Development of the West Dakota Water Development District's Future Use Permit for Water from the Missouri River

In cooperation with the West Dakota Water Development District.

11-12-2019

Kurt Katzenstein, Ph. D. P.E.

South Dakota School of Mines and Technology

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

Our Team!

- Kurt Katzenstein, Ph.D., P.E. (SDSMT)
- Scott Kenner, Ph.D., P.E. (SDSMT)
- Arden Davis, Ph.D., P.E. (SDSMT)
- Mark Anderson (SDSMT - Adjunct)
- Alvis Lisenbee, Ph.D. (SDSMT - Deceased)

- Three Undergraduate Students:
  - Kaleb Hedman (CEE - Rapid City, SD)
  - Regan Wess (GEOE – Fort Collins, CO)
  - Haley Noteboom (GEOE – Orange City, IA)

Project Background

- Since 1976, the WDWDD has maintained future use permit 1443-2 which would allow for the use of up to 10,000 acre-ft/year (13.8 cfs) of Missouri River water for “Future municipal, industrial, commercial, and rural water system use”

- Rapid City also holds a future use permit for Missouri River water of 66,000 acre-ft/year (92 cfs).

Future Use Permits for Missouri River Water

1688A-3	Lake Andes-Wagner	07/01/1969	393,000 ac-ft/yr
2042-3	City of Sioux Falls	12/28/1973	47,000 ac-ft/yr
2671-3	WEB Water Dev	04/07/1976	20,000 ac-ft/yr
1442-2	West River Water	09/02/1976	10,000 ac-ft/yr
1443-2	West Dakota WDD	09/03/1976	10,000 ac-ft/yr
3142-3	City of Mitchell	09/09/1976	18,100 ac-ft/yr
1492-2	City of Rapid City	12/13/1976	66,600 ac-ft/yr
3371-3	City of Yankton	12/21/1976	27,000 ac-ft/yr
3429-3	WEB Water Dev	12/30/1976	10,000 ac-ft/yr
3574-3	East Dakota WDD	02/09/1977	400,000 ac-ft/yr
3574A-3	Clay Rural Water	02/09/1977	145,000 ac-ft/yr
4290-3	City of Mobridge	06/02/1978	8,700 ac-ft/yr
4456-3	Aurora Brule RWS	12/17/1979	1,740 ac-ft/yr
4456A-3	Aurora Brule RWS	12/17/1979	621 ac-ft/yr
4673-3	City of Elk Point	03/17/1981	1,010 ac-ft/yr

SD DENR

Project Objectives

1. Examination of various population growth projections for Rapid City and adjacent area, and implications to future water demand.

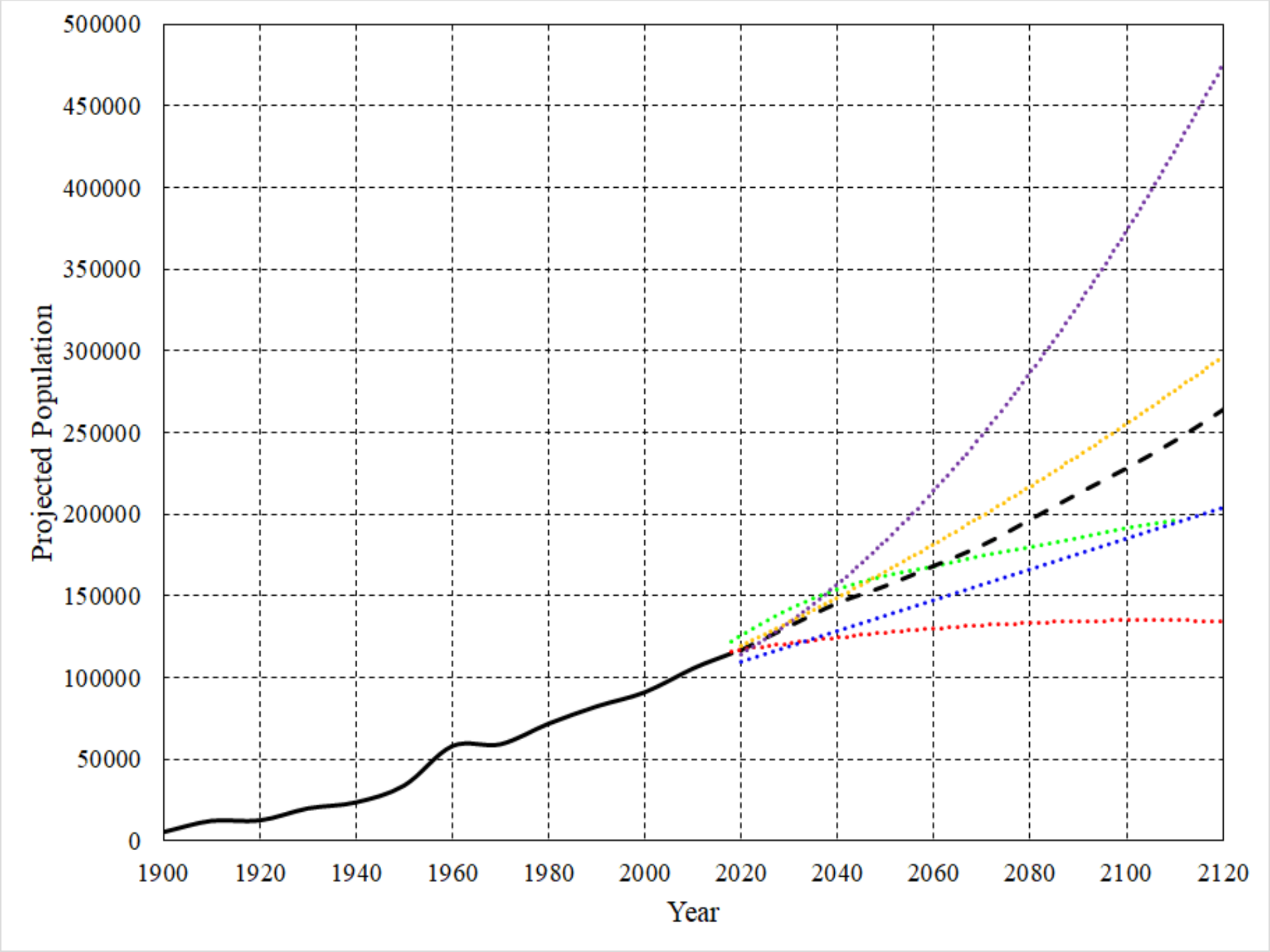
2. Documentation of current water supply/sources/rights.

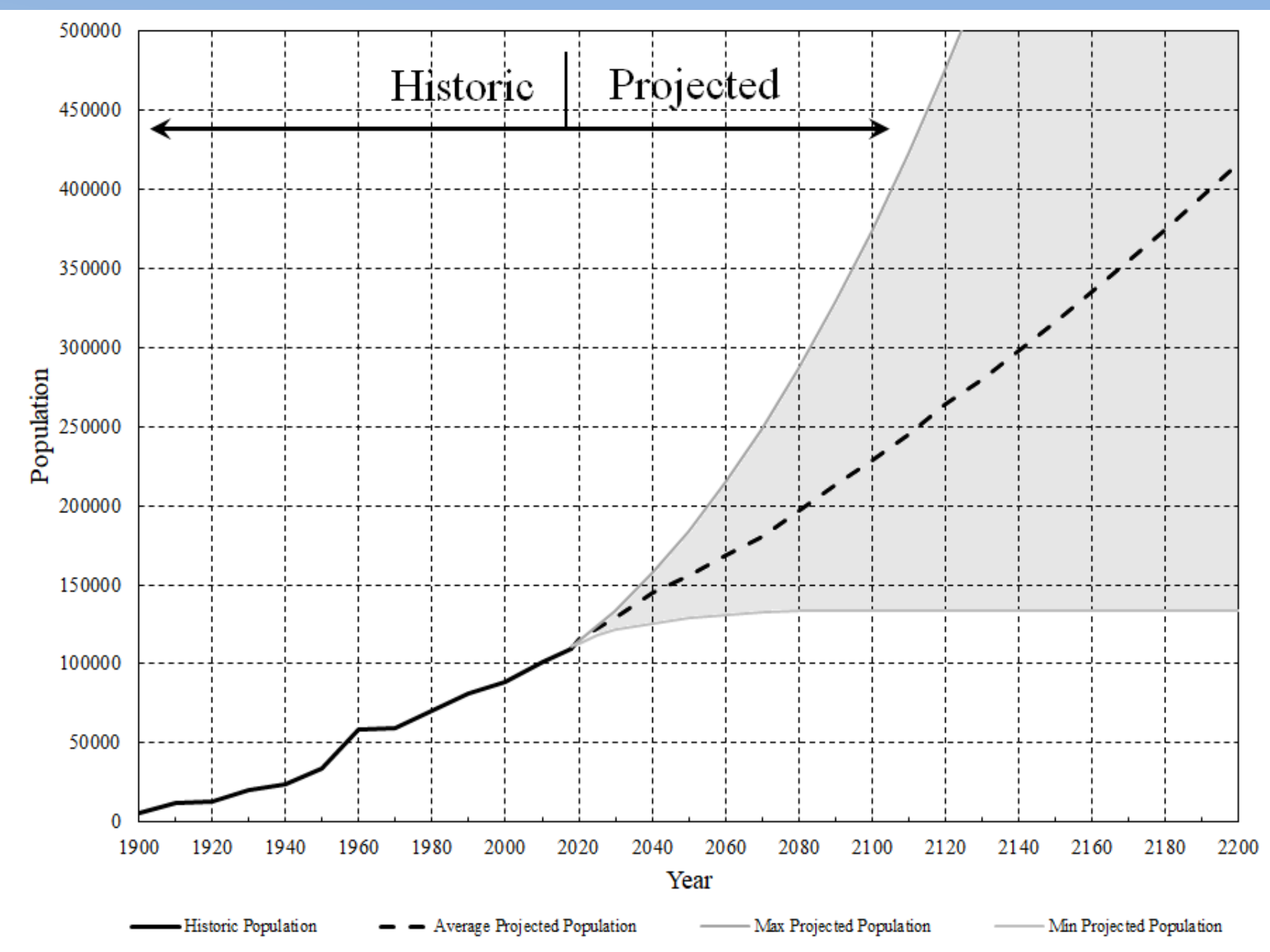
3. Development of options for use of Missouri River water rights

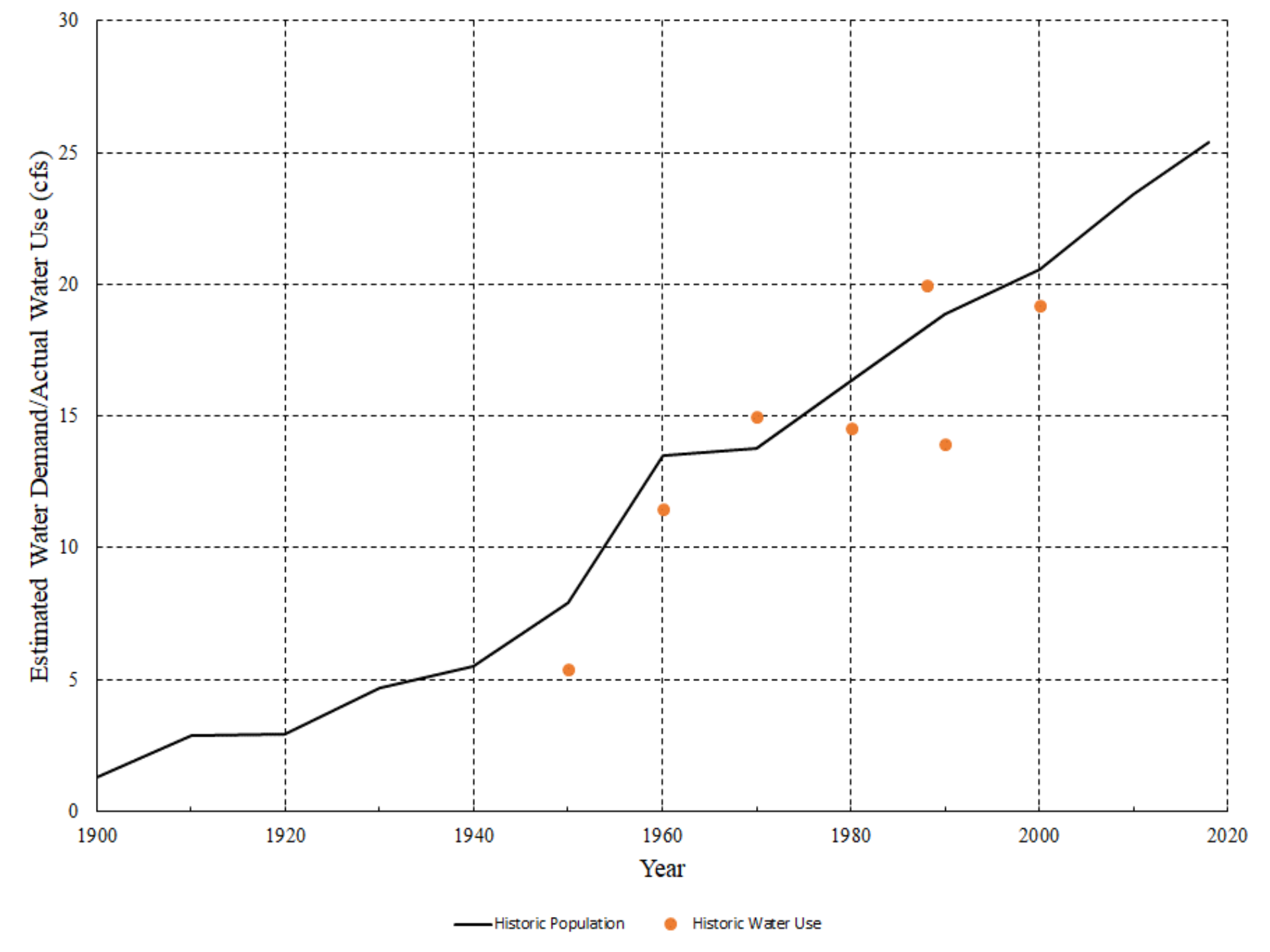
1. Population/Water Demand Growth

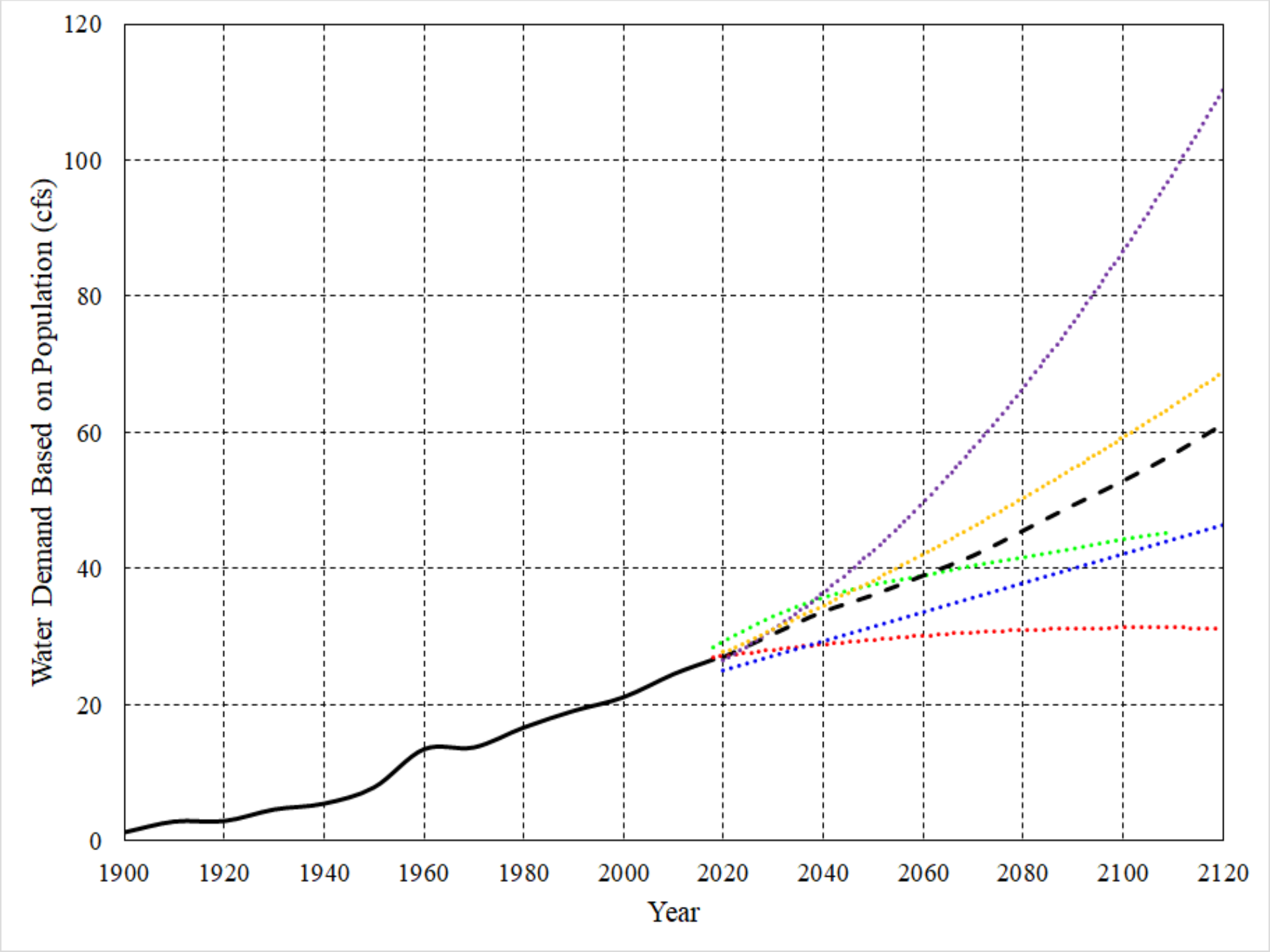
- Multiple projection assumptions were used in order to generate a range of future populations for both Rapid City and Pennington County.

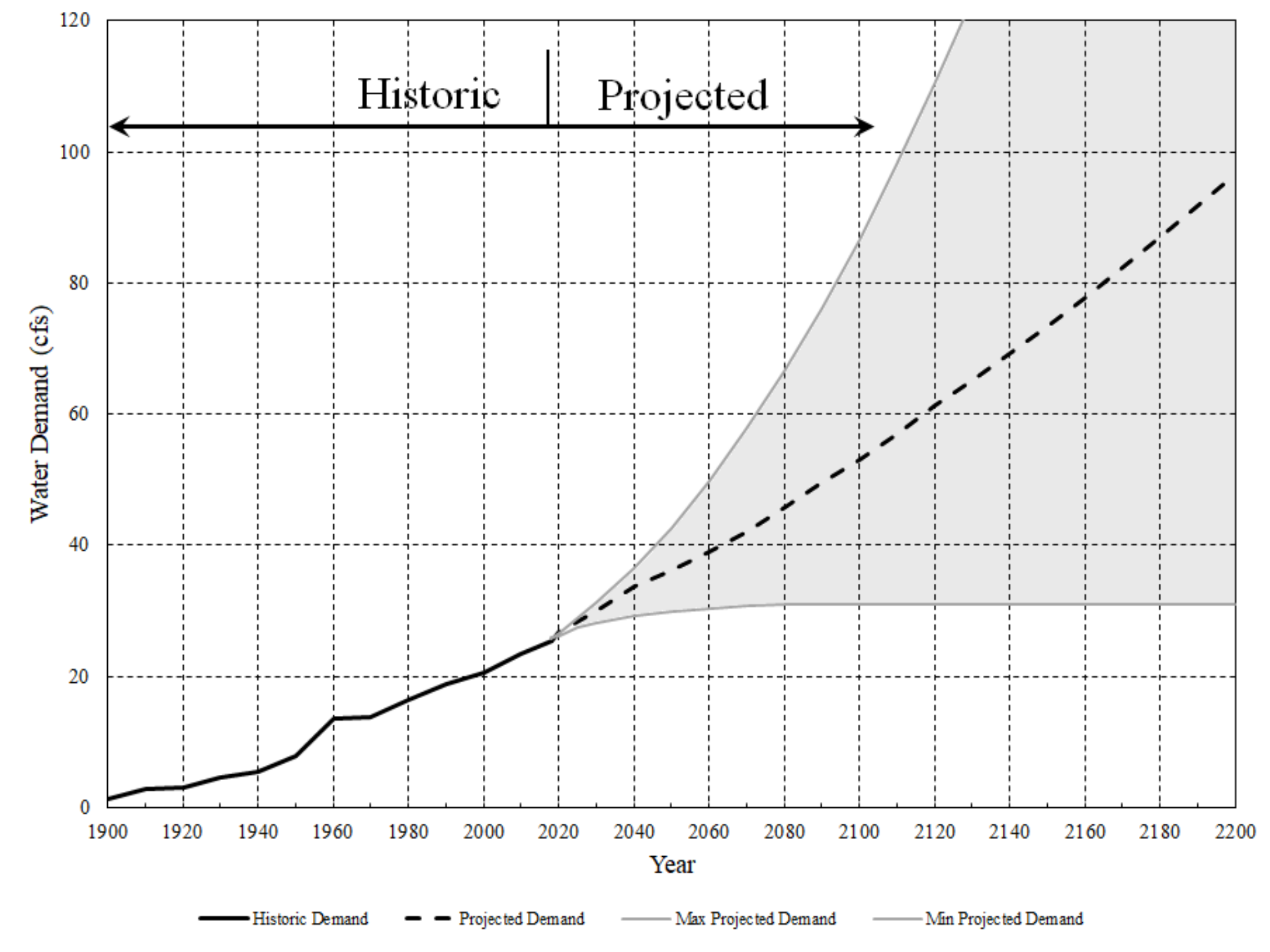
- Can be translated to water demand with time. We assumed 150 gpd/person (after Long and Putnam, 2002)


500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
Projected Population
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
Year


Historic
Projected
Population
Year
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
Historic Population
Average Projected Population
Max Projected Population
Min Projected Population

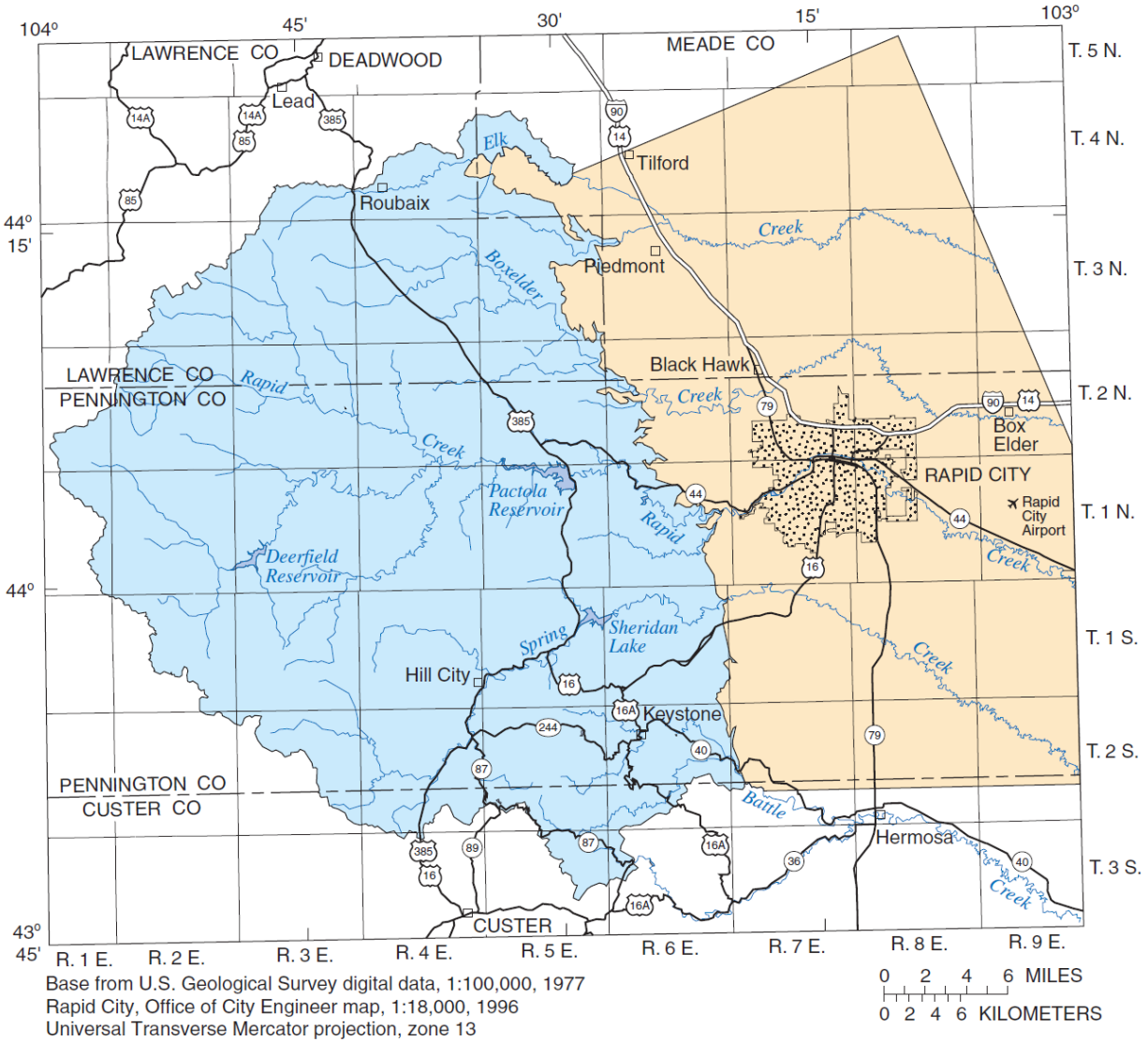

Estimated Water Demand/Actual Water Use (cfs)
30
25
20
15
10
5
0
1900
1920
1940
1960
1980
2000
2020
Year
Historic Population
Historic Water Use


Water Demand Based on Population (cfs)
120
100
80
60
40
20
0
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
Year

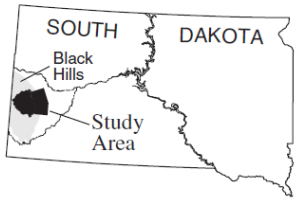

Historic
Projected
Water Demand (cfs)
Year
0
20
40
60
80
100
120
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
Historic Demand
Projected Demand
Max Projected Demand
Min Projected Demand

2. Current Water Supplies/Sources/Rights

- We reviewed published literature regarding existing sources of water for the region.
  - USGS reports, Burns and McDonnell, U.S. Bureau of Reclamation, theses, etc.
- Available water resources are influenced by:
  - Climate, influence of pumping on spring flow, etc.
- We can then compare available resources with predicted demand…



Base from U.S. Geological Survey digital data, 1:100,000, 1977
Rapid City, Office of City Engineer map, 1:18,000, 1996
Universal Transverse Mercator projection, zone 13



EXPLANATION

DRAINAGE AREAS USED IN CALCULATION OF STREAMFLOW LOSSES

AQUIFER ANALYSIS AREA

Long and Putnam, 2002

Groundwater Availability

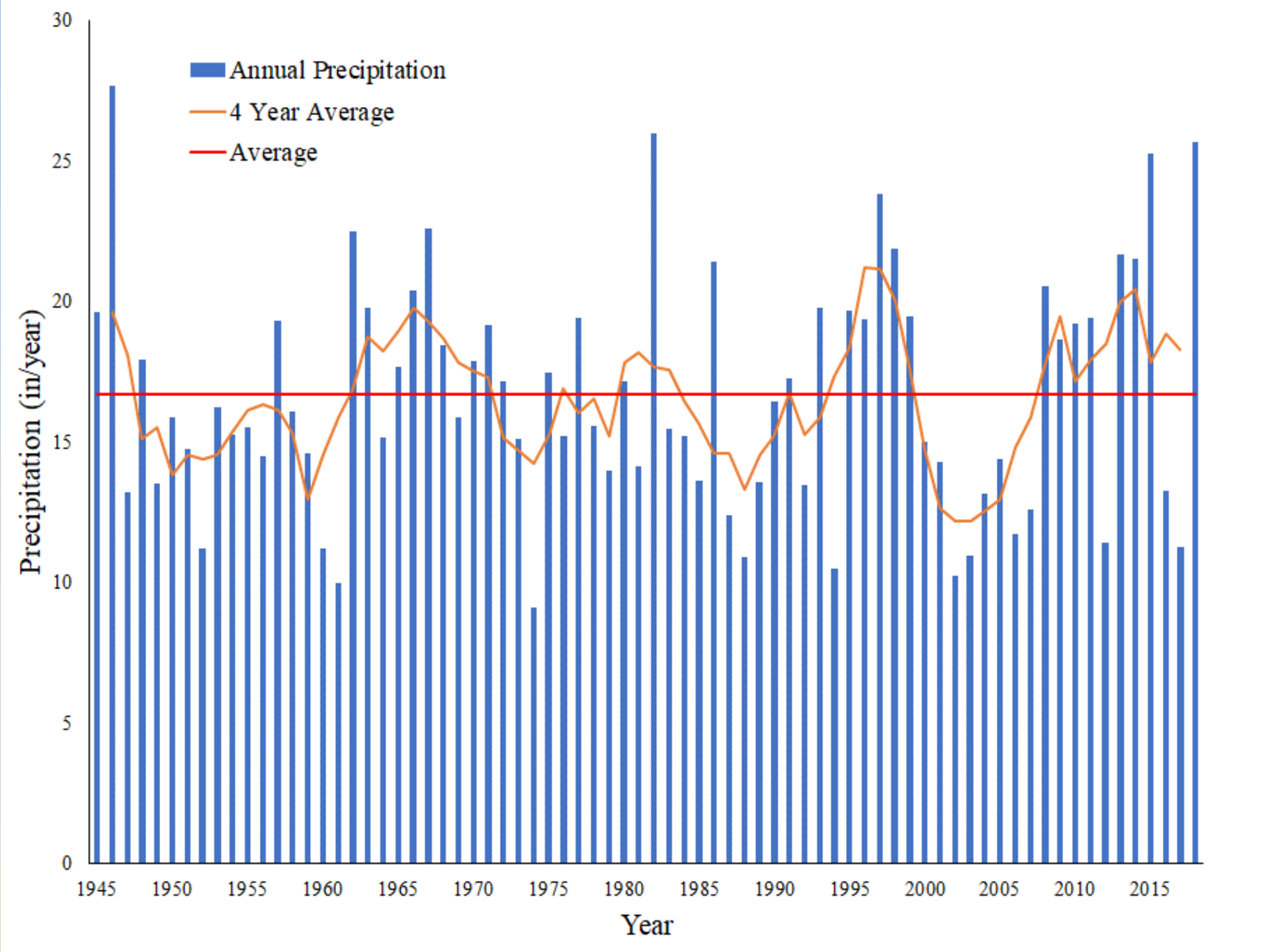
- Long and Putnam (2002) suggested that:
  - Inflow into the Madison and Minnelusa aquifers from precipitation directly on the outcrops and streamflow losses in the Rapid City region ranges from approximately 44.5 – 110 cfs depending upon climatic conditions.
  - Regional outflow is estimated to vary from 47.5 – 59.6 cfs (not counting water use)
  - This leaves a budget for use of -3.0 – 50.4 cfs for the Rapid City region.
  - Estimated available groundwater values for dry, average and wet years of 0 cfs, 20.8 cfs, and 50.4 cfs respectively, are assumed in the following discussion

Surface Water Availability

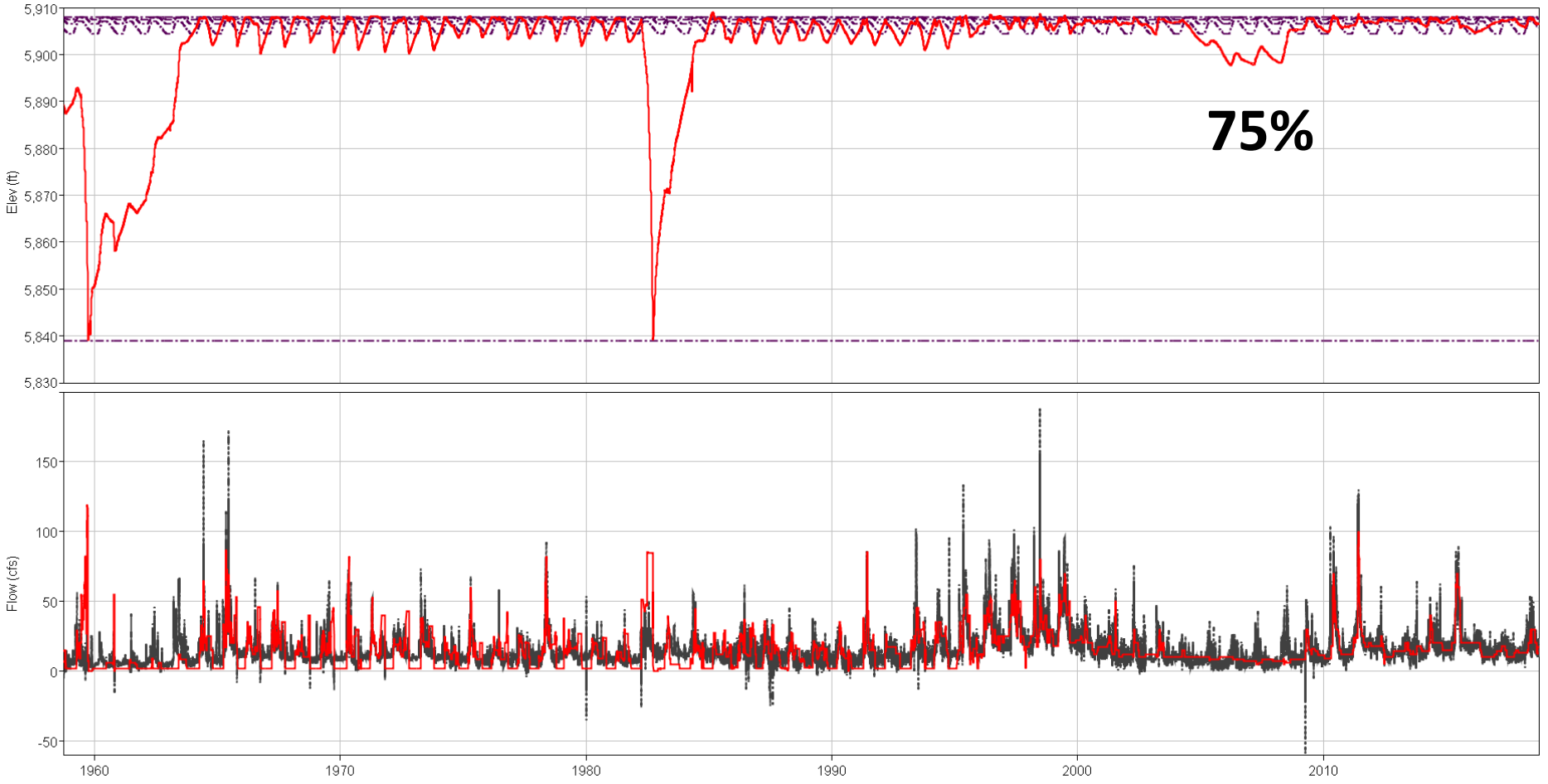
- The USGS stream gage at Rapid City (0641400) suggests 25th, 50th and 75th percentile mean annual flow values of 43.3 cfs, 60.7 cfs and 82.5 cfs, respectively.

- In order to ensure stream health and proper habitat for fish, the Tennant (1975) and Tessman (1980) methods were utilized.
  - Tennant suggested for "good survival habitat" that 30% of the mean streamflow should be maintained (18.2 cfs).
  - Tessman evaluates the required flow based on relationships between the mean monthly flow and the mean annual flow. As this study is dealing with annual data, the lowest recommended mean monthly flow was assumed (24.3 cfs).
  - For this study, the Tennant and Tessman recommendations were averaged. This suggests 21.3 cfs as a flow needed to maintain adequate stream habitat and is therefore unavailable for use.

- Estimated available consumptive surface water from Rapid Creek for dry, average and wet years of 22.0 cfs, 39.4 cfs, and 61.2 cfs respectively, are assumed in the following discussion.

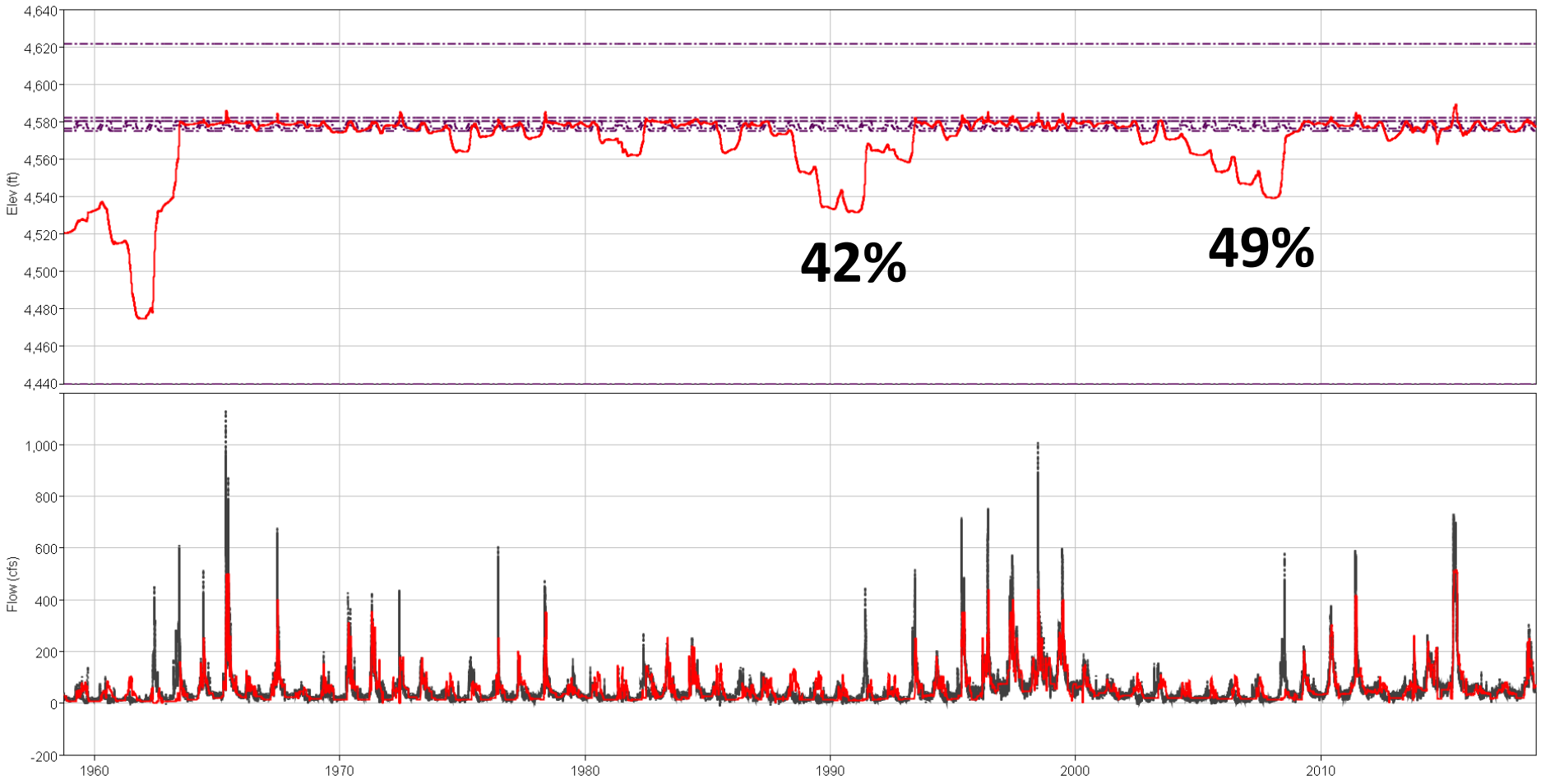

Annual Precipitation
4 Year Average
Average
Precipitation (in/year)
Year
0
5
10
15
20
25
30
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

Deerfield Water History

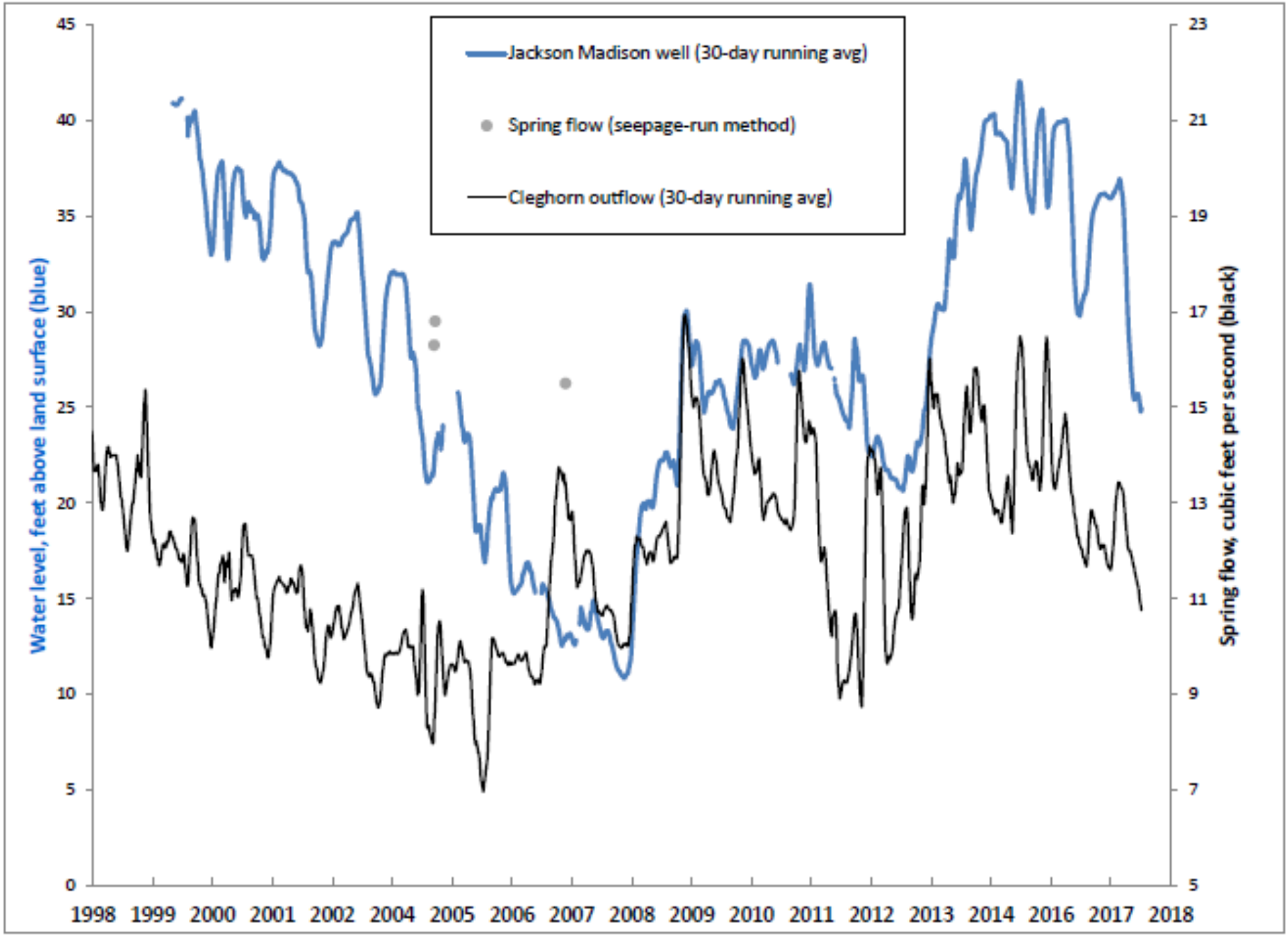


Squillace, 2019

Pactola Water History



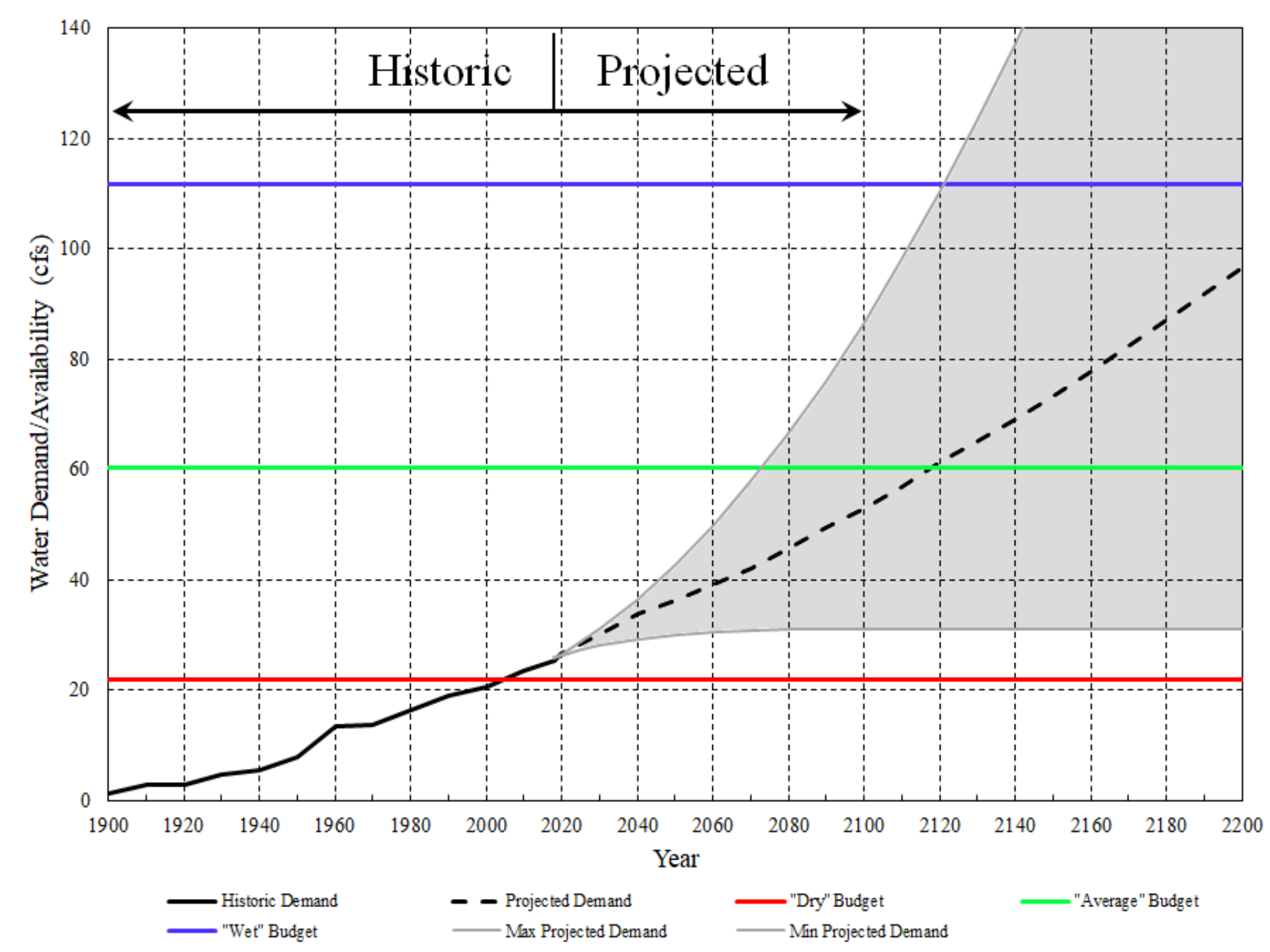
Squillace, 2019


Jackson Madison well (30-day running avg)
Spring flow (seepage-run method)
Cleghorn outflow (30-day running avg)
Water level, feet above land surface (blue)
Spring flow, cubic feet per second (black)
45
40
35
30
25
20
15
10
5
0
23
21
19
17
15
13
11
9
7
5
1998
1999
2000
2001
2002
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2016
2017
2018

USGS

Assumed Water Budget

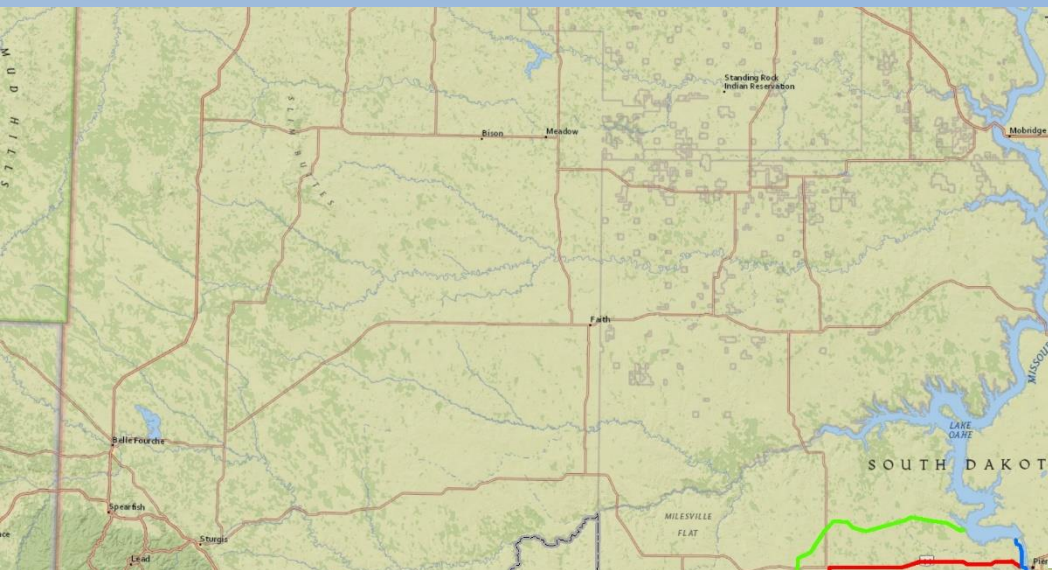
Climate Condition	Groundwater (cfs)	Surface Water (cfs)	Total (cfs)
Dry	0	22.0	**22.0**
Average	20.8	39.4	**60.2**
Wet	50.4	61.2	**111.6**

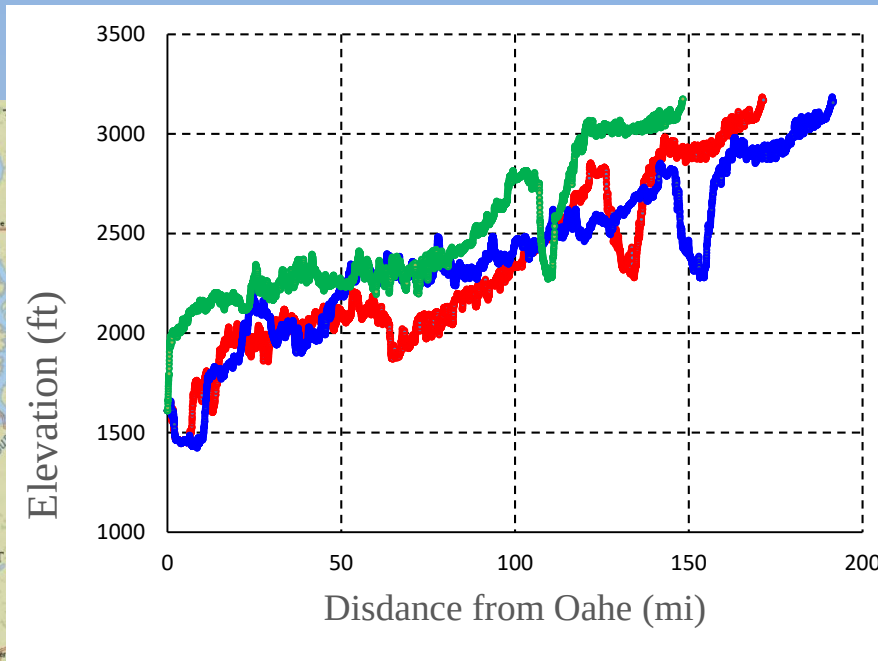

Historic
Projected
Water Demand/Availability (cfs)
Year
0
20
40
60
80
100
120
140
1900
1920
1940
1960
1980
2000
2020
2040
2060
2080
2100
2120
2140
2160
2180
2200
Historic Demand
Projected Demand
"Dry" Budget
"Average" Budget
"Wet" Budget
Max Projected Demand
Min Projected Demand

3. Development/Use of 1443-2

- Pipeline Alignment?
  - Most likely alignments would follow existing public rights of way along highways.
  - Could utilize public land
- Pipeline Size?
  - Possible diameters vary from 2’ – 8’ depending upon desired capacity and flow velocity
- Pump Station Locations?
  - A function of topography coupled with friction loss and system capacity

Possible Alignments





Pipeline Design

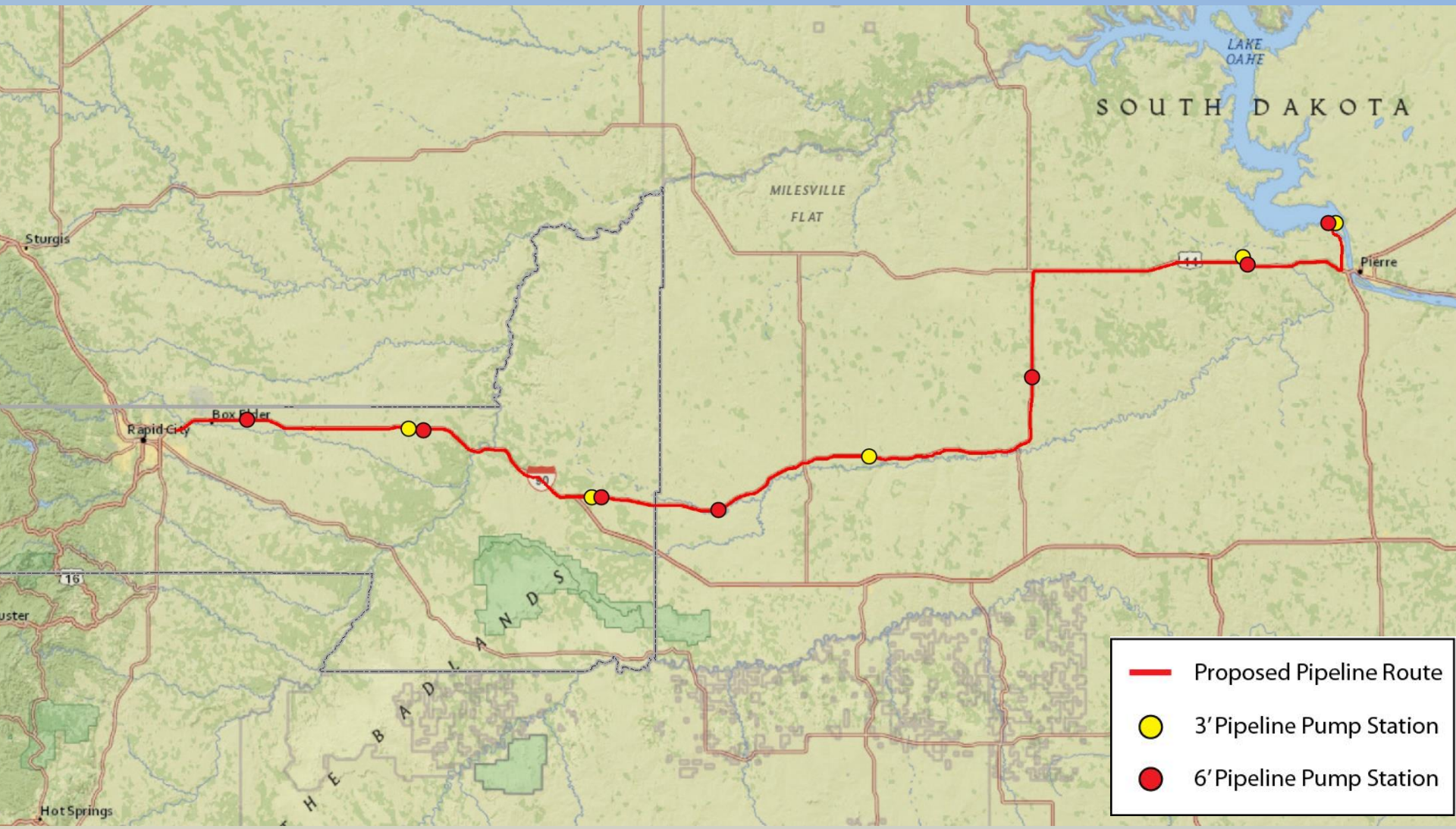
- Preliminary Design Specifications:
  - Length: ~171 miles
  - WDWDD allotment (~14 cfs)
    - 3 ft diameter pipe
    - 1 intake pump station
      - Three 4.46 cfs pumps working in parallel (one extra on standby)
    - 5 boost stations
      - Two 6.68 cfs pumps working in parallel (one extra on standby)
  - WDWDD and Rapid City allotments (~105 cfs)
    - 6 ft diameter pipe
    - 1 intake pump station
      - Three 34.9 cfs pumps working in parallel (one extra on standby)
    - 6 boost stations
      - Three 34.9 cfs pumps working in parallel (one extra on standby)

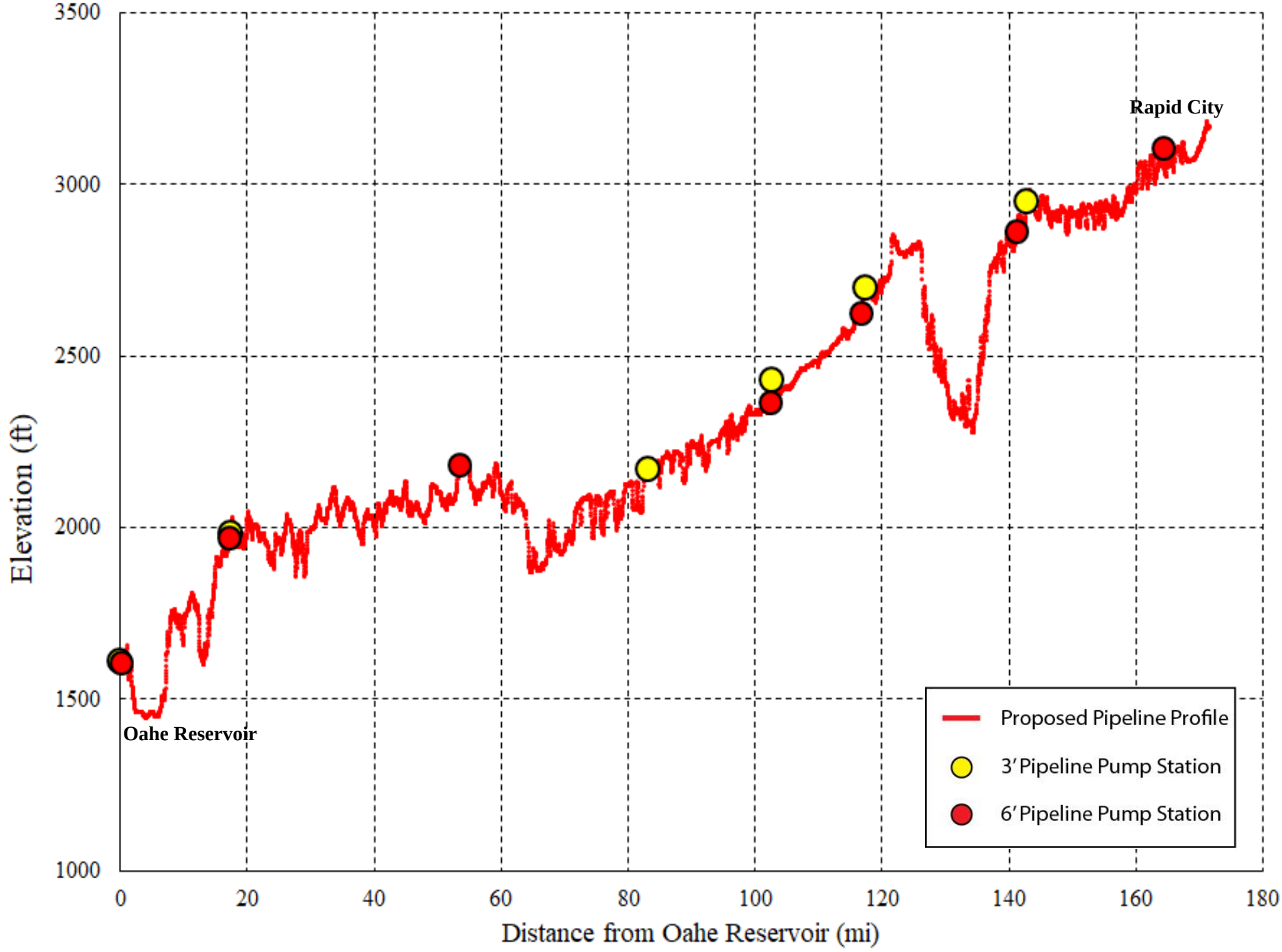
Thanks to Will Lind at Dakota Pump for preliminary pump designs!

Preliminary Pump Station Locations

- Locations based on pump characteristics working against head loss from elevation, pipe friction and minor losses.
  - Elevation head loss: ~1560 ft
  - Head loss due to pipe friction:
    - ~260 ft (3’ diameter pipe)
    - ~357 ft (6’ diameter pipe)
  - Minor head loss:
    - ~5 ft (3’ diameter pipe)
    - ~18 ft (6’ diameter pipe)
  - Total head loss:
    - ~1825 ft (3’ diameter pipe)
    - ~1935 ft (6’ diameter pipe)

Possible Pump Station Locations




3500
3000
2500
2000
1500
1000
Elevation (ft)
0
20
40
60
80
100
120
140
160
180
Distance from Oahe Reservoir (mi)
Rapid City
Oahe Reservoir
Proposed Pipeline Profile
3' Pipeline Pump Station
6' Pipeline Pump Station

Other Pipeline Considerations

- Reservoirs needed at each pump station
- Major storage reservoir needed once water reaches western Pennington County
- Water quality considerations both for consumption as well as pipeline longevity

Cost Estimate (WDWDD Allotment)

Expense Category	Cost Estimate
36” Ductile Iron Pipe (excavation, pipe material and appurtenances)	$340/ft
Intake Pump Station	$7,500,000
Each 14 cfs Boost Station (including 2 million gallon reservoir)	$5,900,000
Engineering, legal, admin, environmental, easements, permits, etc.	35% const. cost
Contingency	25% const. cost
Total	**~$555,000,000**

Power Consumption/Cost (assuming constant 14 cfs)

- ~5.2 Megawatts
- ~45.6 Gigawatt-hours annually
- As much as ~$1,400,000 to ~$2,300,000 annually depending upon wholesale power price ($0.03 to $0.05 per kilowatt-hour assumed).

Cost Estimate (WDWDD and Rapid City Allotments)

Expense Category	Cost Estimate
72” Ductile Iron Pipe (excavation, pipe material and appurtenances)	$850/ft
Intake Pump Station	$45,500,000
Each 105 cfs Boost Station (including 10 million gallon reservoir)	$39,800,000
Engineering, legal, admin, environmental, easements, permits, etc.	25% const. cost
Contingency	25% const. cost
Total	**~$1,870,000,000**

Power Consumption/Cost (assuming constant 105 cfs)

- ~26.2 Megawatts
- ~229.0 Gigawatt-hours annually
- As much as ~$7,000,000 to ~$11,500,000 annually depending upon wholesale power price ($0.03 to $0.05 per kilowatt-hour assumed).

Other Sources?

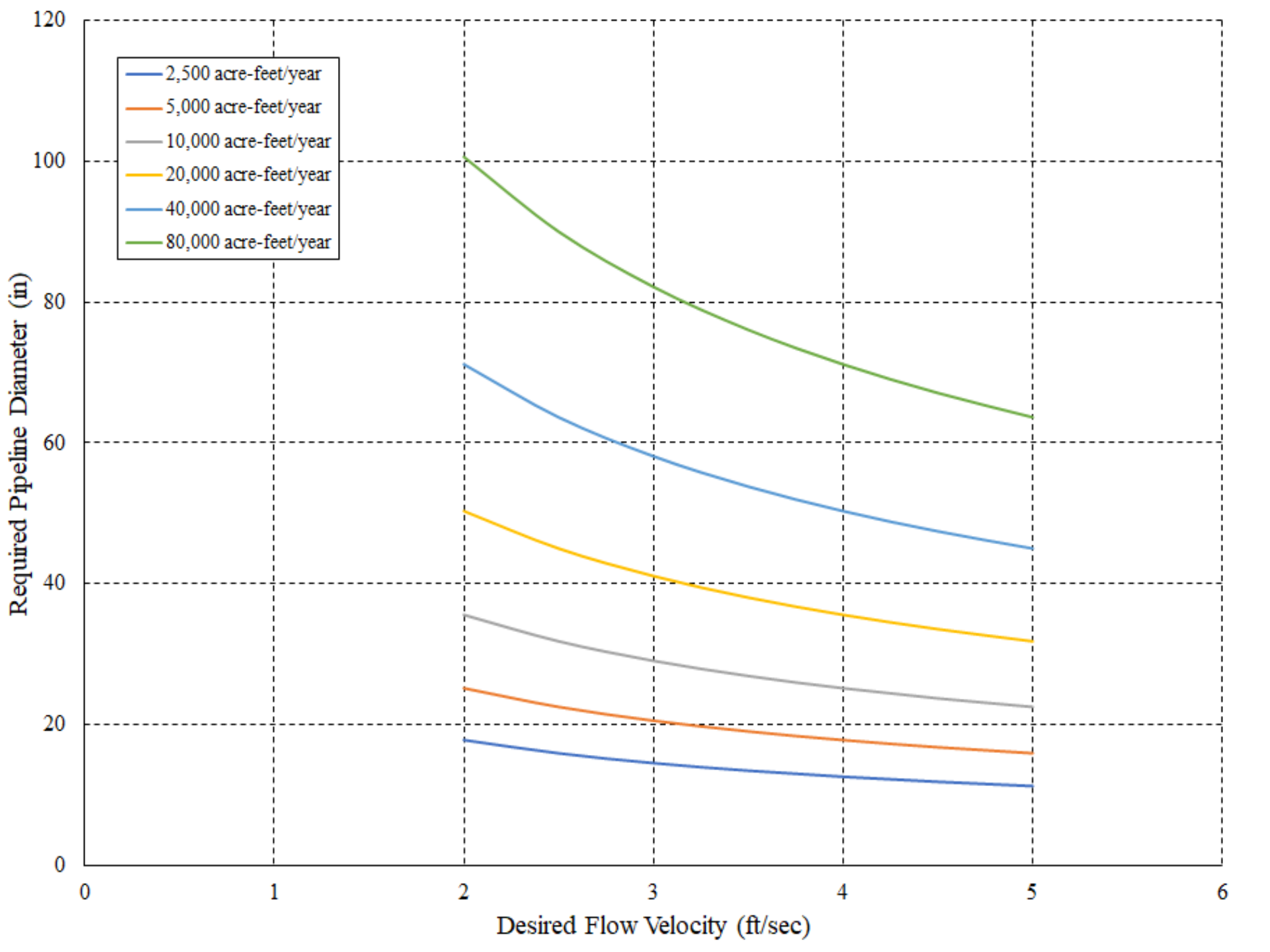
- The only other viable surface water source near the study area is the Cheyenne River.
  - Rights are fully allocated to the Angostura Irrigation District

- Could utilize smaller surface watersheds and groundwater resources north and south of the study area but as population increases, it is likely that those resources will be allocated locally.

Conclusions

- Based on current use and water demand projections, the region's ability to provide water during drought conditions without utilizing surface water and groundwater storage is limited and will worsen as population increases.
  - Our projections suggest that even during an "average" year, the average predicted demand will surpass supply in about 2120.
- Existing Future Use Permits for the Missouri River could play a major role in filling this need and should therefore be retained/renewed.
- While expensive and challenging, it is feasible to transport Missouri River water to the Rapid City region.


Questions?
Kurt Katzenstein
Kurt.Katzenstein@sdsmt.edu


2,500 acre-feet/year
5,000 acre-feet/year
10,000 acre-feet/year
20,000 acre-feet/year
40,000 acre-feet/year
80,000 acre-feet/year
Required Pipeline Diameter (in)
Desired Flow Velocity (ft/sec)
0
20
40
60
80
100
120
0
1
2
3
4
5
6