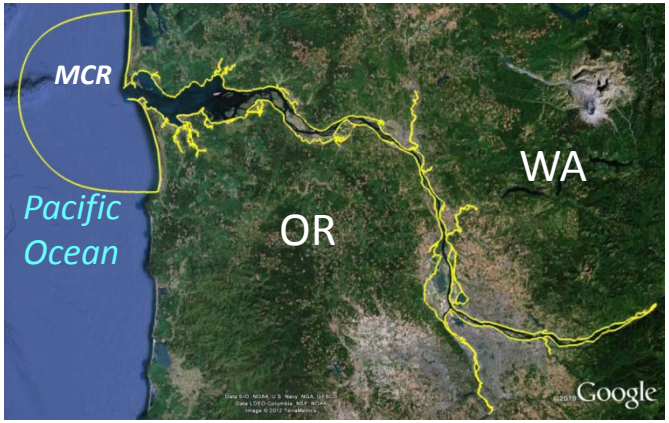
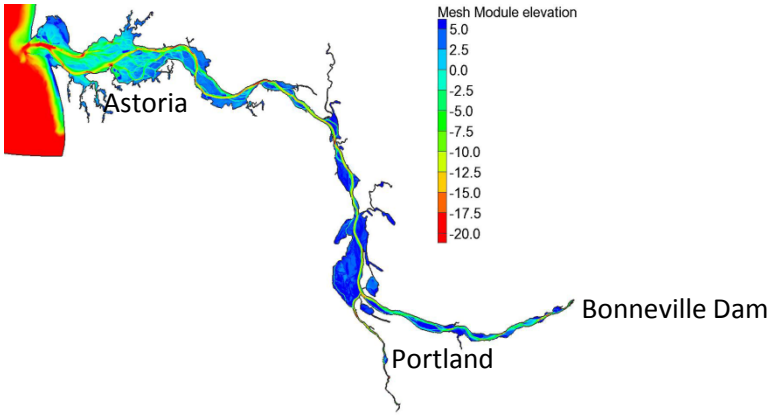
AdH Application within the Lower Columbia River (LCR)

Results shown herein are based on the Adaptive Hydraulics (AdH) model, including the Lower Columbia and Willamette Rivers, was recently developed at the U.S. Engineer Research and Development Center (ERDC) Coastal and Hydraulics Lab (CHL), Estuarine Engineering Branch. AdH is the US Army Corps of Engineers' (USACE) next generation unstructured multi-dimensional, mass conserving, finite element, physics-based hydrodynamic model code that utilizes automatic, run-time grid refinement and un-refinement to obtain the best hydrodynamic solution for the least computational cost (https://adh.usace.army.mil).

The lower Columbia River AdH model was calibrated and validated for the time period of 1 April – 30 October 2009. The LCR model development and application were joint supported by CHL-ERDC and Portland District (NWP). Modelled fluvial input is from Bonneville Dam, Sandy River, Willamette River, and Lewis River. Tide is modelled from the Pacific Ocean.



100 miles

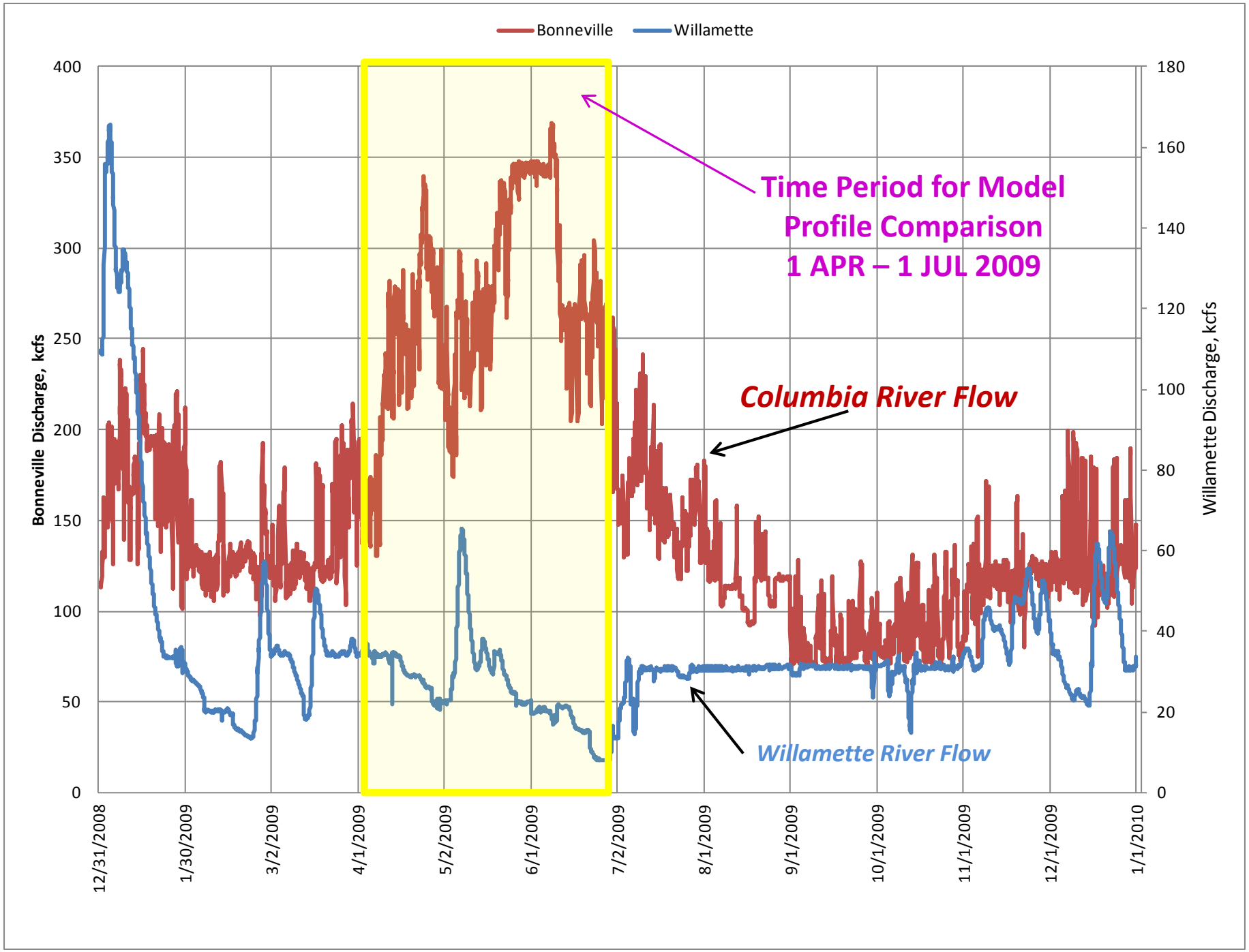


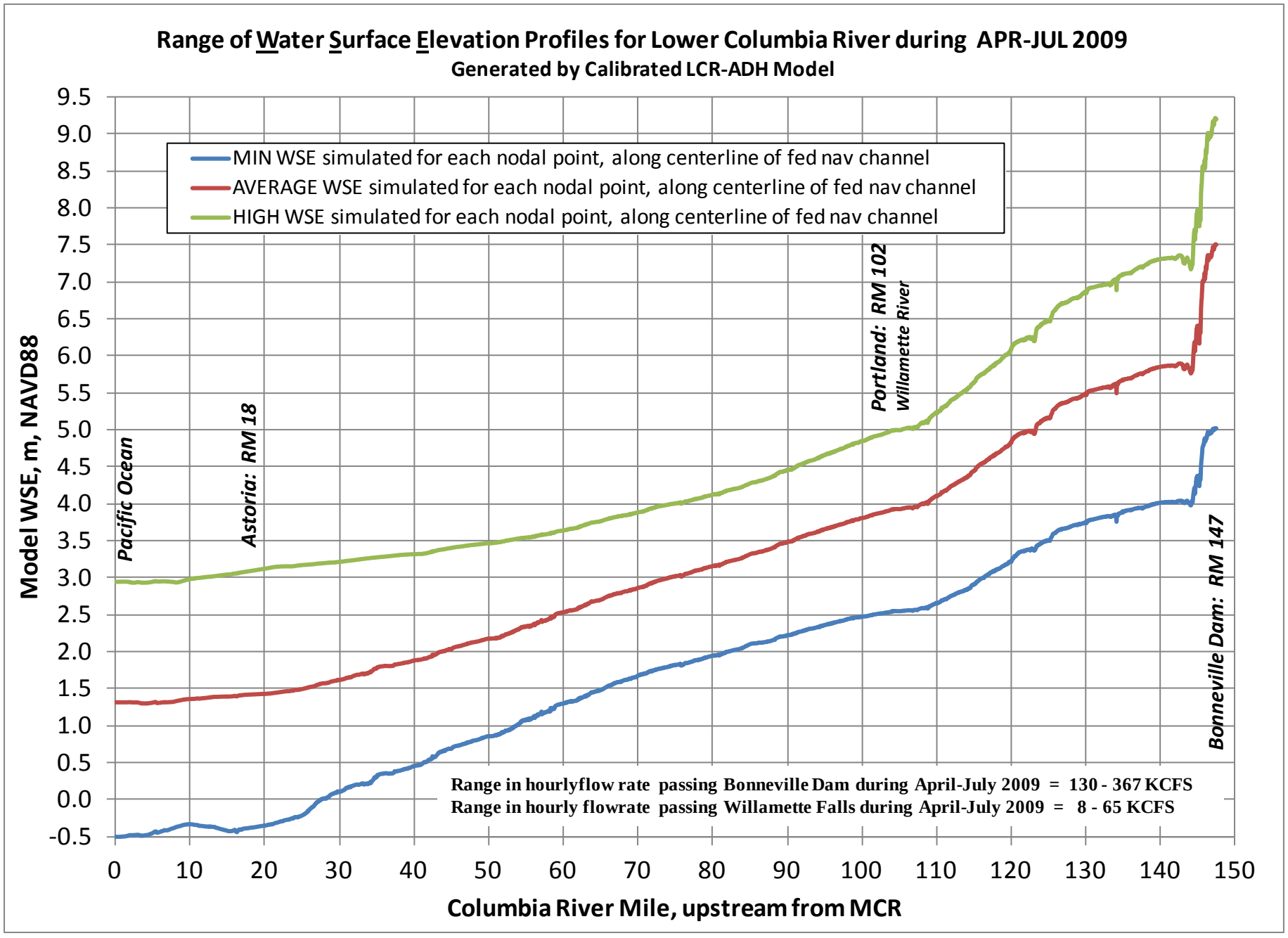
LCR AdH model: ~ 220,000 nodes and ~400,00 elements

The following plots show the variability of the WSE along the lower Columbia River during the ADH model calibration period (APR - JUL 2009). The range in observed river flowrate for the Columbia and Willamette Rivers during this period is shown in the figure. The profiles were generated by querying the ADH WSE solution file for the:

-Minimum (MIN) value
-Average (AVG) value
- Maximum (HIGH or MAX) value

WSE at each model nodal point within the LCR model domain, for each solution time step. The attached graphic shows each of these values along the LCR navigation channel centerline. Note that each of the profiles shown may not reflect a realized instantaneous condition along the LCR. Each WSE profile is a construct of min, avg, max values; which may occur at different times within the APR-JUL simulation.


Bonneville
Willamette
Time Period for Model
Profile Comparison
1 APR – 1 JUL 2009
Columbia River Flow
Willamette River Flow
Bonneville Discharge, kcfs
Willamette Discharge, kcfs
400
350
300
250
200
150
100
50
0
180
160
140
120
100
80
60
40
20
0
12/31/2008
1/30/2009
3/2/2009
4/1/2009
5/2/2009
6/1/2009
7/2/2009
8/1/2009
9/1/2009
10/1/2009
11/1/2009
12/1/2009
1/1/2010


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
Generated by Calibrated LCR-ADH Model
MIN WSE simulated for each nodal point, along centerline of fed nav channel
AVERAGE WSE simulated for each nodal point, along centerline of fed nav channel
HIGH WSE simulated for each nodal point, along centerline of fed nav channel
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Columbia River Mile, upstream from MCR
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS

*Application of LCR AdH model to Evaluate Water Surface Elevation Changes within the LCR** due to Projected Sea Level Rise (SLR)*

The following information is relevant to the Lower Columbia River, and can be used to evaluate the potential effect of Future Sea Level Change on river profile, from RM 0 to Bonneville Dam (RM 147). Use this information in conjunction with applicable USACE Guidance, specified below.

Determine Applicable USACE future Sea Level Change Scenario (curves 1-3) for project location from the link below:

http://corpsclimate.us/ccaceslcurves.cfm

Refer to the below link for Engineering Technical Letter (ETL 1100-2-1) for USACE procedures for Evaluating Sea Level Change: Impacts, Responses, and Adaptation:

http://www.publications.usace.army.mil/Portals/76/Publications/EngineerTechnicalLetters/ETL_1100-2-1.pdf

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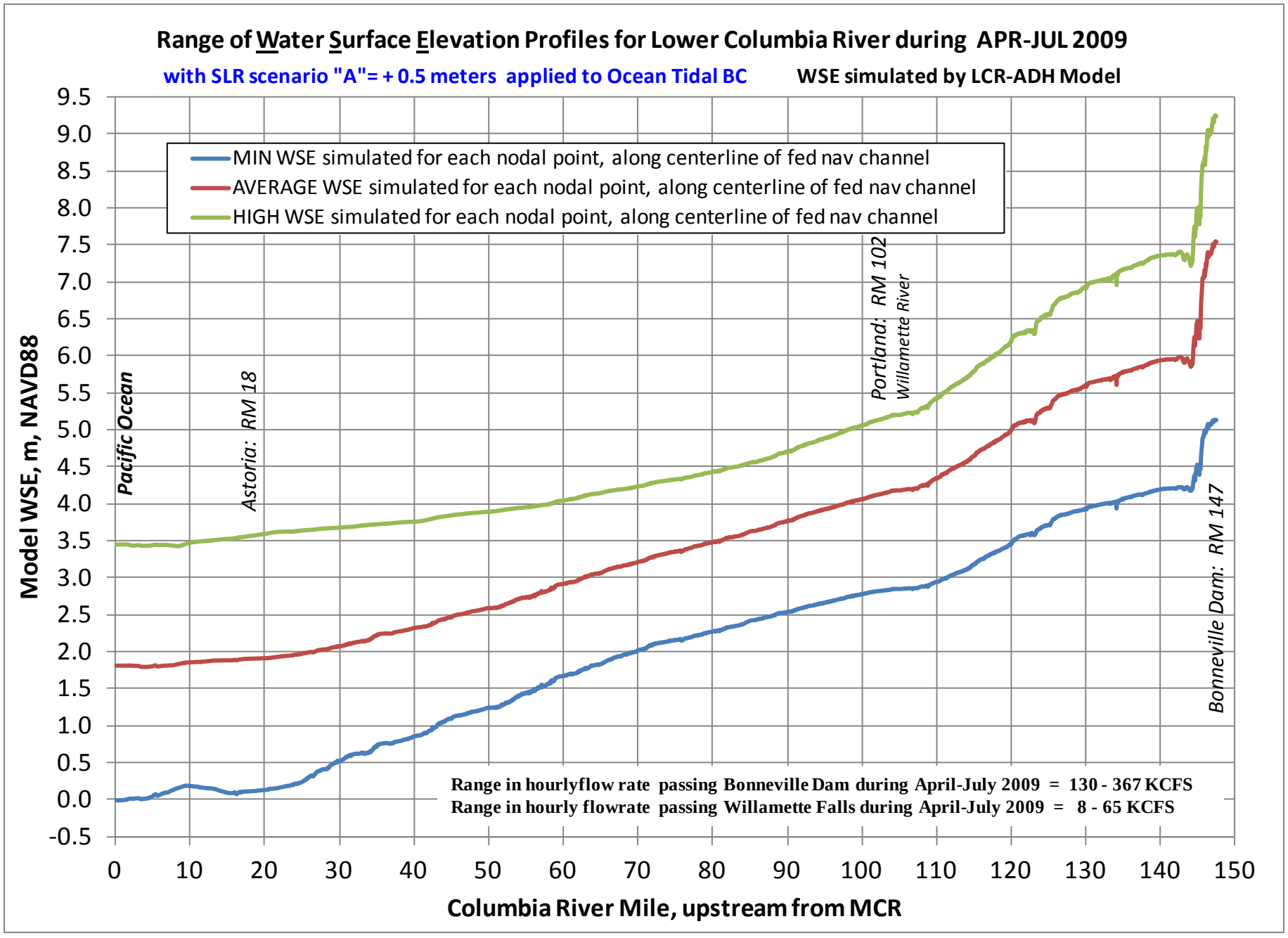
The AdH model was run for 1 APR – 1 JUL 2009 with observed transient riverine & Tributary boundary conditions applied at:

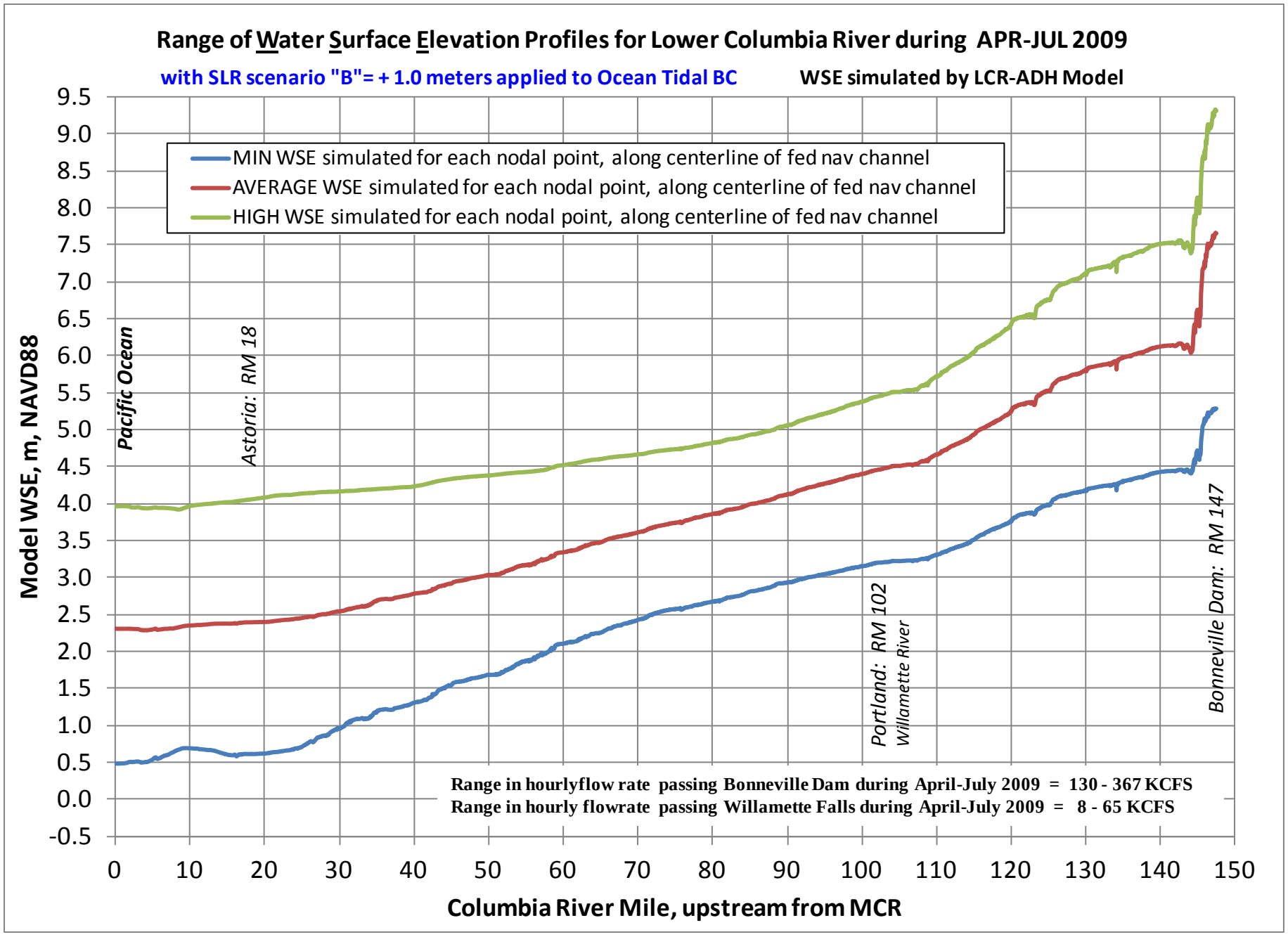
- **-Bonneville Dam (Columbia River)**
- **- Sandy River**
- **-Willamette Falls (Willamette River)**
- **-Lewis River**
- **-Cowlitz River**

The observed ocean tidal boundary condition was adjusted to emulate the effect of SLR for each of three SLR scenarios:

- **-SLR scenario "A" = +0.50 meters, above present condition (SLR curve #3 at 50 years from present, or SLR curve #2 at 70 years from present)**
- **-SLR scenario "B" = +1.0 meters , above present condition (SLR curve #3 at 75 years from present)**
- **-SLR scenario "C" = +1.5 meters, above present condition (SLR curve #3 at 100 years from present)**

**** The AdH model simulation for WSE along the LCR profile are based on the assumption that the river bed morphology remains constant through time (morphology does not respond to SLR conditions). SLR was estimated using EC-165-2-211, applicable to Astoria, OR.**


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
with SLR scenario "A"= + 0.5 meters applied to Ocean Tidal BC
WSE simulated by LCR-ADH Model
MIN WSE simulated for each nodal point, along centerline of fed nav channel
AVERAGE WSE simulated for each nodal point, along centerline of fed nav channel
HIGH WSE simulated for each nodal point, along centerline of fed nav channel
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
with SLR scenario "B"= + 1.0 meters applied to Ocean Tidal BC
WSE simulated by LCR-ADH Model
MIN WSE simulated for each nodal point, along centerline of fed nav channel
AVERAGE WSE simulated for each nodal point, along centerline of fed nav channel
HIGH WSE simulated for each nodal point, along centerline of fed nav channel
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
0
10
20
30
40
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70
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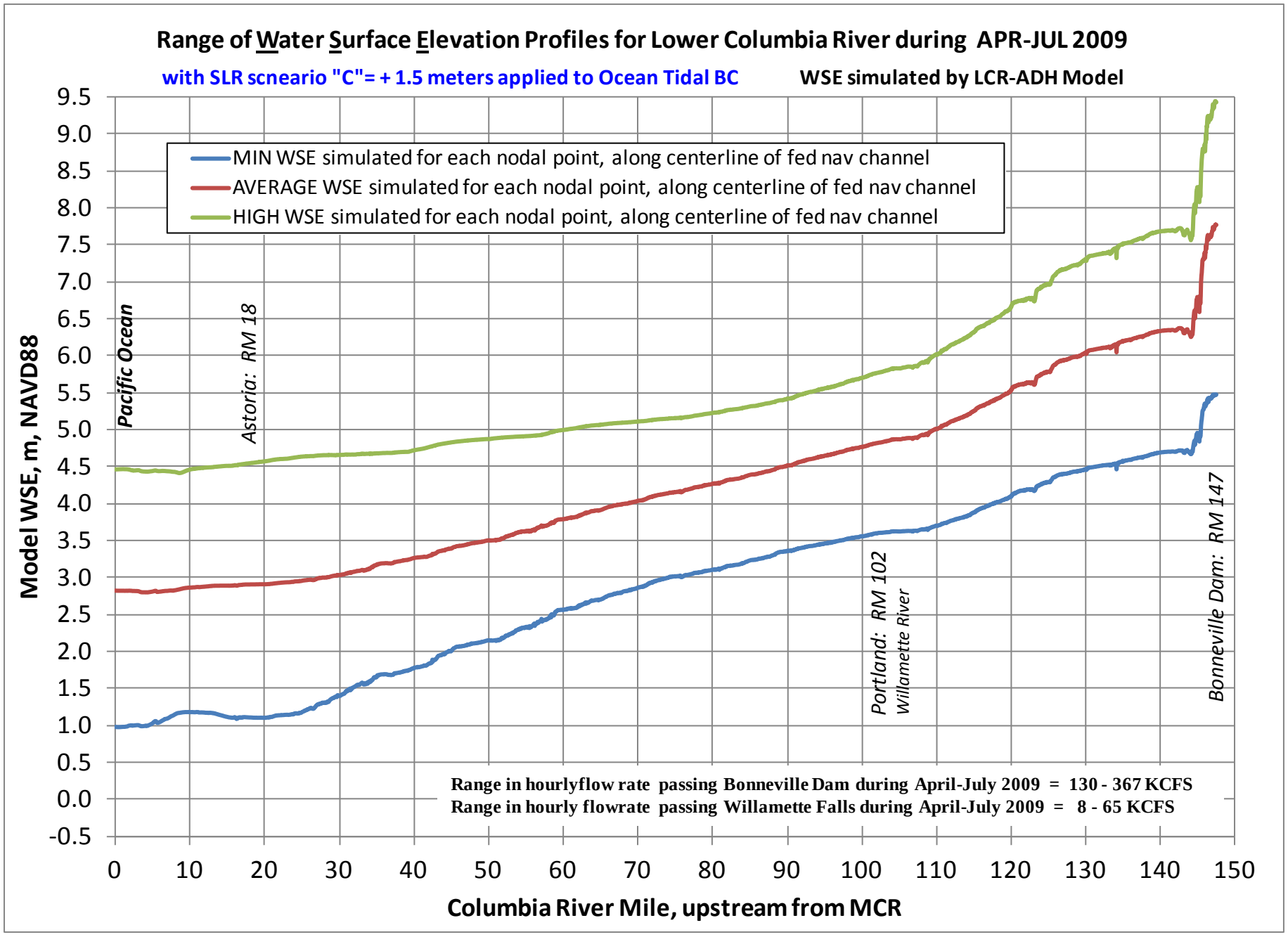
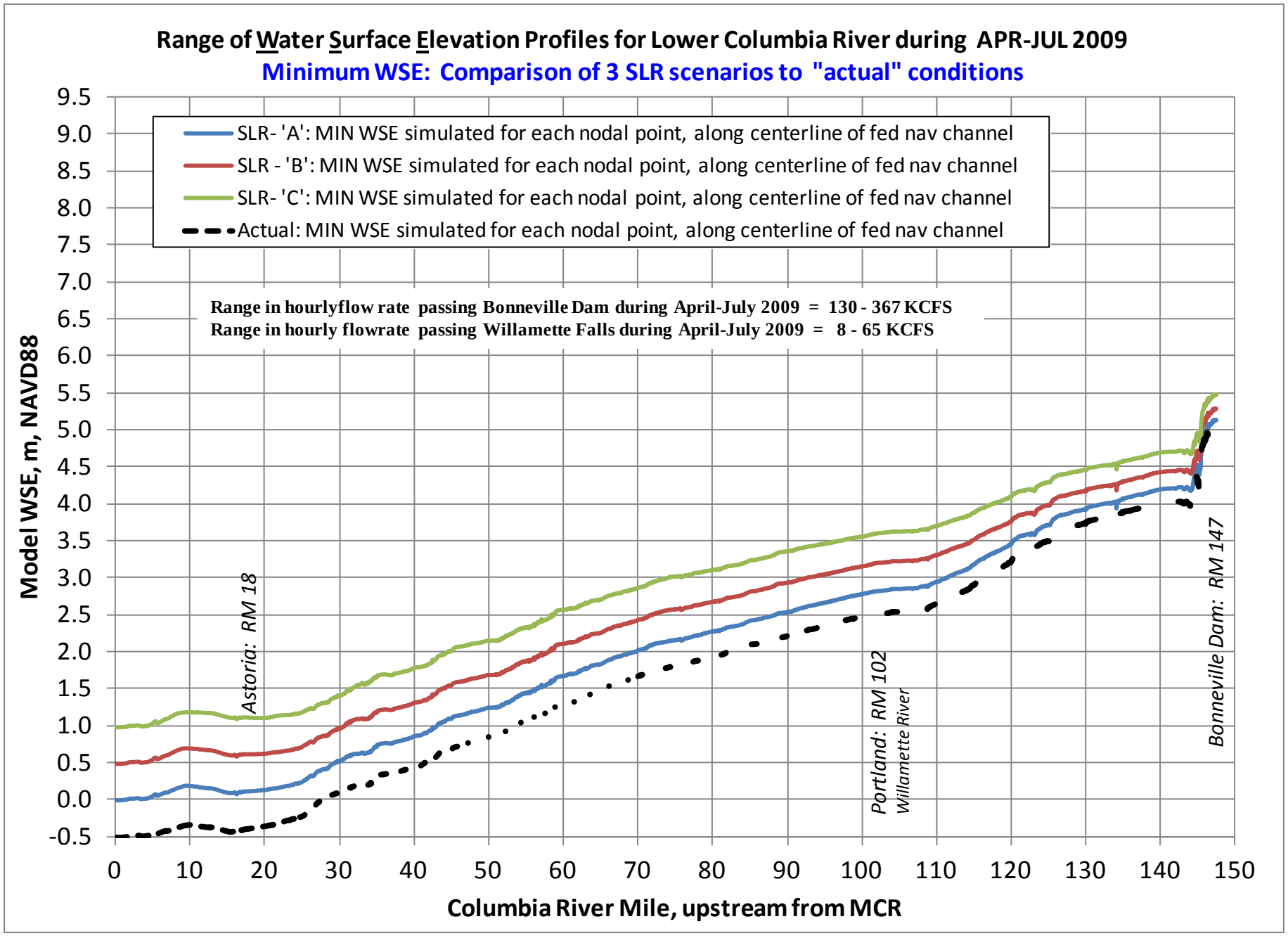
90
100
110
120
130
140
150
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
with SLR scneario "C"= + 1.5 meters applied to Ocean Tidal BC
WSE simulated by LCR-ADH Model
MIN WSE simulated for each nodal point, along centerline of fed nav channel
AVERAGE WSE simulated for each nodal point, along centerline of fed nav channel
HIGH WSE simulated for each nodal point, along centerline of fed nav channel
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
Minimum WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR- 'A': MIN WSE simulated for each nodal point, along centerline of fed nav channel
SLR - 'B': MIN WSE simulated for each nodal point, along centerline of fed nav channel
SLR- 'C': MIN WSE simulated for each nodal point, along centerline of fed nav channel
Actual: MIN WSE simulated for each nodal point, along centerline of fed nav channel
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
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0.5
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-0.5
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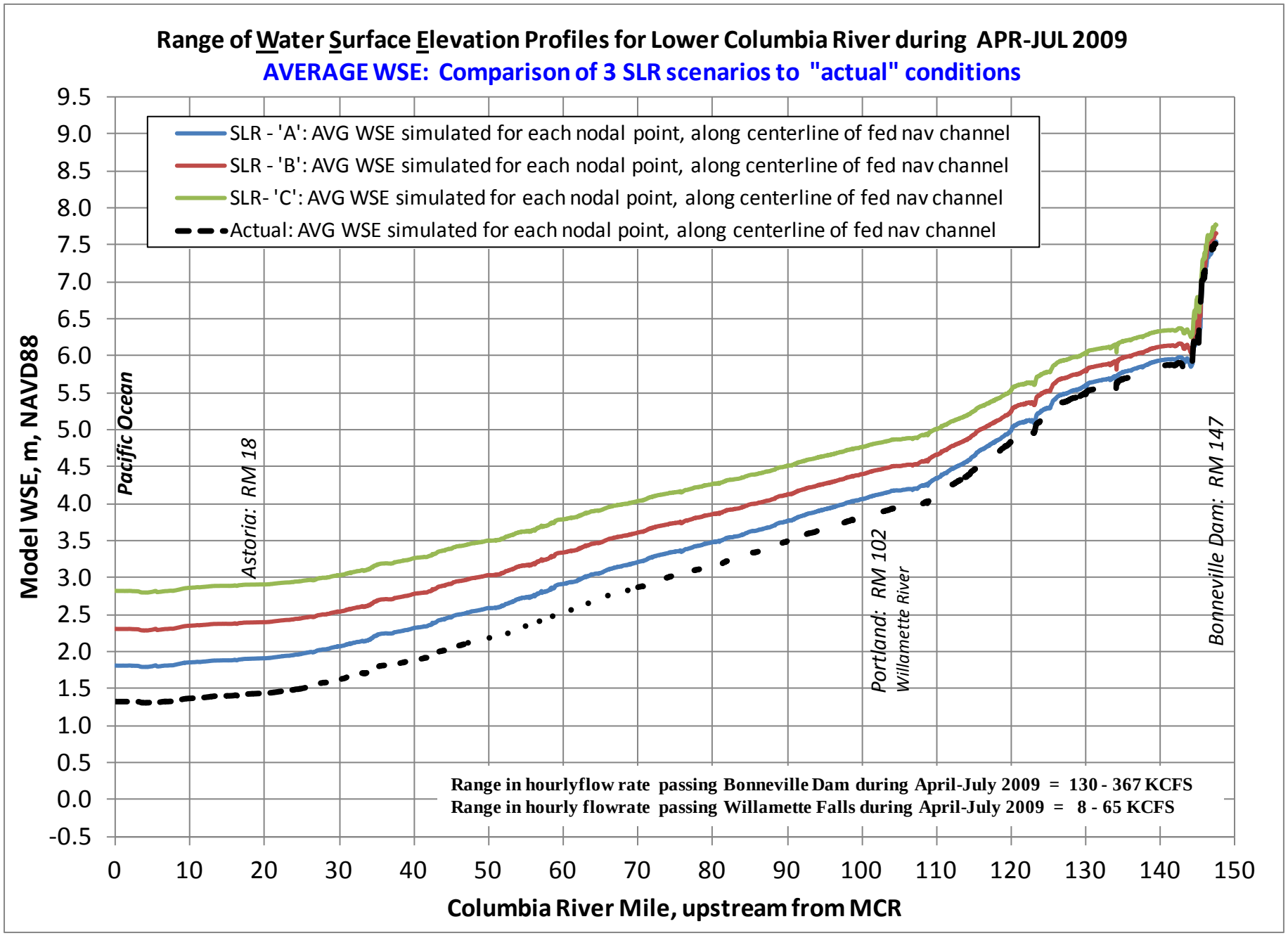
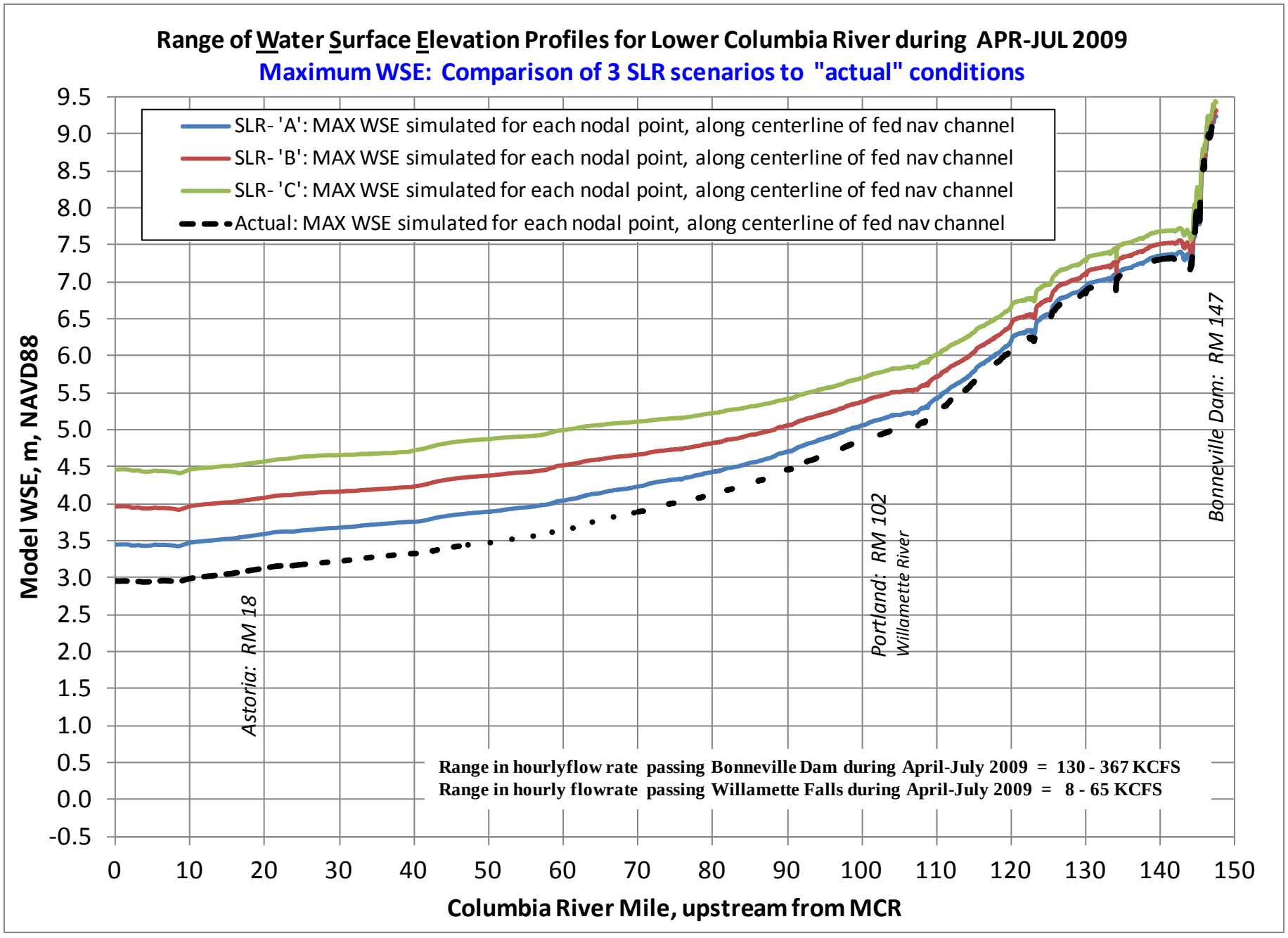
Columbia River Mile, upstream from MCR
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
AVERAGE WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR - 'A': AVG WSE simulated for each nodal point, along centerline of fed nav channel
SLR - 'B': AVG WSE simulated for each nodal point, along centerline of fed nav channel
SLR- 'C': AVG WSE simulated for each nodal point, along centerline of fed nav channel
Actual: AVG WSE simulated for each nodal point, along centerline of fed nav channel
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
Maximum WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR- 'A': MAX WSE simulated for each nodal point, along centerline of fed nav channel
SLR- 'B': MAX WSE simulated for each nodal point, along centerline of fed nav channel
SLR- 'C': MAX WSE simulated for each nodal point, along centerline of fed nav channel
Actual: MAX WSE simulated for each nodal point, along centerline of fed nav channel
Model WSE, m, NAVD88
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
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10
20
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90
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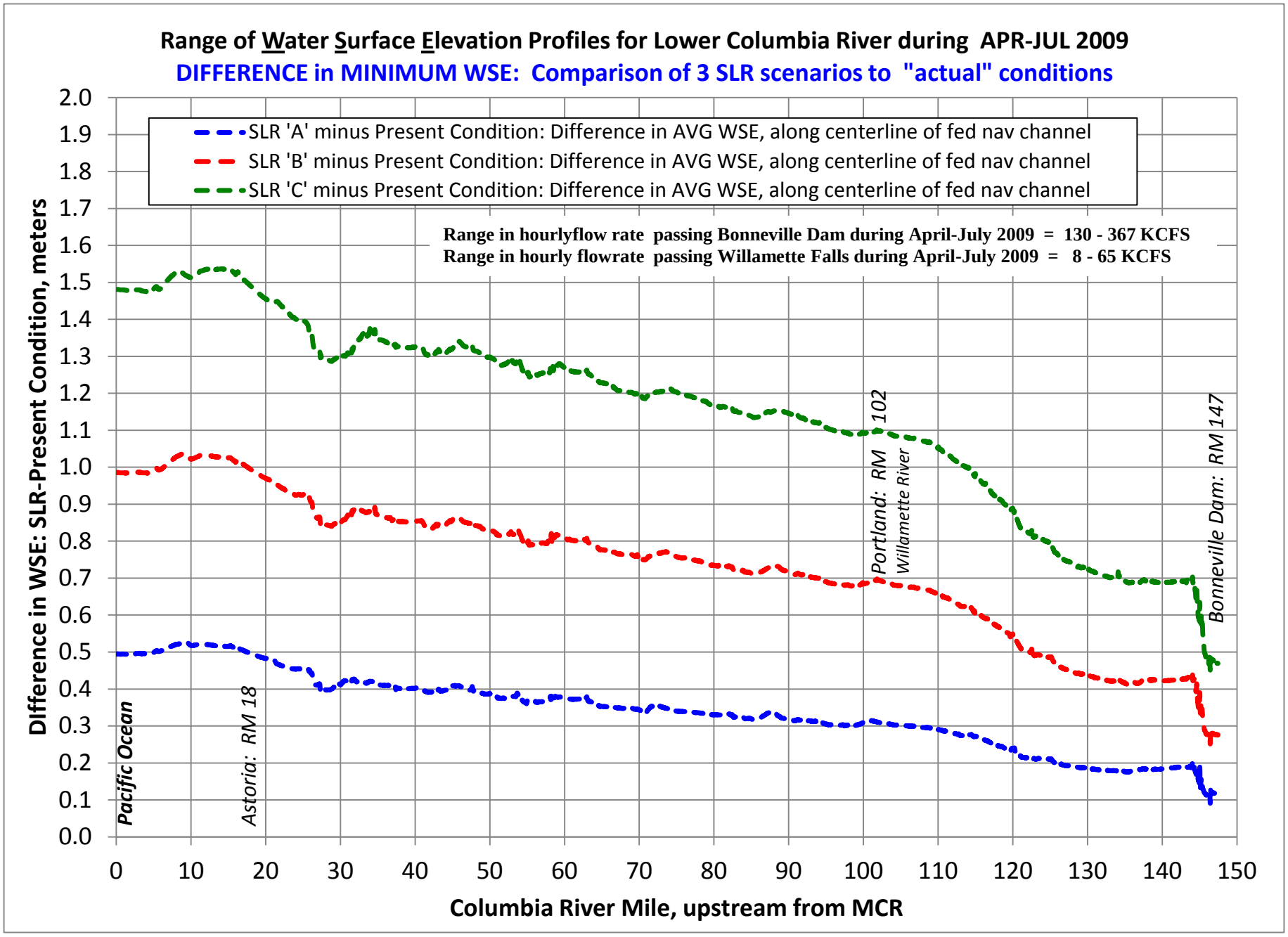
110
120
130
140
150
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
DIFFERENCE in MINIMUM WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR 'A' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'B' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'C' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
Difference in WSE: SLR-Present Condition, meters
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
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0.3
0.2
0.1
0.0
Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
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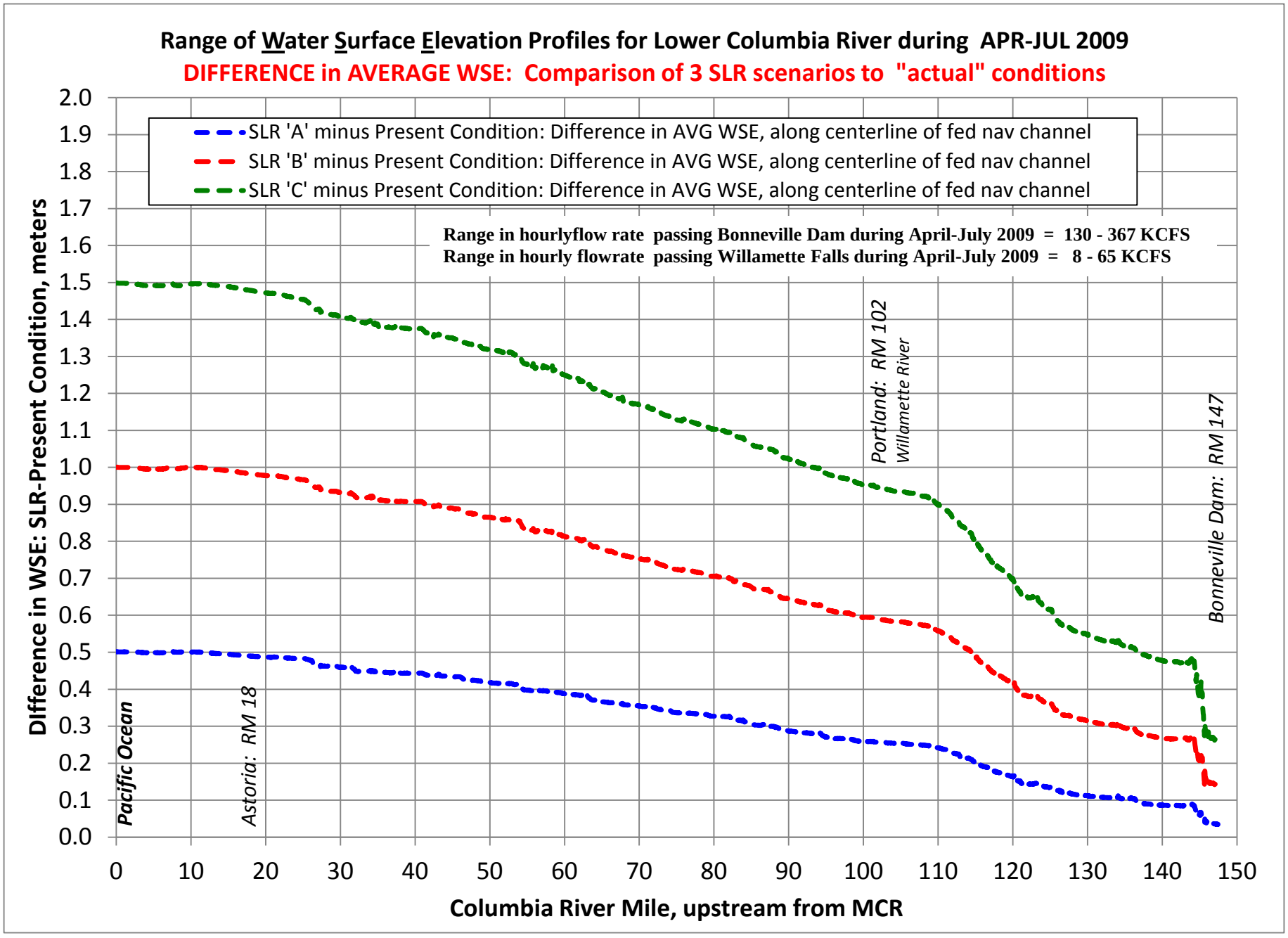
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
DIFFERENCE in AVERAGE WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR 'A' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'B' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'C' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
Difference in WSE: SLR-Present Condition, meters
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
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0.2
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Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
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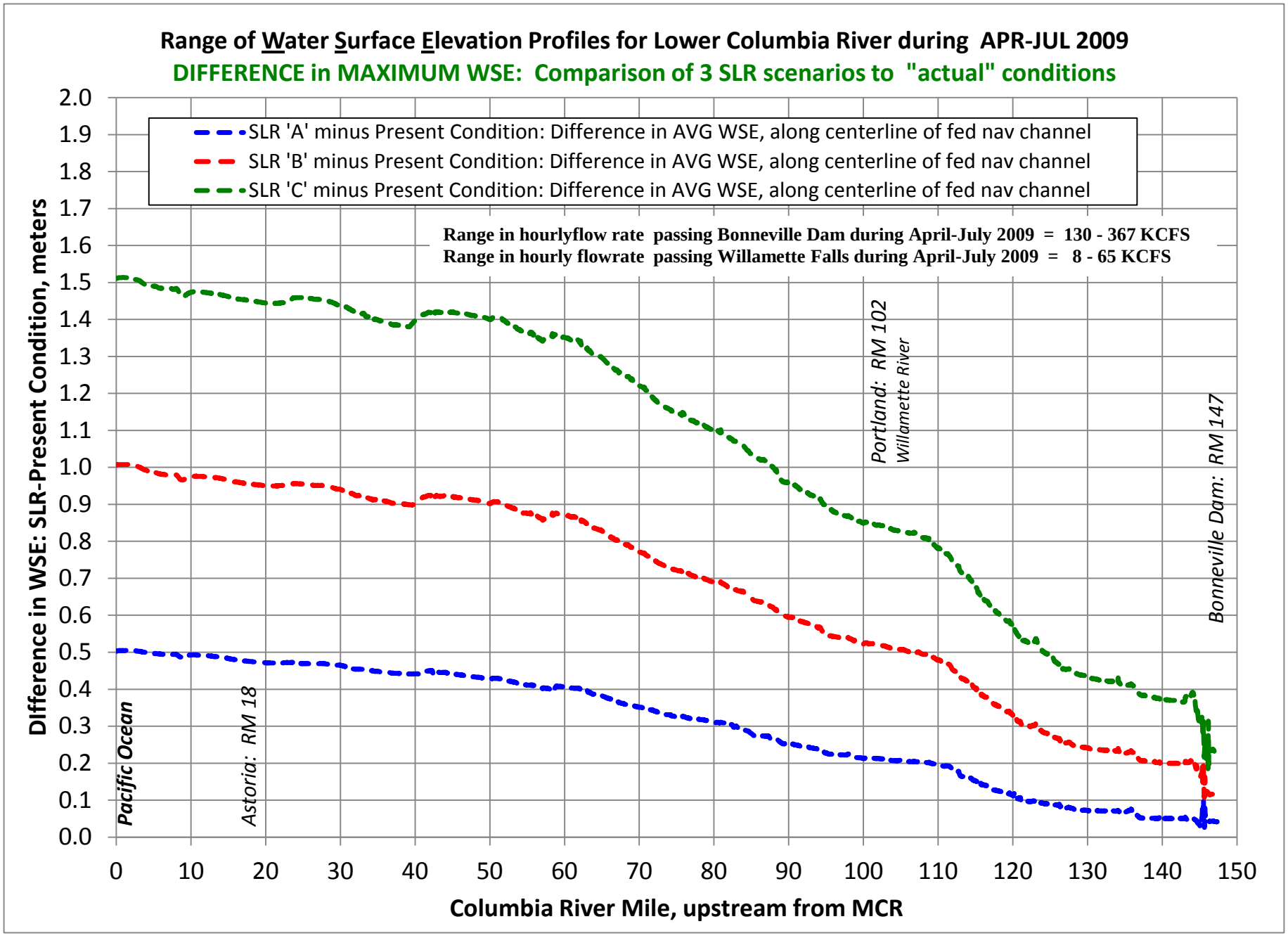
Columbia River Mile, upstream from MCR


Range of Water Surface Elevation Profiles for Lower Columbia River during APR-JUL 2009
DIFFERENCE in MAXIMUM WSE: Comparison of 3 SLR scenarios to "actual" conditions
SLR 'A' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'B' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
SLR 'C' minus Present Condition: Difference in AVG WSE, along centerline of fed nav channel
Range in hourlyflow rate passing Bonneville Dam during April-July 2009 = 130 - 367 KCFS
Range in hourly flowrate passing Willamette Falls during April-July 2009 = 8 - 65 KCFS
Difference in WSE: SLR-Present Condition, meters
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
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Pacific Ocean
Astoria: RM 18
Portland: RM 102
Willamette River
Bonneville Dam: RM 147
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10
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110
120
130
140
150
Columbia River Mile, upstream from MCR