BURNS – Kenneth King climbed into his Ford pickup and slowly drove through a muddy alfalfa field as his dog Molly easily kept pace. He pointed to a spot in the field to the right and said, "What I'm hoping to do here is – see I've got this low spot here?"

Water & Power

This story is part of an occasional WyoFile series on the interrelationship of water and energy in Wyoming.

King hit the brakes and pointed in another direction. "And that's my irrigation well? And I'm hoping to just pump water that will run into the pond and let trucks come in and suck it out."

Ranching and farming in the far southeast of Wyoming is an unassuming affair, completely dependent on the sparse amount of rainfall in the region and whatever volume of water an electric pump can coax from the shallow aquifers below.

Three "Groundwater Control Areas" have been in place here for many years, established by the state due to rapidly declining groundwater levels. Irrigators reflexively object when anyone proposes drilling a new water well in the region because most everyone agrees that freshwater aquifers here are over–appropriated.

Yet instead of using the family's adjudicated water right to irrigate his fields nine miles north of Burns next year, King plans to sell a good portion of the water to oil companies.

"Last summer I didn't irrigate. So I'm willing to quit irrigating again for this next year or two and sell as much water as I can," said King.

SHIFTING RESOURCES

Electric utility rates are on the rise, narrowing the profit margin for crop irrigation. King figures he can make a heck of a lot more money by selling water for 35 cents per

barrel – at least for a few years while the oil industry drills exploratory wells into the Niobrara oil formation, which many people expect to be the source of major new oil production in Wyoming. Thirty-five cents per barrel is 10-times what King might earn off his water when he uses it for irrigation.

Burns area farmer and rancher Kenneth King hopes to divert a portion of his adjudicated water normally used for irrigation for sale to drillers in the oil industry. Photo: Dustin Bleizeffer/WyoFile (click to enlarge)

King said it would be nice to earn some extra money to pay off debt and buy a new truck. And King isn't the only one hoping to cut back on crop irrigation to make money in the oil industry.

Dozens of irrigators in southeast Wyoming are vying to sell their water to oil drillers. In recent months, the Wyoming State Engineer's Office has approved 40 "temporary water use agreements," which are required to divert irrigation water to another use. More than a dozen applications still await approval.

"I heard one guy in Goshen County is making $1,600 a week selling his water," King said.

But others in the region worry about what might happen if Niobrara oil drillers are successful. The industry and dozens of irrigators may become dependent on the business arrangement for five or 10 years of drilling, shifting a declining water resource away from agriculture to an industrial use.

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"It would help our nation if we didn't have to buy all that oil from other nations. ... But I'm very concerned about our food supply," said Laramie County commissioner Diane Humphrey.

Demands on land and water continually increase. As a landowner, Humphrey said she understands the need to earn a living off those basic resources. Even if it's unconventional.

"Farmers in this country are dedicated to producing enough food for the world. But a lot of times we find other ways to use (land and water)," Humphrey said.

EXPLORATORY OIL RUSH

Last year EOG Resources Inc. drilled a new well into the Niobrara formation using horizontal drilling and multiple–zone hydraulic fracturing techniques. That well, just across the border in Colorado was a gusher, flowing 50,000 barrels of oil during the first 90 days.

The success of the Colorado well, known as the "Jake" well, meant that the industry's highly–refined horizontal drilling and completion technologies are likely to unlock oil in other areas of the vast Niobrara formation, oil that had earlier been considered impossible to produce economically. The "chalk" formation underlies the Denver –Julesburg Basin – or DJ Basin – spanning much of southeast Wyoming and large areas of Nebraska and Colorado.

Now there's a rush on exploratory drilling from Greeley, Colo., to north of Wheatland. Drilling is most concentrated in Laramie County. Of the 223 horizontal well applications approved in southeast Wyoming in recent months, 96 are in Laramie County, according to the Wyoming Oil and Gas Conservation Commission.

The Niobrara formation is nearly two miles below the surface in southeast Wyoming. Once the vertical portion of a well reaches the formation, drillers angle the bit and drill horizontally for another 1–1.5 miles through the formation.

WATER FOR OIL

It takes a good deal of water to drill a Niobrara oil well. Water is required to make the drilling fluid, or mud, that controls downhole pressure, and it is used to flush cuttings to the surface.

But the biggest consumptive use of water in the process is hydraulic fracturing, or "fracking." In this process a mixture of water, sand and some chemicals is pumped into the wellbore under high pressure to crack open the oil–bearing shale or chalk and

stimulate the flow of hydrocarbons. Each horizontal Niobrara oil well may consist of 15–20 – possibly more – separate "frack" zones.

Much of the information about these horizontal Niobrara wells is held confidential for the first six months or so, as allowed under rules by the Wyoming Oil and Gas Conservation Commission. So nobody is sure yet just how much water it takes to drill and hydraulically fracture a Niobrara oil well. But if it compares to shale gas wells in the Marcellus play in Pennsylvania, it could take about 500,000 gallons of water to drill and 4.5 million gallons to hydraulically fracture each well, according to Chesapeake Energy, a company with large interests in both the Marcellus and Niobrara plays.

BARRELS AND DOLLARS

Five million gallons of water would fill 119,047 barrels. It equals about 11.5 acre–feet of water. If an irrigator were to sell that much water next year at 35 cents per barrel, he'd get $41,666 dollars.

John Barnes, surface water administrator for the Wyoming State Engineer, offered this back–of–the–envelope calculation. If a farmer can raise 5 tons of alfalfa per acre and get $70 per ton, then he'd gross $350 for an acre–foot of water, minus a lot of overhead costs and physical labor.

If the farmer can sell water to oil drillers at 42 cents per barrel, he can make $3,250 for that same acre-foot of water.

"These guys are astute businessmen," said Barnes. "(Agriculture) is a marginal operation. So if (farmers) can do this for a couple of years, that may allow them to pay down their debt, or this may be the money they need to retire on."

Barnes said he and his staff have heard, unofficially, that the average Niobrara oil well could require 4 million gallons of water total for drilling and fracking. But even if it is closer to the 5 million gallons required for a Marcellus well, how much water is that? Chesapeake Energy compares it to the amount of water New York City consumes in seven minutes, and how much water a 1,000 megawatt coal-fired power plant consumes in 12 hours.

Five million gallons is about half the volume of water the city of Gillette consumes on an average day.

ZERO–SUM

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A loaded water tanker exits a ranch on Campstool Road in Laramie County. Oil companies drilling exploratory wells in the Niobrara formation require millions of gallons of water to drill and complete each well. Photo: Dustin Bleizeffer/WyoFile (click to enlarge)

For decades, farmers and communities in the Great Plains region have drawn heavily from the shallow Ogallala – or High Plains – aquifer. In most areas, demand for water from the Ogallala outpaces the natural repletion rate, which means the water table drops. Some hydrologists estimate that continually increasing demand for Ogallala water could dry up the aquifer in two or three decades.

Most all irrigation operations in Laramie County that tap into groundwater tap into the Ogallala aquifer. But there are other shallow groundwater formations in greater southeast Wyoming with even more serious water depletion rates. In recent years, the Wyoming State Engineer's Office has measured alarming drops in groundwater throughout the southeast corner of the state.

One monitoring well southeast of Carpenter has recorded a 37 foot drop in the water table over the past 35 years. Another monitoring well in Laramie County has measured an annual drop of 9 inches since 1978. Some irrigators complain they can't even pump their appropriated volume of water. Their pumps are sucking air long before irrigation season is over.

The Wyoming State Engineer's Office insists that taking water normally used for irrigation and diverting it to oil drillers must be a zero-sum game. If a landowner's annual appropriation is 20 acre feet and he sells 15 acre feet to oil drillers, he only has 5 acre feet left for irrigation that year.

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Diverting irrigation water to sell to drillers requires a "temporary water use agreement" from the State Engineer' Office. Barnes said that the 40 temporary water use agreements approved in recent months total 4,600 acre feet of appropriated water.

Barnes has another back-of-envelope calculation based on early estimations of the Niobrara oil play. He said if the industry moves into full–field development of 12,000 wells, at 4 million gallons of water per well the industry would require 15,000 to 20,000 acre feet of water over the life of the drilling phase, which could last 5-10 years or more.

He said there's more than enough appropriated water in southeast Wyoming to meet that need.

Still, the use of that much water and the potential drawdown concerns irrigators – even those willing to suspend their irrigation operations for a couple of years. King and several others formally objected when another rancher in the Burns area applied for a permit to drill a new water well.

"If you have an adjudicated water right you can irrigate with it, or if you want to give up irrigation you can sell it," said King.

But a new water well? "That would be a new straw in the aquifer," said King.

Despite the state's insistence that the diversion of irrigation water for oil drilling is a zero–sum game, some ranchers and farmers worry it won't work out that way.

Laramie County rancher Trevor Witt said he believes that if the drilling industry is buying, an irrigator may actually sell more than he would have pulled from the aquifer during a normal or wet year.

It's a concern shared by Wyoming State Engineer Pat Tyrrell. In a November 1 policy memorandum to his groundwater and surface water administrators, Tyrrell said the office has received temporary water use agreement applications that "purport to make use of a water right for a well that has scant or no recent historic use under its permit."

Tyrrell notified staff that temporary water use agreements – particularly in the groundwater control areas – will only be considered for water used in irrigation activity that has been documented for the past five years. To do that, staff members ask to review utility bills and metering information.

Approval of an agreement also requires that each irrigation well be equipped with a flow meter to report water production, and equipped with back–flow prevention devices.

The diversion of water from irrigation to drilling is also a concern for ranchers like Witt who don't have adjudicated water rights. When his neighbors go from irrigation to dryland farming that means their farms will likely yield only one cutting annually compared to two or three cuttings. And that means the local supply of hay may decrease.

Witt said he usually buys supplemental hay from nearby ranches as he needs it. But if that's not available, he may have to drive to Fort Collins, Colo., to buy large loads of hay at auction.

"That hits your bottom line," said Witt.

This is the first of a two-part report examining the oil and gas industry's use of water resources in Wyoming. On December 7, WyoFile reports on emerging solutions for natural gas producers who also produce a lot water, and must either dispose of it or find beneficial uses for the resource.

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gti

Gas Shale Produced Water

Tom Hayes, GTI

Presentation to the RPSEA/GTI
Gas Shales Forum

June 4, 2009

gti

Shale Gas and Water Management

- Shale gas production represents a very large potential economic opportunity
- The use of water for hydraulic fracturing is a necessary step to complete shale gas wells and initiate gas production
- Up to 4 million gallons of water are used to "frac" a horizontal well
- Sand and chemicals are added to the water that is pumped downhole for the frac job
- Emerging from the completed well is a flowback water stream millions of gallons of water containing salts and constituents that must be managed in an environmentally responsible manner

gti

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ATTACHMENT C

SMITH RANCH-HUP/REYNOLDS RANCH

PRODUCTION, RESTORATION, AND GROUNDWATER WITHDRAWAL RATE SCHEDULE

PRODUCTION - SMITH RANCH

Development Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
MU1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU3	15	15	15	15	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU4/4A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU15	12	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU15A	12	9	9	9	11	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU7	0	7	7	7	11	11	11	21	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU9	24	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU10	0	12	12	12	12	12	12	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU11	0	0	0	12	12	12	12	12	24	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUK	15	15	15	15	15	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUE	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUH	8	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUF	2	12	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUI	8	2	2	3	3	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUJ	8	2	2	3	3	5	5	5	5	5	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0
Total Production Bleed (gpm)	109	99	95	94	79	67	62	54	54	33	9	9	9	0	0	0	0	0	0	0	0	0	0	0	0

PRODUCTION - REYNOLDS RANCH

Development Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
MU27	0	0	45	45	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU21	0	0	0	0	0.0	45	45	0.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU22	0	0	0	0	0	0	0	45	45	45	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU23	0	0	0	0	0	0	0	0	0	0	0	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60	60	0	0	0	0	0	0	0	0	0	0	0
MU26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60	60	0	0	0	0	0	0	0
MU28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	60	60	60	60	0	0
Total Production Bleed (gpm)	0	0	45	45	45	45	45	45	45	45	45	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0	0

TOTAL PRODUCTION

Total Production Bleed, ALL	109	99	140	139	124	112	107	99	99	78	54	69	69	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	0	0

RESTORATION - SMITH RANCH

Development Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
MU1	83	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU2	0	0	119	119	113	113	113	79	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU3	0	0	0	0	0	83	125	162	152	102	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU4_4A	50	112	112	112	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU15	0	0	0	27	152	152	152	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU15A	0	0	0	0	0	0	0	103	88	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU7	0	0	0	0	0	0	0	0	0	114	75	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU9	0	0	169	151	101	102	101	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU10	0	0	0	0	0	0	0	0	147	89	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU11	0	0	0	0	0	0	0	0	0	83	213	152	152	152	63	0	0	0	0	0	0	0	0	0	0
MUC	7	175	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUD	0	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUD_Ext	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUE	1	15	127	152	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUH	0	0	0	0	0	53	203	203	203	118	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUF	0	0	0	137	203	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MUI	0	0	0	0	0	0	0	0	0	0	52	203	169	0	0	0	0	0	0	0	0	0	0	0	0
MUK	0	0	0	0	0	0	0	0	0	83	190	152	25	0	0	0	0	0	0	0	0	0	0	0	0
MUJ	0	0	0	0	0	0	0	0	0	0	0	0	0	153	169	0	0	0	0	0	0	0	0	0	0
Total Restoration Bleed (gpm)	212	489	527	698	581	520	693	647	590	590	530	506	345	305	231	0	0	0	0	0	0	0	0	0	0

RESTORATION - REYNOLDS RANCH

Development Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
MU27	0	0	0	0	0	163	163	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU21	0	0	0	0	0	0	0	0	163	163	163	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU22	0	0	0	0	0	0	0	0	0	0	0	0	163	163	163	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	163	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MU24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	163	163	0	0	0	0	0	0	0	0	0	0	0
MU25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	163	163	163	163	0	0	0	0	0	0
MU26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	163	163	163	0	0
MU28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	163	163
Total Restoration Bleed (gpm)	0	0	0	0	0	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163

TOTAL RESTORATION

	212	489	527	698	581	683	856	810	752	752	692	669	508	468	394	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163

TOTAL RESTORATION + PRODUCTION

	320	587	667	837	705	794	963	909	851	830	746	738	577	528	454	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	163	163

Notes:
1) Units in gpm
2) RO Reject (Bleed) = 25% of RO Feed
3) All rates rounded to nearest gpm

AQUI-VER, INC.

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ATTACHMENT D

LUDEMAN PROJECT AND DEEP DISPOSAL WELL IMPACT ASSESSMENT

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ATTACHMENTS

1. INTRODUCTION

Power Resources, Inc. d/b/a, Cameco Resources (Cameco), has conducted an assessment to evaluate the hydrologic impacts of the Uranium One Ludeman ISR Project (Ludeman Project) as part of the Cumulative Hydrologic Impact Assessment for the Smith Ranch Highland-Reynolds Ranch Facility (SRH-RR). The Ludeman Project is located approximately four miles south of the SRH-RR southern permit boundary (**Figure 1**). This assessment was requested by the United States Nuclear Regulatory Agency (NRC) in their review of the SRH-RR license renewal application, Environmental Report (ER), Request for Additional Information (RAI) CI-2. Specifically, RAI CI-2 states:

> ***"Please provide an assessment of the impacts of the proposed Ludeman Project by Uranium One in the cumulative impacts analysis for the Smith Ranch site.***
>
> *In Table 2-1 of the ER, the Ludeman Project, an RFFA, is proposed to be developed within the same geographic area modeled for Smith Ranch site cumulative impacts; however, it is not clear how or if the Ludeman Project was addressed in Cameco's cumulative impact analysis. For example, the model of cumulative hydrologic impacts for the Smith Ranch site is presented in Appendix E of the ER, but the impacts of the Ludeman Project's operations are not evaluated in the ER's Appendix E's model. Additionally, the anticipated volumes of liquid process wastes at the Ludeman Project to be disposed via deep well injection should be included in Cameco's assessment of cumulative impacts to deep aquifers from deep well injection.*
>
> *Cameco's cumulative impact assessment should include impacts from the proposed Ludeman Project."*

The Ludeman Project is located approximately four miles south of the SRH-RR southern permit boundary, as shown in **Figure 1**.

2. ISR WELLFIELD IMPACT ASSESSMENT

Uranium One conducted an analysis of the hydrologic impacts of their ISR wellfields in their response to ER RAI 56 for the Ludeman Project (**Attachment D1**). Their analysis included calculation of the Radius of Influence (ROI) of ISR wellfields within 2 kilometers of each of phase of their operation. Cameco's evaluation of the hydrologic impacts of the Ludeman ISR wellfields is an extension of Uranium One's impact assessment to include the evaluation of drawdown impacts beyond 2 kilometers (km) of the Ludeman Project boundary and including the SRH-RR license area.

The hydrologic impacts of the Ludeman ISR wellfields were evaluated using the identical methodology, aquifer parameters, and operating assumptions utilized by Uranium One in their response to RAI 56 (**Attachment D1**). Drawdown calculations were conducted using WinFlow® analytical flow modeling software developed by Environmental Simulations, Inc. Results of drawdown calculations presented by Uranium One in **Attachment D1** were compared to results of Cameco's drawdown calculations to ensure consistency of results. Drawdown calculations were then extended to the SRH-RR license area for purposes of estimated cumulative hydrologic impacts of the Ludeman Project and the SRH-RR ISR facility.

2.1 Ludeman ISR Wellfield Impacts

Results of the Ludeman Project hydrologic impact assessment are illustrated on the drawdown contour maps in **Figures 2 through 6**. Drawdown in excess of 15 meters (50 feet) is predicted within Ludeman ISR wellfields and at Project boundaries, with drawdown decreasing with distance to slightly less than 0.3 meter (1-foot) at the nearest SRH-RR wellfield locations. The maximum drawdown at SRH-RR caused by Ludeman ISR development is predicted to occur in the 80-Sand (equivalent to the O4-Sand at SRH-RR) near MU-10 in development year 11.

2.2 SRH-RR ISR Wellfield Impacts

Results of the SRH-RR hydrologic impact assessment are presented in **Figures 4-4 through 4-15** of the SRH-RR Cumulative Hydrologic Impact Assessment Report. Drawdown in excess of 6 meters (20 feet) is predicted within SRH-RR ISR wellfields and at the permit boundary, with drawdown decreasing with distance to less than 0.15 meters (0.5 feet) at the nearest Ludeman Project wellfield locations. The maximum drawdown impact at the Ludeman Project caused by SRH-RR development is predicted to occur in the O4-Sand (equivalent to the 80-Sand at the Ludeman Project) near proposed Wellfield 1 in development year 11.

2.3 Cumulative Hydrologic Impacts

As previously described, drawdown in excess of 15 meters (50 feet) is predicted within Ludeman Project wellfields and at Project boundaries as a result of Ludeman ISR operations. Likewise, drawdowns in excess of 20 feet (6 meters) are predicted at SRH-RR wellfields and at the permit boundary as a result of SRH-RR operations. In contrast, results of this analysis indicate a small incremental increase in drawdown of less than 0.3 meters (1-foot) is predicted as a result of Ludeman and SRH-RR impacts on one another. Given these results, cumulative hydrologic impacts resulting from the combined Ludeman Project and SRH-RR operations are very similar to individual facility impacts, and should not adversely impact ISR operations or water resources at either facility.

3. DEEP DISPOSAL WELL IMPACT ASSESSMENT

3.1 SRH-RR Deep Disposal Well Impacts

Cameco is in the process of evaluating the hydrologic impact of Deep Disposal Wells (DDW's) as part of a combined Aquifer Exemption Boundary revision process. As part of this evaluation, the 10- and 20-year Cone of Influence (COI) radius and Emplaced Fluid (EF) radius were calculated. The COI radius represents the maximum radial distance that hydraulic influence (drawdown) could be observed in the target formation due to waste injection. The EF radius represents the maximum radial distance that injected waste could be expected to travel in the target formation. The greater of the COI radius or the EF radius is considered to be the Final Radius of Review (FROR) for the DDW.

The calculated FROR, COI radius, and EF radius of DDW's at SRH-RR are provided in **Attachment D2** along with relevant calculation input parameters. The 20-year FROR for SRH-RR DDW's ranges from approximately 0.5 to 2.86 miles. The FROR associated with SRH-RR DDW's is illustrated in **Figure 7**.

3.2 Ludeman Deep Disposal Well Impacts

Information presented in Section 4.1 of the Ludeman Project EA Report indicates Uranium One plans to install up to six DDW's to support ISR operations. Estimated hydrologic impacts of these wells, including FROR, COI radius, and EF radius have not been published by Uranium One, and there is insufficient information concerning proposed injected waste volumes, rates, duration and site-specific aquifer characteristics to justify precise impact calculations at this time. However, because the target injection interval for the Ludeman Project and SRH-RR DDW's is the same (e.g. Parkman, Teapot, and/or Tekla Formations), DDW's should possess similar injection characteristics and we can infer that the hydraulic impacts from Ludeman Project DDW's should be reasonably similar to SRH-RR DDW impacts. Given an estimated maximum 11-year lifespan of DDW's for the Ludeman Project, an FROR of 3.2 kilometers (2.0 miles) for Ludeman Project DDW's is considered reasonable and conservative for purposes of this assessment.

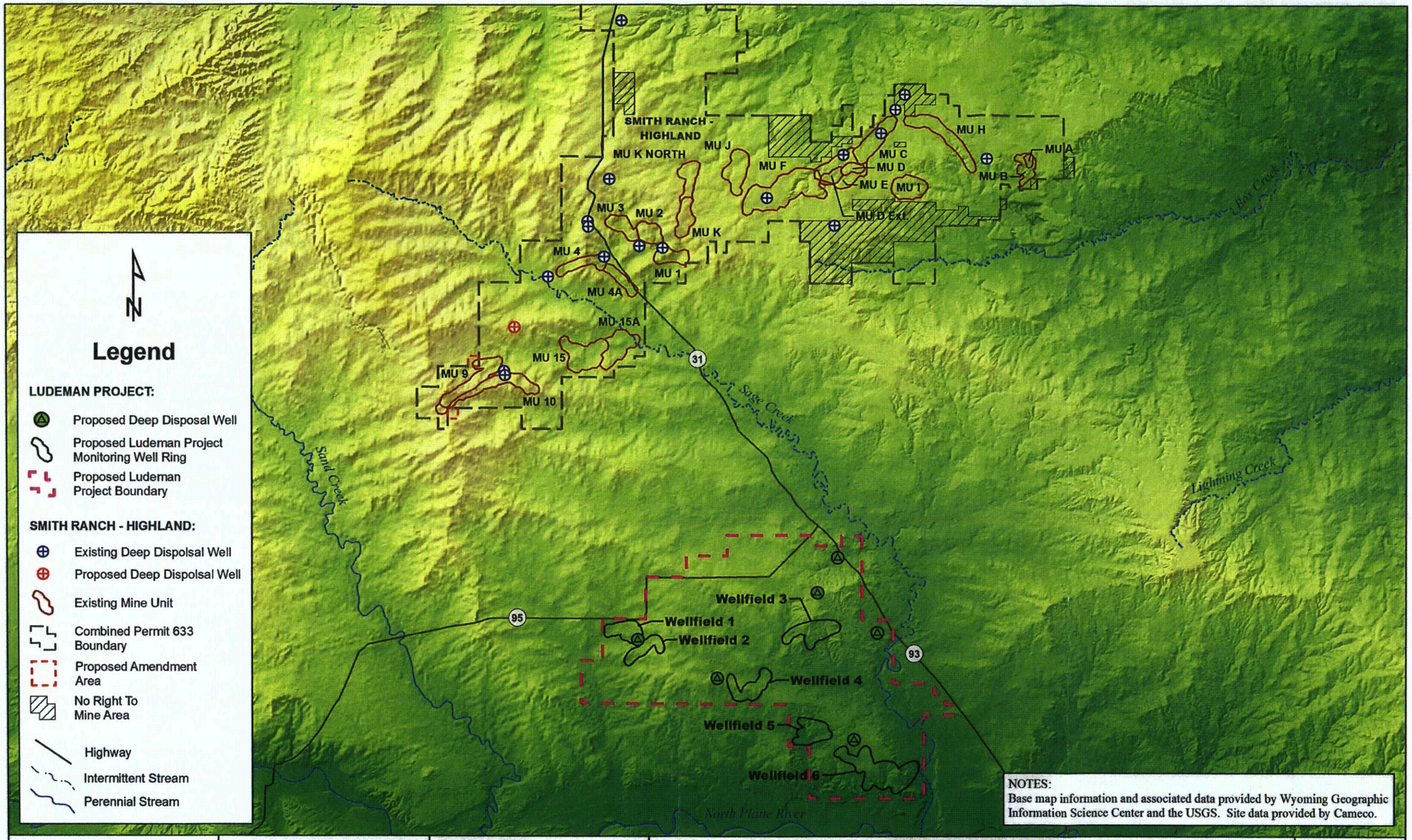
The estimated FROR for the Ludeman Project and SRH-RR DDW's are shown in **Figure 7**. Results of this analysis indicate the combined operation of DDW's at the Ludeman Project and SRH-RR should not hydraulically influence or otherwise adversely impact one another.

4. SUMMARY AND CONCLUSIONS

Cameco has conducted an assessment to evaluate the hydrologic impacts of the Uranium One Ludeman ISR Project (Ludeman Project) as part of the Cumulative Hydrologic Impact Assessment for the Smith Ranch Highland-Reynolds Ranch Facility (SRH-RR). This assessment included an evaluation of the cumulative hydraulic impacts resulting from ISR wellfields and Deep Disposal Wells (DDW's) at the Ludeman Project and SRH-RR.

Results of the ISR wellfield impact assessment indicates the cumulative hydrologic impacts resulting from the combined Ludeman Project and SRH-RR operations are similar to individual facility impacts, and should not adversely impact ISR operations or water resources at either facility. Likewise, results of the DDW impact assessment indicates the operation of DDW's at the Ludeman Project and SRH-RR should not hydraulically influence or otherwise adversely impact one another.

FIGURES



NOTES:
Base map information and associated data provided by Wyoming Geographic Information Science Center and the USGS. Site data provided by Cameco.

AquiferTek

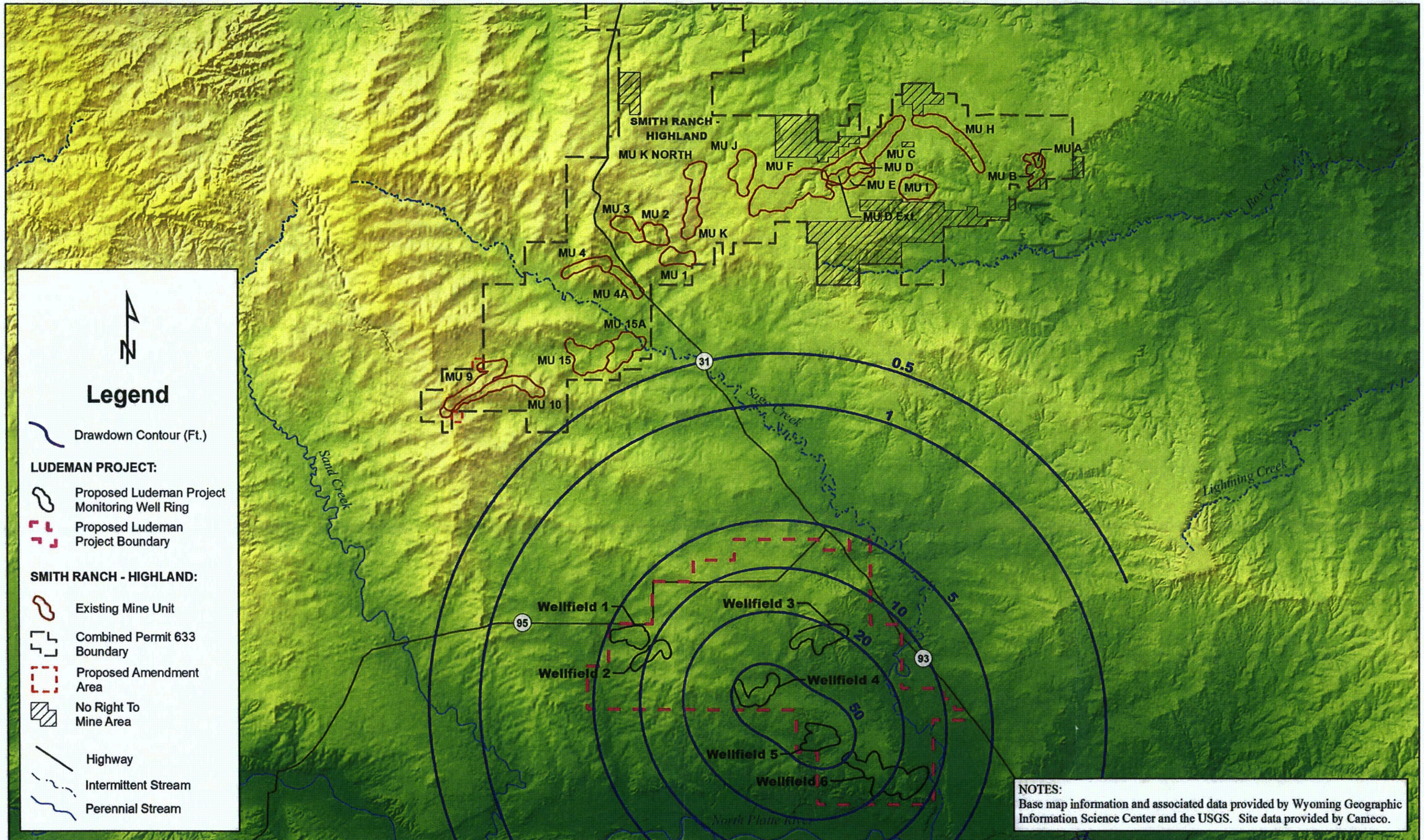
0 5,625 11,250 22,500
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

SITE OVERVIEW
LUDEMAN AND SRH-RR ISR FACILITIES

CONVERSE COUNTY - WYOMING

FIGURE:
1



AquiferTek

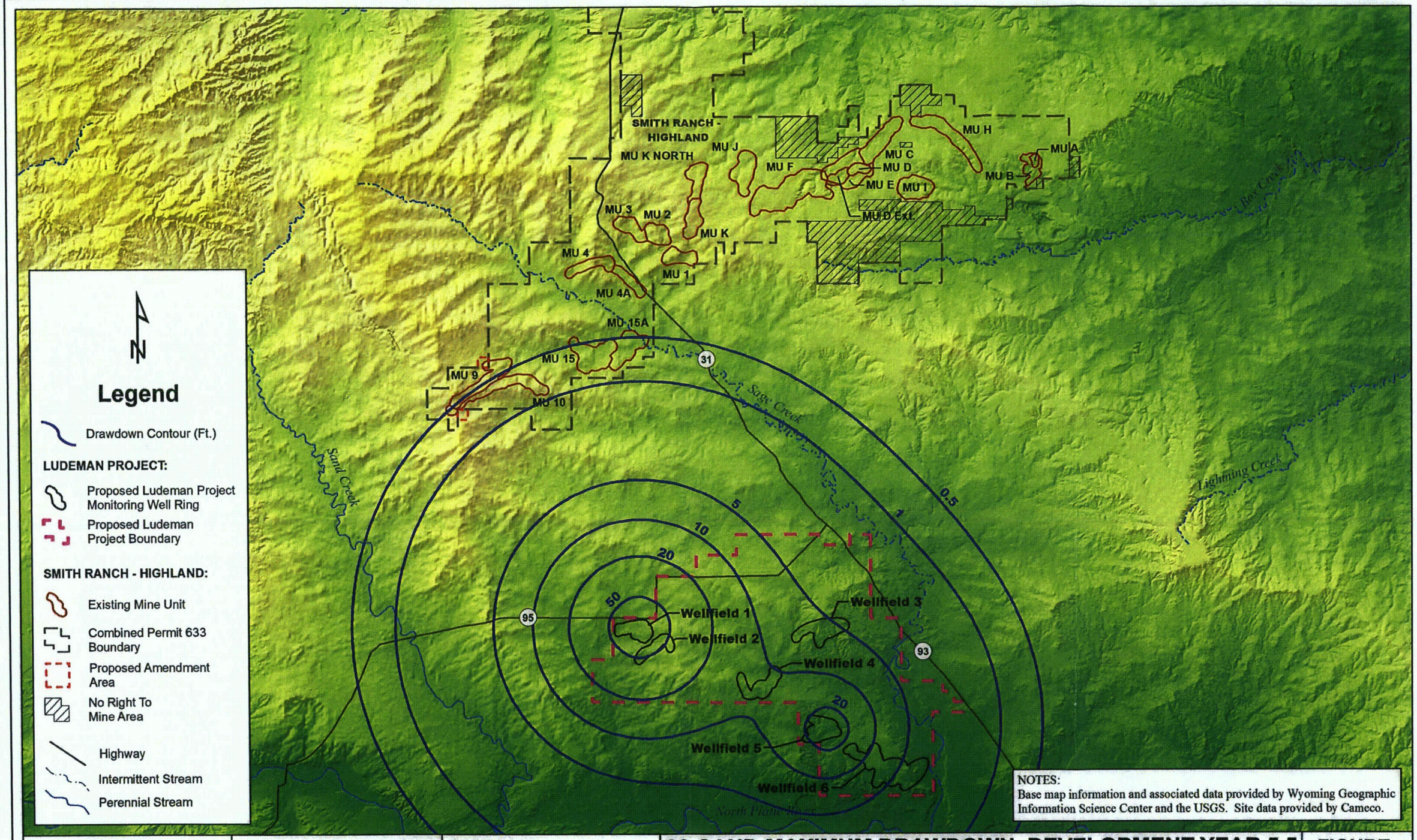
0 5,625 11,250 22,500
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

70-SAND MAXIMUM DRAWDOWN, DEVELOPMENT YEAR 9
LUDEMAN ISR FACILITY

CONVERSE COUNTY - WYOMING

FIGURE: 2



AquiferTek

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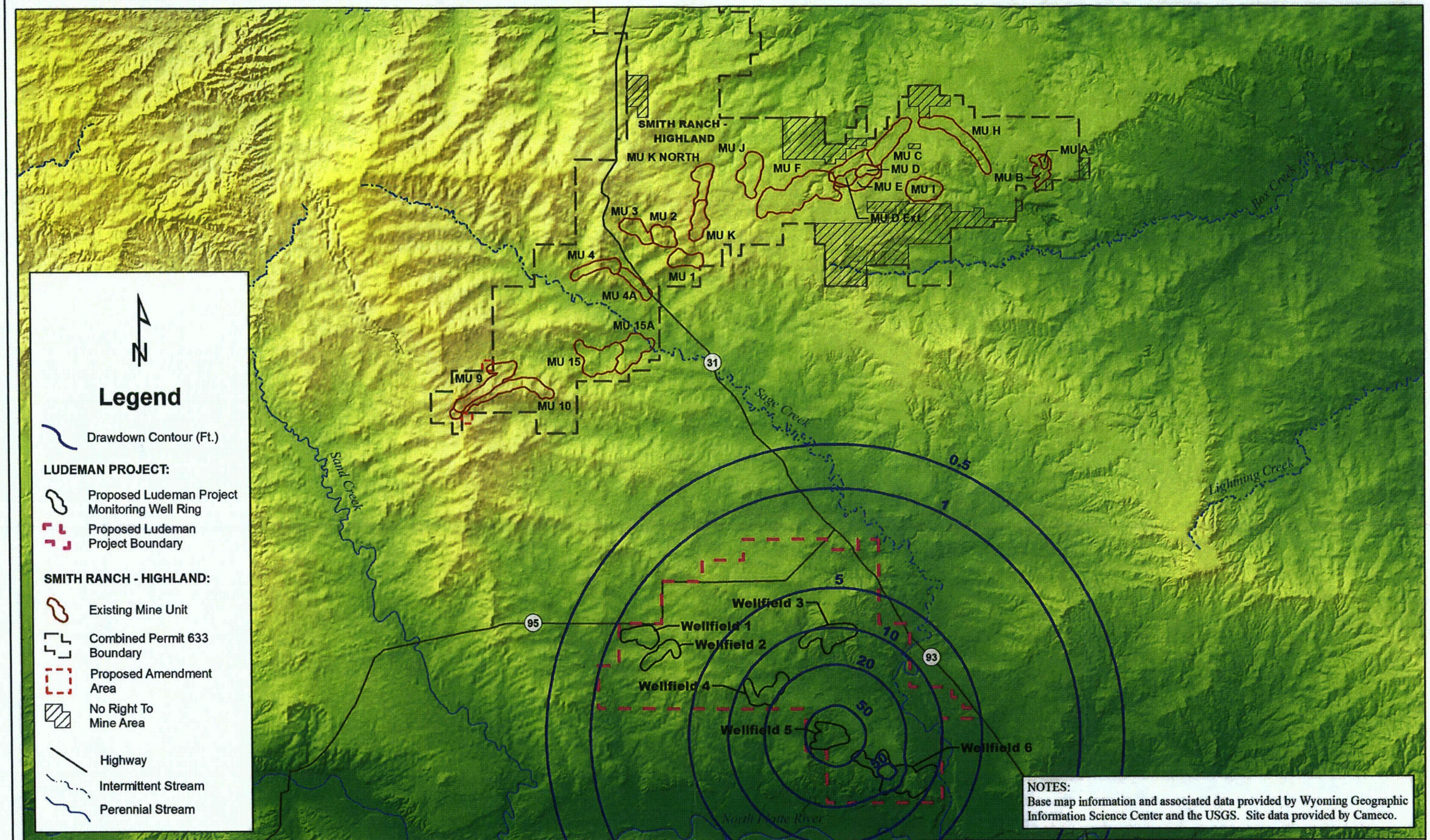
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

80-SAND MAXIMUM DRAWDOWN, DEVELOPMENT YEAR 5.5
LUDEMAN ISR FACILITY

CONVERSE COUNTY - WYOMING

FIGURE:
3



AquiferTek

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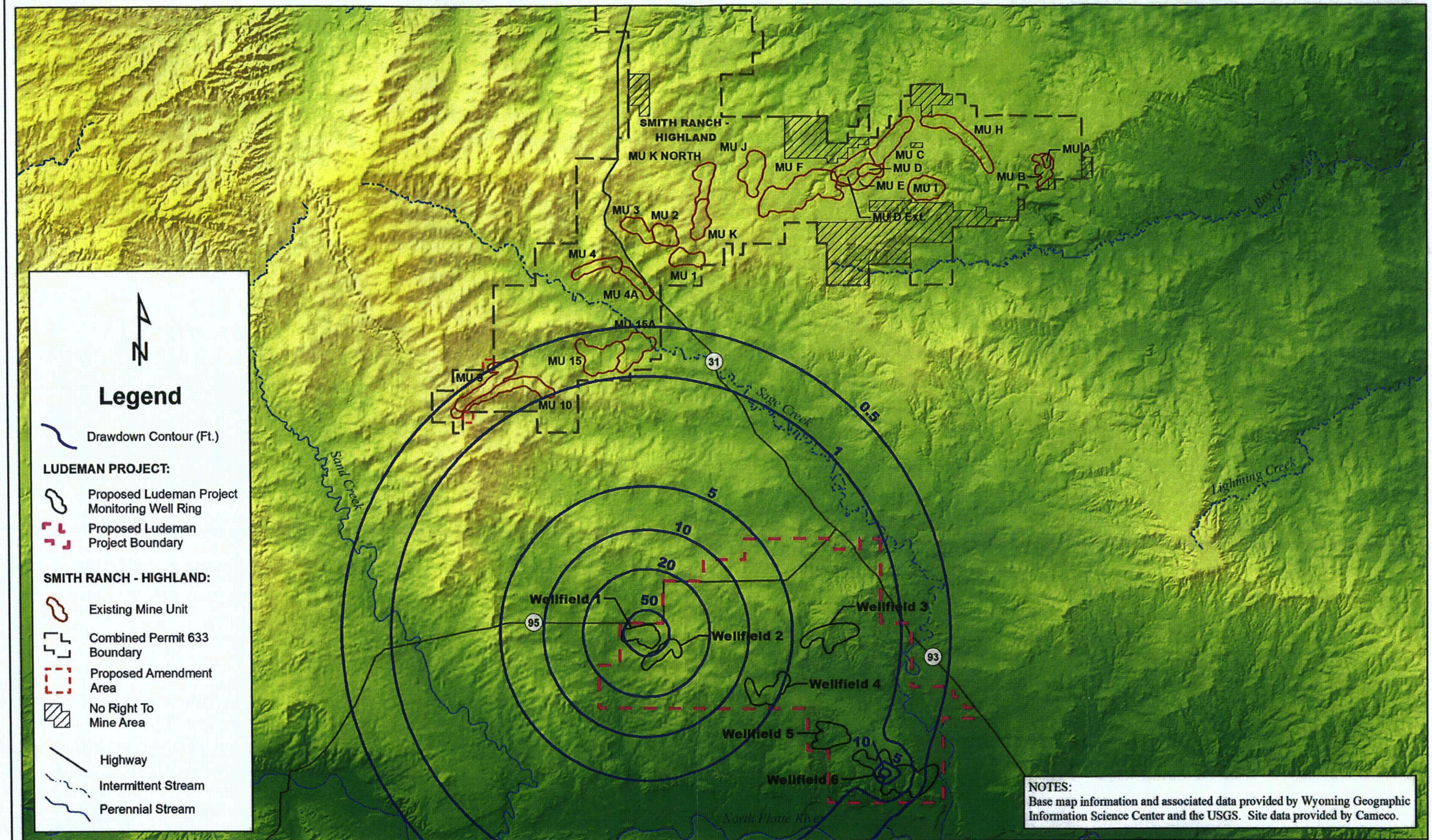
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

80-SAND MAXIMUM DRAWDOWN, DEVELOPMENT YEAR 11
LUDEMAN ISR FACILITY

CONVERSE COUNTY - WYOMING

FIGURE:
4



NOTES:
Base map information and associated data provided by Wyoming Geographic Information Science Center and the USGS. Site data provided by Cameco.

AquiferTek

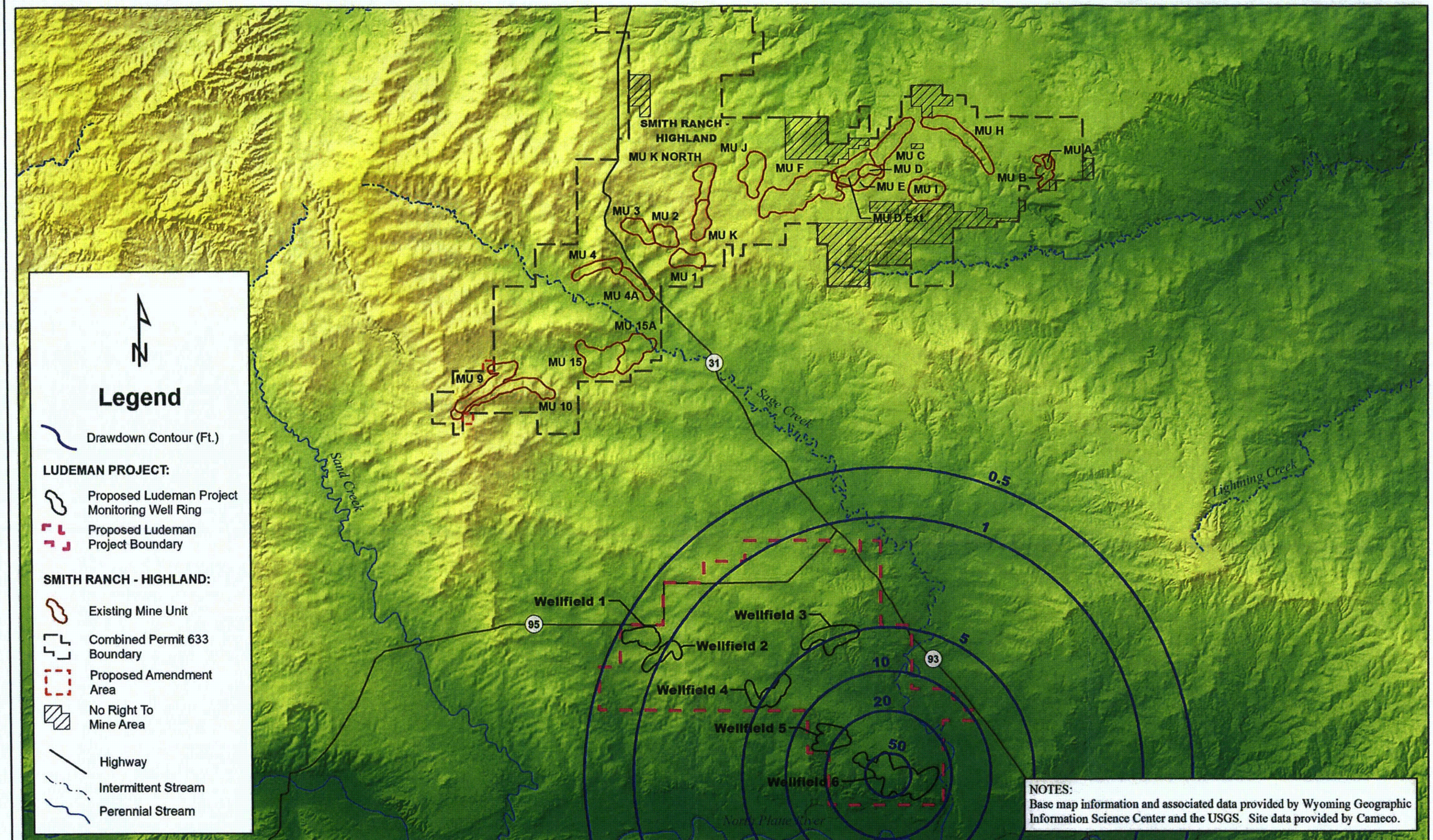
0 5,625 11,250 22,500
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

90-SAND MAXIMUM DRAWDOWN, DEVELOPMENT YEAR 5.5
LUDEMAN ISR FACILITY

CONVERSE COUNTY - WYOMING

FIGURE: 5



AquiferTek

0 5,625 11,250 22,500
Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
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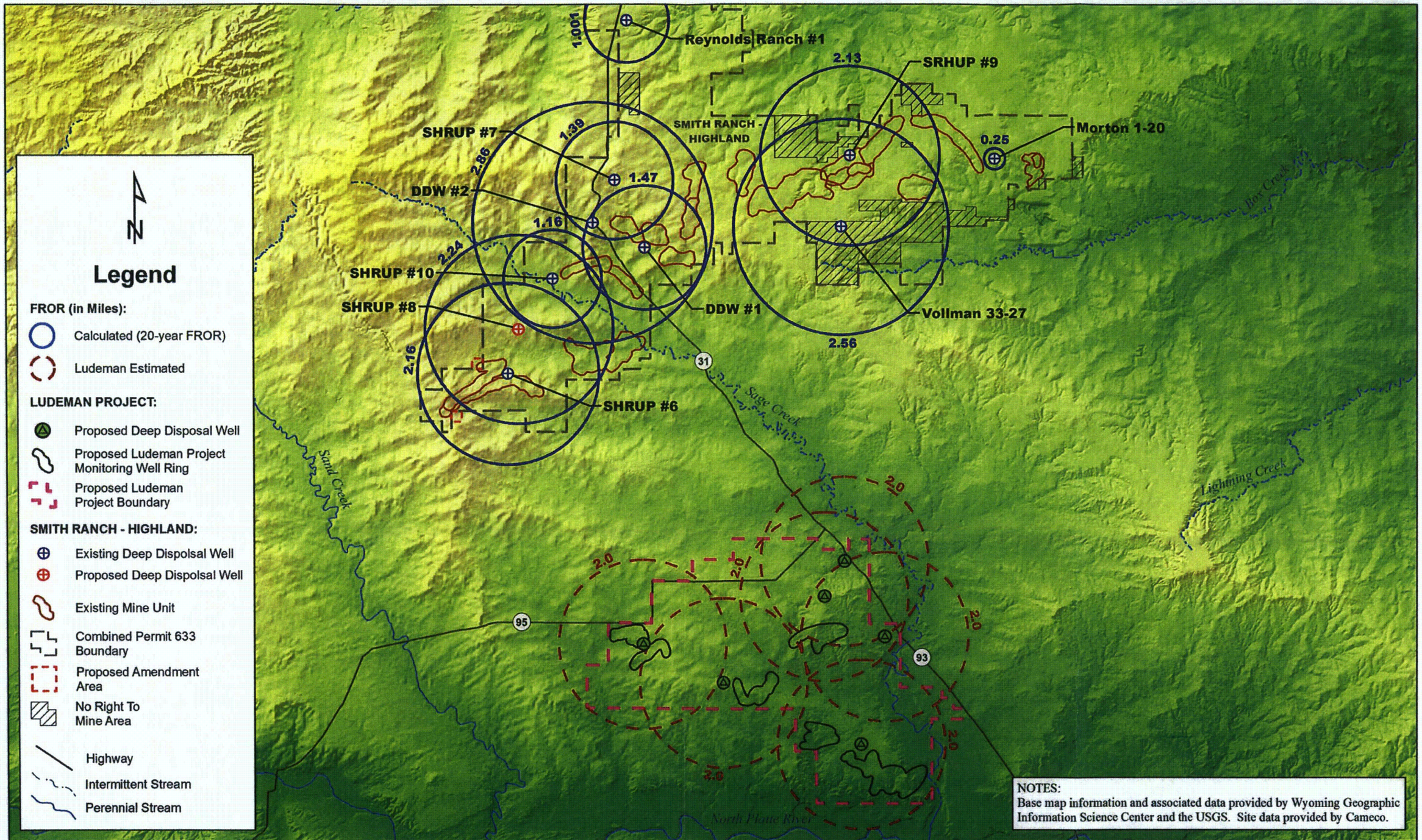
90-SAND MAXIMUM DRAWDOWN, DEVELOPMENT YEAR 11
LUDEMAN ISR FACILITY

CONVERSE COUNTY - WYOMING

FIGURE: 6



AquiferTek

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Feet
1 inch = 11,250 feet
STATE PLANE NAD 27

PROJECT Ludeman
DATE: 5/28/2014
DRAWN BY: CLIN
REVIEWED BY: BLEWIS

DEEP DISPOSAL WELL FINAL RADIUS OF REVIEW (FROR) LUDEMAN AND SRH-RR ISR FACILITIES

CONVERSE COUNTY - WYOMING

FIGURE: 7