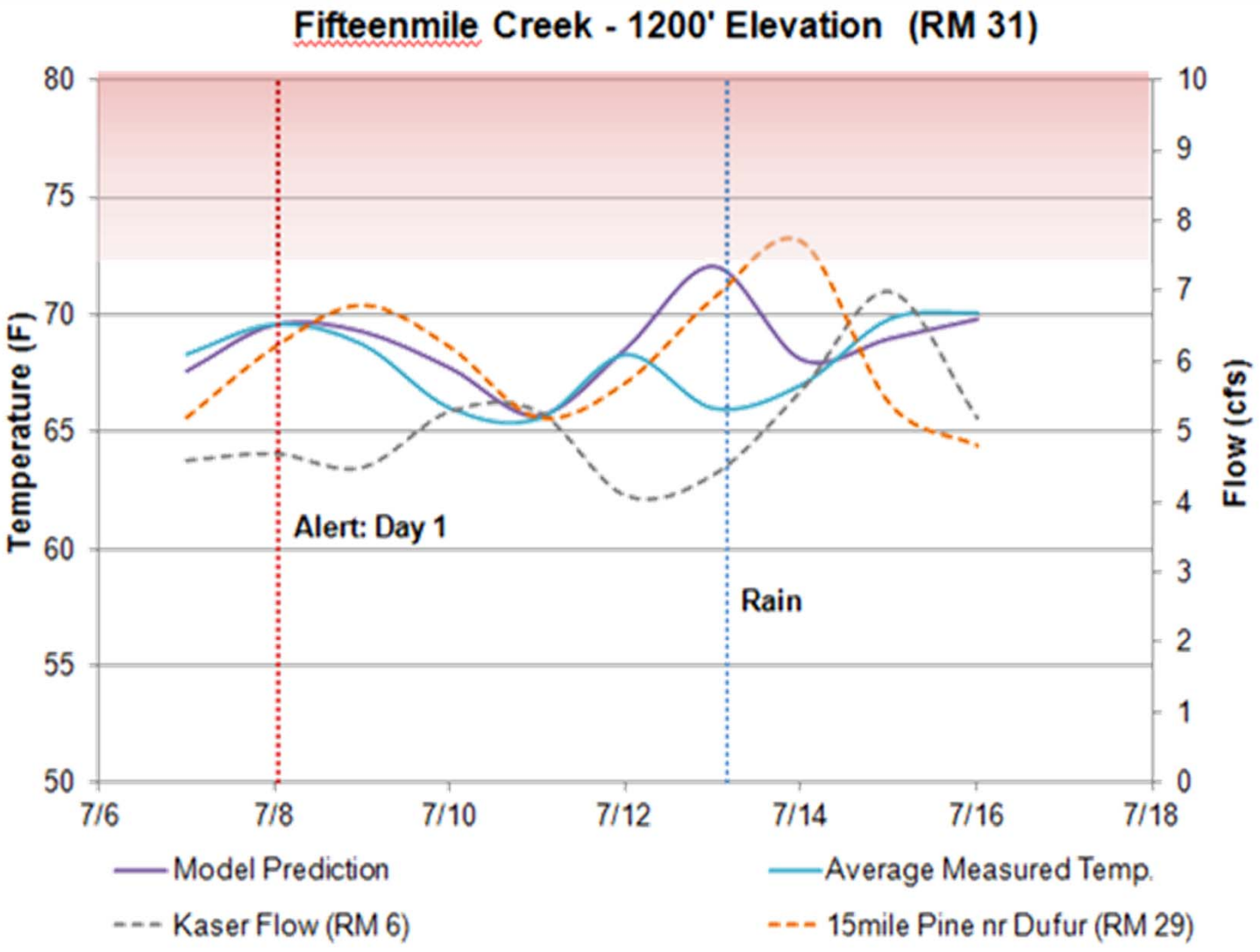
December 2014

Prepared by:
Fifteenmile Watershed Irrigators

In cooperation with:
The Freshwater Trust
Fifteenmile Watershed Council
Oregon Water Resources Department
Oregon Department of Fish & Wildlife
Confederated Tribes of Warm Springs
Wasco County Soil & Water Conservation District
Wy'East RCD
Oregon Department of Environmental Quality
National Oceanic & Atmospheric Administration

With generous support from:
Oregon Watershed Enhancement Board


Questions?



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2013 FAST alert

- *One alert*: 6/27 –7/3
  - Regulation: 6/28 -to 1960
  - 7/2 –to 1909

- Actual temperatures > 72 deg
- 7 senior (1860 –1896) irrigators participated

- ~4.5 cfs left in stream

- No fish mortalities

Measured Stream Temperatures 2013 (daily average Deg. F) on Fifteenmile Creek

	Elevation (ft) 200′	900′	1200′	1525′
6/27 – Alert	• 68.7	66.9	61.3	56.4
6/28 – Reg 1960	• ***73.0***	71.6	65.4	59.3
6/29	• ***75.6***	***75.0***	69.1	62.3
6/30	• ***75.4***	***75.7***	***72.2***	62.8
7/1	• ***77.9***	***78.6***	***72.8***	65.3
7/2 – Reg 1909	• ***77.5***	***79.2***	69.8	66.4
7/3 – End Alert	• ***73.9***	***76.3***	65.9	64.2
7/4	• 69.4	71.8	65.9	62.0

* Red color indicates above threshold for alert

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2014 FAST Alert – incl. Compensation

One alert: 7/8 –7/15

- Regulation: junior to 1909
  - 14 participants
  - 9 compensated
  - 5 voluntary
- all senior to 1909
- ~4.38 cfs/day left in stream
- No fish mortalities

Creek		Approximate POD location	Reduction rate
8mile	voluntary	RM 8.9	0.55 cfs
8mile	Opt. 1	RM 18.7	0.45 cfs
15mile	Opt. 1 & 3	RM 6.1-13.5	0.75 cfs
15mile	Opt. 1	RM 19	0.12 cfs
15mile	Opt. 3	RM 31	0.39 cfs part of alert
15mile	Opt. 3	RM 31.4	0.59 cfs first 2 days 1.2 cfs rest of alert
15mile	voluntary	RM 32	1.04 cfs part of alert
15mile	voluntary	RM 32.7	0.33 cfs
15 mile	voluntary	RM 33.8	0.26 cfs
15mile	Opt. 1	RM 35.4	0.47 cfs
15mile	Opt. 1	RM 35.7	0.11 cfs
15mile	voluntary	RM 35.9	0.31 cfs

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ad Lethality

t (1970, as cited by USEPA 1999) found that Columbia River steelhead, which were ted to a river temperature of 19C, had a lethal threshold of 21C. Bell (1986) reviewed studies and states that the lethal threshold for steelhead is 23.9C. According to the hia Department of Fish and Game (2001, p.419), temperatures of 21.1C have been d as being lethal to adults.

k Lethality

oratory study Brett (1952) acclimated five different species of juvenile salmon to various atures ranging from 5-24°C. At temperatures of 24°C and below there was 100% survival luring the one-week duration of the experiment. Brett (1952) concluded that the lethal ature (temperature where survival becomes less than 100%) was between 24.0 and 24.5°C, ultimate upper lethal temperature was 25.1°C (temperature at which 50% of the ion is dead after infinite exposure). A review of numerous studies led Bell (1986) to e that the upper lethal temperature for Chinook is 25C. Myrick and Cech (2001) d literature on studies from the Central Valley and found data to suggest that the chronic re >7 days) upper lethal limit for juvenile Chinook is approximately 25°C.

ethality

iew of various literature sources, Bell (1986) found that the upper lethal temperature for 25.6C. Brett (1952) concluded that the ultimate upper lethal temperature of juvenile lmon was 25.0°C (temperature at which 50% of the population is dead after infinite e). Thomas et al. (1986) conducted a study to determine the mortality of coho subjected uating temperatures. It was determined that the LT50 (the temperature at which 50% of ulation will die) for fish acclimated to a 10-13°C cycle was 26°C for presmolts (age-2 d 28°C for age-0 fish.