Water Management and Treatment In The Natural Gas Industry

Garfield County Energy Advisory Board

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Water Sources and Uses

- Functional Definitions (not Websters')
  - Fresh Water – water from traditional (and legal) fresh-water sources such as lakes, rivers, streams, municipal providers
  - Produced Water – water that is entrained with natural gas in the geologic formation from which the gas is produced. Sometimes referred to as "formation water". In this area, the formations that have historically been developed for gas - and have associated produced water - are separated from shallow fresh water by several thousand feet of rock. Produced water in this area is saline which prohibits direct discharge or use for potable or agricultural purposes
  - Flow-back Water – water that is used during the well completion process to hydraulically fracture the gas-producing formation that is flowed back to the surface after well completion.

- Water is Used for Drilling and Completing Wells
  - Drilling – generally uses fresh water due to mud requirements (on the order of 2,500 – 3,000 barrels (bbls) of water per well – a bbl is 42 gallons)
  - Completions (hydraulic fracturing) – can use either fresh or recycled produced/flow-back water (amount varies, but generally on the order of 50,000 – 100,000 bbls of water per well)

State of the Art Ca. 2005

- Drilling
  - Fresh Water – fresh water used for drilling commonly transported to the location via tanker truck (≈ 30 tanker trucks per well)
  - Water was commonly placed into a reserve pit and trucked off location for disposal when drilling was completed
- Completions
  - Completion Water – either fresh water or recycled produced/flow-back water transported to the location via tanker truck (≈ 750+ tanker trucks per well)
  - Water was commonly flowed back into a reserve or other pit and trucked off location for disposal
    - Some water may have been evaporated on site
    - Recycling/reuse of water was somewhat limited
- Disposal Options
  - Evaporation – either on site or at off site facilities. Some off site facilities could be relatively distant
  - Injection – use of injection wells in this area was limited. Some water was being trucked to relatively distant facilities (NM) for injection
  - Treatment – very little treatment of water was being done at this time but some operators were experimenting with technologies to treat water for reuse and/or discharge

State of the Art Today

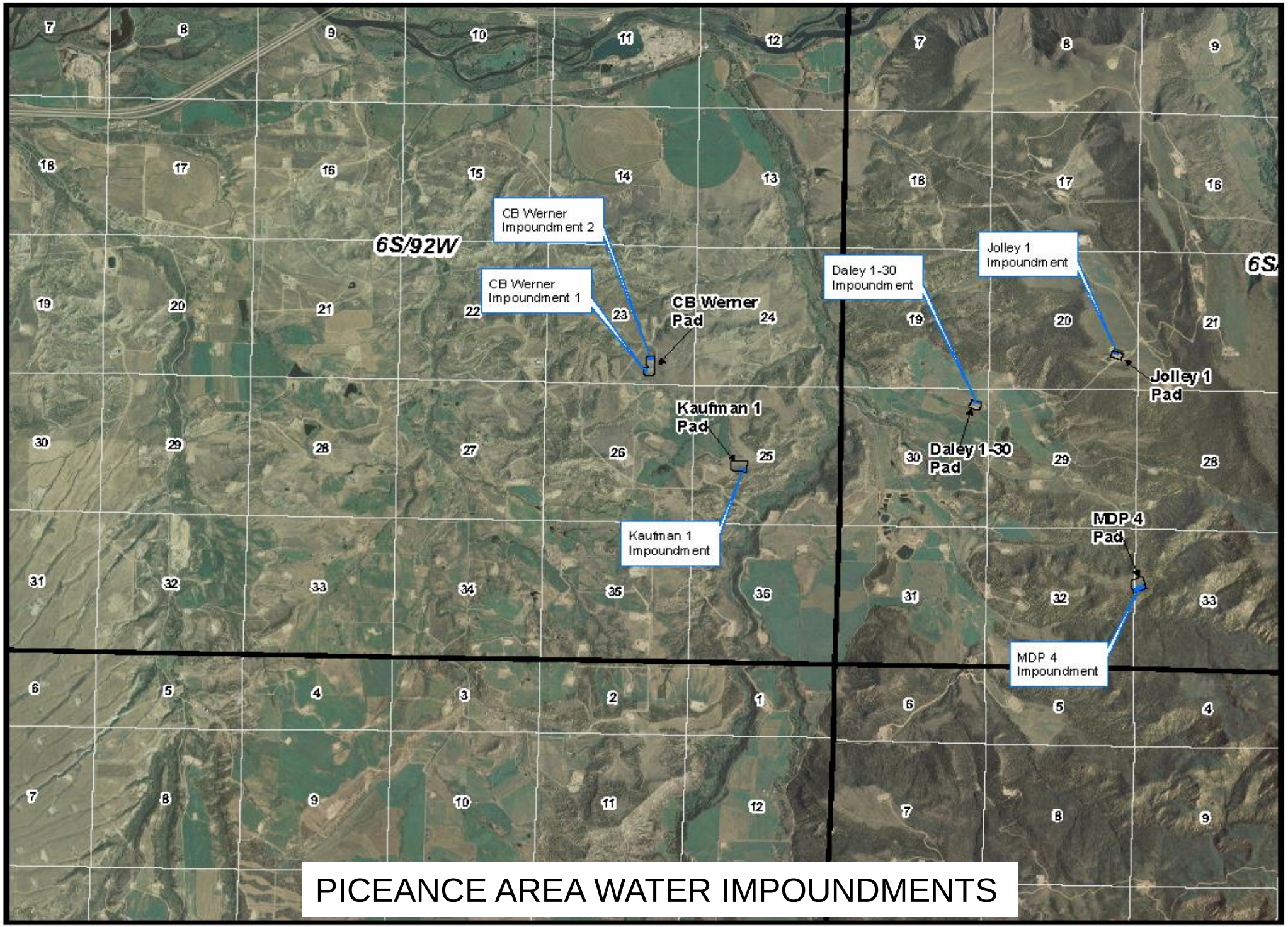
- What's Changed
  - Transportation – many operators have invested in pipeline infrastructure for transporting water (fresh and produced/flow-back) to and from well pads
    - This has greatly reduced truck traffic and associated issues
  - Closed-Loop Drilling Systems – the use of these systems has enabled operators to reuse much of the water – and drilling mud and other additives – during the drilling process
    - Has reduced truck traffic and demand on fresh-water sources
  - Recycling/reuse of water – many operators have aggressive programs to recycle and reuse as much water as possible, particularly with flow-back water. Typically, 60-80% of water used for well completions is recovered and reused for subsequent well completions
    - Has reduced truck traffic, demand for sources of water for well completions and, in many cases, the immediate need for disposal of the water
  - Water disposal - there is still a need for disposal of water
    - Injection wells – much more prevalent use today
    - Evaporation – still used but less well-site evaporation and more centralized or commercial facilities are used
  - Treatment – operators and others have invested a lot of time and money trying to find cost-effective ways to treat produced/flow-back water for discharge or for beneficial use but there is still a ***lot*** of room for technological advances

Water Treatment

- Typical Treatment Options
  - Most treatment options in common use are those that treat produced/flow-back water for reuse in well completions
    - Filtration
    - Oil-Water separation
    - Electrocoagulation
    - Treatment to reduce biological components
- More Sophisticated Systems Have Been Developed by a Multitude of Vendors and Universities and Evaluated by Numerous Operators
  - Theoretically, these systems could produce water that meets requirements for surface discharge
  - Most systems have proven to be not effective in meeting discharge requirements and/or were prohibitively expensive

BBC's Water Management System

- Program Consists of Numerous Facilities to Maximize Recycling/Reuse
  - Water lines are built with gas lines to every pad
    - In some cases, temporary surface lines are used for completions
  - Large water impoundments placed strategically throughout field
    - Water is treated (mechanically & chemically)
    - Water is pumped to and from impoundments through pipelines
  - Operate 4 disposal well facilities throughout the field
    - Each facility has additional storage (tanks) and treatment
    - Location of facilities allows use of electric pumps
- Benefits of the program
  - Significantly reduces truck traffic (estimated 80%+ reduction)
  - Limits use of fresh water
    - Only fresh water use has been for drilling
    - All well completions have used recycled water
  - Added scale of facilities allows more efficient treatment and emissions controls



PICEANCE AREA WATER IMPOUNDMENTS

Pad Location

Existing Impoundment

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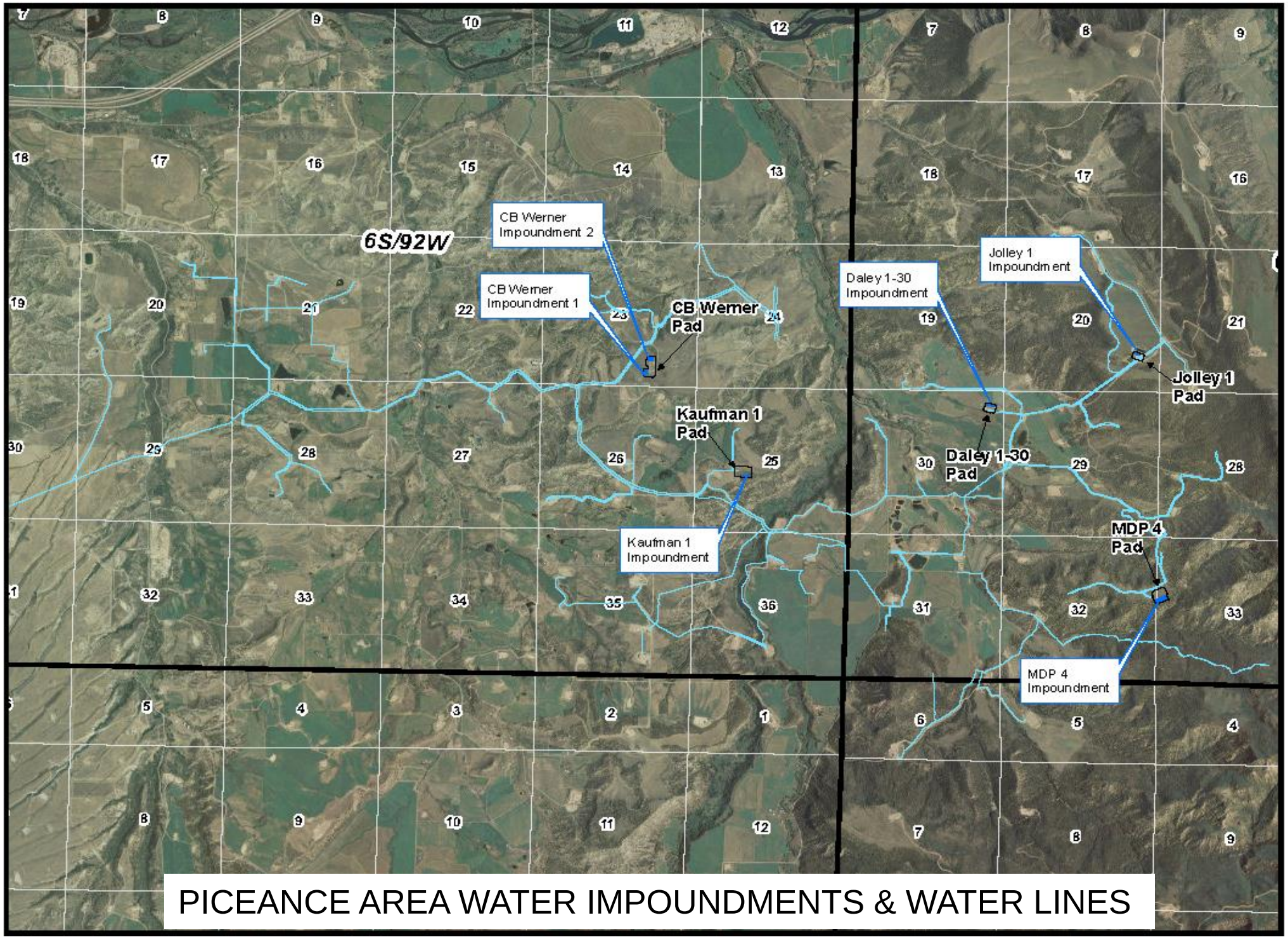

PICEANCE AREA WATER IMPOUNDMENTS & WATER LINES

Pad Location

Existing Impoundment

Water Lines

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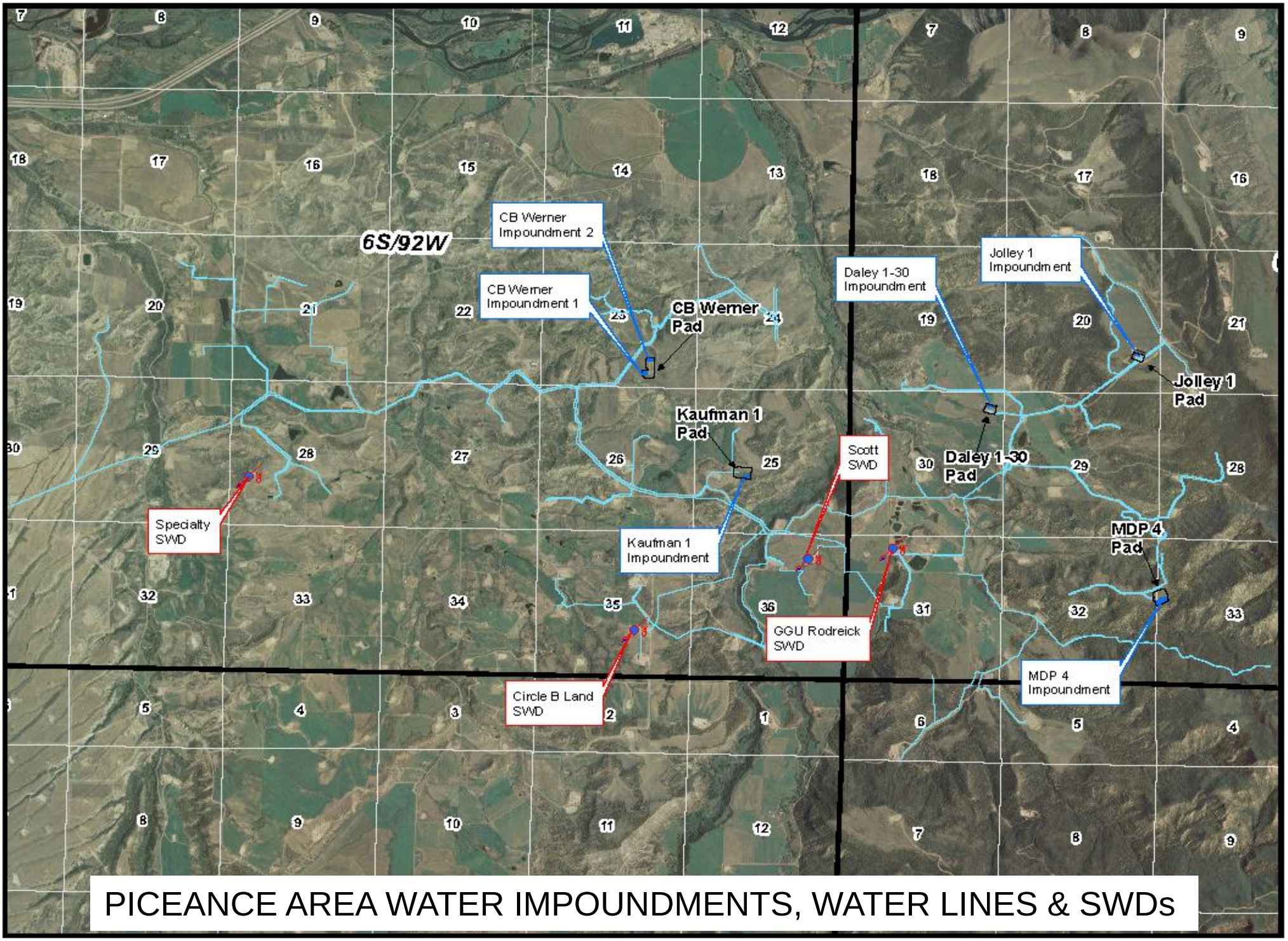

PICEANCE AREA WATER IMPOUNDMENTS, WATER LINES & SWDs

Pad Location
Existing Impoundment
Water Lines
SWD Wells

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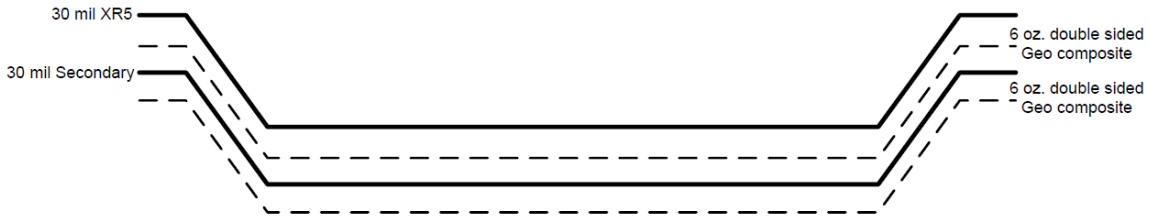
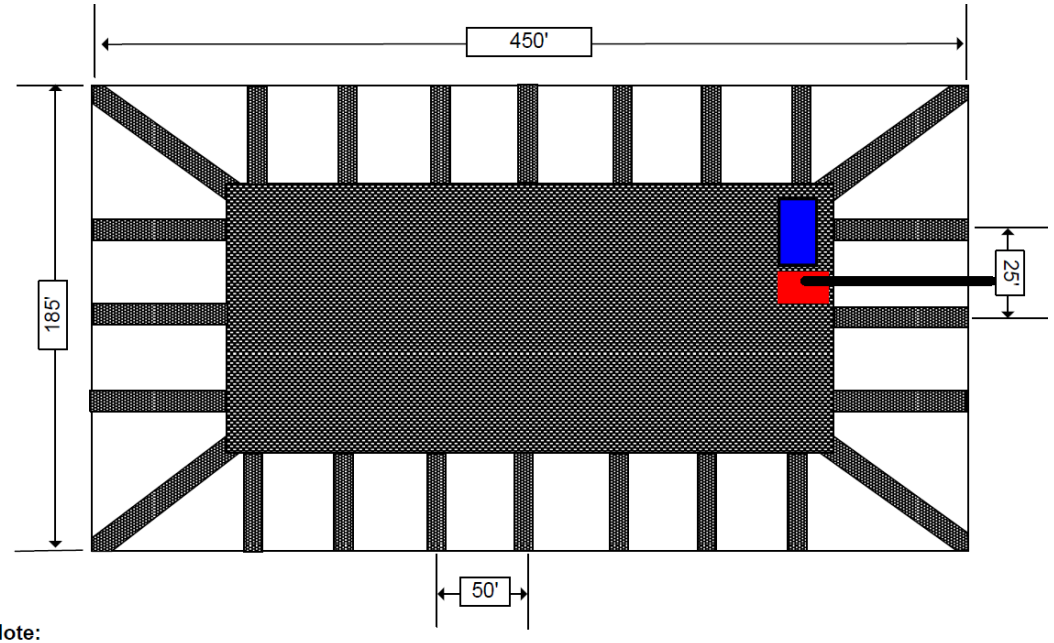
2012

From native soil up:

1. 6 oz. double sided Geo composite on 100% of pit from anchor ditch to anchor ditch
2. 30 mil anti skid double E30WBS liner for secondary liner
3. 6 oz. double sided Geo composite on bottom of pit and runners to top of anchor ditch (50' span between on sides, 25' span on ends)
4. 30 mil XR 5 liner for primary liner
5. Vent pockets at top of every vent grid.





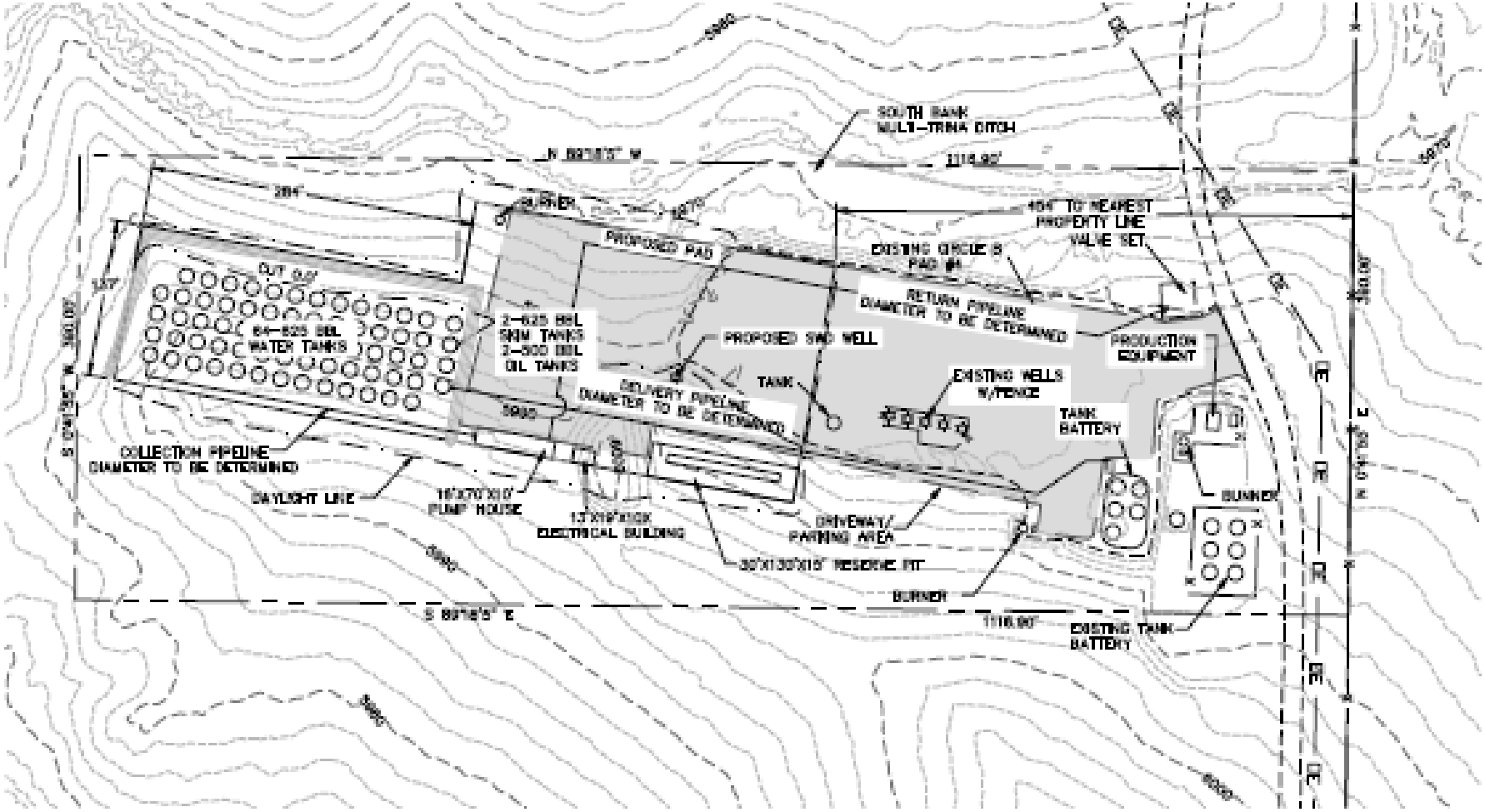
Note:

Leak Detection Sump Placement
Suction Line Sump
* Construct suction line sump approximately 6 feet long and leave 2 feet of native soil between leak detection sump to separate.

BBC's Circle B #4 Water Handling Facility

- This facility is one of 4 that handle water from throughout BBC's Piceance operations. Water handled at this facility is managed to further reduce hydrocarbon concentrations and presence of solids so that the water can be either
  - Returned to the field for reuse in well completions, or
  - Disposed of in the on-site injection well

BBC's Circle B #4 Water Handling Facility



WATER STORAGE FACILITY DETAIL
SCALE 1"=100'

LEGEND

OVERHEAD ELECTRIC	OE
ROADS	
DITCH	
FENCE	X
PARKING/ ACCESS	

BBC's Circle B #4 Water Handling Facility

Summary

- Significant advances have been made over the past several years in how water is transported, managed, and recycled/reused
- Cost effective treatment technologies that can treat produced/flow-back water so that it can be discharged or put to beneficial are not currently available or have not been adequately proven so that there is wide-scale deployment
- There is still plenty of room for new technology development and innovation to assist the industry in managing water