WWDC Wind/Bighorn River Basin Plan, Groundwater Study (Level I)

WSGS – USGS – WRDS 2008-2010

Scott Quillinan

Geologist

Wyoming State Geological Survey (WSGS)

Laramie, Wyoming

WBH Groundwater Study Team

WWDO *Project Manager – Jodi Pavlica*

- **WSGS** – Laramie – *Scott Quillinan*
- **USGS** – Cheyenne – *Tim Bartos*
- **WRDS** – University of Wyoming – *Steve Gray*
- **Energy Compliance** - *Paul Taucher*

Chapter 1: Introduction

- **1.1 Legal Authorities**
  - **1.1.1** Wyoming Water Law - Groundwater Appropriation, Development, and Use
  - **1.1.2** Wyoming Water Law - Groundwater Quality
  - **1.1.3** Other Agencies - Groundwater Responsibilities
  - **1.1.4** Interstate Agreements
- **1.2 WWDC/WSGS Contract Scope**
- **1.3 Agency Participation**
- **1.4 Acknowledgements**

Platte river Groundwater Study

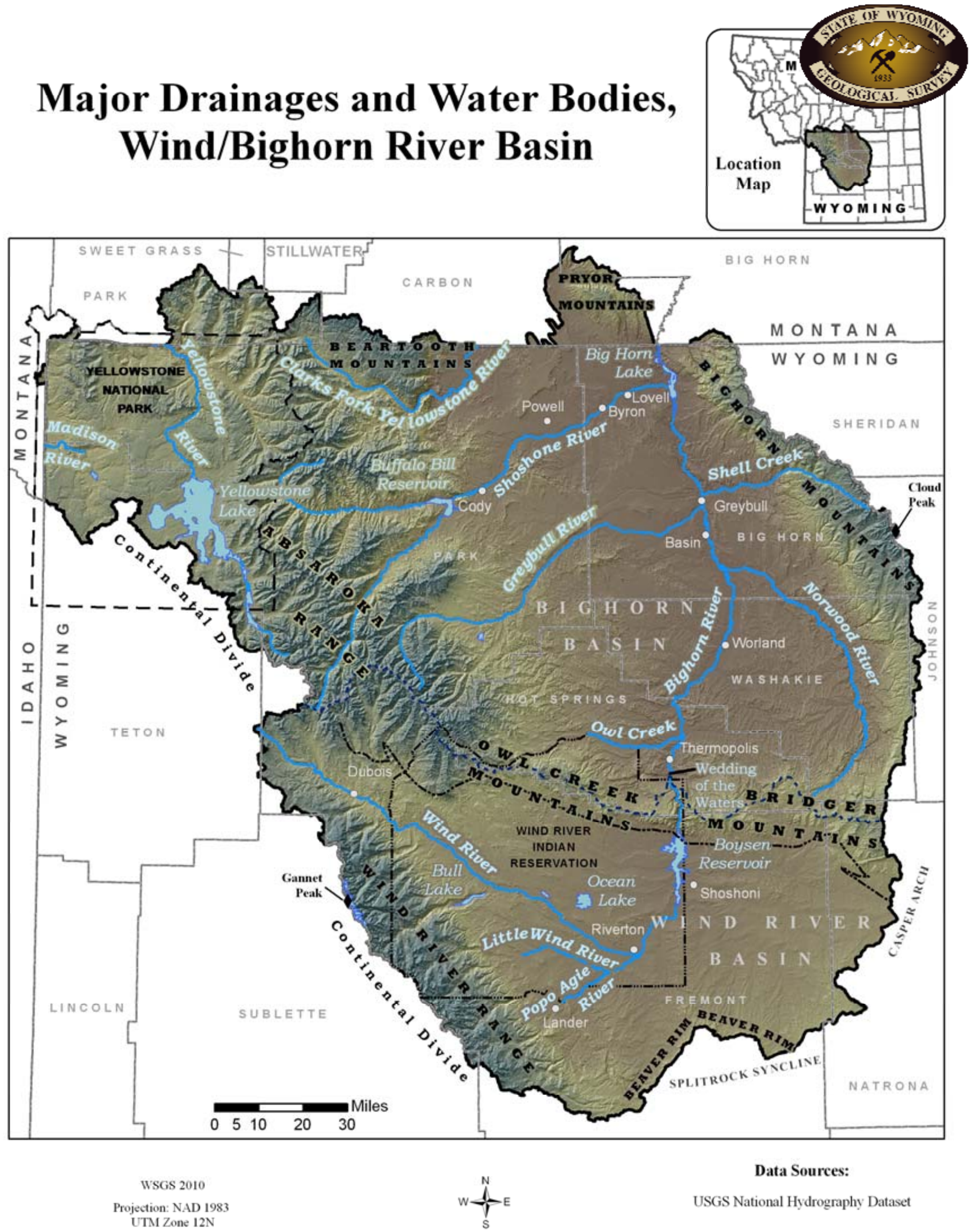
- Identify & inventory the “major” aquifers present within the drainage basin area
- Determine 3-dimensional configuration of the aquifers (outcrop areas, geologic structures, & depths)
- Estimate aquifer recharge rates, storage quantities, & discharge rates
- Identify areas with interaction between groundwater & surface water
- Assess the quantity & quality of groundwater available in the aquifers
- Investigate the usage of groundwater in the basin

Chapter 2: Background

- **2.1 Previous Regional Hydrogeologic Investigations**
- **2.2 Sources of Data**
- **2.3 Differences from Previous Regional Studies**
- **2.4 Significant Updates to the Available Groundwater Determination**
  - **2.4.1** Plates, Figures, and Associated GIS Data
  - **2.4.2** Plates and Figures Descriptions

Chapter 3: Description of the study area

- **3.0 DESCRIPTION OF THE STUDY AREA**
- **3.1 Physiography, Landforms, Topography, and Surface Drainage**
- **3.2 Climate, Precipitation, and Vegetation**
- **3.3 Setting - WBRB**
  - **3.3.1**Physiography and Topography
  - **3.3.2**Surface Drainage
  - **3.3.3**Population Distribution, Land Use, and Land Ownership



Chapter 4: Geologic Setting

- **4.1 General / Historical Geology**
- **4.2 Structural Geology**
- **4.3 Stratigraphy**
- **4.4 Wind River Basin and Surrounding Mountain Ranges**
- **4.5 Bighorn Basin and Surrounding Mountain Ranges**
- **4.6 Owl Creek-Bridger Mountains**
- **4.7 Volcanic and Geothermal Areas**
  - **4.7.1** Absaroka Mountain Range and Volcanic Province
  - **4.7.2** The Yellowstone Plateau
  - **4.7.3** Geothermal Resources
- **4.8 Mineral Resources**

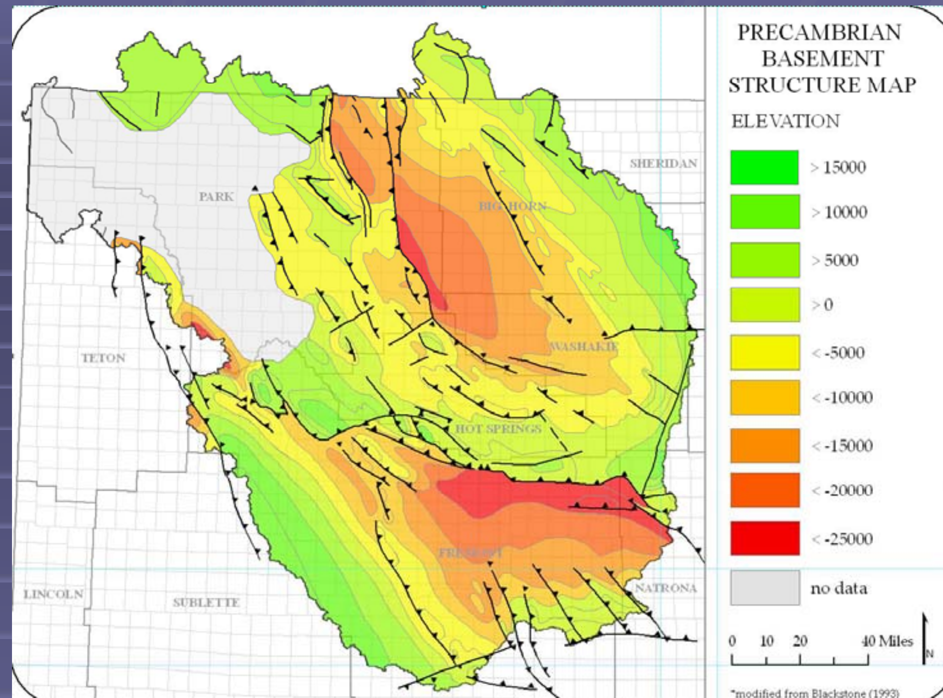
Ch 4. General Geology

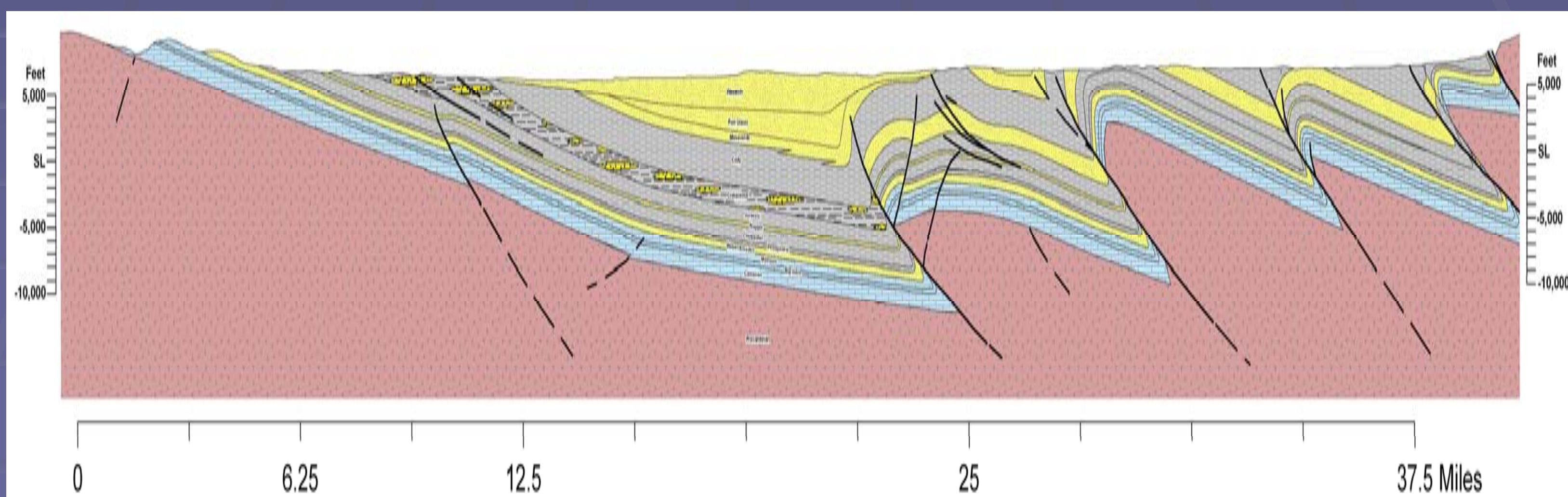
Precambrian (basement)

Igneous and Metamorphic Rock

Foundation for sediments

The Rockies are a result basement involved uplift





Ch 4. General Geology

<u>Paleozoic strata 570-290 mya</u>
Marine and Non-marine transgressive/regressive environments

Marine limestones and dolomites

Long periods of erosion-unconformities

Ch 4. General Geology

Mesozoic 240-66 Mya

Early

shallow seas-

Inter-bedded sandstone, siltstone, shale, carbonates and evaporates

Late Triassic/Early Jurassic-

Terrestrial environment,
marginal marine, eolian, fluvial sandstone and shales.

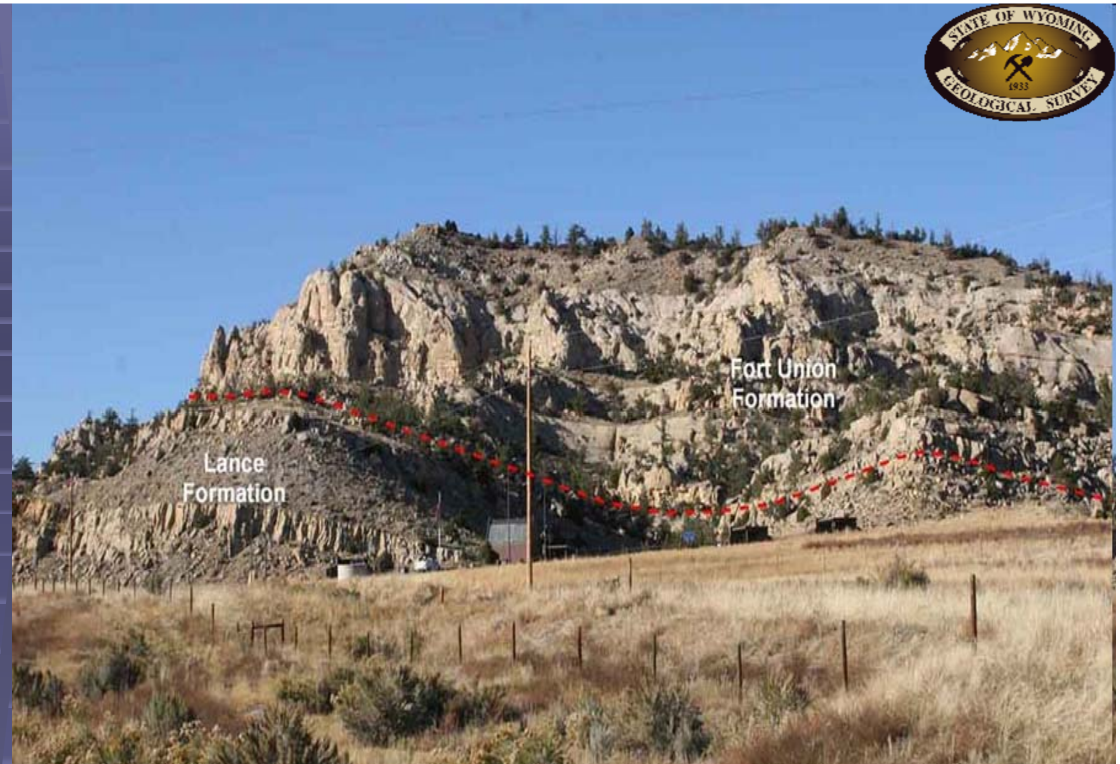
Ch 4. General Geology

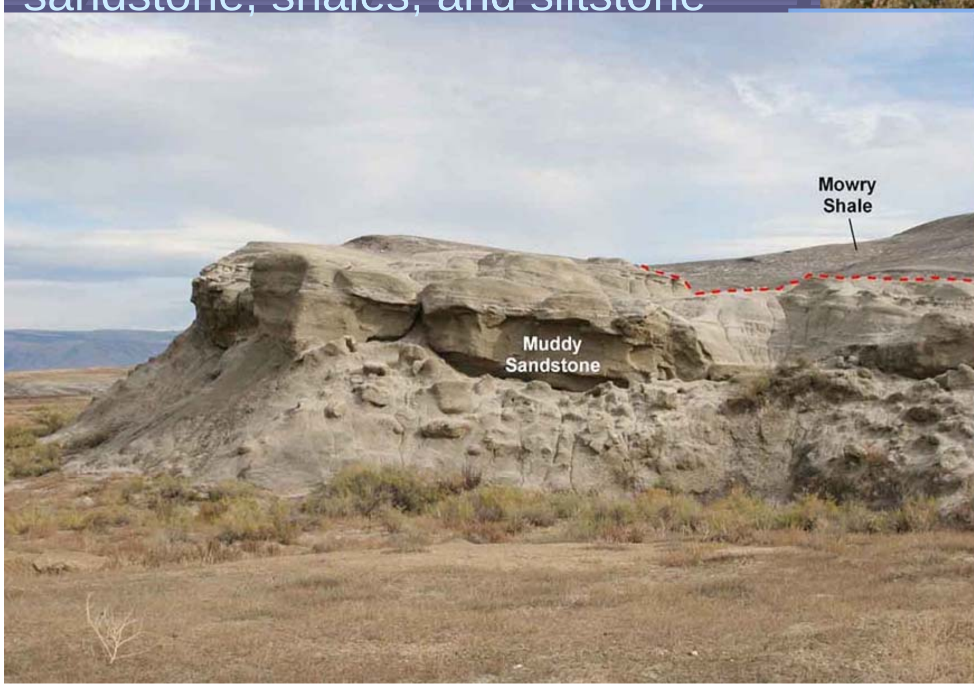
Mesozoic cont.

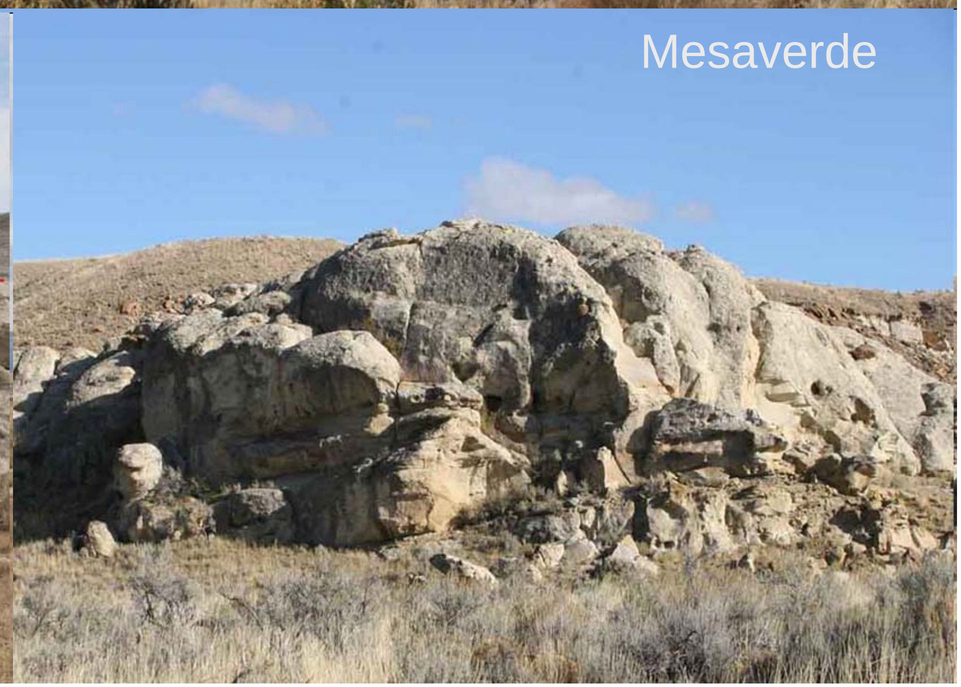
Cretaceous seas

Early– thick section of inter-bedded shale, sandstone, siltstone, and claystone (terrestrial, shallow marine and deltaic)

Late- Thick transgressive and regressive cycles of thick sandstone, shales, and siltstone







Ch 4. General Geology

Cenozoic (66- present)
Laramide Orogeny

Basement cored mountains.

The uplifts and distant volcanic activity provided the source of several thousand feet of Tertiary sediment.

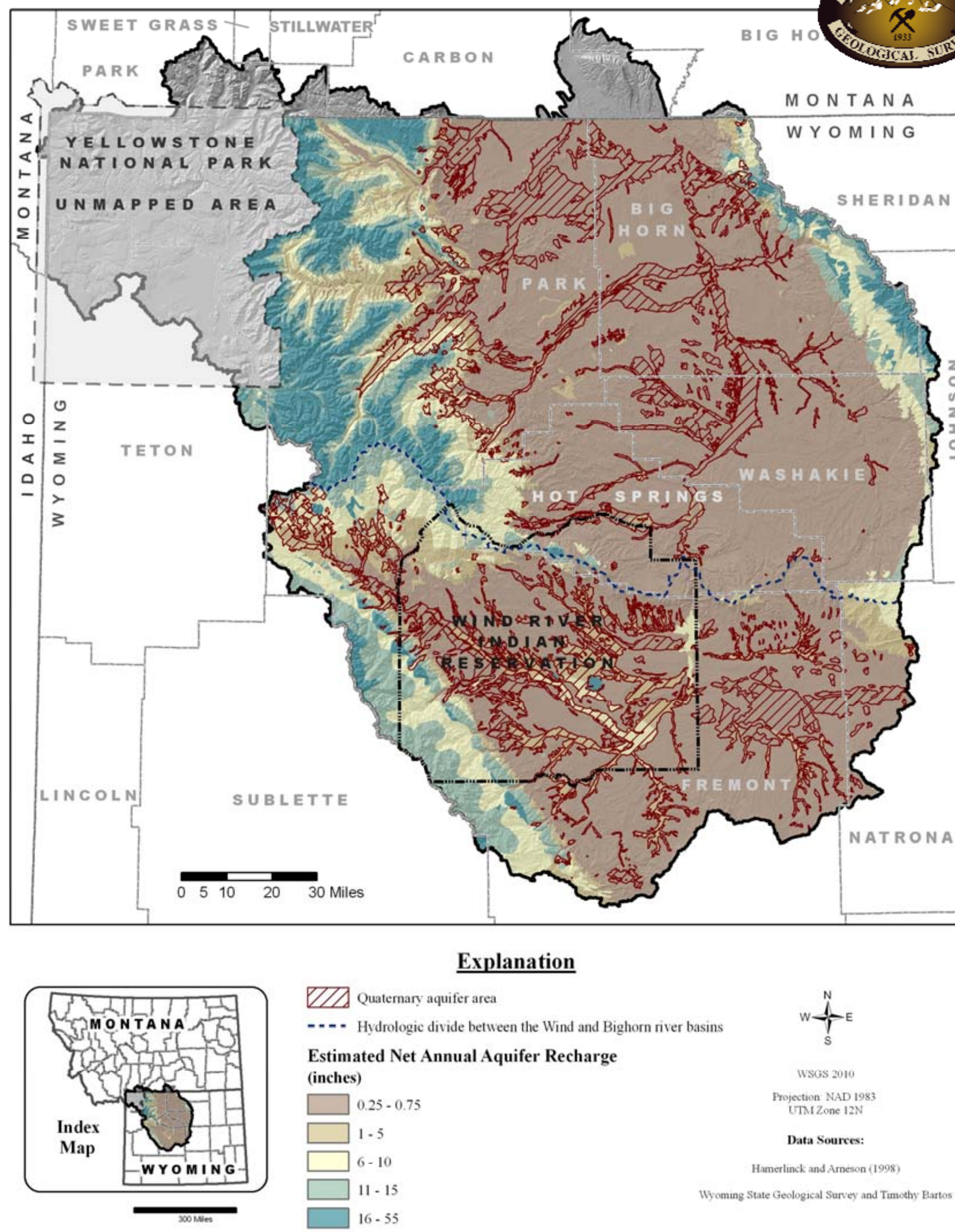
Ch 4. General Geology

Cenozoic cont.

Unconsolidated Pliocene and Quaternary terrace and alluvial deposits

Deposits are composed of conglomerate, gravel, sand and finer grained clastics.

Glacial, interglacial and fluvial deposits



Chapter 5: Hydrogeology and Groundwater Quality

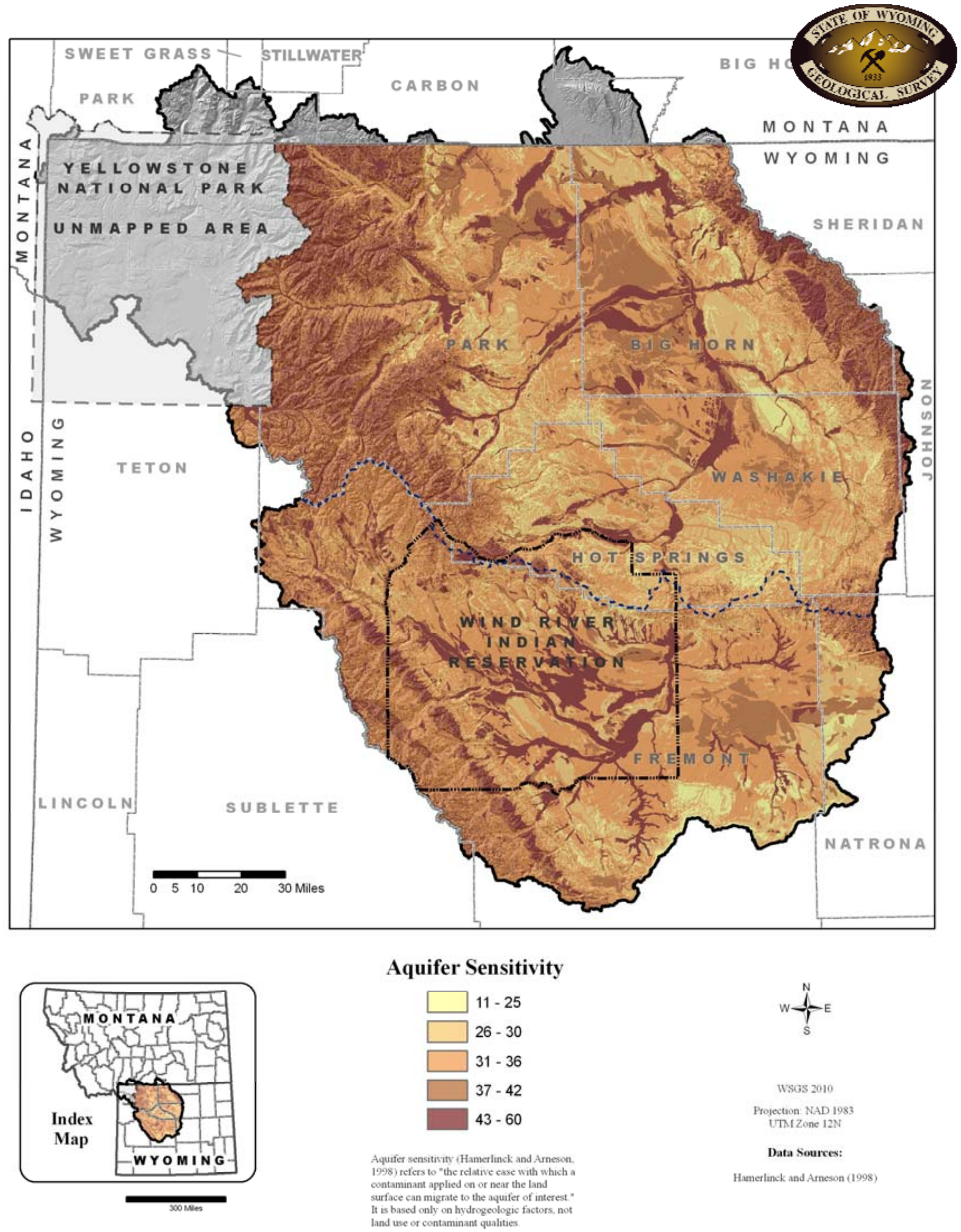
- **5.1 Definitions and Concepts**
  - **5.1.1** Definitions
  - **5.1.2** Types of Groundwater Flow
  - **5.1.3** Groundwater Recharge, Discharge, and Flow
    - **5.1.3.1** *Groundwater Recharge*
    - **5.1.3.2** *Groundwater Discharge*
    - **5.1.3.3** *Groundwater Flow*
  - **5.1.4** Groundwater Storage and Safe / Sustainable / Optimal Yield
- **5.2 Geologic Units, Hydrogeologic Units, and Nomenclature**
- **5.3 Wyoming Statewide Aquifer Classification System**
- **5.4 Influence of Structures on Groundwater Circulation**
- **5.5 Implications of Basin Centered Gas Systems Exploration Model on Deep -Basin Groundwater Resource Potential**
- **5.6 Natural Groundwater Quality and Hydrogeochemistry**
- **5.7 Aquifer Sensitivity and Potential Groundwater Contaminant Sources**
  - **5.7.1** Wyoming Groundwater Vulnerability Assessment Handbook and Aquifer Sensitivity
  - **5.7.2** Potential Sources of Groundwater Contamination

Aquifer sensitivity

Groundwater is a resource only to the extent that it's quality is as such it be exploited for beneficial use.

Thus protecting groundwater from contamination is more rational then cleaning it up.

Depth to initial groundwater
Geohydrology
Soil media
Average rainfall
Slope
Impact of vadose zone



Data from Hammerlink and Arneson 1998

- **WDEQ Water Quality Division:**
  - Known contaminated sites under the Groundwater Pollution Control Program
  - Class I, III, IV, V injection wells under the Underground Injection Control **(UIC)** Program
  - Wyoming Pollutant Discharge Elimination System **(WYPDES)** and National Pollutant Discharge Elimination System **(NPDES)** discharge points
  - Public Owned Treatment Works **(POTWs)** and septic systems (Water and Wastewater Program)
  - Concentrated Animal Feeding Operations **(CAFOs)**
  - Pesticides / herbicides **(Nonpoint Source Program)**

- **WDEQ Solid and Hazardous Waste Division:**
  - Known contaminated sites under the Voluntary Remediation Program **(VRP)**
  - Permitted disposal pits and other small Treatment Storage and Disposal **(TSD)** facilities
  - Landfills
  - Above and underground storage tanks

- **WDEQ Land Quality and Abandoned Mine Land Division:**
  - Active and inactive mines **(LQD/AML)**
  - Gravel Pits, Quarries, etc.

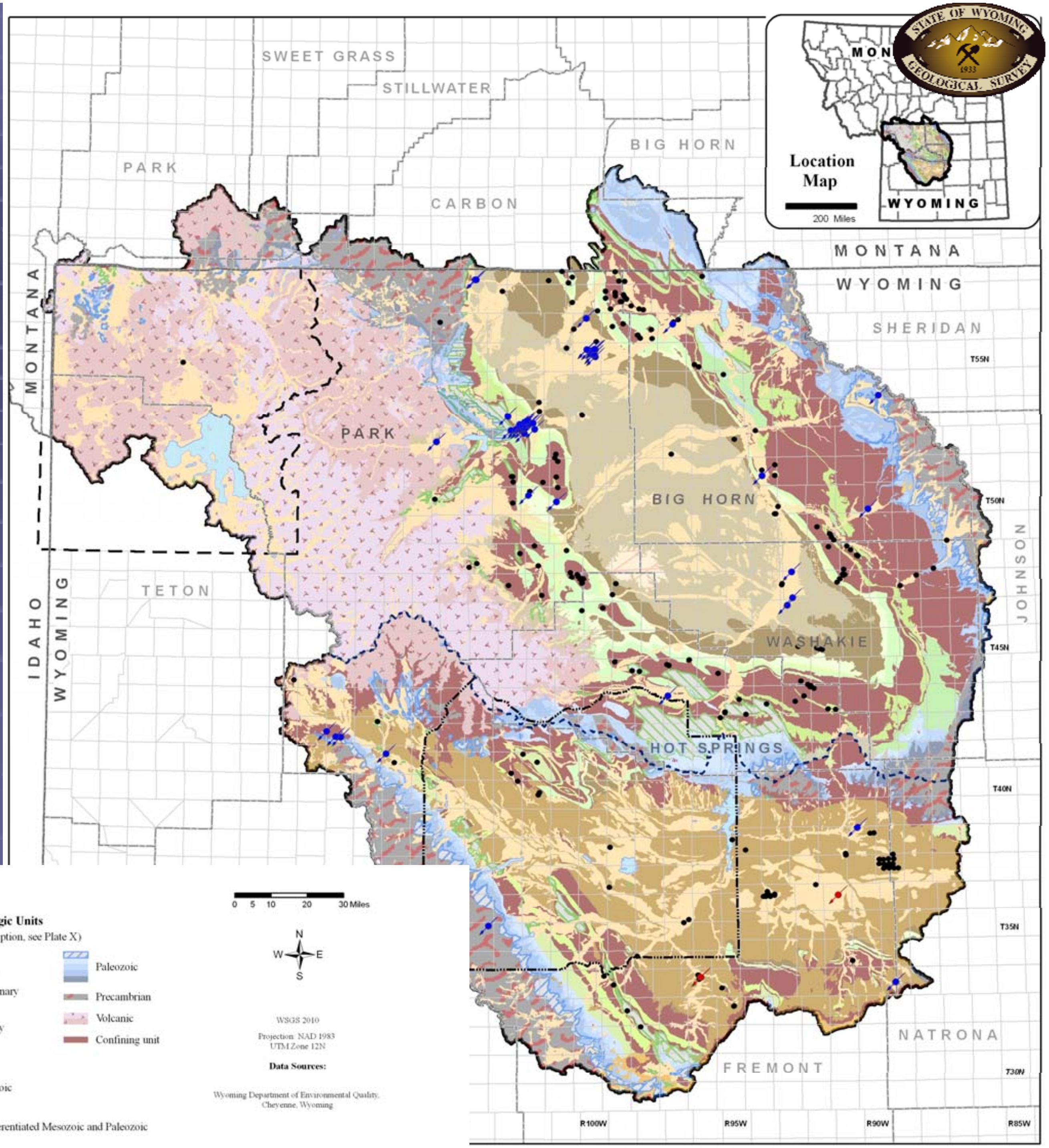
- **Wyoming Oil & Gas Conservation Commission:**
  - Class II disposal wells
  - Produced water pits

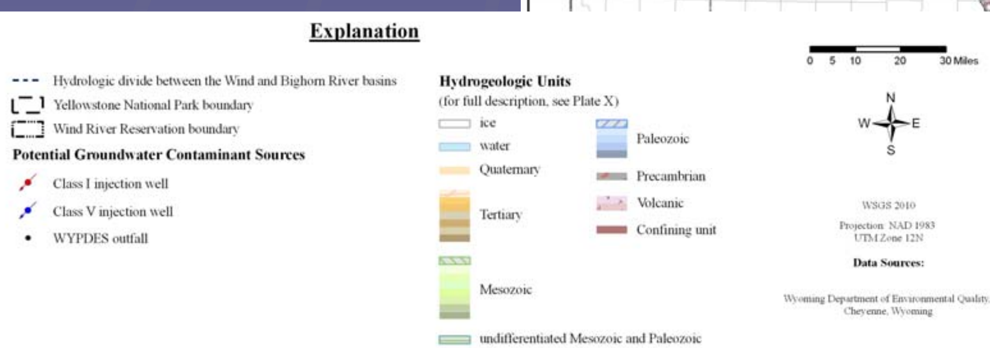
Potential Groundwater contaminant sources

Does **not** indicate contamination

Figure 5-4

WDEQ UIC Program Class I and Class V injection wells, WYPDES Program outfalls



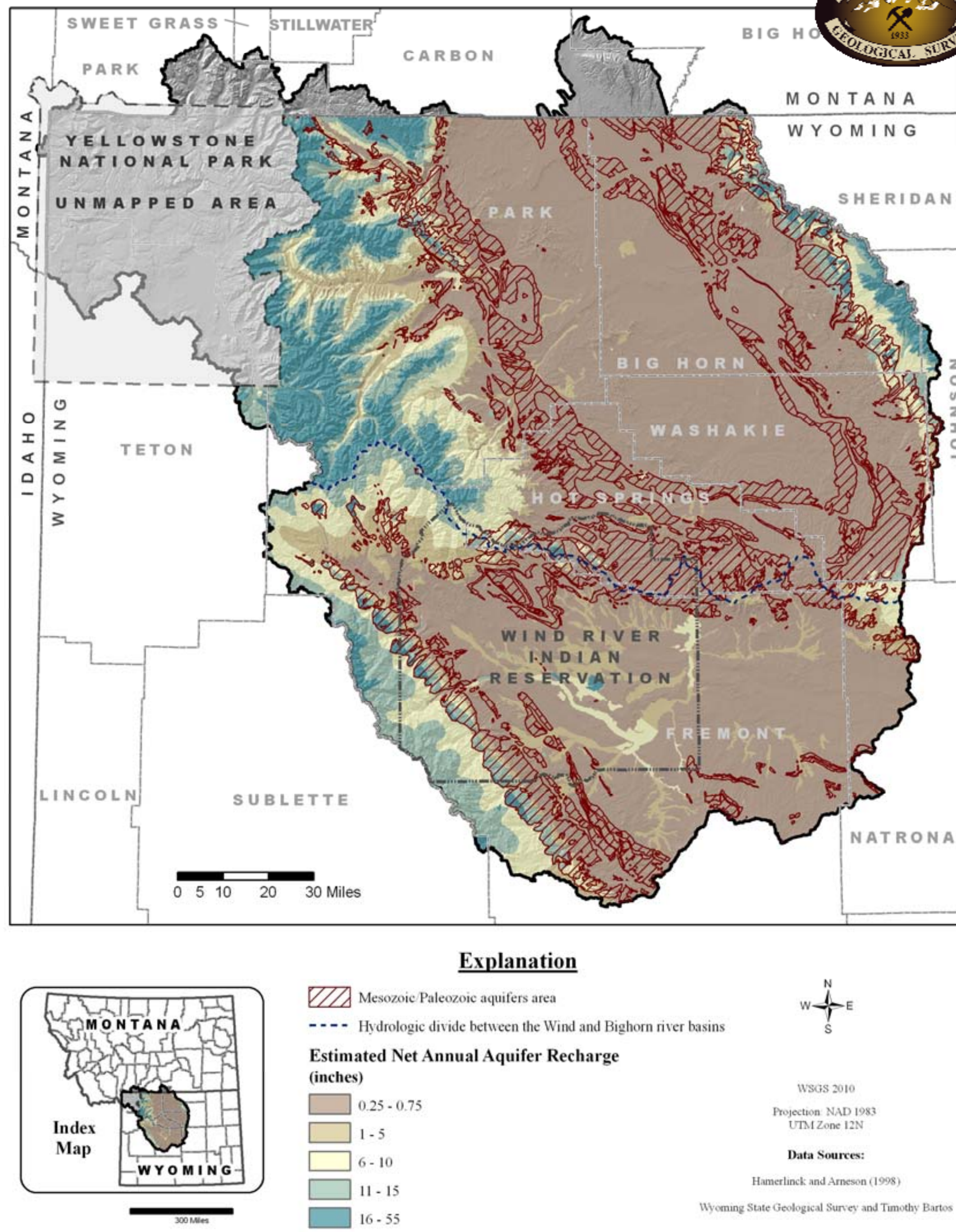


Chapter 6: WBRB Hydrogeology and Groundwater Resources

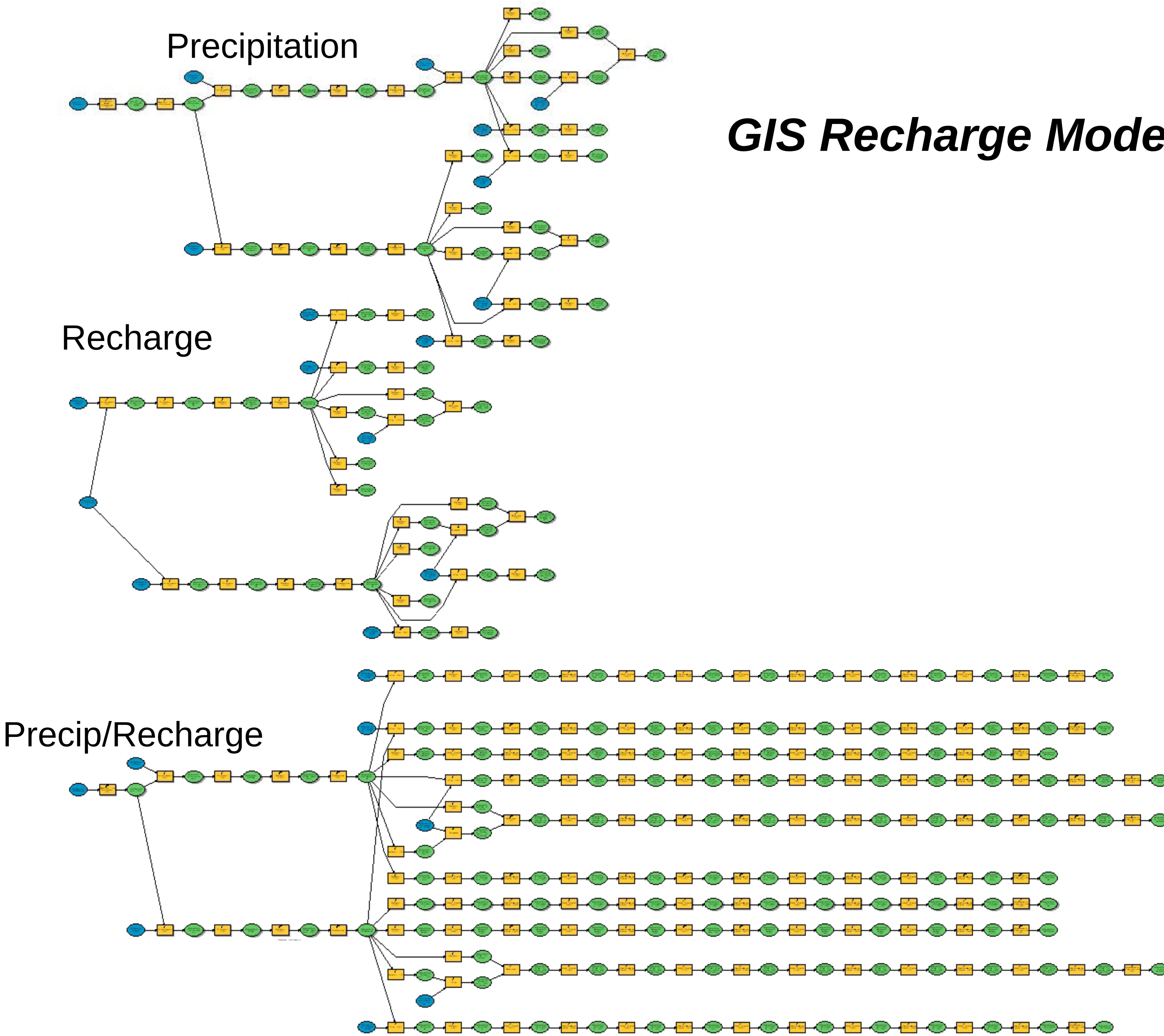
- **6.1 Hydrostratigraphy**
  - **6.1.1** Wind River Basin Hydrostratigraphy (Richter, 1981)
  - **6.1.2** Bighorn Basin Hydrostratigraphy (Libra, et.al. 1981)
- **6.2 Total Groundwater Resource in the Wind-Bighorn River Basin**
  - **6.2.1** Amount of Groundwater in Storage
    - **6.2.1.1** Total Volume of Groundwater
    - **6.2.1.2** Total Volume of Available Groundwater
  - **6.2.2** Amount of Average Annual Recharge

Estimated Recharge

- Recharge was calculated for the Qt, the combine Qt/T, Mz, Pz, and Precambrian aquifer systems.
- Recharge volume general calculation
  - **Area** of Exposed Aquifer **(ft2)** x Average annual **recharge rate (ft)** = Total average annual **recharge volume (ft3)**
  - Outcrop area calculated from Plate IV, annual recharge rate from Hammerlink and Arneson (1998)
  - Does not include recharge via irrigation or from other surface waters

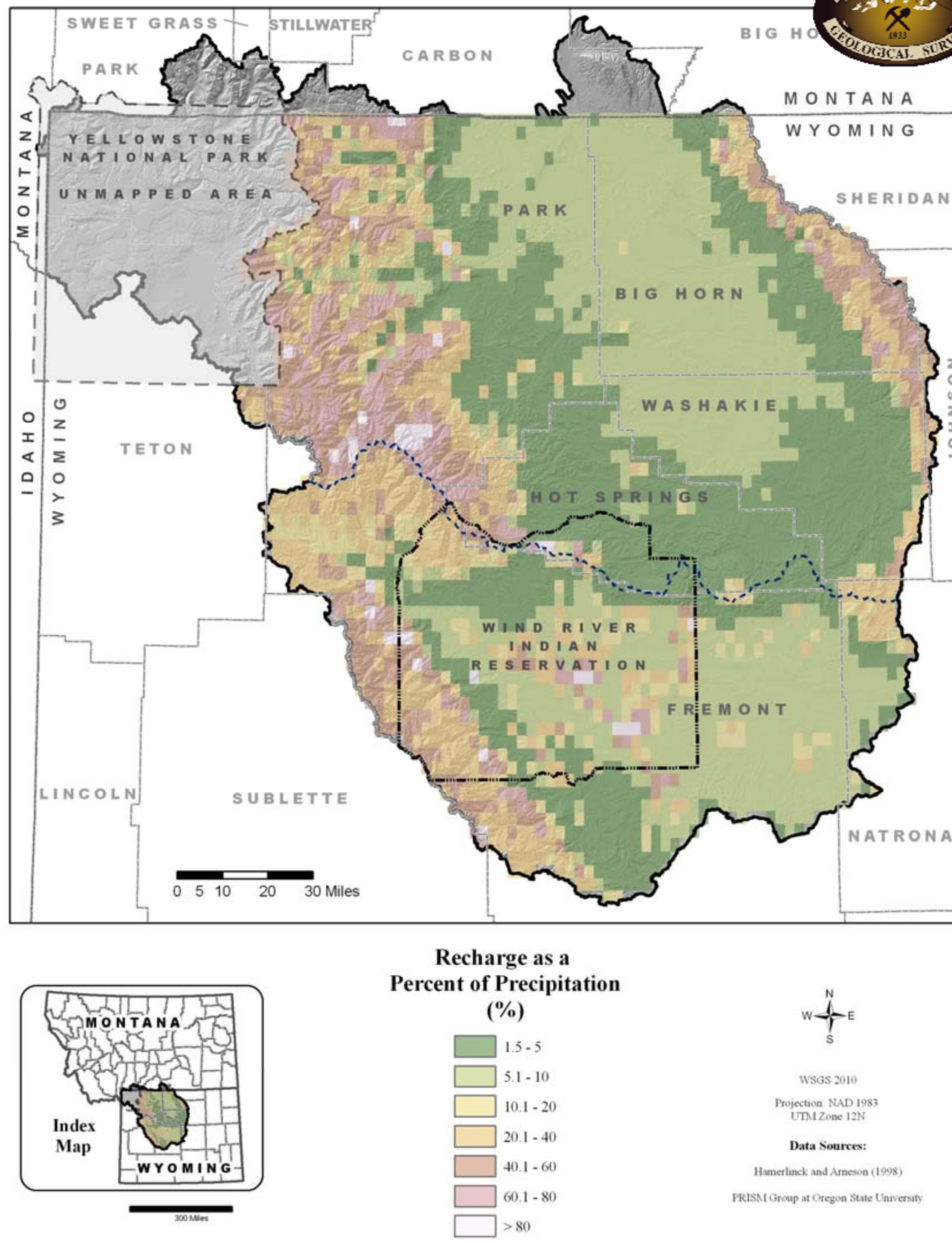


GIS Recharge Models



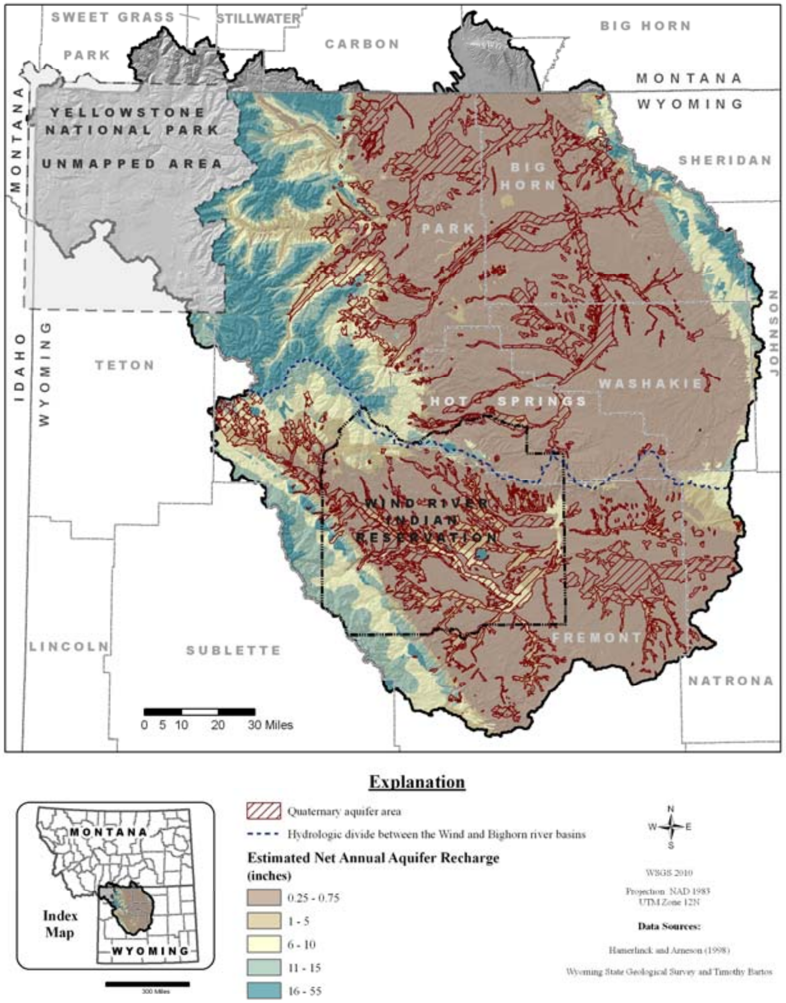
Recharge as a Percent of Precipitation

Data in the report are presented in tables and visually

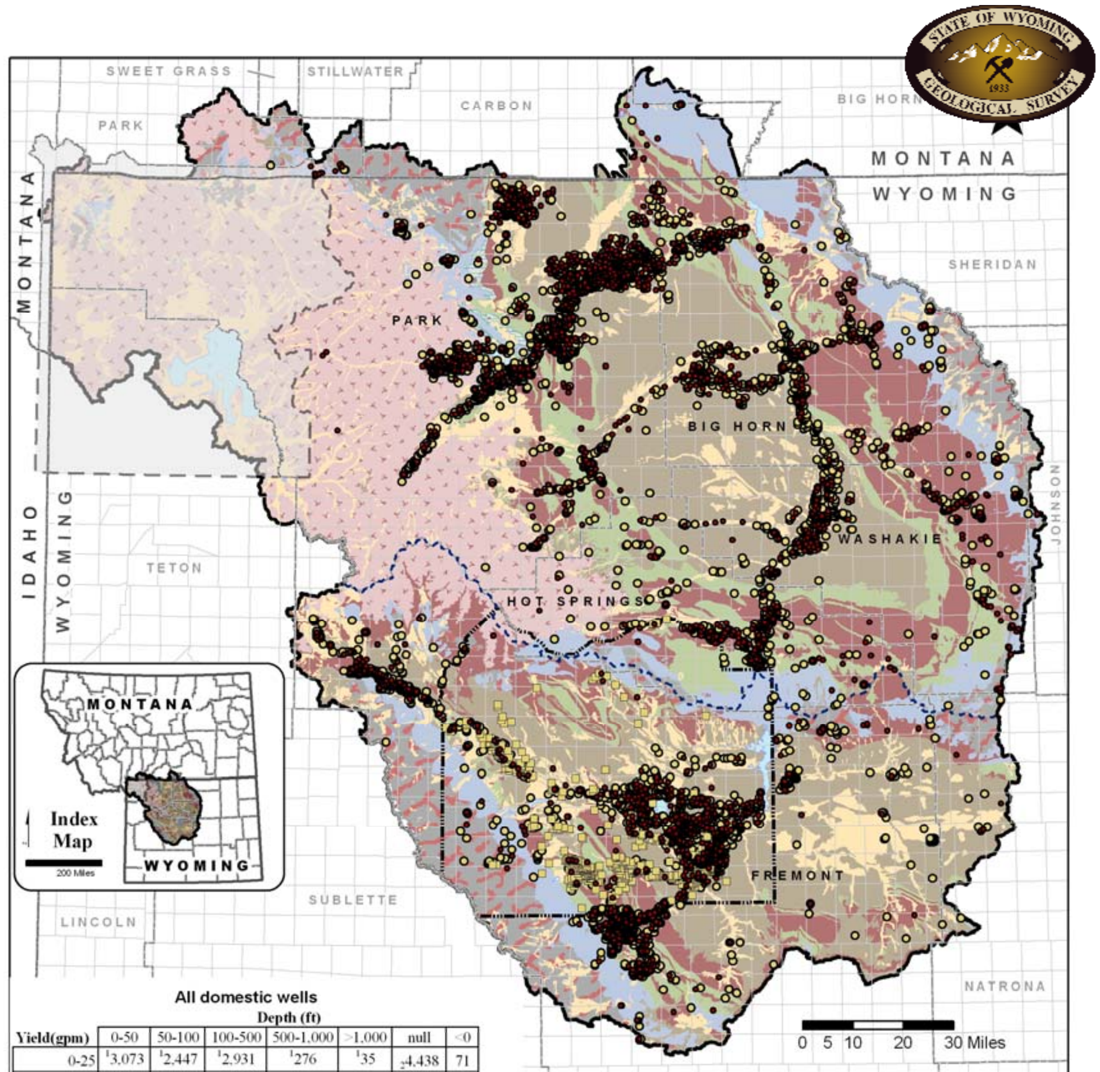


Chapter 7: Geologic and Hydrogeologic Units

- **7.2 BIGHORN BASIN**
  - **7.2.1 Quaternary unconsolidated-deposit aquifers**
    - **7.2.1.1** Physical characteristics
    - **7.2.1.2** Recharge, discharge, and groundwater movement
    - **7.2.1.3** Chemical characteristics
    - **7.2.1.4** Alluvium
    - **7.2.1.5** Terrace deposits
- **7.2.2White River and Wagon Bed aquifers**
- **7.2.3Upper Cretaceous/lower Tertiary aquifer system**
  - **7.2.3.1 Willwood and Fort Union aquifers**
    - **7.2.3.1.1** Physical characteristics
    - **7.2.3.1.2** Chemical characteristics
  - **7.2.3.2 Willwood Formation**
  - **7.2.3.3 Fort Union Formation**



▪7.2.1Quaternary unconsolidated-deposit aquifers



All domestic wells

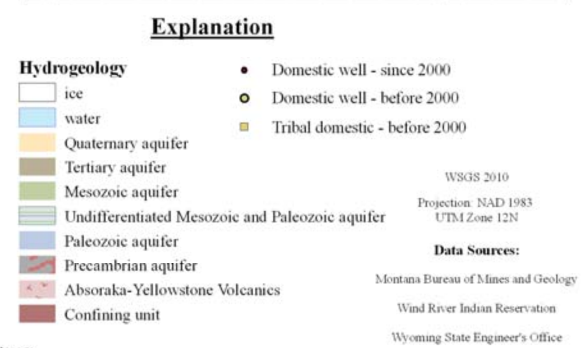
Yield(gpm)	Depth (ft) 0-50	50-100	100-500	500-1,000	>1,000	null	<0
0-25	[1]3,073	[1]2,447	[1]2,931	[1]276	[1]35	[2]4,438	71
25-100	[1]20	[1]19	[1]16	9	4	[2]77	0
100-500	2	5	5	9	6	[2]27	0
500-1,000	1	0	0	0	1	11	0
>1,000	1	0	1	0	2	11	0
<0	10	8	11	1	2	1	10

New domestic wells since 2000

Yield(gpm)	Depth (ft) 0-50	50-100	100-500	500-1,000	>1,000	null	<0
0-25	[1]512	[1]327	[1]438	[1]57	[1]9	1764	2
25-100	[1]2	[1]4	[1]2	0	0	13	0
100-500	0	1	0	3	2	7	0
500-1,000	0	0	0	0	0	3	0
>1,000	0	0	0	0	0	1	0
<0	0	0	0	0	0	0	0

[1] Data includes Montana wells

[2] Data includes Wind River Indian Reservation wells
Note: reservation wells do not have depth data. Therefore, all of these fall in the null depth category.



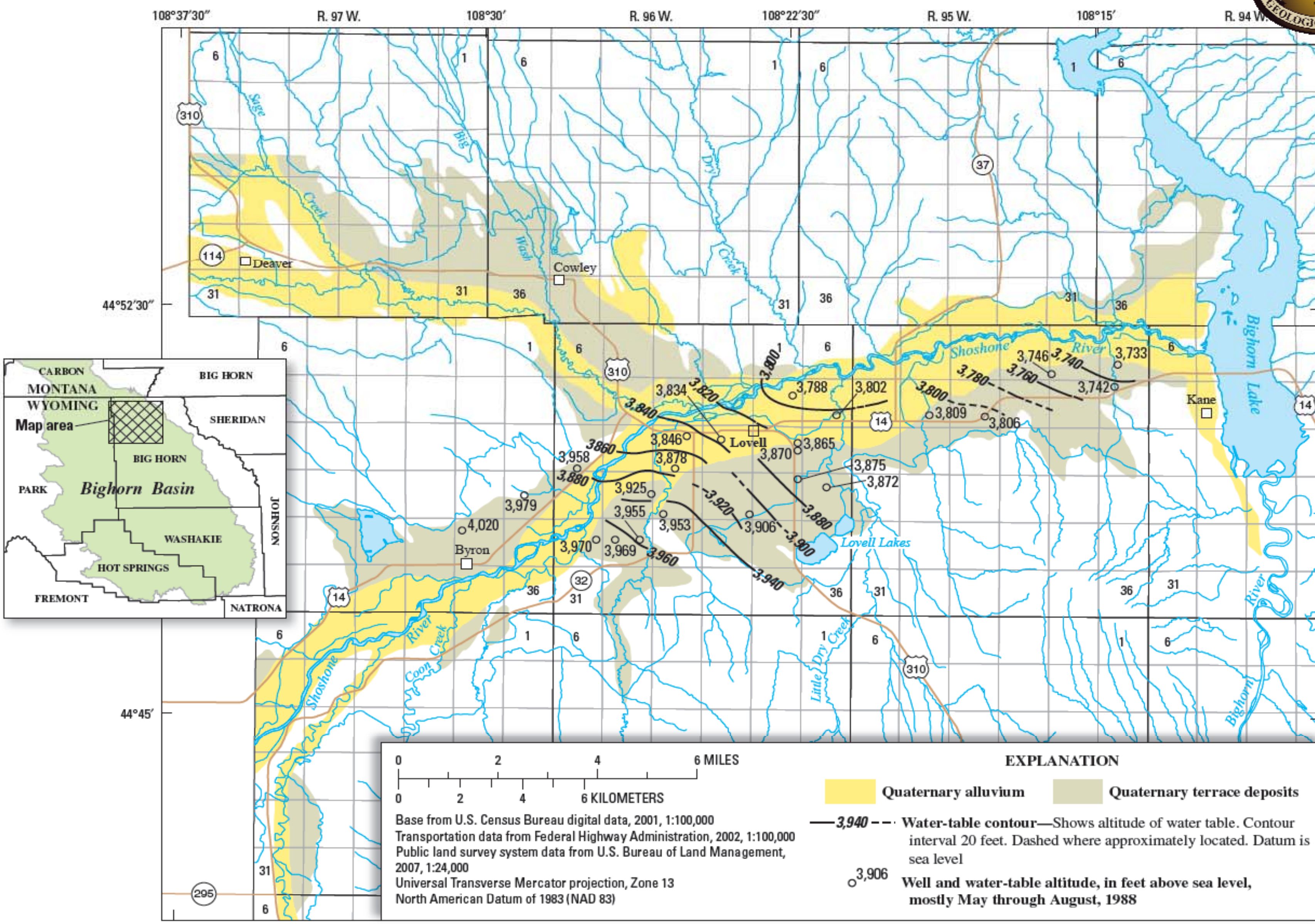
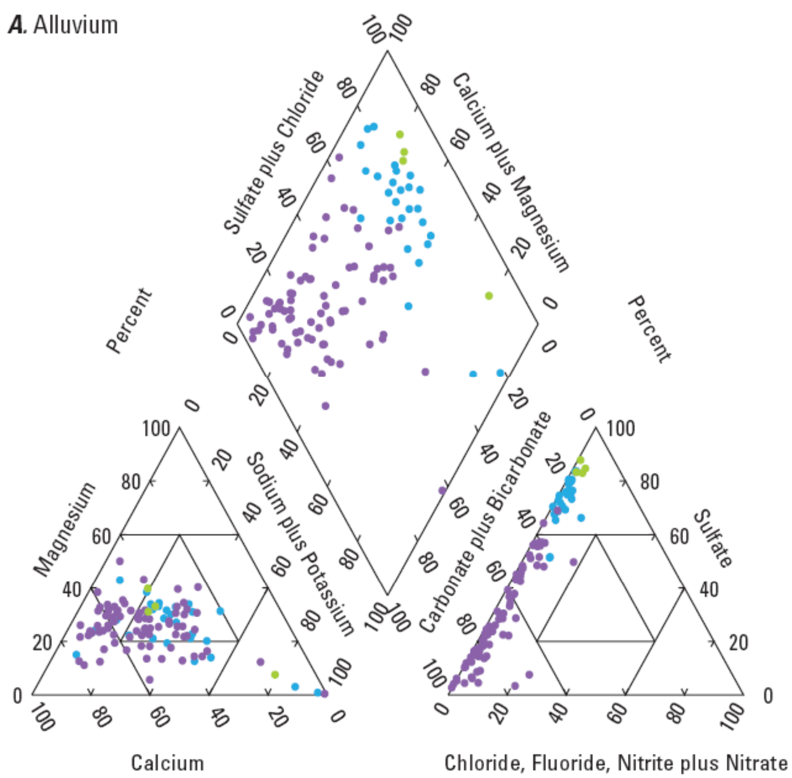


Figure 7-6. Water-table contours in Quaternary alluvium and terrace deposits along the Shoshone River, Wyoming (modified from Plafcan et al., 1993, fig. 9).

Quaternary unconsolidated-deposit aquifers

7.2.1.3 Chemical characteristics



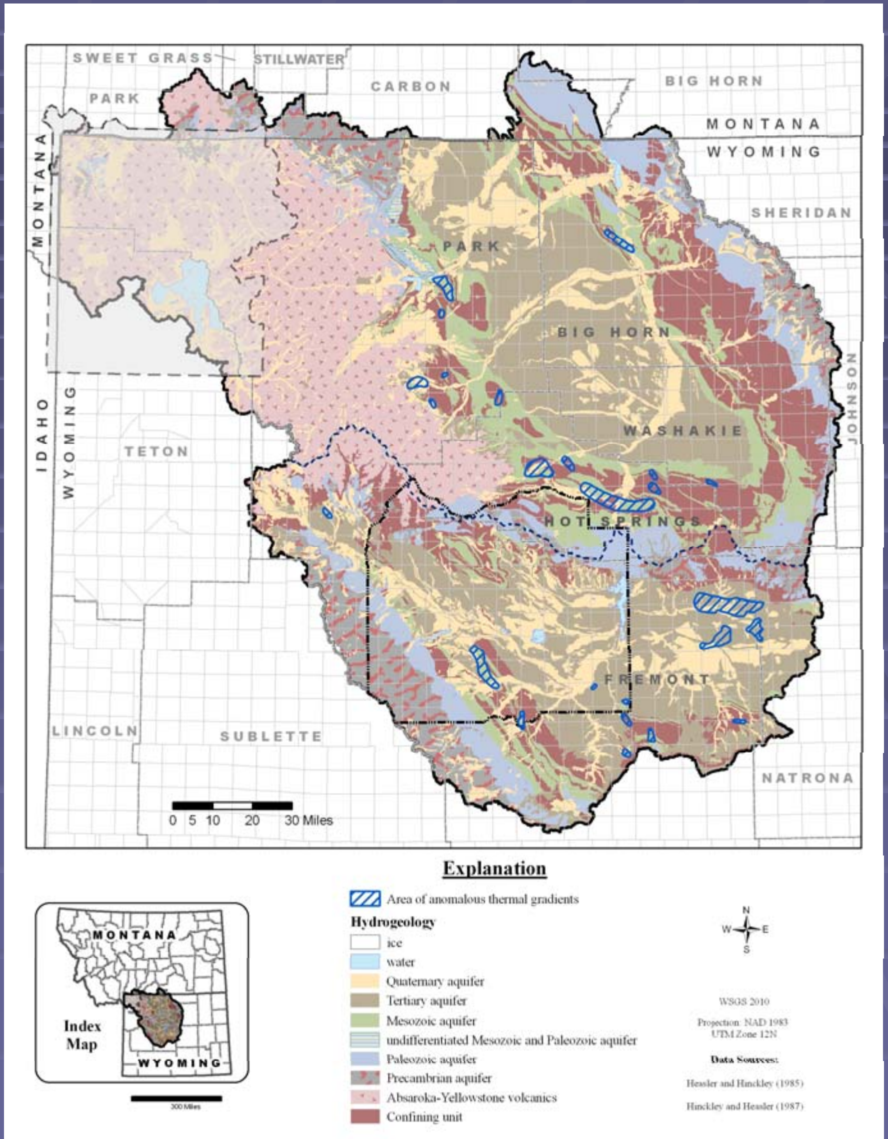
Appendix E1. Summary statistics for environmental water samples, Wind River Basin, Wyoming.

[--, not applicable; µS/cm, microsiemens per centimeter; $CaCO_3$, calcium carbonate; N, nitrogen; P, phosphorus. Values in black are in millig
unless otherwise noted; values in blue are in micrograms per liter]

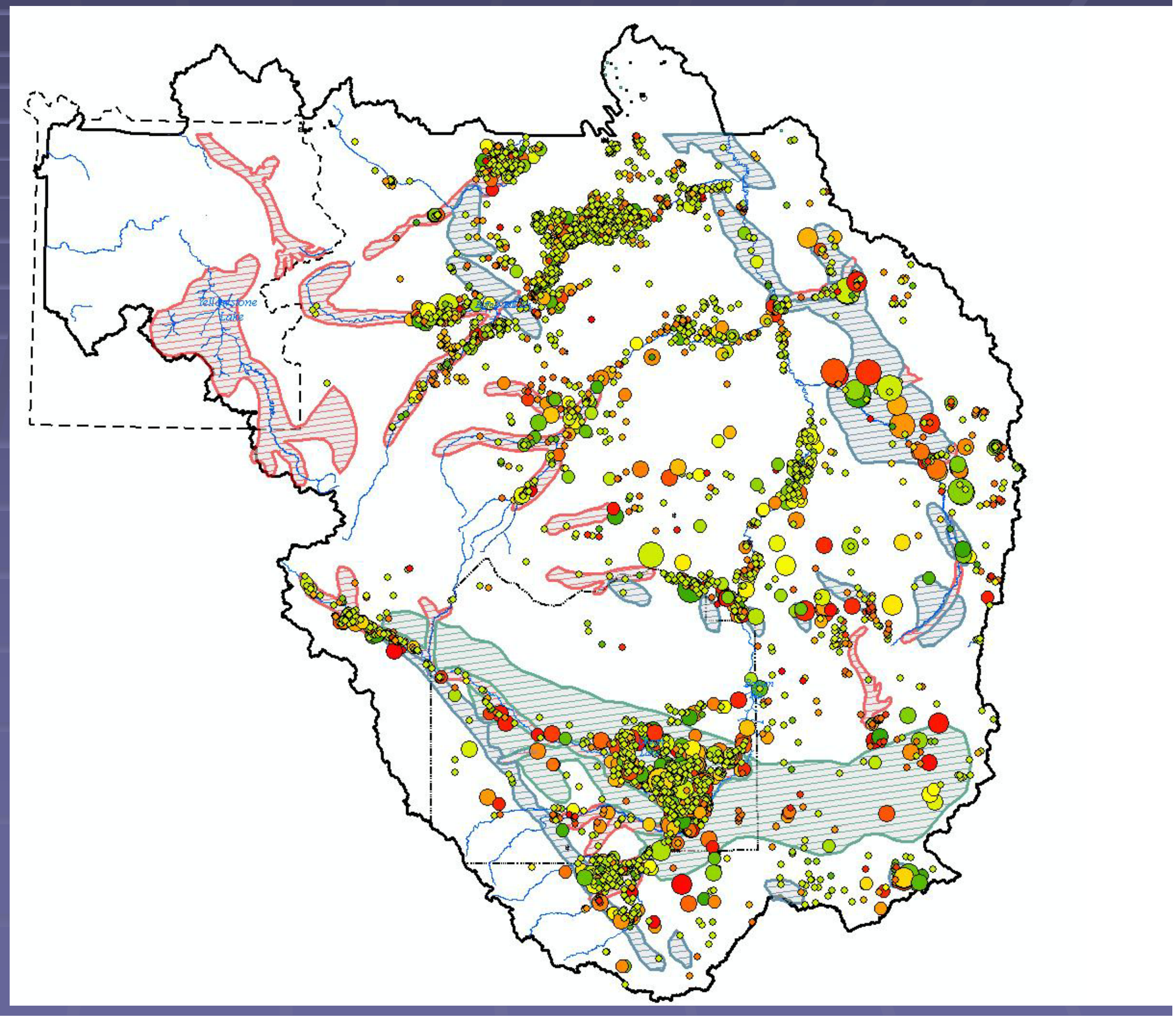
Rock-stratigraphic unit	Characteristic or constituent	Minimum	25th percentile	Median	75th percentile	Maximum	Sample size
Cenozoic rock-stratigraphic units							
Alluvium	pH (standard units)	6.8	7.4	7.6	8.0	11.4	120
	Specific conductance (µS/cm)	116	506	820	1,460	11,700	123
	Hardness (as $CaCO_3$)	3.0	189	320	570	2,500	107
	Calcium	0.88	52.0	78.0	138	600	110
	Magnesium	0.21	15.0	26.5	54.0	250	110
	Potassium	0.40	2.0	3.1	6.0	20.0	109
	Sodium-adsorption ratio (unitless)	0.10	0.60	1.4	2.5	45.0	105
	Sodium	2.0	20.0	53.0	121	1,100	110
	Alkalinity (as $CaCO_3$)	85.0	187	242	291	431	110
	Bromide	0.01	0.01	0.02	0.07	0.25	11
	Chloride	0.10	4.8	8.0	20.0	105	110
	Fluoride	0.10	0.20	0.43	0.81	1.6	108
	Silica	7.9	13.5	16.0	24.5	68.0	58
	Sulfate	2.8	45.4	151	595	2,600	110
	Total dissolved solids	102	299	539	1,170	4,630	110
	Ammonia (as N)	--	0.015	0.022	0.033	--	28
	Nitrate+nitrite (as N)	--	0.068	0.18	0.60	--	45
	Nitrate (as N)	--	0.19	0.81	1.9	--	65
	Nitrite (as N)	--	0.004	0.006	0.009	--	30
	Orthophosphate (as P)	--	0.008	0.014	0.020	--	26
	Phosphorus (as P)	--	0.004	0.008	0.016	--	11
	Phosphorus, unfiltered (as P)	--	0.010	0.020	0.030	--	11
	Aluminum	--	1.0	1.3	1.7	--	15
	Antimony	--	0.047	0.064	0.086	--	14
	Arsenic	--	0.35	0.51	0.76	--	21
	Barium	--	20.9	36.2	62.6	--	20
	Boron	--	64.3	144	295	--	44
	Cadmium	--	0.024	0.032	0.041	--	20
	Chromium	--	0.47	0.69	1.00	--	20
	Cobalt	--	0.43	1.1	1.9	--	11
	Copper	--	2.0	4.1	8.0	--	20
	Iron	--	13.0	63.3	420	--	61
	Iron, unfiltered	--	80.0	205	450	--	26
	Lead	--	<0.001	0.005	0.054	--	20
	Lithium	--	9.1	24.0	84.6	--	10
	Manganese	--	2.4	14.1	100	--	42

Chapter 8: Groundwater Use

- 8.1 Groundwater Associated with Energy Development
  - 8.1.1 Oil and Gas Use
  - 8.1.2 Geothermal Use
- 8.2 Groundwater Interference/Interconnection with Surface water
  - 8.2.1Interference Between Wells and Drawdown
  - 8.2.2 Interconnection Between Groundwater and Surface water



Chapter 9: Groundwater Development Considerations



Appendices

- A - Descriptions of the Digital GIS Geologic Units - WBRB WY/MT
- B – WWDC and Other Studies
- C - References Since 2002
- D - Academic Bibliography (Including USGS)
- E1-3, F1-3 Statistics for environmental/produced water (Wind, Bighorn, Abasaroka Range)
- G1-3, H1-3 Trilinear diagrams for environmental /produced water (Wind, Bighorn, Abasaroka Range)

Plates

- I - Geologic Map and Basement Complex Structure Map
- II , III - Relation of rock-stratigraphic units to hydrogeologic units, WBRB, Wyoming.
- IV –Hydrogeologic Map with Structures and Selected Lineaments
- V - Chart of GIS Geologic Units Assigned to Hydrogeologic Units
- VI -Geologic Cross Sections
- VII, VIII - Isopach Maps of Selected Aquifers / Aquifer Systems
- IX - Summaries of well yield, spring discharge, and hydraulic properties
- X - Wells and Springs Locations
- XI - Wells Permitted and Constructed since January 1, 2000, 2003 Potential Groundwater Development Areas
- XII, XIII, XIV, Potentiometric surface Maps of the Tensleep Sandstone and Madison-Bighorn Aquifer-Bighorn Basin

Thank you, Questions?

Scott Quillinan
(307) 766-2286, x233
scottyq@uwyo.edu