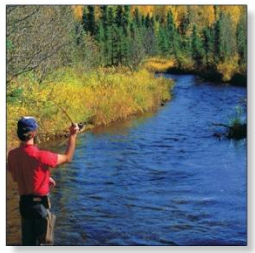
ESHMC Training – Comparison of Fully Populated and Superposition Versions of ESPAM2.0

Presented by Jennifer Sukow, P.E., P.G.

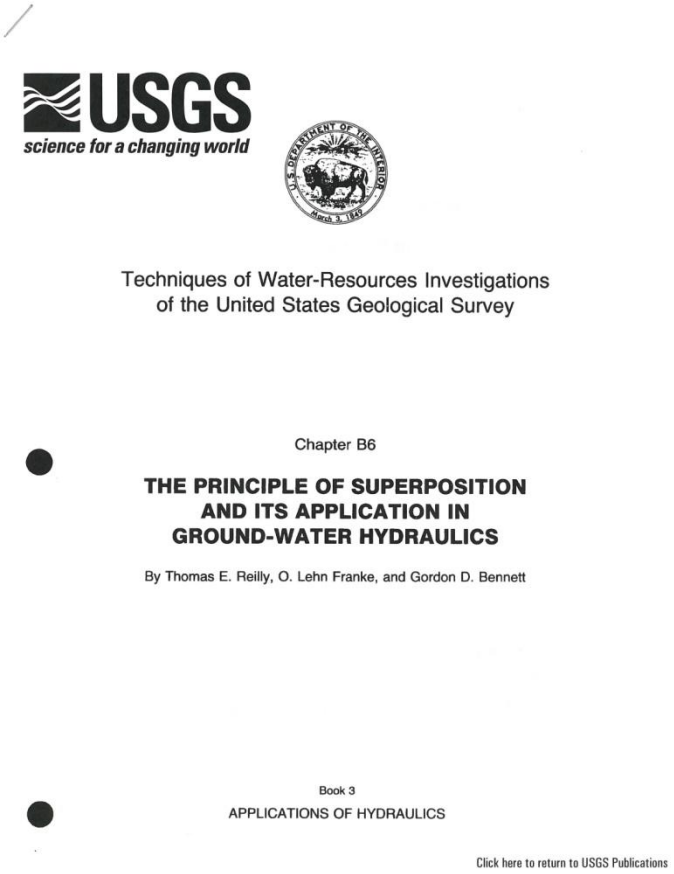
June 15, 2012

PRINCIPLE OF SUPERPOSITION

- Net effect of multiple applied stresses = sum of effects of each applied stress
- Example: Response to NIR, gw pumping, and tributary underflow = Response to NIR + response to gw pumping + response to tributary underflow
- USGS reference (Reilly, Franke, and Bennett, 1987)
  - http://pubs.usgs.gov/twri/twri3-b6/

PRINCIPLE OF SUPERPOSITION



USGS
science for a changing world

Techniques of Water-Resources Investigations
of the United States Geological Survey

Chapter B6

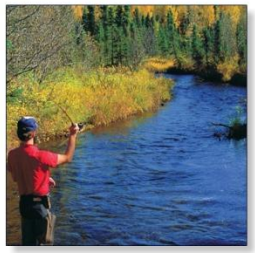
THE PRINCIPLE OF SUPERPOSITION
AND ITS APPLICATION IN
GROUND-WATER HYDRAULICS

By Thomas E. Reilly, O. Lehn Franke, and Gordon D. Bennett

Book 3
APPLICATIONS OF HYDRAULICS

Click here to return to USGS Publications

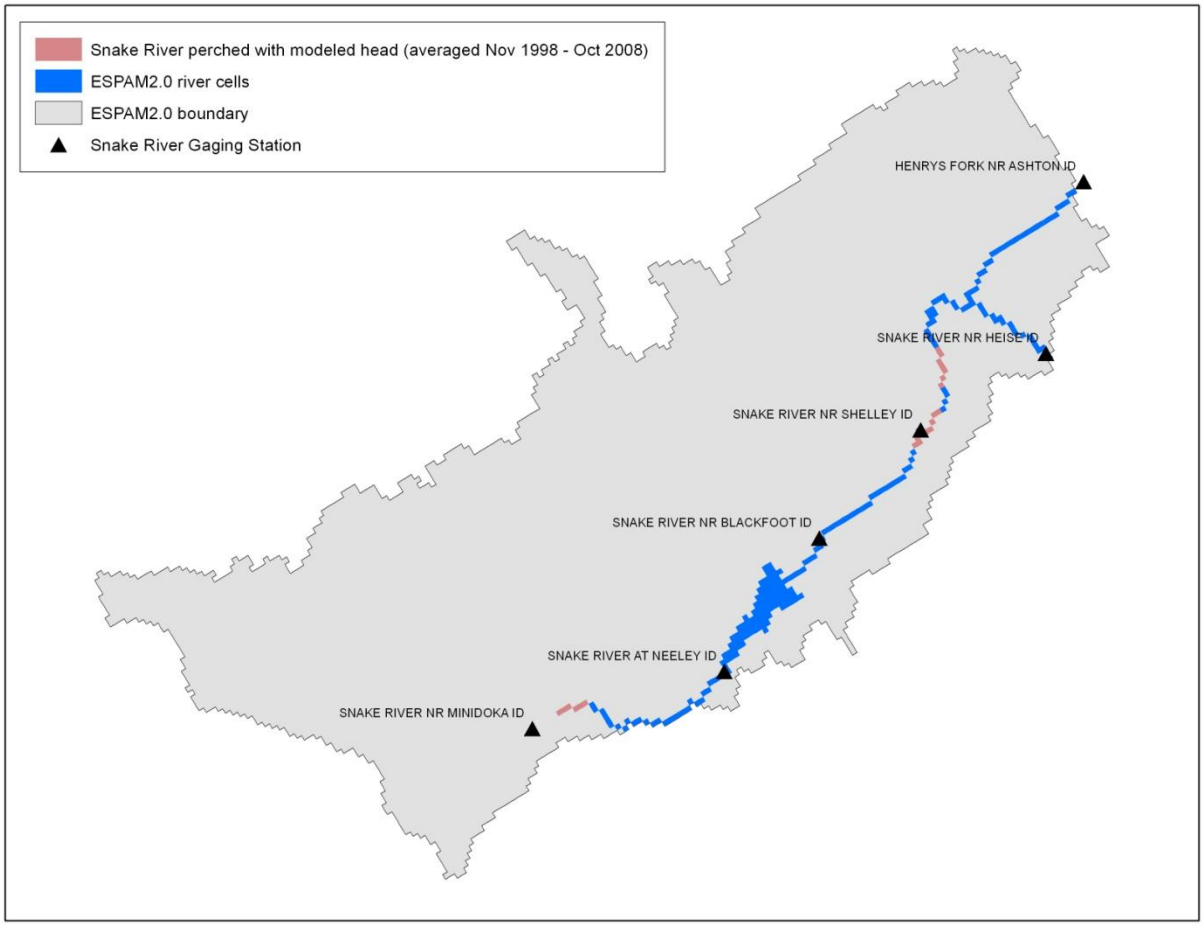
- Strictly valid only for linear systems
- Often applied to mildly nonlinear systems if it can be shown that the resulting error will be acceptably small (Reilly et al, 1987)

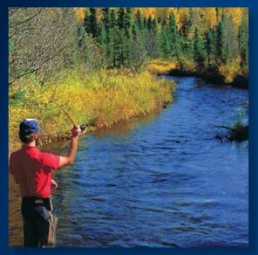



SUPERPOSITION FOR ESPAM2.0

- Is ESPAM2.0 linear?
  - No, applied stress may result in aquifer head falling below drain or river bottom elevations
- Is ESPAM2.0 mildly nonlinear?
  - Maybe, depends on the simulated stress
  - Flow is described by linear differential equations for flow in confined aquifers
  - Many simulations will not result in aquifer head falling below drain elevations
  - The effects of perched river cells, may or may not be significant

ESPAM2.0 PERCHED RIVER CELLS



SUPERPOSITION FOR ESPAM2.0

- Is difference in results from superposition and fully populated versions acceptably small for anticipated simulations?
- Simulated five curtailment scenarios with both the fully populated and superposition versions
- Evaluated difference in responses at springs and river reaches

COMPARISON

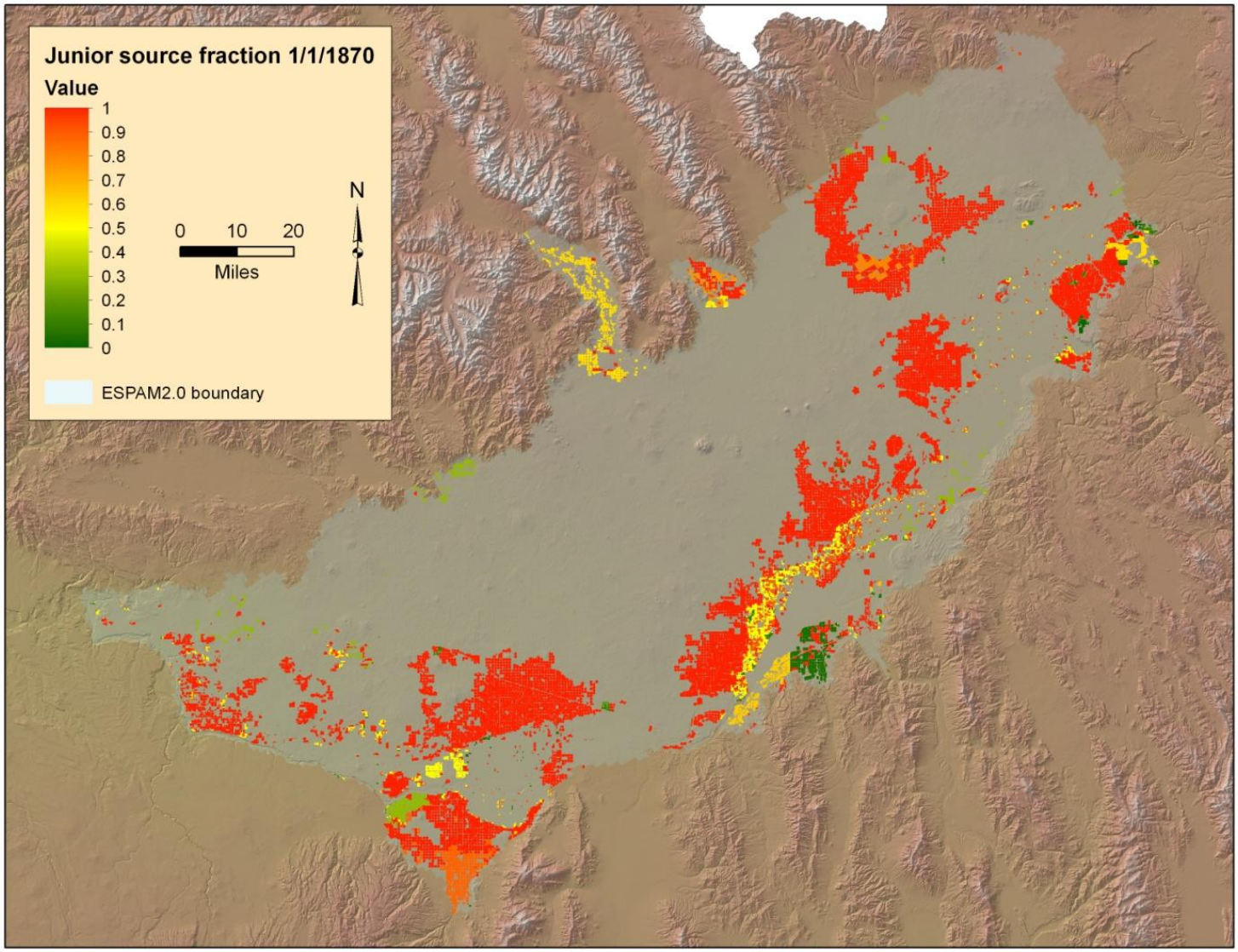
Fully populated model

- Select initial conditions (10-yr average water budget and river stage)
- All components of net recharge included in stress file
- Run two simulations
  - Baseline conditions with10-year average stress file representing all components of net recharge
  - Changed conditions with junior irrigation withdrawals added to stress file as injection wells
- Calculate difference between simulations to determine predicted effects of curtailment

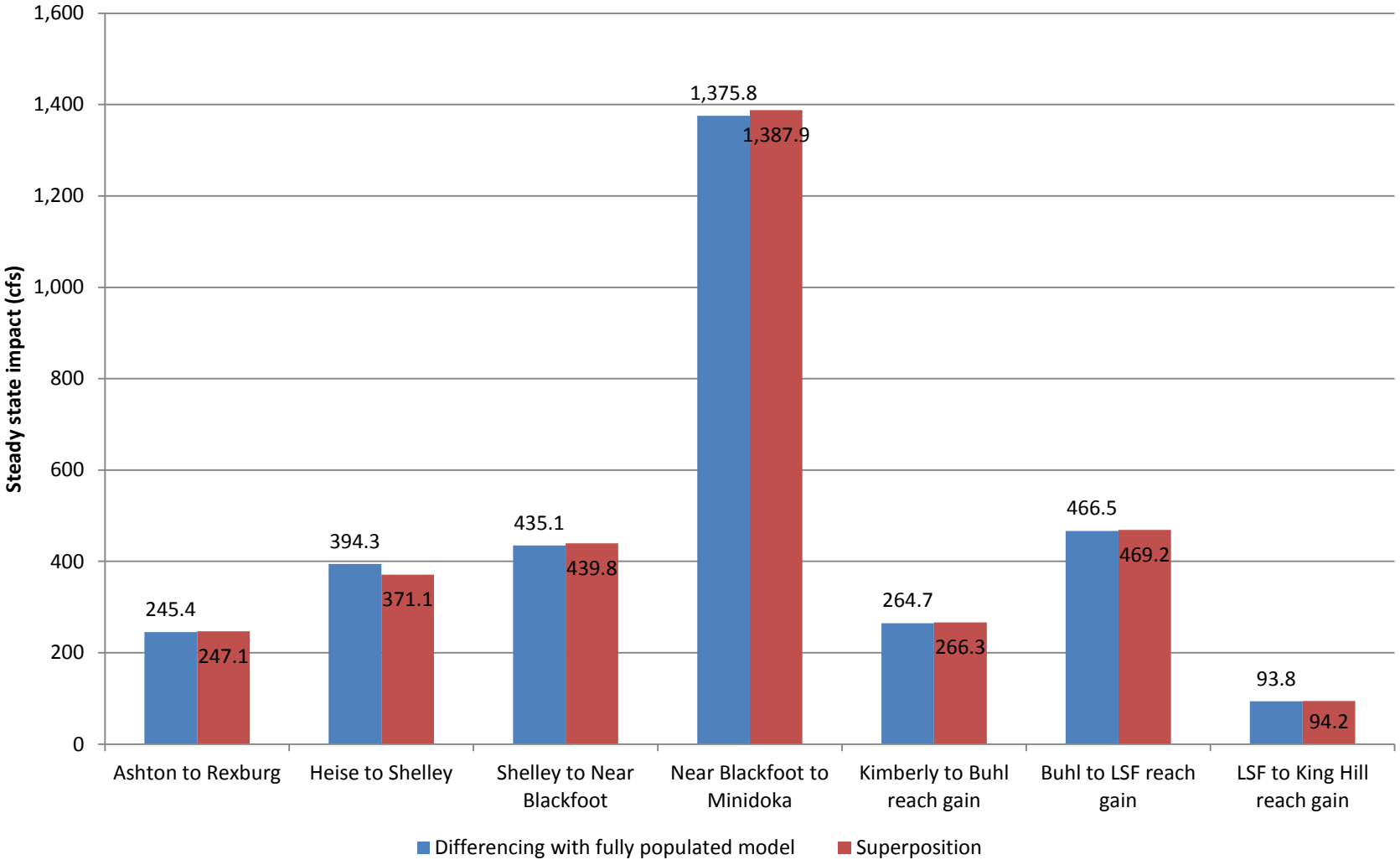
Superposition model

- Start with zero gradient
- Only component of interest (junior irrigation withdrawals) included in stress file
- Run one simulation with injection equal to junior irrigation withdrawals
- Simulation results are the predicted effects of curtailment, additional post-processing not needed

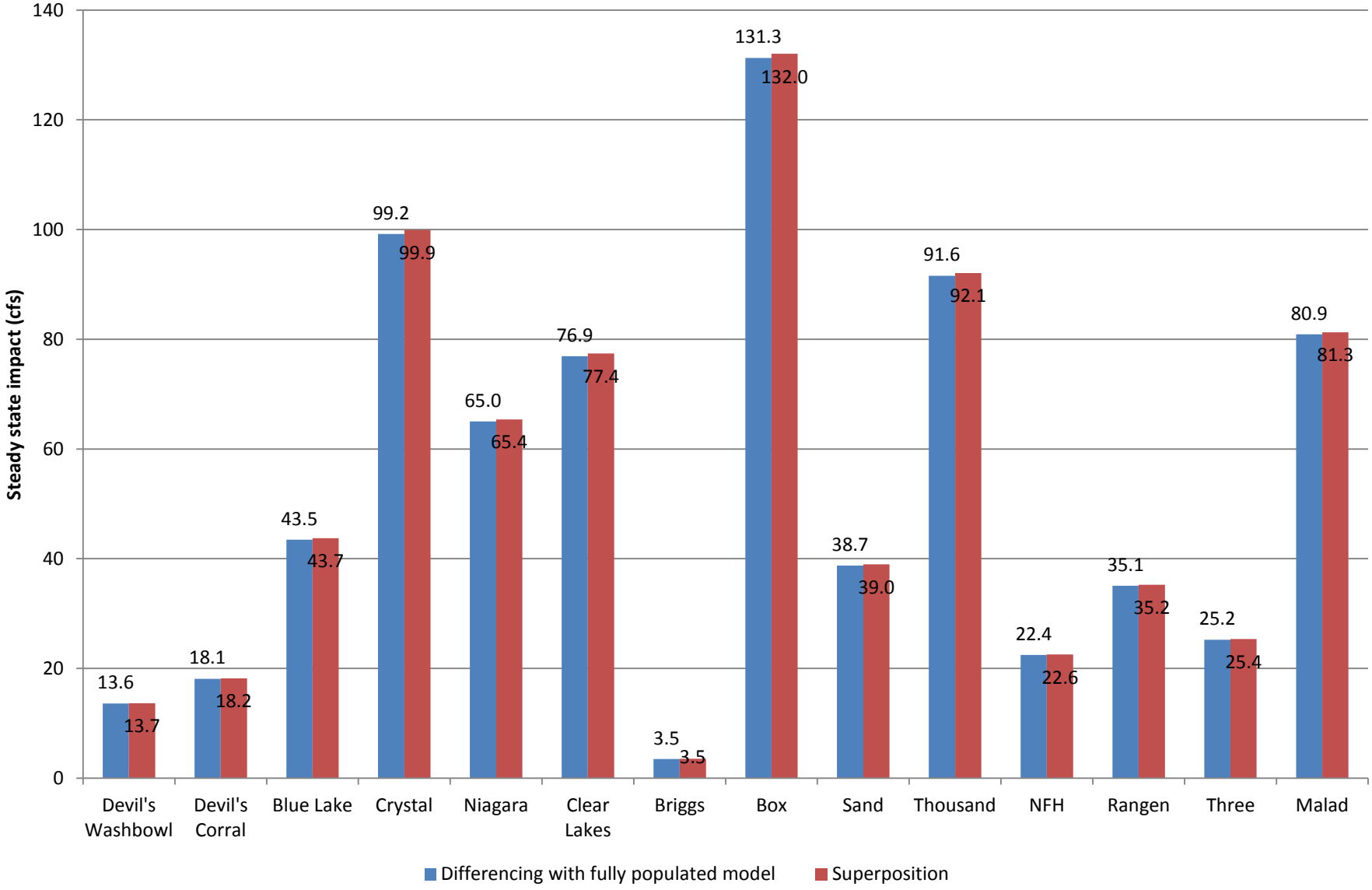
SIMULATED CURTAILMENT, 1/1/1870



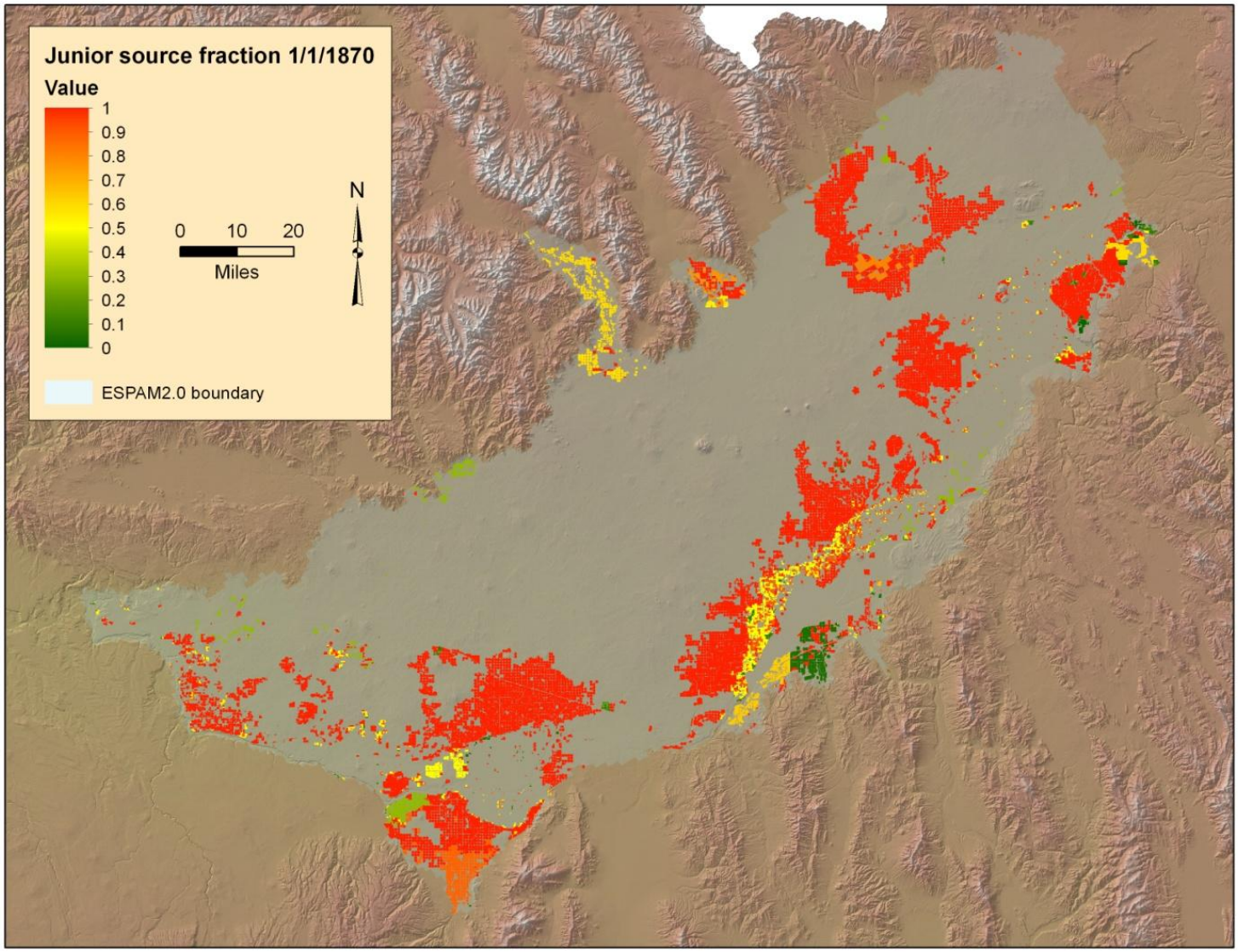
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1870



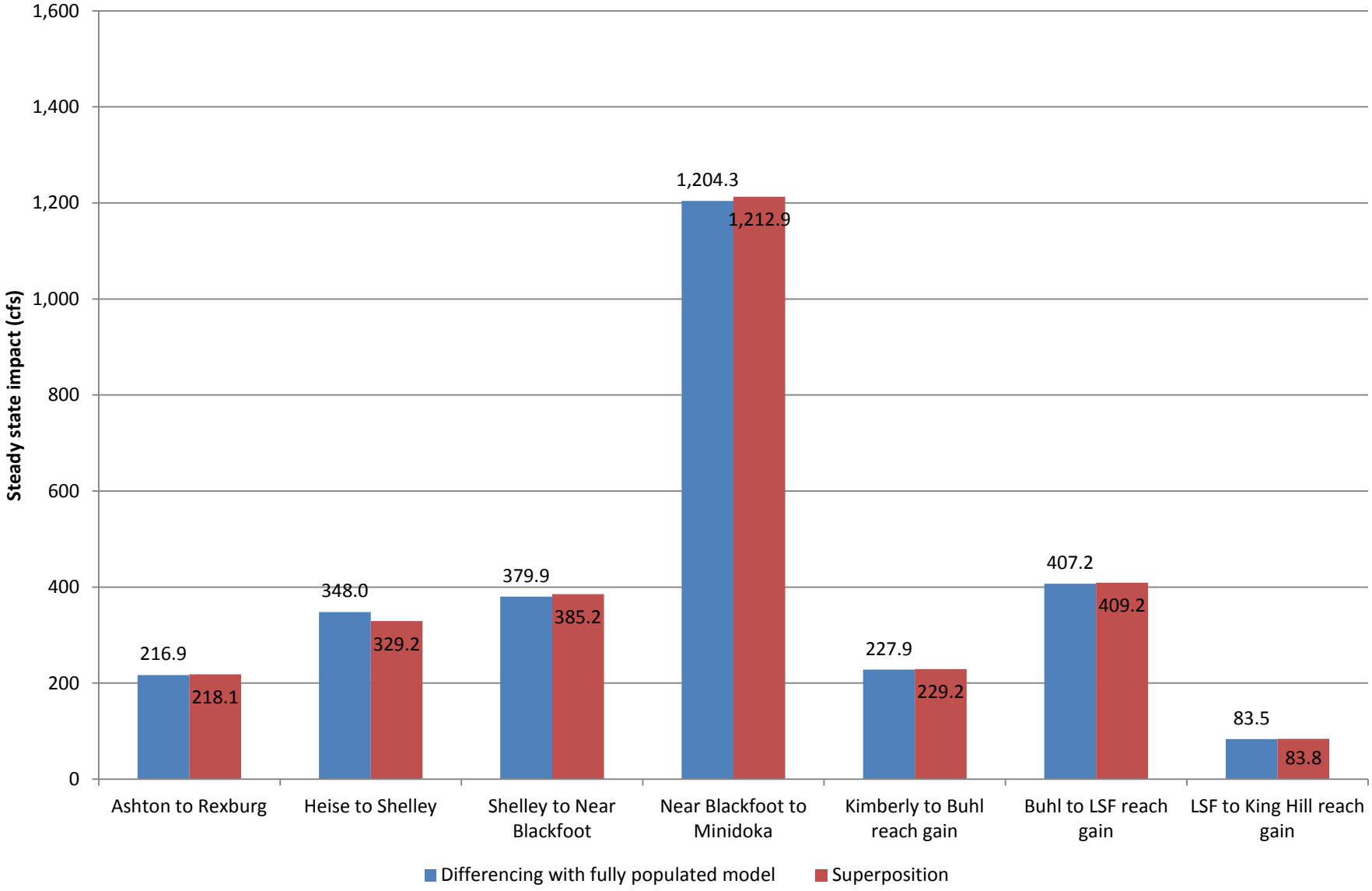
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1870



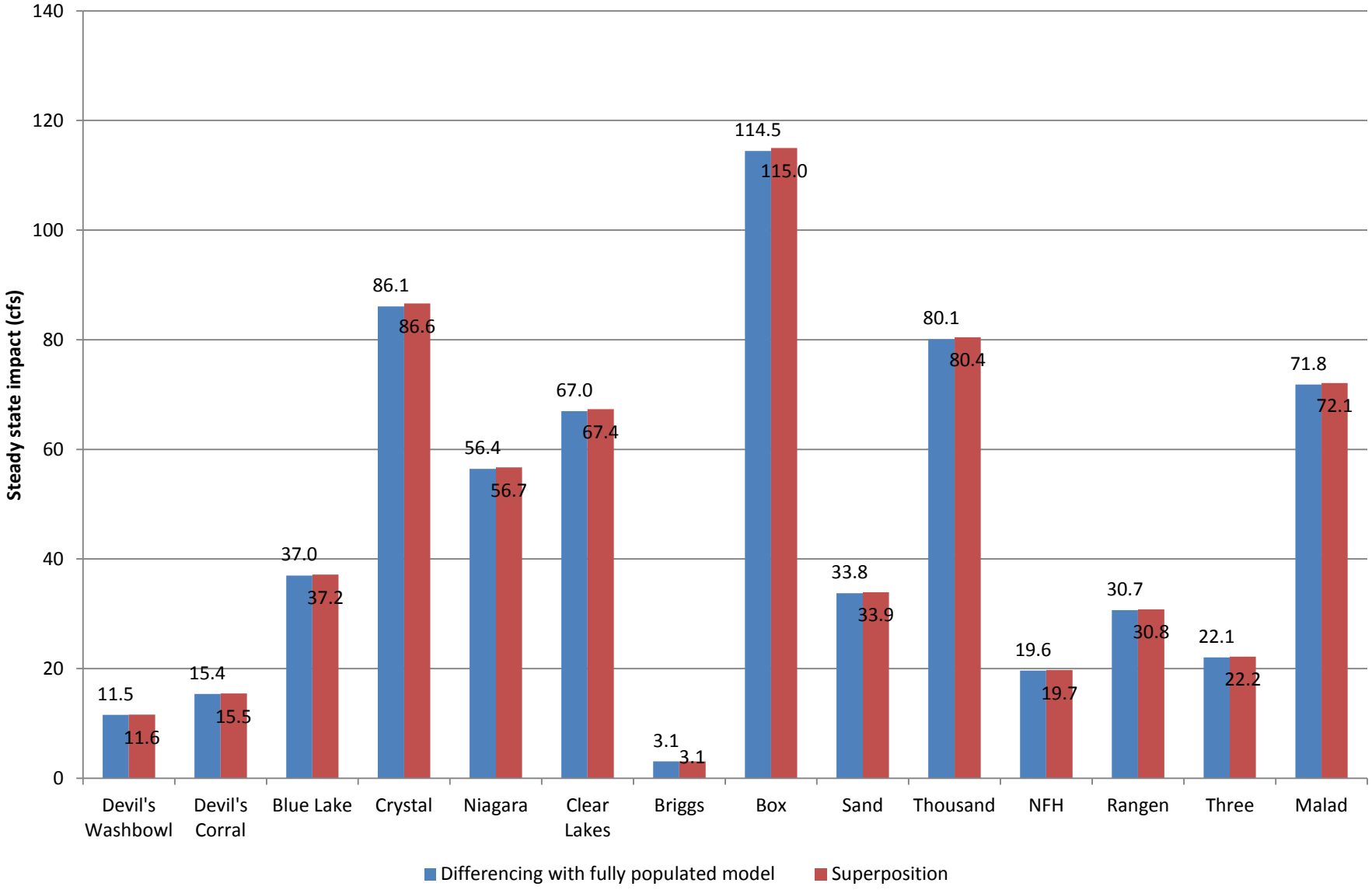
SIMULATED CURTAILMENT, 1/1/1949



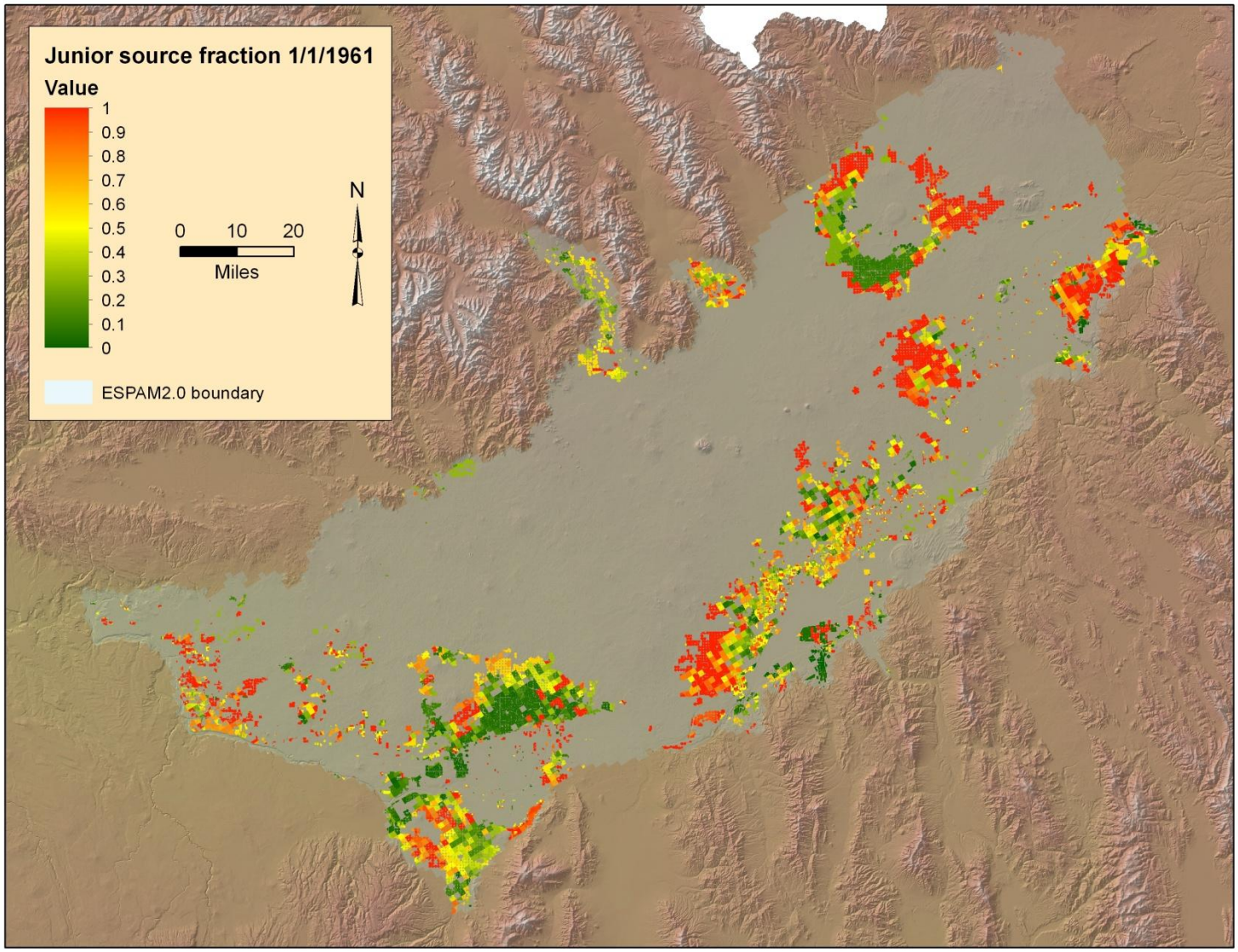
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1949



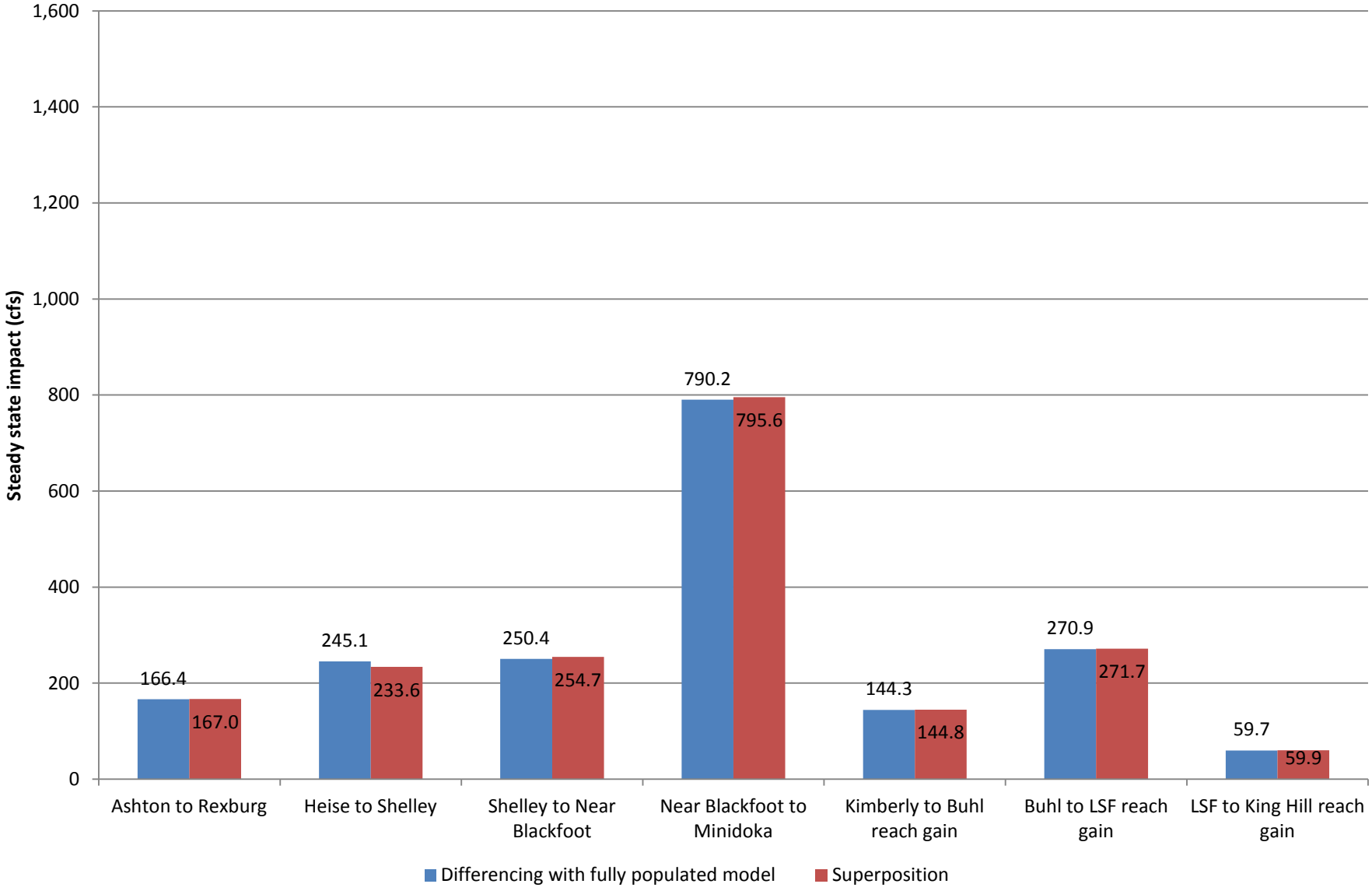
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1949



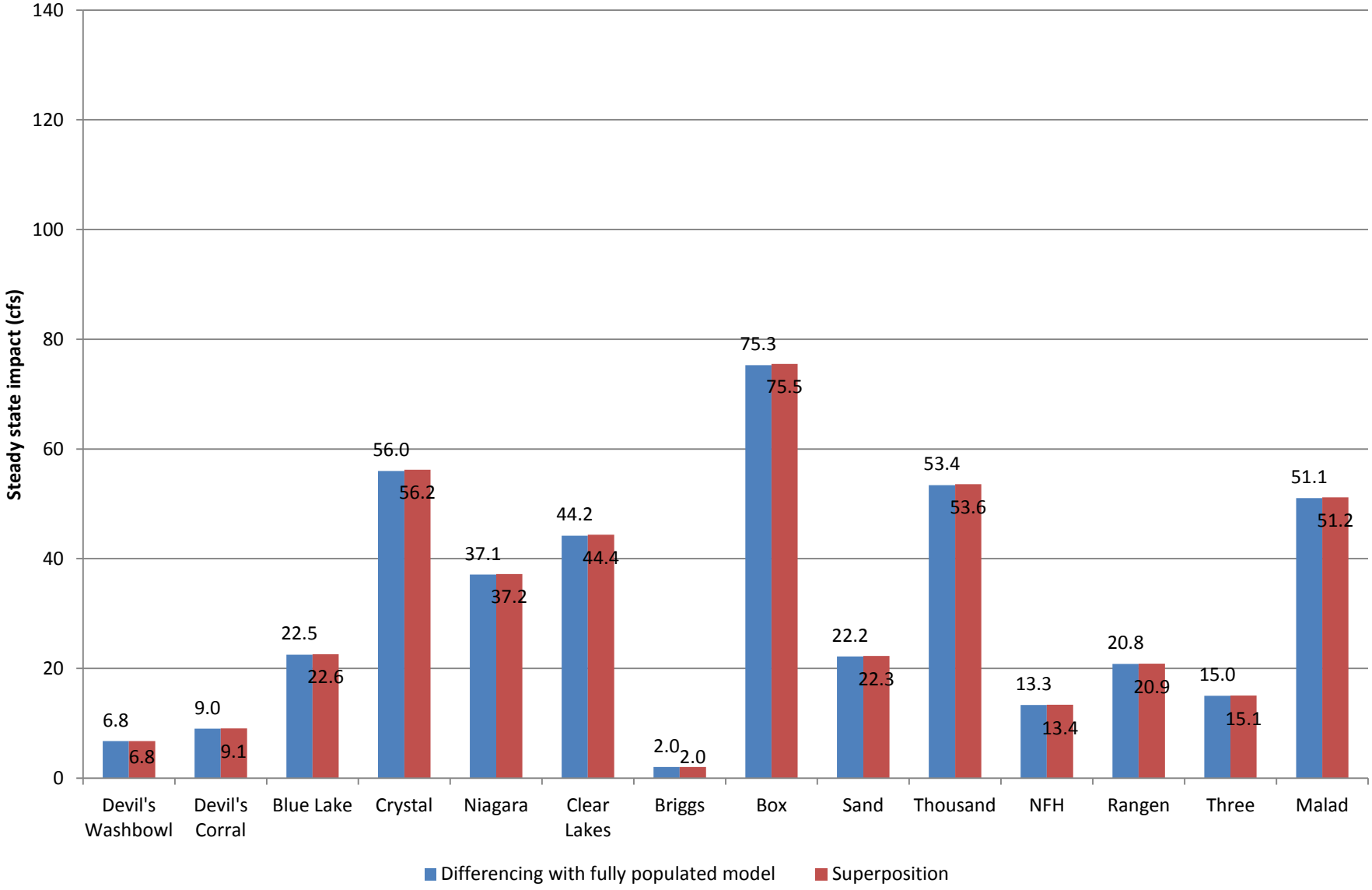
SIMULATED CURTAILMENT, 1/1/1961



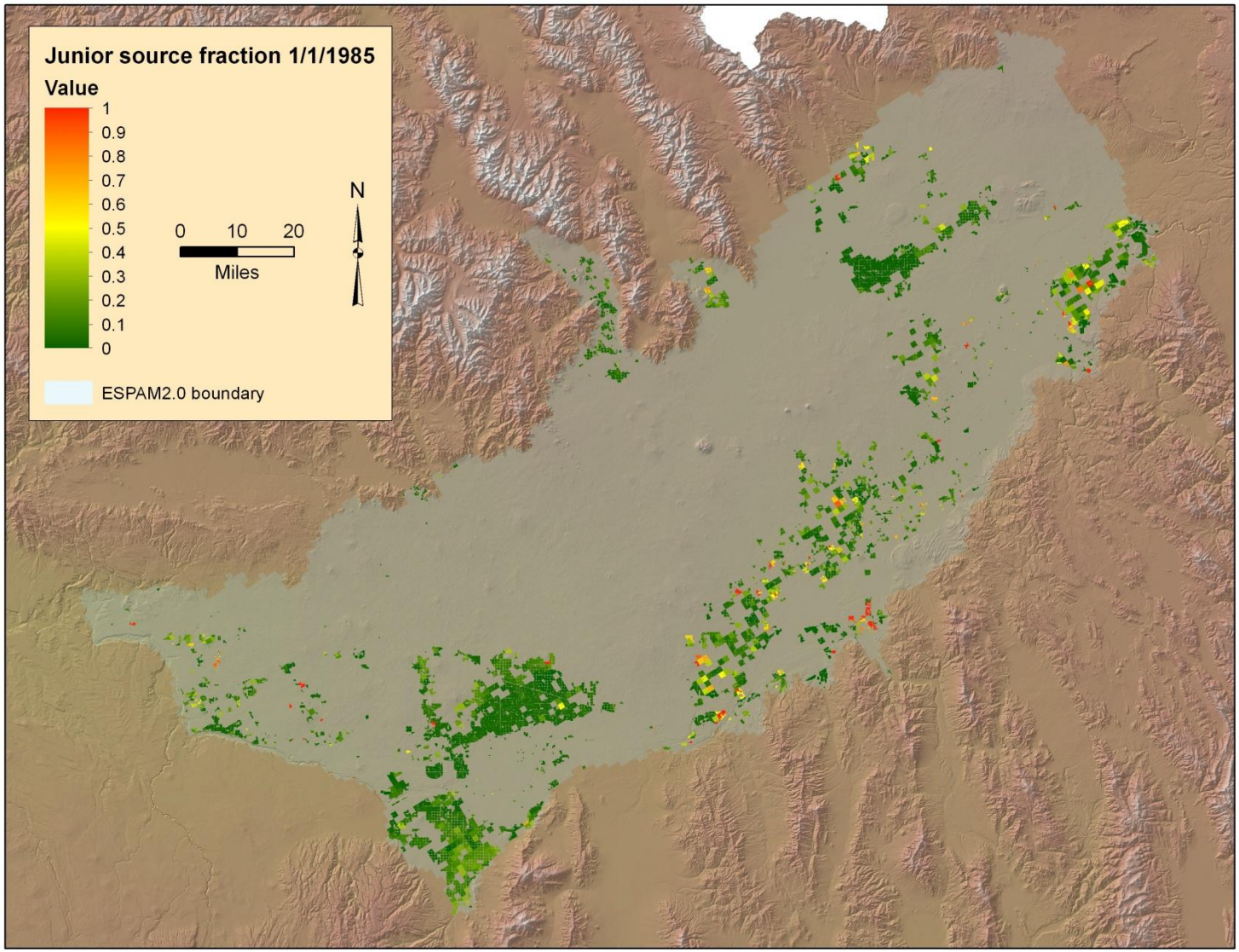
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1961



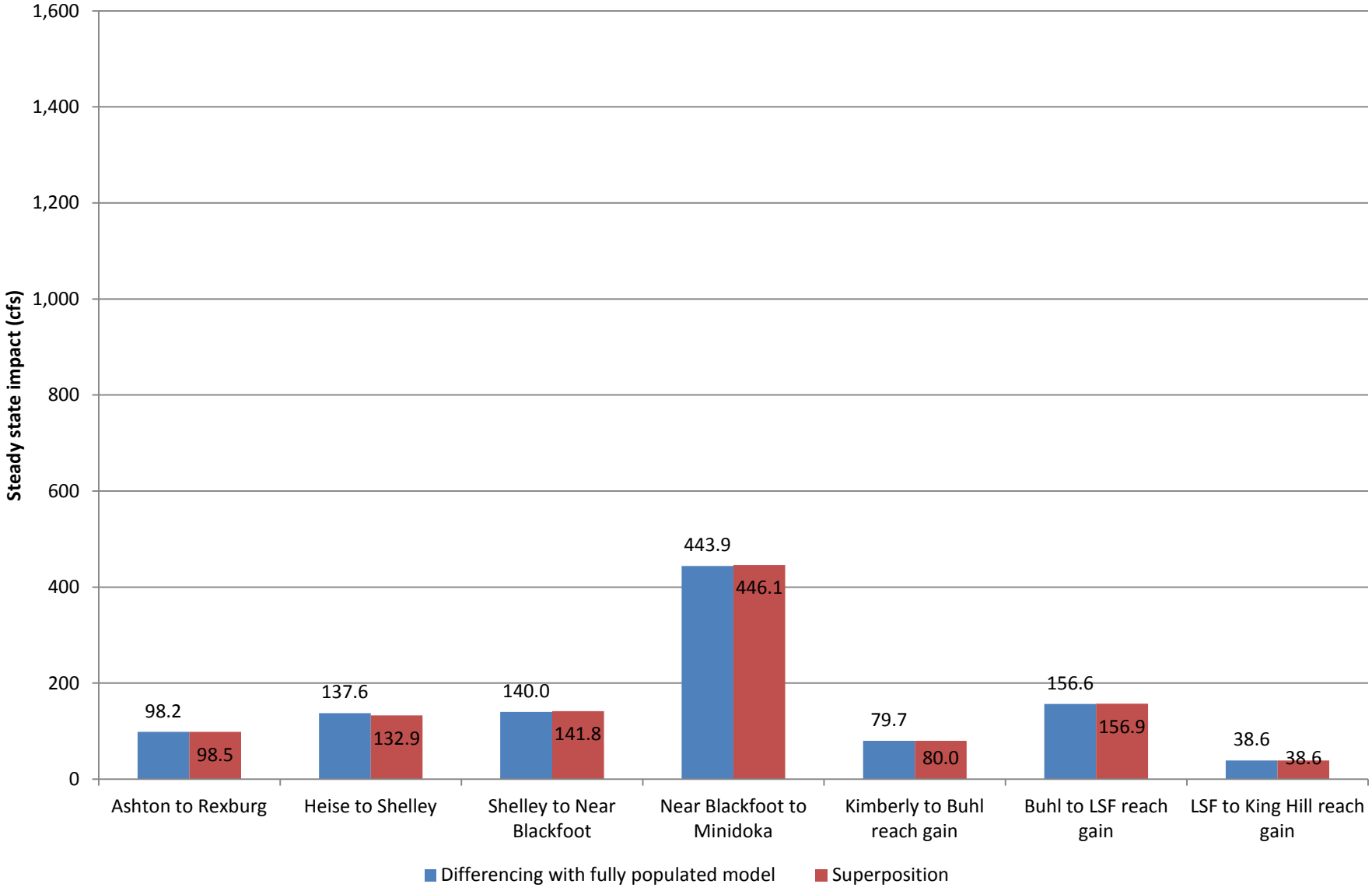
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1961



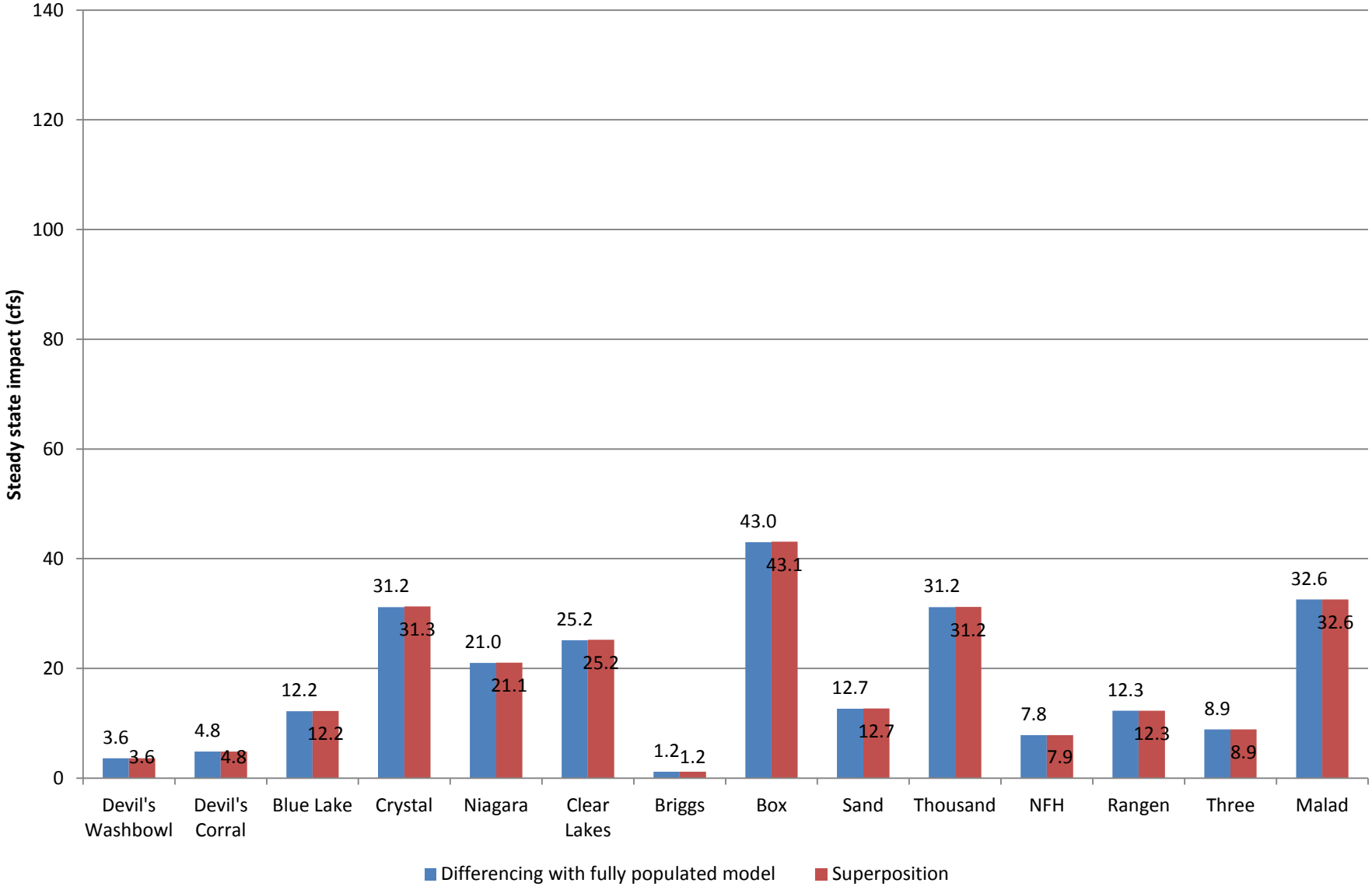
SIMULATED CURTAILMENT, 1/1/1973



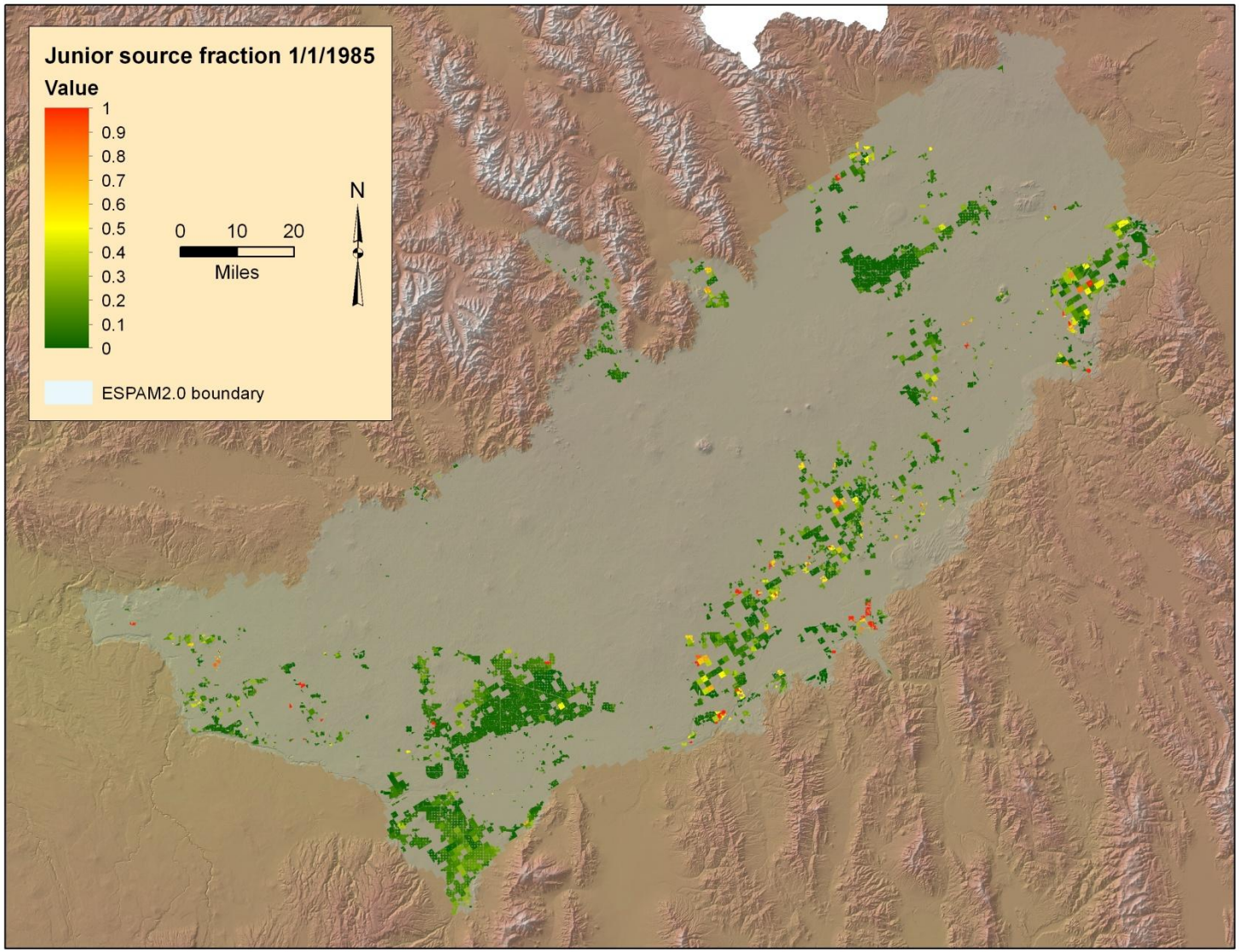
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1973



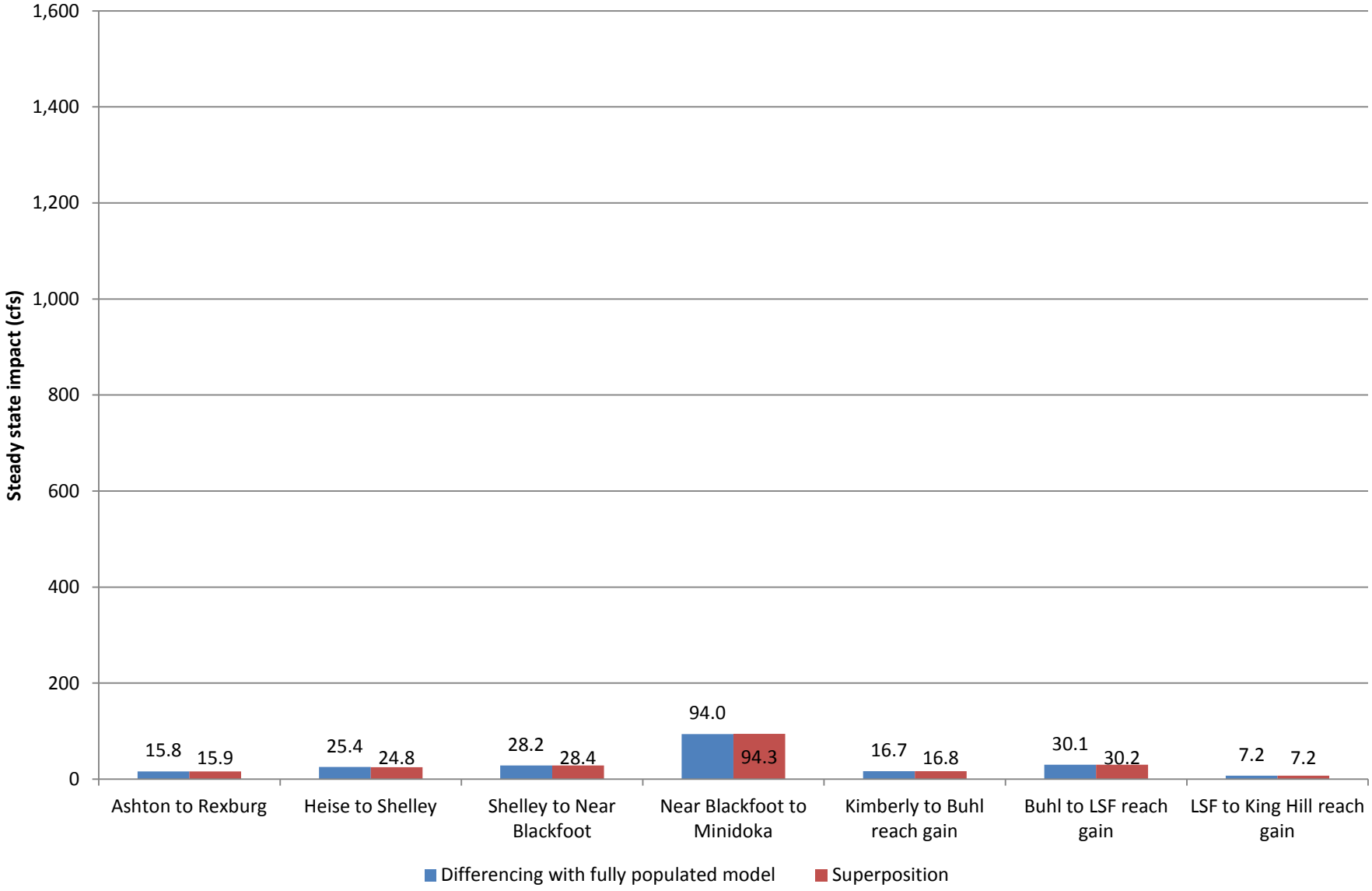
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1973



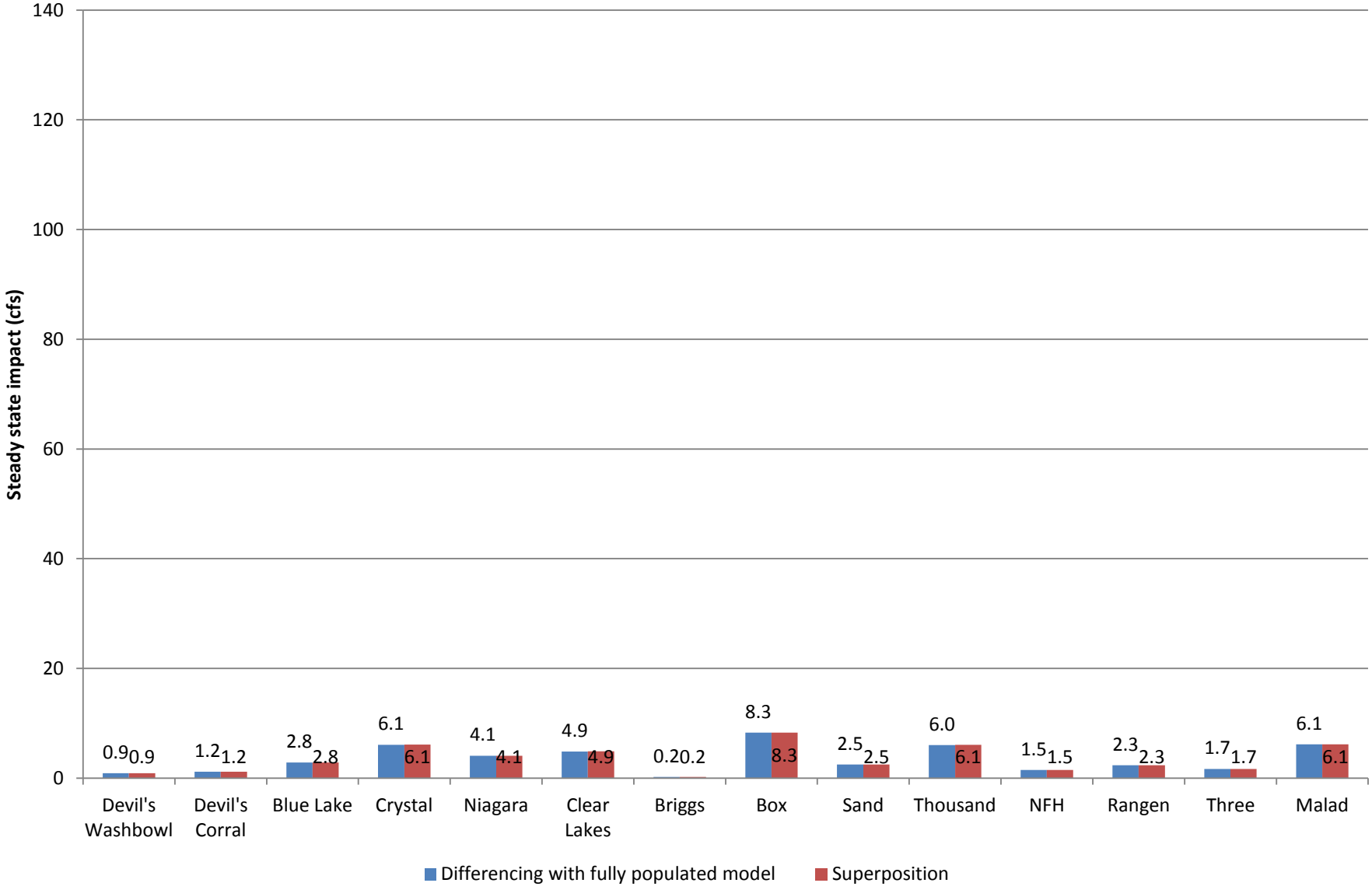
SIMULATED CURTAILMENT, 1/1/1985

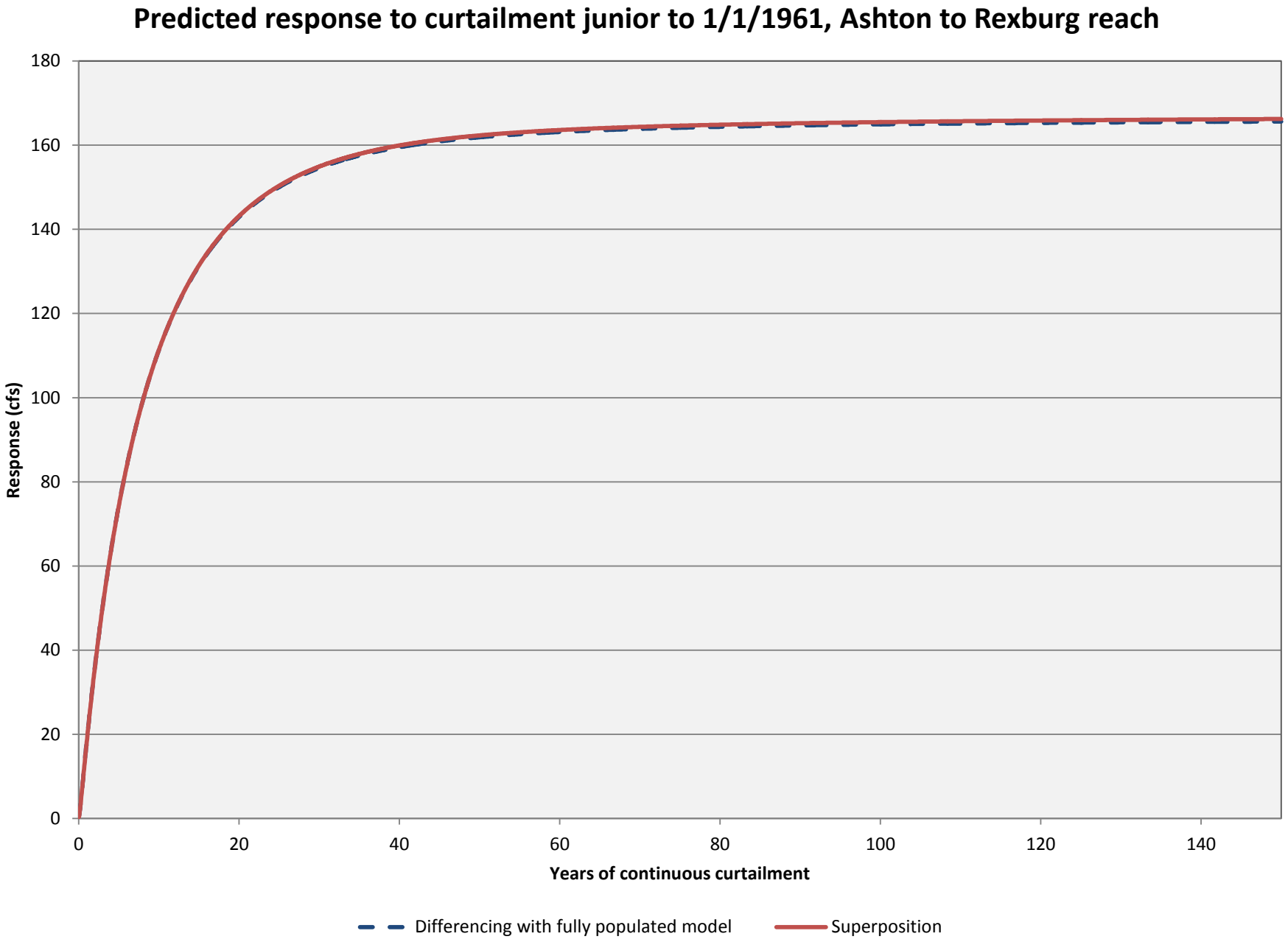


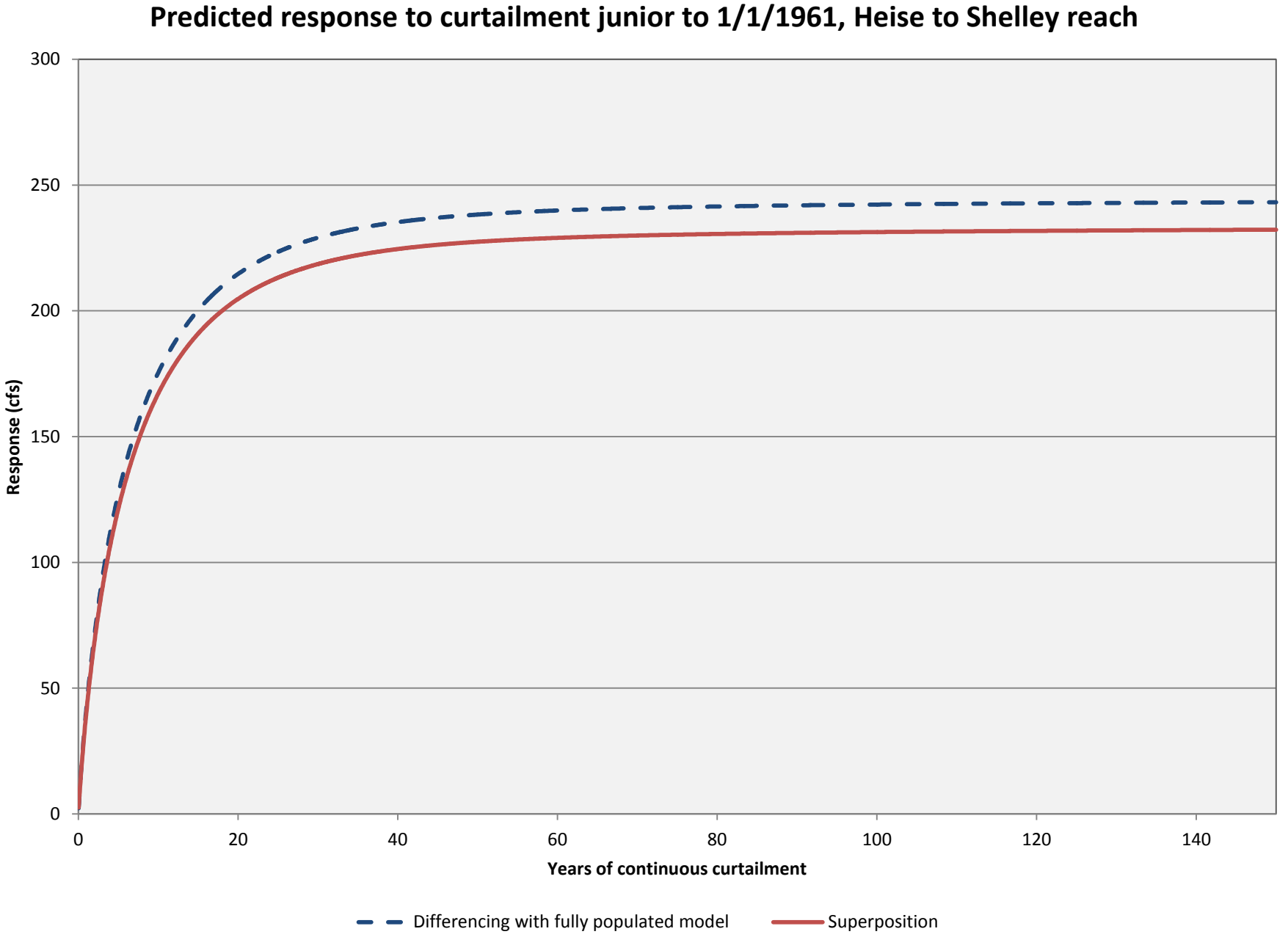
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1985

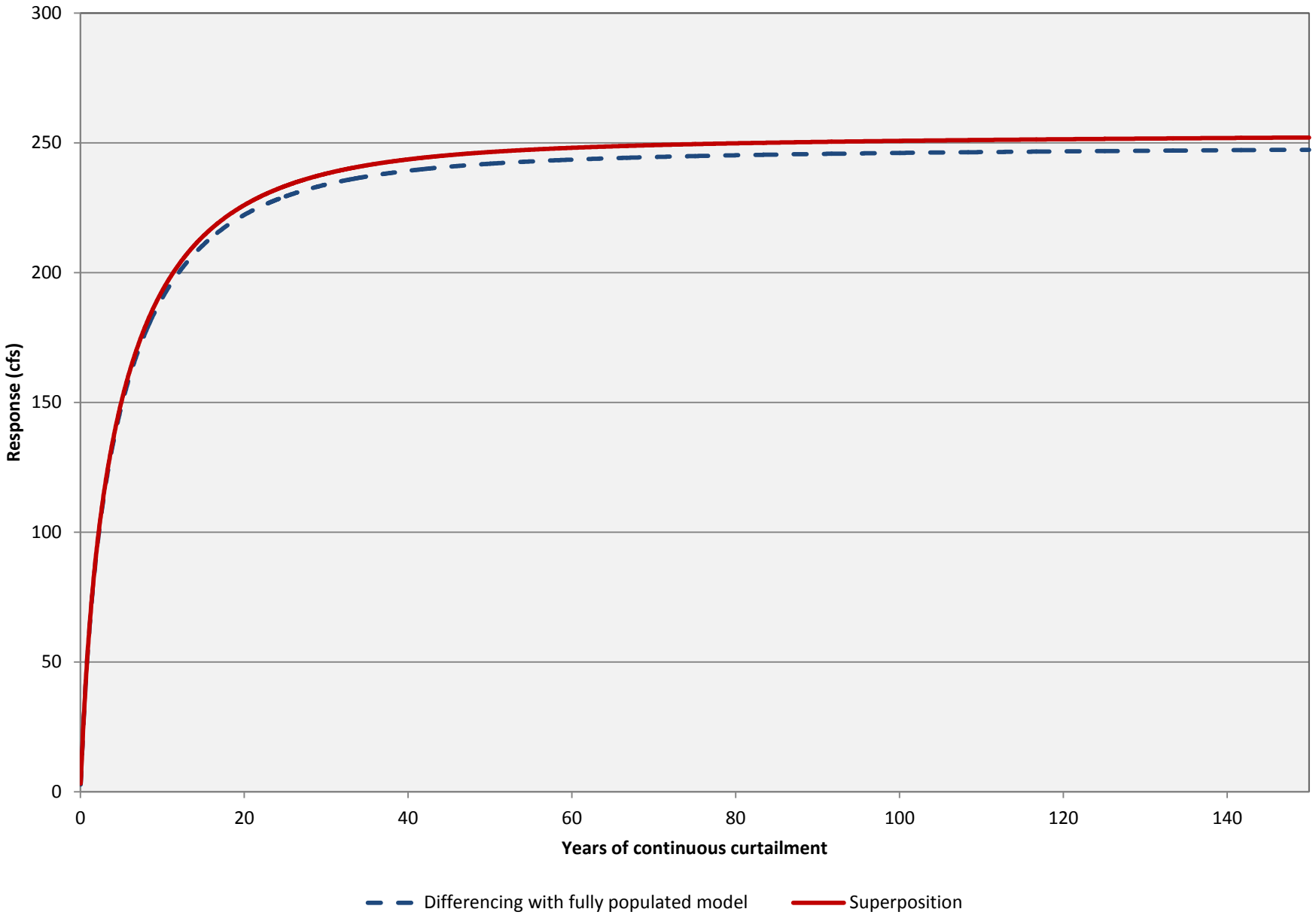


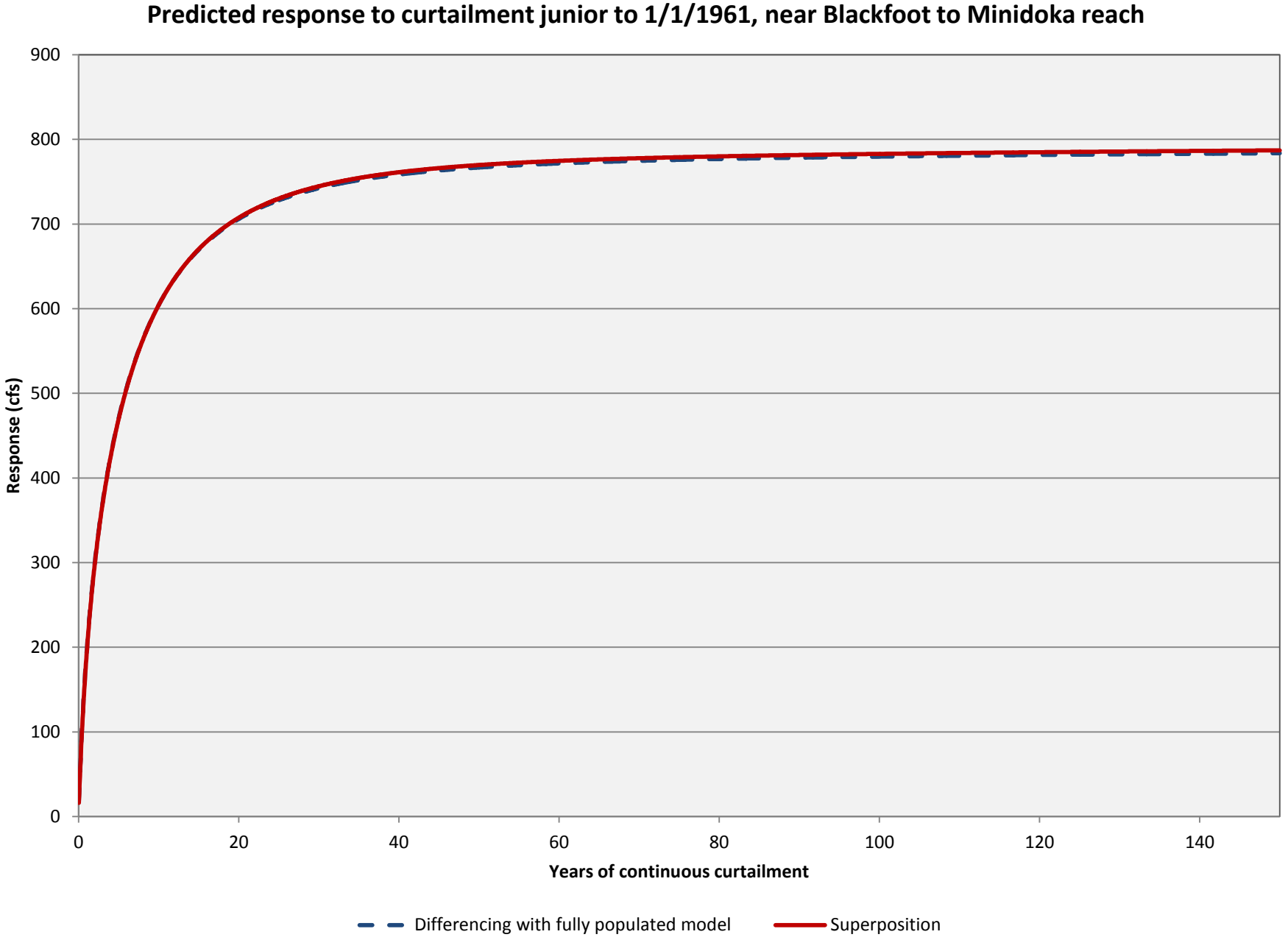
Comparison of model calculated impacts to reach gains for curtailment of groundwater rights junior to 1/1/1985

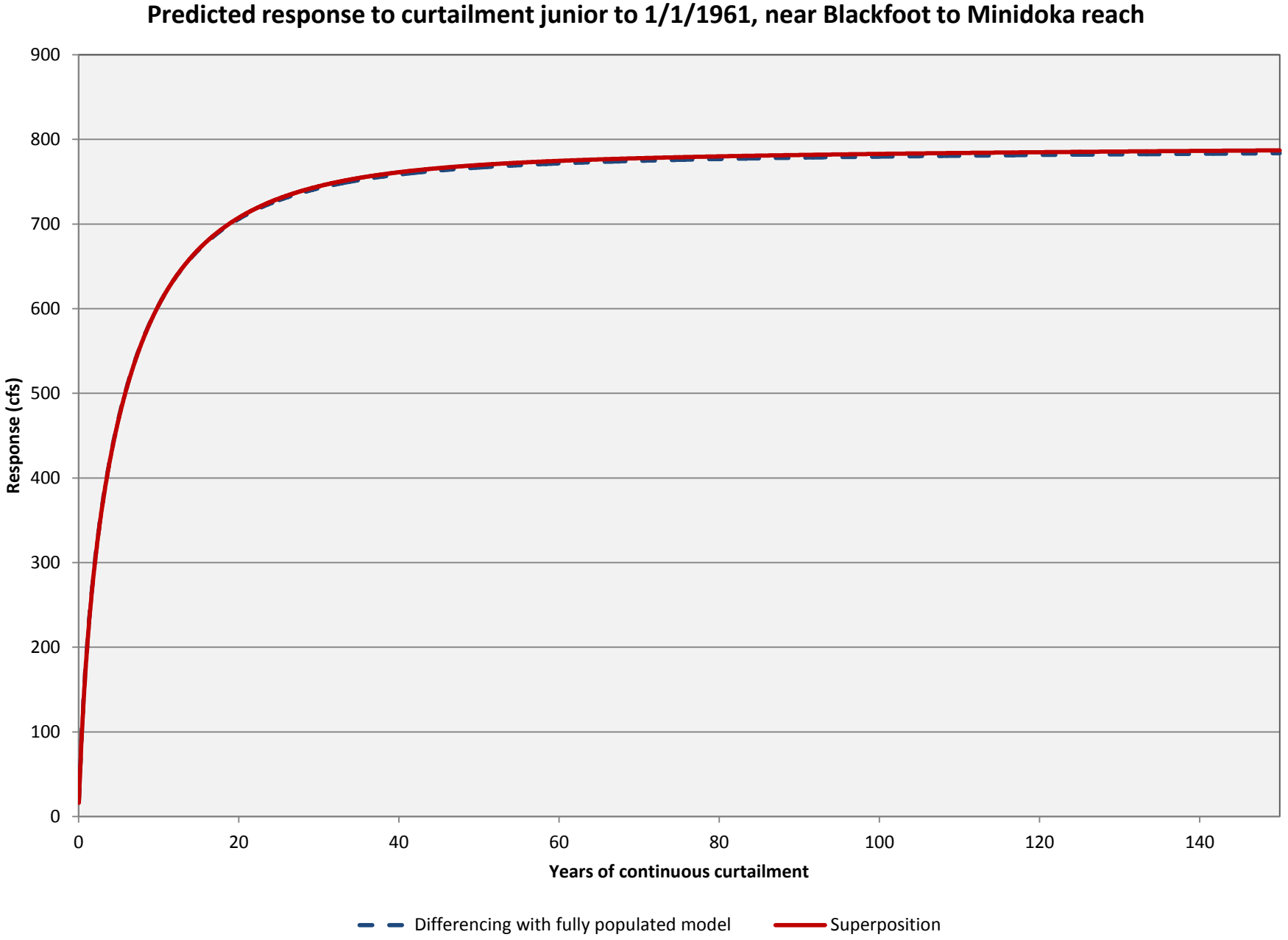


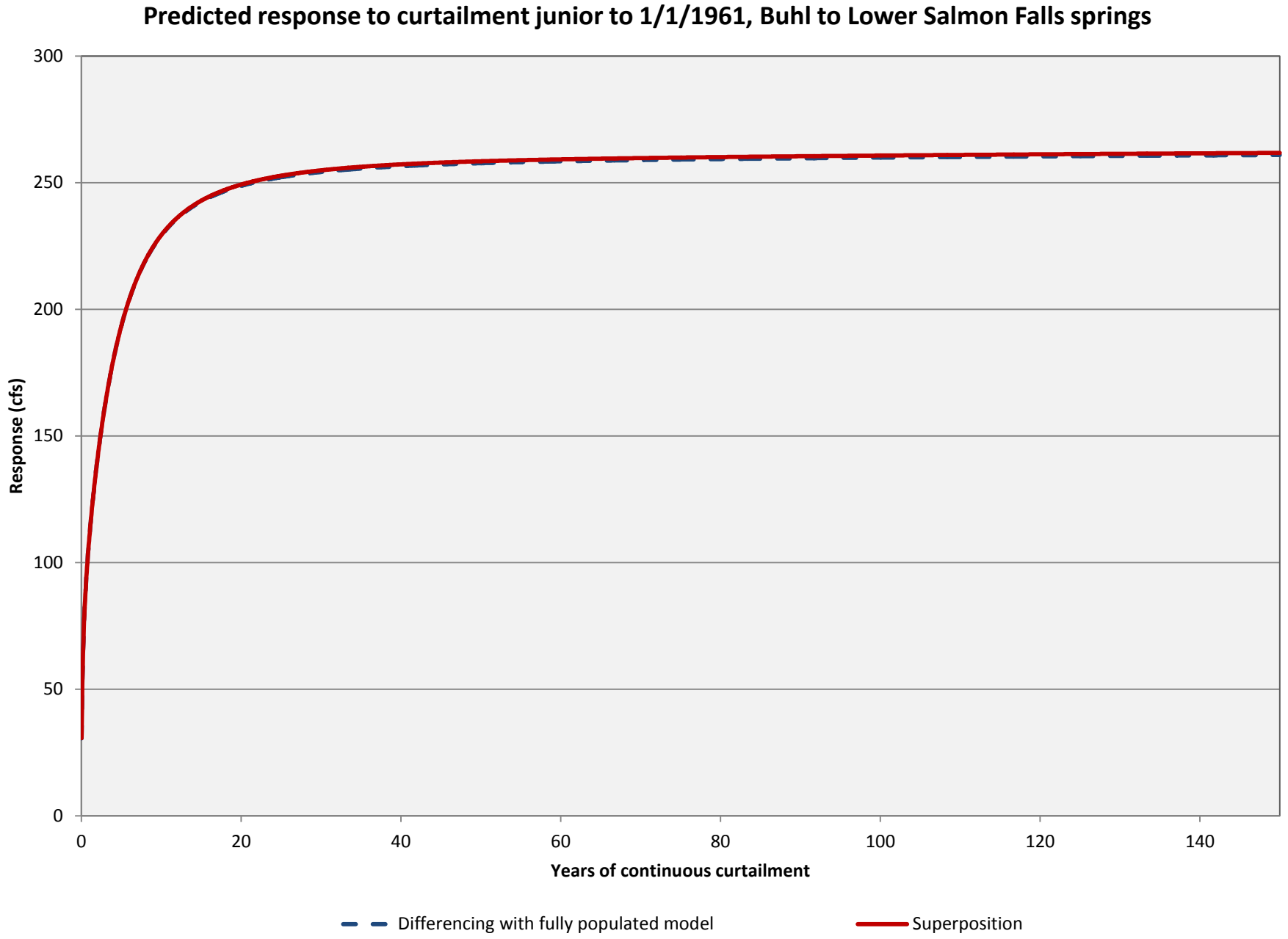

Predicted response to curtailment junior to 1/1/1961, Ashton to Rexburg reach
Response (cfs)
180
160
140
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition

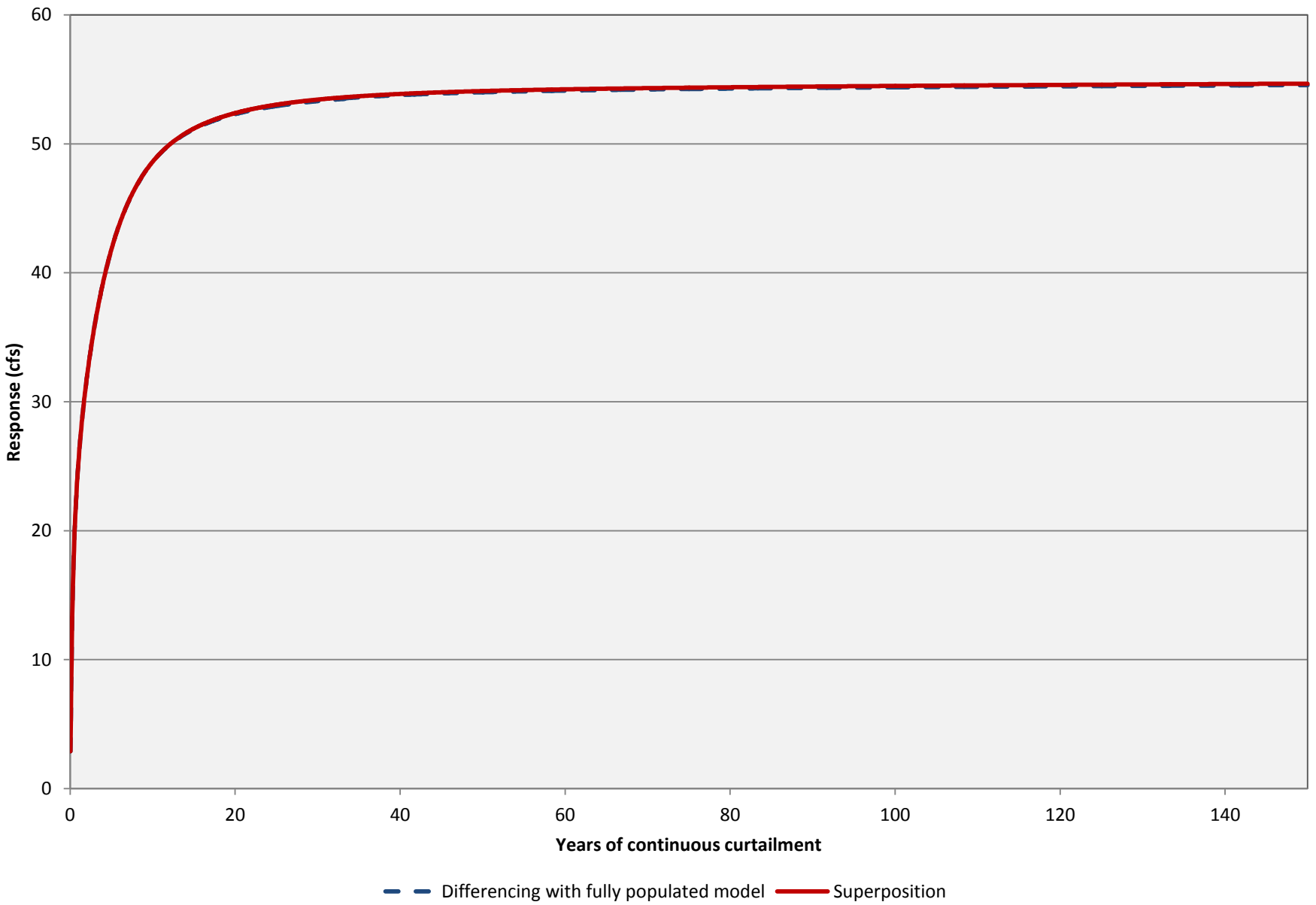

Predicted response to curtailment junior to 1/1/1961, Heise to Shelley reach
300
250
200
150
100
50
0
Response (cfs)
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition


Predicted response to curtailment junior to 1/1/1961, Shelley to near Blackfoot reach
300
250
200
150
100
50
0
Response (cfs)
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition


Predicted response to curtailment junior to 1/1/1961, near Blackfoot to Minidoka reach
900
800
700
600
500
400
300
200
100
0
Response (cfs)
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition


Predicted response to curtailment junior to 1/1/1961, near Blackfoot to Minidoka reach
900
800
700
600
500
400
300
200
100
0
Response (cfs)
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition


Predicted response to curtailment junior to 1/1/1961, Buhl to Lower Salmon Falls springs
Response (cfs)
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition


Predicted response to curtailment junior to 1/1/1961, LSF to King Hill springs
Response (cfs)
0
10
20
30
40
50
60
0
20
40
60
80
100
120
140
Years of continuous curtailment
Differencing with fully populated model
Superposition

Difference in predicted steady state response

Priority date	Total applied stress (cfs)	Ashton to Rexburg	Heise to Shelley	Shelley to Nr Blackfoot	Nr Blackfoot to Minidoka	Kimberly to King Hill	Individual spring reaches
1/1/1870	3,276	0.7%	-5.9%	1.1%	0.9%	0.6%	0.2% to 0.7%
1/1/1949	2,868	0.5%	-5.4%	1.4%	0.7%	0.5%	0.1% to 0.6%
1/1/1961	1,927	0.4%	-4.7%	1.7%	0.7%	0.3%	0.1% to 0.4%
1/1/1973	1,095	0.2%	-3.4%	1.3%	0.5%	0.2%	0.0% to 0.3%
1/1/1985	218	0.2%	-2.1%	0.7%	0.4%	0.2%	0.0% to 0.1%

(Superposition prediction – fully populated prediction)/fully populated prediction

CONCLUSIONS

- For curtailment scenarios, the difference between superposition and fully populated model predictions is acceptably small
- The superposition version of the model is suitable for simulation of curtailment of groundwater pumping
- The superposition version of the model is also expected to be suitable for simulations where applied stress is small compared to the fully populated model water budget
- Simulations that involve very large changes in the model water budget, or place a large localized stress near a drain or river reach may require use of the fully populated model