INTRODUCTION

Significant volumes (>1 trillions barrels) of co-produced water are generated daily during production operations for oil and gas in North Dakota. Most produced water is brine (sulfate) with very high concentrations of total dissolved solids. Produced water has historically been considered a waste in the oil and gas industry. Subsurface injection is the industry-preferred alternative for produced water disposal. Because produced water is brine, produced water disposal wells are referred to as brine disposal wells (BDWs).

THE DAKOTA GROUP

Geology of the area is the major factor in determining if injection is a viable option for produced water disposal. North Dakota’s Inyan Kara fan is a sheet sequence of geologic units (Dakota Group) present at an optimal depth for produced water disposal. The Dakota Group consists of four formations in ascending order (see Cross sections A-A’ and B-B’):

- Pierre Formation – marine shale
- Missoula Formation – marine sandstone
- Williston Basin Formation – mixed marine and non-marine sandstone and shale
- Inyan Kara Formation – mixed marine and non-marine sandstone and shale

Overlying the Dakota Group are several thousand feet of Cretaceous marine deposits including the Pierre Formation, a very thick, impermeable shale. The Jurassic Swift Formation, an uncertain unit underlying the Dakota Group, consists of marginal marine with interbedded limestone. The Dakota Group is approximately 3,000 ft thick at depths of approximately 6,000 ft in the west of the Hazen 100K Sheet.

These Cretaceous and Jurassic units provide a complete succession of rocks for produced water injection. Of specific importance is the Inyan Kara formation, which consists of sandstones and shales deposited in incised valleys along the coastline of the Cretaceous Western Interior Seaway. These valleys were cut by north-northwesterly flowing rivers that drained into the seaway from highlands in southern North Dakota, Minnesota, and Montana. The valley fill in the Cretaceous seaway originated from North Dakota twice over a period of approximately 10 million years. The seaway transgressed back into the area forming incised valleys, and sands were deposited in the valleys at various levels within the Inyan Kara formation. The thickest sands are typical of the seaway completely filled all of North Dakota and the underlying marine units were deposited.

Inyan Kara sandstones deposited in these valleys are thick, porous (20-30% porosity), and permeable (Perry trend) enough to contain the injected water and have the lateral continuity of the units allows for injected water to move into the formation (see Cross sections A-A’ and B-B’), especially along valley trends. Although some lateral continuity is important, these units are often good confining units, which allow for good vertical injection similar to carbonate aquifers. The ability for sandstone to contain the injectate fluid allows for excellent confining layers that will vertically contain injected produced water. The SWD concept is that produced water will remain vertical and not migrate laterally away from the disposal well. The SWD concept relies on the geology of the Dakota Group to be thick enough that injection into the SWD will vertically confine the produced water. However, wells across the Hazen 100K that were available for interpretation and assessment of sandstone thickness are not SWD-thick. Therefore, this map should be used only to verify areas of greater sandstone thickness for injection of produced water.

ISOPACH OF INYAN KARA FORMATION SANDSTONES

Note: Due to a lack of well control, isopach contours were neither interpreted nor included on this map.

This map presents locations of wells that have penetrated the Inyan Kara formation in the Hazen 100K. The map and associated cross-sections were prepared in order to identify favorable areas where the potential for dealing with produced water is greatest. Geophysical features such as sand and shale are also presented to better aid in well placement. The map and cross-sections were prepared using wireline logs (gamma ray and resistivity) from 19 wells across the Hazen 100K that were available for interpretation and assessment of sandstone thickness. No SWD well data are available in the Hazen 100K as of publication date.

CONTROL WELL-TYPE/RESERVOIR QUALITY

- >100 ft vertically contiguous sands
- 50-100 ft vertically contiguous sands
- <50 ft vertically contiguous sands

Central position include Inyan Kara formation (sandstone) sections to assist the user in evaluating general trends of potentially contiguous sandstone bodies. These maps do not contain a grid and should be used at approximately the size of the map. Therefore, this map should be used only for general orientation and information, not for development purposes. The maps and associated cross-sections were prepared using produced water disposal well maps across the Hazen 100K that were available for interpretation and assessment of sandstone thickness. No SWD well data are available in the Hazen 100K as of publication date.