# Cuyama Valley Groundwater Basin

# Draft Groundwater Sustainability Plan: Basin Settings



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## Acronyms

| | |
|---|---|
| µg/L | micrograms per liter |
| µS/cm | microsiemens per centimeter |
| AF | acre-feet (foot) |
| AFY | acre-feet per year |
| Basin | Cuyama Valley Groundwater Basin |
| CALSIMETAW | California Simulation of Evapotranspiration of Applied Water |
| CBGSA | Cuyama Basin Groundwater Sustainability Agency |
| CBWRM | Cuyama Basin Water Resources Model |
| CUVHM | Cuyama Valley Hydrologic Model |
| DWR | California Department of Water Resources |
| EKI | EKI Environment & Water, Inc. |
| GAMA | California Groundwater Ambient Monitoring and Assessment Program |
| GDE | groundwater dependent ecosystem |
| GPS | global positioning system |
| GSP | *Groundwater Sustainability Plan* |
| HCM | hydrogeologic conceptual model |
| InSAR | interferometric synthetic-aperture radar |
| Ma | million years |
| MCL | maximum contaminant level |
| METRIC | Mapping Evapotranspiration at High Resolution and Internalized Calibration |
| Navstar | A network of United States that provide global positioning system services |
| NCCAG | Natural Communities Commonly Associated with Groundwater |
| NRCS | Natural Resources Conservation Service |
| NWIS | National Watershed Information System |
| PG&E | Pacific Gas & Electric |
| PRISM | Parameter-Elevation Regressions on Independent Slopes Model |
| RWQCB | Regional Water Quality Control Board |
| SAGBI | Soil Agricultural Groundwater Banking Index |

## Acronyms

| | |
|---|---|
| SBCF | Santa Barbara Canyon Fault |
| SBCWA | Santa Barbara County Water Agency |
| SGMA | Sustainable Groundwater Management Act |
| SR | State Route |
| TDS | total dissolved solids |
| UNAVCO | A non-profit university-governed consortium facilitating geoscience research and education using geodesy |
| USGS | United States Geological Survey |

# 2. Basin Settings: Overview

This Cuyama Valley Groundwater Basin (Basin) Settings chapter contains three main sections as follows:

- **Hydrogeologic Conceptual Model (HCM)** – The HCM section (Section 2.1) provides the geologic information needed to understand the framework that water moves through in the Basin. It focuses on geologic formations, aquifers, structural features, and topography.
- **Groundwater Conditions** – The Groundwater Conditions section (Section 2.2) describes and presents groundwater trends, levels, hydrographs and level contour maps, estimates changes in groundwater storage, identifies groundwater quality issues, addresses subsidence, and addresses surface water interconnection.
- **Water Budget –** The Water Budget section (Section 2.3) describes the data used to develop the water budget. Additionally, this section discusses how the budget was calculated, provides water budget estimates for historical conditions, and current conditions and projected conditions.

## 2.1 Basin Settings: HCM

This section of Chapter 2 describes the HCM for the Basin. Additionally, this HCM section satisfies Section 354.8 of the Sustainable Groundwater Management Act (SGMA) regulations. As defined in the regulations promulgated by the Department of Water Resources (DWR), the HCM:

1. "Provides an understanding of the general physical characteristics related to regional hydrology, land use, geology geologic structure, water quality, *principal aquifers*, and principal aquitards of the *basin setting;*
2. Provides the context to develop water budgets, mathematical (analytical or numerical) models, and monitoring networks, and
3. Provides a tool for stakeholder outreach and communication."

This HCM was developed to understand and then convey information about the physical conditions by which water moves through the Basin. This information is also used to support development of water budgets (Section 2.3).

### 2.1.1 Useful Terms

This chapter includes descriptions of geologic formations and structures, aquifers, and properties of geology related to groundwater, among other related components.

A glossary of technical terms is below. The terms listed here are intended as a guide for readers, and are not a definitive definition of any term.

- **Formation –** A formation, or geologic formation, is a unit of rock of similar properties, such as grain size, mineral composition, or depositional environmental. Geologic formations are distinct from surrounding rock types and are large enough to be mapped regionally. If the formation contains a dominant rock type, such as sandstone, it may be included in the name of the formation.
- **Basement rocks –** Basement rocks are the oldest and deepest rocks in the subsurface. Basement rocks are typically crystalline and metamorphic or igneous in origin, and groundwater generally only moves through fractures in the rock instead of pore spaces like in sedimentary rocks. No sedimentary layers are found below the basement rocks.
- **Water bearing formation –** A water bearing formation is a rock formation that is saturated and contains water within the pores or fractures of the unit. One or more water bearing formations compose an aquifer.
- **Aquifer –** An aquifer is an underground reservoir of water stored within the pores and fractures of rocks and sediments.
- **Unconfined aquifer –** An unconfined aquifer is an aquifer that does not have an impermeable layer above it (such as a clay layer). With an unconfined aquifer, the upper water surface is defined as the water table and is at atmospheric pressure. Water seeps from the ground surface directly into the aquifer, as there are not impermeable layers to prevent the water from entering the aquifer.
- **Cross section –** A cross section is a diagram that identifies subsurface layers located beneath a surficial trend. Stratigraphic cross sections depict geologic formations in the subsurface in relation to elevation. Cross sections are useful tools to interpret geology in the subsurface and visualize the relative thickness and distribution of geologic formations. Cross sections are often presented with an accompanying map that acts as a reference to spatially locate the trend of the cross section at the surface. To read cross sections, use the location and trend of the surficial lines on the location map as a key. For instance, where A-A' is marked on the map represents where the cross section named A-A' is located spatially
- **Hydraulic conductivity** – Hydraulic conductivity is defined as the "measure of a rock or sediment's ability to transmit water," typically measured in feet or meters per unit of time (day, hour, minute) (DWR, 2003). Rocks and sediments with high values of conductivity, such as gravels or coarse sands, are able to sustain groundwater flow better than rocks and sediments with low values of conductivity. Rocks and sediments with near zero values of hydraulic conductivity, such as very fine-grained sandstones, shale, or granites, do not transmit groundwater and are barriers to flow. Values of conductivity are used in the groundwater model to determine how quickly formations transmit groundwater and where barriers to groundwater flow (i.e., formations with very low values of conductivity) exist.
- **Hydrogeology** – The study of groundwater and aquifers.

- **Primary aquifer –** According to SGMA regulations, primary aquifers must be identified. In the Goundwater Sustainability Plan (GSP), aquifers requiring specific monitoring and management must also be identified. Primary aquifers are regionally extensive and are sources of groundwater used for beneficial uses.
- **Aquitard –** An aquitard is a layer of strata that has a low conductivity that groundwater flows very slowly through. Aquitards can be regional, such as the Corcoran Clay in the Cuyama Valley, where it prevents flow from upper strata to lower strata across the western side of the valley, or it can be localized, which is common in most alluvial settings. Localized aquitards restrict vertical flows in a small region of an aquifer, and water will generally move laterally around localized aquitards as it flows by gravity toward the bottom of the aquifer.
- **Piper diagrams** – A Piper diagram is used to characterize the chemical quality of a water sample, and involves plotting the relative proportions of major ions. Piper diagrams show the relative abundance of major cations (e.g., sodium, potassium, calcium, magnesium) and anions (e.g., bicarbonate, carbonate, sulfate, chloride, fluoride) commonly found in water on a charge equivalent basis, as a percentage of the total ion content of the water. Piper diagrams are useful for understanding what kind of salts make up the total dissolve solids (TDS) in a location.

### 2.1.2 Regional Geologic and Structural Setting

The Basin is located at the southeastern end of the California Coast Ranges and north of the Western Transverse Ranges (Figure 2-1), and is in an area of high tectonic activity. The Basin is bounded on the north and south by faults, and is located near major fault zones such as the San Andreas and Santa Maria River fault zones. Because the Basin is located in a mountainous region with high tectonic activity, it has a number of structural features generated by this activity. The Basin has been deformed by this tectonic activity, and is generally a synclinal basin, with multiple synclines that are oriented to the northwest and a number of faults that cross the Basin.

Tectonic activity from the northwest movement of the San Andreas Fault system has led to the development of a fold and thrust belt, which has driven the deformation of the Cuyama Valley for the past four million years (United States Geological Survey [USGS], 2013c). The Cuyama Valley was formed by a downfaulted block of the earth's crust called a graben. This block is bordered on the north by the Morales and Whiterock faults and on the south by the South Cuyama and Ozena faults. Along these borders the faults have thrust older rocks of pre-Pliocene age over the rocks of Pliocene age and younger. In the eastern part of the valley the north-bordering faults approach the San Andreas Fault zone and the south-bordering faults approach the Big Pine Fault. (Singer and Swarzenski, 1970)

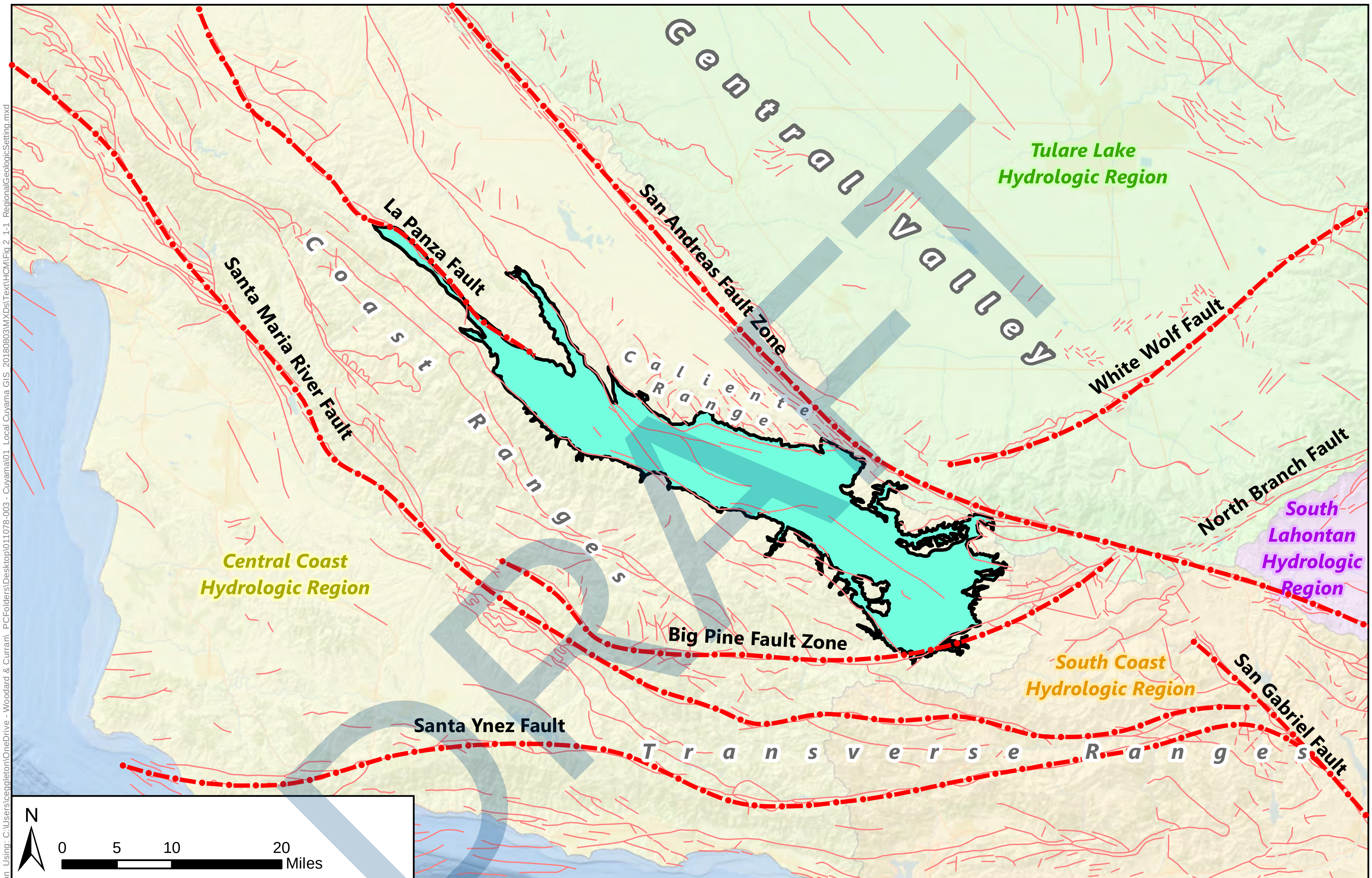




**Figure 2-1: Regional Geologic Setting**

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*Legend*

Cuyama Basin

Faults

Fault Data Sources:
Fault Activity Map of California (2010) from the California Department of Conservation. Retrieved 6/13/2018.
<http://maps.conservation.ca.gov/cgs/fam/>
California Geologic Map Data from United States Geologic Survey. Retrieved 2/8/2018.
<https://mrdata.usgs.gov/geology/state/state.php?state=CA>

Figure Exported: 10/18/2018 By: cengleton Using: C:\Users\cengleton\OneDrive - Woodard & Curran\ PCFolders\Desktop\011078-003 - Cuyama\01 Local Cuyama GIS_20180803\MXDs\Text\HCM\Fig 2_1-1_RegionalGeologicSetting.mxd

### 2.1.3 Geologic History

The Basin has a long history of deformation and deposition, most of this influenced by tectonic activity and cycles of marine transgression and regression. Formations in the Basin reflect variable depositional environments, from the middle bathyal shales and siltstones to the nonmarine sandstone, conglomerate, and mudstones. Marine rocks are dominant in the western part of the Basin and interfinger to the east with nonmarine rocks (Ellis, 1994).

A major late Eocene/early Oligocene (38 to 28 million years (Ma)) unconformity affected all regions south of the San Andreas Fault, shown in the geologic record by nonmarine Oligocene (23 Ma) rocks overlying a thick section (i.e., several kilometers) of upper Eocene (56 Ma) marine rocks (Kellogg et al., 2008; Ellis, 1994). This unconformity is a result of the Ynezian orogeny (around 30 Ma) during which pre-Oligocene marine rocks were folded and uplifted above younger, Oligocene-age sediments (Kellogg et al., 2008).

Following a period of orogeny, deformation changed to extension from the late Oligocene and early Miocene (around 23 Ma) and the Basin became a major extensional basin (Ellis, 1994). This period also correlated with two transgressive-regressive cycles, where the sea advanced and retreated over geologic time over the sediments now in the Basin due to tectonic subsidence (Bazeley, 1988). Sediments deposited during this period reflect the cyclical nature of sea-level rise and are generally categorized by marine strata in the west and nonmarine strata to the east. Formations deposited during ocean transgression are thick marine sediments, including the Vaqueros Formation, Monterey Formation, Branch Canyon Sandstone, and Santa Margarita Sandstone (Kellogg et al., 2008; Lagoe, 1981). Many of the marine units interfinger with terrestrial units and eventually pinch out to zero thickness in the east. During the late Miocene (8 Ma), the sea regressed from the western part of the region, evident in the geologic record where the nonmarine Caliente Formation interfingers with the similarly aged marine Santa Margarita Sandstone and unconformably overlies the Branch Canyon Sandstone (Kellogg et al., 2008). By the middle Miocene (15 Ma), the eastern Cuyama Valley area was characterized by a shelf and nonmarine deposition. Deformation by the middle Miocene changed from extension to right-lateral strike slip motion, resulting in the development of the Russell fault.

Deformation from Oligocene extension and Miocene strike-slip faulting regimes was buried by the folding, uplift, and thrust faulting during the Pliocene through Pleistocene compression (beginning around 4 Ma) (Ellis, 1994). Compression led to the uplift of the Coast and Transverse mountain ranges surrounding the current topographic valley and the converging thrust faults that surround the present day topographic basin, including the Whiterock, Morales, and South Cuyama faults (USGS, 2013b). The transition to a predominantly compressional system led to the development of a thrust system across the older extensional basin and began thrusting older sediments above younger sediments through the Cuyama Valley (Davis et al., 1988). Older, inactive faults and rocks were buried by the deposition of the younger Morales Formation, Older Alluvium, and Younger Alluvium. Thrust and compression continued into the Quaternary (3 to 2.5 Ma) and uplifted the Caliente Range and thrusted Miocene-aged rocks of the Caliente Range southward over Quaternary alluvium on the Morales fault (USGS, 2013b; Ellis, 1994).

The Morales Formation and Older Alluvium are folded into synclines along the north and south margins of the valley near the bounding thrust faults (USGS, 2013b). The end of the Pliocene (around 2 Ma) marks the complete withdrawal of the sea from the area and the final sea regression marks the change in deposition of marine sediments to the continental clay, silt, sand, and gravel of the Morales Formation and alluvium (Singer and Swarzenski, 1970; Ellis, 1994). Fluvial deposits of claystone, sandstone, and conglomerate became the primary forms of sedimentation.

### 2.1.4 Geologic Formations/Stratigraphy

The Basin is composed of a sequence of unconsolidated to partly consolidated nonmarine deposits of Pliocene to Pleistocene age unconformably overly consolidated marine and nonmarine sedimentary rocks of late Cretaceous to middle Cenozoic age on top of Mesozoic crystalline granitic and gneissic bedrock (Davis et al., 1988). The unconsolidated to partly consolidated nonmarine deposits are the primary water-bearing units in the Basin and are described in further detail in Section 2.1.7. Individual geologic units found in the Basin are described in detail below, in order of youngest to oldest in deposition. Geologic units mapped at the surface are shown in Figure 2-2. A generalized stratigraphic column of the Cuyama Valley is shown in Figure 2-3.

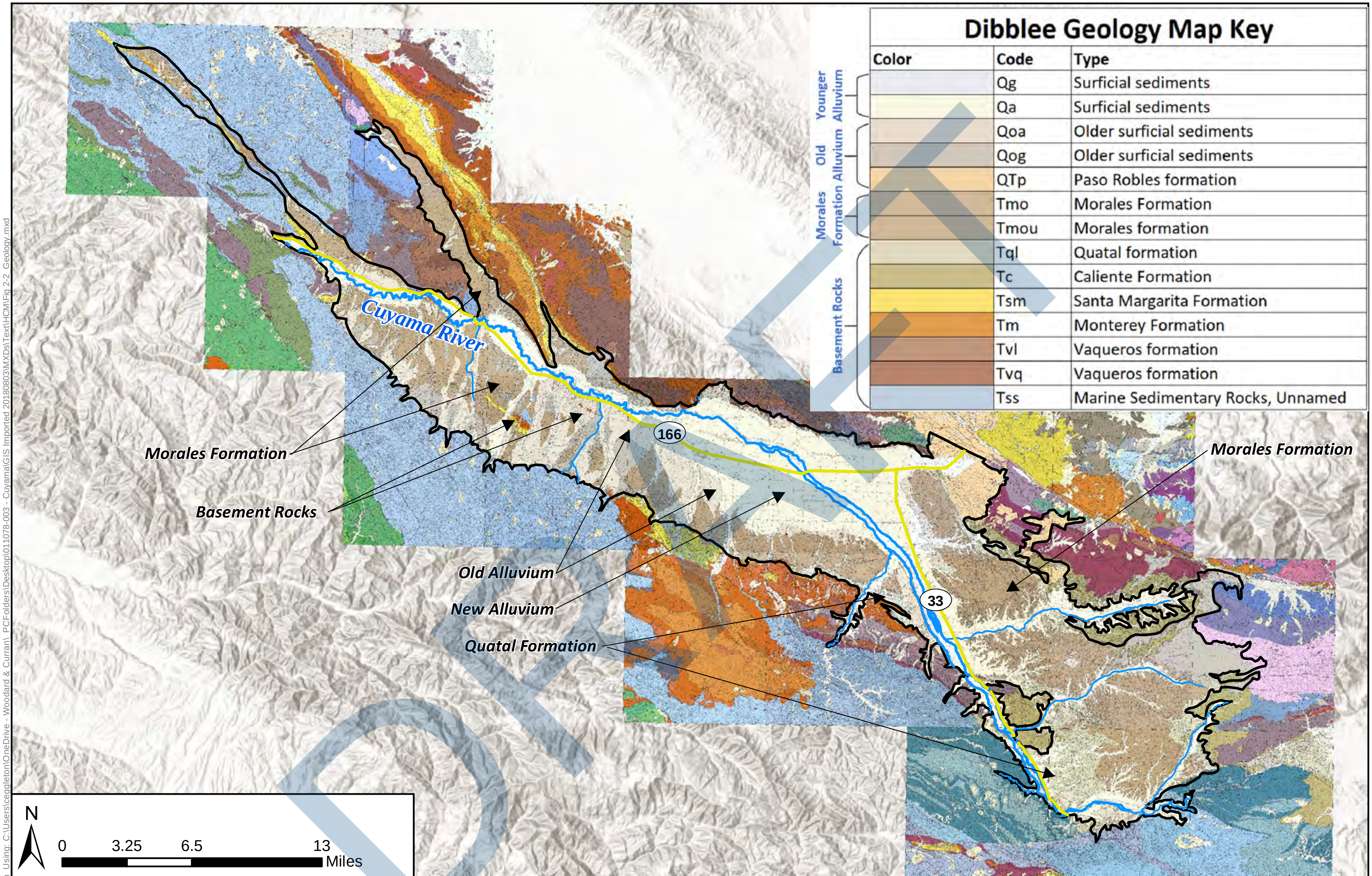


**Figure 2-2: Geologic Map**

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Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Streams
- Highways

Data Source: Thomas W. Dibblee, Jr., Dibblee Foundation Relased in June 2012, Purchased from AAPG as GeoTIF 28 March 2018.

Figure Exported: 8/21/2018 By: ceggleton Using: C:\Users\ceggleton\OneDrive - Woodard & Curran\ PCFolders\Desktop\011078-003 - Cuyama\GIS Imported 20180803\MXDs\Text\HCM\Fig 2-2 Geology.mxd

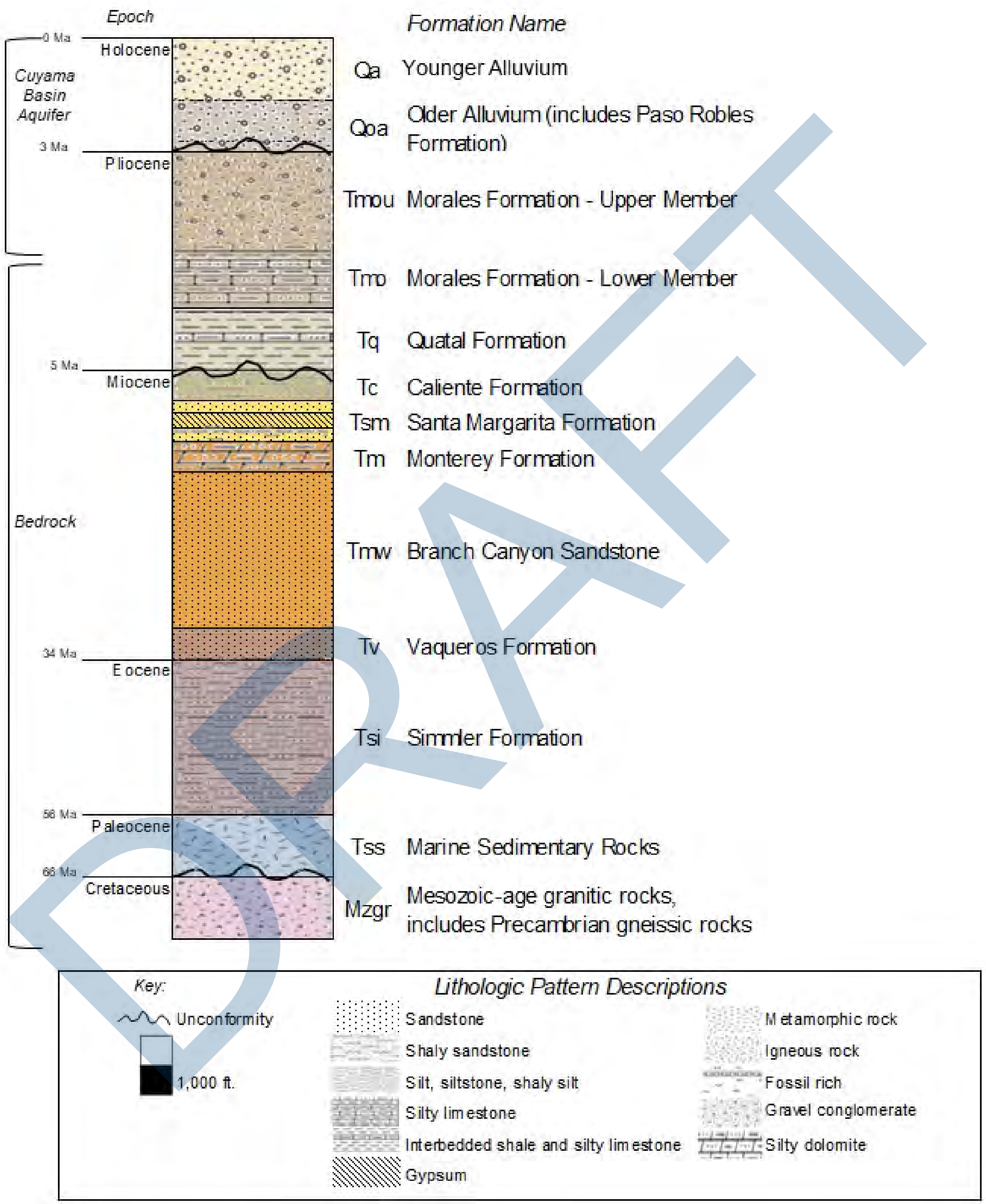
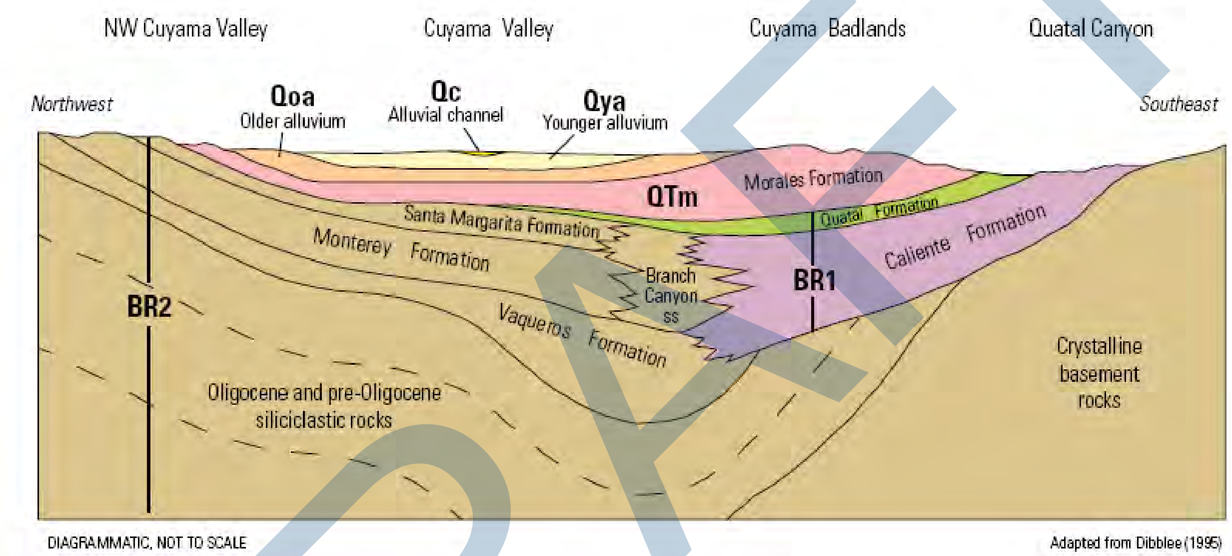





**Figure 2-3: Generalized Stratigraphic Column of the Cuyama Valley**

## Stratigraphic Units of the Cuyama Basin Aquifer

Stratigraphic units in this section are presented in order from youngest to oldest. The USGS prepared a generalized stratigraphic diagram of the Basin and surrounding area in 2013 (Figure 2-4). The diagram shows the relationship of the Young Alluvium, Older Alluvium, Morales Formation, and basement rocks in and near the Basin. The diagram shows that the Morales formation is thicker to the east, and that the Caliente Formation is interfingered with a number of other basement rock formations (Santa Margarita, Monterey, Vaqueros) beneath the Basin (USGS 2013a). This diagram shows the general relationship of formations in the Cuyama area and is not a precise representation of unit thickness.




*Source: USGS, 2013a.*

**Figure 2-4. Generalized Stratigraphic Diagram**

### *Recent and Younger Alluvium*

The youngest deposit of the Basin is the Recent and Young alluvium. Recent alluvium is made up of active fluvial channel deposits associated with the Cuyama River and other active channels. Deposits include river-bed gravels and grain sizes range from silt to boulder size and are found along active fluvial channels in the Basin. The Younger Alluvium is inactive fluvial deposits consisting of unconsolidated to partly consolidated sand, gravel, and boulders, with some clay deposited as part of stream channels, floodplains, alluvial fans, or stream terraces (USGS, 2013c). Younger Alluvium is exposed throughout the central portion of the Central Valley and along the active channels and flood plains of the Cuyama River and other streams. The deposits thicken to the east, typically ranging from 5 to 50 feet in the west and thickening from 630 to 1,100 feet in the east (Singer and Swarzenski, 1970). Recent and Younger alluvium are primarily Holocene in age, but the Younger alluvium can date back to the Pleistocene (USGS, 2013c). The Younger and Recent alluvium are the principal water-bearing formations in the Basin.

Older studies do not distinguish Younger Alluvium from Older Alluvium (Upson and Worts, 1951; Singer and Swarzenski, 1970), but more recent studies (Kellogg et al., 2008) mapped the two alluvium units as distinguishable mappable units at the surface, and in 2013, the USGS identified differences in the two units using electric log signatures. A greater degree of consolidation, dissection, and local deformation distinguishes the Older Alluvium deposits from the Younger alluvium.

### *Older Alluvium*

Older Alluvium is primarily Pleistocene in age and is composed of unconsolidated to partly consolidated sand, gravel, and boulders with some clay (USGS, 2013a). The percentage of clay increases in the western part of the Cuyama Valley. Older Alluvium deposits are typically more consolidated and deformed than Younger alluvium deposits and contain a higher clay content. The Older alluvium is dissected alluvial fans, colluvial deposits and sediments on multiple terraces and alluvial surfaces and is found exposed on uplifted alluvial surfaces along the south side of the Cuyama Valley and on the caps of the Turkey Trap and Graveyard ridges (USGS, 2013a). Older Alluvium is typically 400 to 600 feet thick, but increases in thickness up to 1,000 feet near the axis of the Cuyama Valley and decreases in thickness west of the Russell fault (USGS, 2013a; Cleath-Harris, 2018). The Older Alluvium overlies the Morales Formation unconformably, west of the Cuyama Badlands (Ellis, 1994).

### *Paso Robles Formation*

The Paso Robles Formation is part of the Quaternary alluvium series and is commonly grouped with the Older Alluvium. The Paso Robles Formation is a gray, crudely bedded alluvial gravel derived from Miocene rocks and basement rocks of western San Emigdio Mountains east of San Andreas Fault (Davis et al., 1988). The Formation is composed of pebbles, gravel, sand, and some cobbles. The Paso Robles Formation is sandwiched between two unconformities; it rests uncomformably below the Older Alluvium and with angular discordance above the Morales Formation (Davis et al., 1988; Ellis, 1994). The Paso Robles Formation is present only in a small northeastern portion of the Basin.

### *Morales Formation*

The Pliocene to Pleistocene-aged Morales Formation (Morales) is divided into two members, the upper and lower. The Morales Formation is the oldest formation to respond to the modern topography of the Basin, indicating its deposition simultaneous to acceleration of tectonic-driven subsidence (Yeats et al., 1989). The contact between the upper and lower members of the Morales is used to define the base of water-bearing units of the Basin (USGS, 2013a).

The Morales is massively bedded and ranges from 1,000 to 5,000 feet in thickness east of the Russell fault and up to 1,200 feet thick west of the Russell fault (USGS, 2013a; Cleath-Harris, 2018). Thickness of the Morales Formation is disputed amongst published references. In 1970, Singer and Swarzenski reported the Morales Formation to be up to 10,000 feet in thickness along the northern margin of the Valley (Singer and Swarzenski, 1970). The Morales Formation is found throughout the Valley and is widely exposed to the east of the Cuyama River near Ventucopa and the Cuyama Badlands. Its lateral extent is generally limited by faults. The Morales Formation is overlain unconformably by the older and Younger Alluvium (Hill, 1958).

#### *Upper* Morales

The upper member of the Morales is composed of partly consolidated, poorly sorted deposits of gravelly arkosic sand, pebbles, cobbles, siltstone, and clay of Pleistocene age (Davis et al., 1988). The upper Morales is a water-bearing unit and the base of this member marks the base of aquifer materials in the Basin. The upper Morales is thickest to the east near the Cuyama Badlands, approximately 2,200 feet, and shallows to the west, less than 800 feet west of the Russell fault (Hill, 1958; Cleath-Harris, 2018). In the central portion of the Basin, south of the Cuyama River, the upper Morales is around 1,500 feet thick (Ellis, 1994). In some areas, such as near Ballinger Canyon, the Morales shows some degree of angular unconformity (Ellis, 1994).

### Stratigraphic Units Below the Basin Aquifer

#### *Lower Morales*

The lower member of the Morales consists of clay, shale, and limestone with lacustrine clay beds with distinct coarse-grained intervals, boulder trains, and gravelly channel deposits (USGS, 2013a). The lower member of the Morales finer grained than the upper Morales and is less permeable. The lower Morales is not considered a water bearing unit. South of the Cuyama River, the lower part of the Morales consists of about 1,300 feet of gray, gypsiferous, lacustrine claystones (Hill, 1958). The lower Morales lies conformably on the Quatal Formation and, in western areas of the Basin, unconformably on other marine units (Ellis, 1994).

#### *Quatal Formation*

The Quatal Formation is a sequence of fluvial and lacustrine claystone, siltstone, and sandstone which unconformably underlies the Morales Formation. Near the Cuyama Badlands, the formation is up to 820 feet of gypsiferous claystone while in other areas the unit is nonmarine sandstones interbedded with the claystone (USGS, 2013a). The Quatal Formation thins to the west and pinches out to zero in thickness near the town of Cuyama. In the eastern and central parts of the Basin, the Quatal Formation is a distinct stratigraphic marker that defines the bottom of the Morales Formation (USGS, 2013a). The Quatal Formation is not a water bearing unit and is not considered a part of the Basin groundwater system.

#### *Caliente Formation*

The Caliente Formation is composed of nonmarine sandstones, claystones, and conglomerates of Miocene age (Davis et al., 1988). Layers of volcanic ash and basalt sills and dikes are commonly found in the formation and tertiary basalt is found interbedded with the formation in the Caliente Range (Davis, 1988; Dudek, 2016). The formation is exposed on the eastern half the Valley, along the Basin edge in the Caliente Ranges and in a footwall block of the Pine Mountain fault (Kellogg et al., 2008). The fluvial Caliente Formation was deposited in the east at the same time the marine Branch Canyon Sandstone and Santa Margarita Formation were being deposited to the west (Ellis, 1994). The Caliente Formation conformably overlies and interfingers with the marine sedimentary rocks of the Santa Margarita Formation and pinches out to zero thickness to the west (Kellogg et al., 2008; Davis et al., 1988).

### *Santa Margarita Formation*

The Santa Margarita Formation is composed of shallow-marine, consolidated sandstones from the middle to late Miocene (USGS, 2013b). The formation contains a gypsum member and a sandstone-mudstone member. The gypsum member consists of a greenish-gray, medium to thin bedded gypsum, up to 82 feet thick (Kellogg et al., 2008). The sandstone and mudstone member consists of interbedded layers of arkosic sandstone, mudstone, and siltstone, up to 400 feet thick (Kellogg et al., 2008). The sandstone sequence is rich in shallow marine molluscan fossils. The formation unconformably underlies the Morales Formation in the northwest of the Valley and grades into the Caliente Formation to the east (Hill, 1958). Locally, the formation contains layers of volcanic ash, basalt sills, dikes and flow units (Davis et al., 1988). The Santa Margarita Formation is the youngest marine unit in the Basin and marks the final phase of marine sedimentation and sea transgression (Lagoe, 1981).

### *Monterey Formation*

The Monterey Formation consists of intervals of dolomitic marine shale, mudstone, and siltstone. The formation is subdivided into two members: the upper Whiterock Bluff Shale member and the lower Saltos Shale member (Davis et al., 1988). The Whiterock Bluff Shale is a calcareous in the lower two-thirds and becomes gradually siliceous in the upper one-third and is found up to 1,200 feet in thickness (Bazeley, 1988; Hill, 1958). The Saltos Shale member is a calcareous shale with turbiditic sandstones and was deposited at the same time as the fluvial Caliente Formation, but in the western, bathyal portion of the Basin (Davis et al., 1988; USGS, 2013b). The Saltos Shale member is found up to 2,250 feet thick (Hill, 1958). The formation is middle Miocene in age and is cut with layers of volcanic ash and Miocene-age basalt sills (Davis et al., 1988). In the Caliente Mountain Range, tertiary basalt is found interbedded with the Monterey Formation (Davis et al., 1988). To the east, the Monterey Formation grades into the Branch Canyon Sandstone. The formation is conformably overlain by the Santa Margarita Formation.

### *Branch Canyon Sandstone*

The Branch Canyon Sandstone is Middle Miocene in age and is a shallow marine sandstone (Davis et al., 1988). Like the Monterey and Santa Margarita formations, the Branch Canyon Sandstone contains layers of volcanic ash and is cut by basalt sills and dikes (Davis et al., 1988). The sandstone grades into the Caliente Formation to the east and is up to 2,500 feet thick (Kellogg et al., 2008). The easternmost extent of the Branch Canyon Sandstone represents an early Miocene wave-dominated shoreline and is defined by the gradational change into the nonmarine Caliente Formation to the east (Davis et al., 1988; Bazeley, 1988).

### *Vaqueros Formation*

Most of the oil produced in the Basin comes from the Vaqueros Formation. The formation is late Oligocene to early Miocene in age and is a marine clastic unit that is subdivided into three members: the upper, shallow-marine Painted Rock Sandstone member, the middle, bathyal Soda Lake Shale member, and the lower, shallow-marine Quail Canyon Sandstone member (Davis et al., 1988). The Vaqueros Formation represents a shallow-marine, high-energy, shoreface environment where the lower half represents a transgressive environment and the upper half represents a regressive environment (Bazeley, 1988). To the east, the Vaqueros Formation grades into the lower part of the nonmarine Caliente Formation. In the Cuyama Badlands, the Vaqueros Formation rests on the Simmler Formation and crystalline basement rocks, while in the central portion of the Basin, the Vaqueros Formation rests on Paleogene sedimentary rocks (Ellis, 1994). The Branch Canyon Sandstone and Monterey Formation are conformably above the Vaqueros Formation (Davis et al., 1988).

#### *Simmler Formation*

The Simmler Formation is a terrestrial sandstone, siltstone, and conglomerate of the Oligocene epoch (Davis et al., 1988). The Simmler Formation contains a shale member containing intervals of claystones and siltstones interbedded with coarse sandstones and a sandstone member containing sandstones interbedded with siltstones and claystones (Kellogg et al., 2008). The formation is as thick as 2,800 feet and overlies the Eocene-Oligocene unconformity (Kellogg et al., 2008). To the east, the Simmler Formation interfingers with a thin section of the marine Vaqueros Formation, marking the beginning of marine regression in the early to middle Miocene (Kellogg et al., 2008). Sediments of the Simmler Formation were sourced from the erosion of the Santa Barbara Canyon area and were deposited on a wide, delta plain (Bazeley, 1988). Though rare, the Simmler Formation can contain interbedded mafic volcanics (Yeats et al., 1989).

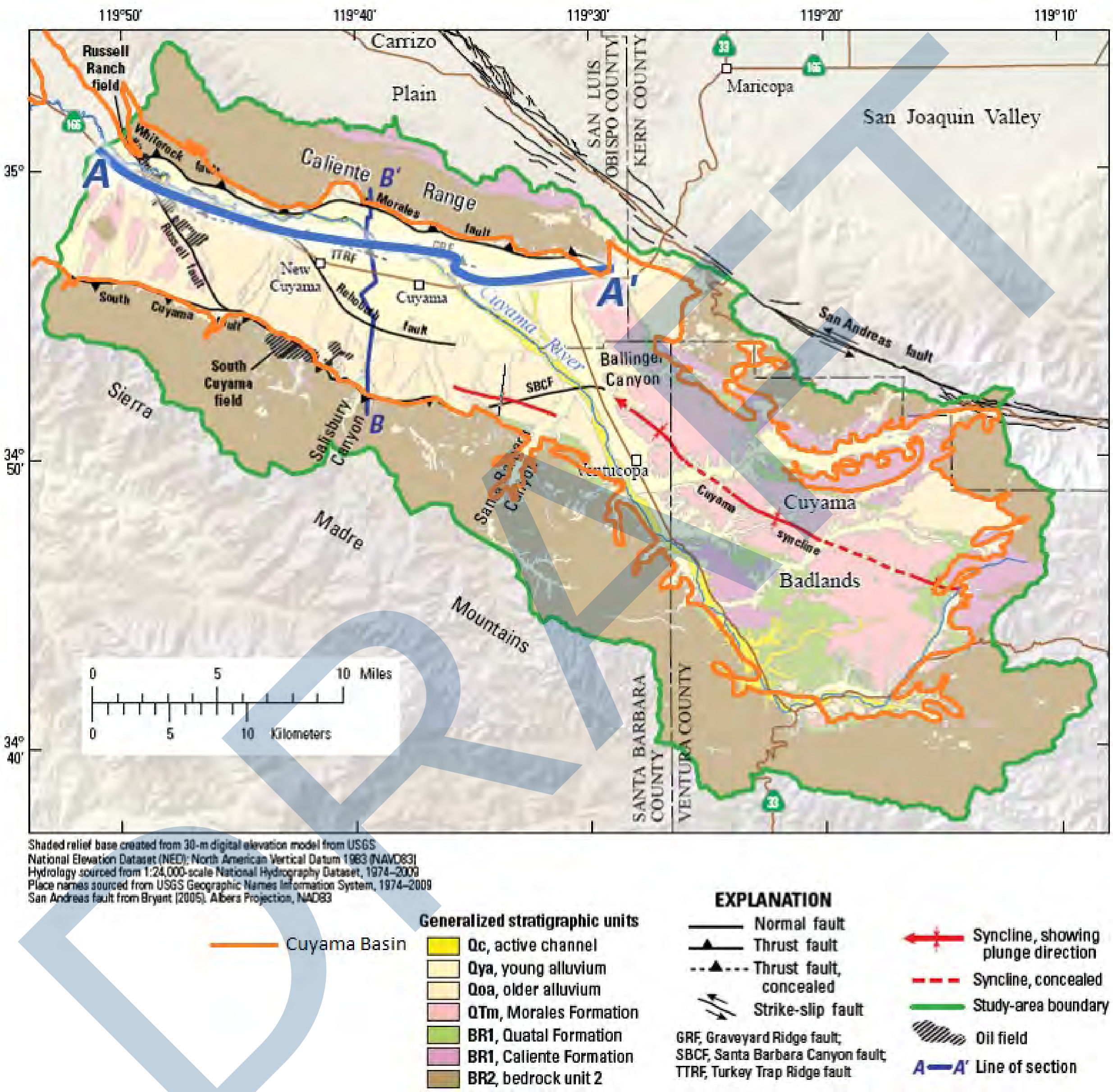
#### *Marine Sedimentary Rocks*

Late Cretaceous to Eocene marine rocks are unnamed but are part of the crystalline basement of the Cuyama Valley (Davis et al., 1988). The strata are unconformably overlain by a thick section of middle and upper Cenozoic rocks and are primarily exposed in the La Panza and Sierra Madres ranges and the hanging walls of the South Cuyama, La Panza, and Ozena faults (Davis et al., 1988).

### Formations Older Than Marine Sedimentary Rocks

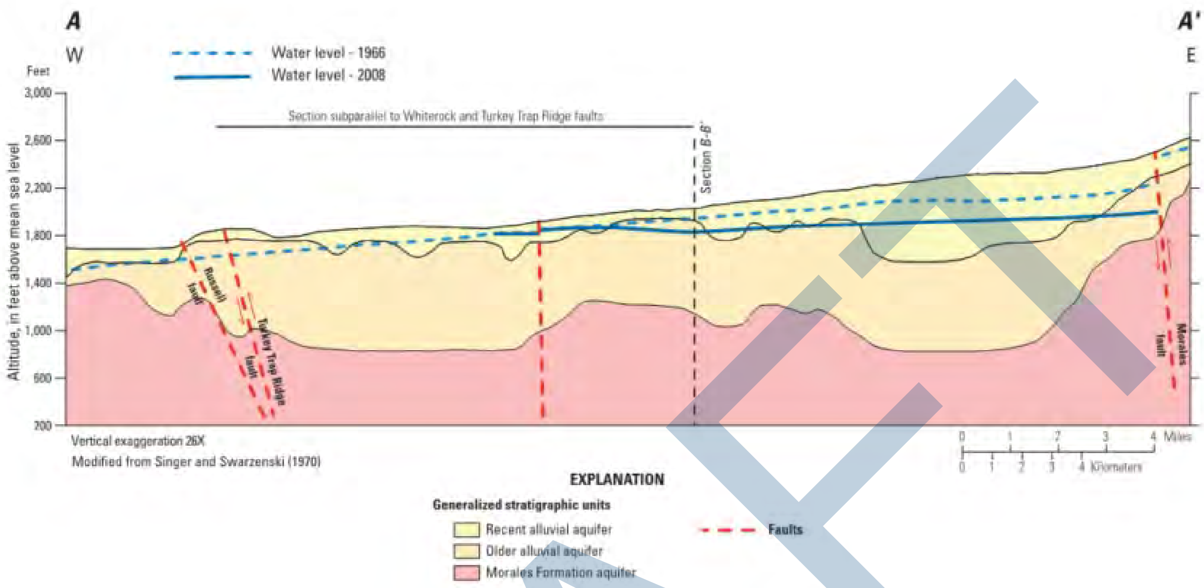
The crystalline rocks of the Cuyama Valley are composed of Mesozoic age granitic rocks and Precambrian age gneissic rocks (Davis et al., 1988). Cretaceous granitic rocks are exposed in the La Panza Range and near the San Andreas Fault, 12 to 18 miles southeast of the Cuyama Valley (USGS, 2013b). Precambrian granitic gneissic rocks outcrop east of the Cuyama Badlands and the La Panza Range (USGS, 2013b). Total thickness is unknown.

Figure 2-5 shows the locations of cross sections across the central portion of the Basin prepared by USGS in 2013. Figure 2-5 shows a west-east cross section that runs near the towns of New Cuyama and Cuyama labeled A-A’, and a south-north cross section labeled B-B’. Figure 2-6 shows the A-A’ cross section and Figure 2-7 shows the B-B’ cross section. Cross-section A-A’ shows the layering of Recent and Old alluvial aquifers and the Morales Formation aquifer. It also shows where the Russell Fault and Turkey Trap Ridge Fault cross the cross section, and shows groundwater elevation. Figure 2-7 shows cross section B-B’, which shows layering of the aquifers and the locations where the Rehoboth and Graveyard Ridge fault cross the cross section.



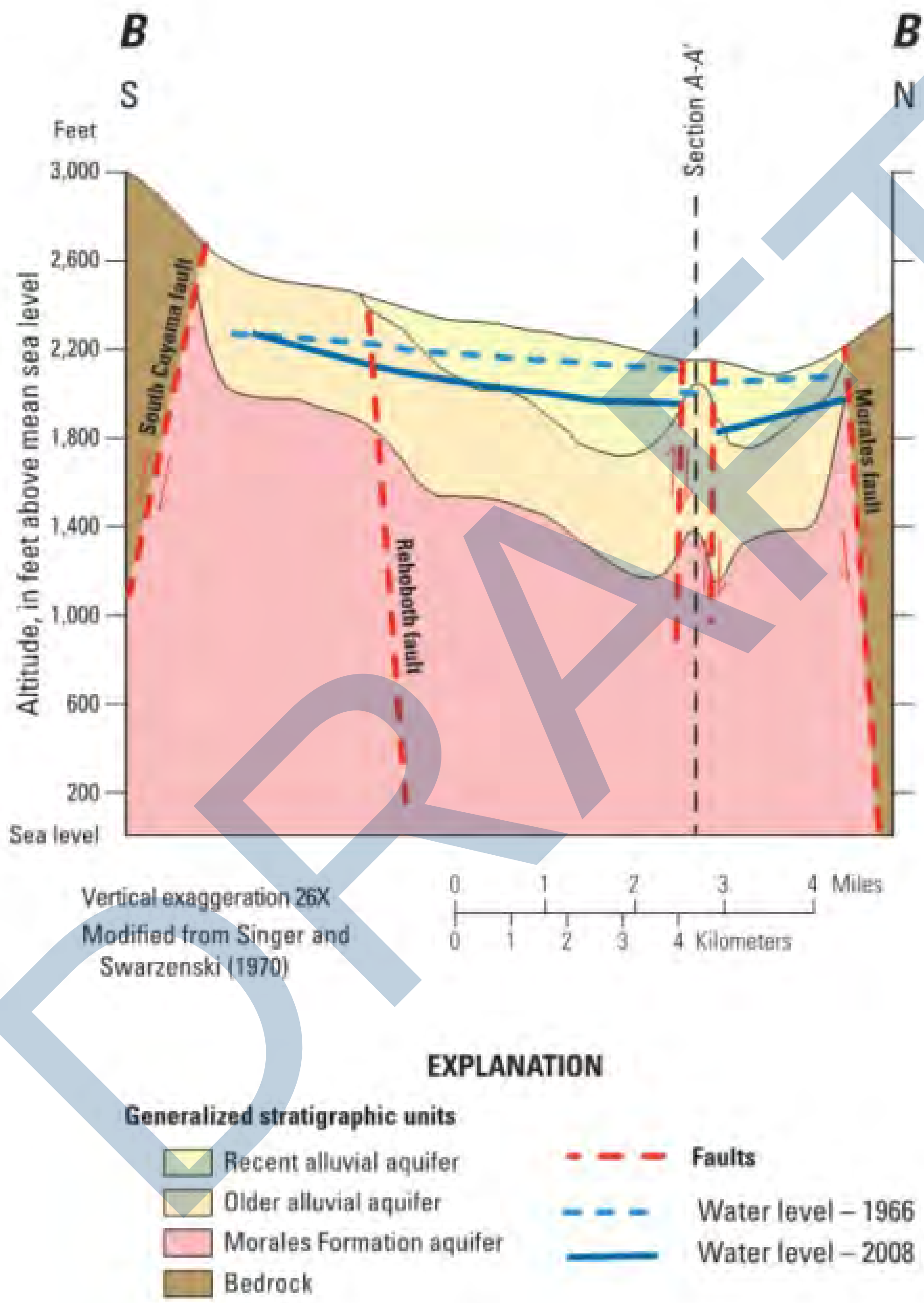

*Source: USGS, 2015.*

**Figure 2-5: Location of USGS 2015 Cross Sections**




*Source: USGS, 2015*

**Figure 2-6: USGS Cross Section A-A'**




*Source: USGS, 2015*

**Figure 2-7: USGS Cross Section B-B'**

### 2.1.5 Faults and Structural Features

The Basin is bounded by faults and contains a number of tectonic features including synclines, faults, and outcrops of basement rocks in the Basin. Major faults and synclines are shown in

Figure 2-8. Outcrops of basement rocks are shown on the geologic maps (Figure 2-2 and Figure 2-5).

#### Synclines

There are a number of synclines in the Basin; they are generally oriented to the northwest/southeast consistent with how the majority of the Basin is oriented.

##### *Cuyama Syncline*

The Cuyama Syncline is located in the southeastern portion of the Basin. It stretches from the Ballinger Canyon south into the Cuyama Badlands, ending along the Cuyama River. The Cuyama Syncline plunges from the Ventucopa area northwestward to beneath the valley from the Ventucopa area to the southeast. The syncline is known from subsurface data from oil exploration wells beneath the valley and exposed near the town of Ventucopa and in the Cuyama Badlands. (USGS, 2013a). The axis of the syncline strikes roughly parallel to the San Andreas Fault (N50ºW) and plunges to the northwest (13ºNW) (Singer and Swarzenski, 1970; Ellis, 1994). The Cuyama syncline was a depocenter (a site of sediment accumulation) during the deposition of the Morales Formation (Ellis, 1994). The syncline has folded water and non-water bearing formations and is favorable to the transmission of water from the southeast end of the valley but otherwise has no pronounced effect on the occurrence of groundwater (Upson and Worts, 1951).

##### *Syncline Near the Santa Barbara Canyon Fault*

Near the Santa Barbara Canyon Fault, A syncline is indicated by the USGS. The syncline runs generally east-west and is roughly 5 miles long. It ends near the southern edge of the South Cuyama fault (USGS, 2013a).

##### *Syncline in the Northwestern Portion of the Basin*

There is a syncline in the western portion of the Basin that roughly follows a west-northwest direction near the southern border of the Basin, located southwest of the Russel fault, near an outcrop of the Santa Margarita formation (Cleath-Harris, 2018). The full extent of this syncline, and its length are not documented at this time, but likely extends 5 to 10 miles, which is the length of documented faults in the area, as mapped by Dibblee. (Dibblee, 2005)

#### Major Faults

There are a number of faults within the Basin, many of which take the form of 'fault zones' where there are multiple individual faults close together oriented in the same direction. This section describes each major fault individually, with consideration that there are often additional small faults near each major fault. Major faults are shown in Figure 2-8.

### *Russell Fault*

The Russell fault is a subsurface, right lateral, strike-slip fault that is 7 miles long and runs roughly parallel to the Russell Ranch oil field through the western portion of the Basin.

The Russell fault offsets the top of bedrock by as much as 1,500 feet (Nevins, 1982), and has had approximately 18 miles of right-lateral offset documented on the NW-striking Russell fault in the northwestern part of the Cuyama Valley have occurred between 23 and 4 Ma (USGS, 2013a; Ellis, 1994). The fault is referred to as strike-slip by several authors, and normal fault by others, and is sometimes referred to as both strike slip and normal within the same document (USGS, 2013a). Water bearing units on the western (upthrown) side of the Russell fault become thinner to the west of the Russell Fault and become thicker to the east of the Russel Fault due to this uplift. Alluvium is generally limited to stream channels and the Cuyama River bed on the western side of the fault.

The Russell fault has been analyzed by a number of authors who have come to differing conclusions regarding the fault's potential to be a barrier to groundwater flow. In 1989, Yeats stated that "the base of the Morales Formation is not cut by the fault" (Yeats et al., 1989). Using tectonic activity and decreasing offset of younger beds, Yeats concluded that the Vaqueros Formation is primarily impacted as it was deposited during the fault's most active period and that by the time the Morales Formation was deposited 19 million years later, activity on the fault had ceased (Yeats et al., 1989). The USGS in 2008 initially concluded that the fault was not a barrier to flow (USGS, 2013c). The USGS in 2013 studied the fault using interferometric synthetic-aperture radar (InSAR) data and concluded that "the Russell fault did not appear to be acting as a barrier to groundwater flow" (USGS, 2013c). In 2015 the USGS identified the Russell fault as a barrier to flow and used it as a no flow boundary in the Cuyama Valley Hydrologic Model (CUVHM) (USGS, 2015). Based on the conclusions of the USGS, Dudek stated that the fault has indicators that it obstructs groundwater flow due to truncation of older geologic formations and standing moisture near the fault and prepared a basin boundary modification request based on the conclusion that the fault is a barrier to flow (Dudek, 2016). In addition, Cleath-Harris determined that the fault is a barrier to flow and prepared a technical memorandum to document their study of the fault's behavior (Cleath-Harris, 2018). In 2016, DWR denied a request for a basin boundary modification motivated by claims that the Russell Fault is a barrier to groundwater flow and divides groundwater in the central portion of the Basin from groundwater in the west. DWR rejected the Basin boundary modification request, citing a lack of hydrogeologic data that supported evidence of barrier. EKI Environment & Water, Inc. (EKI) reviewed the USGS's work in 2017 and concluded the fault potential to be a barrier is not understood and recommended additional study to refine the fault's properties (EKI, 2017).

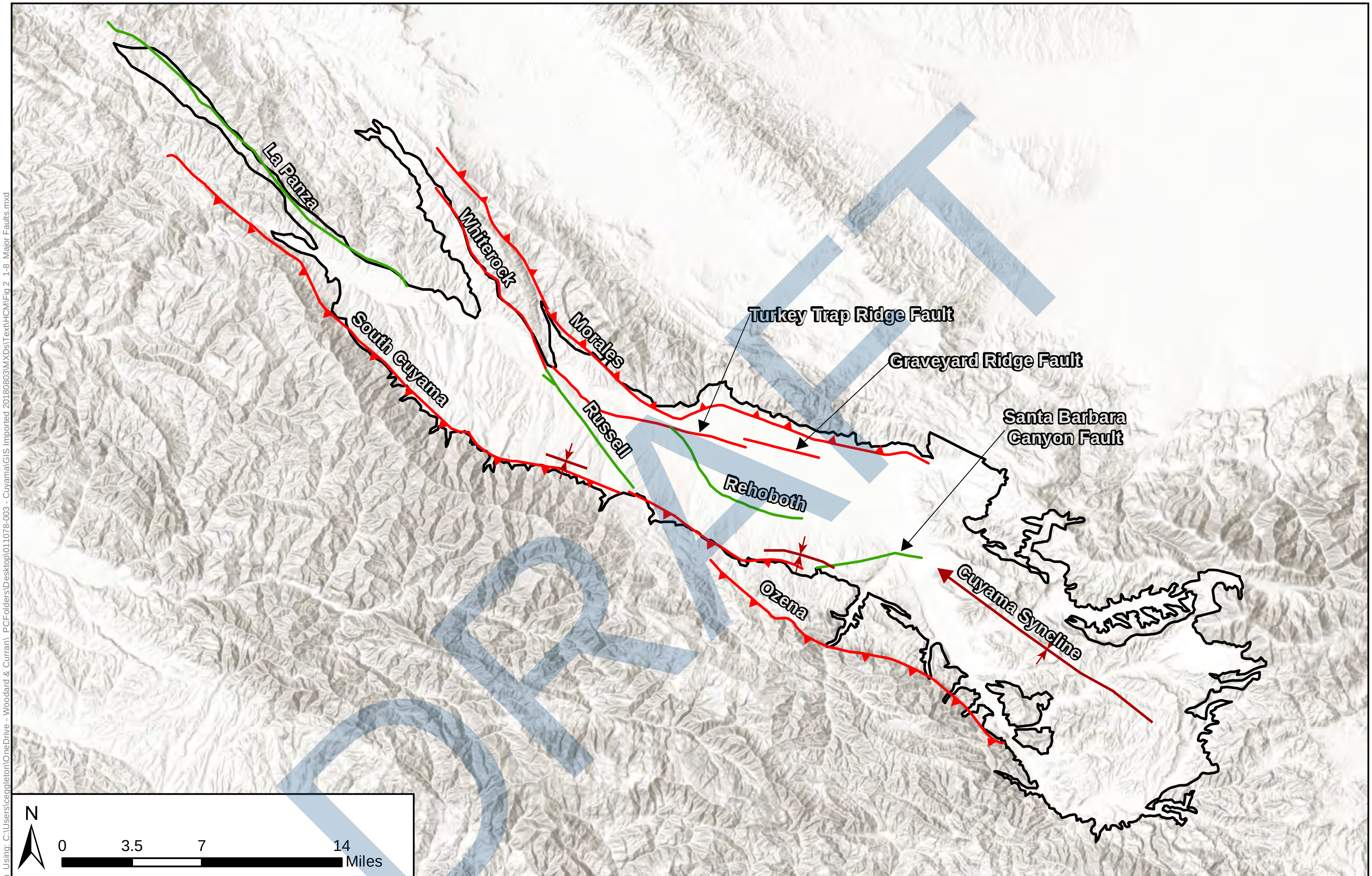





**Figure 2-8: Major Faults**

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*Legend*

**Fault Types**

Normal

Syncline

Thrust

Thrust Fault, Concealed

Cuyama Basin

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## Rehoboth Fault

The Rehoboth fault is a normal, subsurface fault that bisects the central portion of the Basin. The fault is approximately 8 miles long and trends to the southeast. The USGS concluded that evidence of the fault is inferred based on water level-changes in the west-central part of the valley and offset of the Morales Formation (USGS, 2013b; USGS, 2013a). The top of the Morales Formation is offset 160 feet on the northeast side of the fault and the offset increases with depth (USGS, 2013a). Surface exposures of the Older Alluvium do not appear to be offset along the trace of the fault, indicating the motion of the Rehoboth fault ceased prior to the deposition of the older and Younger Alluvium (USGS, 2013a).

Despite stating that the Rehoboth fault does not “have a discernible effect on the elevation” of the Older Alluvium and Younger Alluvium and that the fault was “not a significant barrier to groundwater flow” as symmetrical subsidence and uplift was observed on both sides of the fault, the USGS included the Rehoboth fault as a leaky, horizontal barrier to groundwater flow in the CUVHM (USGS, 2013a; USGS, 2013b; USGS, 2015). In the CUVHM, the Rehoboth fault impedes underflow in the Older Alluvium and Morales Formation along the Sierra Madre Foothills region (USGS, 2015). The USGS also listed the Rehoboth fault as affecting the younger and Older Alluviums and the Morales Formation in a summary table of “Geologic Units affected by Cuyama Valley faults” (USGS, 2013a).

## Whiterock Fault

The Whiterock fault is a surface and subsurface thrust fault that runs along the northern finger of the Cuyama Basin. The fault can be traced further south under the Basin near the Cuyama River and State Route (SR) 166, though it is subsurface (Calhoun, 1985). The fault dips northeast and is late Oligocene to early Miocene in age (Davis et al., 1988). The Whiterock fault is exposed at the surface where it thrusts the Monterey Formation over the Morales Formation (Davis et al., 1988). Activity along the fault began after movement ceased on the Russell fault and tectonically overrides the Russell fault (Nevins, 1982; Calhoun, 1985). The fault cuts the Morales Formation south of the Cuyama River but does not affect the younger or Older Alluviums (DeLong et al., 2011; Nevins, 1982).

## Turkey Trap Ridge Fault and Graveyard Ridge Fault

The Turkey Trap Ridge fault and the Graveyard Ridge fault are normal, subsurface faults that trend slightly north of west in the center of the Cuyama Valley (USGS, 2013a). The primary difference between the two faults is that the Turkey Trap Ridge fault is 11 miles long and located southwest of the Graveyard Ridge fault; the Graveyard Ridge fault is 4 miles long. Both faults are located north of SR 166 and are oriented in a “left-stepping, echelon pattern” (USGS, 2013a). Seismic reflection profiles collected along the ridges indicate they are bounded by north-dipping, south-directed, reverse faults along the south sides (USGS, 2013a). Both faults are considered to be barriers to groundwater. Evidence of the faults and their no-flow zones include springs and seeps along the base of the faults in the 1940-50s and water-level changes across the faults of 80 to 100 feet in the area near these ridges (Upson and Worts, 1951; Singer and Swarzenski, 1970).

In 1970, Singer and Swarzenski reported that water removed by pumping from this region was slow to replenish because faults restrict movement of water from neighboring areas. The impediment to flow could be related to the hydraulic properties of the faults themselves or fault juxtaposition of older, slightly less permeable Older Alluvium to the north against Younger Alluvium to the south of the faults (USGS, 2013a).

### South Cuyama Fault

The South Cuyama fault is a surficial, thrust fault that defines a 39-mile stretch of the Basin's southwestern boundary. The fault thrusts the Eocene-Cretaceous aged marine sediments against the Older Alluvium and Morales Formation and impedes groundwater flow across the fault zone.

### Ozena Fault

The Ozena fault is a 17-mile long surficial, thrust fault located 3 miles south of the Cuyama Basin and locally cuts through the southeastern canyons of the Basin. Less than 1 mile of the Ozena fault is within the Cuyama Basin boundary. The fault trends west to northwest and runs parallel to the Basin boundary.

### Santa Barbara Canyon Fault

The Santa Barbara Canyon fault is a normal, subsurface fault that runs 5 miles perpendicular to the Santa Barbara Canyon. The fault is east-west striking and offsets basin deposits with impermeable Eocene-Cretaceous marine rocks (typically the Simmler and Vaqueros Formations) (Bazeley, 1988). Evidence of the fault comes from reported seasonal springs, a steep hydraulic gradient in the southeastern part of the Cuyama Valley near the fault, and the truncation of distinct gravel beds (Singer and Swarzenski, 1970). Water levels in the Ventucopa area have been reported 98 feet higher than water levels to the north (Singer and Swarzenski, 1970). The fault is considered a barrier to groundwater flow as it prevents groundwater flow from moving across the boundary bounded by the marine rocks (USGS, 2015). The USGS in 2013 also concluded that the Santa Barbara Canyon fault was a barrier to groundwater flow: "Relatively small amount of vertical offset in the Santa Barbara Canyon fault indicates changes in water levels across the fault documented in previous studies are perhaps the result of distinct fault-zone properties rather than juxtaposition of units of differing water-transmitting ability" (USGS, 2013a).

### La Panza Fault

The La Panza fault is a surficial thrust fault that trends west to northwest along 22 miles of the western margin of the Basin (USGS, 2013b). The present day thrust fault is a reactivated Oligocene extensional fault that was once part of the same system with the Ozena fault (USGS, 2013b; Yeats et al., 1989). The fault defines the west-central margin of the Basin as it juxtaposes older non-water bearing Eocene to Cretaceous marine rocks and the Simmler Formation against the younger, water bearing alluvium and Morales Formation, impeding groundwater flow across the fault.

### *Morales Fault*

The Morales fault is a 30-mile-long thrust fault that forms the boundary along the north central portion of the Basin. The Morales thrust fault has a dip of approximately 30 degrees (Davis et al., 1988).

### *Unnamed Fault Near Outcrop of Santa Margarita Formation*

A fault located southwest of the Russell fault runs southeast to northwest and is located next to an outcrop of the Santa Margarita formation inside the Basin (Dibblee, 2005). The fault runs parallel to the long side of the outcrop and bounds the syncline that is to the south of the outcrop. The fault's extent is not well documented, and its surficial exposure is roughly 5 miles long.

### *Outcrops of Bedrock Inside the Basin*

There are a number of outcrops of non-aquifer material within the Basin. The outcrops occur primarily in the eastern upland portion of the Basin and the western portion, near and to the west of the Russell Fault. Outcrops of basement rock in the western portion of the Basin occur in a different manner than those in the eastern portion, outcrops in the eastern portion are likely depositional contacts with the Morales Formation that were missed during basin delineation by DWR.[1] Outcrops in the western portion are likely tied to tectonic activity and faulting.

Outcrops of basement rock in the eastern upland portion of the Basin are shown in Figure 2-2. The Quatal Formation, and the Caliente Formation are present within the Basin boundary near the edges of the Basin. The Quatal formation is exposed at the surface near the Cuyama River, and in the higher elevation portions of the Basin, and in a band near the Quatal Canyon. The Caliente Formation is exposed at the surface within the Basin in the northeast portion of the Basin, near and along the Quatal Canyon. Another outcrop of Caliente Formation is present near the Cuyama River, but that outcrop has been excluded from the Basin during the Basin's delineation by DWR and is visible in Figure 2-2.

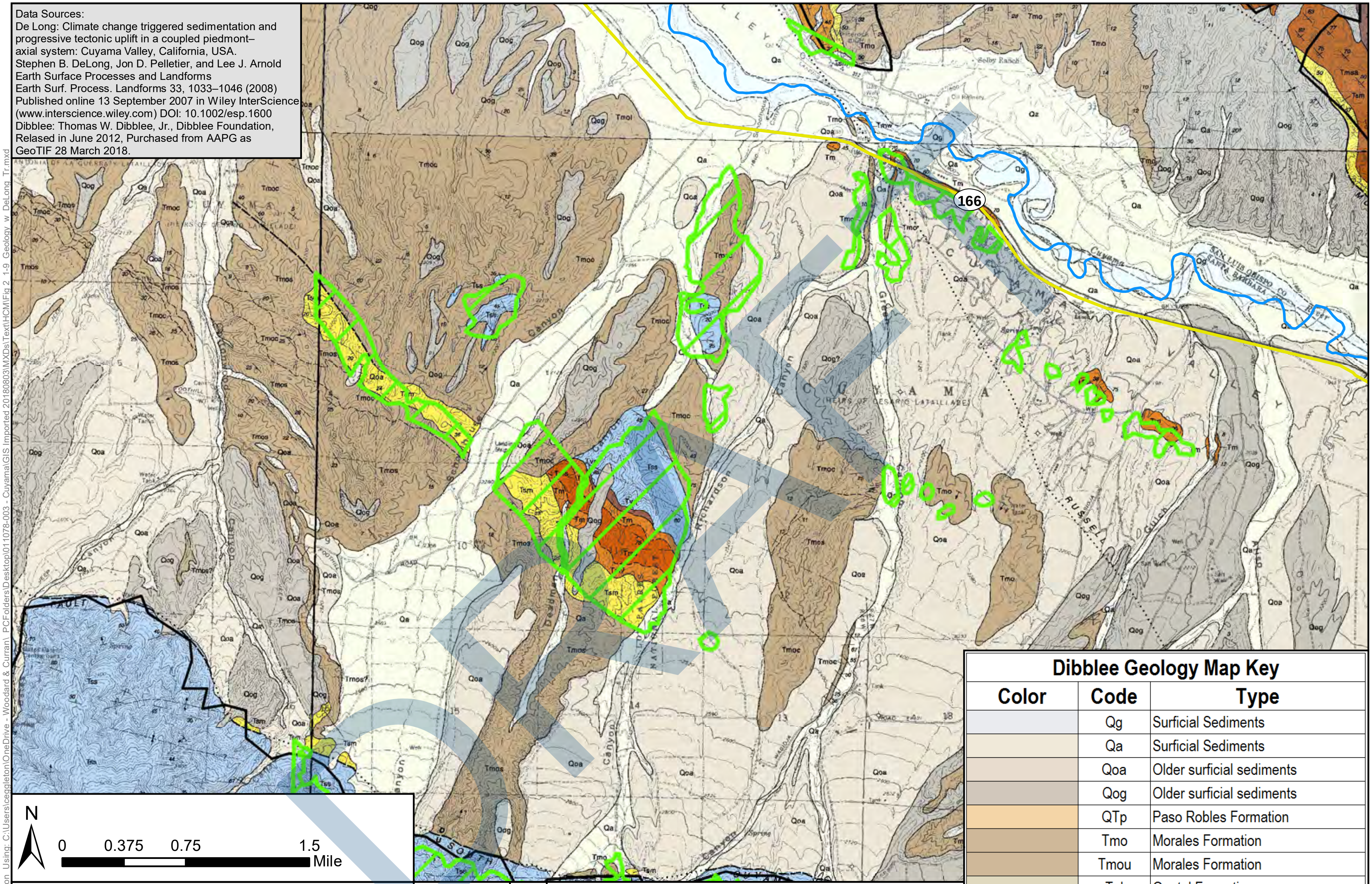
Outcrops of basement rock in the western portion of the Basin are exposed at the surface in limited areas and are tied to tectonic activity in the area.

shows the outcrops of bedrock near the Russell Fault with an overlay of areas identified by DeLong as "Tr," or out of basin bedrock, overlain on the geologic mapping performed by Dibblee. In general, the outcrops identified by DeLong and Dibblee largely overlap and indicate that in separate field study efforts, the outcrops were identified independently by different geologists. As shown in

[1] DWR delineates basins based on the type of restrictions to groundwater flow. The boundaries of the Cuyama Basin were delineated by DWR because they were the boundary between permeable sedimentary materials (within the Basin) and impermeable bedrock (outside the Basin). DWR defines this boundary as "Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock."

Figure 2-9, outcrops of non-aquifer materials are present near the Russell Fault, next to the Cuyama River, as well as to the south of the Cuyama River, both in small outcrops that are partially linear in nature, and larger outcrops that are located next to faults, such as where the Santa Margarita, Monterey and Marine Sedimentary Formations are present. The presence of these non-aquifer materials in this area likely restricts groundwater movement by limiting the extent of permeable materials in this portion of the Basin.

Data Sources:
De Long: Climate change triggered sedimentation and progressive tectonic uplift in a coupled piedmont–axial system: Cuyama Valley, California, USA.
Stephen B. DeLong, Jon D. Pelletier, and Lee J. Arnold
Earth Surface Processes and Landforms
Earth Surf. Process. Landforms 33, 1033–1046 (2008)
Published online 13 September 2007 in Wiley InterScience (www.interscience.wiley.com) DOI: 10.1002/esp.1600
Dibblee: Thomas W. Dibblee, Jr., Dibblee Foundation, Relased in June 2012, Purchased from AAPG as GeoTIF 28 March 2018.




N
0 0.375 0.75 1.5 Mile

**Figure 2-9: Geology with De Long "Tr" Overlay**

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*Legend*

- Cuyama Basin
- De Long Geology "Tr" - Out of Basin Bedrock
- Highways
- Cuyama River

**Dibblee Geology Map Key**

| Color | Code | Type |
|---|---|---|
| | Qg | Surficial Sediments |
| | Qa | Surficial Sediments |
| | Qoa | Older surficial sediments |
| | Qog | Older surficial sediments |
| | QTp | Paso Robles Formation |
| | Tmo | Morales Formation |
| | Tmou | Morales Formation |
| | Tql | Quatal Formation |
| | Tc | Caliente Formation |
| | Tsm | Santa Margarita Formation |
| | Tm | Monterey Formation |
| | Tvl | Vaqueros Formation |
| | Tvq | Vaqueros Formation |
| | Tss | Marine Sedimentary Rocks, |

Figure Exported: 8/21/2018 By: ceggleton Using: C:\Users\ceggleton\OneDrive - Woodard & Curran\ PCFolders\Desktop\011078-003 - Cuyama\GIS Imported 20180803\MXDs\Text\HCM\Fig 2 1-9 Geology w DeLong Tr.mxd

## 2.1.6 Basin Boundaries

The Basin has multiple types of basin boundaries. The majority of the boundaries are in contact with impermeable bedrock and faults, and a small portion is bounded by a groundwater divide between this Basin and the Carrizo Plain groundwater basin.

### Lateral Boundaries

The Cuyama Basin is geologically and topographically bounded; to the north by the Morales and Whiterock faults and the Caliente Range, to the west by the South Cuyama and Ozena faults and the Sierra Madre Range, to the east within the Los Padres National Forest and Caliente Range, and to the south by the surface outcrops of Pliocene and younger lithologies, which are surrounded by Miocene and older consolidated rocks (Dudek, 2016). The boundaries of the Cuyama Basin were delineated by DWR in Bulletin 118 because they were the boundary between permeable sedimentary materials and impermeable bedrock. DWR defines this type boundary as: “Impermeable bedrock with lower water yielding capacity. These include consolidated rocks of continental and marine origin and crystalline/or metamorphic rock” (DWR, 2003). The thrust faults bounding the Cuyama Basin juxtapose younger, water-bearing lithologies against older, impermeable rocks. The consolidated continental and marine rocks and shales of the bordering mountain ranges mark a transition from the permeable aquifer sediments to impermeable bedrock.

### Boundaries with Neighboring Subbasins

The Cuyama Basin shares a boundary to the east with the Carrizo Plain Groundwater Basin (Carrizo Plain Basin) and the Mil Potrero Area Groundwater Basin, as shown in Figure 1-3. The Cuyama and Carrizo Plain basins share a 4-mile boundary along Caliente Ranges, which is a groundwater divide basin boundary. DWR defines this type of boundary as “A groundwater divide is generally considered a barrier to groundwater movement from one basin to another for practical purposes. Groundwater divides have noticeably divergent groundwater flow directions on either side of the divide with the water table sloping away from the divide” (DWR, 2003).

The Cuyama and Mil Potrero basins are share a less than 1 mile boundary along the San Emigdio Canyon. The division between the Cuyama and Mil Potrero basins is also a groundwater divide basin boundary.

### Bottom of the Cuyama Basin

The bottom of the Basin is generally defined by the base of the upper member of the Morales Formation (USGS, 2015). The lower member of the Morales Formation is composed of clay, shale, and limestone and is less permeable than the upper member of the Morales Formation (USGS, 2013a). The USGS describes the Morales Formation (both the upper and lower member combined) as up to 5,000 feet thick (USGS, 2013a). The top of the Morales Formation is generally encountered 750 feet below ground surface (bgs) but ranges up to 1,750 feet bgs in the Sierra Madre Foothills (USGS, 2013a). When referring to the Morales Formation in the context of the Cuyama aquifer, this is a reference to only the upper member of the Morales Formation.

### 2.1.7 Principal Aquifers and Aquitards

There is one principal aquifer in the Basin composed of the Younger Alluvium, Older Alluvium, and the Morales Formation. DWR's *Groundwater Glossary* defines an aquifer as "a body of rock or sediment that is sufficiently porous and permeable to store, transmit, and yield significant or economic quantities of groundwater to wells and springs." Most of the water pumped in the valley is contained in the younger and Older Alluviums. These two units are indistinguishable in the subsurface and are considered, hydrologically, one unit. There are no major stratigraphic aquitards or barriers to groundwater movement, amongst the alluvium and the Morales Formation. The aquifer is considered to be continuous and unconfined with the exception of locally perched aquifers resulting from clays in the formations.

#### Aquifers

The aquifers making up the principal aquifer in the Cuyama Basin are Younger Alluvium, Older Alluvium, and the Upper Member of the Morales Formation. These units consist of unconsolidated to partly consolidated sand, gravel, silt, clay, and cobbles within alluvial fan and fluvial deposits and in total range from 3,000 to 4,000 feet in thickness (Upson and Worts, 1951). Rocks older than the upper Morales Formation are generally considered either non-water bearing or contain water, but the water is released too slowly or of quality that is too poor for domestic and irrigation uses (USGS, 2013a). Historically, most of the water pumped in the Cuyama Valley has been extracted from the Younger and Older alluvium.

#### Recent and Younger Alluvium

Historically, most of the water pumped in the Cuyama Basin was sourced from the saturated portions of the Younger and Older alluvium (Singer and Swarzenski, 1970). Groundwater is found in the permeable Holocene alluvial fill and in the underlying, less permeable, Pliocene-Pleistocene continental deposits. Younger Alluvium deposits thicken to the east, typically ranging from 5 to 50 feet in the west and thicken from 630 to 1,100 feet in the east (Singer and Swarzenski, 1970).

The Younger Alluvium varies compositionally across the Basin (Upson and Worts, 1951). The Recent and Younger alluvium is the primary source of groundwater on the western side of the Basin. In the west, Younger Alluvium consists of interbedded layers of sand and gravel and thick beds up clay (ranging from 1 to 36 feet thick) (Upson and Worts, 1951). Clay beds, found 100 to 150 feet bgs, define the base of the Younger Alluvium (Upson and Worts, 1951). Wells in the western part of the Basin that are screened in the Younger Alluvium are shallow but have moderately large yields, as the sands and gravels have high permeabilities (Singer and Swarzenski, 1970).

In the south-central part of the Basin, the alluvium contains more gravel and is less fine grained compared to western alluvium. The alluvium is predominantly sand and silt with some beds of gravel and clay, though no continuous layers of any material exist (Upson and Worts, 1951).

### Older Alluvium

Older Alluvium consists of unconsolidated to partly consolidated sand, gravel, boulders, and some clay. Similar to the Younger Alluvium, clay content increases to the west (Upson and Worts, 1951). Like the Younger Alluvium, historically most of the water pumped in the Cuyama Basin was sourced from the saturated portions of the younger and Older Alluvium (Singer and Swarzenski, 1970). More wells are perforated in the Older Alluvium in the western portion of the Basin than to the east (USGS, 2013c). In most regions of the Basin, the top of the saturated zone (the water table) is either deep in the alluvium or below its base (Upson and Worts, 1951).

### Upper Morales Formation

The Pliocene to Pleistocene-aged Morales Formation is divided into two members, the upper and lower. The upper member of the Morales Formation is composed of partly consolidated, poorly sorted deposits of gravelly arkosic sand, pebbles, cobbles, siltstone, and clay and is considered water bearing (USGS, 2013a). Water bearing properties of the Morales Formation are not well defined, but available data indicate that the hydraulic conductivity of the formation varies greatly laterally and with depth (USGS, 2013c). Permeabilities of the upper Morales Formation vary greatly laterally and with depth; the highest values occur in the syncline beneath the central part of the valley and decrease to the west (Singer and Swarzenski, 1970). In the east and southeastern parts of the valley where the Morales Formation crops out, the formation is coarse grained and moderately permeable, but land is topographically unsuited to agricultural development and few wells have been installed.

### Aquifer Properties

The highest yielding wells are screened in the alluvium and located in the north-central portion of the Basin. Pumping in the alluvium also occurs in the eastern part of the Cuyama Valley, along the Cuyama River and its tributary canyon as far as a few miles upstream from Ozena (Singer and Swarzenski, 1970).

### Hydraulic Conductivity

DWR defines hydraulic conductivity as the “measure of a rock or sediment’s ability to transmit water” (DWR, 2003). The hydraulic conductivity is variable within the principal aquifer, varying laterally, vertically, and amongst the three aquifer formations. In general, conductivity is highest near the center of the Basin and decreases to the west and east with the highest values associated with the Younger Alluvium and the Morales Formation with the lowest. Conductivity data are widely available for the central portion of the Basin (near the towns of New Cuyama and Cuyama) and near the western vineyards; data are sparse elsewhere.

Available data from field tests (including pump and slug tests) were reviewed from the following sources:

- 3 multi-completion USGS wells (USGS, 2013c)
- 51 PG&E wells (USGS, 2013c)
- 66 private landowner wells in the central portion of the Basin
- 2 private landowner wells in the western portion of the Basin

Figure 2-10 shows the locations of these wells. Dates of field tests range from 1942 (PG&E tests) to 2018 (Grapevine Capital tests), and wells are screened in all three of the main aquifer formations, including the Younger Alluvium, Older Alluvium, and Morales Formation. Additional sources include the USGS's 2015 *Hydrologic Models and Analysis of Water Availability in Cuyama Valley, California,* which describes conductivity values used in the CUVHM, along with Singer and Swarzenski (1970) and a 2011 USGS study. The CUVHM characterizes the recent and Younger Alluvium as having the highest hydraulic conductivity of all aquifer units (USGS, 2015). Conductivity values calculated from field tests for the wells are used to characterize each aquifer formation, as described below and summarized in Table 2-1.

**Recent and Younger Alluvium** – As shown in Table 2-1, wells screened exclusively in the Younger Alluvium in the central portion of the Basin have hydraulic conductivities ranging from 1 to 31.9 feet per day and a median conductivity of 9.5 feet per day. Wells screened in both the younger and Older Alluvium in the central portion of the Basin had a higher median conductivity of 10.1 feet per day. Field tests are lower than those reported by the USGS in 2015 which reported hydraulic conductivity for the recent and Younger Alluvium ranged from 5.2 to 85 feet per day (USGS, 2015). Within the Recent and Younger Alluvium, the highest horizontal conductivity is near the Cuyama River. Vertical conductivity ranges from 0.2 feet per day in tributaries crossing the alluvium in areas west of the Russell fault up to 49 feet per day in the Cuyama River in the Ventucopa Uplands (USGS, 2015).

**Older Alluvium** – In the central portion of the Basin, hydraulic conductivity in the Older Alluvium ranges from 0 to 81.2 feet per day, with a median conductivity of 16 feet per day. Field tests are higher than those reported by the USGS in 2015, which reported conductivity for the Older Alluvium ranges from 0.3 to 28 feet per day in the central Basin (USGS, 2015; USGS, 2011). West of the Russell fault, conductivity ranges from 0.77 to 1.79 feet per day with a median value of 1.24 feet per day in areas west of the Russell Fault, near the vineyards. Conductivity generally decreases with depth. Field data show that while the range in hydraulic conductivity for wells screened in both the Older Alluvium and Morales Formation is lower than wells screened exclusively in the Older Alluvium (ranging from 0 to 61.2 feet per day), the median value is higher at 21.4 feet per day. The USGS calculated the median hydraulic conductivity for the Older Alluvium (15 feet per day) to be about five times the estimated value for the Morales Formation (i.e., 3.1 feet per day) (USGS, 2013c).

**Morales Formation** – The Morales Formation has the lowest hydraulic conductivity of all aquifer units. In the central portion of the Basin, conductivity for wells exclusively screened in the Morales Formation range from 1.6 to 9.9 feet per day, with a median value of 3.15 feet per day. Two wells were interpreted to be screened exclusively in the Morales Formation west of the Russell fault; hydraulic conductivity for these wells ranges from 1.6 – 1.98 feet per day. The hydraulic conductivity of the Morales Formation decreases with depth and the lower member of the formation (the clay and limestone unit) has a lower conductivity than the upper member (sandstone). The highest values in the Morales Formation occur in the central portion of the valley and decrease west (Singer and Swarzenski, 1970).

**Table 2-1: Summary of Hydraulic Conductivities in Aquifer Formations**

| Well Owner | Number of Wells | Formation(s) Well is Screened In | Conductivity Range (feet/day) | Median Conductivity (feet/day) |
|---|---|---|---|---|
| USGS | 6[a] | Older Alluvium | 1.5 – 18.1 | 15 |
| | 6[a] | Upper Morales Formation | 1.6 – 9.9 | 3.15 |
| PG&E[b] | 22 | Younger Alluvium | 1 - 30 | 9 |
| | 19 | Younger and Older Alluvium | 0.1 - 37 | 4.5 |
| | 8 | Older Alluvium | 0.1 – 17 | 4 |
| | 2 | Older Alluvium and Upper Morales Formation | 0.1 – 4 | 2 |
| Private Landowners, Central Portion of the Basin[c] | 2 | Younger Alluvium | 28.9 – 31.9 | 30.4 |
| | 19 | Younger Alluvium and Older Alluvium | 3.9 – 68.6 | 17.1 |
| | 6 | Younger Alluvium and Upper Morales Formation | 1 – 21.3 | 12 |
| | 16 | Older Alluvium | 3.2 – 81.2 | 17.15 |
| | 23 | Older Alluvium and Upper Morales Formation | 3.6 – 61.2 | 23 |
| Private Landowners, Western Portion of the Basin[c] | 4 | Older Alluvium | 0.77 – 1.79 | 1.47 |
| | 6 | Older Alluvium and Upper Morales Formation | 0.64 – 1.59 | 1.22 |
| | 2 | Upper Morales Formation | 1.6 – 1.98 | 1.79 |

Notes:
[a]Three wells with four completions each; each well completion is reported as a single well.
[b]Conductivity estimated using transmissivity field tests.
[c]Conductivity estimated using specific capacity field tests.

## Specific Yield

DWR defines specific yield as the "amount of water that would drain freely from rocks or sediments due to gravity and describes the portion of groundwater that could actually be available for extraction" (DWR, 2003). Specific yield is a measurement specific to unconfined aquifers, such as the primary aquifer in the Cuyama Basin.[2] The dewatered alluvium has an average specific yield of 0.15 (Singer and Swarzenski, 1970). The USGS estimated the specific yields of the three aquifer formations during CUVHM calibration, calculating that the recent alluvium had the lowest specific yield ranging from 0.02 to 0.14, the Older Alluvium has a specific yield ranging from 0.05 to 0.19, and the Morales Formation has the highest specific yield ranging from 0.06 to 0.25 (USGS, 2015).

## Specific Capacity

Specific capacity is defined as "the yield of the well, in gallons per minute, divided by the pumping drawdown, in feet" (Singer and Swarzenski, 1970). Specific capacity in the aquifer varies laterally and vertically but is typically highest in the Younger Alluvium and lowest in the Morales Formation. Wells perforated in the Younger Alluvium have a median specific capacity of 60 gallons per minute (gpm) per foot (USGS, 2013c). Wells perforated in both the Younger and Older alluvium have a median specific capacity of 40 gpm per foot (USGS, 2013c). Wells perforated in the Older Alluvium have a median specific capacity of 20 gpm per foot (USGS, 2013c). The silt and clay content of the Older Alluvium increases to the west and corresponds to a decrease in specific capacity in the alluvium; specific capacities are less on the western half of the valley compared to the eastern half. However, a greater percentage of wells in the western part are perforated in the Older Alluvium (USGS, 2013c). The specific capacity of the Morales Formation varies laterally but is generally less than the specific capacity of the younger and Older Alluvium. In the western part of the valley, the Morales Formation has a specific capacity ranging from 5 to 25 gpm per foot. In the north north-central portion of the Basin the specific capacity increases to 25 to 50 gpm per foot (Singer and Swarzenski, 1970).

## Transmissivity

DWR defines transmissivity as the "aquifer's ability to transmit groundwater through its entire saturated thickness" (DWR, 2003). Using aquifer tests from 63 wells (shown in Figure 2-10), estimates of transmissivity ranged from 560 to 163,400 gallons per day per foot (gpd/foot) and decreased with depth (USGS, 2013c). Among the aquifer units, wells screened in the Younger Alluvium had the highest transmissivity, with a median value of 15,700 gpd/foot (USGS, 2013c). Wells screened in Older Alluvium had a transmissivity three times less than the Younger Alluvium wells, at a median value of 5,000 gpd/foot (USGS, 2013c). Wells screened in both the younger and alluvium had a median transmissivity of 11,300 gpd/foot (USGS, 2013c). Data from the 61 wells were not available for the Morales Formation, but a transmissivity estimate from two wells screened in both the Older Alluvium and Morales Formation averaged 4,900 gpd/foot (USGS, 2013c). Using groundwater level contours, Singer and Swarzenski determined the range of transmissivity values in the Morales Formation to change much

[2] For confined aquifers, the measurement of "storativity" is used instead of specific yield.

more than the transmissivity values of the younger and Older Alluvium; in general, values are highest in the central portion of the valley and decline to the west as the thicknesses of the younger and Older Alluvium become more shallow.

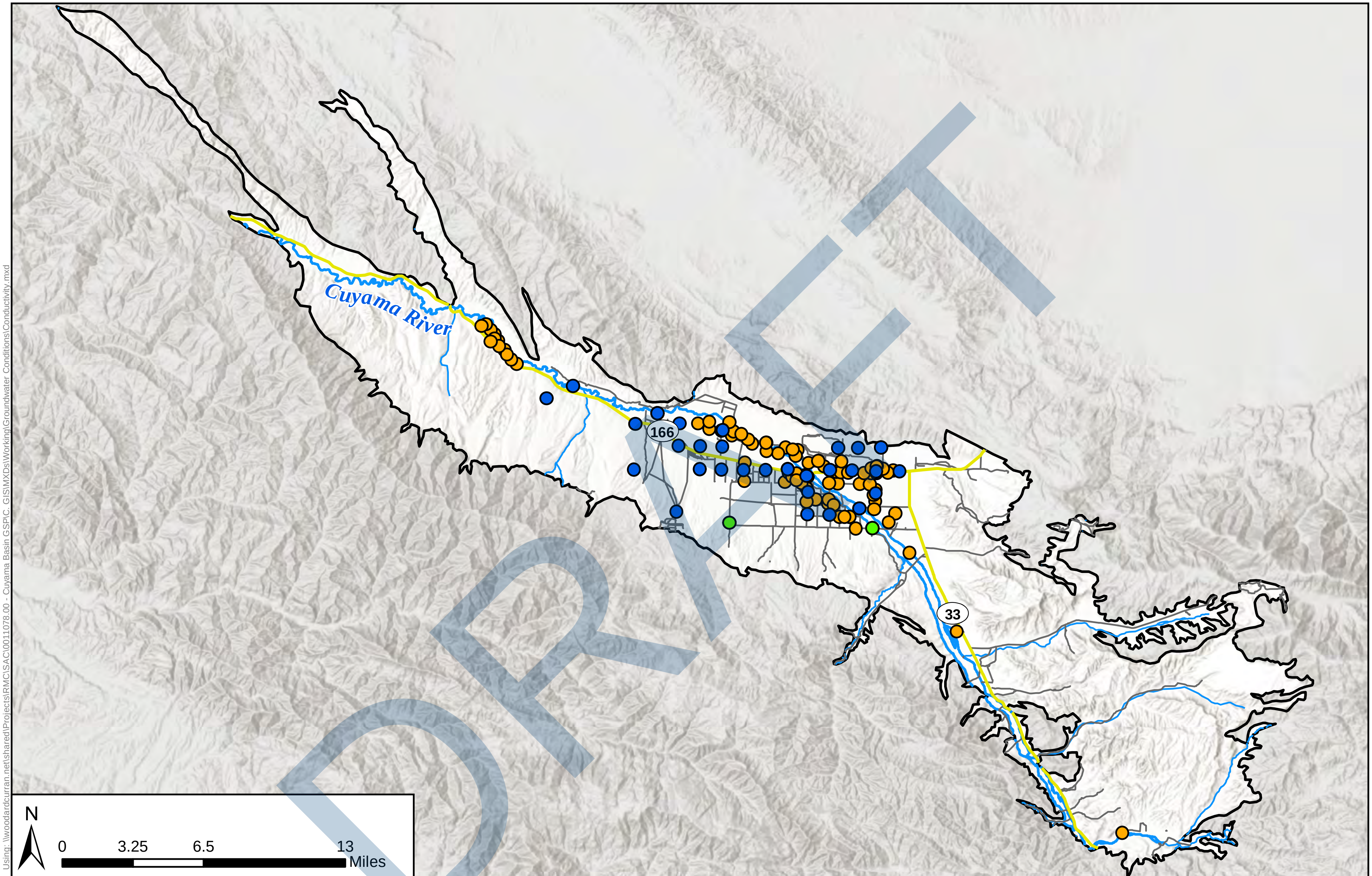


**Figure 2-10: Location of Aquifer Testing Wells**

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*Legend*

- Highways
- Local Roads
- Cuyama River
- Streams
- Cuyama Basin

**Well Owner**

- Private Landowners
- PG&E
- USGS

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### 2.1.8 Natural Water Quality Characterization

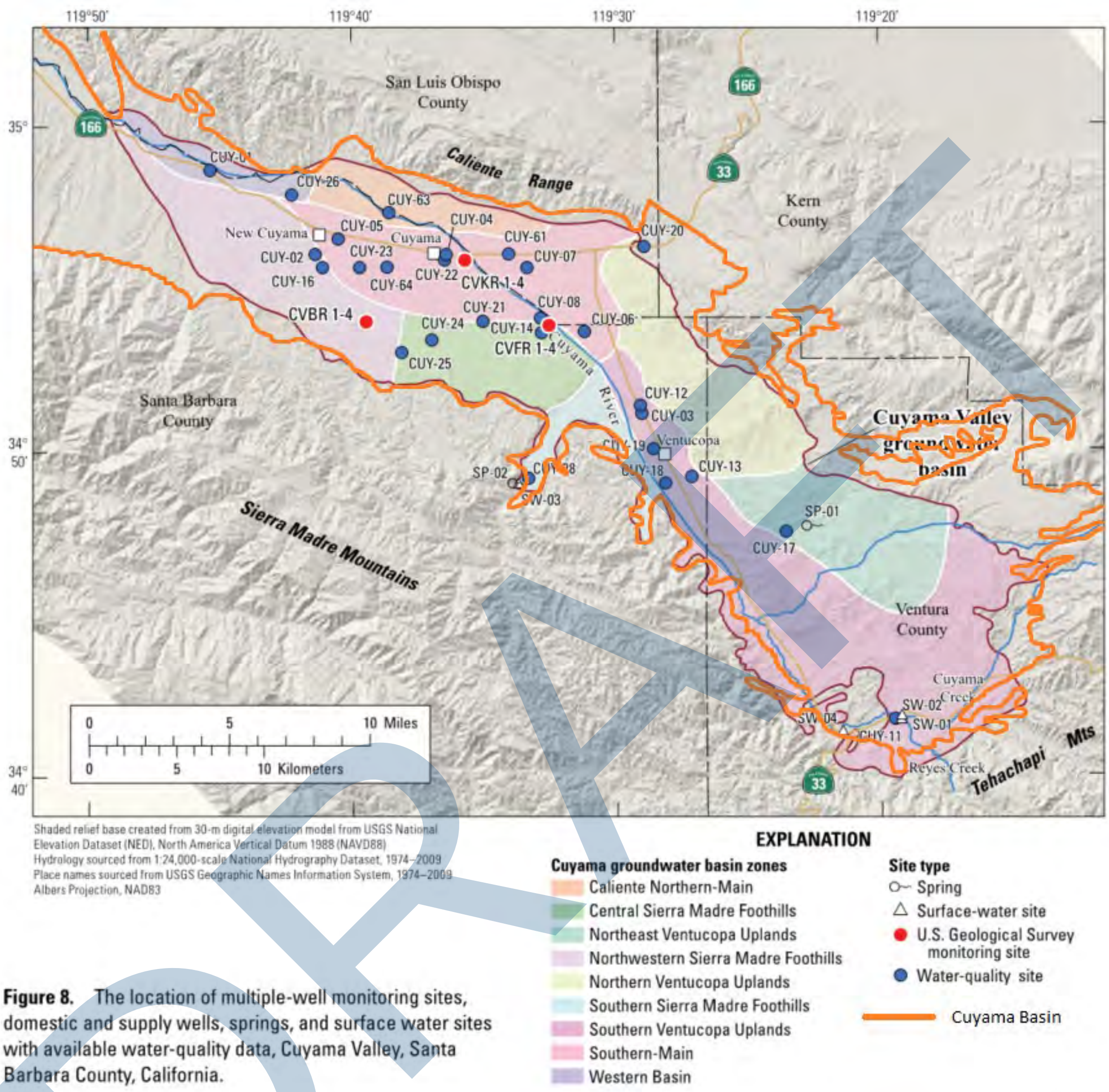
Water quality in the Basin has historically had a high level of TDS and sulfates. High concentrations of other constituents, such as nitrate, arsenic, sodium, boron, and hexavalent chromium are localized (USGS, 2013c). Locations where water quality measurements were taken by the USGS are shown in Figure 2-11.

Singer and Swarzenski studied groundwater in the Basin in 1970. Groundwater ranged from hard to very hard and is predominantly of the calcium-magnesium-sulfate type (Singer and Swarzenski, 1970). Averages of concentrations include 30 milligrams per liter (mg/L) chloride, 0.20 mg/L of boron, and 1,500 to 1,800 mg/L TDS (Singer and Swarzenski, 1970). Along the periphery of the Basin, groundwater quality is variable. Along the southern boundary and near the eastern badlands, the groundwater quality reflects the recharge from springs and runoff from the Sierra Madre Mountains; TDS concentrations range from 400 to 700 mg/L and most of the water is sodium calcium bicarbonate (Singer and Swarzenski, 1970). Along the eastern edge of the valley, near the Caliente Range, water quality declines as concentrations of sodium, chloride, TDS, and boron increase. Concentrations of boron range up to 15 mg/L, concentrations of chloride increase up to 1,000 mg/L, and TDS concentrations range from 3,000 to 6,000 mg/L (Singer and Swarzenski, 1970).

Singer and Swarzenski in 1970 also concluded that the Basin's water quality potentially results from the mixing of water from the marine rocks: "This water quality presumably results from the mixing of water from the marine rocks of Miocene age with the more typical water from the alluvium and is characterized by increased sodium, chloride, and boron. Although chloride and boron concentrations commonly are less than 30 and 0.20 mg/L, respectively, in the central part of the valley, the water from many wells is close to the Caliente Range contains several hundred to nearly 1,000 mg/L of chloride and as much as 15 mg/L of boron." (Singer and Swarzenski, 1970). Singer and Swarzenski did not provide a map showing their sampling locations.

In 2011, the USGS published the *Kirschenmann Road Monitoring Well Site Open File Report* (USGS, 2011), which included analysis of major-ion composition for samples collected from the multiple-well monitoring site CVKR, and samples from selected water supply and irrigation wells in the Cuyama Valley. Figure 2-12 shows a Piper diagram of the major-ion analysis. Figure 2-12 shows that groundwater in the central portion of the Basin shares similar major-ions, and is largely chloride, fluoride, sulfate and calcium magnesium type water. Figure 2-13 shows the locations USGS sampled to perform this analysis.

In 2017 EKI compiled water quality data contained in the appendices of the USGS report *Geology, Water-Quality, Hydrology, and Geomechanics of the Cuyama Valley Groundwater Basin, California, 2008-12* (USGS 2013c). and prepared a Piper diagram with the data (Figure 2-14). The locations of the data used in this Piper diagram are shown in Figure 2-15. The Piper diagram shows the majority of samples indicate that water in the Basin can be characterized as calcium-magnesium sulfate waters, which agrees with conclusions made by USGS in 2013.




Source: USGS, 2013c.

**Figure 2-11: Location of USGS 2013 Groundwater Quality Sampling Sites**

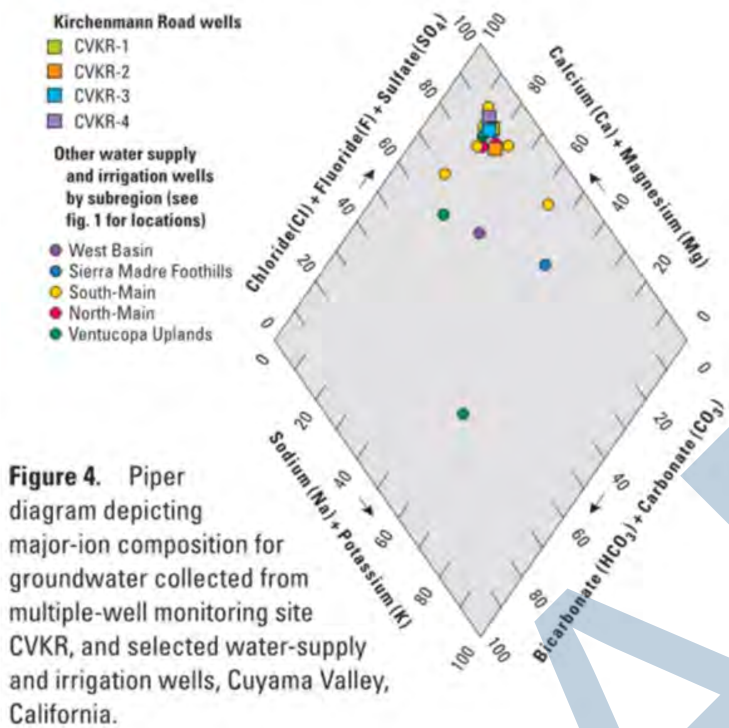



**Figure 2-12: Piper Diagram for Well CVKR1-4**

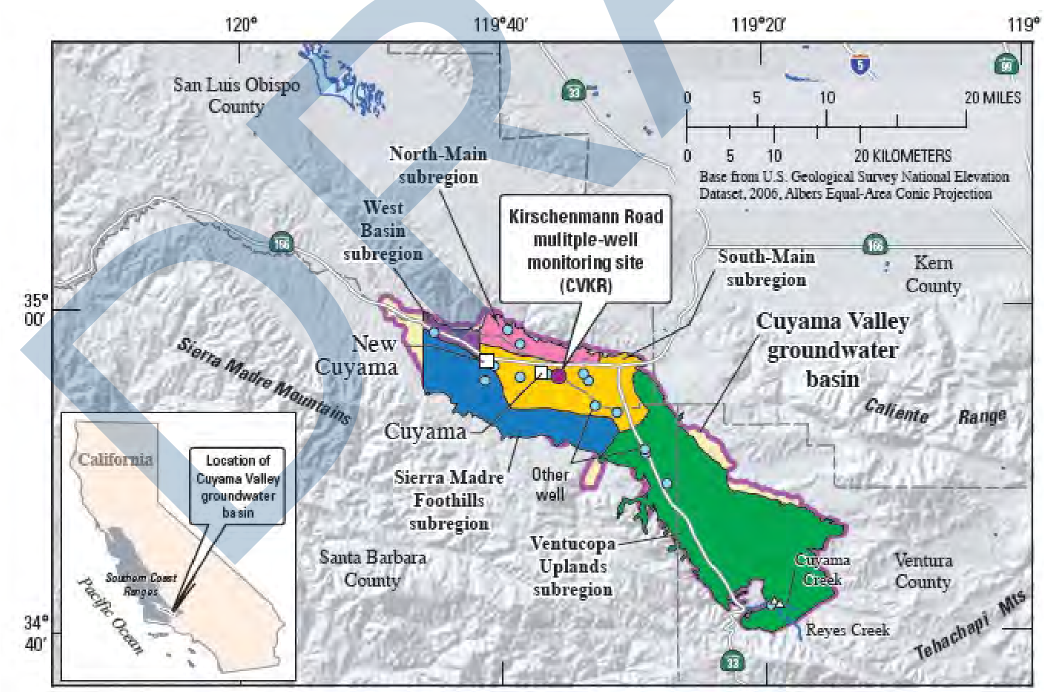



**Figure 2-13: Location Map for Samples Used in Figure 2-12**

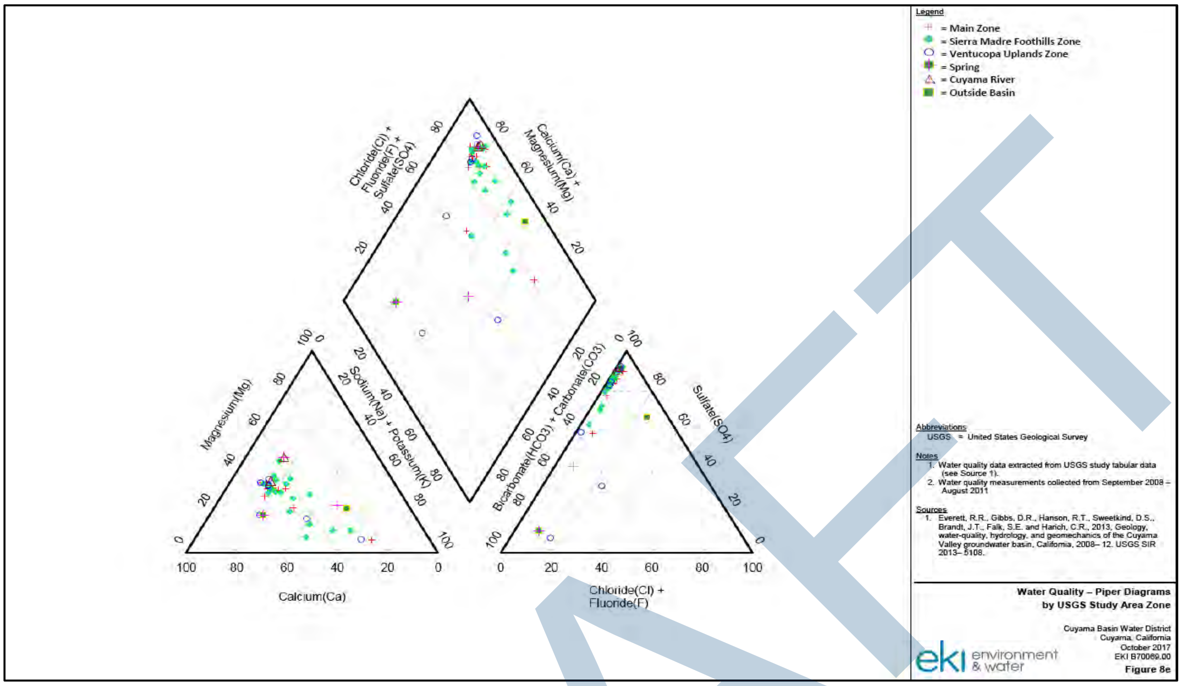



Figure 2-14: Piper Diagram of USGS 2013 Water Quality Sampling

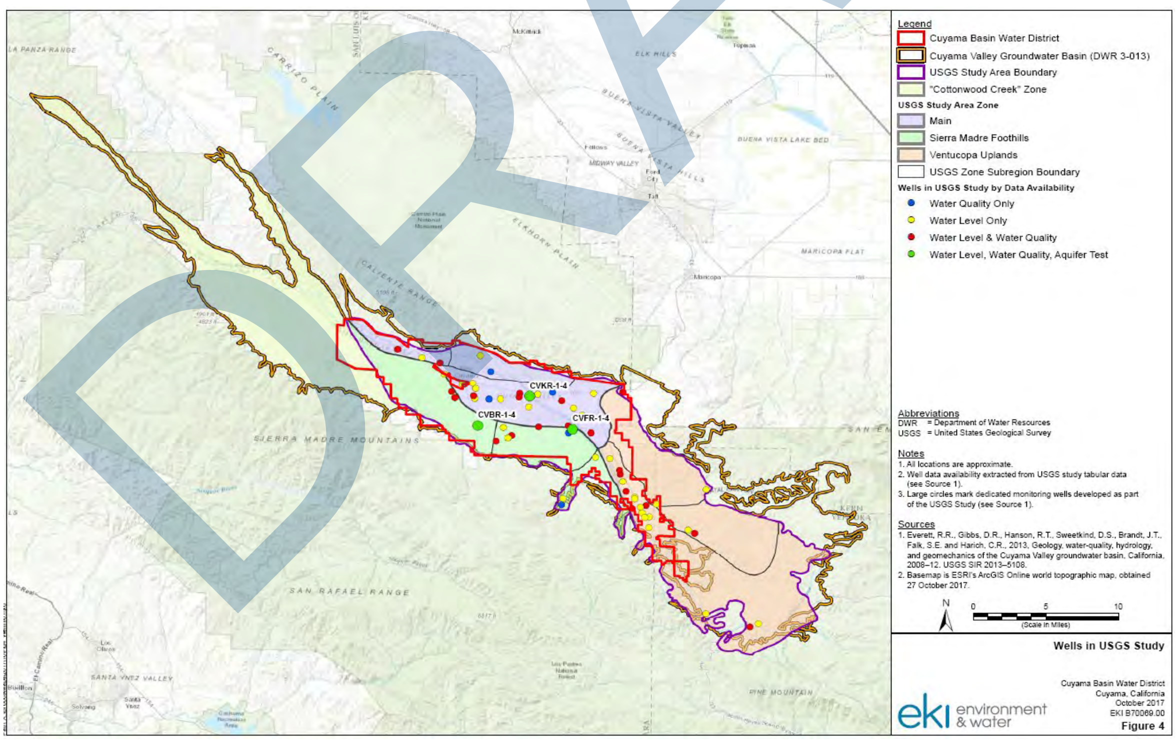



Figure 2-15: Location Map of USGS 2013 Sampling

### Aquifer Use

The Cuyama Valley is dependent on groundwater as its sole source of supply. Groundwater is used for irrigation, domestic and municipal use (USGS, 2013c). The majority of agricultural activity occurs between the New Cuyama and Ventucopa areas, and west of the Russell fault near the north fork.

## 2.1.9 Topography, Surface Water and Recharge

This section describes the topography, surface water, soils, and groundwater recharge potential in the Basin. There are no imported water supplies to the Cuyama Basin and are not discussed in this section.

### Topography

The Basin is lowest in the northwest, and highest in the southeast. The lowest elevation in the Basin is located at the west edge where the Cuyama River exits at approximately 1,300 feet, while the highest point is approximately 7,250 feet on the eastern boundary. Figure 2-16 shows the topographic characteristics of the Basin. The south facing northern slopes of the valley are generally steeper than the north facing south slopes. The eastern portion of the Basin along the valley walls becomes steep, characterized by mountainous runoff-cut topography.

### Surface Water Bodies

The Cuyama River is the primary surface water feature in the valley and flows from an elevation of 3,800 feet on the eastern side to the west of the Basin to 1,300 feet at the western outlet of the Basin. The Cuyama River travels approximately 55 miles through the Basin and has a slope ratio of approximately 1:125. The river is perennial, with most dry seasons seeing little to no flows. Large flows usually occur in flashes due to the small watershed and storms that provide precipitation onto the surrounding Coastal Range Mountains. Peak flows through the Cuyama River, dated between 1929 and 2017, range from approximately 6,000 cubic feet per second to the highest recorded flow of 15,500 cubic feet per second on February 18, 2017 (National Watershed Information System [NWIS], 2018). There are approximately four main perennial streams that feed the Cuyama River: Aliso Creek, Santa Barbara Creek, Quatal Canyon Creek, and Cuyama Creek. However, during precipitation events many more smaller streams flow from the valley walls and surrounding mountains. Figure 2-17 shows the locations of surface water bodies in the Basin.

Downstream on the Cuyama River lies Twitchell Reservoir, however this is an artificial body of water outside of the Basin.

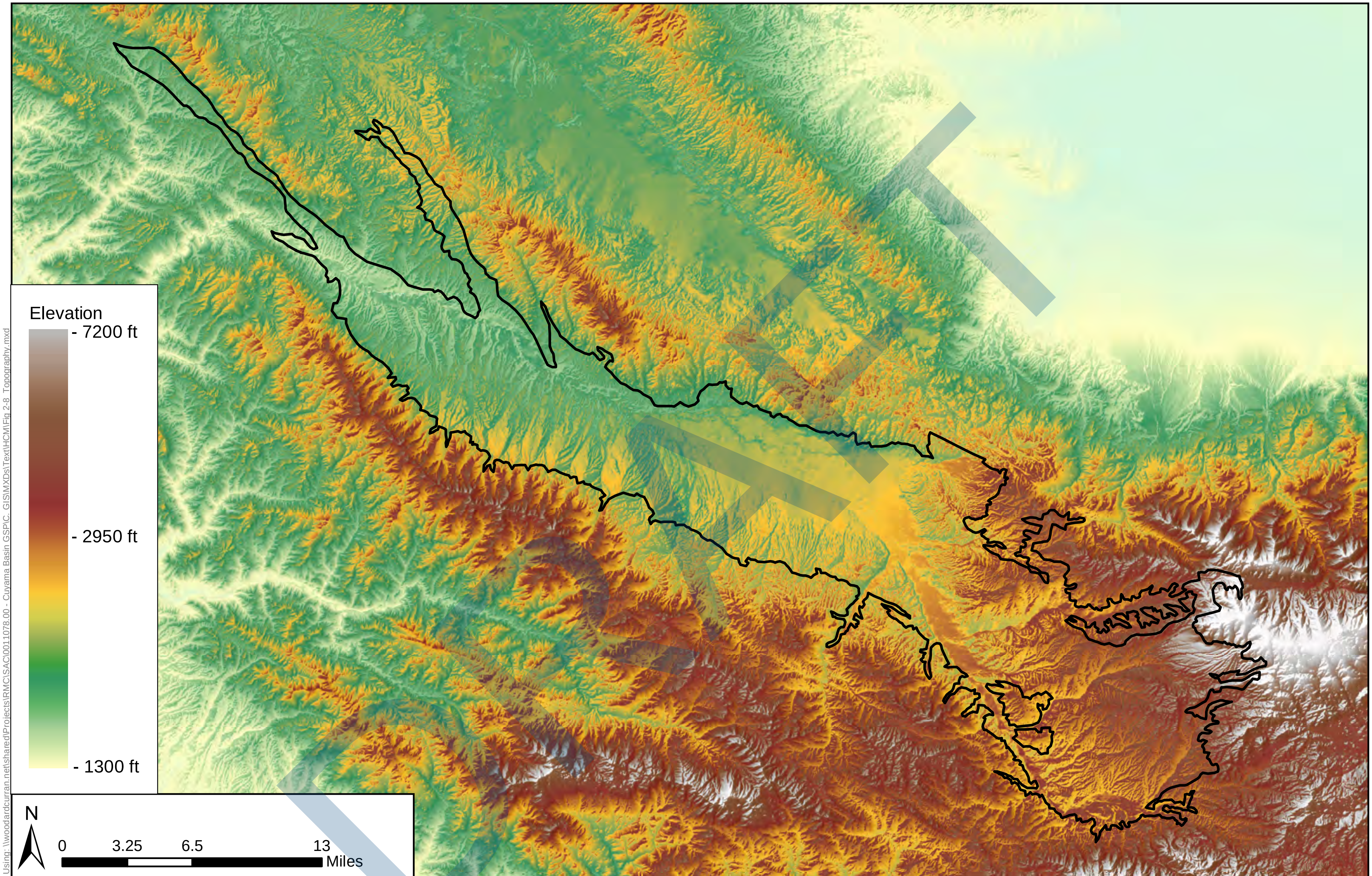



**Figure 2-16: Topography**

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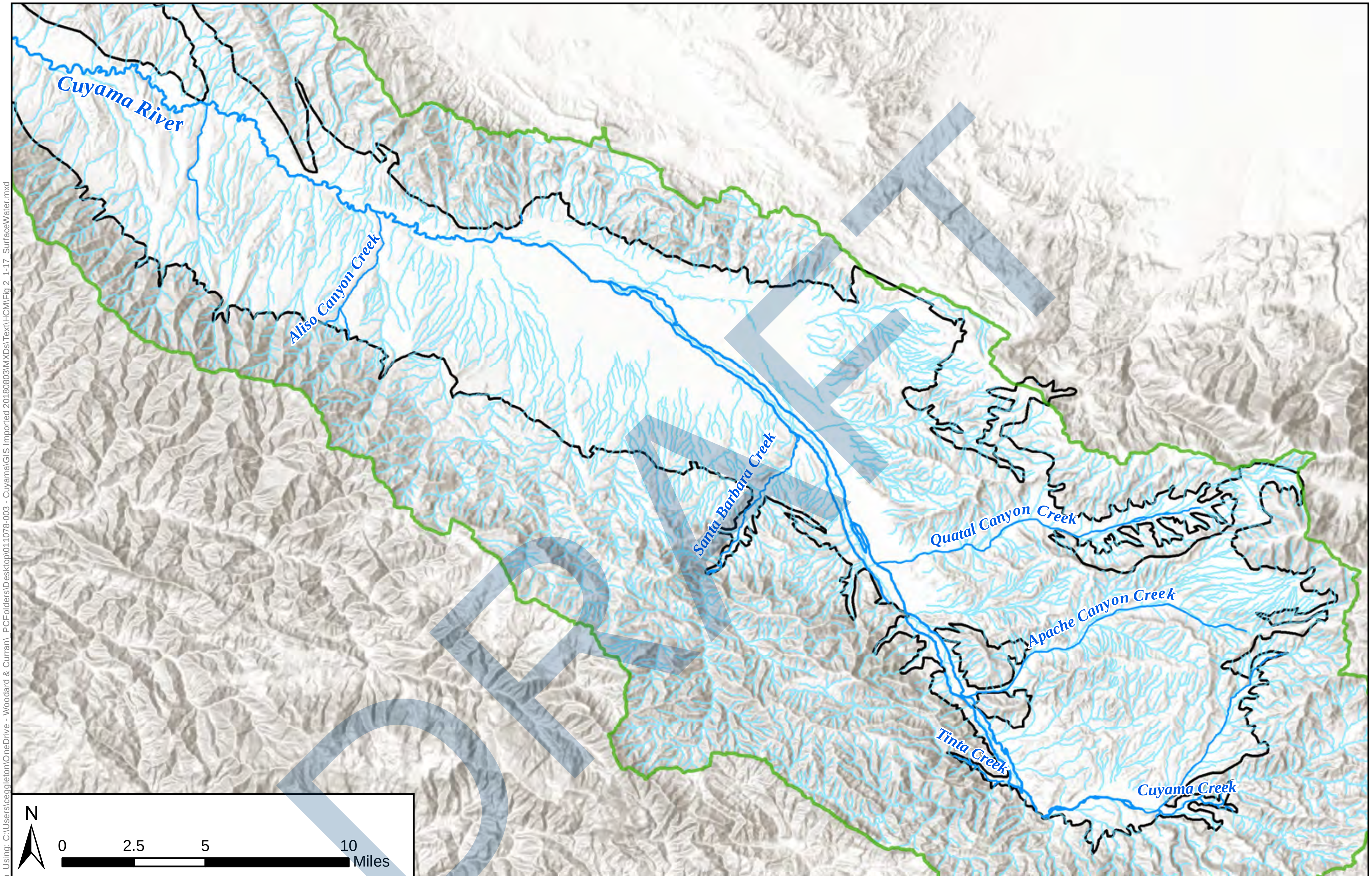




**Figure 2-17: Surface Water**

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*Legend*

- Cuyama Basin
- Cuyama Watershed
- Cuyama River
- Major Cuyama GW Basin Streams
- All Other NHD Flow Lines, Creeks, and Streams in the Cuyama Watershed

## Areas of Recharge, Potential Recharge, and Groundwater Discharge Areas

Areas of recharge and potential recharge lie primarily within the central and low-lying areas of the Cuyama Valley. Agricultural and open space lands are considered areas of potential recharge. Figure 2-18 shows areas with their potential for groundwater recharge, as identified by the Soil Agricultural Groundwater Banking Index (SAGBI). SAGBI provides an index for the groundwater recharge for agricultural lands by considering deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. SAGBI data categorizes 22,675 acres out of 37,568 acres (60 percent) of agricultural and grazing land within the Basin as moderately good, good, or excellent for groundwater recharge (University of California, Davis, 2018). SAGBI data shown in

Figure 2-18 is derived from "modified" SAGBI data. "Modified" SAGBI data show higher potential for recharge than unmodified SAGBI data because the modified data assume that the soils have been or will be ripped to a depth of 6 feet, which can break up fine grained materials at the surface to improve percolation.

Groundwater discharge areas are identified as springs located within the Basin.

Figure 2-18 shows the location of historical springs identified by the USGS (NWIS, 2018). The springs shown in represent a dataset collected by the USGS and are not a comprehensive map of springs in the Basin.

## Soils

Soils in the Basin were categorized by the National Resource Conservation Service (NRCS). The Basin is comprised mostly of fine- to coarse-loamy soils (NRCS STATSGO2, 2018). As shown in Figure 2-19, the valley bottom and primary soil surrounding the Cuyama River and its tributaries is primarily fine-loamy soils, while the northern boundary of the Basin has coarse-loamy soils.

Figure 2-20 shows soils by hydrologic soil group. Hydrologic soil groups were calculated by the NRCS on a by-county basis. As shown in Figure 2-20, interpretations of soil groups varied by county in each study. In general, hydrologic soil groups are sorted by permeability, with class A being the most permeable and class D being the least permeable. Figure 2-20 shows that in general most of the soils in the Basin have lower permeabilities and are listed as class C or D, with higher permeabilities being located near streams and rivers.

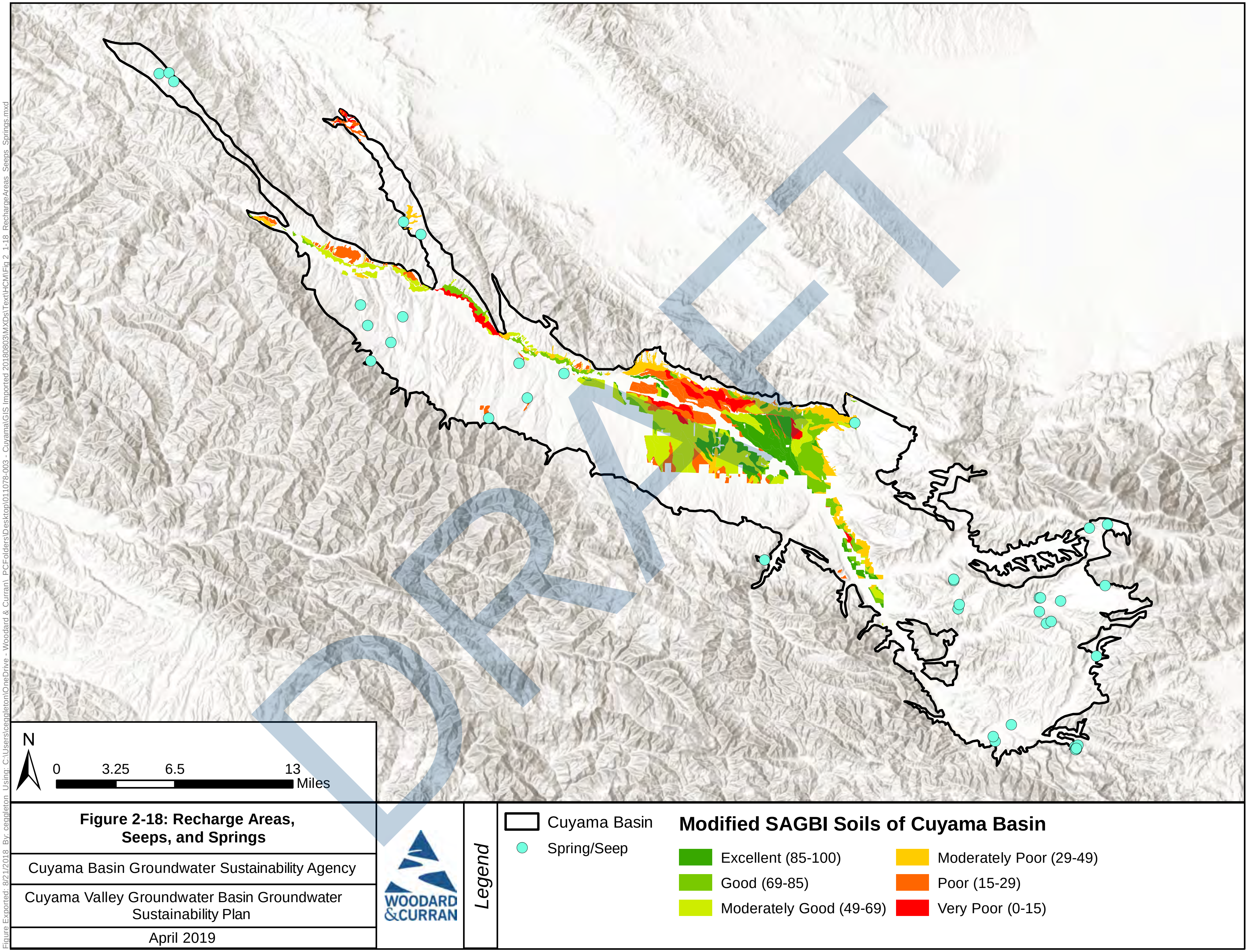


**Figure 2-18: Recharge Areas, Seeps, and Springs**

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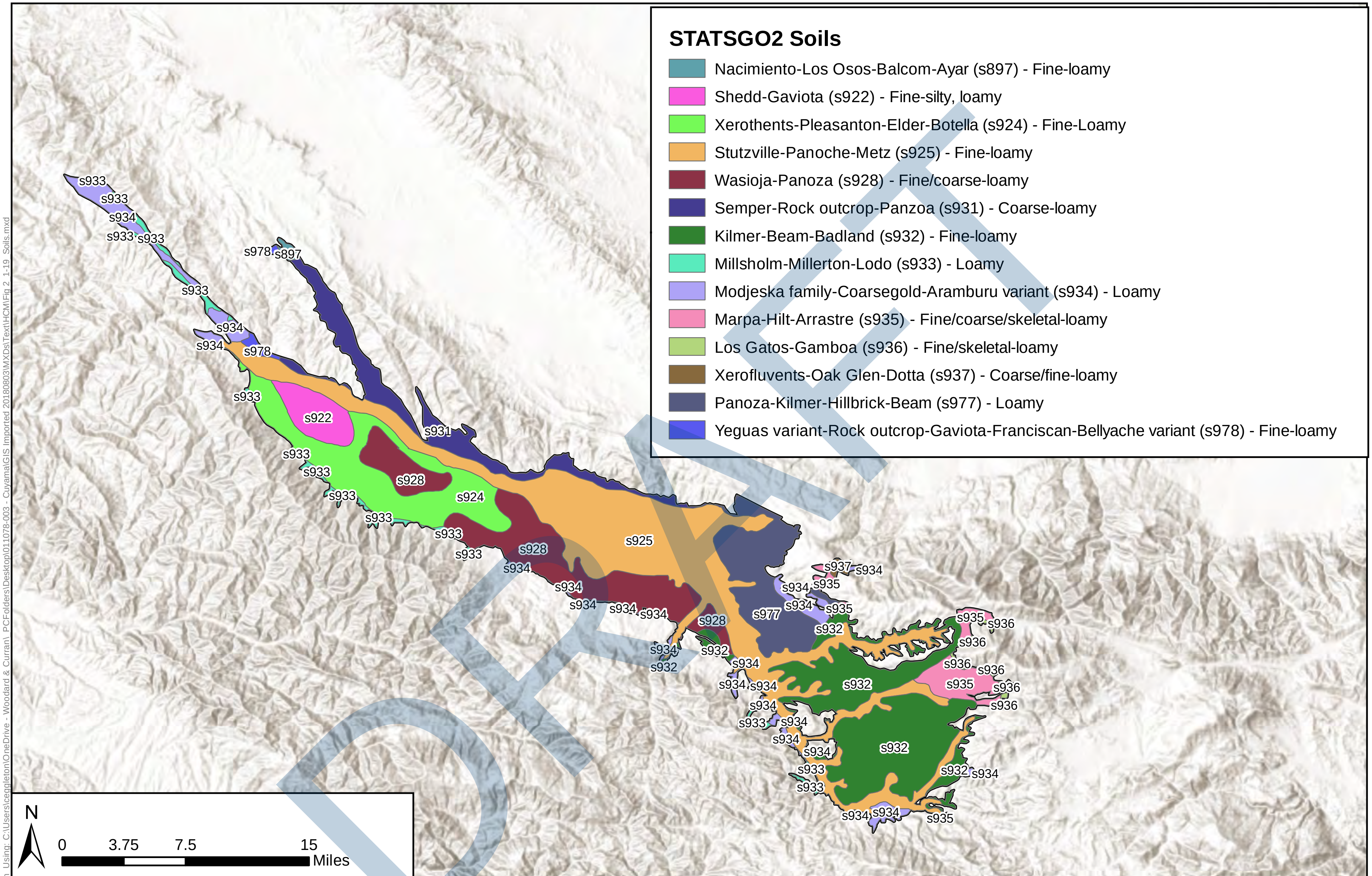




**Figure 2-19: Soils**

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Cuyama Basin

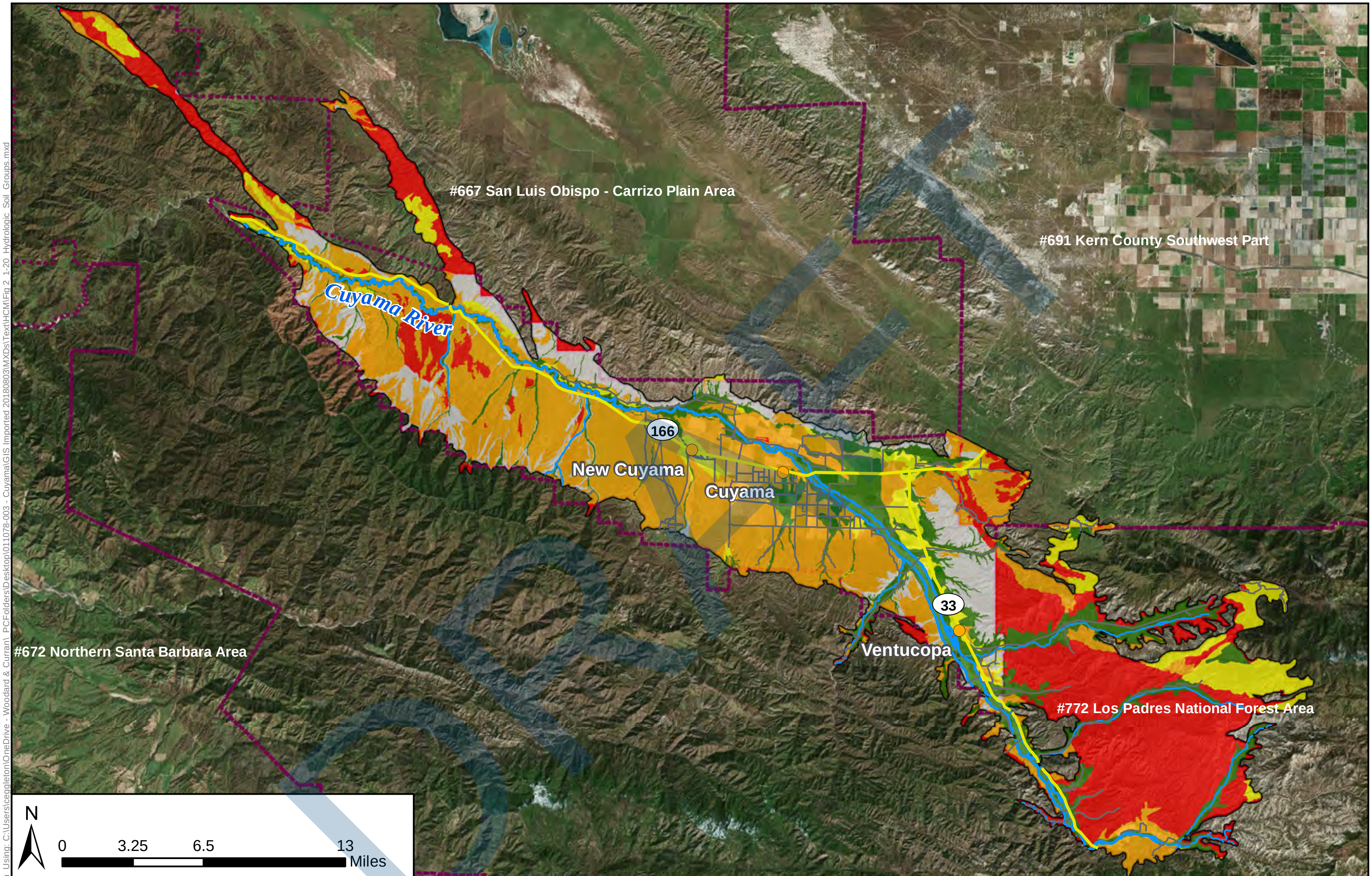




**Figure 2-20: Hydrologic Soil Groups**

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*Legend*

- Cuyama Basin
- Cuyama River
- Streams
- Towns
- Highways

**Hydrologic Soil Group**

- A
- B
- C
- D
- Not classified

Soil Survey Boundary

**Soil Survey Key:**

#772 Los Padres National Forest Area

Soil Survey Number — Survey Name

### 2.1.10 Hydrogeologic Conceptual Model Data Gaps

The following are the HCM data gaps that were identified during the development of this GSP. There is no consensus about whether faults are barriers to flow in the Basin, and if so, at what depth are they a barrier to flow. There is also confusion about whether smaller faults and fault splays are barriers to flow. Aquifer properties in areas where aquifer testing has not been conducted are not well defined, and are estimated. The connection between groundwater levels upstream of Ventucopa and in the Ventucopa region are not well understood; additionally, it is not well understood if groundwater flows are channelized in the Ventucopa and upland regions. Lastly, connectivity between the alluvium west of the Russel Fault and areas in upland areas is not agreed upon. Other data gaps may be discovered during implementation of the GSP.

## 2.2 Basin Settings: Groundwater Conditions

This section of Chapter 2 satisfies Section 354.8 of the SGMA regulations, and describes the historical and current groundwater conditions in the Basin. Water budget components follow in Section 2.3.

As defined by the SGMA regulations, this section does the following:

- Defines current and historical groundwater conditions in the Basin
- Describes the distribution, availability, and quality of groundwater
- Identifies interactions between groundwater, surface water, groundwater-dependent ecosystems, and subsidence
- Establishes a baseline of groundwater quality and quantity conditions that will be used to monitor changes in the groundwater conditions relative to measurable objectives and minimum thresholds
- Provides information to be used for defining measurable objectives to maintain or improve specified groundwater conditions
- Supports development of a monitoring network to demonstrate that the Cuyama Basin Groundwater Sustainability Agency (CBGSA) is achieving Basin sustainability goals

The majority of published information about groundwater in the Basin is focused on the central part of the Basin, roughly from an area a few miles west of New Cuyama to roughly Ventucopa. The eastern uplands and western portion of the Basin have been studied less, and consequentially, fewer publications have been written about those areas, and less historical information is available in those areas.

The groundwater conditions described in this section are intended to convey the present and historical availability, quality, and distribution of groundwater and are used elsewhere in the GSP to define measurable objectives, identify sustainability indicators, and establish undesirable results.

Groundwater conditions in the Basin vary by location. To assist in discussion of the location of specific groundwater conditions, Figure 2-21 shows selected landmarks in the Basin to assist discussion of the location of specific groundwater conditions. Figure 2-22 shows major faults in the Basin in red, highways in yellow, towns as orange dots, and canyons and Bitter Creek in purple lines that show their location.

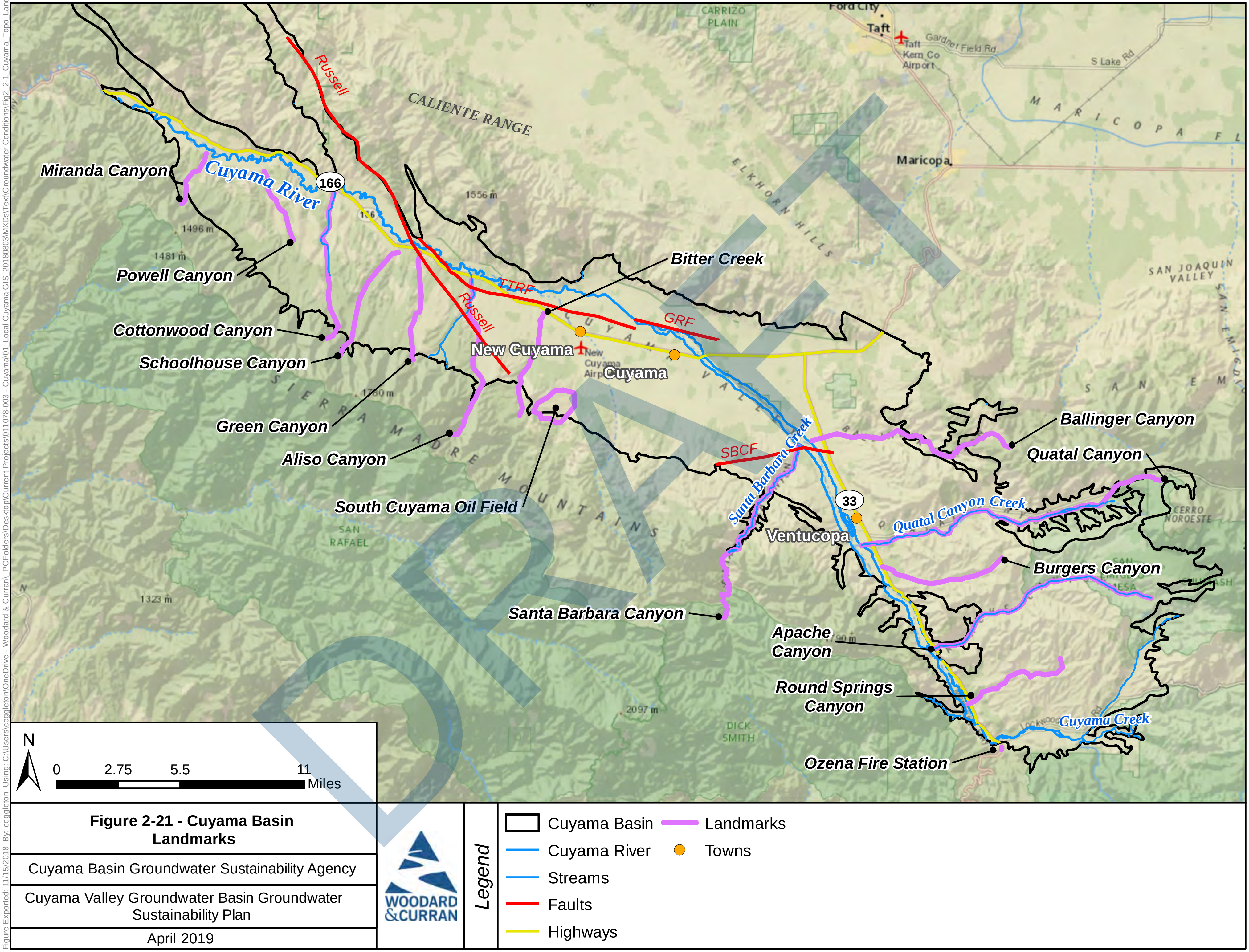


**Figure 2-21 - Cuyama Basin Landmarks**

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### 2.2.1 Useful Terms

This section of Chapter 2 includes descriptions of the amounts, quality, and movement of groundwater, among other related components. A list of technical terms and their definitions are below. These definitions are given to guide readers through the section and are not a definitive definition of any term.

- **Depth to groundwater –** This is the distance from the ground surface to groundwater, typically reported at a well.
- **Horizontal gradient** – The horizontal gradient is the slope of groundwater from one location to another when one location is higher, or lower than the other. The horizontal gradient is shown on maps with an arrow showing the direction of groundwater flow in a horizontal direction.
- **Vertical gradient** – A vertical gradient describes the movement of groundwater perpendicular to the ground surface. Vertical gradient is measured by comparing the elevations of groundwater in wells that are of different depths. A downward gradient is one where groundwater is moving down into the ground, and an upward gradient is one where groundwater is upwelling towards the surface.
- **Contour map –** A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, which indicates that at all locations that line is drawn, it represents groundwater being at the elevation indicated. There are two versions of contour maps shown in this section as follows:
    - — Elevation of groundwater above mean sea level, which is useful because it can help identify the horizontal gradients of groundwater, and
    - — Depth to water (i.e. the distance from the ground surface to groundwater), which is useful because it can help identify areas of shallow or deep groundwater.
- **Hydrograph –** A hydrograph is a graph that shows the changes in groundwater elevation over time for each monitoring well. Hydrographs show how groundwater elevations change over the years and indicate whether groundwater is rising or descending over time.
- **Maximum contaminant level (MCL)** – An MCL is a standard set by the State of California regarding drinking water quality. An MCL is the legal threshold on the amount of a substance that may appear in public water systems. MCLs are different for different constituents in drinking water.
- **Elastic land subsidence** – Elastic land subsidence is the reversible and temporary fluctuation in the earth's surface in response to seasonal periods of groundwater extraction and recharge.
- **Inelastic land subsidence** – Inelastic land subsidence is the irreversible and permanent decline in the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system.

## 2.2.2 Groundwater Elevation Data Processing

Groundwater well information and groundwater level monitoring data were compiled from four public sources, with additional data compiled from private landowners. These include the following:

- USGS
- DWR
- Santa Barbara County Water Agency (SBCWA)
- San Luis Obispo County
- Private landowners

Data provided by these sources included well information such as location, well construction, well owner, ground surface elevation and other related components, as well as groundwater elevation data including information such as date measured, depth to water, groundwater surface elevation, questionable measurement code, and comments. At the time that this analysis was performed, groundwater elevation data was available for the time period from 1949 to June 2018.[3] There are many wells with monitoring data from some time in the past, but no recent data, while a small number of wells have monitoring data recorded for periods of greater than 50 years. Figure 2-22 through Figure 2-25 show well locations with available monitoring data, and the entity that maintains monitoring records at each well. These figures also show in a larger, darker symbol if the monitoring well has been measured in 2017 or 2018.

Figure 2-22 shows the locations of well data received from the DWR database. As an assessment of which wells have been monitored recently, the wells with monitoring data collected between January 2017 and June 2018 were identified. Roughly half of the wells from DWR's database contain monitoring data in 2017-18, with roughly half the wells having no monitoring data during this period. Wells in DWR's database are concentrated in the central portion of the Basin, east of Bitter Creek and north of the Santa Barbara Canyon Fault (SBCF). Many wells in DWR's database have been typically measured bi-annually, with one measurement in the spring, and one measurement in the fall.

Figure 2-23 shows the locations of well data received from the USGS database. Many of these wells are duplicative of wells contained in the DWR database. The majority of wells from the USGS database were not monitored in 2017-18. Wells that were monitored in 2017-18 are concentrated in the western portion of the Basin, west of New Cuyama, with a small number of monitoring wells in the central portion of the Basin and near Ventucopa. Many wells in the USGS database haves been typically measured bi-annually, with one measurement in the spring, and one measurement in the fall.

[3] The analysis shown in this section was performed in the summer of 2018 and does not reflect data that may have been collected after June 2018. In addition, the analysis reflects the available data as provided by each entity - an assessment has not been performed on the standards and protocols followed by each entity that compiles and maintains the available datasets.

Figure 2-24 shows the locations of well data received from Santa Barbara and San Luis Obispo counties. Wells from both counties were monitored in 2017-18. Wells monitored by Santa Barbara County are concentrated in the western portion of the Basin west of Bitter Creek. The two wells monitored by San Luis Obispo County are in the central portion of the Basin; these wells also appear in the USGS database. Data are collected in many of these wells on a bi-annual basis, with one measurement in the spring, and one measurement in the fall, with some measurements at some wells occurring on a quarterly basis.

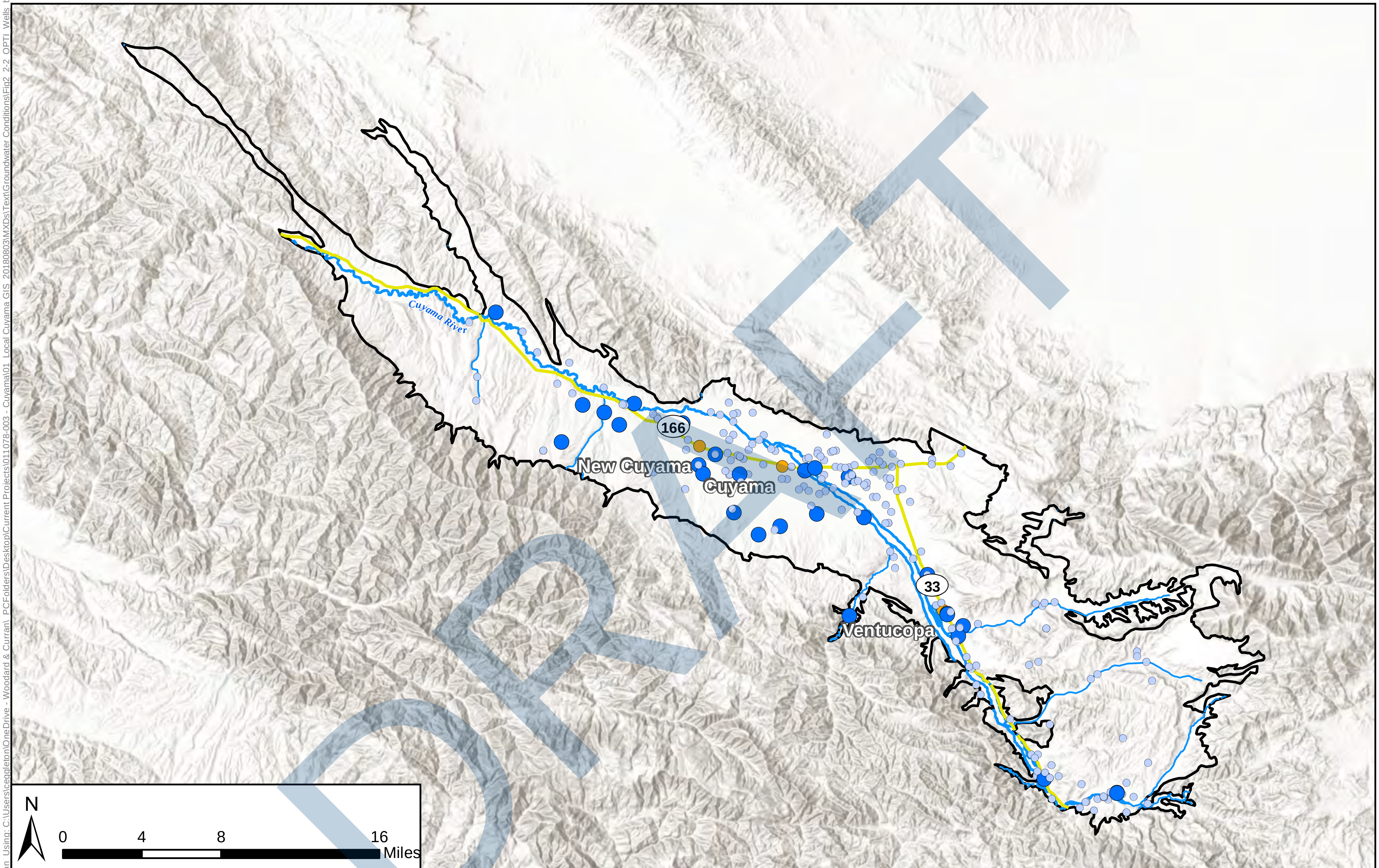


**Figure 2-22: Cuyama GW Basin Wells with Monitoring Data Provided by DWR**

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- DWR Database Wells Last Measured in 2017-2018
- DWR Database Wells Last Measured 2016 and Earlier

Figure Exported: 11/13/2018 By: ceggleton Using: C:\Users\ceggleton\OneDrive - Woodard & Curran_PCFolders\Desktop\Current Projects\011078-003 - Cuyama\01_Local Cuyama GIS_20180803\MXDs\Text\Groundwater Conditions\Fig2_2-2_OPTI_Wells_by_Agency

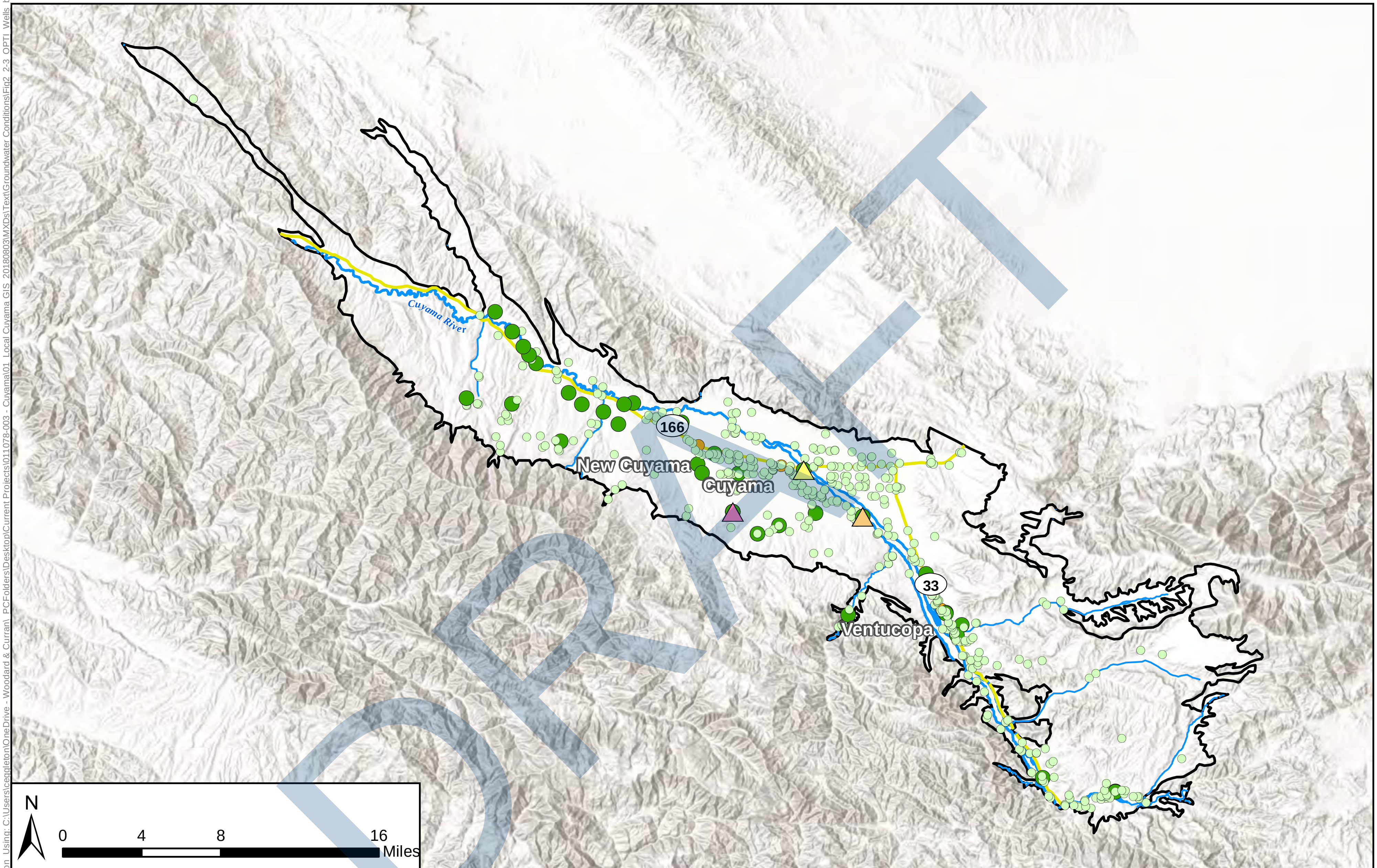


**Figure 2-23: Cuyama GW Basin**
**Wells with Monitoring Data Provided by USGS**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- USGS Database Wells Last Measured in 2017-2018
- USGS Database Wells Last Measured 2016 or Earlier
- CVBR Multi-Completion Well
- CVFR Multi-Completion Well
- CVKR Multi-Completion Well

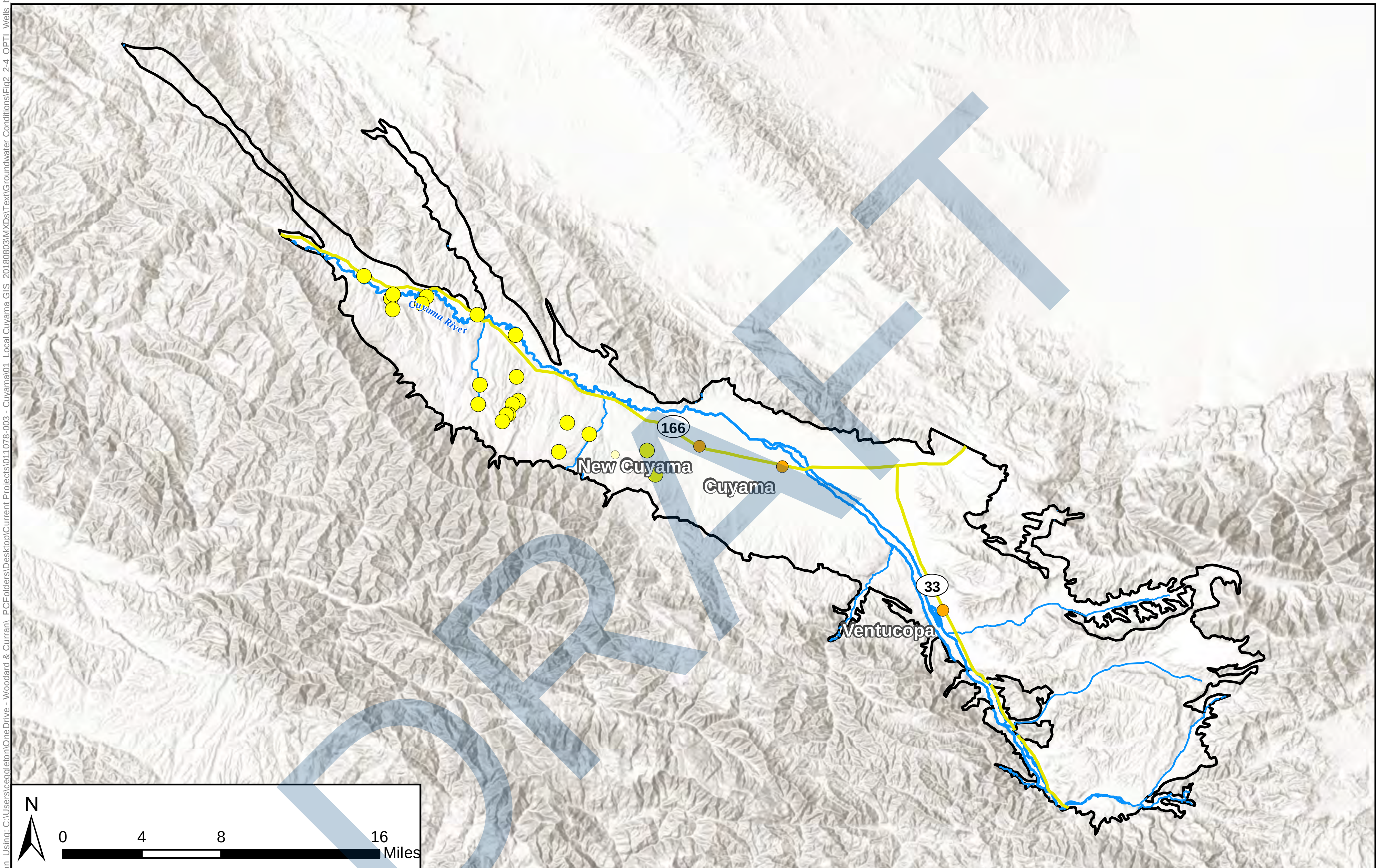


**Figure 2-24: Cuyama GW Basin Wells with Monitoring Data Provided by Local Agencies**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- County Database Wells Last Measured in 2017-2018
- County Database Wells Last Measured 2016 or Earlier

Figure 2-25 shows the locations of well data received from private landowners. The majority of wells provided by private landowners are located in the central portion of the Basin, between the Cuyama River and Highway 33, generally running along SR 166. Additional wells provided by private landowners are located along the Cuyama River and SR 166, near the Russell Ranch Oilfields. Associated data provided with private landowners varies by source. Some data and measurements were taken annually, while other well owners were taken biannually or quarterly.

Figure 2-26 shows the locations of collected data from all entities by their last measured date. Wells with monitoring data in 2017-2018 are shown in bright green triangles. There are recent measurements in many different parts of the Basin as follows:

- Near the Cuyama River in the eastern uplands and near Ventucopa
- In the central portion of the Basin, especially north of SR 166 but with some wells located in the southern portion of the central basin
- In the western portion of the Basin east of Aliso Canyon. An additional concentration of recent monitoring points is present along the Cuyama River near the Russell Ranch Oilfields.

Figure 2-27 shows a comparison of data provided by private landowners and data compiled from the DWR and the USGS databases in the central portion of the Basin. This figure was developed to provide information on the consistency between data from these differing sources. The figure shows the location of compared wells, and the measurements on those wells by source. The measurements of groundwater elevation among the measured wells indicate that the monitoring by the private landowners and agencies approximately match in tracking historical trends from the public databases.

Figure 2-28 shows a comparison of data collected from other private landowners, and data collected from SBCWA. This figure was developed to provide information on the consistency between data from these differing sources. The figure shows the location of compared wells, and the measurements on those wells by source. A long-term comparison is not possible due to the shorter measurement period of the Santa Barbara County wells, but the measurements of groundwater elevation among the measured wells indicate that the monitoring by private landowners in the western portion of the Basin and the county are similar in elevation, with the county's data showing slightly higher elevations.

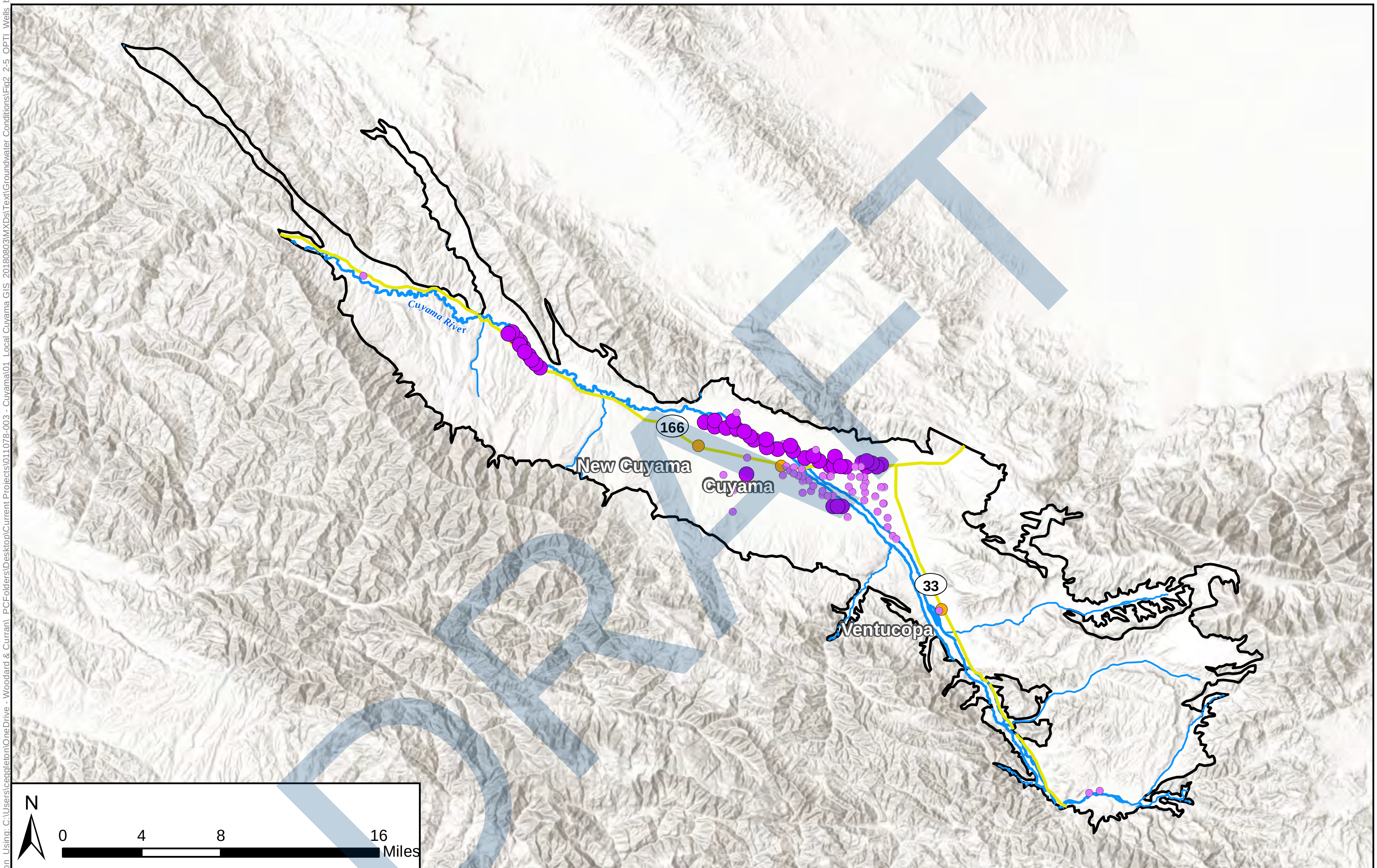


**Figure 2-25: Cuyama GW Basin Wells with Monitoring Data Provided by Private Landowners**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Private Landowners Reported Wells Last Measured in 2017-2018
- Private Landowners Reported Wells Last Measured 2016 and Earlier

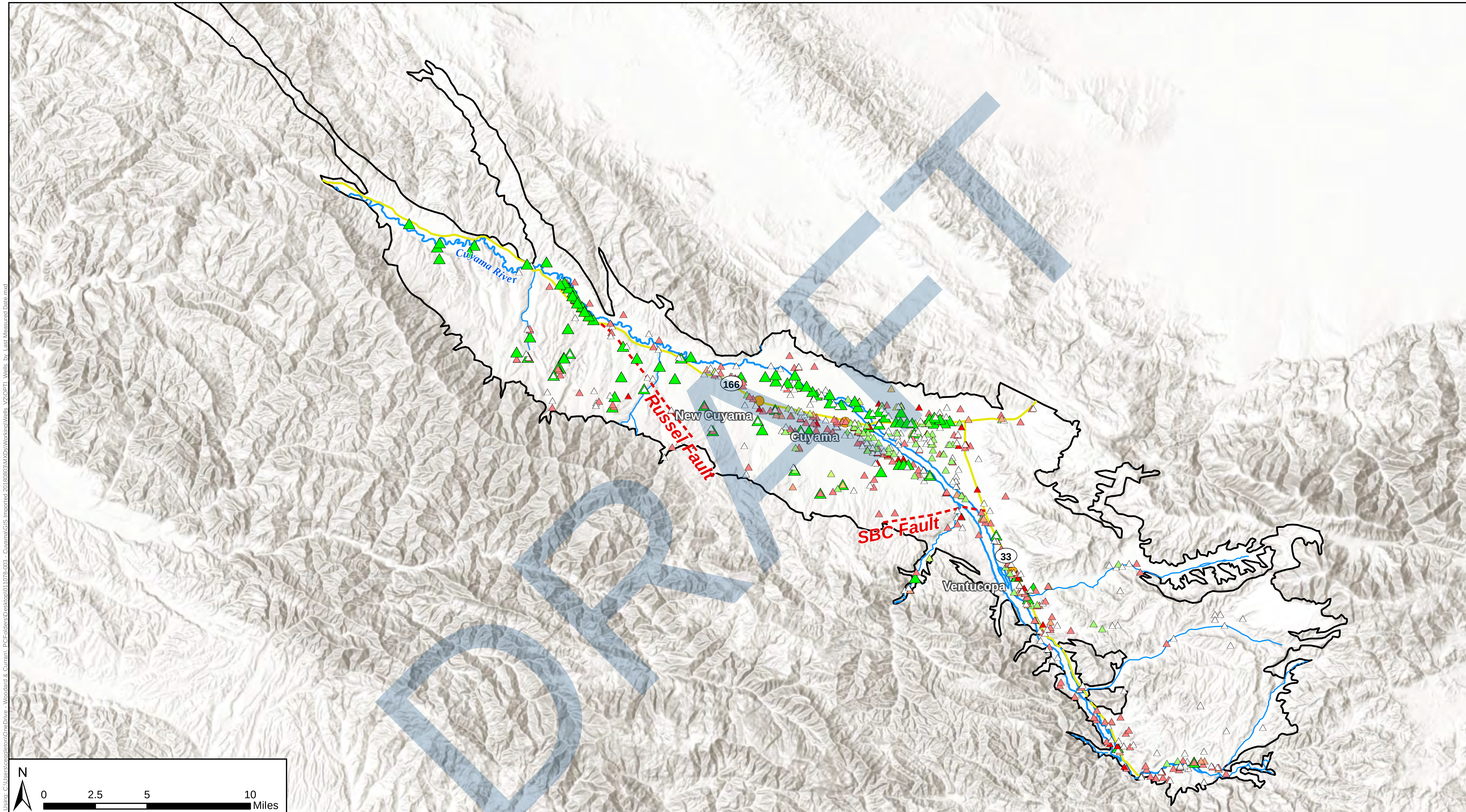


**Figure 2-26: Cuyama GW Basin Wells by Last Measurement Date**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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Legend

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Fault

**Most Recent Year with Measurements**

- 2017 - 2018
- 2010 - 2016
- 2000 - 2009
- 1990 - 1999
- 1980 - 1989
- 1970 - 1979
- 1960 - 1969
- 1950 - 1959
- Pre-1950
- No Measurment Data

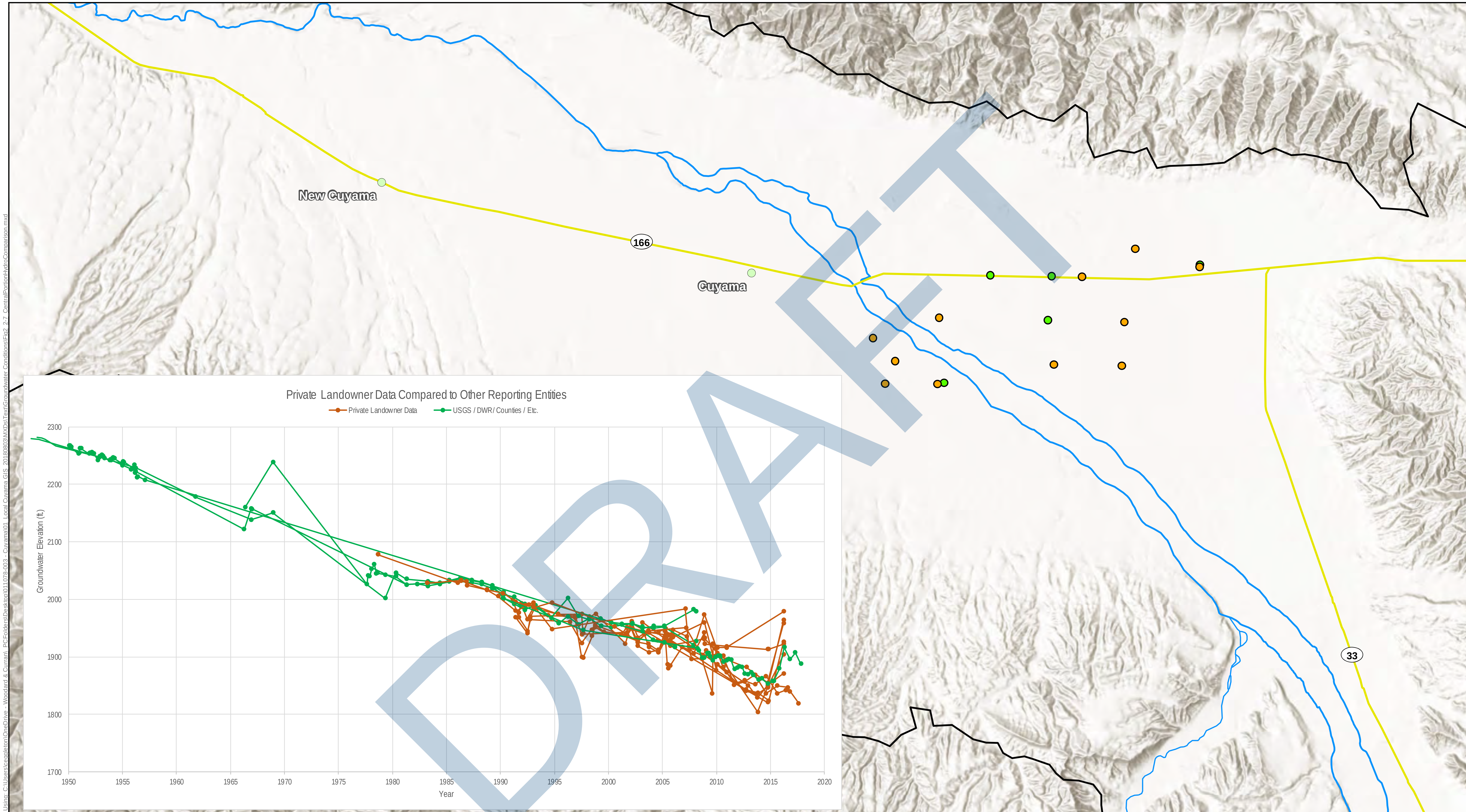


**Figure 2-27: Central Cuyama GW Basin Wells and Hydrographs by Data Source**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- USGS, DWR, County, Etc., Wells
- Private Landowners

N

0 0.5 1 2 Miles

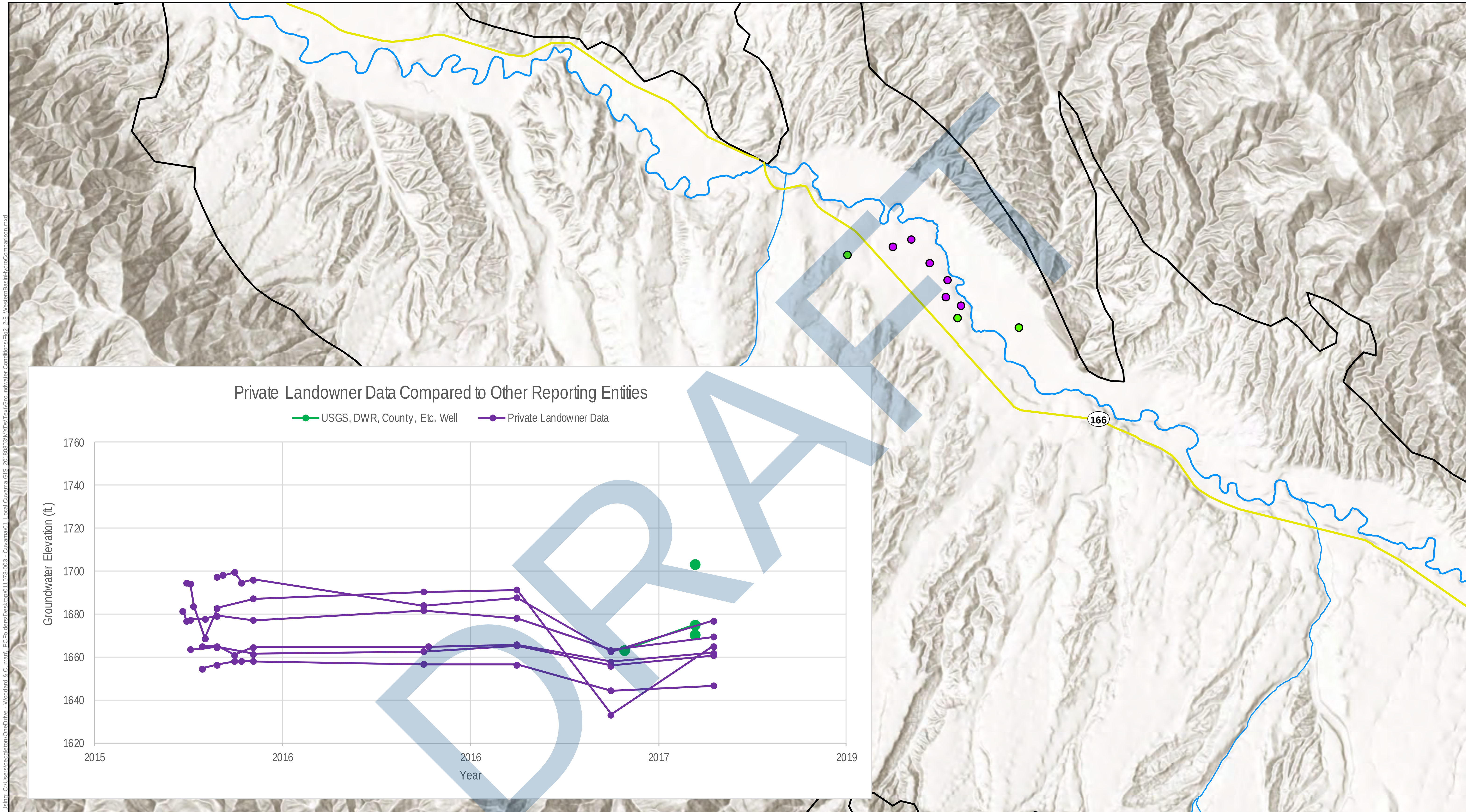


**Figure 2-28: Western Cuyama GW Basin Wells and Hydrographs by Data Source**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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### 2.2.3 Groundwater Trends

This section describes groundwater trends in the Basin generally from the oldest available studies and data to the most recent. Groundwater conditions vary widely across the Basin. In the following sections, historical context is provided by summarizing information from relevant studies about conditions from 1947 to 1966, followed by discussion of how groundwater conditions have changed based on available historical groundwater level monitoring data.

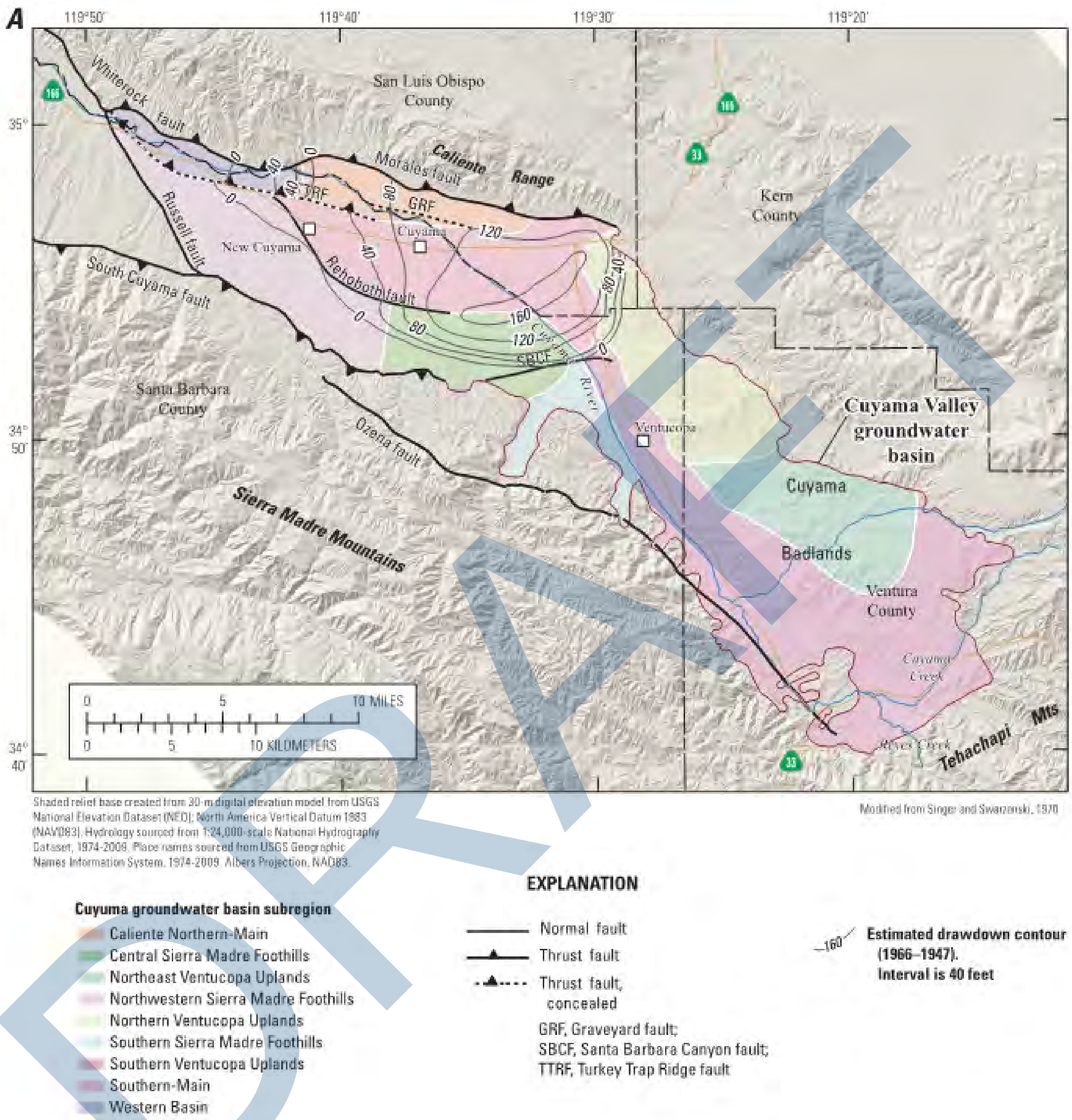
#### Historical Context – 1947 to 1966 Groundwater Trends

This section discusses public reports about conditions from 1947 to 1966. Information about groundwater conditions in the Basin during this period are limited to reports that discuss the central portion of the Basin and scattered groundwater elevation measurements in monitoring wells.

A USGS report titled *Water Levels in Observation Wells in Santa Barbara County, California* (USGS, 1956) discussed groundwater elevation monitoring in the Basin. The report states that ,prior to 1946, there was no electric power in the Cuyama Valley, which restricted intensive irrigation, and that groundwater levels in the central portion of the Basin remained fairly static until 1946. The report states that: "Declines in groundwater began after 1946," and that groundwater declined "as much as 8.8 feet from the spring of 1955 to 1956; the average decline was 5.2 feet. The decline of water levels at the lower and upper ends of the valley during this period was not so great as in the middle portion and averaged 1.7 and 2.2 feet respectively. Since 1946, water levels in observation wells have decline on the average about 27 feet" (USGS, 1956).

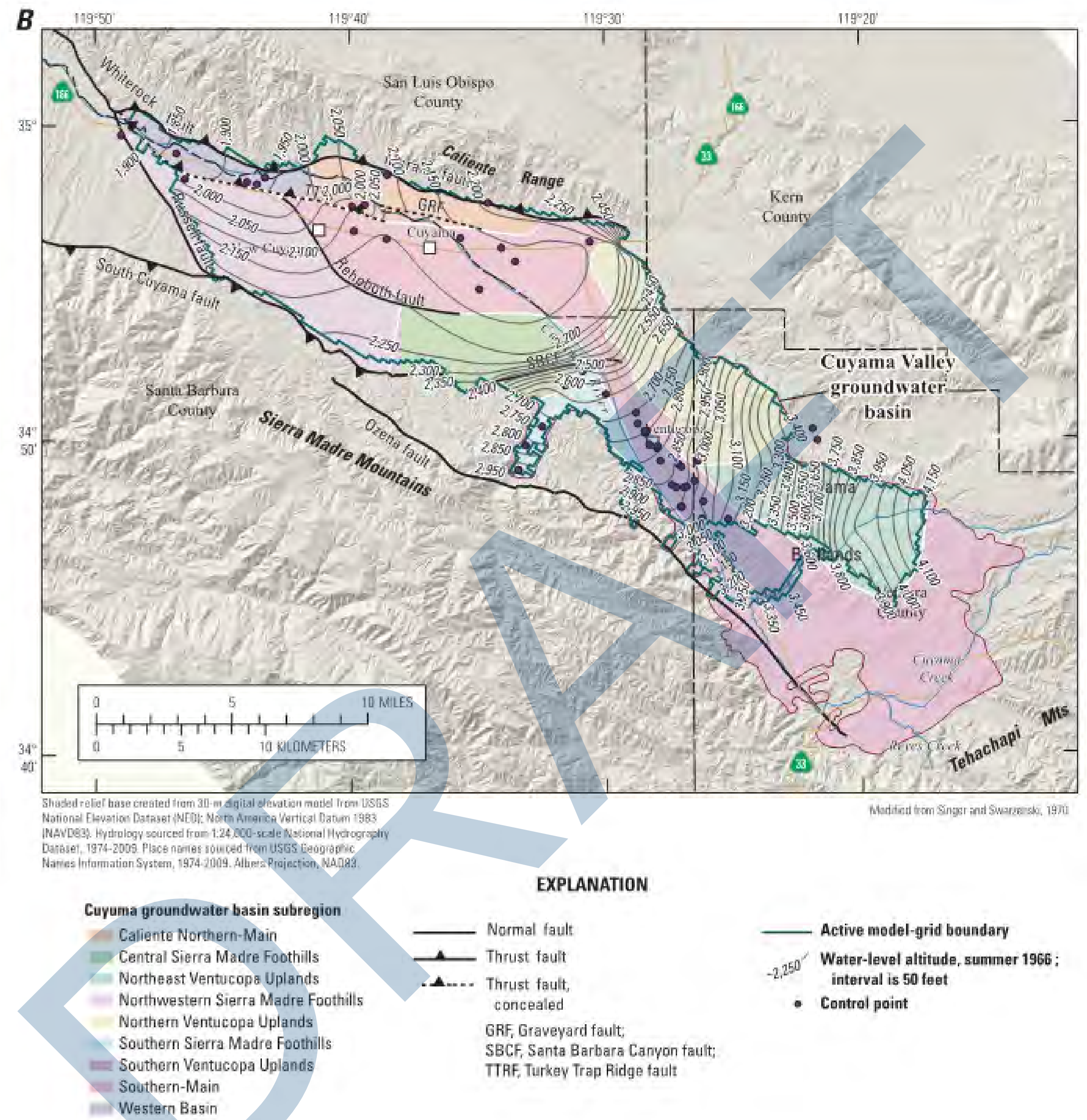
A USGS report titled *Hydrologic Models and Analysis of Water Availability in the Cuyama Valley, California* (USGS, 2015) presents two maps generated by using CUVHM simulated data. Figure 2-29 shows the estimated drawdown in the central portion of the Basin from 1947 to 1966. Figure 2-29 shows that estimated drawdown ranged from zero at the edges of the central basin to over 160 feet in the southeastern portion of the central Basin.

Figure 2-30 shows the estimated contours of groundwater elevation for September 1966. These contours show a low area in the central portion of the central Basin, and a steep groundwater gradient in the southeast near Ventucopa and in the highlands. A gentle groundwater gradient occurs in the southwestern portion of the central Basin, generally matching topography.




*Source: USGS, 2015*

**Figure 2-29: Water Level Drawdown Contours, 1966 to 1947**




*Source: USGS, 2015*

**Figure 2-30: 1966 Water Level Contours**

## Groundwater Trends According to Available Monitoring Data

To understand how groundwater conditions have changed in the Basin in recent decades, analysts developed and analyzed groundwater hydrographs, vertical gradients and contours, which are discussed below.

### Groundwater Hydrographs

Groundwater hydrographs were developed to provide indicators of groundwater trends throughout the Basin. Measurements from each well with historical monitoring data were compiled into one hydrograph for each well. These hydrographs are presented in Appendix A.

In many cases, changes in historical groundwater conditions at particular wells have been influenced by climactic patterns in the Basin (Section 2.3). Historical precipitation is highly variable, with several relatively wet years and some multi-year droughts.

Groundwater conditions generally vary in different parts of the Basin. Figure 2-31 shows hydrographs in select wells in different portions of the Basin. These wells were selected they broadly represent Basin conditions in their areas. More information about conditions is below.

- In the area southeast of Round Springs Canyon, near Ozena Fire Station (Well 89), groundwater levels have stayed relatively stable with a small decline during the 2012 to 2015 drought, and showed quick recovery.
- In the vicinity of Ventucopa (at Well 62), groundwater levels have followed climactic patterns and have generally been declining since 1995.
- Just south of the SBCF (at Well 101), groundwater levels have been fairly stable and are closer to the surface than levels in Ventucopa.
- North of the SBCF and east of Bitter Creek in the central portion of the Basin (at Wells 55 and 615), groundwater levels have been declining consistently since 1950.
- In the area west of Bitter Creek (at Wells 119 and 830), groundwater levels are near ground surface near the Cuyama River, and are below ground in the area to the south, uphill from the river. Levels have been generally stable since 1966.

Figure 2-32 shows selected hydrographs for wells in the area near Ventucopa. Near Ventucopa, hydrographs for Wells 85 and 62 show the same patterns and conditions from 1995 to the present and show that groundwater levels in this area respond to climactic patterns, but also have been in decline since 1995 and are currently at historic low elevations. The hydrograph for Well 85 shows that prior to 1985 groundwater levels responded to drought conditions but recovered during wetter years. Well 40 is located just south of the SBCF and its hydrograph indicates that groundwater levels in this location have remained stable from 1951 to 2013, when monitoring ceased. Wells 91 and 620 are north of the SBCF and their hydrographs show more recent conditions, where depth to water has declined consistently and is below 580 feet below ground surface (bgs).

Figures 2-33 and 2-34 show hydrographs of discontinued and currently monitored wells in the central portion of the Basin, north of the SBCF and east of Bitter Creek. The hydrographs of discontinued wells in this area are shown in Figure 2-33. These hydrographs show consistent declines of groundwater levels and little to no response to either droughts or wetter periods. The hydrograph for Well 35 shows a consistent decline from 1955 to 2008, from 30 feet bgs to approximately 150 feet bgs. Well 472 shows a decline from approximately 5 feet bgs in 1949 to approximately 85 feet bgs in 1978.

Figure 2-34 shows hydrographs of currently monitored wells in the central portion of the Basin. In general, these hydrographs show that groundwater levels are decreasing, with the lowest levels in the southeast portion of the area just northwest of the SBCF, as shown in the Well 610 hydrograph, where groundwater levels were below 600 feet bgs. Levels remain lowered along the Cuyama River, as shown in the hydrographs for Wells 604 and 618, which are currently approximately 500 feet bgs. Groundwater levels are higher to the west (Well 72) and towards the southern end of the area (Well 96). However, almost all monitoring wells in this area show consistent declines in elevation.

Figure 2-35 shows hydrographs of monitoring wells in the western portion of the Basin, west of Bitter Creek. Hydrographs in this area show that generally, groundwater levels are near the surface near the Cuyama River, and further from the surface to the south, which is uphill from the river. The hydrograph for Well 119 shows a few measurements from 1953 to 1969, and three more recent measurements. All measurements for Well 119 show a depth to water of 60 feet bgs. The hydrograph for Well 846 shows that in 2015 depth to water was slightly above 40 feet and is slightly below 40 feet in 2018. The hydrograph for Well 840 shows a groundwater level near ground surface in 2015, and a decline to 40 feet bgs in 2018. Hydrographs for wells uphill from the river (Wells 573 and 121) show that groundwater is roughly 70 feet bgs in this area. Hydrographs for Wells 571 and 108, at the edge of the Basin have recent measurements, and show groundwater levels that range from 120 to 140 feet bgs.

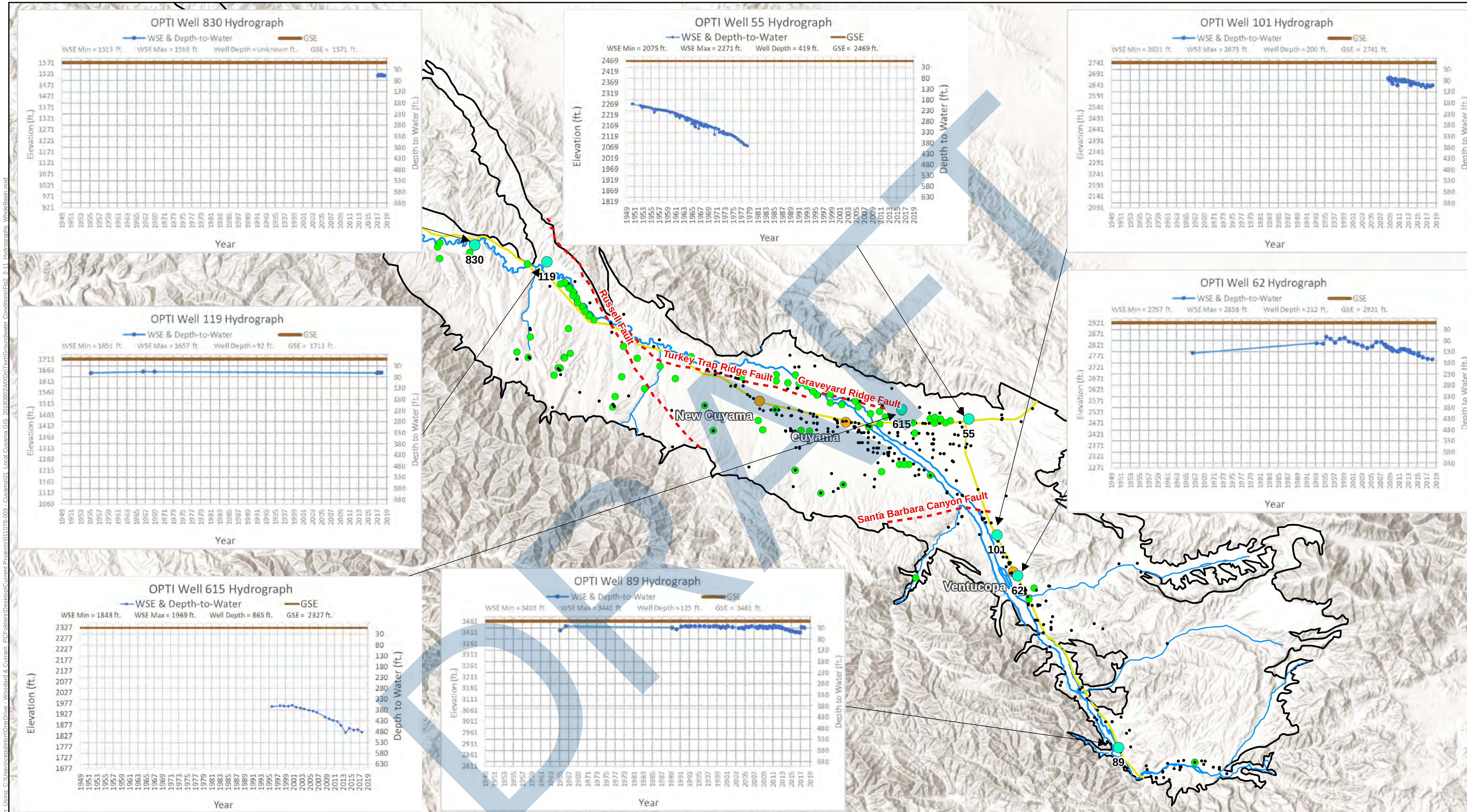



**Figure 2-31: Cuyama GW Basin Hydrographs**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Faults
- Hydrographed Wells
- Currently Monitored Wells
- Not Currently Monitored

N

0 2.5 5 10 Miles

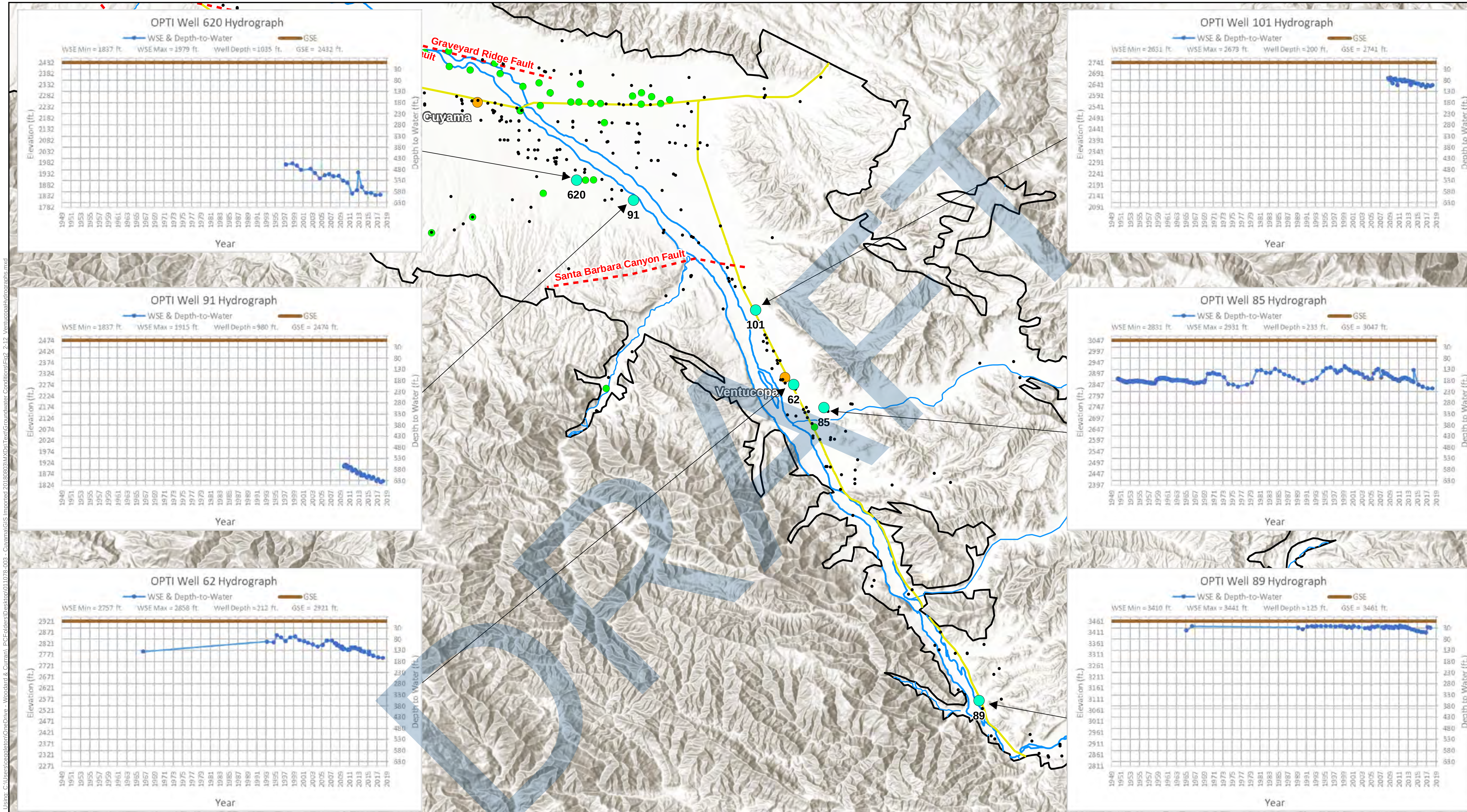


**Figure 2-32: Cuyama GW Basin Hydrographs for the Ventucopa Area of the Basin**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Faults
- Hydrographed Wells
- Currently Monitored Wells
- Not Currently Monitored

N

0 1.25 2.5 5 Miles

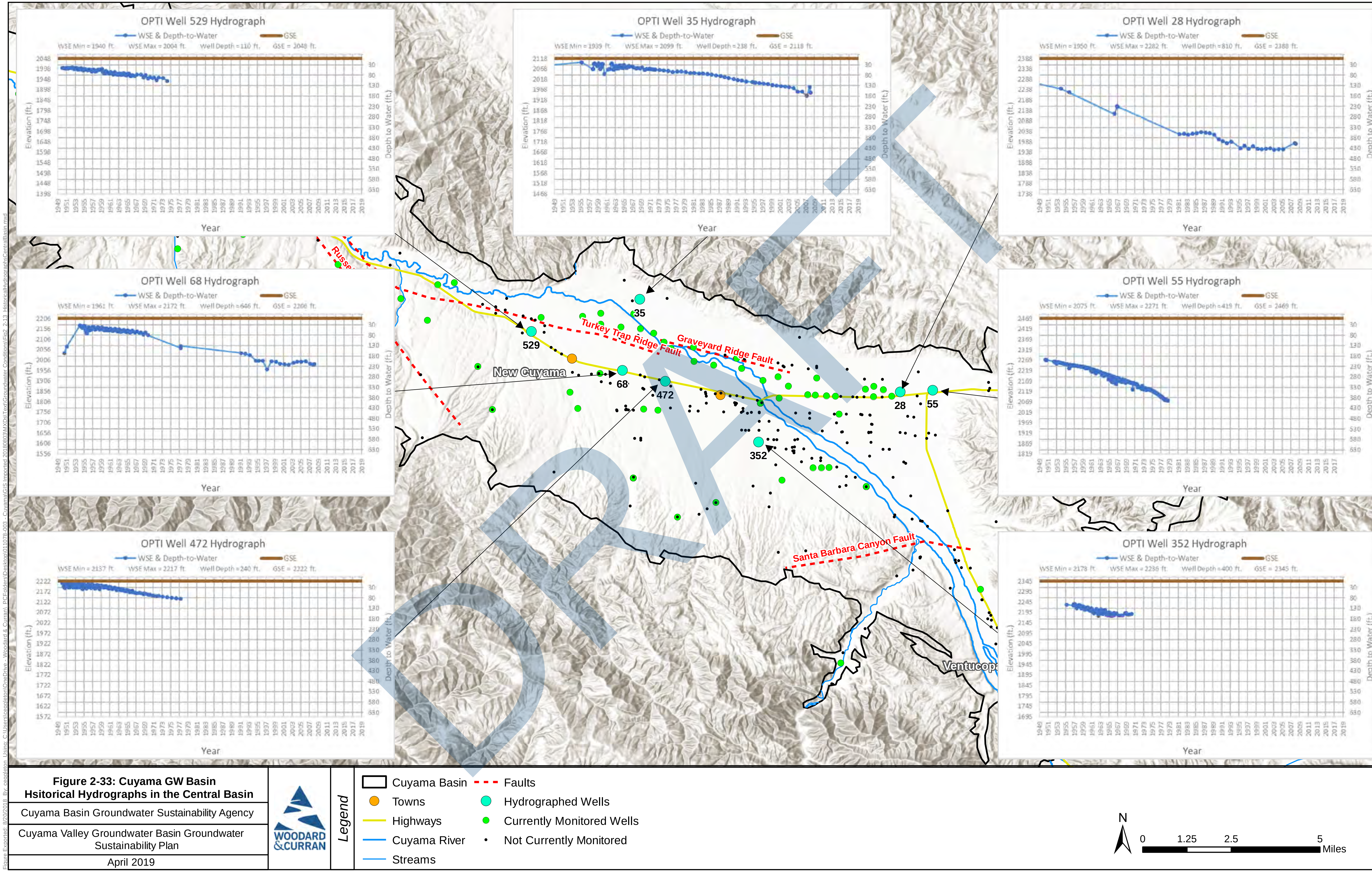


**Figure 2-33: Cuyama GW Basin Hsitorical Hydrographs in the Central Basin**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

April 2019

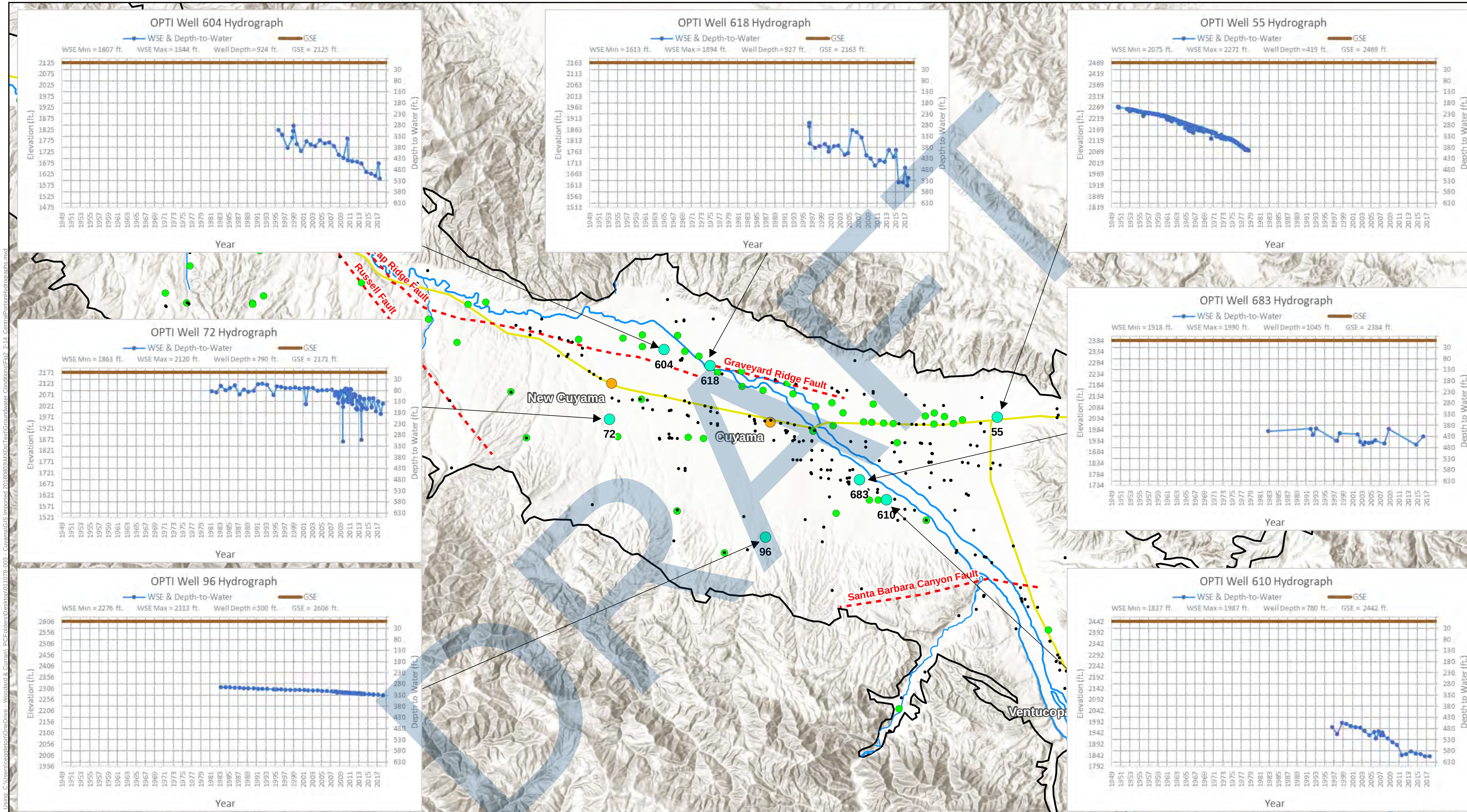


**Figure 2-34: Cuyama GW Basin Hydrographs for the Central Portion of the Basin**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Faults
- Hydrographed Wells
- Currently Monitored Wells
- Not Currently Monitored

N

0 1.25 2.5 5 Miles

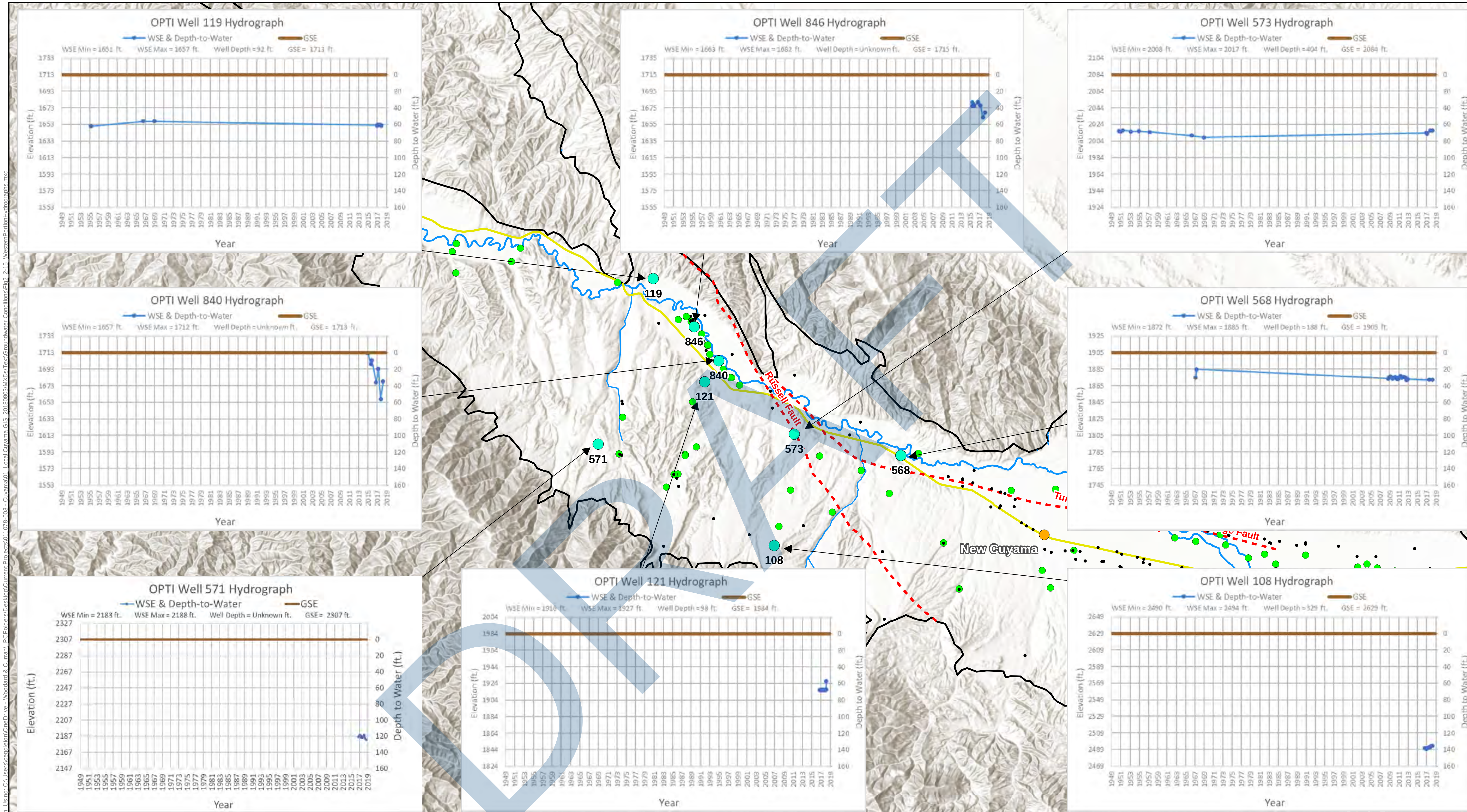




**Figure 2-35: Cuyama GW Basin Hydrographs for the Westside Area of the Basin**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

April 2019

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Faults
- Hydrographed Wells
- Currently Monitored Wells
- Not Currently Monitored

N

0 1.25 2.5 5 Miles

### Vertical Gradients

A vertical gradient describes the movement of groundwater perpendicular to the ground surface. A vertical gradient is typically measured by comparing the elevations of groundwater in a well with multiple completions that are of different depths. If groundwater elevations in the shallower completions are higher than in the deeper completions, the gradient is identified as a downward gradient. A downward gradient is one where groundwater is moving down into the ground. If groundwater elevations in the shallower completions are lower than in the deeper completions, the gradient is identified as an upward gradient. An upward gradient is one where groundwater is upwelling towards the surface. If groundwater elevations are similar throughout the completions, there is no vertical gradient to identify. An understanding of the Basin's vertical gradients is required by Section 354.16(a) of the SGMA regulations, and this understanding further describes how groundwater moves in the Basin.

There are three multiple completion wells in the Basin. A multiple completion well includes perforations at multiple intervals, and therefore provides information at multiple depths in the well. Figure 2-23 shows the locations of the multiple completion wells in the Basin, and are located in the central portion of the Basin, north of the SBCF and east of Bitter Creek.

Figure 2-36 shows the combined hydrograph for the multiple completion well CVFR, which was installed by USGS.[4] CVFR is comprised of four completions, each at different depths as follows:

- CVFR-1 is the deepest completion with a screened interval from 960 to 980 feet bgs
- CVFR-2 is the second deepest completion with a screened interval from 810 to 830 feet bgs
- CVFR-3 is the third deepest completion with a screened interval from 680 to 700 feet bgs
- CVFR-4 is the shallowest completion with a screened interval from 590 to 610 feet bgs

The hydrograph of the four completions shows that they are close to the same elevation at each completion, and therefore it is unlikely that there is any vertical gradient at this location.

Figure 2-37 shows the combined hydrograph for the multiple completion well CVBR, which was installed by USGS. CVBR is comprised of four completions, each at different depths as follows:

- CVBR-1 is the deepest completion with a screened interval from 830 to 850 feet bgs
- CVBR-2 is the second deepest completion with a screened interval from 730 to 750 feet bgs
- CVBR-3 is the third deepest completion with a screened interval from 540 to 560 feet bgs
- CVBR-4 is the shallowest completion with a screened interval from 360 to 380 feet bgs

The hydrograph of the four completions shows that at the deeper completions, groundwater elevations are slightly lower than the shallower completions in the winter and spring, and deeper completions are

[4] All three multiple completion wells were installed by the USGS as part of the Cuyama Valley Water Availability Study in cooperation with SBCWA

generally lower than the shallower completion in the summer and fall. This indicates that during the irrigation season, the deeper portions of the aquifer are likely to be where pumping occurs. This pumping removes water from the deeper portion of the aquifer, creating a vertical gradient during the summer and fall. By the spring, enough water has moved down or horizontally to replace removed water, and the vertical gradient is significantly smaller at this location in the spring measurements.

Figure 2-38 shows the combined hydrograph for the multiple completion well CVKR, which was installed by the USGS. CVKR is comprised of four completions, each at different depths as follows:

- CVKR-1 is the deepest completion with a screened interval from 960 to 980 feet bgs
- CVKR-2 is the second deepest completion with a screened interval from 760 to 780 feet bgs
- CVKR-3 is the third deepest completion with a screened interval from 600 to 620 feet bgs
- CVKR-4 is the shallowest completion with a screened interval from 440 to 460 feet bgs

The hydrograph of the four completions shows that at the deeper completions are slightly lower than the shallower completions in the spring at each completion, and deeper completions are generally lower in the summer and fall. This indicates that during the irrigation season, the deeper portions of the aquifer are likely to be where pumping occurs. This pumping removes water from the deeper portion of the aquifer, creating a vertical gradient during the summer and fall. By the winter and spring, enough water has moved down to replace removed water, and the vertical gradient is very small at this location in the spring measurements.


**Figure 2-36: Hydrographs of CVFR1-4**

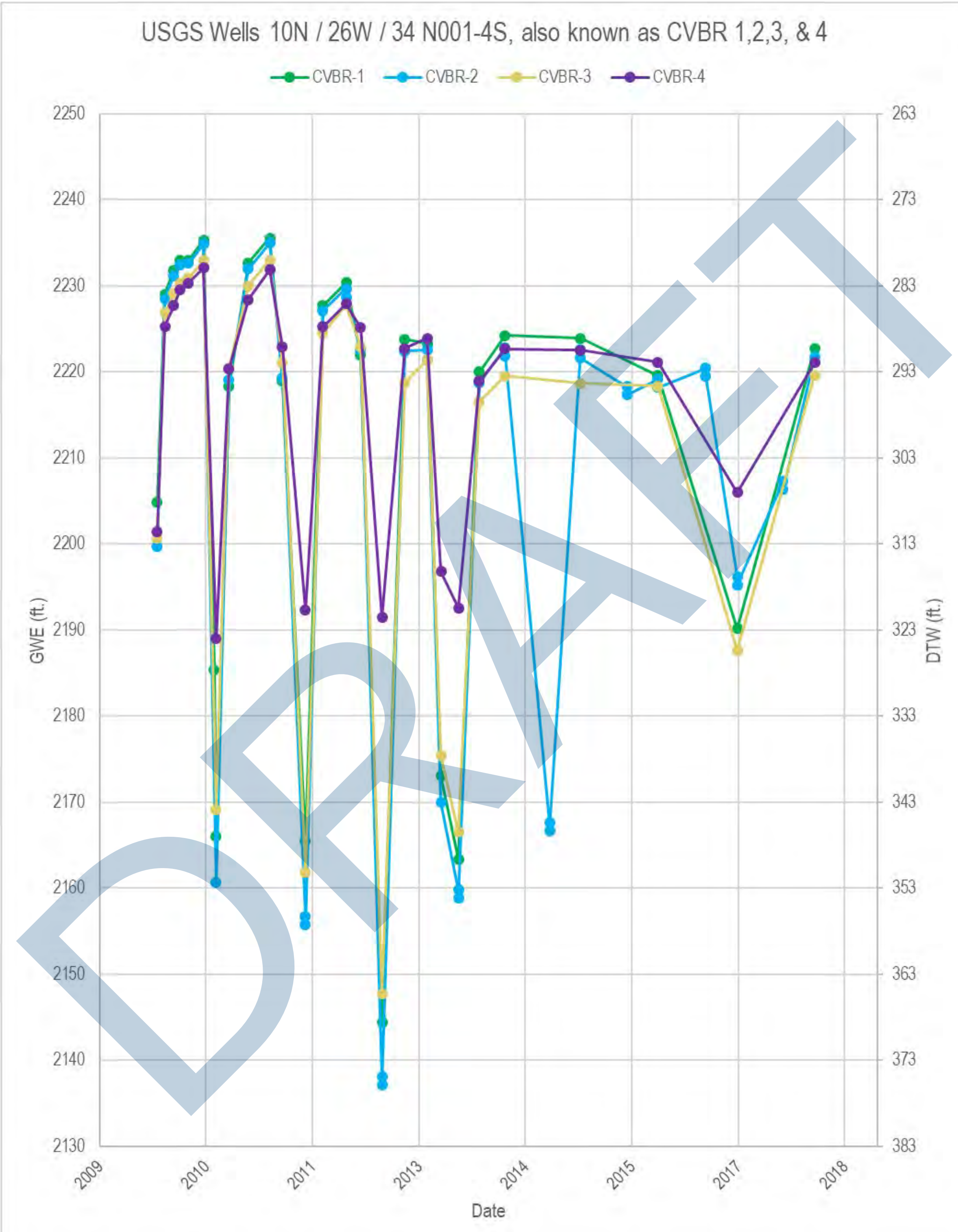



**Figure 2-37: Hydrographs of CVBR1-4**

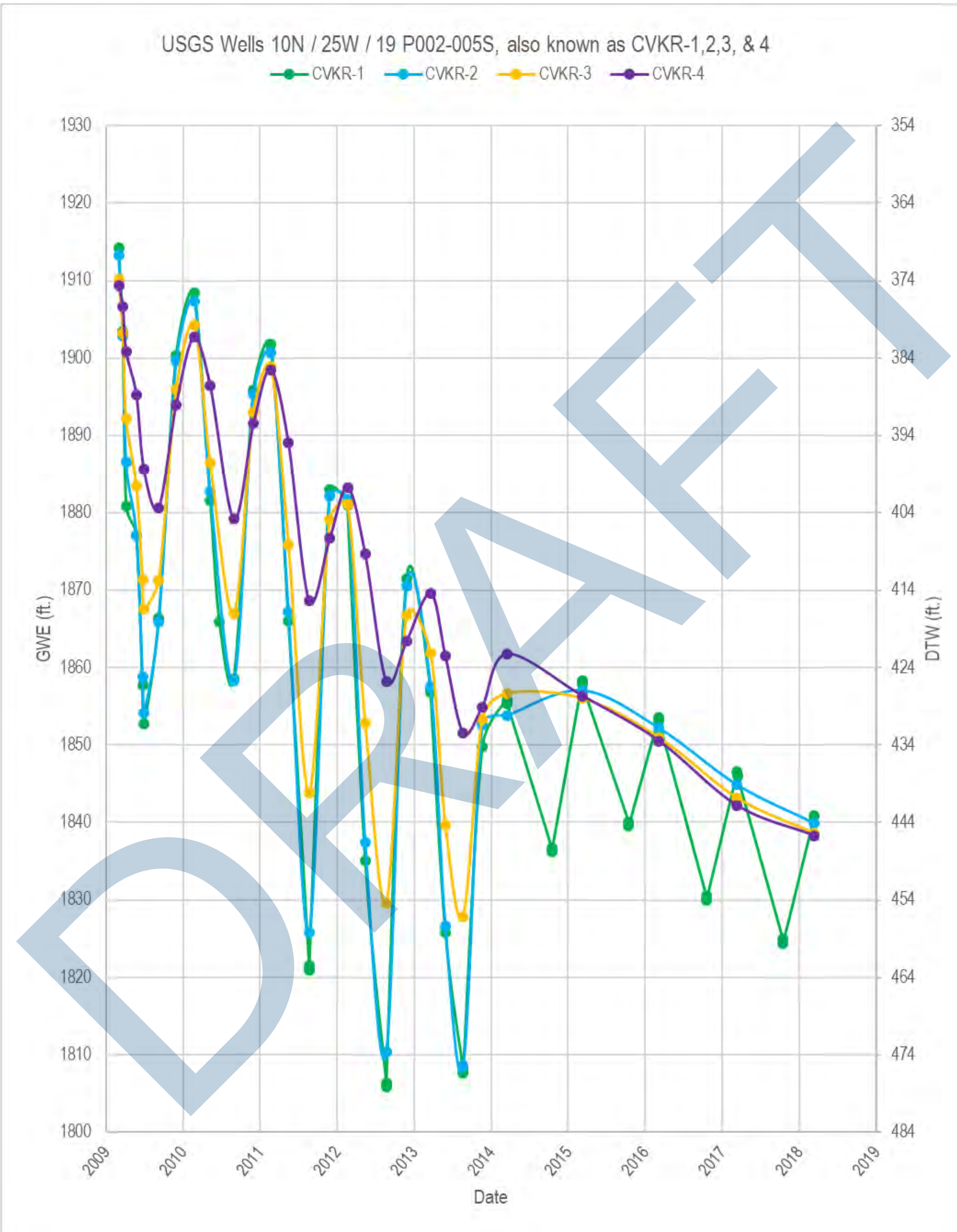



**Figure 2-38: Hydrographs of CVKR1-4**

## Groundwater Contours

Analysts prepared groundwater contour maps to improve understanding of recent groundwater trends in the Basin. Analysts used the data collected and described in Section 2.2.2 to develop these maps. A contour map shows changes in groundwater elevations by interpolating groundwater elevations between monitoring sites. The elevations are shown on the map with the use of a contour line, which indicates that at all locations that line is drawn, the line represents groundwater at the elevation indicated. There are two versions of contour maps used in this section: one that shows the elevation of groundwater above mean sea level, which is useful because it can be used to identify the horizontal gradients of groundwater, and one that shows contours of depth to water, the distance from the ground surface to groundwater, which is useful because it can identify areas of shallow or deep groundwater.

Analysts prepared groundwater contour maps for both groundwater elevation and depth to water for the following periods:

- Spring 2018
- Fall 2017
- Spring 2017
- Spring 2015
- Fall 2014

These years were selected for contours because they are representative of current conditions, and because these years identify conditions near January 1, 2015, when SGMA came into effect. The contour maps are described below.

Each contour map follows the same general format. Each contour map is contoured at a 50-foot contour interval, with contour elevations indicated in white numeric labels, and measurements at individual monitoring points indicated in black numeric labels. Areas where the contours are dashed and not colored in are inferred contours that extend elevations beyond data availability and are included for reference only. The groundwater contours were also based on assumptions in order to accumulate enough data points to generate useful contour maps. Assumptions are as follows:

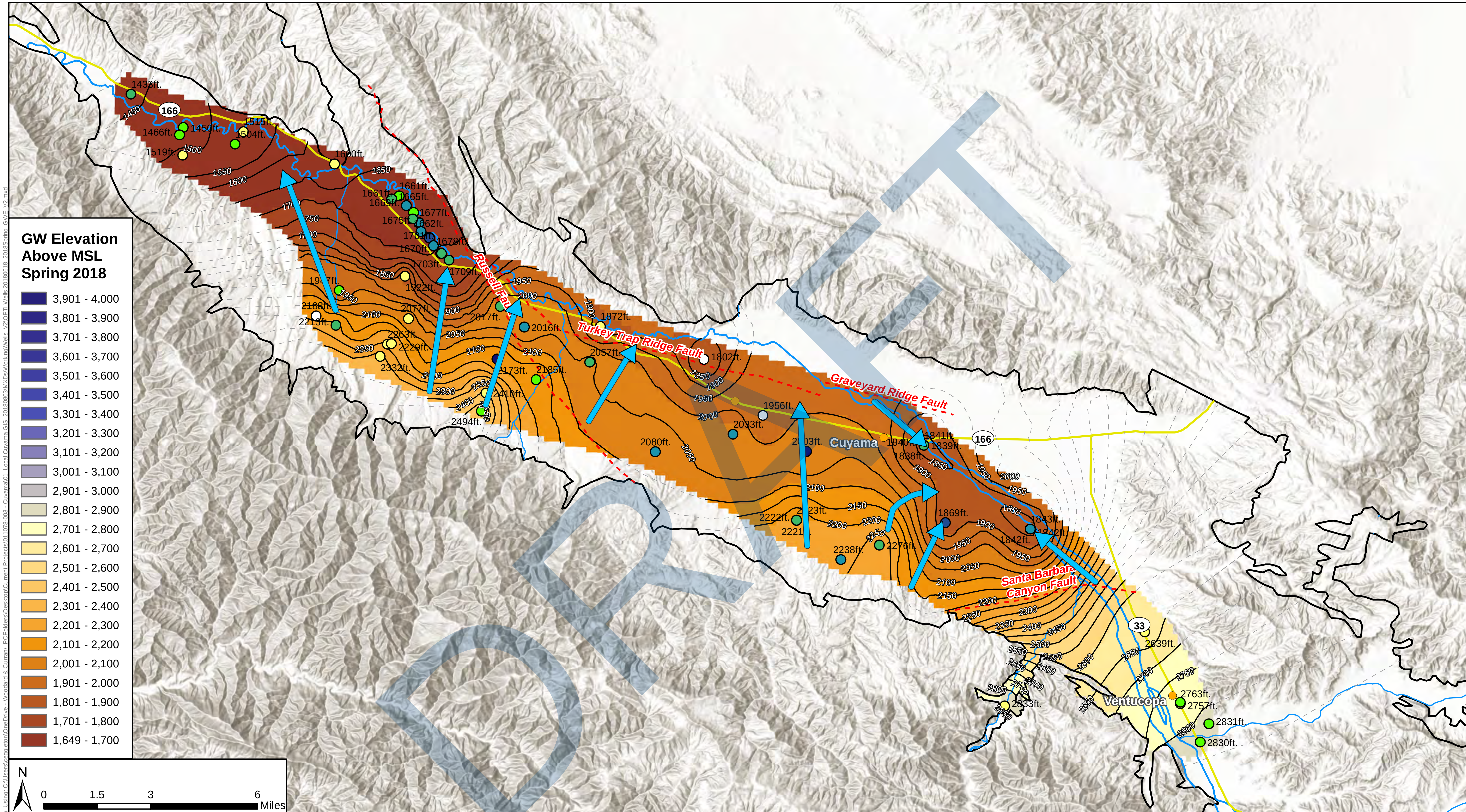
- Measurements from wells of different depths are representative of conditions at that location and there are no vertical gradients. Due to the limited spatial amount of monitoring points, data from wells of a wide variety of depths were used to generate the contours.
- Measurements from dates that may be as far apart temporally as three months are representative of conditions during the spring or fall season, and conditions have not changed substantially from the time of the earliest measurement used to the latest. Due to the limited temporal amount of measurements in the Basin, data from a wide variety of measurement dates were used to generate the contours.

These assumptions generate contours that are useful at the planning level for understanding groundwater levels across the Basin, and to identify general horizontal gradients and regional groundwater level trends. The contour maps are not indicative of exact values across the Basin because groundwater contour maps approximate conditions between measurement points, and do not account for topography. Therefore, a well on a ridge may be farther from groundwater than one in a canyon, and the contour map will not reflect that level of detail.

Expansion and improvement of the monitoring network to generate a more accurate understanding of groundwater trends in the Basin is discussed in Chapter 4.

Figure 2-39 shows groundwater elevation contours for spring of 2018, along with arrows showing the direction of groundwater flow. In the southeastern portion of the Basin near Ventucopa, groundwater has a horizontal gradient to the northwest. The gradient increases in the vicinity of the SBCF and flows to an area of lowered groundwater elevation southeast of the town of Cuyama. From the town of New Cuyama to the west, groundwater has a horizontal gradient that generally flows to the northeast, from areas with higher elevation topography towards areas with lower elevation topography where the Cuyama River is located.

Figure 2-40 shows depth to groundwater contours for spring of 2018. Just south the SBCF, groundwater is near 100 feet bgs. North of the SBCF, depth to groundwater declines rapidly and is over 600 feet bgs. Depth to groundwater reduces to the west towards New Cuyama, where groundwater is around 150 feet bgs. West of Bitter Creek, groundwater is shallower than 100 feet bgs in most locations, and is shallower than 50 feet bgs in the far west and along the Cuyama River.




Legend

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Elevation Above MSL
- Inferred Groundwater Elevation Above MSL
- Groundwater Flow Direction

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 2/1/2018 - 4/30/2018 due to limited data availability.

Contours Interval: 50 ft.

**Figure 2-39: Cuyama GW Basin Wells by Groundwater Surface Elevation**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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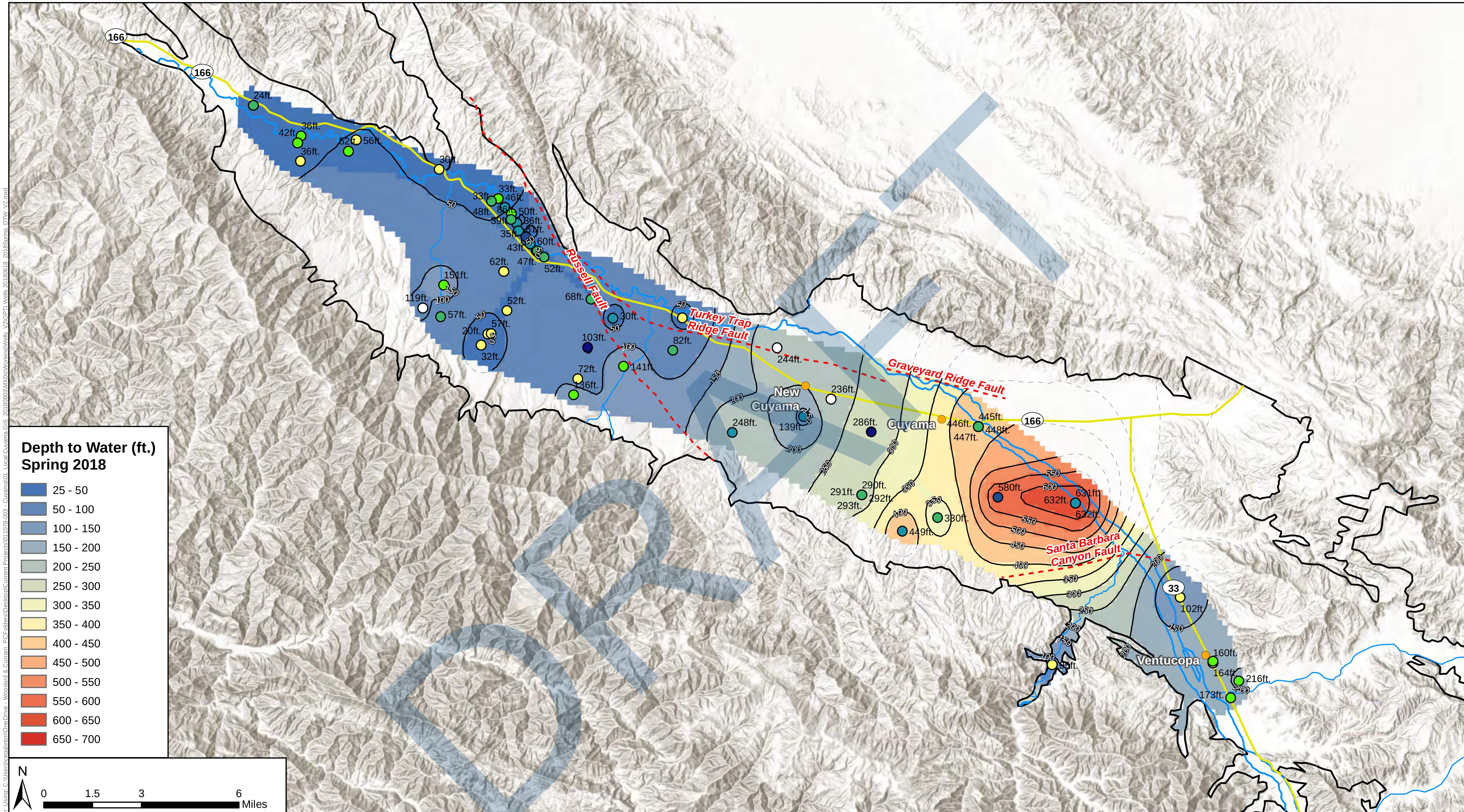


**Figure 2-40: Cuyama GW Basin Wells by Depth to Water**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Depth-to-Water Contours below Groundsurface
- Inferred Groundwater Depth-to-Water Contours below Groundsurface

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 2/1/2018 - 4/30/2018 due to limitated data availability.

Contours Interval: 50 ft.

The remaining contour maps for spring 2017, fall 2017, spring 2015, and fall 2014 are shown below. These dates were selected to show the changes over the most recent period of three years for which data were available in the spring (from 2015 to 2018) and from the fall (from 2014 to 2017).

Figure 2-41 shows groundwater elevation contours for fall of 2017. Because more data were available in this time frame, the contour map shows increased detail in some areas. In the southeastern portion of the Basin near the Ozena fire station, groundwater gradients appear to indicate flows that follow the Cuyama River. The contour map shows a steep gradient across the SBCF and flows to an area of lowered groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, groundwater has a horizontal gradient that generally flows to the northeast, from areas with higher elevation topography towards areas with lower elevation topography where the Cuyama River is located.

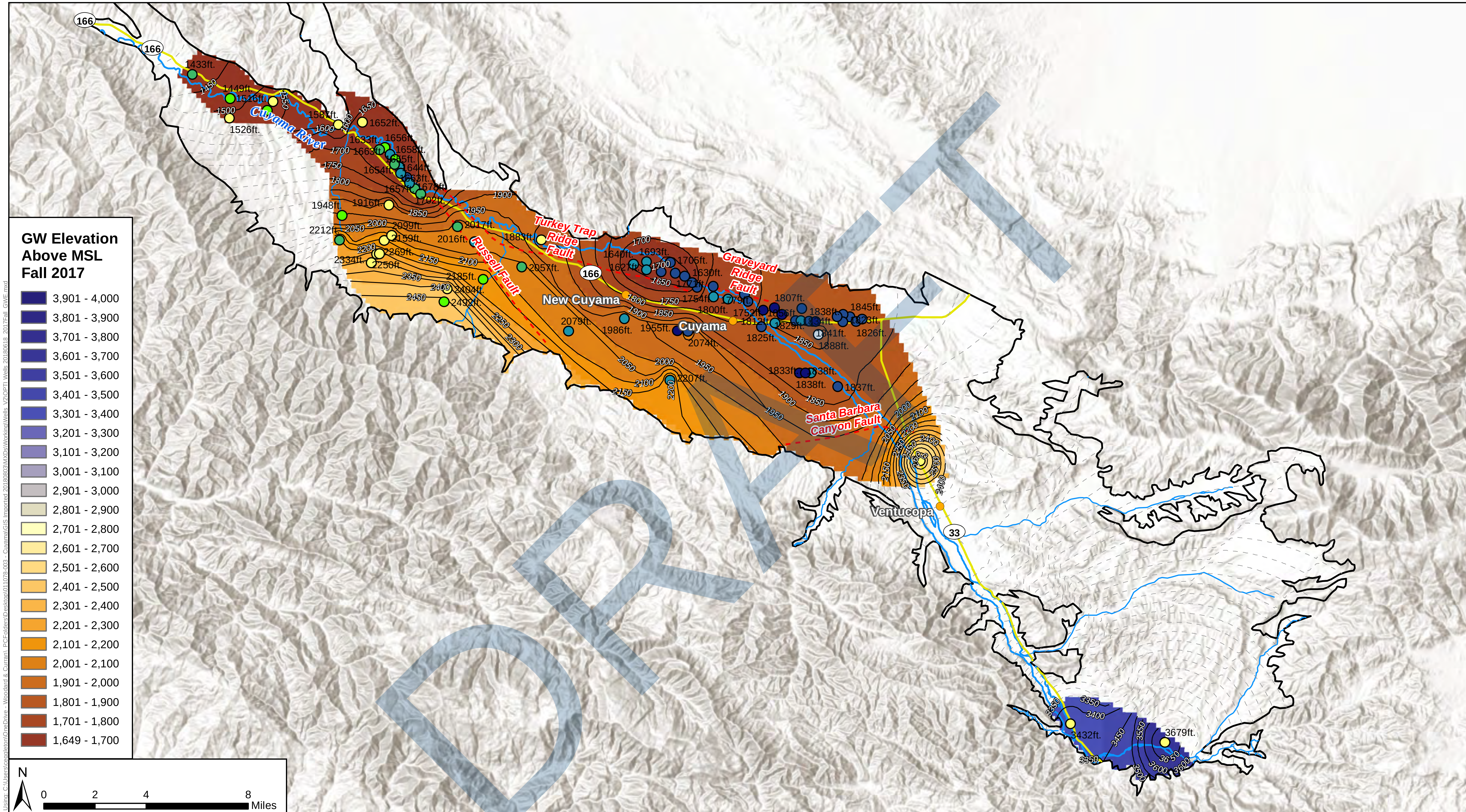


**Figure 2-41: Fall 2017 Groundwater Elevation**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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WOODARD & CURRAN

*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Elevation Above MSL
- Inferred Groundwater Elevation Above MSL

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 8/1/2017 - 11/30/2017 due to limitaed data availbility.

Contours Interval: 50 ft.

Figure 2-42 shows depth to water contours for fall of 2017. Because more data were available in this time frame, the contour map has increased detail in some areas. In the southeastern portion of the Basin near the Ozena fire station, depth to water is under 50 feet bgs. There is a steep gradient near the SBCF, and groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 400 and 500 feet bgs, with depth to groundwater decreasing to the west of New Cuyama. West of Bitter Creek, groundwater is generally shallower than 100 feet below bgs, and is shallower than 50 feet bgs along the Cuyama River in most cases.

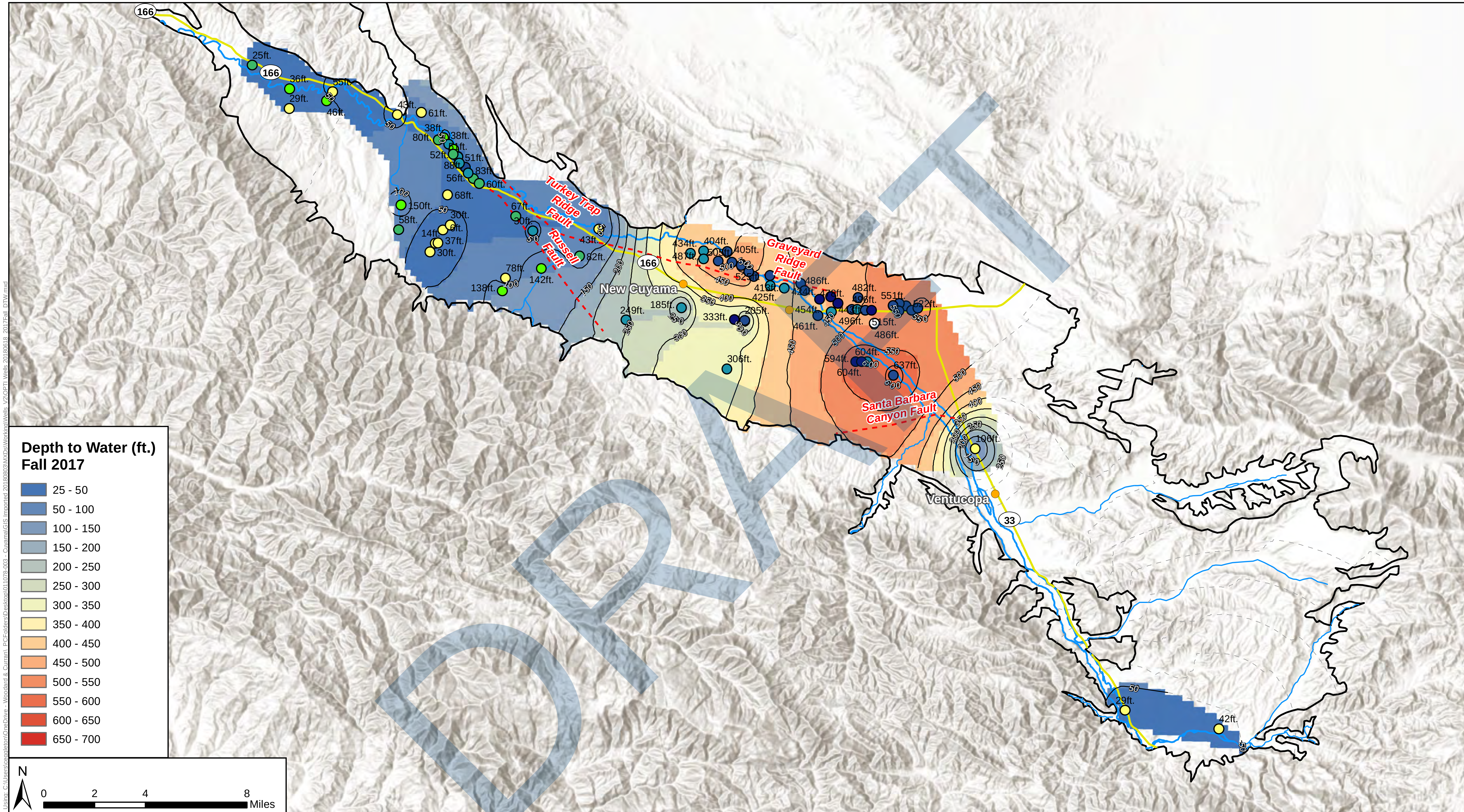


Figure 2-42: Fall 2017
Depth to Water

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Depth-to-Water Contours below Groundsurface
- Inferred Groundwater Depth-to-Water Contours Below Groundsuface

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 8/1/2017 - 11/30/2017 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-43 shows groundwater elevation contours for spring of 2017. Because more data were available in this time frame, the contour map has increased detail in some areas. In the southeastern portion of the Basin near the Ozena fire station, groundwater gradients appear to indicate flows that follow the Cuyama River. The contour map shows a steep gradient across the SBCF and flows to an area of lowered groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, groundwater has a horizontal gradient that generally flows to the northeast, from areas with higher elevation topography towards areas with lower elevation topography where the Cuyama River is located.

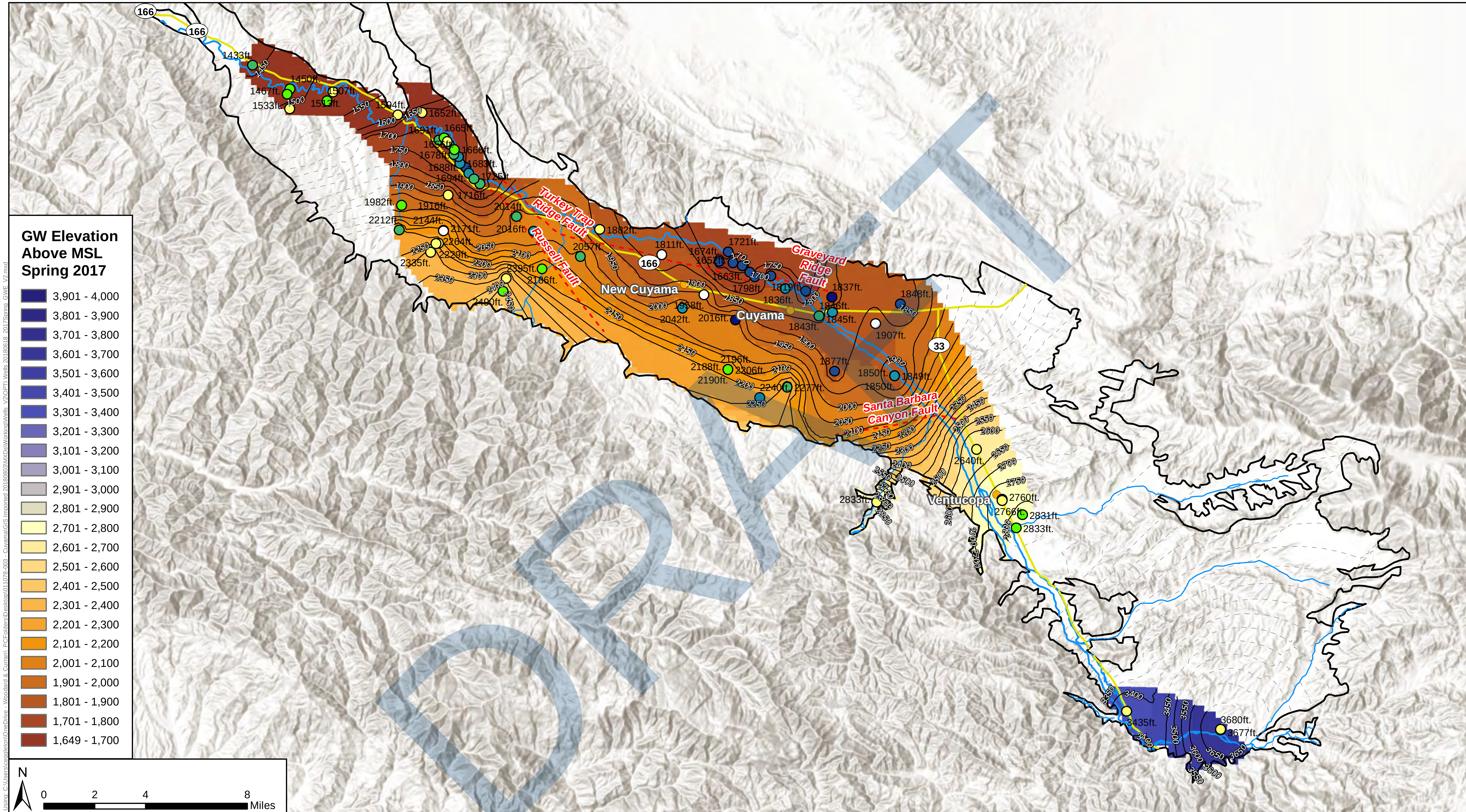


**Figure 2-43: Spring 2017 Groundwater Elevation**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Elevation Above MSL
- Inferred Groundwater Elevation Above MSL

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 1/1/2017 - 4/30/2017 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-44 shows depth to water contours for spring of 2017. In the southeastern portion of the Basin near the Ozena fire station, depth to water is under 50 feet bgs. Depth to groundwater near Ventucopa is between 150 and 200 feet bgs. There is a steep gradient near the SBCF, and groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 350 and 500 feet bgs, with depth to groundwater decreasing to the west of New Cuyama. West of Bitter Creek, groundwater is generally shallower than 100 feet below bgs, and is shallower than 50 feet bgs along the Cuyama River in most cases.

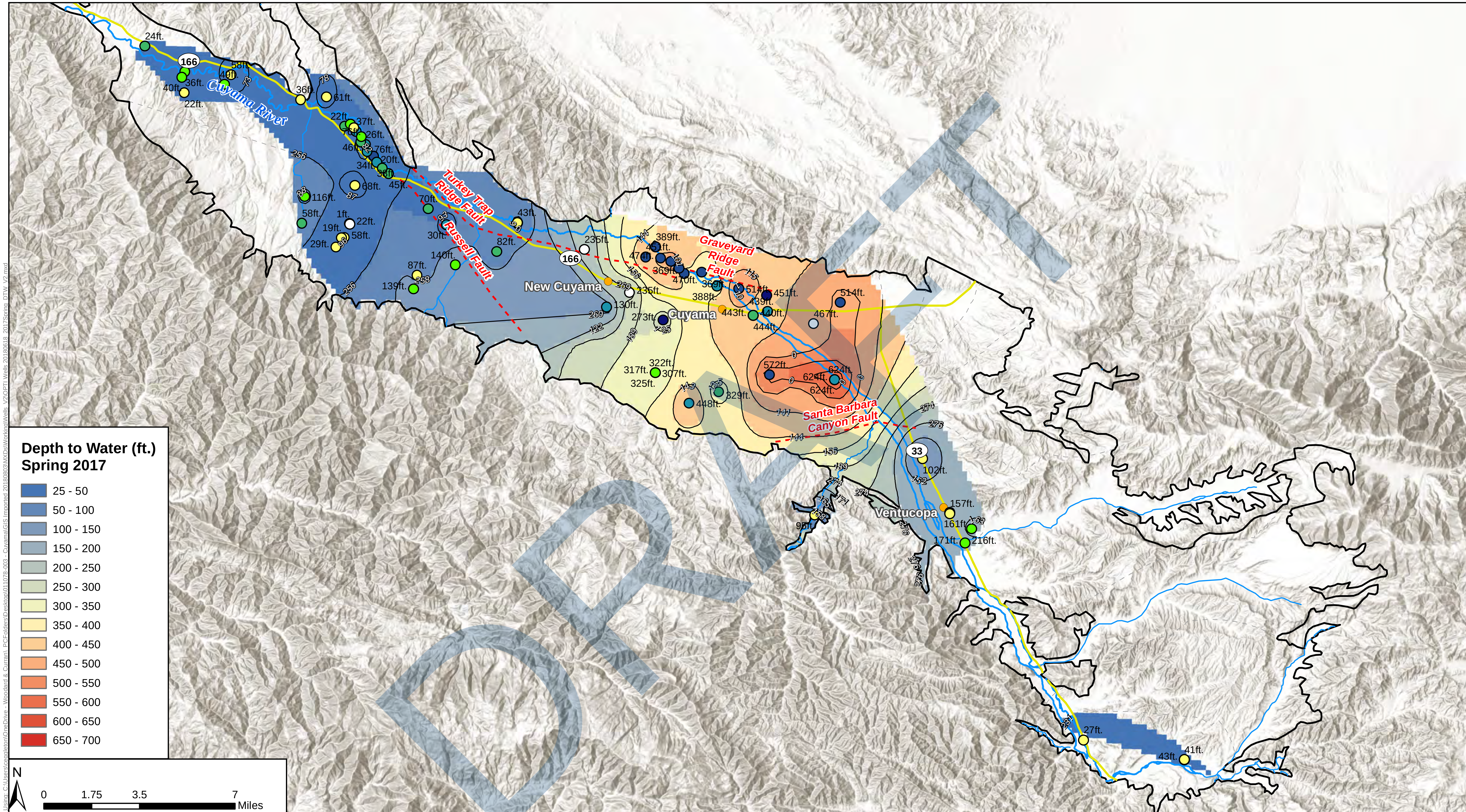


**Figure 2-44: Spring 2017**
**Depth to Water**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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Legend

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Depth-to-Water Contours Below Groundsurface
- Inferred Groundwater Depth-to-Water Contours Below Groundsurface

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 1/1/2017 - 4/30/2017 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-45 shows groundwater elevation contours for spring of 2015. In the southeastern portion of the Basin near the Ozena fire station, groundwater gradients appear to indicate flows that follow the Cuyama River. The contour map shows a steep gradient across the SBCF and flows to an area of lowered groundwater elevation northeast of the town of Cuyama. From the town of New Cuyama to the west, the limited number of data points restrict strong interpretation of the gradient, which is to the northwest.

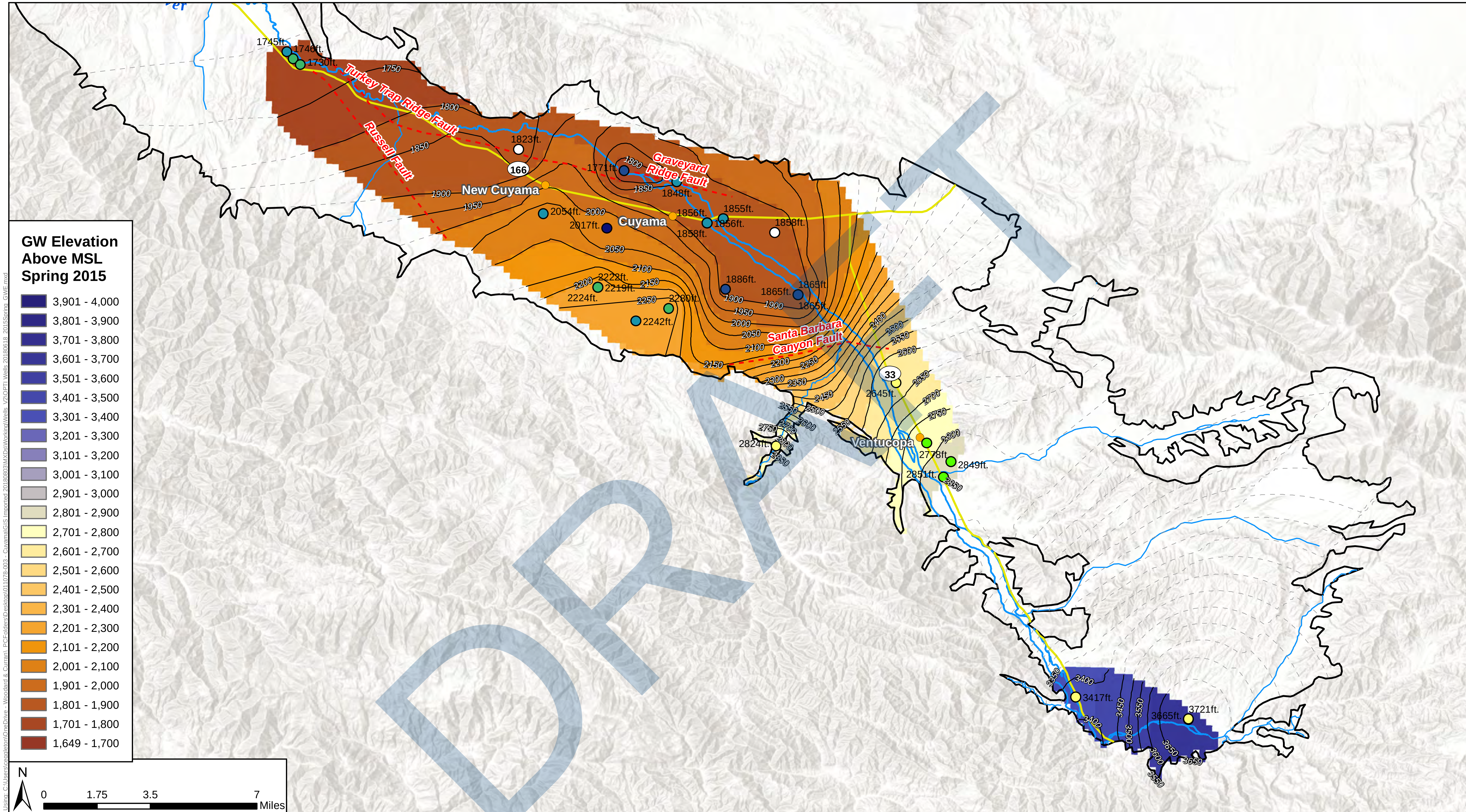


**Figure 2-45: Spring 2015 Groundwater Elevation**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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Legend

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Elevation Above MSL
- Inferred Groundwater Elevation Above MSL

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 2/1/2015 - 4/30/2015 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-46 shows depth to water contours for spring of 2015. In the southeastern portion of the Basin near the Ozena fire station, depth to water is under 50 feet bgs. Depth to groundwater near Ventucopa is between 150 and 200 feet bgs. There is a steep gradient near the SBCF, and groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 350 and 450 feet bgs, with groundwater levels rising to the west of New Cuyama. These depths are in general less severe than those shown for the spring of 2017, reflecting deepening depth to groundwater conditions in the central portion of the Basin. Interpretation from New Cuyama to monitoring points in the northwest is hampered by a limited set of data points.

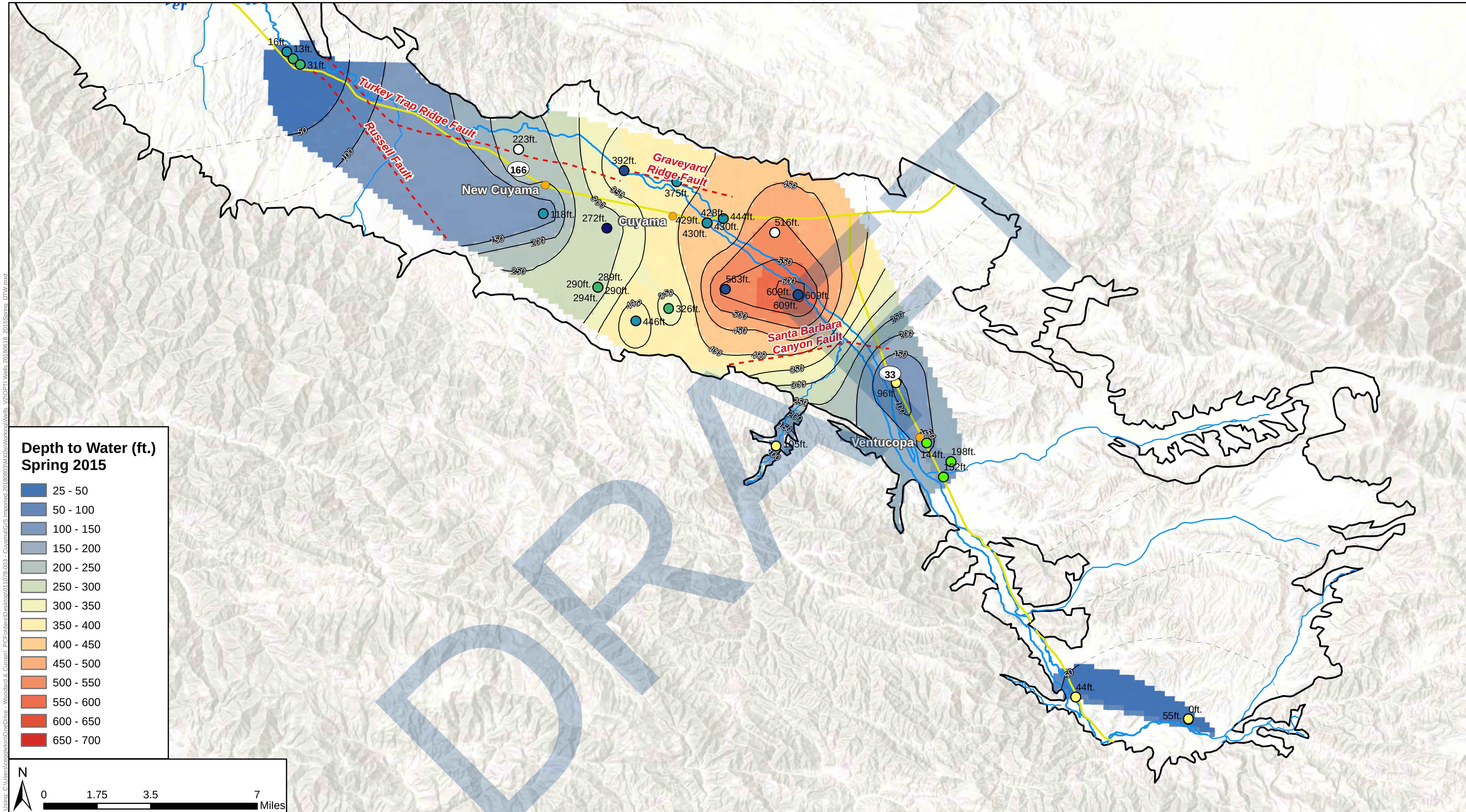


**Figure 2**-46: Spring 2015
Depth to Water

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Depth-to-Water Contours below Groundsurface
- Inferred Groundwater Depth-to-Water Contours below Groundsurface

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1,000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 2/1/2015 - 4/30/2015 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-47 shows groundwater elevation contours for fall of 2014. In the southeastern portion of the Basin near the Ozena fire station, groundwater gradients appear to indicate flows that follow the Cuyama River. The contour map shows a steep gradient across the SBCF and flows to an area of lowered groundwater elevation northeast of the town of Cuyama.

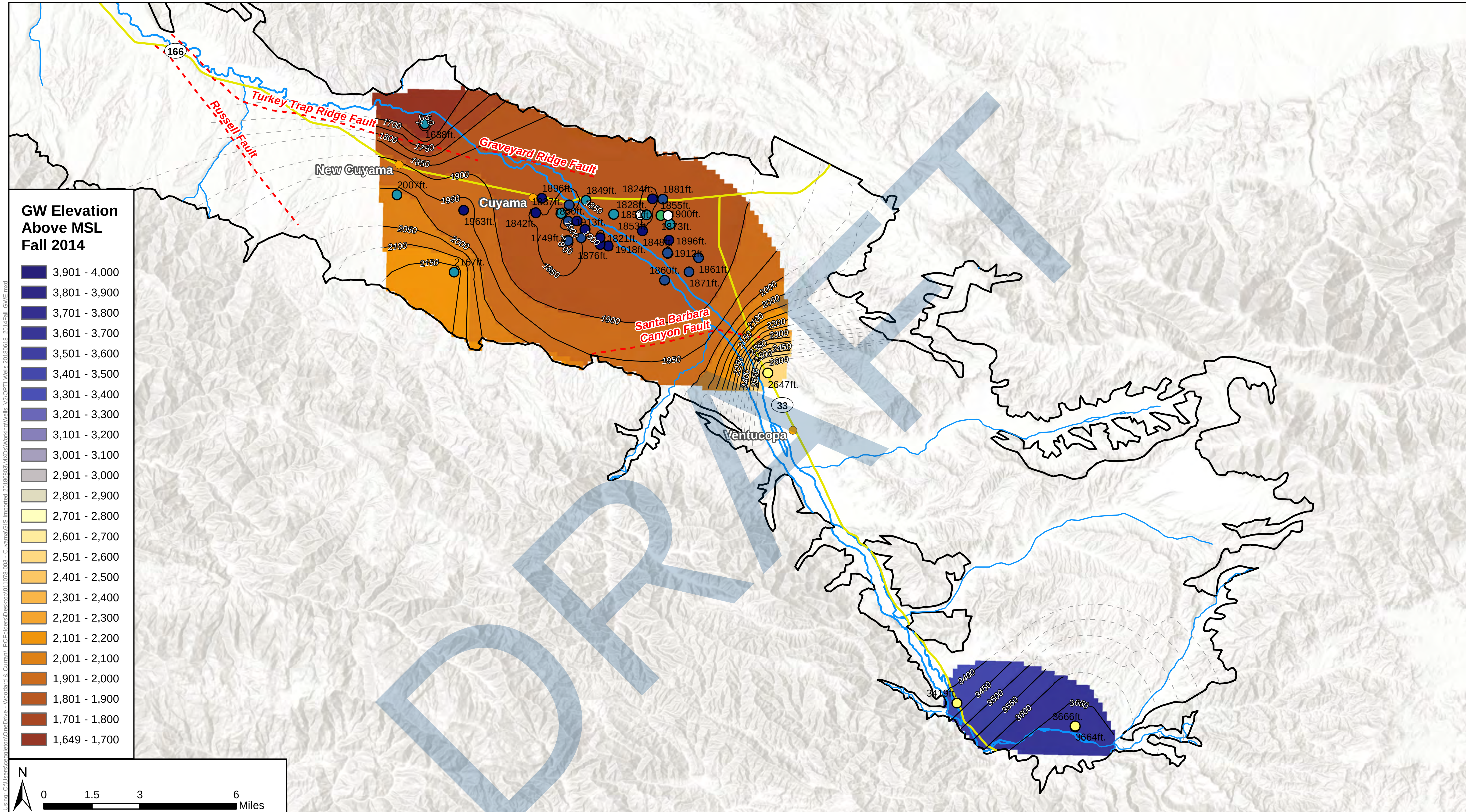


**Figure 2**-*47: Fall 2014*
*Groundwater Elevation*

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Elevation Above MSL
- Inferred Groundwater Elevation Above MSL

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 9/1/2014 - 11/30/2014 due to limitated data availability.

Contours Interval: 50 ft.

Figure 2-48 shows depth to water contours for fall of 2014. In the southeastern portion of the Basin near the Ozena fire station, depth to water is under 50 feet bgs. There is a steep gradient near the SBCF, and groundwater is below 600 feet bgs immediately northwest of the SBCF. The central portion of the Basin generally has a depth to water between 350 and 500 feet bgs, with groundwater levels rising to the west of New Cuyama. These depths are in general less severe than those shown for the fall of 2017, reflecting depth to groundwater conditions in the central portion of the Basin. Interpretation from New Cuyama to monitoring points in the northwest is hampered by a limited set of data points.

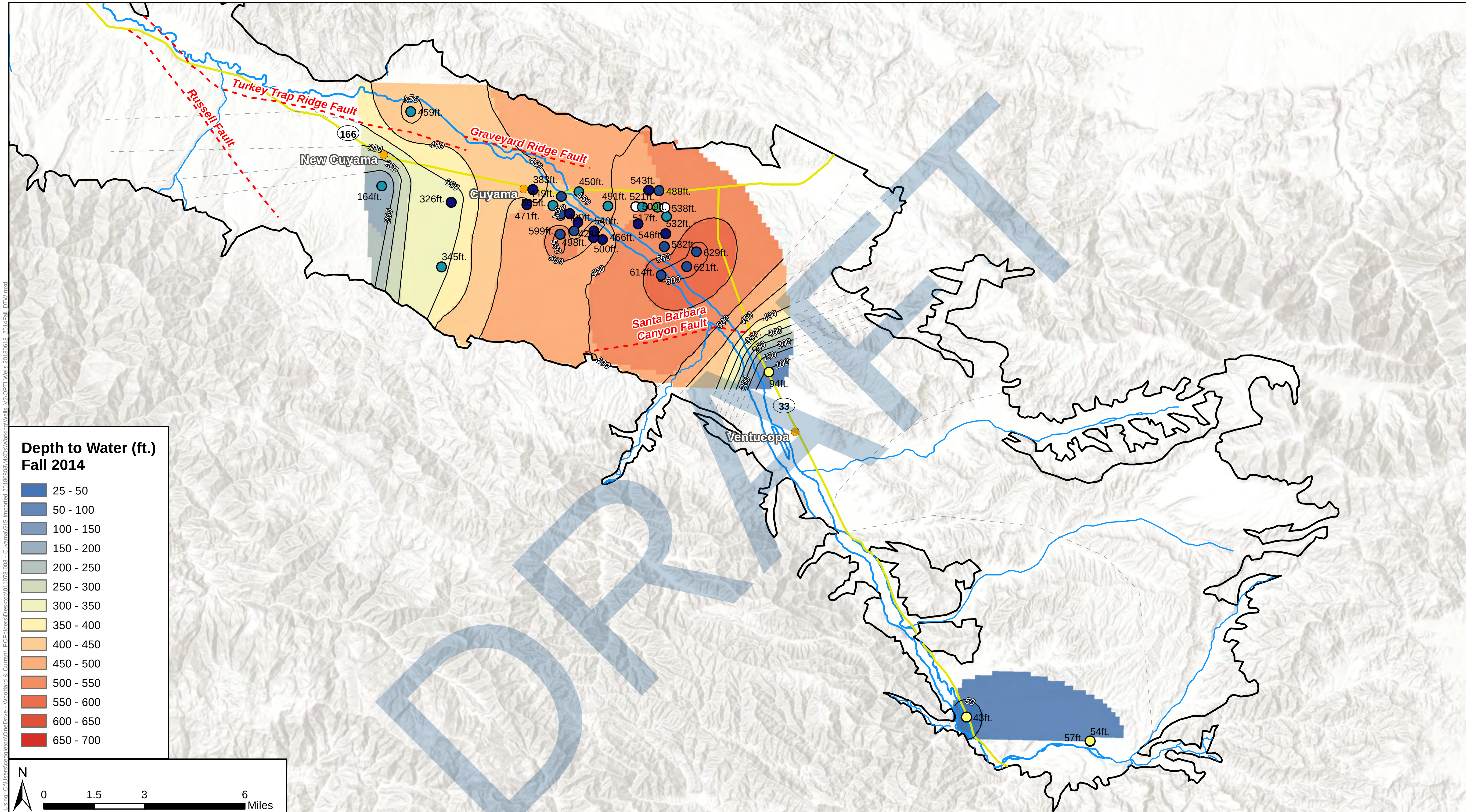


**Figure 2-48: Fall 2014 Depth to Water**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Cuyama River
- Faults
- Groundwater Depth-to-Water Contours below Groundsurface
- Inferred Groundwater Depth-to-Water Contours below Groundsurface

**Well Depth Below GSE**

- Unknown
- 0 - 200 ft
- 200 - 400 ft
- 400 - 600 ft
- 600 - 800 ft
- 800 - 1000 ft
- 1,000 - 1,200 ft

Contours were interpolated using data measured from 9/1/2014 - 11/30/2014 due to limitated data availability.

Contours Interval: 50 ft.

## 2.2.4 Change in Groundwater Storage

Historical change in Basin groundwater storage has shown a consistent decline. Figure 2-49 shows change in storage by year, water year type,[5] and cumulative water volume for the last 20 years. Change in storage was calculated using the Cuyama Basin Water Resources Model (CBWRM). Average annual use over the 20-year period was -23,076 acre-feet. The color of bar for each year of change in storage correlates a water year type defined by Basin precipitation. Change in storage is negative in 18 of the 20 years, and was negative during two of three wet years, as designated by the water year type.

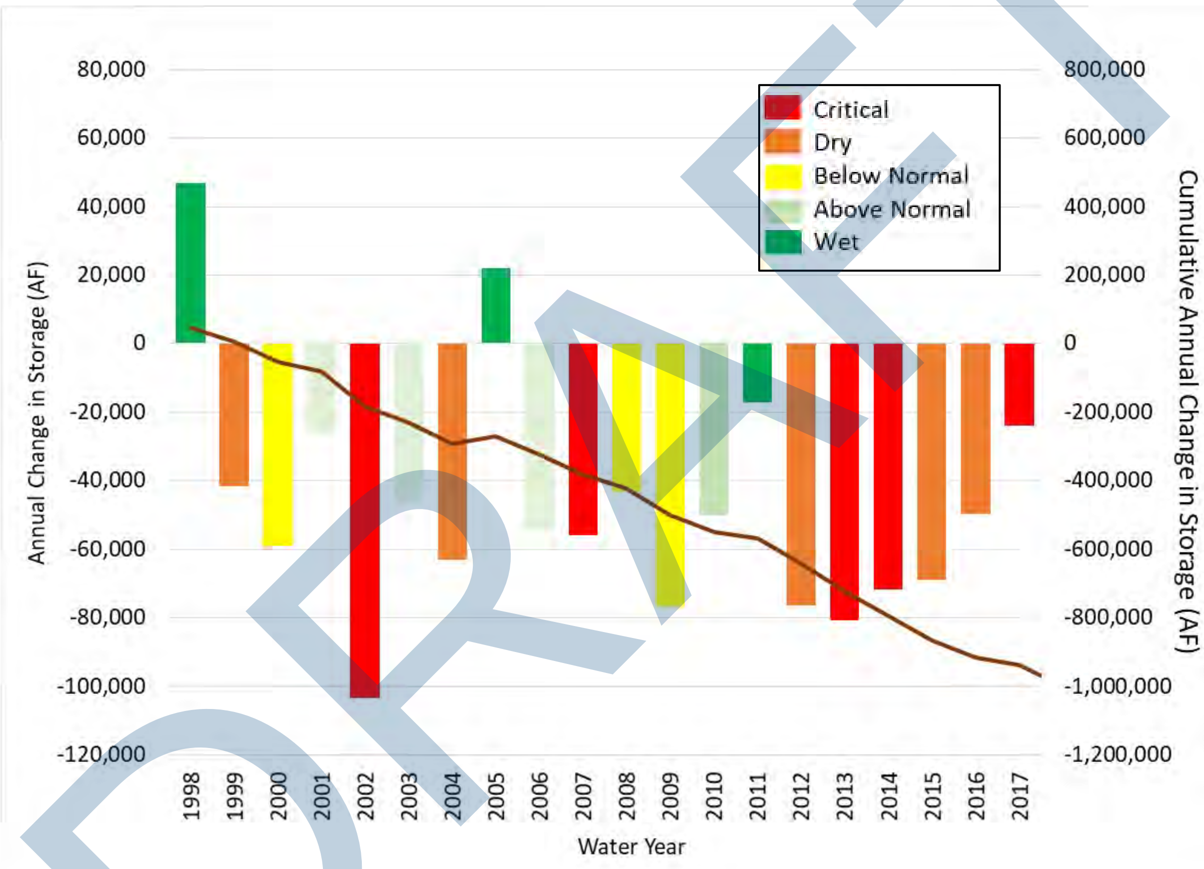


**Figure 2-49. Cuyama Groundwater Storage by Year, Water Year Type, and Cumulative Water Volume**

[5] Water year types are customized for the Basin watershed based on annual precipitation as follows:

- Wet year = more than 19.6 inches
- Above normal year = 13.1 to 19.6 inches
- Below normal year = 9.85 to 13.1 inches
- Dry year = 6.6 to 9.85 inches
- Critical year = less than 6.6 inches.

### 2.2.5 Seawater Intrusion

Seawater intrusion is not an applicable sustainability indicator, because seawater intrusion is not present in the Basin and is not likely to occur due to the distance between the Basin and the Pacific Ocean, its bays, deltas, or inlets.

### 2.2.6 Land Subsidence

In 2015, USGS measured land subsidence as part of its technical analysis of the Cuyama Valley. USGS used two continuous global positioning systems (GPS) sites and five reference point InSAR sites, shown in Figure 2-50 (USGS, 2015). There are 308 monthly observations from 2000 to 2012, and total subsidence from 2000 to 2012 ranged from 0.0 to 0.4 feet. USGS simulated subsidence using the CUVHM, and estimated that inelastic subsidence began in the late 1970s (USGS, 2015).

Subsidence data were collected from the University NAVSTAR Consortium (UNAVCO) database. UNAVCO maintains data on five GPS monitoring stations in the area in and around the Basin. Figure 2-43 shows the monitoring stations and their measurements since 1999. Three stations (P521, OZST, and BCWR) are located just outside the Basin. The three stations' measurements show ground surface level as either staying constant or slightly increasing. The increase is potentially due to tectonic activity in the region. Two stations (VCST and CUHS) are located within the Basin. Station VCST is located near Ventucopa and indicates that subsidence is not occurring in that area. Station CUHS indicates that 300 millimeters (approximately 12 inches) of subsidence have occurred in the vicinity of New Cuyama over the 19 years that were monitored. The subsidence at this station increases in magnitude following 2010, and generally follows a seasonal pattern. The seasonal pattern is possibly related to water level drawdowns during the summer, and elastic rebound occurring during winter periods.

A white paper that provides information about subsidence and subsidence monitoring techniques is in Appendix B.

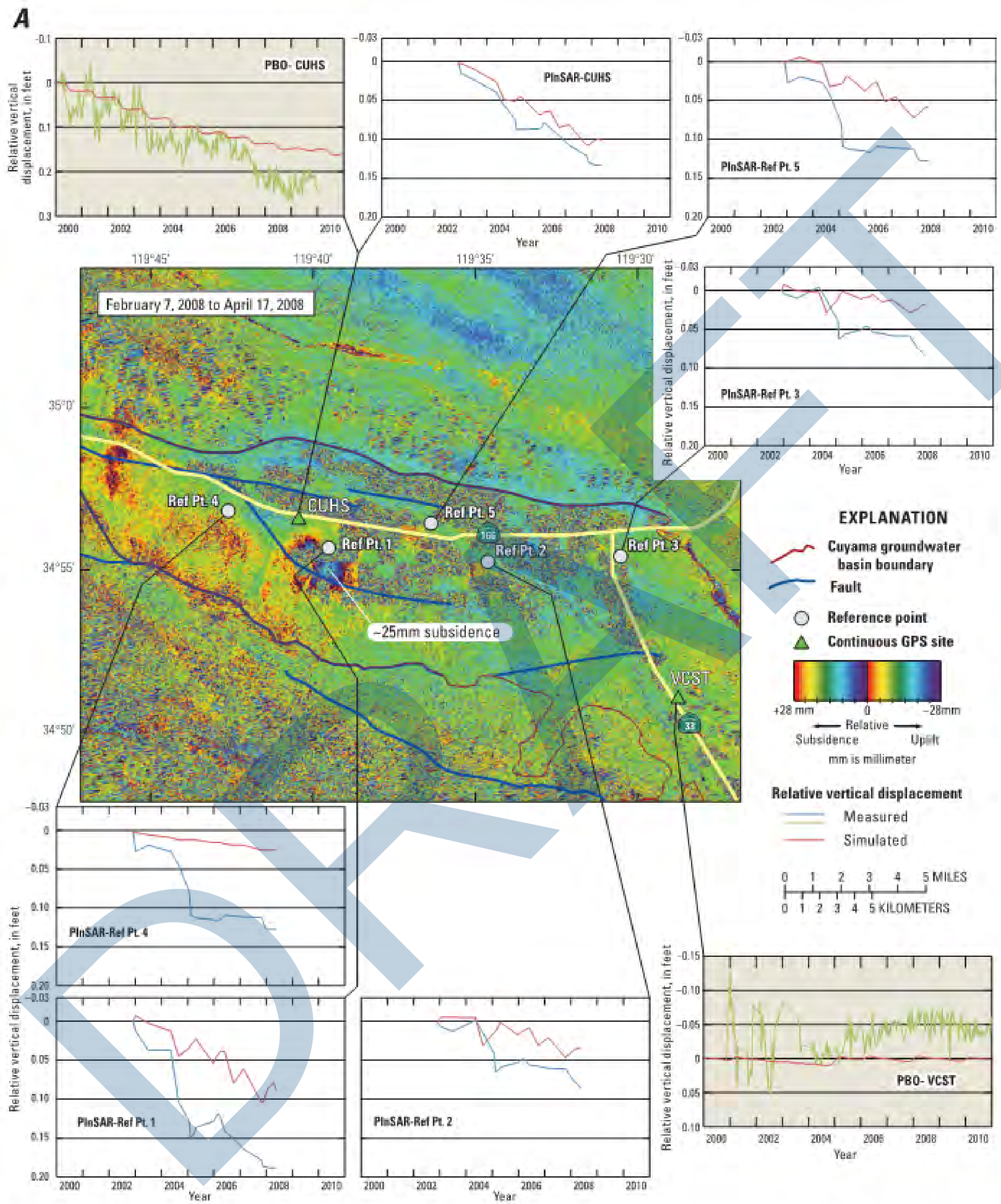




**Figure 29.** Historical subsidence as *A*, map of seasonal InSAR with graphs of simulated and measured time series for selected locations of relative land-surface deformation from Plate-Boundary Observation (PBO) sites and Point InSAR targets, and *B*, simulated total subsidence 1950–2010 for the calibrated hydrologic flow model, Cuyama Valley, California.

*Source: USGS, 2015*

**Figure 2-50: Locations of Continuous GPS and Reference InSAR Sites in the Cuyama Valley**

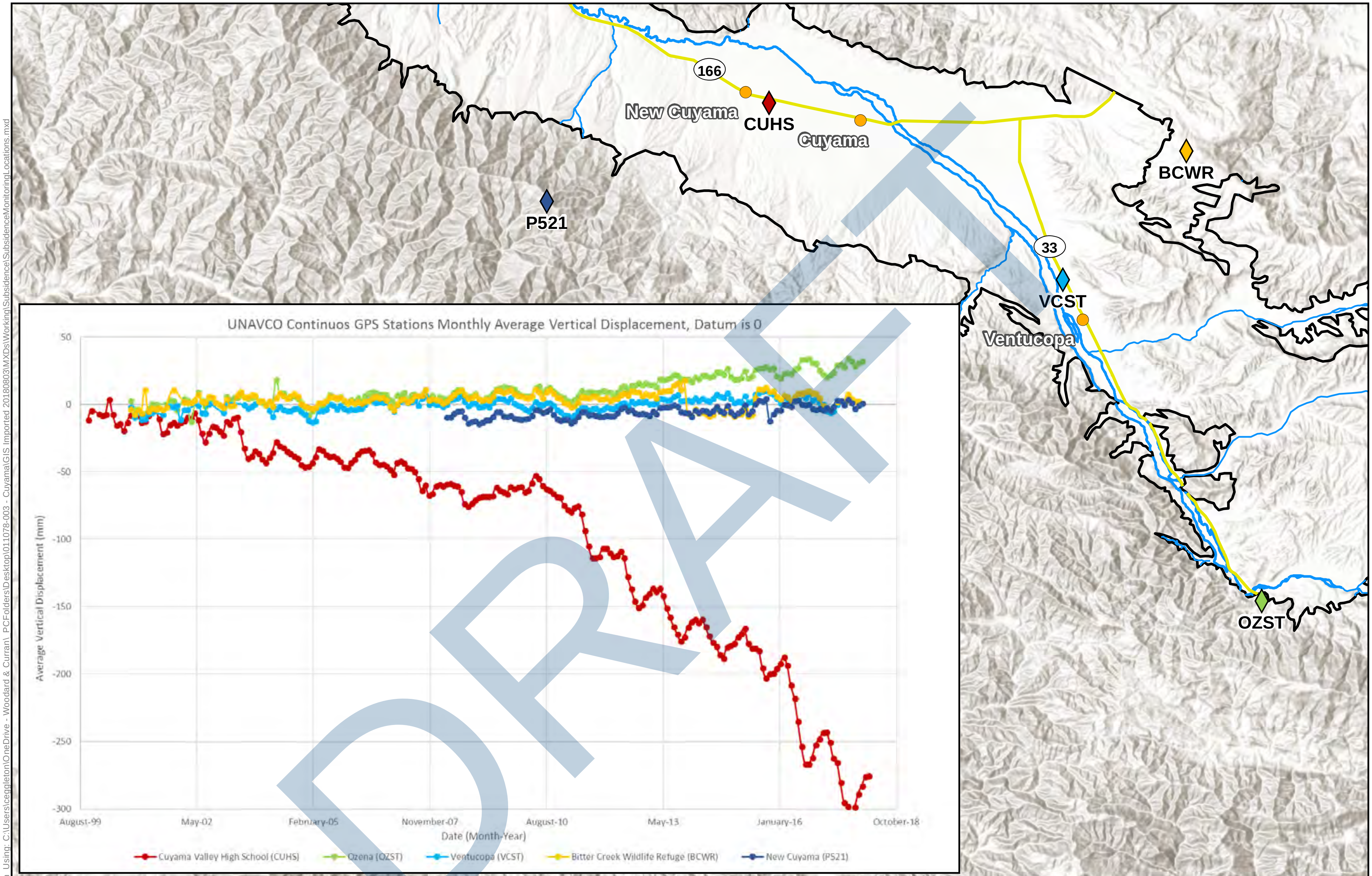


**Figure 2-51: Subsidence Monitoring Locations**

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*Legend*

Cuyama Basin
Towns
Highways
Cuyama River
Streams

0 2.5 5 10 Miles

N

### 2.2.7 Groundwater Quality

This section presents Basin groundwater quality information, including a discussion of available water quality data and references, results of water quality data analysis performed for the GSP, and a literature review of previous studies about water quality in the Basin.

#### Reference and Data Collection

References and data related to groundwater quality were collected from the following sources:

- USGS National Water Quality Monitoring Council. Downloaded data from June 1, 2018 from https://www.waterqualitydata.us/portal/
- DWR GeoTracker California Groundwater Ambient Monitoring and Assessment (GAMA) Program. Downloaded data on June 5, 2018 for each county, from http://geotracker.waterboards.ca.gov/gama/datadownload
- DWR California Natural Resources Agency data. Downloaded on June 14, 2018 from https://data.cnra.ca.gov/dataset/periodic-groundwater-level-measurements
- County of Ventura
- Private landowners

Data were then compiled into a database for analysis.

Analysts also compiled references containing groundwater quality information. The information included in these references were used to enhance understanding of groundwater quality conditions beyond available data. References used in this section include the following:

- Singer and Swarzensky. 1970. *Pumpage and Ground-Water Storage Depletion in Cuyama Valley, 1947-1966.* This report focuses on groundwater depletion, but also includes information about groundwater quality.
- USGS. 2008 *Groundwater-Quality Data in the South Coast Interior Basins Study Unit, 2008: Results from the California Groundwater Ambient Monitoring and Assessment (GAMA) Program*. This study summarizes water quality testing on 12 wells in the Cuyama Valley; wells were tested for a variety of constituents.
- SBCWA. 2011. *Santa Barbara County 2011 Groundwater Report.* This report provides groundwater conditions from throughout the county, and provides water quality information for the Cuyama Valley.
- USGS. 2013c. *Geology, Water-Quality, Hydrology, and Geomechanics of the Cuyama Valley Groundwater Basin, California, 2008-12*. This report investigates a wide variety of groundwater components in the Cuyama Valley, including water quality.

## Data Analysis

Collected data were analyzed for TDS, nitrate, and arsenic. These three constituents were included in analysis because they were cited in previous studies of the Basin, and they were discussed during public meetings as being of concern to stakeholders in the Basin.

Figure 2-52 shows TDS of groundwater measured in wells in 1966. In 1966, TDS was above the MCL of 1,500 micrograms per liter (mg/L) in over 50 percent of measurements. TDS was over 2,000 mg/L near the Cuyama River in the southeast portion of the Basin near the Ozena Fire Station, Santa Barbara Canyon, and upper Quatal Canyon, indicating that high TDS water was entering the Basin from the watershed above these measurement points. TDS measurements were over the MCL throughout the central portion of the Basin, where irrigated agriculture was operating, near the towns of Cuyama and New Cuyama, and along the Cuyama River to the northwest of New Cuyama. TDS was less than 500 mg/L in a number of measurements between Bitter Creek and Cottonwood Canyon, indicating that lower TDS water was entering the Basin from the watersheds in this area.

Figure 2-53 shows TDS of groundwater measured in wells between 2011 and 2018. Multiple years of collected data were used to generate enough mapped data density for comparison to 1966 data. From 2011 to 2018 period, TDS was above the MCL in over 50 percent of measurements. TDS was over 1,500 mg/L near the Cuyama River in the southeast portion of the Basin near the Ozena Fire Station, and in Santa Barbara Canyon, indicating that high TDS water was entering the Basin from the watershed above these measurement points. TDS measurements were over the MCL throughout the central portion of the Basin where irrigated agriculture was operating. A number of 500 to 1,000 mg/L TDS concentrations were measured near New Cuyama and in upper Quatal Canyon, and along the Cuyama River between Cottonwood Canyon and Schoolhouse Canyon.

Figure 2-54 shows measurements of TDS for selected monitoring points over time. Monitoring points were selected by the number of measurements, with higher counts of measurements selected to be plotted. The charts indicate that TDS in the vicinity of New Cuyama has been over 800 mg/L TDS throughout the period of record, and that TDS has either slightly increased or stayed stable over the period of record. The chart for Well 85 at the intersection of Quatal Canyon and the Cuyama River is generally below 800 mg/L TDS with rapid spikes of TDS increases above that level. The timing of rapid increases in measured TDS correspond with Cuyama River flow events, indicating a connection between rainfall and stream flow and an increase in TDS. This is the only location where this trend was detected.

Figure 2-55 shows measurements of nitrate in 1966. This figure also shows that data collected in 1966 shows the Basin was below the MCL of 10 mg/L throughout, with some measurements above the MCL in the central portion of the Basin where irrigated agriculture was operating.

Figure 2-56 shows measurements of nitrate in groundwater measured in wells between 2011 and 2018. Multiple years of collected data were used to generate enough mapped data density for comparison to 1966 data. This figure also shows that data collected over this period show the Basin was generally below the MCL, with two measurements that were over 20 mg/L.

Figure 2-57 shows arsenic measurements from 2008 to 2018. Data were not available prior to this time in significant amounts.

Figure 2-57 also shows that arsenic measurements were below the MCL of 10 micrograms per liter (µg/L) in the majority of the Basin where data was available. However, high arsenic values exceeding 20 µg/L were recorded at three well locations in the area south of New Cuyama; all of these high concentration samples were taken at depths of 700 feet or greater, and readings in the same area taken at shallower depths were below the MCL.

Figure 2-58 shows the results of a query using the Regional Water Quality Control Board (RWQCB)'s GeoTracker website. GeoTracker documents RWQCB contaminant concerns and mitigation projects. As shown in the figure, most GeoTracker sites show that gasoline, oil and/or diesel fuel have been cited as the contaminant of concern.

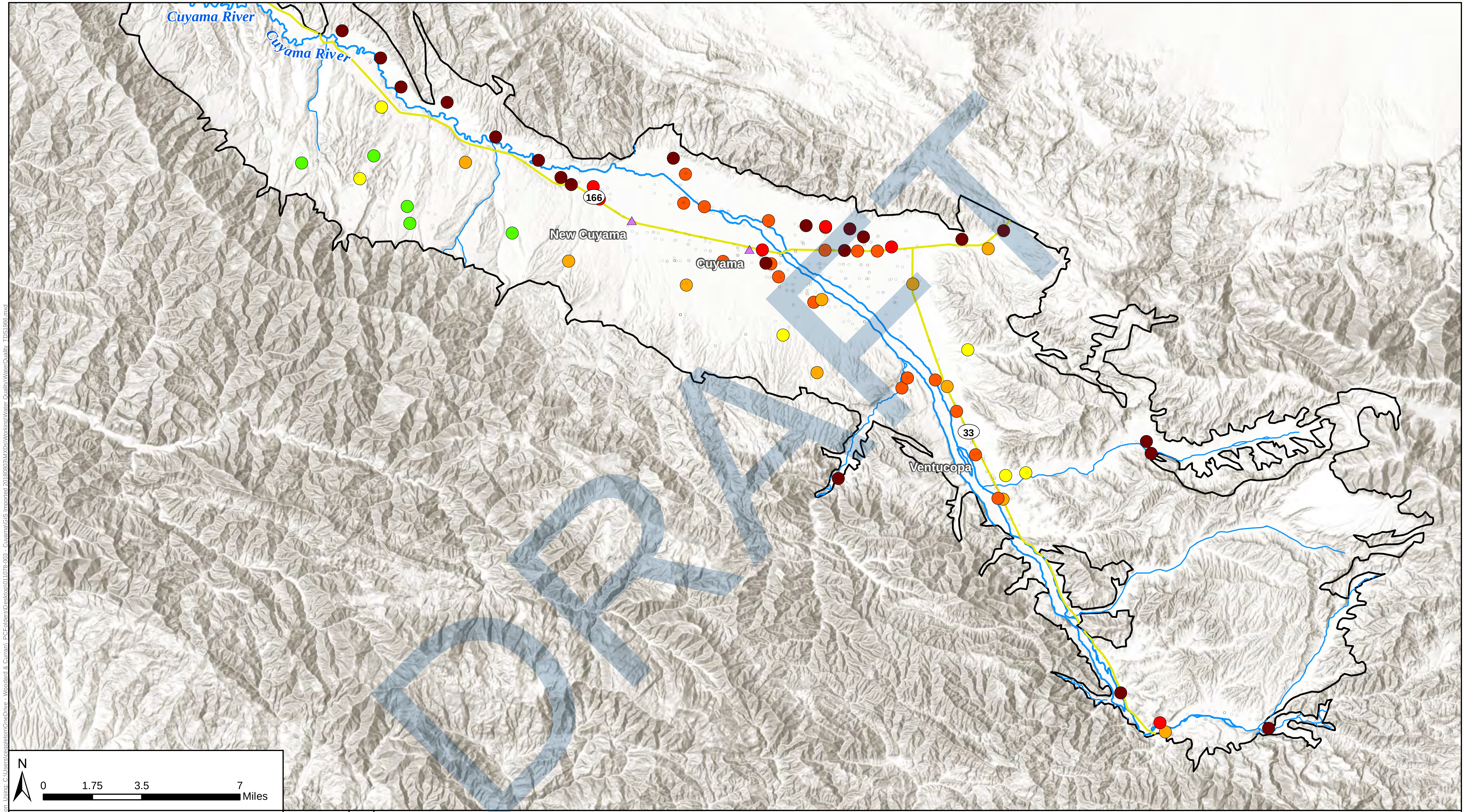


**Figure 2-52: 1966 Average Well Measurements of Total Dissolved Solids, mg/L**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

**TDS, mg/L**

- No Measurements
- < 500 mg/L
- 500 - 1,000 mg/L
- 1,000 - 1,500 mg/L
- 1,500 - 1,750 mg/L
- 1,750 - 2,000 mg/L
- >2,000 mg/L

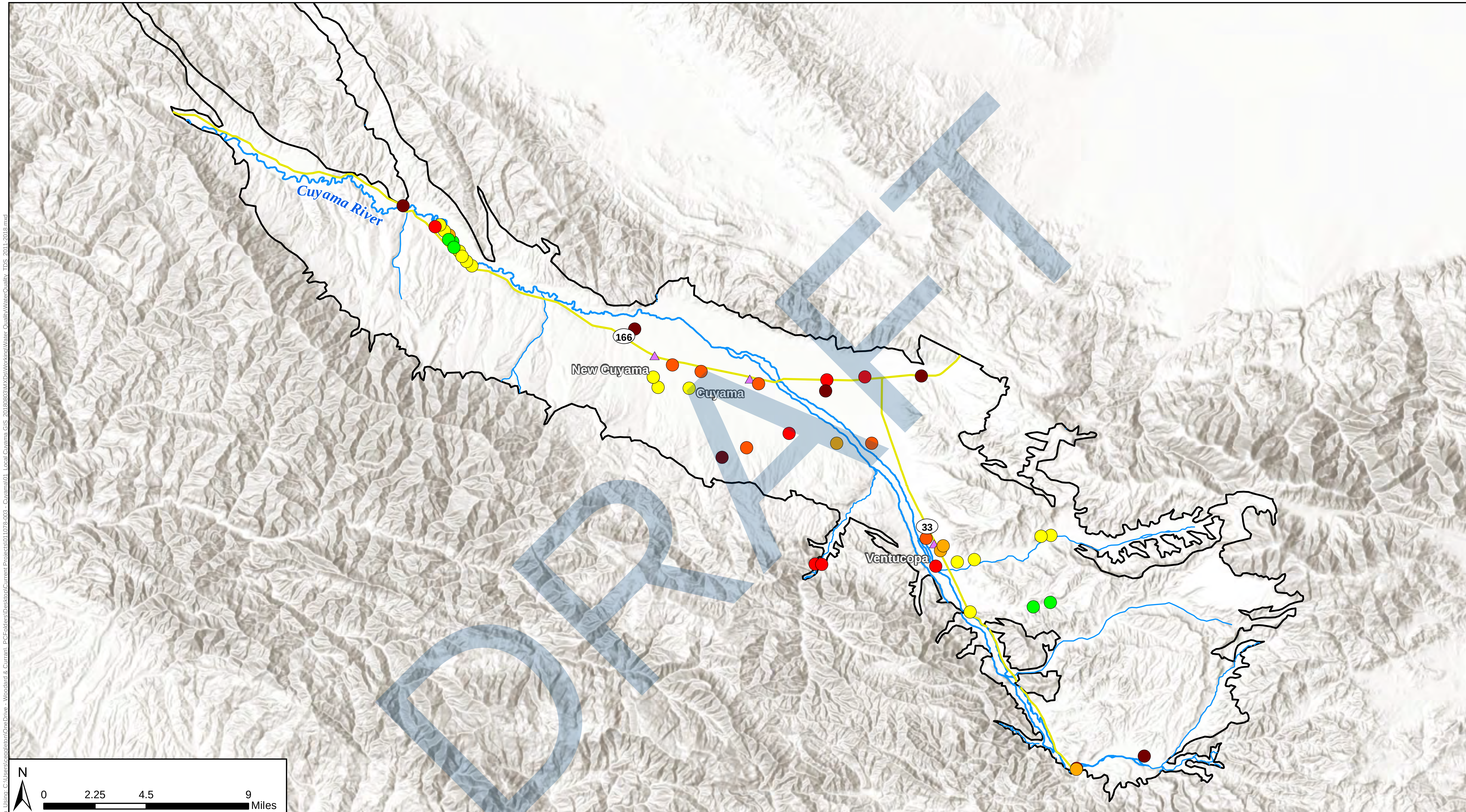


**Figure 2-53: 2011-2018 Average Well Measurements of Total Dissolved Solids, mg/L**

Cuyama Basin Groundwater Sustainability Agency

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*Legend*

**TDS, mg/L**

**Average_Re**

- < 500 mg/L
- 500 - 1,000 mg/L
- 1,000 - 1,500 mg/L
- 1,500 - 1,750 mg/L
- 1,750 - 2,000 mg/L
- > 2,000 mg/L

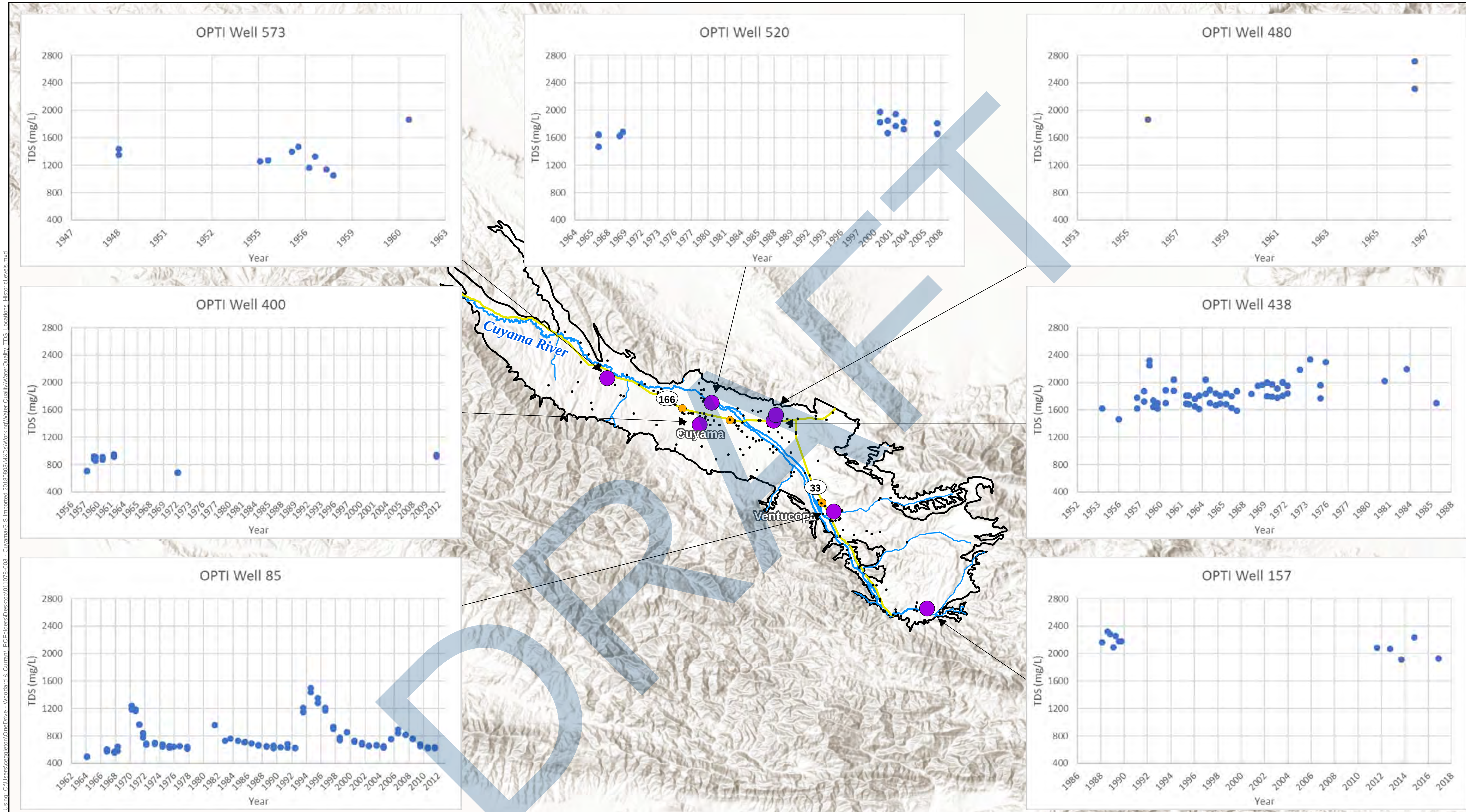


**Figure 2-54: Cuyama Groundwater Basin Historic TDS Levels in Selected Wells**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Cuyama River
- Streams
- Wells with Graphed Data
- Location of TDS WQ Measurements

N

0 4.5 9 18 Miles

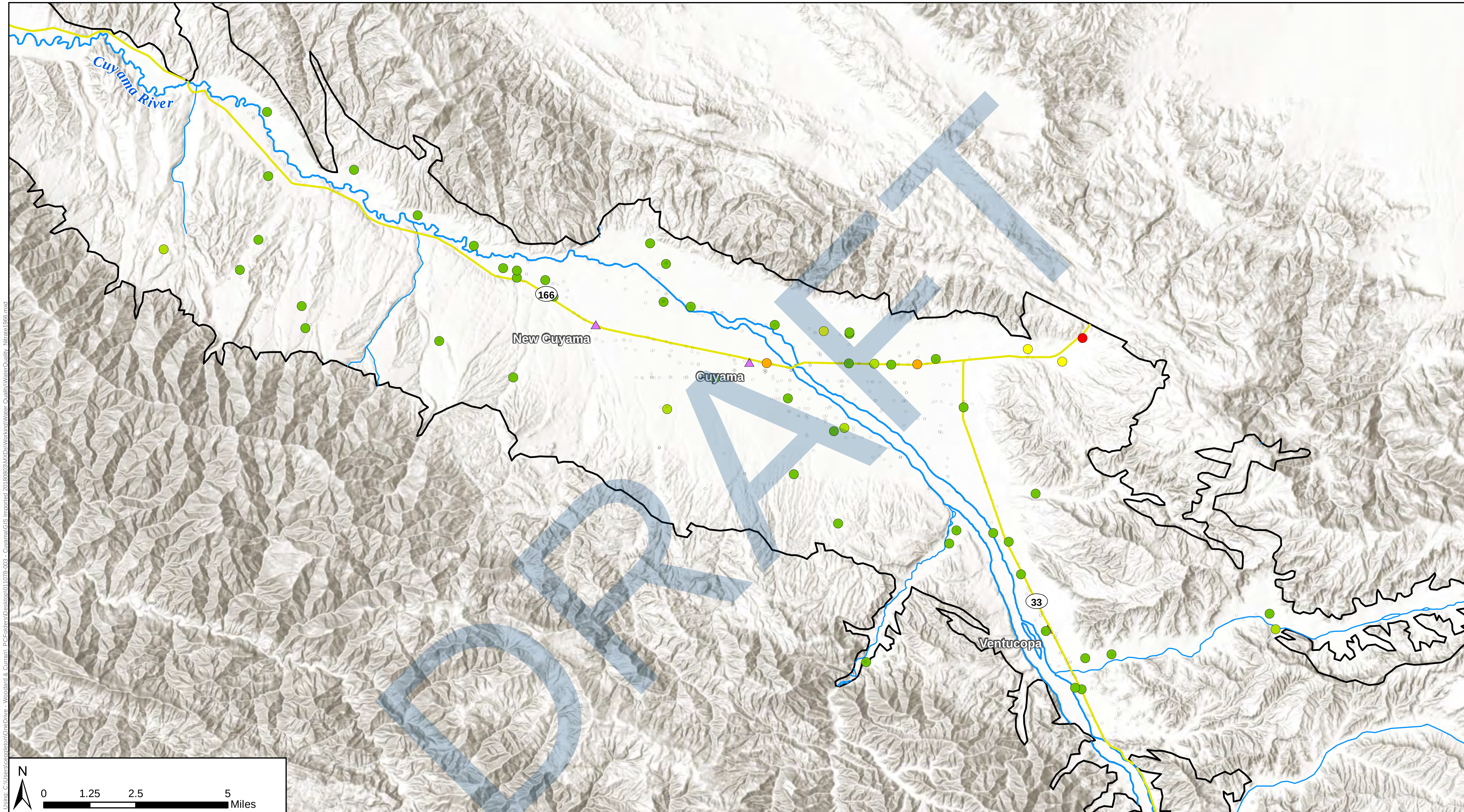


**Figure 2-55: 1966 Average Well Measurements of Nitrate (NO3) as Nitrogen**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

**Nitrate (NO3) as N, mg/L**

- No Measurements
- < 5 mg/L
- 5 - 8 mg/L
- 8 - 10 mg/L
- 10 - 15 mg/L
- 15 - 20 mg/L
- > 20 mg/L

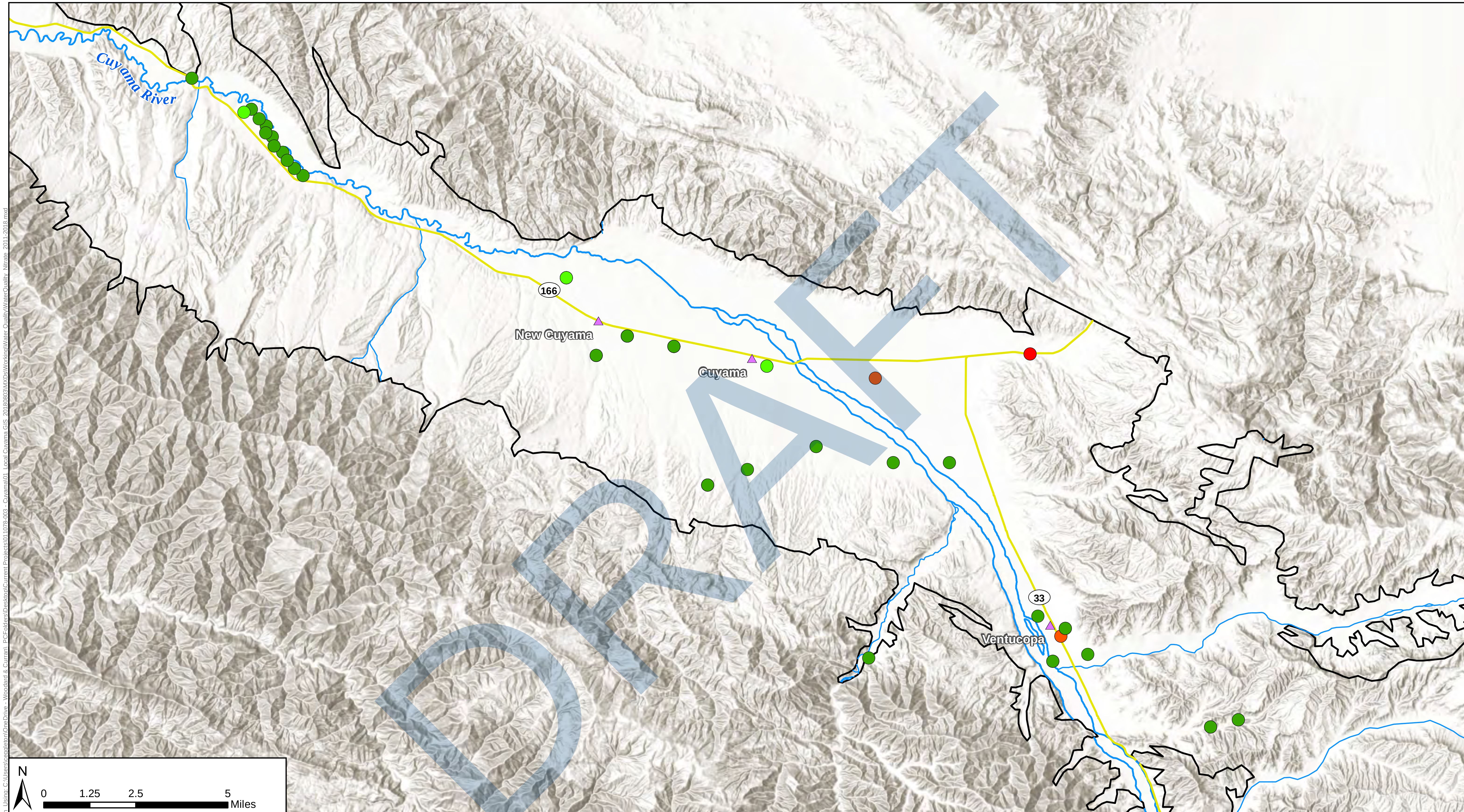


**Figure 2-56: 2011-2018 Average Well Measurements of Nitrate (NO3) as Nitrogen**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

**Nitrate (NO3) as N, mg/L**

- < 5 mg/L
- 5 - 8 mg/L
- 8 - 10 mg/L
- 10 - 15 mg/L
- 15 - 20 mg/L
- > 20 mg/L

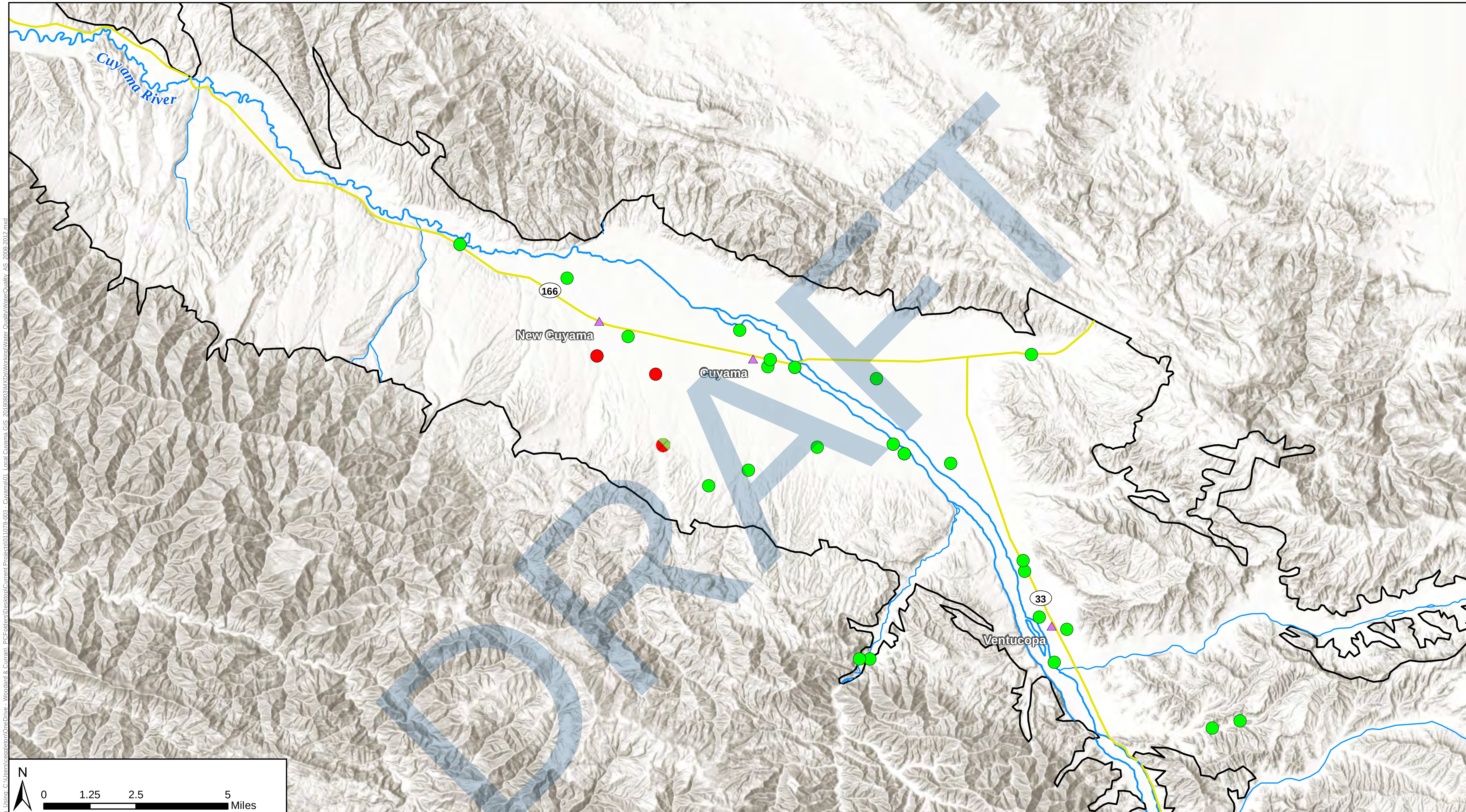


**Figure 2-57: 2008-2018 Average Well Measurements of Arsenic, ug/L**

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*Legend*

**Aresenic (As), ug/L**

- < 5 ug/L
- 5 - 10 ug/L
- 10 - 20 ug/L
- > 20 ug/L

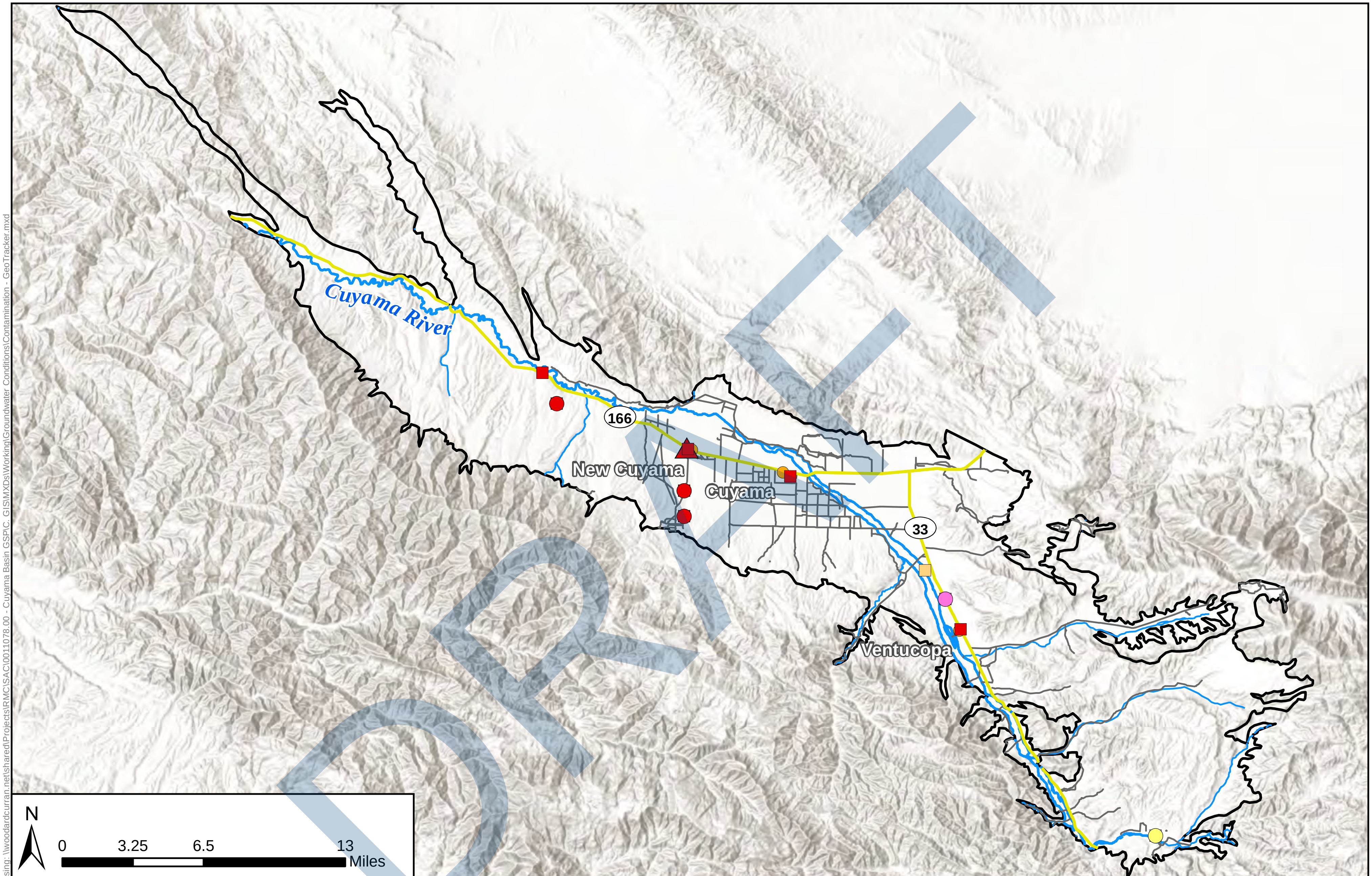


Figure 2-58 - Sites with Water Quality Concerns

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

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*Legend*

- Cuyama Basin
- Towns
- Highways
- Local Roads
- Cuyama River
- Streams

**Site Status**

- Open Sites
- Closed Sites
- Permitted UST

**Contaminant of Concern**

- Gas, Oil &/or Diesel
- TPH & Lead
- VOCs
- Alcohols

### Literature Review

In 1970, Singer and Swarzenski reported that TDS in the central basin was in the range of 1,500 to 1,800 mg/L TDS, and that the cations that contributed to the TDS and the amount of TDS varied by location in the Basin. They also reported that TDS was lower (i.e., from 400 to 700 mg/L) in areas downstream from the Sierra Madre Mountains where TDS was made up of sodium or calcium bicarbonate, and higher (i.e., from 3,000 to 6,000 mg/L) in wells close to the Caliente Range and in the northeastern part of the valley. Singer and Swarzenski stated that the high TDS was generated by mixing of water from marine rocks with more recent water from alluvium. They determined that groundwater movement favors movement of brackish water from the north of the Cuyama River toward areas of groundwater depletion, and that return of some water applied during irrigation and needed for leaching the soil carries dissolved salts with it to the water table (Singer and Swarzensky, 1970).

In 2008, USGS reported GAMA Program results. The GAMA Program sampled 12 Basin wells for a wide variety of constituents. Figure 2-59 shows the location of GAMA Program wells. The GAMA Program identified that specific conductance, which provides an indication of salinity, ranged from 637 to 2,380 microsiemens per centimeter (µS/cm) across the study's 12 wells. The GAMA Program study reported that the following constituents were not detected at levels above the MCL for each constituent in any samples for the following constituents:

- Pesticides or pesticide degradates
- Gasoline and refrigerants
- Aluminum, antimony, barium, beryllium, boron, cadmium, copper, iron, and lead
- Ammonia and phosphate
- Lithium, molybdenum, nickel, selenium, strontium, thallium, tungsten, uranium, vanadium, and zinc
- Bromide, calcium, chloride, fluoride, iodide, magnesium, potassium, silica, and sodium

The GAMA Program reported that there were detections at levels above the MCL for the following constituents:

- Manganese exceeded its MCL in two wells
- Arsenic exceeded the MCL in one well
- Nitrate exceeded the MCL in two wells
- Sulfate exceeded its MCL in eight wells
- TDS exceeded its MCL in seven wells
- VOCs detected in one well

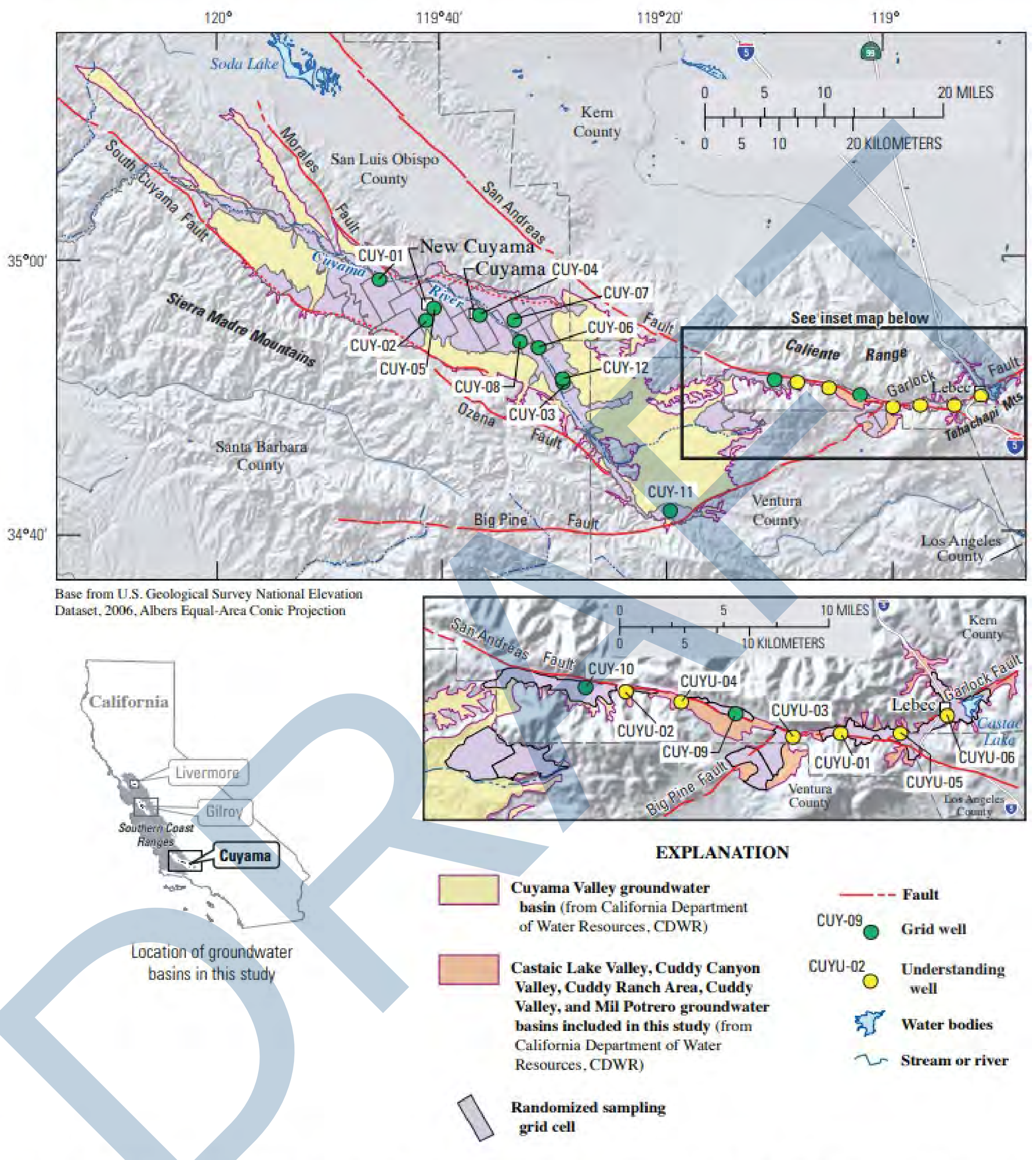


**Figure 5.** The South Coast Interior Basins Groundwater Ambient Monitoring and Assessment (GAMA) study unit showing the distribution of the Cuyama study-area grid cells, the location of sampled grid wells and understanding wells, the Cuyama Valley, Castaic Lake Valley, Cuddy Canyon Valley, Cuddy Ranch Area, Cuddy Valley, and Mil Potrero groundwater-basin boundaries (as defined by the California Department of Water Resources, CDWR), major cities, major roads, topographic features, and hydrologic features. Alphanumeric identification numbers for grid wells

*Source: USGS, 2008*

**Figure 2-59: Locations of GAMA Sample Locations**

In 2011, SBCWA reported that TDS in the Basin typically ranged from 1,500 to 1,800 mg/L in the main part of the Basin, while the eastern portion of the Cuyama Badlands near Ballinger, Quatal, and Apache Canyons had better water quality with TDS typically ranging rom 400 to 700 mg/L. SBCWA noted spikes in TDS in the Badlands Well following the wet rainfall years of 1969 and 1994 and stated that the spikes are attributable to overland flow from rainfall which is flushing the upper part of the Basin after dry periods.

SBCWA reported that boron is generally higher in the upper part of the Basin and is of higher concentration in the uplands than in the deeper wells in the central part of the Basin. Toward the northeast end of the Basin at extreme depth there exists poor quality water, perhaps connate (trapped in rocks during deposition) from rocks of marine origin.

SBCWA also reported: “There was little change in TDS, calcium, magnesium, nitrates and sulfates during the 2009- 2011 period. In some cases, concentrations of these nutrients actually fell during the period, most likely due to a lack of rainfall, recharge and flushing of the watershed. As the Cuyama watershed is mostly dry, water quality data must be examined with caution as sometimes overland flow from rainfall events “flushes” the watershed and inorganic mineral concentrations actually peak during storm flows. Typically, in other areas of Santa Barbara County mineral concentrations are diluted during widespread storm runoff out of natural watersheds.”

In 2013, USGS reported that they collected groundwater quality samples at 12 monitoring wells, 27 domestic wells, and 2 springs for 53 constituents including: field parameters (water temperature, specific conductance, pH, DO, alkalinity), major and minor ions, nitrate, trace elements, stable isotopes of hydrogen and oxygen, tritium and carbon-14 activities, arsenic, iron, and chromium. Figure 2-60 shows the USGS sampling locations, which were presented in a figure from their report. The USGS reported sampling result as follows:

- Groundwater in the alluvial aquifer system has high concentrations of TDS and sulfate
- 97 percent of samples had concentrations greater than 500 mg/L for TDS
- 95 percent of samples had concentrations greater than 250 mg./L for sulfate
- 13 percent of samples had concentrations greater than 10 mg/L for nitrate
- 12 percent of samples had concentrations greater than 10 ug/L for arsenic
- One sample had concentrations greater than the MCL for fluoride
- Five samples had concentrations greater than 50 mg/L for manganese
- One sample had concentration of iron greater than 300 mg/L for iron
- One sample had concentration of aluminum greater than 50 mg/L

USGS reported that nitrate was detected in five locations above the MCL of 10 mg/L. Four wells where nitrate levels were greater than the MCL were in the vicinity of the center of agricultural land-use area. Irrigation return flows are possible source of high nitrate concentrations. There was a decrease in concentrations with depth in the agricultural land use area which indicated the source of higher nitrate concentrations likely to be near the surface. The lowest nitrate levels were outside the agricultural use area, and low concentrations of nitrate (less than 0.02 mg/L) in surface water samples indicated surface water recharge was not a source of high nitrate

The USGS reported that arsenic was found in greater concentration than the MCL of 10 ug/L in four of the 33 wells sampled, and samples of total chromium ranged from no detections to 2.2 ug/L, which is less than the MCL of 50 ug/L. Hexavalent chromium ranged from 0.1 to 1.7 ug/L which is less than the MCL of 50 ug/L.

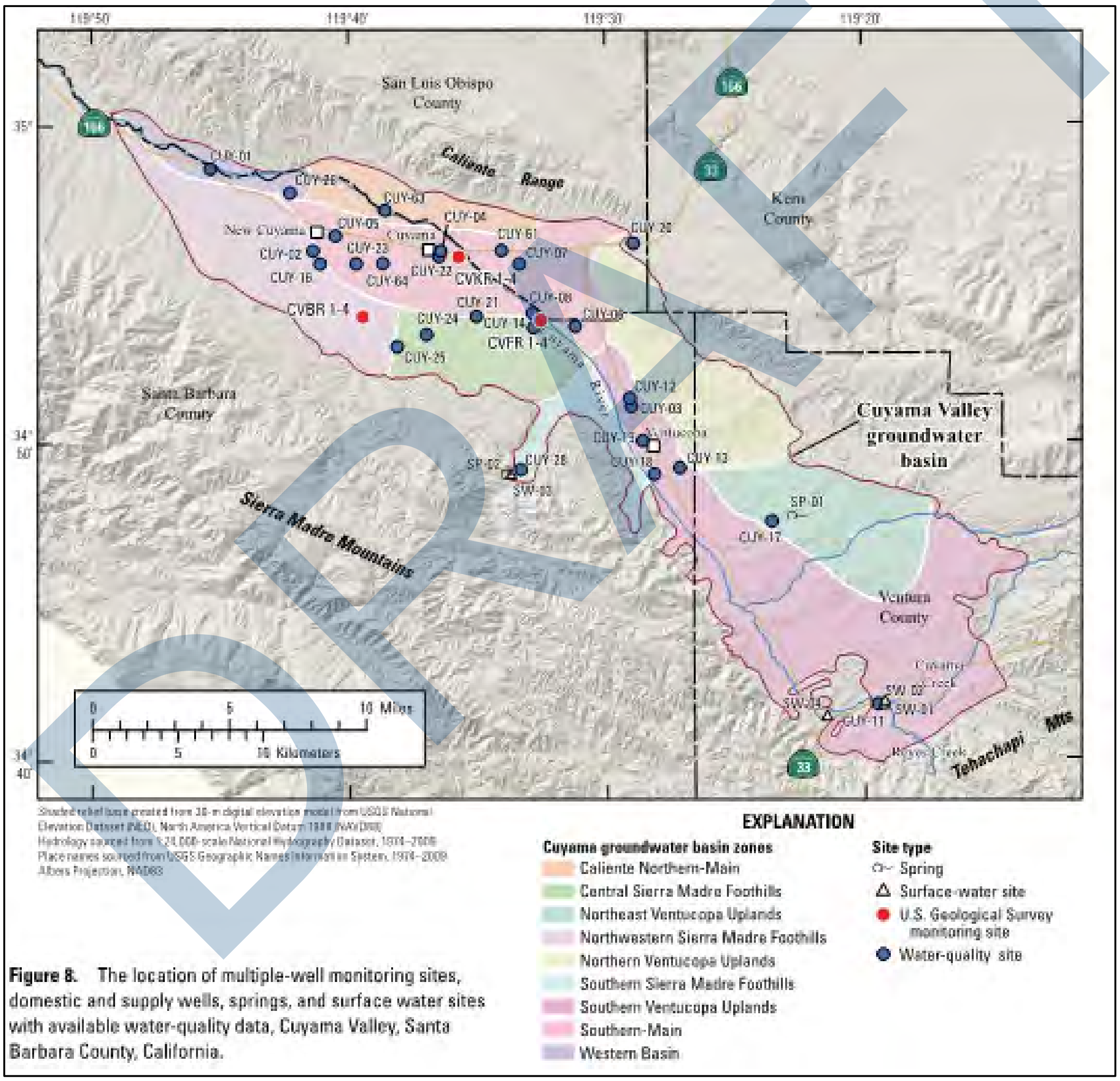


**Figure 8.** The location of multiple-well monitoring sites, domestic and supply wells, springs, and surface water sites with available water-quality data, Cuyama Valley, Santa Barbara County, California.

*USGS 2013c*

**Figure 2-60: USGS 2013c Water Quality Monitoring Sites**

### 2.2.8 Interconnected Surface Water Systems

The CBWRM, described in Appendix C, was used to analyze interactions between surface water flows in the Basin. Surface water flows were assigned reaches, five on the Cuyama River, and four for creeks. Figure 2-61 shows these reaches are shown in Figure 2-51; each reach was assigned a number. Results of the analysis are shown in Table 2-X in AF for each reach. Seven years had higher total depletions than 2017, which had a depletion estimate of 5,016 AF. Reach characteristics are listed below.

- **Reach 1 – Alamo Creek:** This reach was gaining in each year analyzed, with an average gain of 380 AF per year. The highest gain of 692 AF was in 1998, and the lowest gain was 192 AF in 2016.
- **Reach 2 – Cuyama River, from edge of basin to Alamo Creek**: This reach was losing in each year analyzed, with an average loss of 26 AF. The smallest loss was 1 AF in 2007, and the largest loss was -109 AF in 2005.
- **Reach 3 – Cuyama River from Alamo Creek, to Quatal Canyon Creek:** This reach was mostly gaining in each year, and lost in one year. The average of gains and losses was a gain of 931 AF. The highest gain of 2,781 was in 1998, and the loss of 300 AF occurred in 2017.
- **Reach 4 – Quatal Canyon Creek:** This reach was losing in each year analyzed, with an average loss of 83 AF. The smallest loss was 1 AF in 2007, and the largest loss was -347 AF in 1998.
- **Reach 5 – Cuyama River from Quatal Canyon Creek to Santa Barbara Canyon Creek:** This reach was losing in each year analyzed, with an average loss of 926 AF. The smallest loss was 180 AF in 2013, and the largest loss was 2,394 AF in 2005.
- **Reach 6 – Santa Barbara Canyon Creek:** This reach was gaining in each year analyzed, with an average gain of 95 AF per year. The highest gain of 222 AF was in 1999, and the lowest gain was 222 AF in 2016.
- **Reach 7 – Cuyama River from Santa Barbara Canyon Creek to Schoolhouse Canyon Creek:** This reach was losing in each year analyzed, with an average loss of 5,218 AF. The smallest loss was 797 AF in 2013, and the largest loss was 16,472 AF in 1998
- **Reach 8 – Schoolhouse Canyon Creek:** This reach was gaining in each year analyzed, with an average gain of 175 AF/year. The highest gain of 249 AF was in 1998, and the lowest gain was 134 AF in 2017.
- **Reach 9 – Cuyama River west of Schoolhouse Canyon Creek:** This reach was gaining in each year analyzed, with an average gain of 1,333 AF/year. The highest gain of 2,743 AF was in 1998, and the lowest gain was 750 AF in 2015.

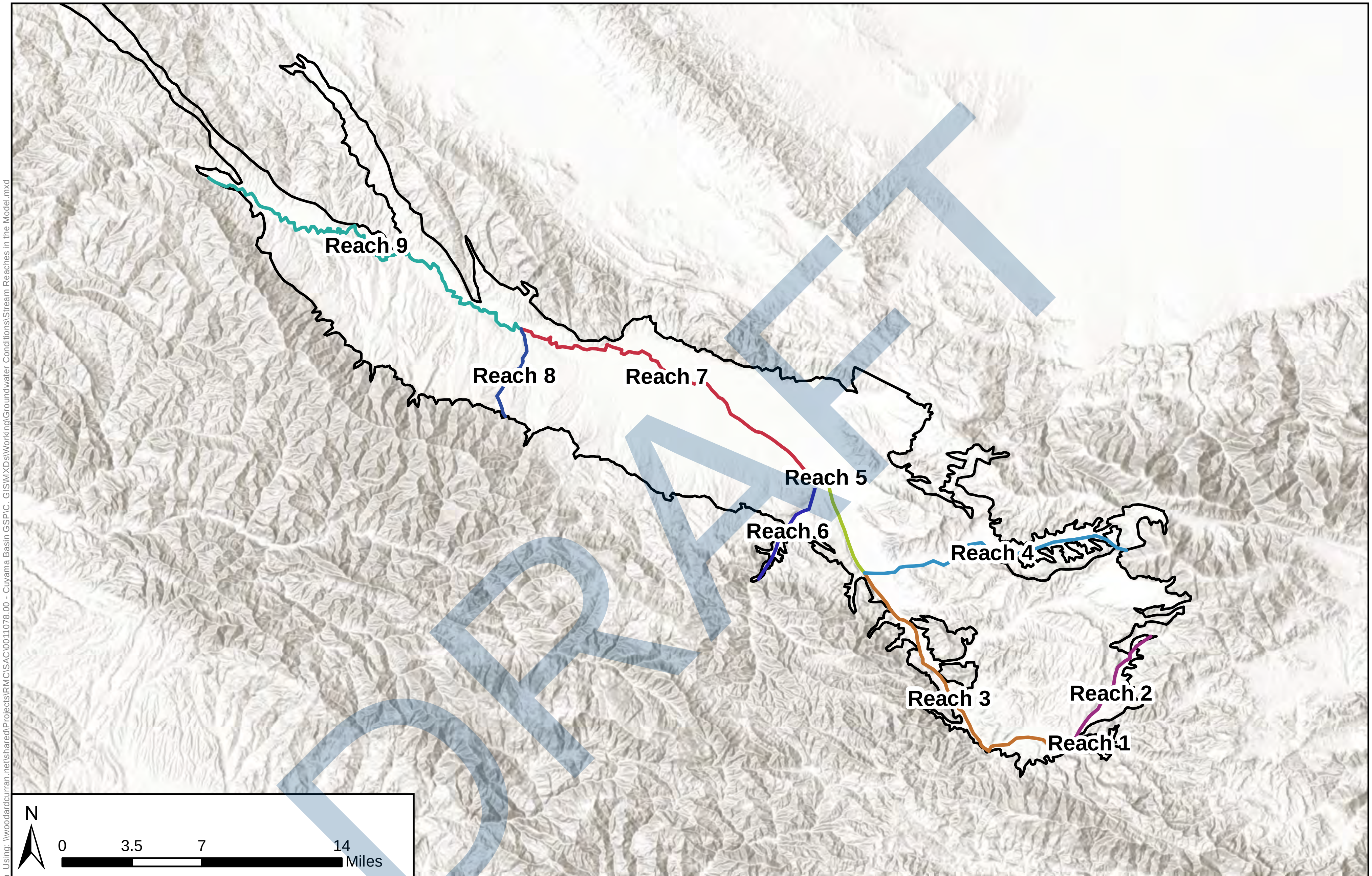




**Figure 2-61: Stream Reaches Used in Cuyama Groundwater Model**

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*Legend*

Cuyama Basin

**Stream Reach**

1
2
3
4
5
6
7
8
9

Figure Exported: 4/18/2019 By: ceggleton Using: \\woodardcurran.net\shared\Projects\RMC\SAC\0011078.00 - Cuyama Basin GSP\C. GIS\MXDs\Working\Groundwater Conditions\Stream Reaches in the Model.mxd

Table 2-2: Stream Depletion by Reach

| Year | Reach 1 (AF) | Reach 2 (AF) | Reach 3 (AF) | Reach 4 (AF) | Reach 5 (AF) | Reach 6 (AF) | Reach 7 (AF) | Reach 8 (AF) | Reach 9 (AF) | Total (AF) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1998 | 692.9 | -100.7 | 2780.8 | -346.8 | -2182.5 | 164 | -16471.5 | 249.3 | 2742.9 | -12471.6 |
| 1999 | 547.1 | -4.3 | 2636.1 | -15.1 | -561.3 | 222.1 | -3060.8 | 234.1 | 2383.5 | 2381.4 |
| 2000 | 492.6 | -19.3 | 1915.6 | -60.8 | -973.6 | 150 | -4602.7 | 218.3 | 2152.4 | -727.5 |
| 2001 | 460.6 | -55.1 | 1300.5 | -194.6 | -1369.1 | 134 | -7776 | 197.8 | 1906.3 | -5395.6 |
| 2002 | 376.6 | -1.2 | 1519.8 | -2 | -268.8 | 99.3 | -1215.9 | 198.7 | 1783.1 | 2489.6 |
| 2003 | 340 | -25.8 | 463.2 | -78 | -1247.9 | 75.8 | -6156.6 | 189.6 | 1320.9 | -5118.8 |
| 2004 | 293 | -13.5 | 706.4 | -37.2 | -711.3 | 61.6 | -3370.3 | 183.1 | 1447.5 | -1440.7 |
| 2005 | 525.5 | -109 | 668.7 | -254.7 | -2394 | 152.8 | -14950.5 | 178 | 1115.9 | -15067.3 |
| 2006 | 583.8 | -23 | 1112.7 | -106.3 | -1302.3 | 155.6 | -7026.4 | 172.2 | 1089.5 | -5344.2 |
| 2007 | 455.6 | -0.7 | 1542.1 | -0.8 | -269.9 | 114.1 | -1327.9 | 172.3 | 1328.8 | 2013.6 |
| 2008 | 426.3 | -26.6 | 797.8 | -92.4 | -1204.7 | 103.2 | -5902.4 | 160.6 | 1105.7 | -4632.5 |
| 2009 | 361.8 | -8.3 | 956.6 | -33.7 | -540.2 | 77.5 | -3191.7 | 164.2 | 997.3 | -1216.5 |
| 2010 | 347.2 | -29.4 | 294.2 | -74.9 | -1091.6 | 72.6 | -5843.1 | 158.2 | 836 | -5330.8 |
| 2011 | 332.3 | -48.6 | 397.4 | -191.5 | -1518.5 | 79.5 | -7937.3 | 143.2 | 899.7 | -7843.8 |
| 2012 | 274.1 | -7.7 | 650.6 | -28.2 | -457.8 | 60.6 | -2720.4 | 153.9 | 1091.8 | -983.1 |
| 2013 | 244.9 | -0.9 | 768.7 | -4.7 | -180.2 | 46.9 | -797.2 | 150.9 | 1169 | 1397.4 |
| 2014 | 226.4 | -11 | 183.1 | -31.2 | -548 | 37 | -2429.6 | 147.9 | 971.8 | -1453.6 |
| 2015 | 211.9 | -7.7 | 211.7 | -16.5 | -350.6 | 30.2 | -1968.7 | 143.9 | 749.5 | -996.3 |
| 2016 | 191.5 | -8.6 | 16.8 | -23 | -447.1 | 27.1 | -2713 | 141.1 | 766.7 | -2048.5 |
| 2017 | 208.2 | -19.9 | -300.4 | -67.8 | -906 | 34.5 | -4900.3 | 133.7 | 801.8 | -5016.2 |
| Annual Average | 379.6 | -26.1 | 931.1 | -83.0 | -926.3 | 94.9 | -5218.1 | 174.6 | 1333.0 | -3340.3 |

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### 2.2.9 Groundwater Dependent Ecosystems

A groundwater dependent ecosystem (GDE) is defined by SGMA emergency regulations in Section 351(m) as referring "to ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface." Section 354.16(g) of the same regulations requires identification of GDEs in the Basin using data available from DWR, or the best available information. GDEs are not mentioned elsewhere in the emergency regulations. Because the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset includes a number of estimates, DWR recommends the verification of NCCAG-identified locations by a licensed biologist.

DWR provided the NCCAG dataset through the SGMA data portal at https://gis.water.ca.gov/app/NCDatasetViewer/ . The NCCAG dataset was compiled using a set of six pre-existing dataset sources, and is explained in detail at: https://gis.water.ca.gov/app/NCDatasetViewer/sitedocs/# . Figure 2-61 shows the locations of areas identified as NCCAG in the dataset.

A Woodard & Curran licensed wetlands biologist verified the NCCAG dataset using remote sensing techniques supported by in-person field verification. This work is documented in a Technical Memorandum (Appendix D). The analysis was performed by groupings, and the results of analysis at the groupings level is shown in Figure 2-62. Analysis concluded that there were 123 probable GDEs and 275 probable non-GDEs in the Basin, as shown in Figure 2-63.

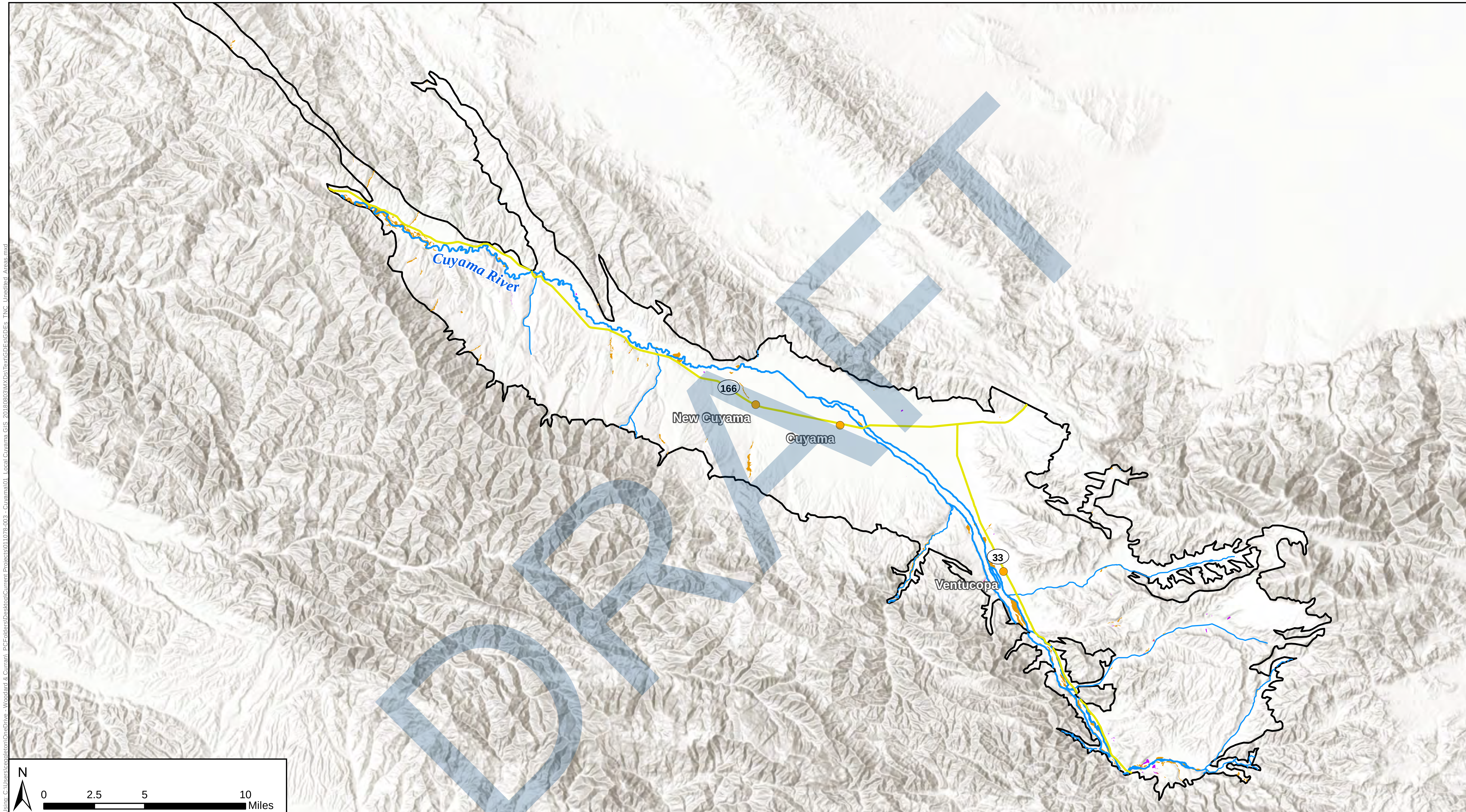


**Figure 2-62 - Cuyama Basin TNC Identified NCCAG Dataset**

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*Legend*

- Cuyama Basin
- TNC Identified Potential GDE Wetland
- TNC Identified Potential GDE Vegetation
- Towns
- Cuyama River
- Streams
- Highways

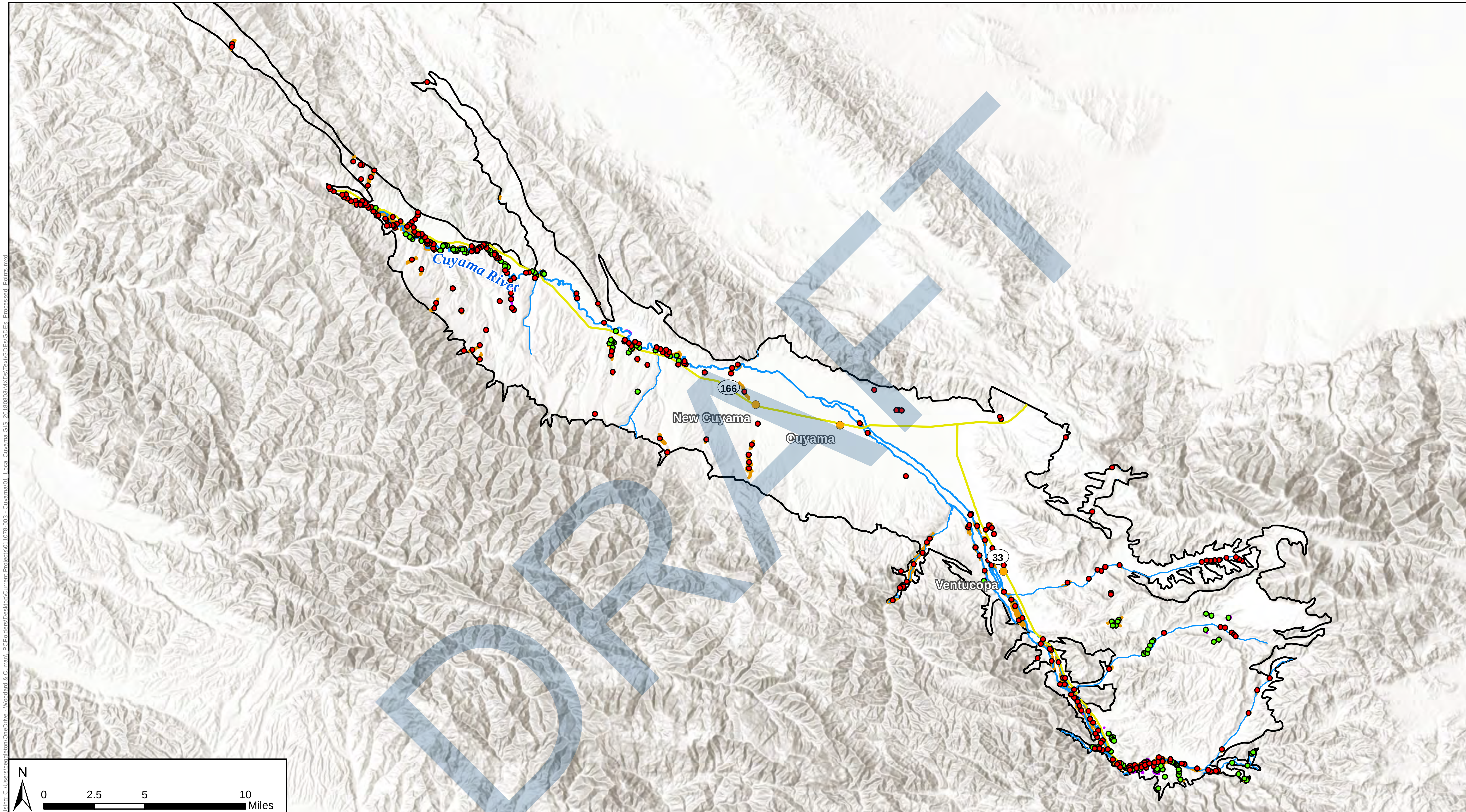


**Figure 2-63 - Cuyama Basin NCAG GDE Point Analysis**

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*Legend*

- Cuyama Basin
- TNC Identified Potential GDE Wetland
- TNC Identified Potential GDE Vegetation
- Cuyama NCAG Probable Non-GDEs
- Cuyama NCAG Probable GDEs
- Towns
- Cuyama River
- Streams
- Highways

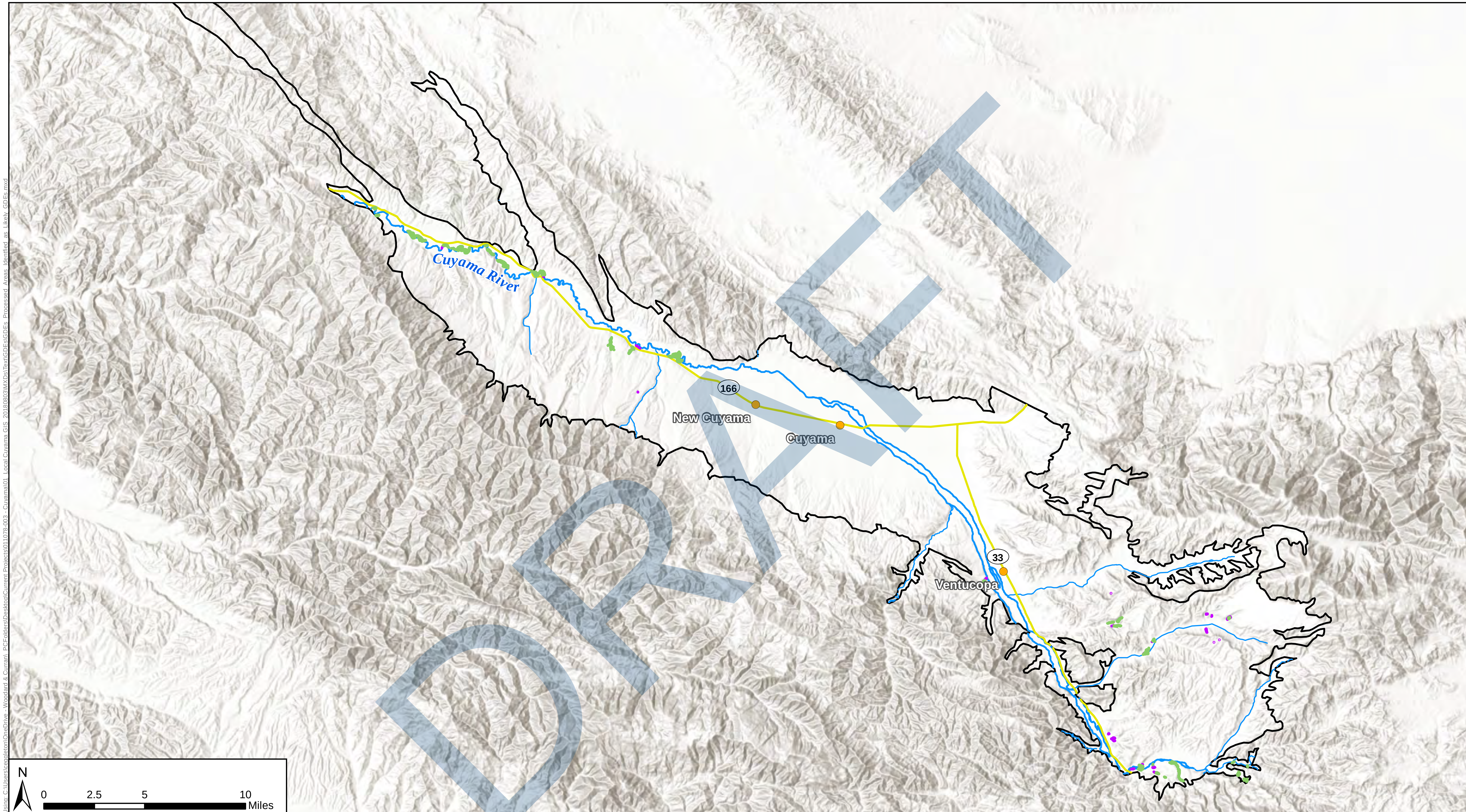


**Figure 2-64 - Cuyama Basin Probable GDEs Based on Analysis**

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*Legend*

- Cuyama Basin
- Towns
- Cuyama River
- Streams
- Highways
- Likely GDE Vegetation
- Liley GDE Weltlands

### 2.2.10 Data Gaps

Groundwater conditions data gaps were identified during the development of this GSP, and when additional questions were asked by stakeholders during GSP development. Data gaps are summarized below.

- Due to sporadic monitoring by a variety of monitoring entities, a long period of record of monitoring for groundwater levels does not exist in many areas in the Basin
- The depths where arsenic occurs are not known, making setting sustainability thresholds for arsenic not feasible
- The Cuyama River is not gaged inside the Cuyama Basin, so flows of the river in the Basin have been estimated based on measurements at downstream gages
- Subsidence in the central portion of the Basin where groundwater levels are lowest is not monitored nor understood
- Vertical gradients in the majority of the Basin are not understood due to the lack of wells with completions of different depths near located near each other
- Salinity in groundwater in the Basin has a number of natural sources, but are not discretely identified
- GDEs could be evaluated in greater detail
- Faults are not well understood with regard to the degree they represent a barrier to flow and at what depth below the surface.
- The size of the Basin regarding groundwater in storage is not well understood.
- Information about many of the wells in the Basin is incomplete, and additional information is needed regarding well depths, perforation intervals and current status

As the CBGSA develops its monitoring networks and implements the GSP, these data gaps will be revisited and re-evaluated for importance during the five-year update of the GSP.

## 2.3 Basin Settings: Water Budget

This section describes the historical, current and projected water budgets for the Basin. As defined by SGMA regulations, this section quantifies the following:

- Total surface water entering and leaving a basin by water source type
- Inflow to the groundwater system by water source type
- Outflows from the groundwater system by water use sector
- The change in the annual volume of groundwater in storage between seasonal high conditions
- If overdraft conditions occur, a quantification of overdraft over a period of years during which water year and water supply conditions approximate average conditions
- The water year type associated with the annual supply, demand, and change in groundwater stored

- An estimate of sustainable yield for the Basin

## Useful Terms

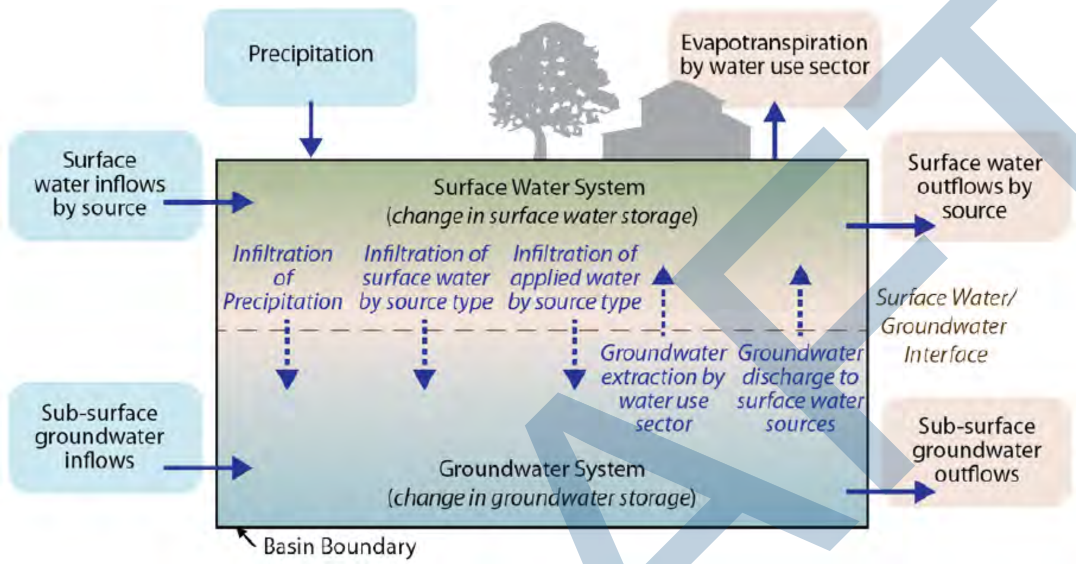
This section of Chapter 2 describe components of water budgets in the Basin. The terms listed here are intended as a guide for readers, and are not a definitive definition of any term.

- **Precipitation** – Precipitation is the volume of rainfall that travels from the soil zone to the unsaturated (vadose) zone of the groundwater aquifer.
- **Applied Water** – Applied water is the volume of water that is applied by an irrigation system to assist crop and pasture growth.
- **Evapotranspiration** – Evapotranspiration is the volume of water entering the atmospheric system through the combined process of evaporation from soil and plant surfaces and transpiration from plants.
- **Domestic Water Use** – Domestic water use is the volume of water used for indoor household purposes, including potable and non-potable water provided to households by a public water supplier (domestic deliveries) and self-supplied water.
- **Deep Percolation** – Deep percolation is the volume of applied water and precipitation that travels from the soil zone to the unsaturated (vadose) zone of the groundwater aquifer.
- **Runoff** – Runoff is the volume of water flowing into the surface water system in a water budget zone from precipitation over the land surface.
- **Stream Seepage** – Stream seepage is the volume of water entering the groundwater system from rivers and streams.
- **Subsurface Inflow** – Subsurface inflow is the volume of water entering as groundwater into the groundwater system through its subsurface boundaries.
- **Change in Storage** – Change in storage is the net change in the volume of groundwater stored in the underlying aquifer.
- **Overdraft –** Overdraft is the long-term negative net change in volume of groundwater stored in the underlying aquifer.
- **Sustainable Yield** – Sustainable yield is the average annual groundwater pumping that can be sustained without any long-term negative net change in groundwater storage.

## Water Budget Information

This water budget was developed to provide a quantitative accounting of water entering and leaving the Basin. Water entering the Basin includes water entering at the surface and entering through the subsurface. Similarly, water leaving the Basin leaves at the surface and through the subsurface. Water enters and leaves naturally, such as through precipitation and streamflow, and through human activities, such as pumping and recharge from irrigation. Figure 2-64 presents a vertical slice through the land surface and aquifer to summarize the water balance components used during analysis.

The values presented in the water budget provide information about historical, current, and projected conditions as they relate to hydrology, water demand, water supply, land use, population, climate change, sea-level rise (which is not applicable in the Basin), groundwater and surface water interaction, and subsurface groundwater flow. This information can help manage groundwater om the Basin by identifying the scale of different uses, highlighting potential risks, and identifying potential opportunities to improve water supply conditions, among other elements.




*(Source: DWR)*

**Figure 2-65:. Generalized Water Budget Diagram**

Water budgets can be developed on different spatial scales. In agricultural use, water budgets may be limited to the root zone in soil, improving irrigation techniques by estimating the inflows and outflows of water from the upper portion of the soil accessible to plants through their roots. In a strictly groundwater study, water budgets may be limited to water flow in the subsurface, helping analysts understand how water flows beneath the surface. Global climate models simulate water budgets that incorporate atmospheric water, allowing for simulation of climate change conditions. In this document, consistent with the SGMA regulations, water budgets investigate the combined surface water and groundwater system in the Basin.

Water budgets can also be developed at different temporal scales. Daily water budgets may be used to demonstrate how evaporation and transpiration increase during the day and decrease at night. Monthly water budgets may be used to demonstrate how groundwater pumping increases in the dry, hot summer months and decreases in the cool, wet winter months. In this section, and consistent with SGMA regulations, this water budget focuses on the full water year (i.e., the 12 months spanning from October of the previous year to September of the current year), with some consideration to monthly variability.

The SGMA regulations require that annual water budgets are based on three different conditions: historical, current, and projected. Water budgets are developed to capture typical conditions during these time periods. Typical conditions are developed through averaging over hydrologic conditions that incorporate droughts, wet periods, and normal periods. By incorporating these varied conditions in the budgets, an analysis of the water system under certain hydrologic conditions such as drought can be performed along with an analysis of long-term average conditions. Information is provided below about the hydrology dataset used to identify time periods for budget analysis, the use of the CBWRM and associated data in water budget development, and about budget estimates.

### Identification of Hydrologic Periods

Hydrologic periods were selected to meet the needs of developing historical, current, and projected water budgets. The SGMA regulations require that the projected water budget reflect 50 years of historical hydrology to reflect long-term average hydrologic conditions. Historical precipitation data for the Basin was used to identify hydrologic periods that would provide a representation of wet and dry periods and long-term average conditions needed for budget analyses. Analysis of a long-term historical period time provides information that is expected to be representative of long-term future conditions.

Figure 2-65 shows annual precipitation in the Basin for water years 1968 to 2017. The chart includes bars displaying annual precipitation for each water year and a horizontal line representing the mean precipitation of 13.1 inches. Rainfall data for the Basin are derived from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) dataset of DWR’s California Simulation of Evapotranspiration of Applied Water (CALSIMETAW) model. Analysts identified periods with a balance of wet and dry periods using the cumulative departure from mean precipitation method. Under this method, the long-term average precipitation is subtracted from annual precipitation in each water year to develop the departure from mean precipitation for each water year. Wet years have a positive departure and dry years have a negative departure; a year with exactly average precipitation would have zero departure. Starting at the first year analyzed, departures are added cumulatively for each year. So, if the departure for Year 1 is 5 inches and the departure for Year 2 is -2 inches, the cumulative departure would be 5 inches for Year 1 and 3 inches (i.e., 5 plus -2) for Year 2. The cumulative departure of the spatially averaged of the rainfall in the Basin is shown on Figure 2-65. The cumulative departure from mean precipitation is based on these data sets, and is displayed as a line that starts at zero and highlights wet periods with upward slopes and dry periods with downward slopes. More severe events are shown by steeper slopes and greater changes. The period from 2013 to 2014 illustrates a short period with dramatically dry conditions (i.e., a 16-inch decline in cumulative departure over two years).

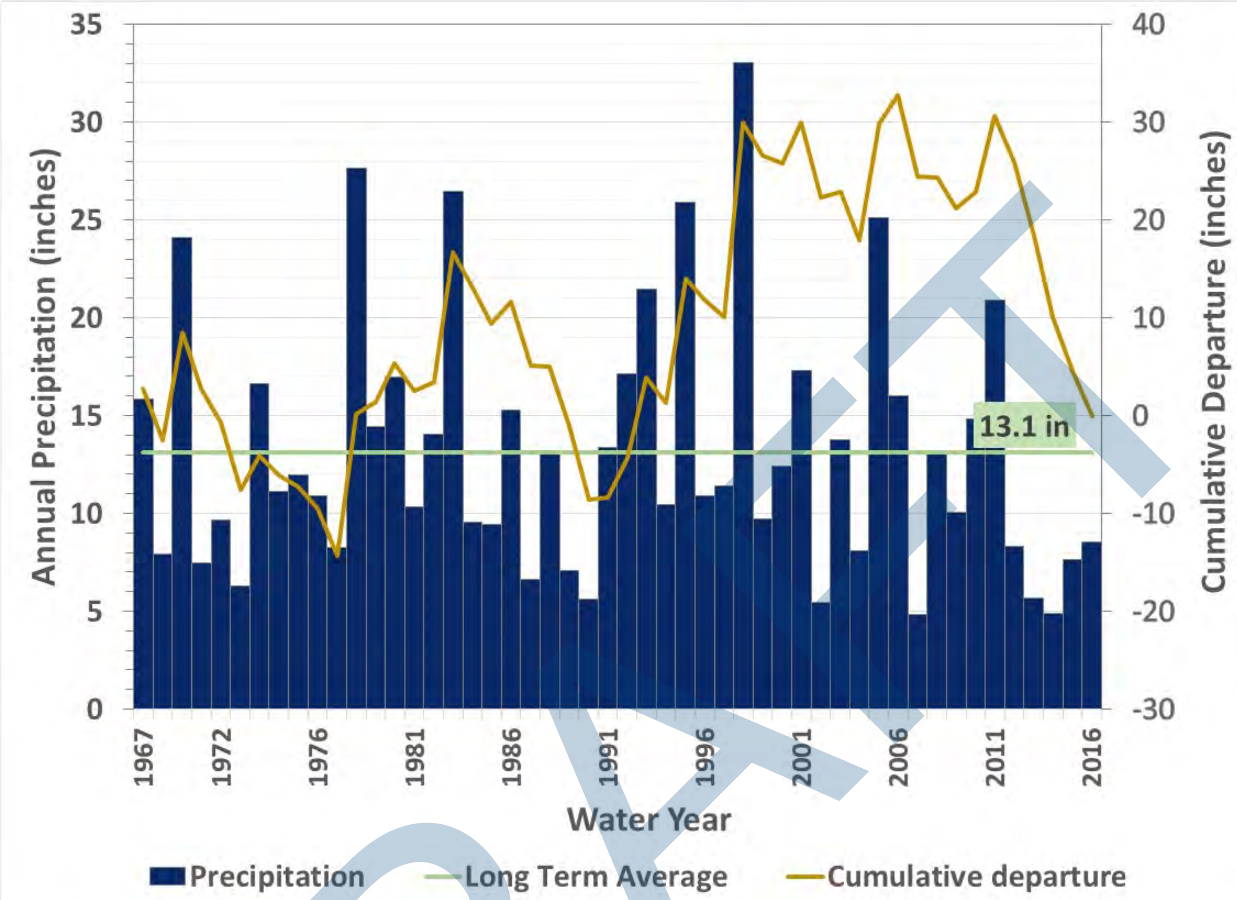


Figure 2-66: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation

### CBWRM Model Use and Associated Data for Water Budget Development

Water budgets were developed using the CBWRM model, which is a fully integrated surface and groundwater flow model covering the Basin. The CBWRM was developed in consultation with members of the Technical Forum, which includes technical staff and consultants representing a range of public and private entities in the Basin. Participants on the Technical Forum are shown in Chapter 1 Section 1.3. The Technical Forum held 14 monthly conference calls over the course of model development. These calls provided opportunities for Technical Forum members to review and comment on all major aspects of model development.

The CBWRM integrates the groundwater aquifer with the surface hydrologic system and land surface processes and operations. The CBWRM was calibrated for the hydrologic period of October 1995 to September 2015 by comparing simulated evapotranspiration, groundwater levels, and streamflow records with historical observed records. Development of the model involved study and analysis of hydrogeologic conditions, agricultural and urban water demands, agricultural and urban water supplies, and an evaluation of regional water quality conditions. The model was developed based on the best available data and information as of June 2018. It is expected that the model will be refined in the future as improved and updated monitoring information becomes available for the Basin. These refinements may result in changes in the estimated water budgets described in this section.

Additional information on the development and calibration of the CBWRM is included in Appendix C.

CBWRM simulations were developed to allow for the estimation of water budgets. Model simulations were used to develop the water budgets for historical, current, and projected conditions, which are discussed in detail below:

- The **historical water budget** was based on a simulation of historical conditions in the Basin.
- The **current water budget** was based on a simulation of current (2017) land and water use over historical hydrologic conditions, assuming no other changes in population, water demands, land use, or other conditions.
- The **projected water budget** was based on a simulation of future land and water use over the historical hydrologic conditions. Since future land and water use in the Cuyama Basin is assumed to be the same as current conditions, the projected water budget is the same as the current water budget.

### Water Budget Definitions and Assumptions

Definitions and assumptions for the historical, current, and projected water budgets are provided below. Table 2-2 summarizes these assumptions.

#### *Historical Water Budget*

The historical water budget is intended to evaluate availability and reliability of past surface water supply deliveries, aquifer response to water supply, and demand trends relative to water year type. The hydrologic period of 1998 through 2017 was selected for the historical water budget to provide a period of representative hydrology while capturing recent Basin operations. The period 1998 through 2017 has an average annual precipitation of 12.2 inches, nearly the same as the long-term average of 13.1 inches and includes the recent 2012 to 2017 drought, the wet years of 1998 and 2005, and periods of normal precipitation.

#### *Current and Projected Water Budget*

While a budget indicative of current conditions could be developed using the historical calibration model, like the historical water budget, such an analysis would be difficult to interpret due to the extreme weather conditions of the past several years and its effect on local agricultural operations. Instead, to analyze the effects of current land and water use on groundwater conditions, and to accurately estimate current inflows and outflows for the Basin, a current and projected conditions baseline scenario was developed using the IWFM. This baseline uses current land and water use conditions approximating year 2017 conditions with a historical precipitation sequence and a year-to-year variance in cropping patterns that matches the historical variability. Because there is no basis to assume any changes in Basin population or land use in the future as compared to current conditions (in the absence of projects or actions), a single baseline has been developed that reflects both current and projected conditions.

The current and projected conditions baseline includes the following conditions:

- Hydrologic period:
  - Water years 1968 to 2017 (i.e., a 50-year hydrology)
- Precipitation is based on:
  - PRISM dataset for the period from 1968 to 2017
- Land use is based on:
  - Land use estimates developed by DWR and the CBGSA using remote sensing data
  - Land use information for historical years provided by private landowners
- Domestic water use is based on:
  - Current population estimates
  - Cuyama Community Services District delivery records
- Agricultural water demand is based on:
  - The IWFM Demand Calculator in conjunction with historical remote sensing technology, Mapping Evapotranspiration at High Resolution and Internalized Calibration (METRIC)

**Table 2-3: Summary of Groundwater Budget Assumptions**

| Water Budget Criteria | Historical | Current and Projected |
|---|---|---|
| **Scenario** | Historical simulation | Current and projected conditions baseline |
| **Hydrologic Years** | Water years 1998 to 2017 | Water years 1968 to 2017 |
| **Development** | Historical | Current |
| **Agricultural Demand** | Historical land use | Current conditions |
| **Domestic Use** | Historical records | Current conditions |

### *Projected Water Budget with Climate Change*

A second projected level water budget has been developed that incorporates the projected effects of climate change. The projected conditions with climate change baseline are the same as the current and projected conditions baseline, except that adjustments have been made to estimated precipitation and agricultural and native vegetation evapotranspiration during the 50-year hydrologic period. The estimated precipitation and evapotranspiration from 1968 to 2017 were adjusted using perturbation factors developed from the Central Tendency climate scenario data provided by DWR. On average, the perturbation factors for this scenario result in an increase in precipitation of about 1.4 percent and in an increase in crop evapotranspiration of about 5.4 percent. Additional information about how precipitation and evapotranspiration were adjusted for climate change can be found in the IWFM documentation in Appendix C.

### Water Budget Estimates

Land surface and groundwater budgets are reported for the historical period, for current and projected conditions, and for projected conditions with climate change.

The following components are included in the land surface water budget:

- Inflows:
  - Precipitation
  - Applied Water
- Outflows:
  - Evapotranspiration
    - Agriculture
    - Native vegetation
  - Domestic water use
  - Deep percolation
    - From precipitation
    - From applied water
  - Runoff
    - Stream seepage to groundwater
    - Flow out of Basin

The following components are included in the groundwater budget:

- Inflows:
  - Deep percolation
  - Stream seepage
  - Subsurface inflow
- Outflows:
  - Groundwater pumping
- Change in storage (where negative values reflect overdraft conditions)

The estimated average annual water budgets are provided in Tables 2-3 and 2-4 for the historical period and for current and projected conditions. The following sections provide additional information regarding each water budget.

**Table 2-4: Average Annual Land Surface Water Budget**

| Component | Historical Water Volume[a] (AFY) | Current and Projected Water Volume[b] (AFY) | Projected Water Volume With Climate Change[b] (AFY) |
|---|---|---|---|
| **Inflows** | | | |
| Precipitation | 226,000 | 230,000 | 233,000 |
| Applied water | 58,000 | 59,000 | 63,000 |
| **Total Inflow** | **285,000** | **289,000** | **296,000** |
| **Outflows** | | | |
| Evapotranspiration | | | |
| Agriculture | 58,000 | 63,000 | 66,000 |
| Native vegetation | 167,000 | 174,000 | 174,000 |
| Domestic water use | 300 | 400 | 400 |
| Deep Percolation | | | |
| Precipitation | 18,000 | 15,000 | 15,000 |
| Applied water | 10,000 | 11,000 | 11,000 |
| Runoff | 32,000 | 26,000 | 29,000 |
| **Total Outflow** | **285,000** | **289,000** | **296,000** |

Notes:
AFY = acre-feet per year
[a]From water years 1998 to 2017
[b]Based on 50-year hydrology

Table 2-5: Average Annual Groundwater Budget

| Component | Historical Water Volume[a] (AFY) | Current and Projected Water Volume[b] (AFY) | Projected Water Volume with Climate Change[b] (AFY) |
|---|---|---|---|
| **Inflows** | | | |
| Deep percolation | 28,000 | 25,000 | 26,000 |
| Stream seepage | 3,000 | 5,000 | 6,000 |
| Subsurface inflow | 5,000 | 5,000 | 5,000 |
| **Total Inflow** | **36,000** | **35,000** | **37,000** |
| **Outflows** | | | |
| Groundwater pumping | 59,000 | 60,000 | 64,000 |
| **Total Outflow** | **59,000** | **60,000** | **64,000** |
| **Change in Storage** | **(23,000)** | **(25,000)** | **(27,000)** |

Notes:
AFY = acre-feet per year
[a]From water years 1998 to 2017
[b]Based on 50-year hydrology

## Historical Water Budget

The historical water budget is a quantitative evaluation of the historical surface and groundwater supply covering the 20-year period from 1998 to 2017. This period was selected as the representative hydrologic period to calibrate and reduce the uncertainty of the IWFM. Proper analysis and calibration of water budgets within IWFM ensures the hydrologic characteristics of the groundwater basin are accurately represented. The goal of the water budget analysis is to characterize the supply and demand, while summarizing the hydrologic flow within the Basin, including the movement of all primary sources of water such as rainfall, irrigation, streamflow, and subsurface flows.

Figure 2-67 summarizes the average annual historical land surface inflows and outflows in the Basin. Figure 2-68 shows the annual time series of historical land surface inflows and outflows.

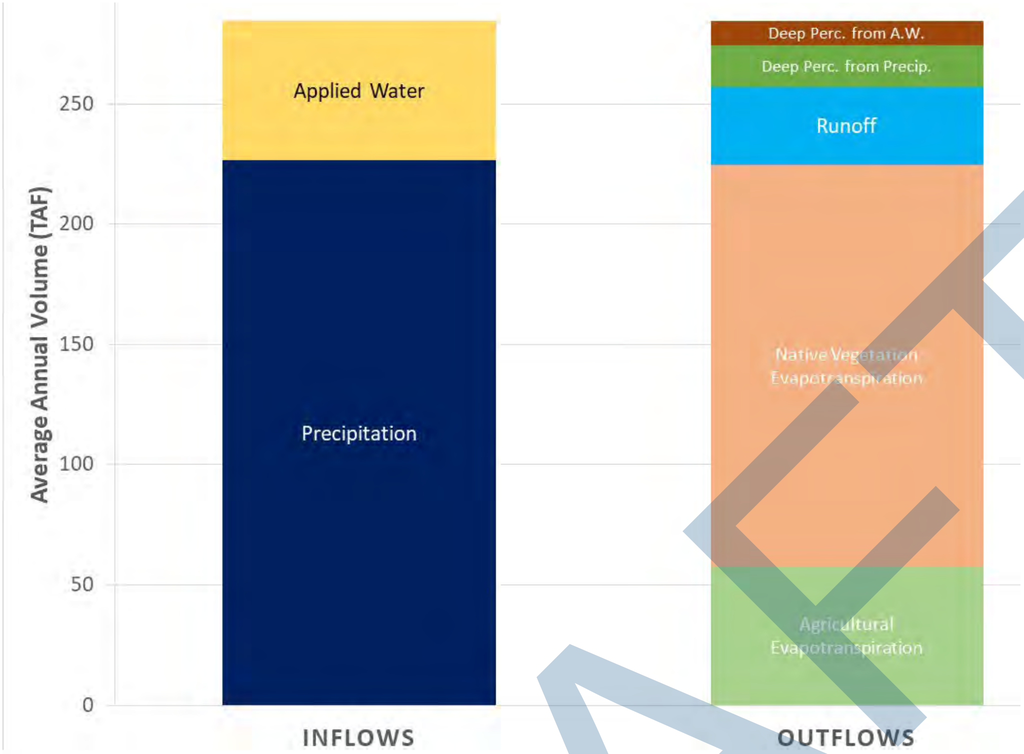



**Figure 2-67: Historical Average Annual Land Surface Water Budget**

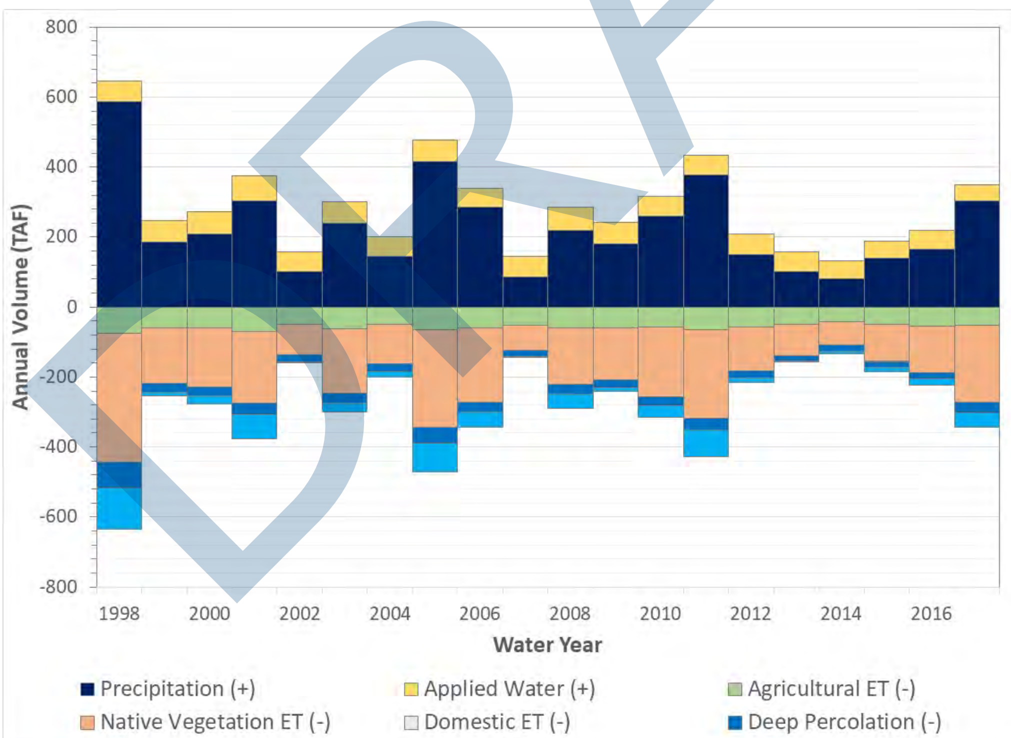



**Figure 2-68: Historical Land Surface Water Budget Annual Time Series**

The Basin experiences about 285,000 AF of land surface inflows each year, of which 226,000 AF is from precipitation and the remainder is from applied water. About 225,000 acre-feet per year (AFY) is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows large year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 132,000 AF to a high of 645,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 108,000 to 444,000 AF.

Figure 2-69 summarizes the average annual historical groundwater inflows and outflows in the Basin. Figure 2-70 shows the annual time series of historical groundwater inflows and outflows. The Basin average annual historical groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage (i.e. overdraft) of 23,000 AF. The groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

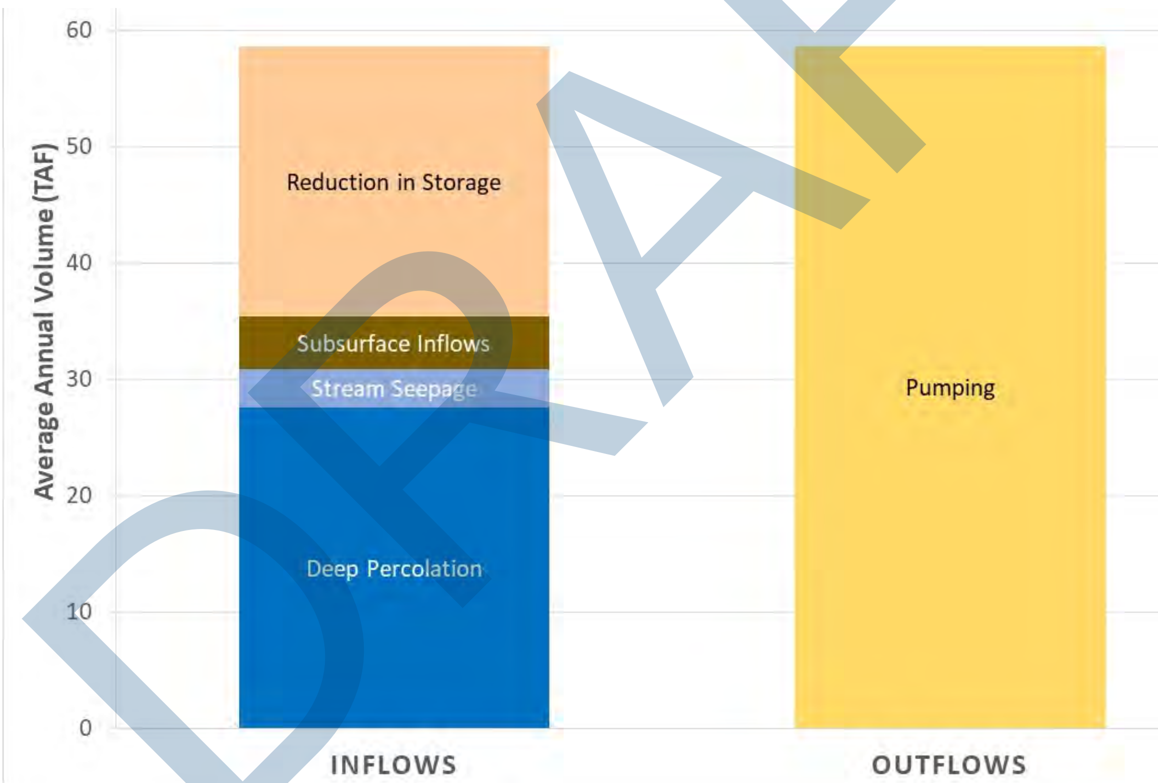



**Figure 2-69: Historical Average Annual Groundwater Budget**

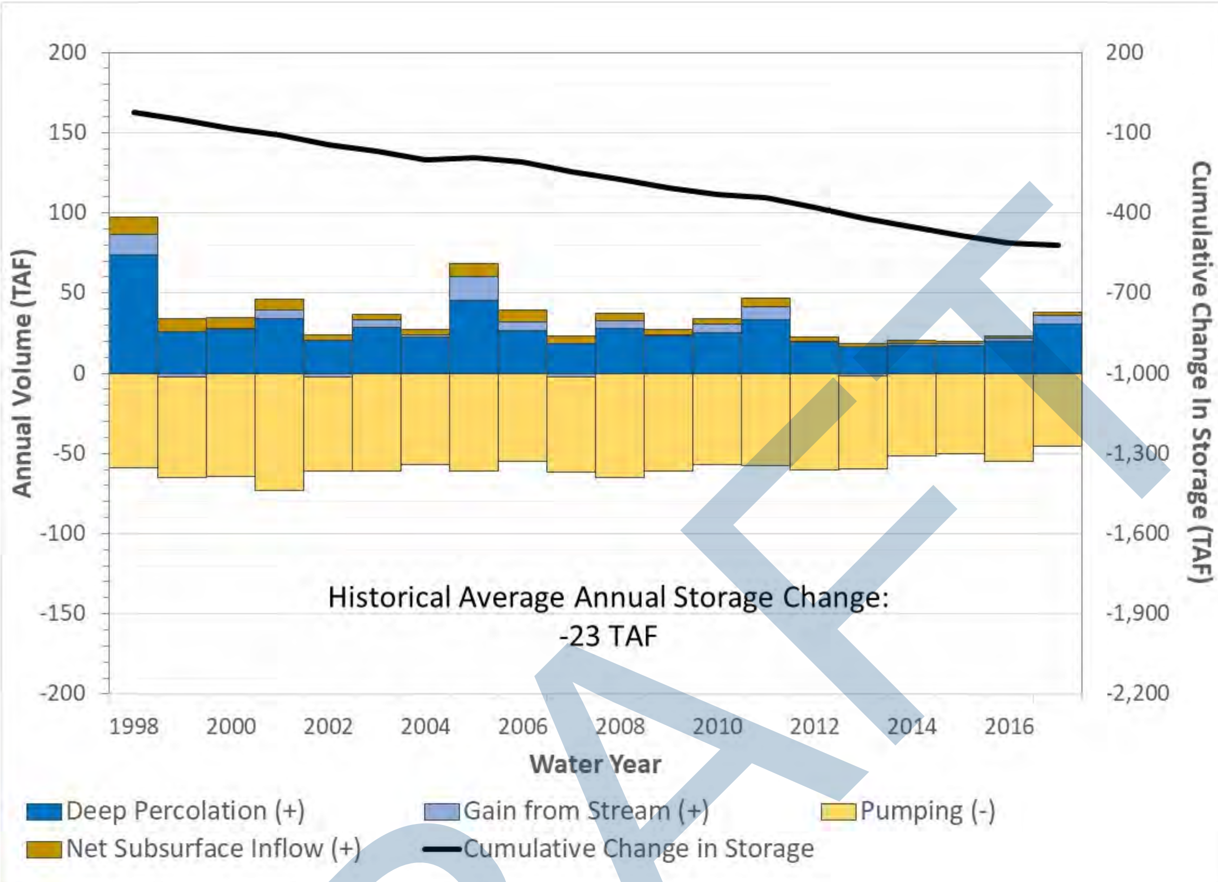



**Figure 2-70: Historical Groundwater Budget Annual Time Series**

### Current and Projected Water Budget

The current and projected water budget quantifies inflows to and outflows from the Basin using 50 years of hydrology in conjunction with 2017 population, water use, and land use information.

Figure 2-71 summarizes the average annual current and projected land surface inflows and outflows in the Basin. Figure 2-72 shows the annual time series of current and projected land surface inflows and outflows.


**Figure 2-71: Current and Projected Average Annual Land Surface Water Budget**

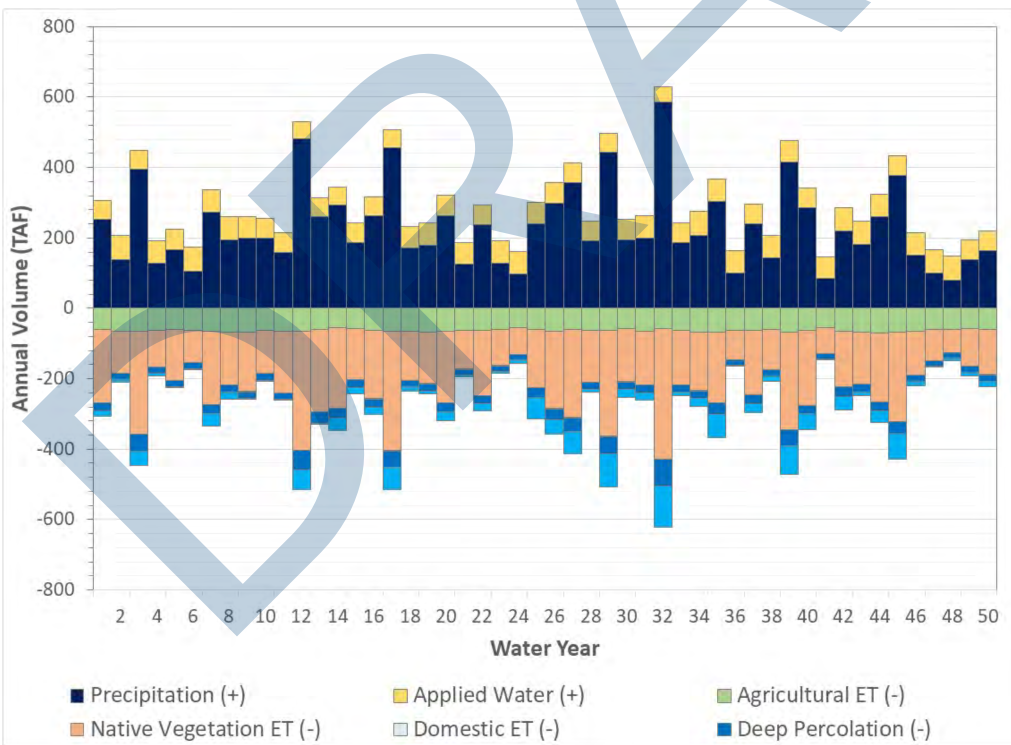



**Figure 2-72: Current and Projected Land Surface Water Budget Annual Time Series**

Under current and projected conditions, the Basin experiences about 290,000 AF of land surface inflows each year, of which 230,000 AF is from precipitation and the remainder is from applied water. About 238,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 147,000 AF to a high of 628,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 127,000 to 429,000 AF.

Figure 2-73 summarizes the average annual current and projected groundwater inflows and outflows in the Basin. Figure 2-74 shows the annual time series of current and projected groundwater inflows and outflows. The Basin average annual current and projected groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage (i.e. overdraft) of 25,000 AF. As with the historical conditions, the groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

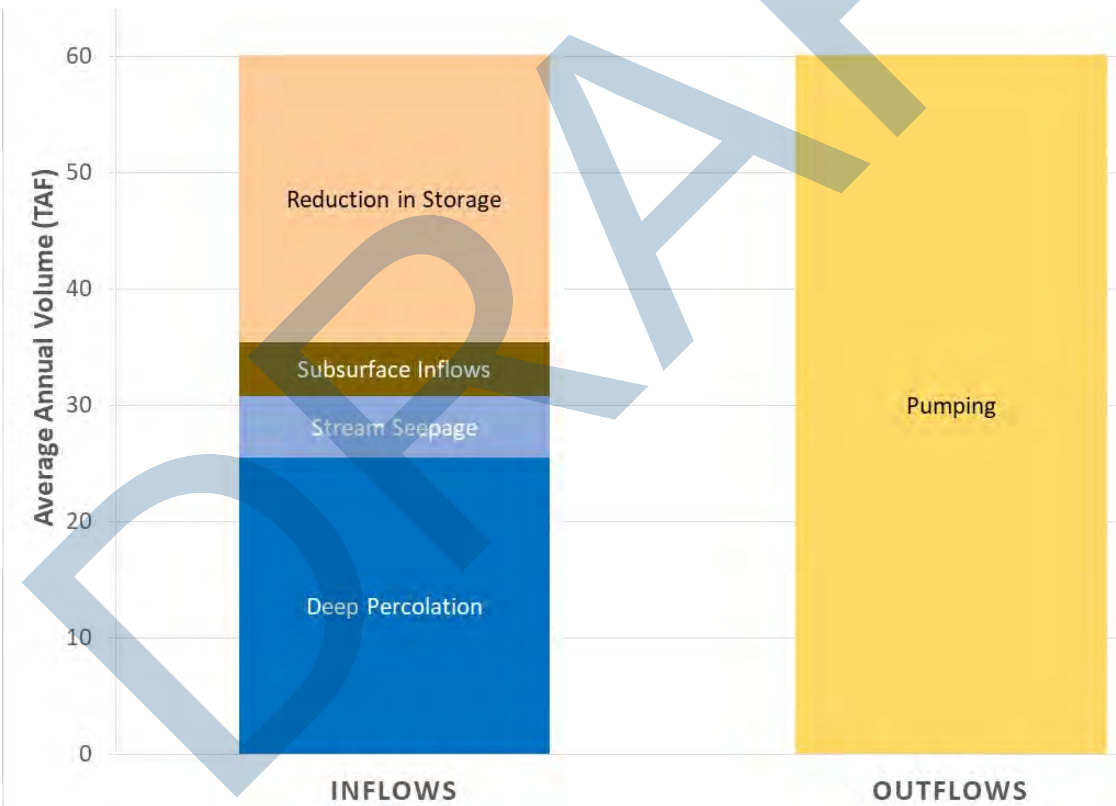


**Figure 2-73: Current and Projected Average Annual Groundwater Budget**

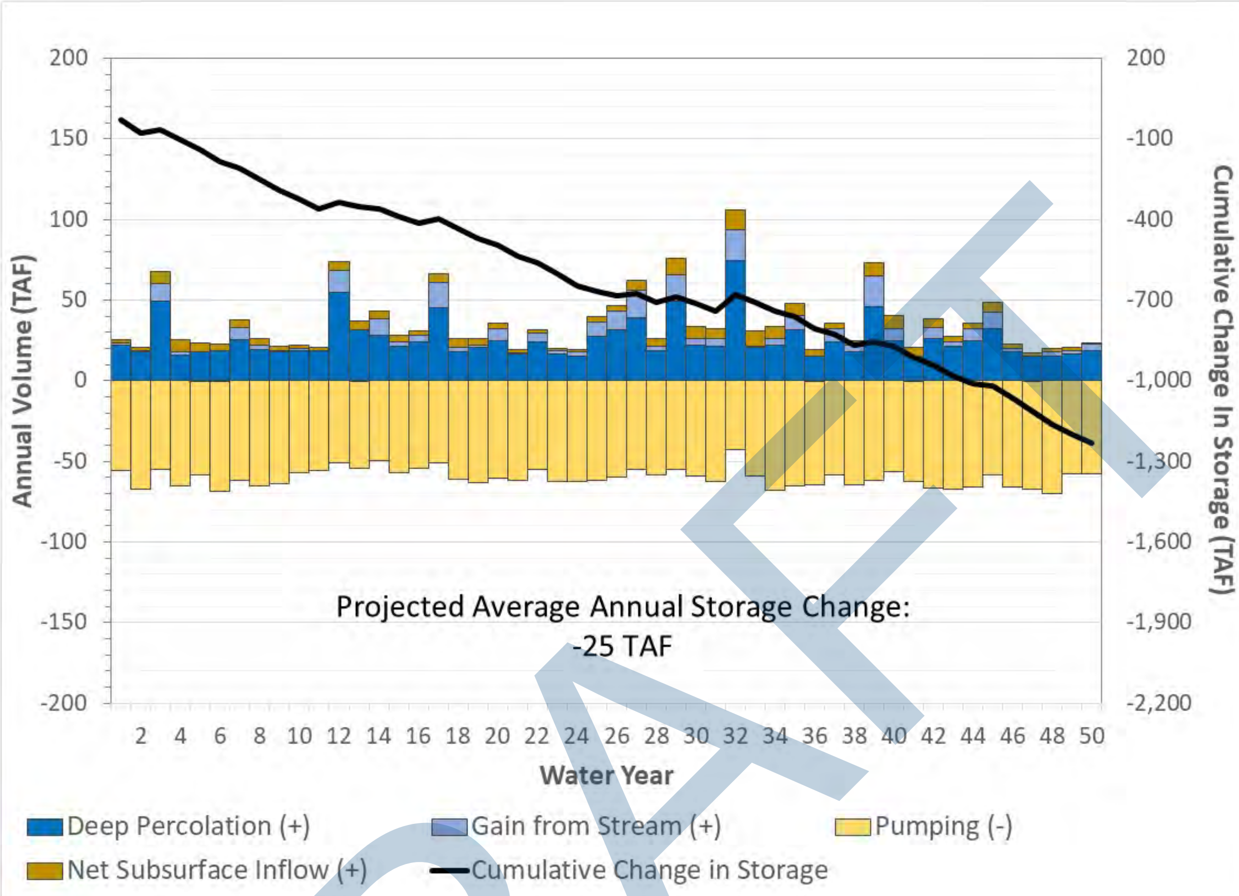



**Figure 2-74: Current and Projected Groundwater Budget Annual Time Series**

The current and projected water demand, water supply, and change in groundwater storage vary by water year type[6], as shown in Table 2-6. In wet years, precipitation meets a relative high proportion of the water demand, which reduces the need for groundwater. By contrast, in drier years more groundwater pumping is required to meet the agricultural demand not met by precipitation. This leads to an increase in groundwater storage in wet years and a decrease in the other year types.

[6] Water year types are customized for the Basin watershed based on annual precipitation as follows:

- Wet year = more than 19.6 inches
- Above normal year = 13.1 to 19.6 inches
- Below normal year = 9.85 to 13.1 inches
- Dry year = 6.6 to 9.85 inches
- Critical year = less than 6.6 inches

| Table 2-6: Current and Projected Average Annual Supply, Demand, and Change in Groundwater Storage by Water Year Type | | | | | |
|---|---|---|---|---|---|
| **Component** | **Water Year Type** | | | | |
| | **Wet** | **Above Normal** | **Below Normal** | **Dry** | **Critical** |
| **Water Demand** | | | | | |
| Agricultural Evapotranspiration (AFY) | 64,000 | 63,000 | 64,000 | 63,000 | 60,000 |
| Domestic Use (AFY) | 500 | 400 | 400 | 300 | 200 |
| **Total Demand** | **64,000** | **63,000** | **64,000** | **63,000** | **60,000** |
| **Water Supply** | | | | | |
| Groundwater Pumping (AFY) | 54,000 | 59,000 | 62,000 | 61,000 | 66,000 |
| **Total Supply** | **54,000** | **59,000** | **62,000** | **61,000** | **66,000** |
| **Change in Storage** | **18,000** | **(21,000)** | **(34,000)** | **(37,000)** | **(46,000)** |

### Projected Water Budget with Climate Change

The projected water budget with climate change quantifies inflows to and outflows from the Basin using 50-years of hydrology in conjunction with 2017 population, water use, and land use information, with historical precipitation and evapotranspiration values modified for climate change.

Figure 2-75 summarizes the average annual current and projected land surface inflows and outflows in the Basin. Figure 2-76 shows the annual time series of current and projected land surface inflows and outflows.

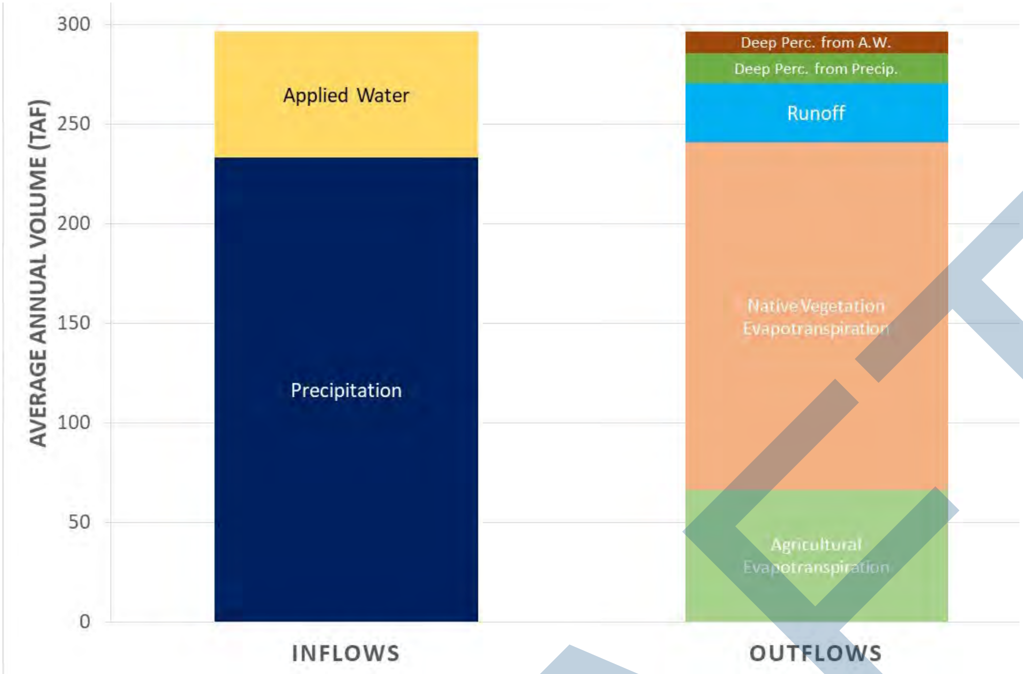



**Figure 2-75: Projected Average Annual Land Surface Water Budget with Climate Change**

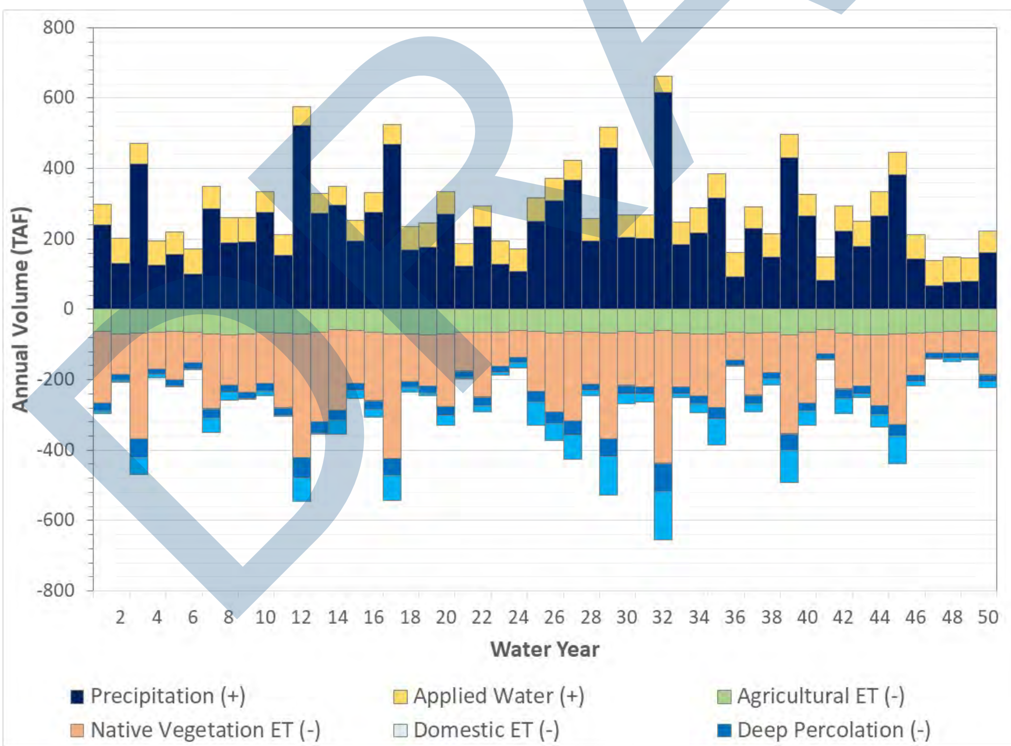



**Figure 2-76: Projected Land Surface Water Budget with Climate Change Annual Time Series**

Under projected conditions with climate change, the Basin experiences about 296,000 AF of land surface inflows each year, of which 233,000 AF is from precipitation and the remainder is from applied water. About 241,000 AFY is consumed as evapotranspiration or domestic use, with the remainder either recharging the groundwater aquifer as deep percolation or stream seepage or leaving the Basin as river flow.

The annual time series shows the year-to-year variability in the availability of water, with land surface inflows ranging from a low of about 138,000 AF to a high of 663,000 AF. These year-to-year changes in inflows result in corresponding differences in outflows, with total annual agricultural, native vegetation and domestic evapotranspiration ranging from 123,000 AF to 438,000 AF.

Figure 2-77 summarizes the average annual projected groundwater inflows and outflows with climate change in the Basin. Figure 2-78 shows the annual time series of projected groundwater inflows and outflows with climate change. The Basin average annual current and projected groundwater budget has greater outflows than inflows, leading to an average annual decrease in groundwater storage (i.e., overdraft) of 27,000 AF. As with the historical conditions, the groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

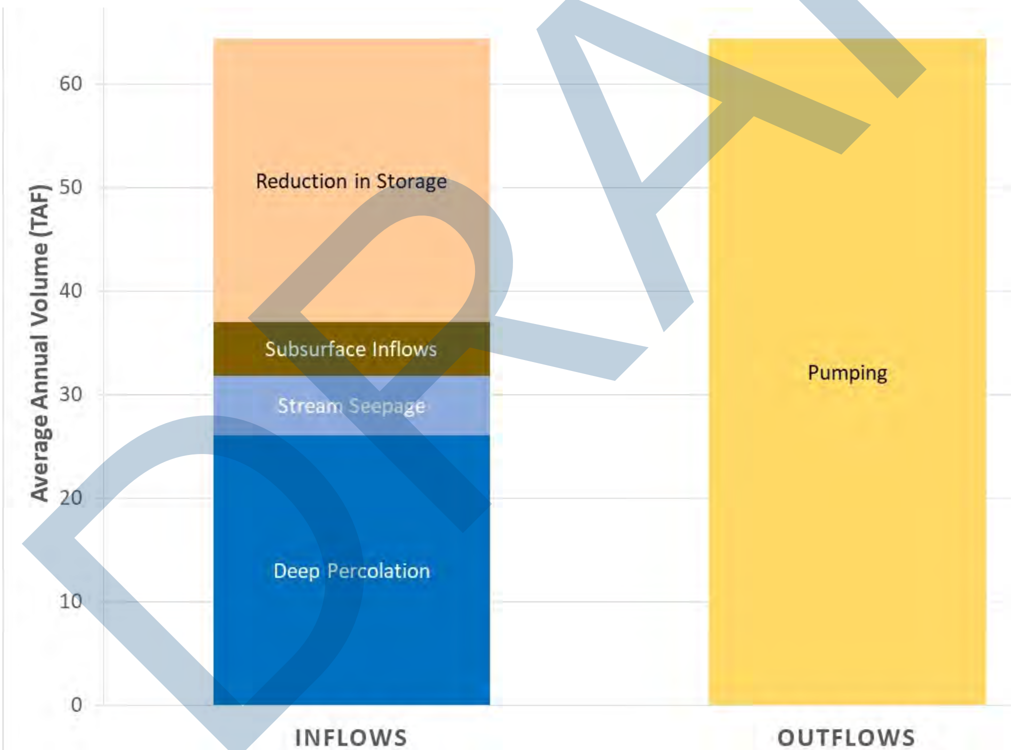


**Figure 2-77: Current and Projected Average Annual Groundwater Budget**

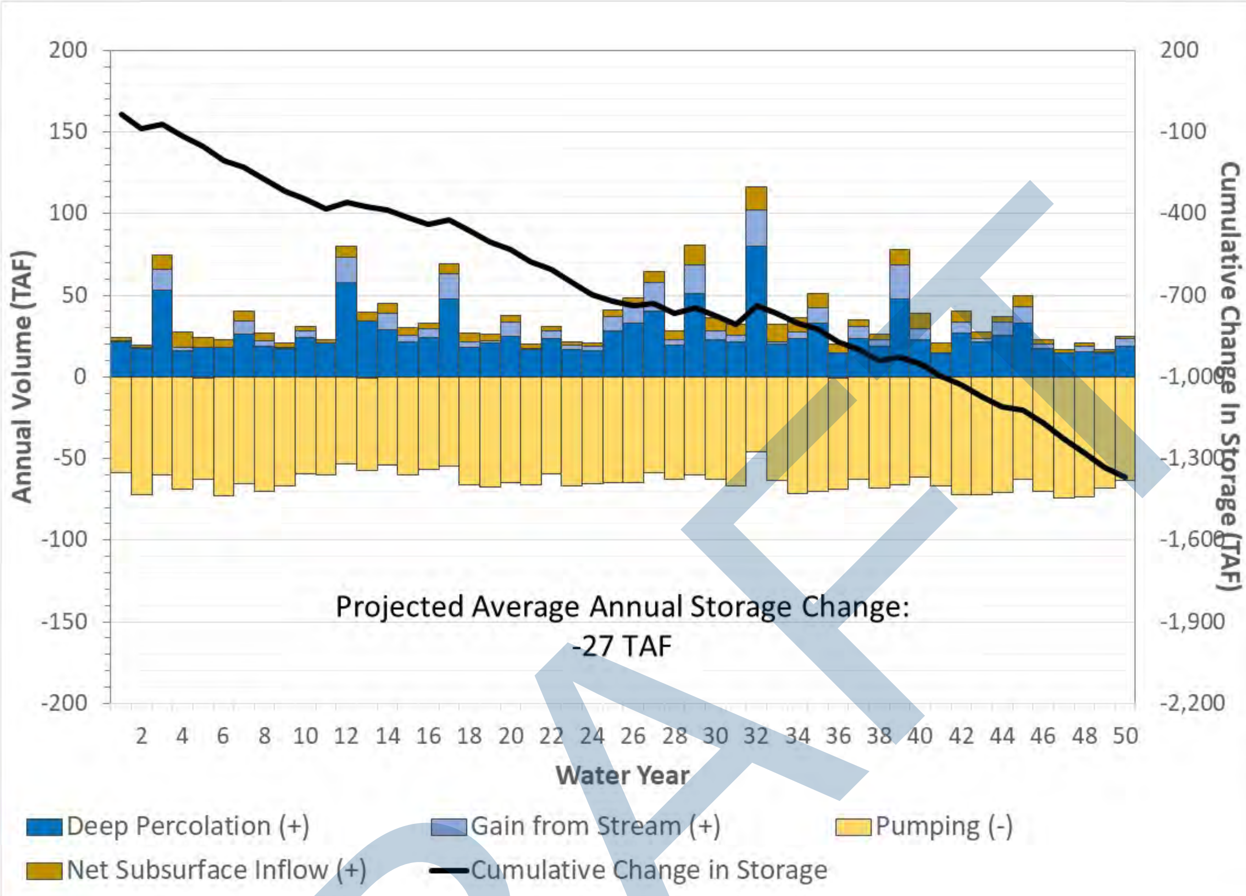



**Figure 2-78: Current and Projected Groundwater Budget Annual Time Series**

## Sustainable Yield Estimates

Four simulations were performed to estimate the sustainable yield in the Basin as follows:

- Current and projected conditions sustainability with pumping reductions only
- Current and projected conditions sustainability with pumping reductions and water supply projects
- Projected sustainability with climate change with pumping reductions only
- Projected sustainability with climate change with pumping reductions and water supply projects

These simulations were performed using the current and projected conditions and projected conditions with climate change baselines described above, with projects and pumping reductions implemented so as to achieve an exact balance between supplies and demands in the Basin-wide groundwater budget on average over the 50-year simulation period.

Each simulation incorporating water supply projects was performed using example projects intended to estimate the potential water supply benefits from those projects. It is anticipated that these projects will be further evaluated and refined in the future prior to potential implementation. The analyses included the following water supply projects:

- **Flood and stormwater capture –** it was assumed that facilities would be developed to capture stormwater flows and recharge them into the groundwater aquifer in the central basin area. It was assumed that approximately 2,500 AF per year could be captured and recharged.
- **Precipitation enhancement –** it was assumed that cloud seeding would be performed to increase precipitation in the upper watershed areas. Based on previous studies of potential cloud seeding programs, it was assumed that precipitation would increase by 10% on average.

Chapter 7 of this GSP describes these potential water supply projects in greater detail. Chapter 7 also describes potential mechanisms to reduce groundwater pumping.

As noted above, these simulations were performed using the best available data and information as of June 2018. It is expected that the model will be refined in the future as improved and updated monitoring information becomes available in the Basin. These refinements will result in changes in the sustainable yield estimates described in this section.

Table 2-7 shows the groundwater budget for each sustainability scenario. Because there is no long-term average change in groundwater storage in these scenarios, the groundwater pumping represents the overall estimated sustainable yield in each scenario. The Basin sustainable yield is estimated to be about 20,000 to 21,000 AFY without water supply projects (i.e., a 67 percent reduction in groundwater pumping compared to baseline) and about 27,000 AFY with water supply projects (i.e., a 55 to 63 percent reduction in groundwater pumping compared to baseline).

| Table 2-7: Average Annual Groundwater Budget for Sustainability Scenarios | | | | |
|---|---|---|---|---|
| **Component** | **Current and Projected Conditions with Pumping Reductions Only (AFY)** | **Projected Conditions with Climate Change with Pumping Reductions Only (AFY)** | **Current and Projected Conditions with Pumping Reductions and Water Supply Projects (AFY)** | **Projected Conditions with Climate Change with Pumping Reductions and Water Supply Projects (AFY)** |
| **Inflows** | | | | |
| Deep percolation | 12,000 | 11,000 | 18,000 | 18,000 |
| Stream seepage | 4,000 | 5,000 | 4,000 | 4,000 |
| Subsurface inflow | 4,000 | 5,000 | 5,000 | 5,000 |
| **Total Inflow** | **20,000** | **21,000** | **27,000** | **27,000** |
| **Outflows** | | | | |
| Groundwater pumping | 20,000 | 21,000 | 27,000 | 27,000 |
| Total Outflow | 20,000 | 21,000 | 27,000 | 27,000 |
| **Change in Storage** | **(0)** | **(0)** | **(0)** | **(0)** |
| **Reduction in groundwater pumping relative to Baseline** | **(40,000)** | **(43,000)** | **(33,000)** | **(37,000)** |
| **Percent reduction** | **-67%** | **-67%** | **-55%** | **-63%** |
| Notes:<br>All sustainability scenarios are simulated using the 1968 to 2017 hydrologic period. | | | | |



## 2.4 References

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# Appendix A

## Cuyama Valley Groundwater Basin Hydrographs

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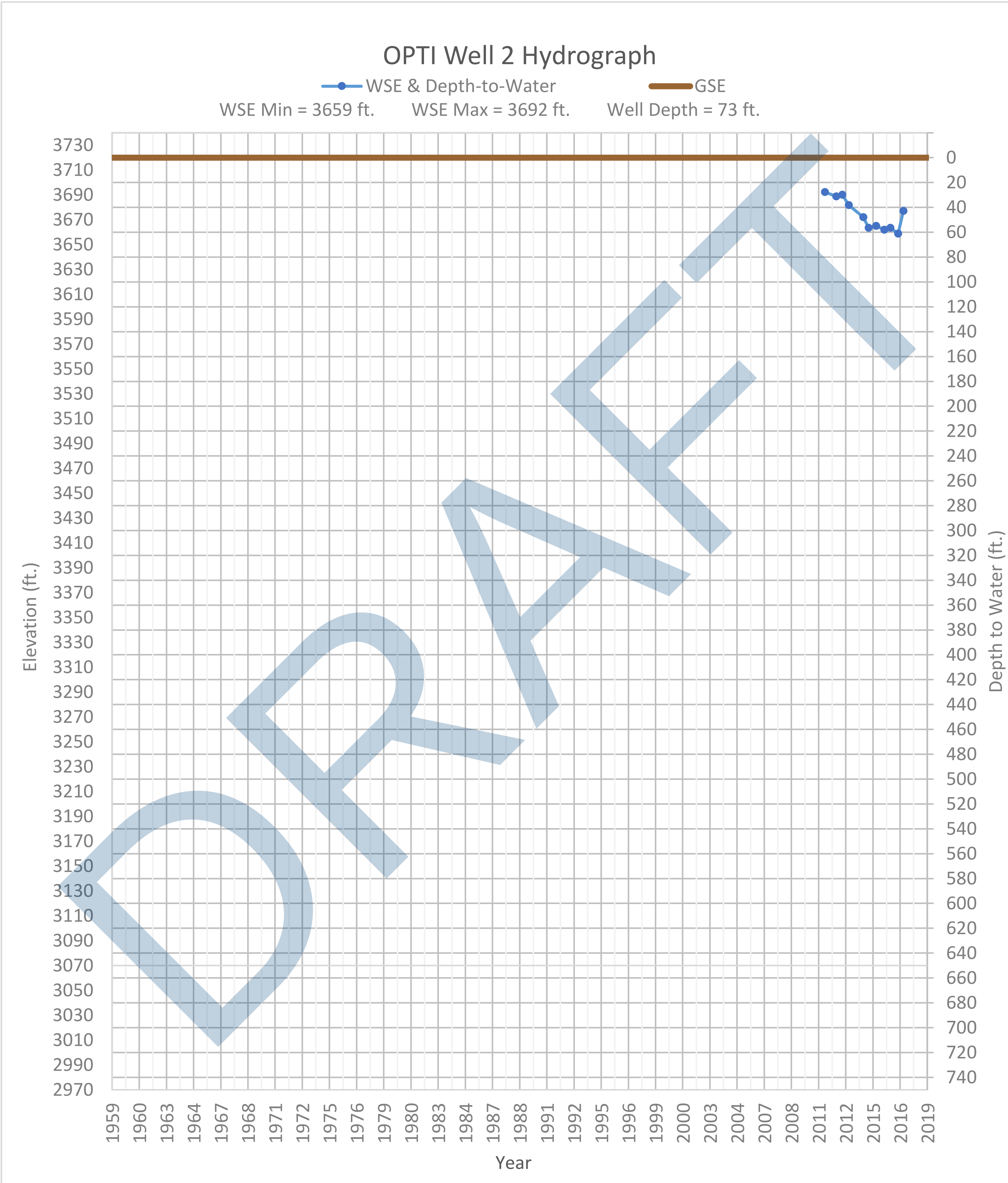
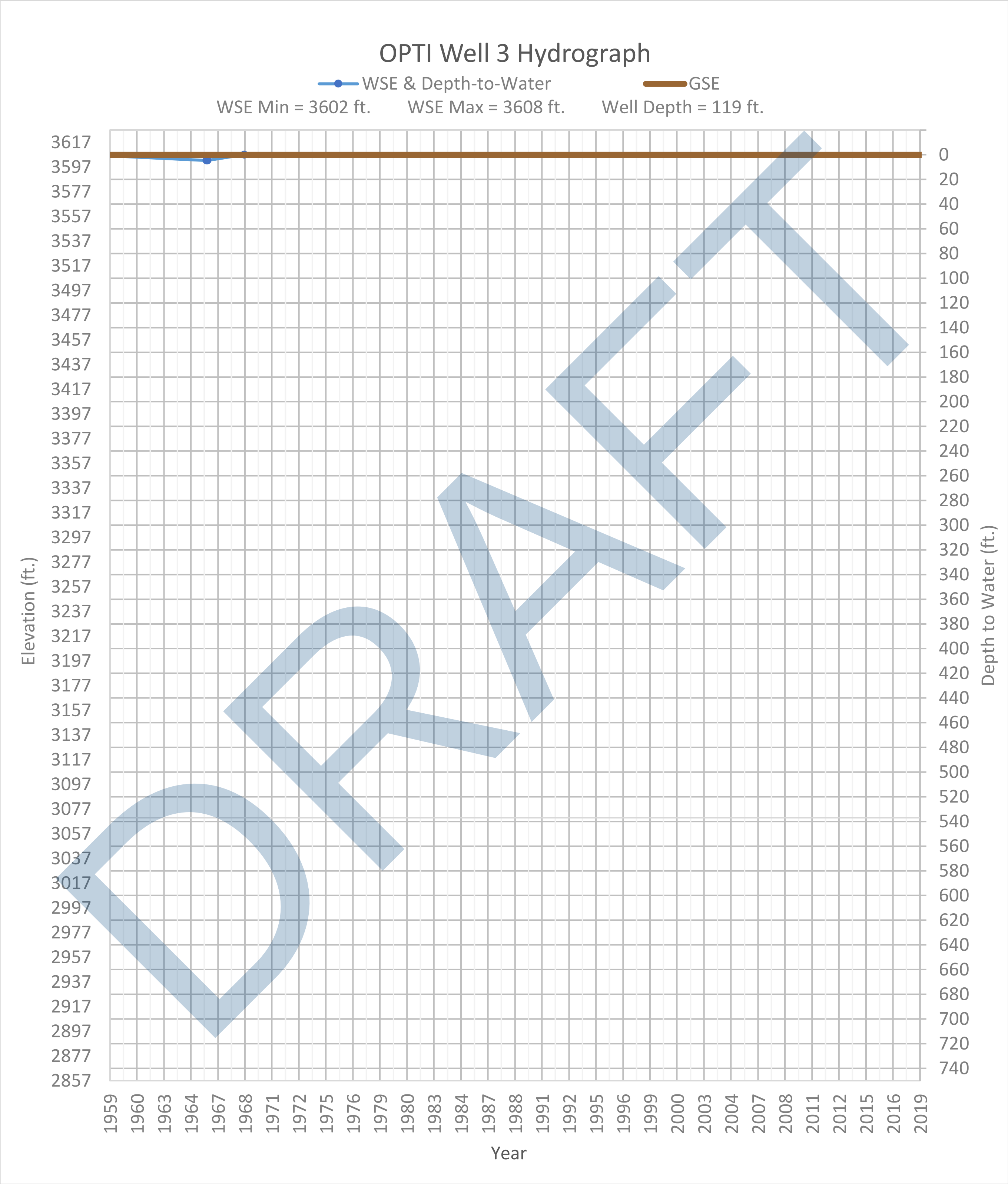
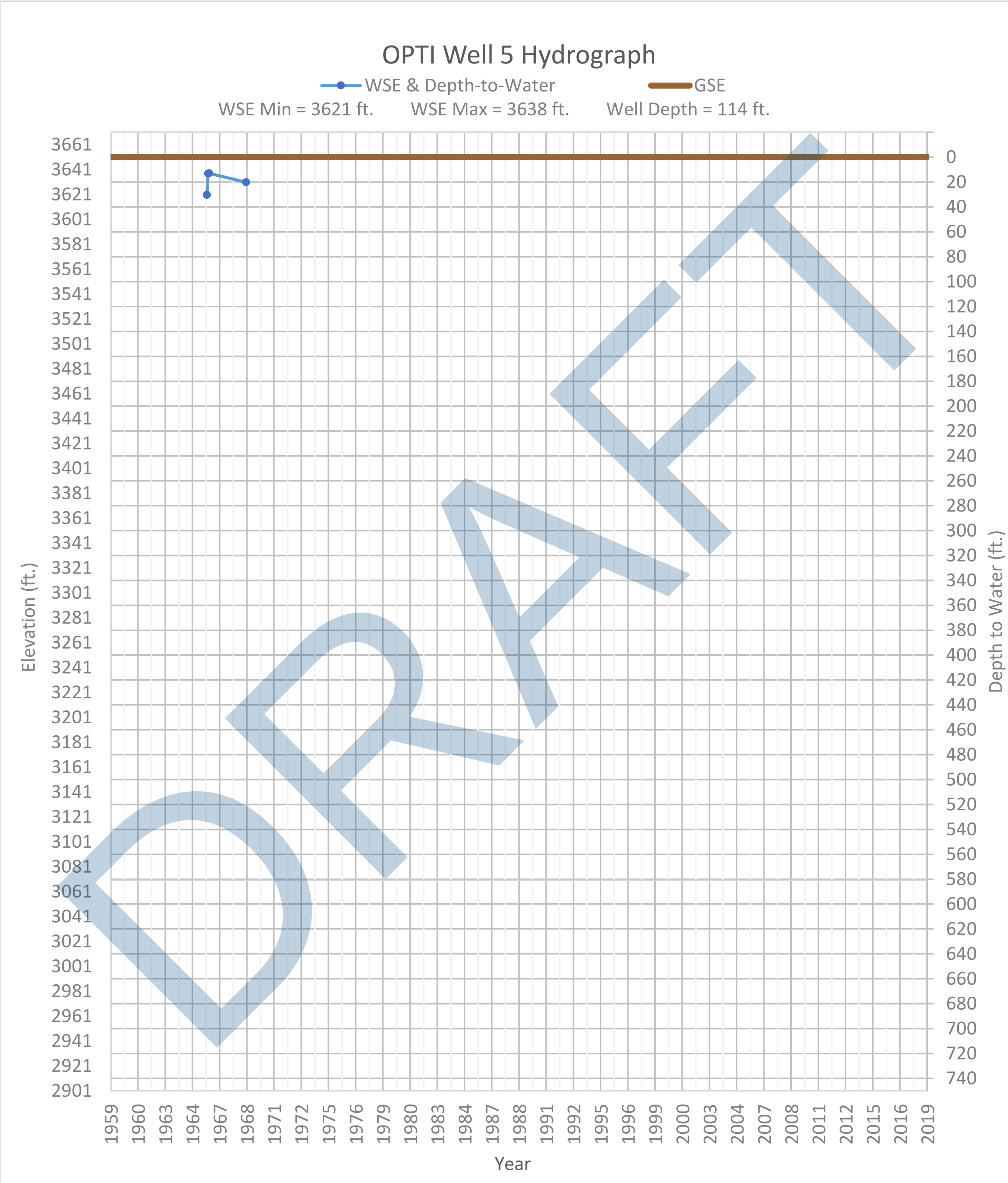
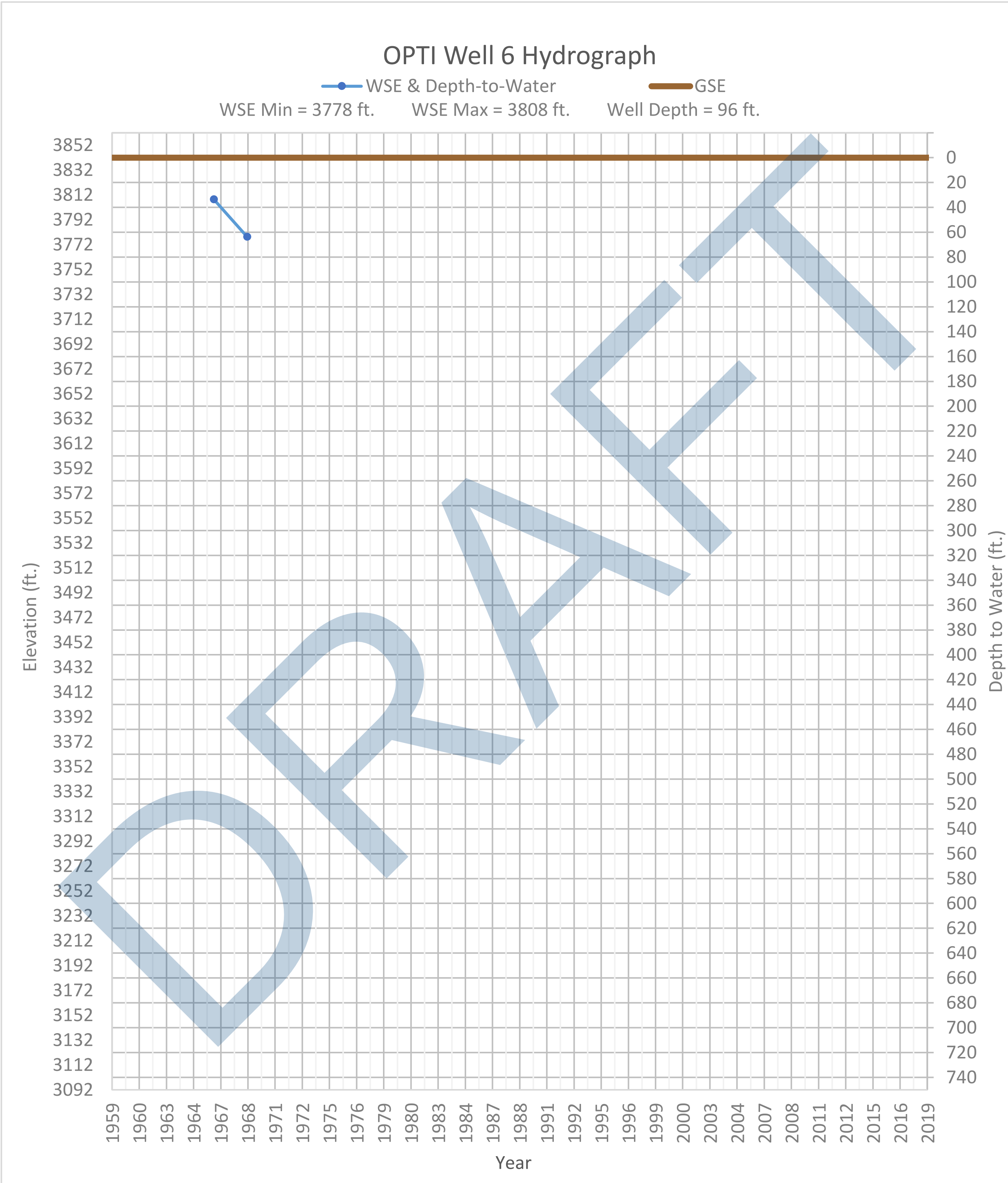

OPTI Well 2 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3659 ft.
WSE Max = 3692 ft.
Well Depth = 73 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

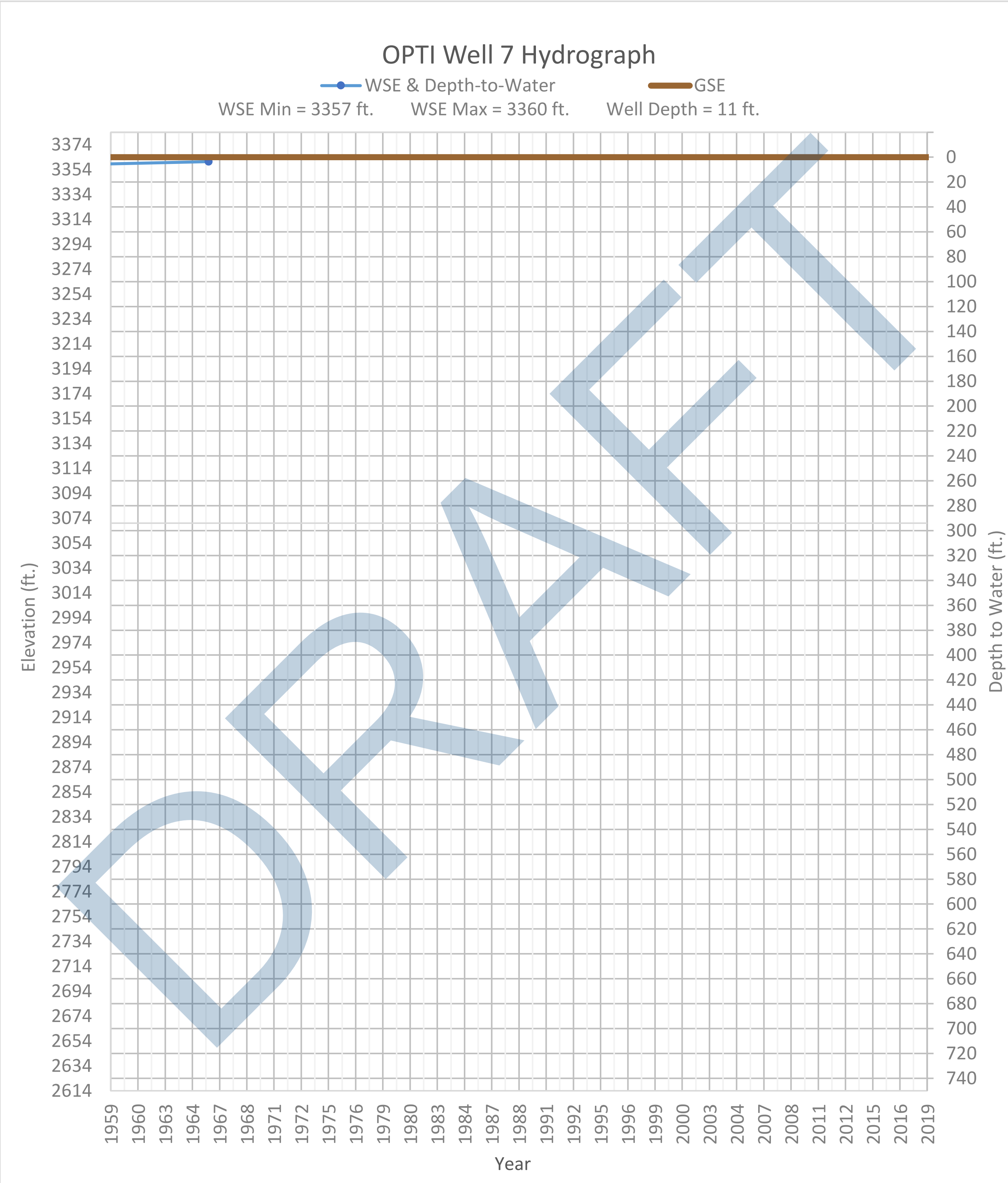


OPTI Well 3 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3602 ft.
WSE Max = 3608 ft.
Well Depth = 119 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

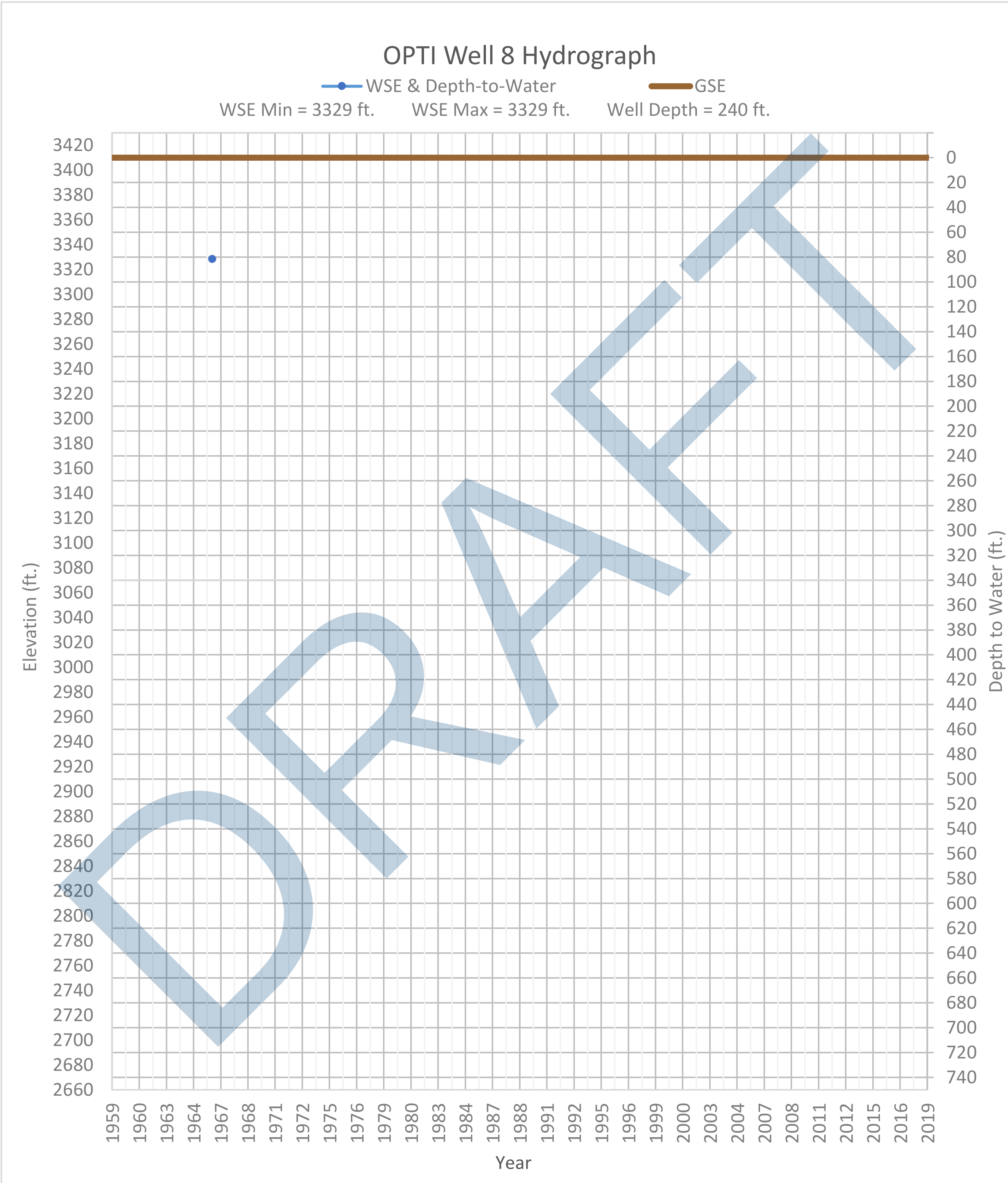

OPTI Well 5 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3621 ft.
WSE Max = 3638 ft.
Well Depth = 114 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



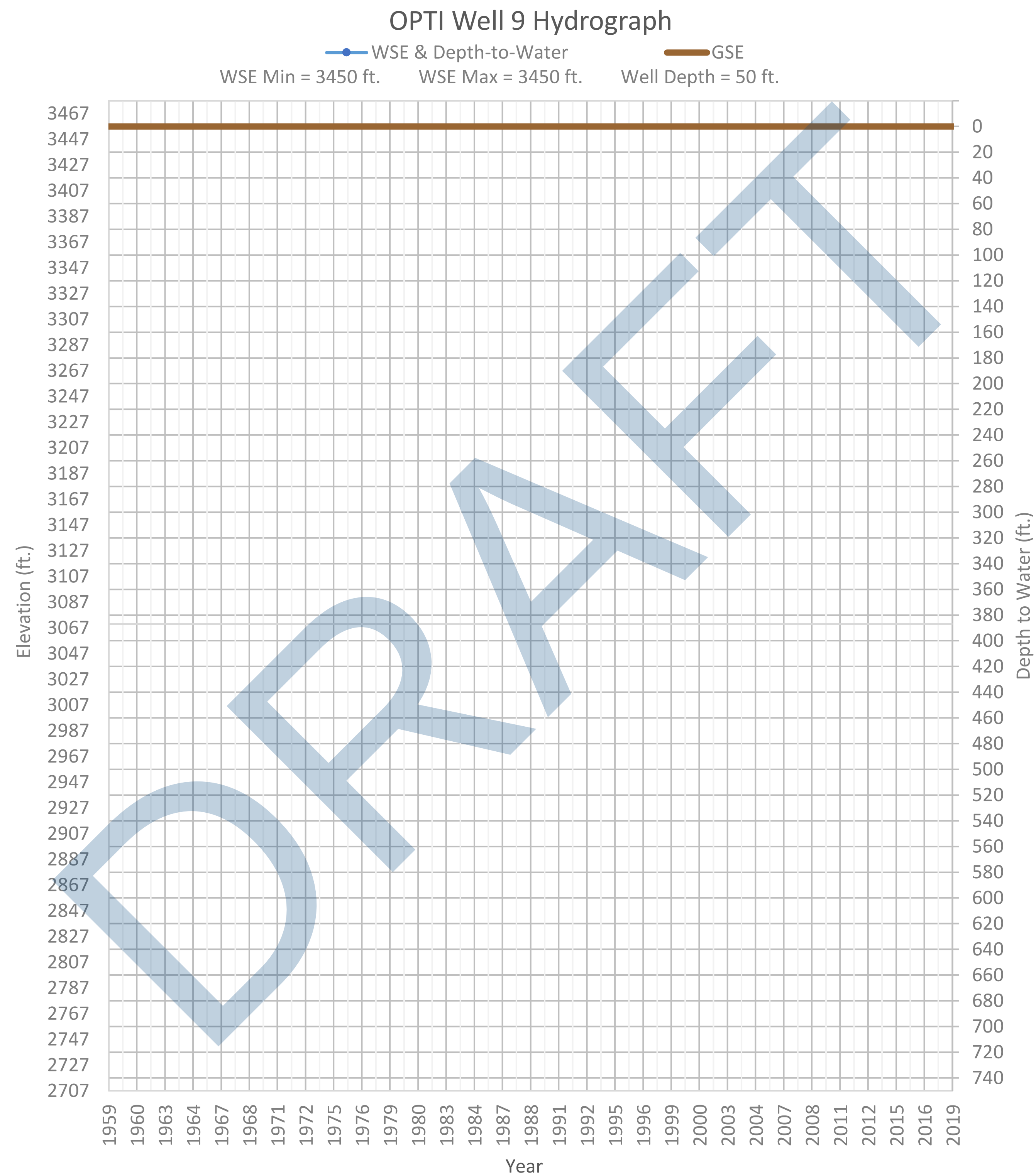
OPTI Well 6 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3778 ft.
WSE Max = 3808 ft.
Well Depth = 96 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



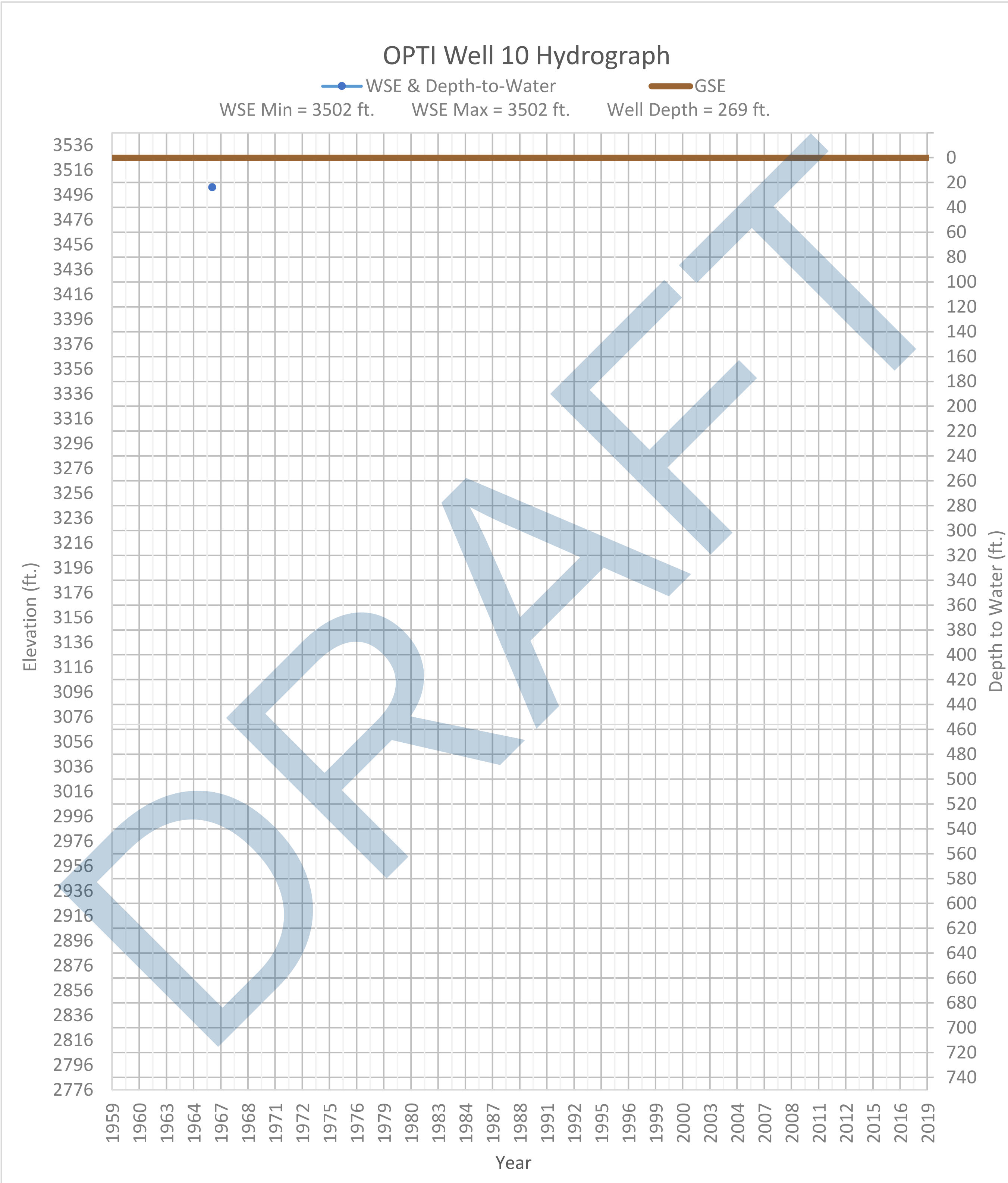
OPTI Well 7 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3357 ft.
WSE Max = 3360 ft.
Well Depth = 11 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



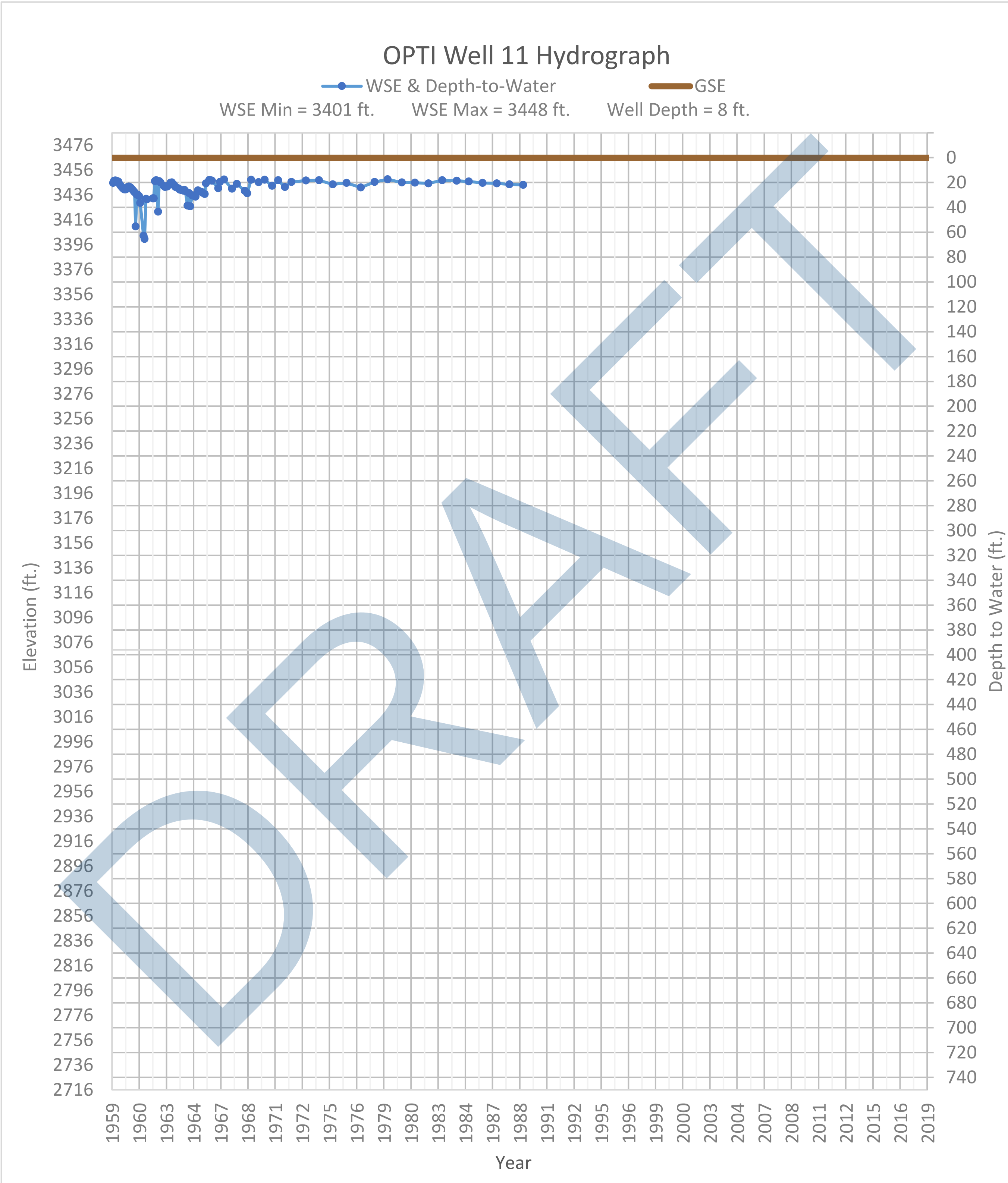
OPTI Well 8 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3329 ft.
WSE Max = 3329 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



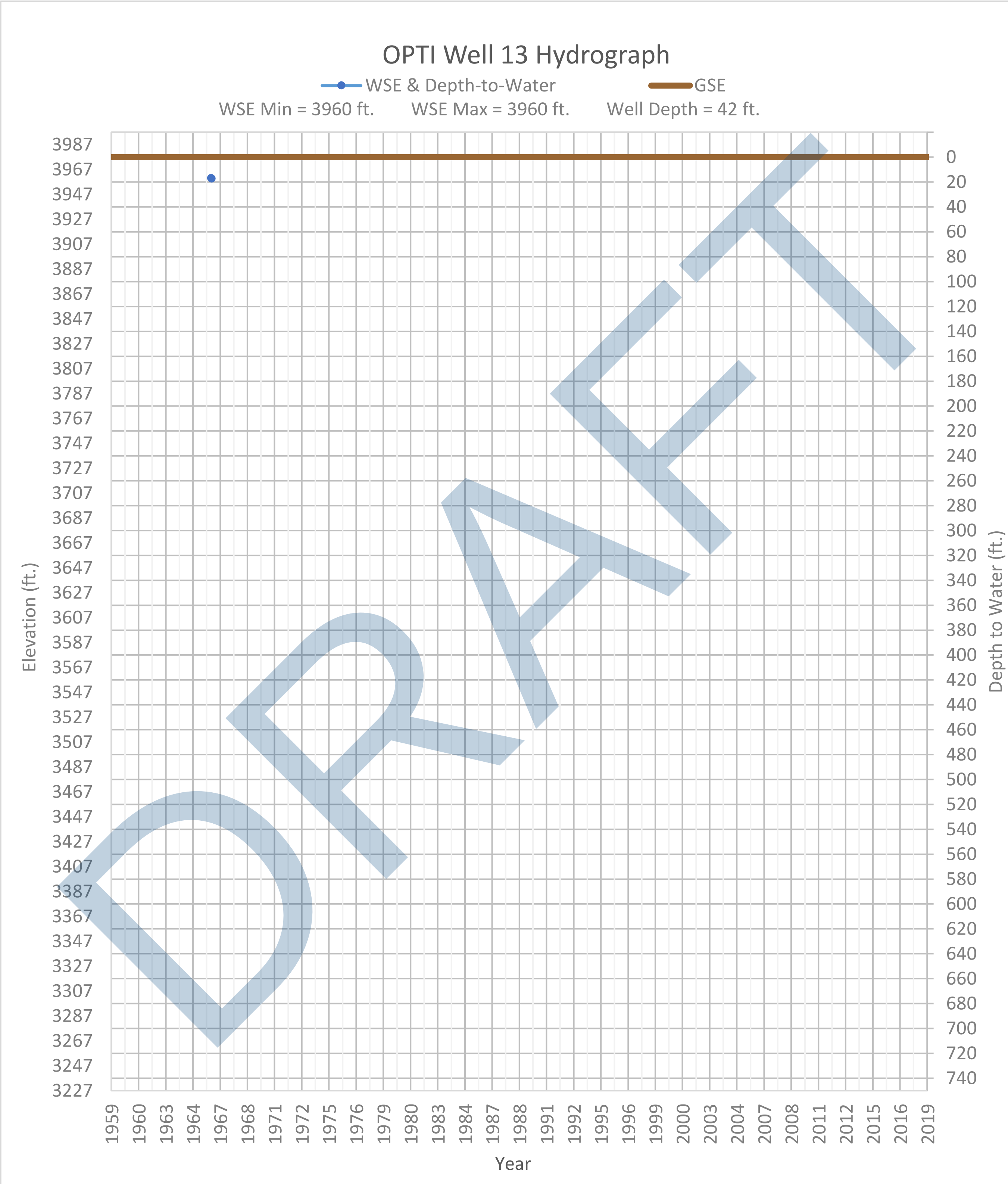
OPTI Well 9 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3450 ft.
WSE Max = 3450 ft.
Well Depth = 50 ft.
Elevation (ft.)
3467
3447
3427
3407
3387
3367
3347
3327
3307
3287
3267
3247
3227
3207
3187
3167
3147
3127
3107
3087
3067
3047
3027
3007
2987
2967
2947
2927
2907
2887
2867
2847
2827
2807
2787
2767
2747
2727
2707
Depth to Water (ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
Year
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
1984
1987
1988
1991
1992
1995
1996
1999
2000
2003
2004
2007
2008
2011
2012
2015
2016
2019
DRAFT



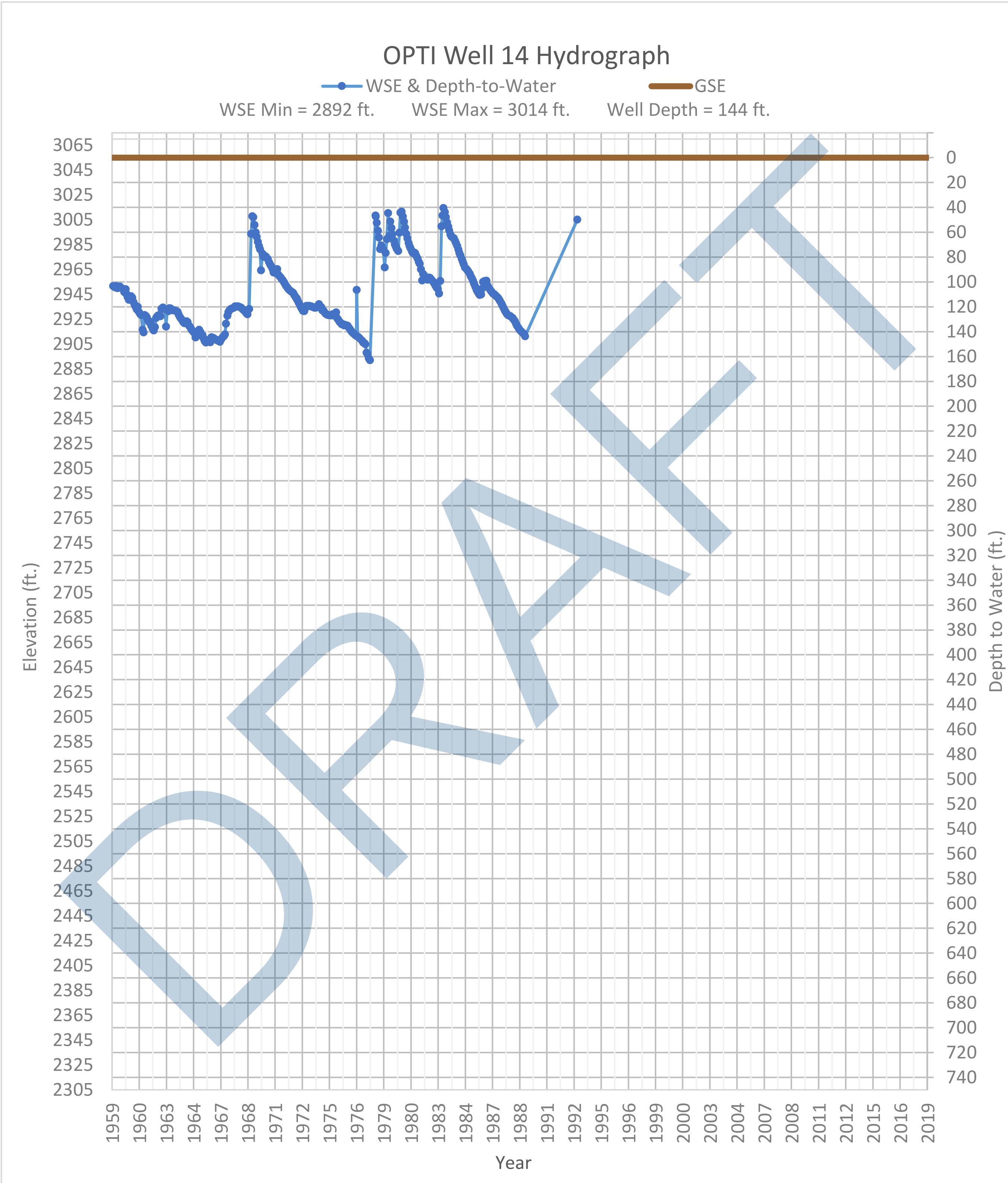
OPTI Well 10 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3502 ft.
WSE Max = 3502 ft.
Well Depth = 269 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



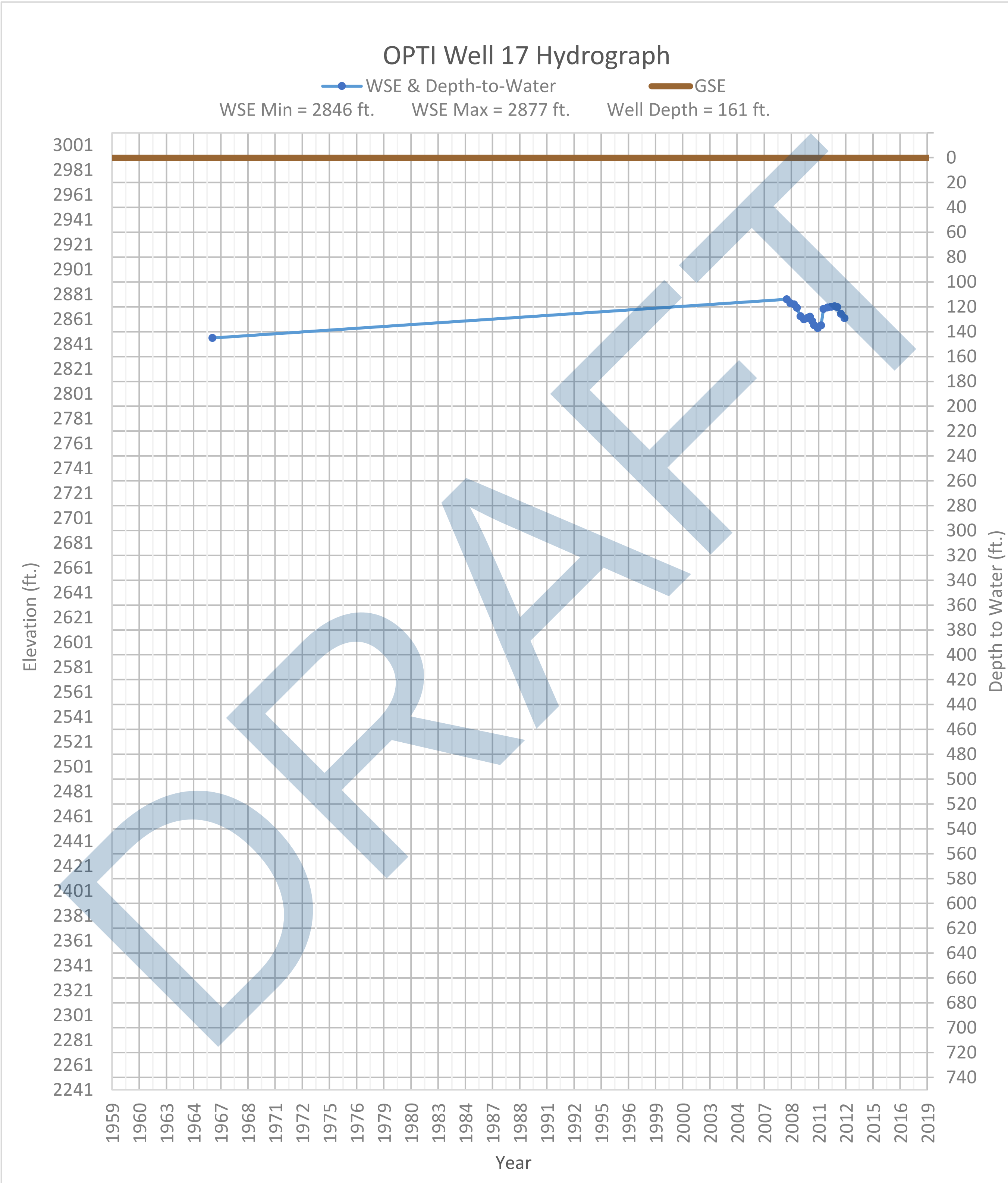
OPTI Well 11 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3401 ft.
WSE Max = 3448 ft.
Well Depth = 8 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



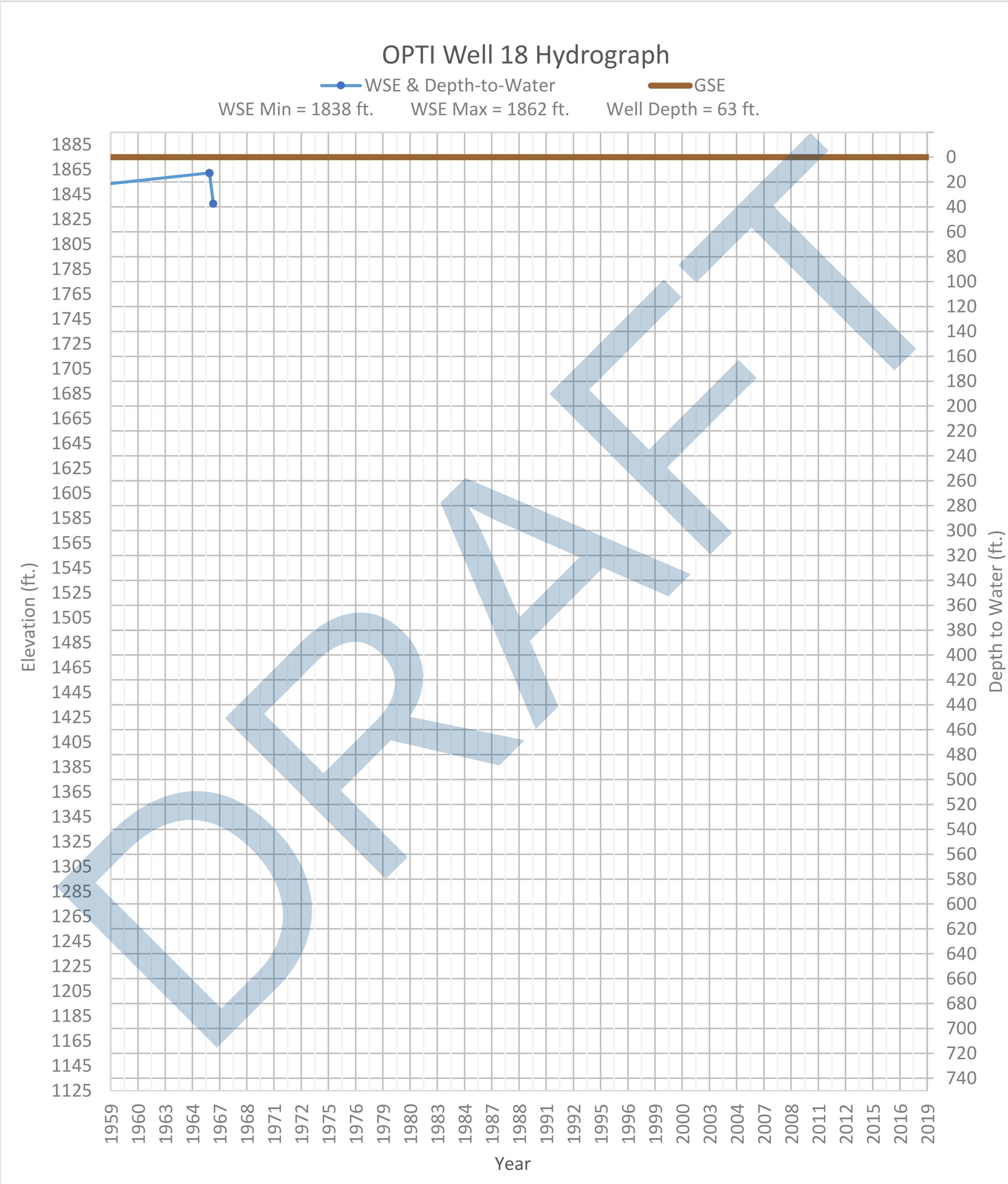
OPTI Well 13 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3960 ft.
WSE Max = 3960 ft.
Well Depth = 42 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



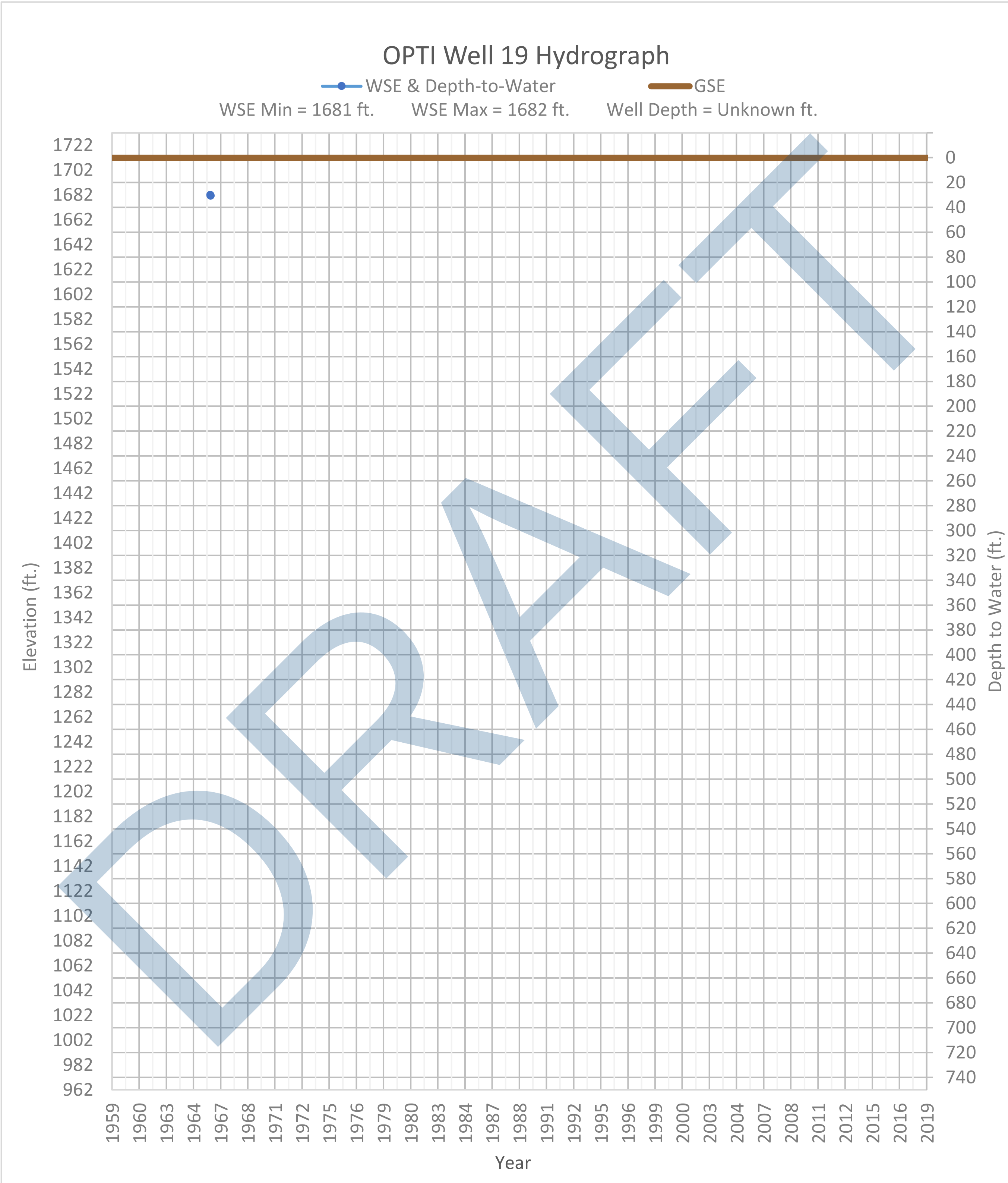
OPTI Well 14 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2892 ft.
WSE Max = 3014 ft.
Well Depth = 144 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



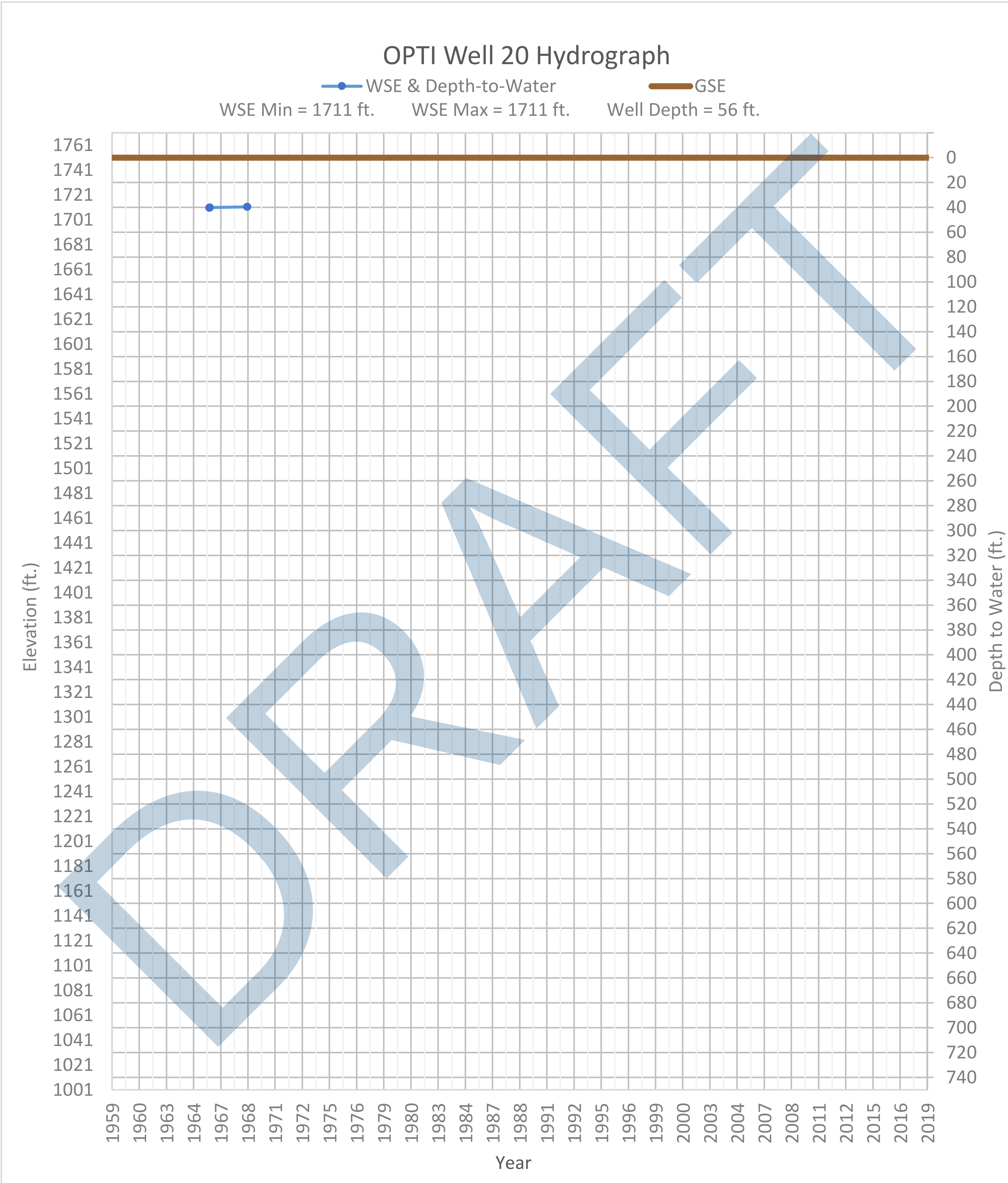
OPTI Well 17 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2846 ft.
WSE Max = 2877 ft.
Well Depth = 161 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



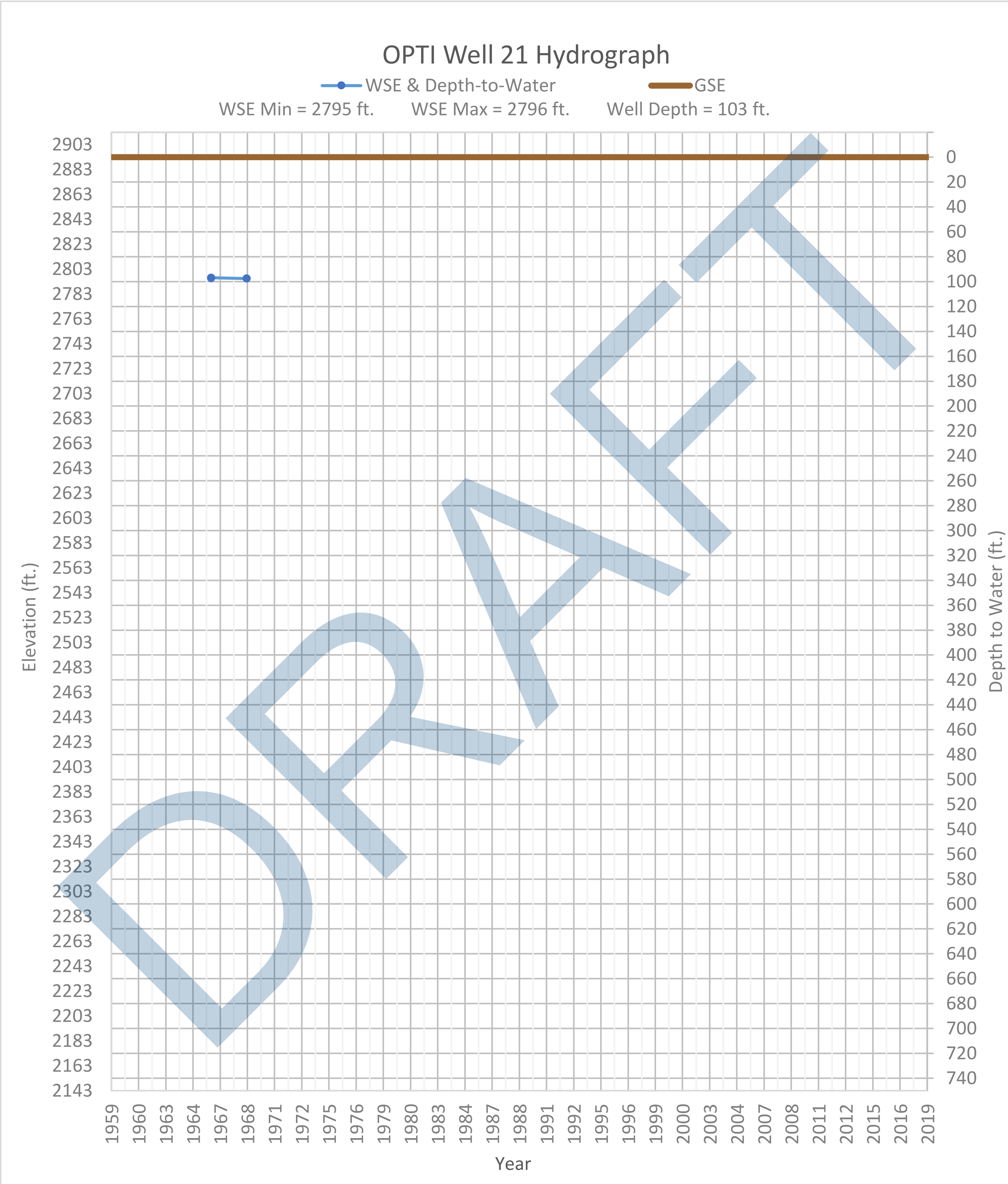
OPTI Well 18 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1838 ft.
WSE Max = 1862 ft.
Well Depth = 63 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



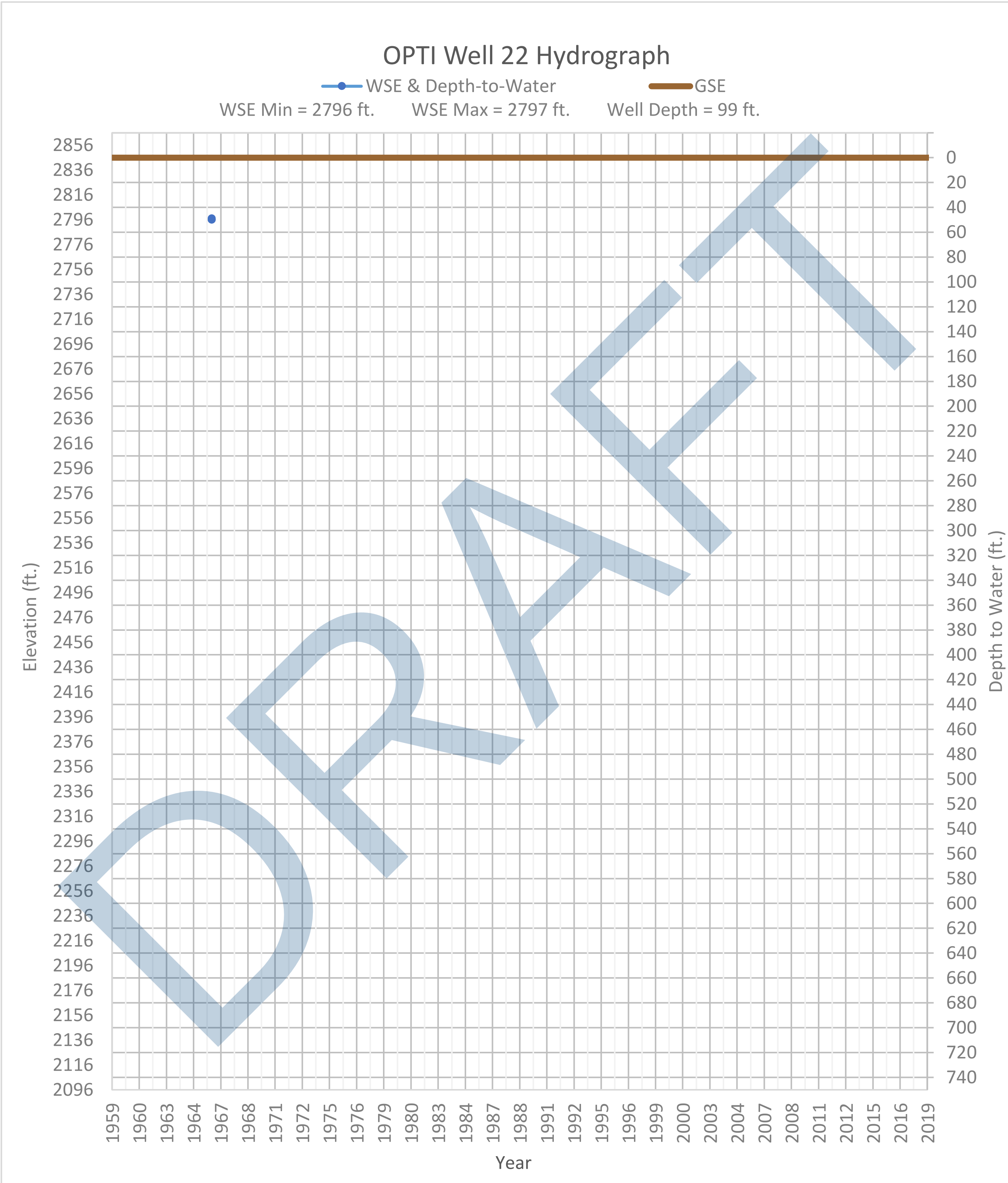
OPTI Well 19 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1681 ft.
WSE Max = 1682 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



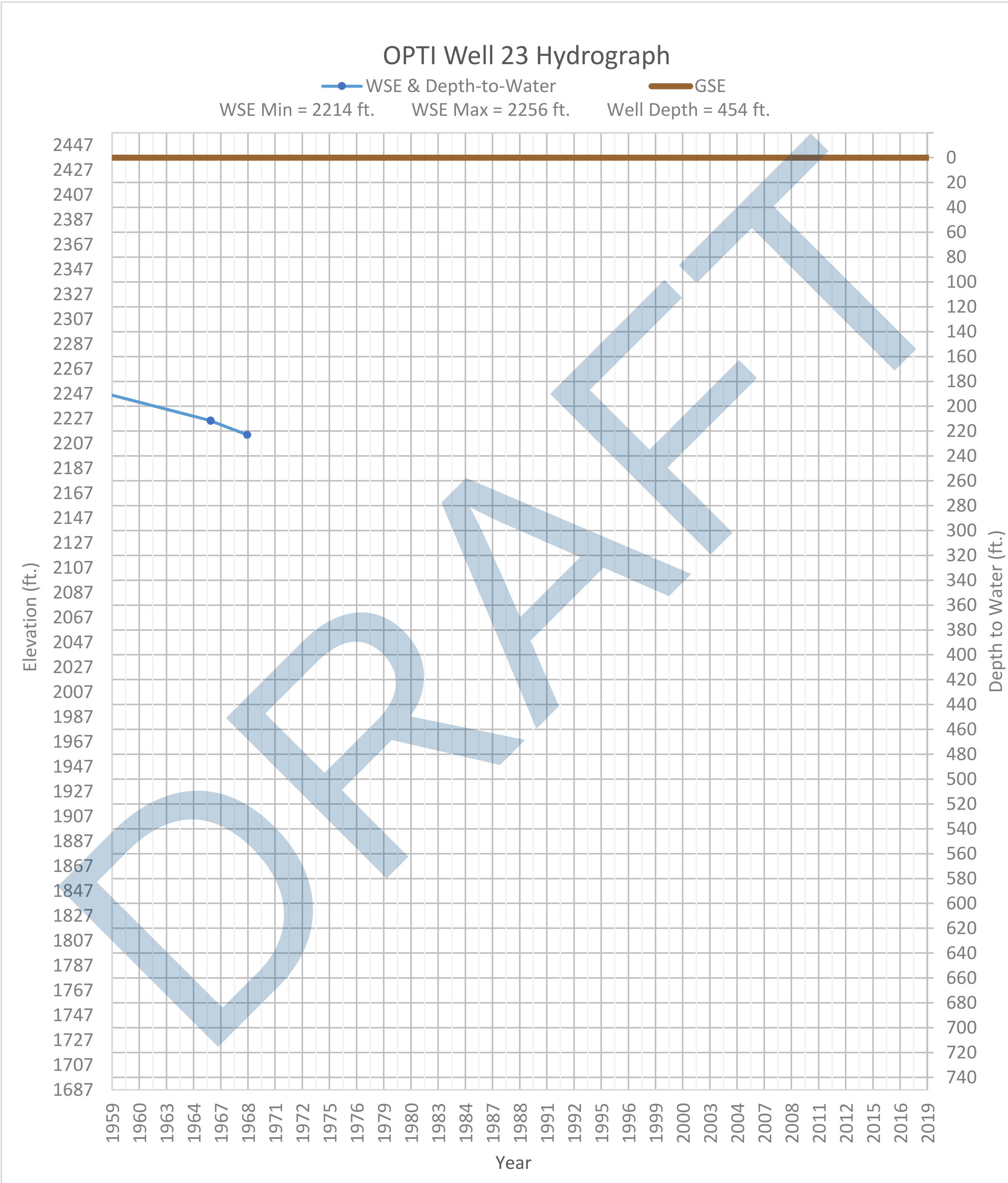
OPTI Well 20 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1711 ft.
WSE Max = 1711 ft.
Well Depth = 56 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

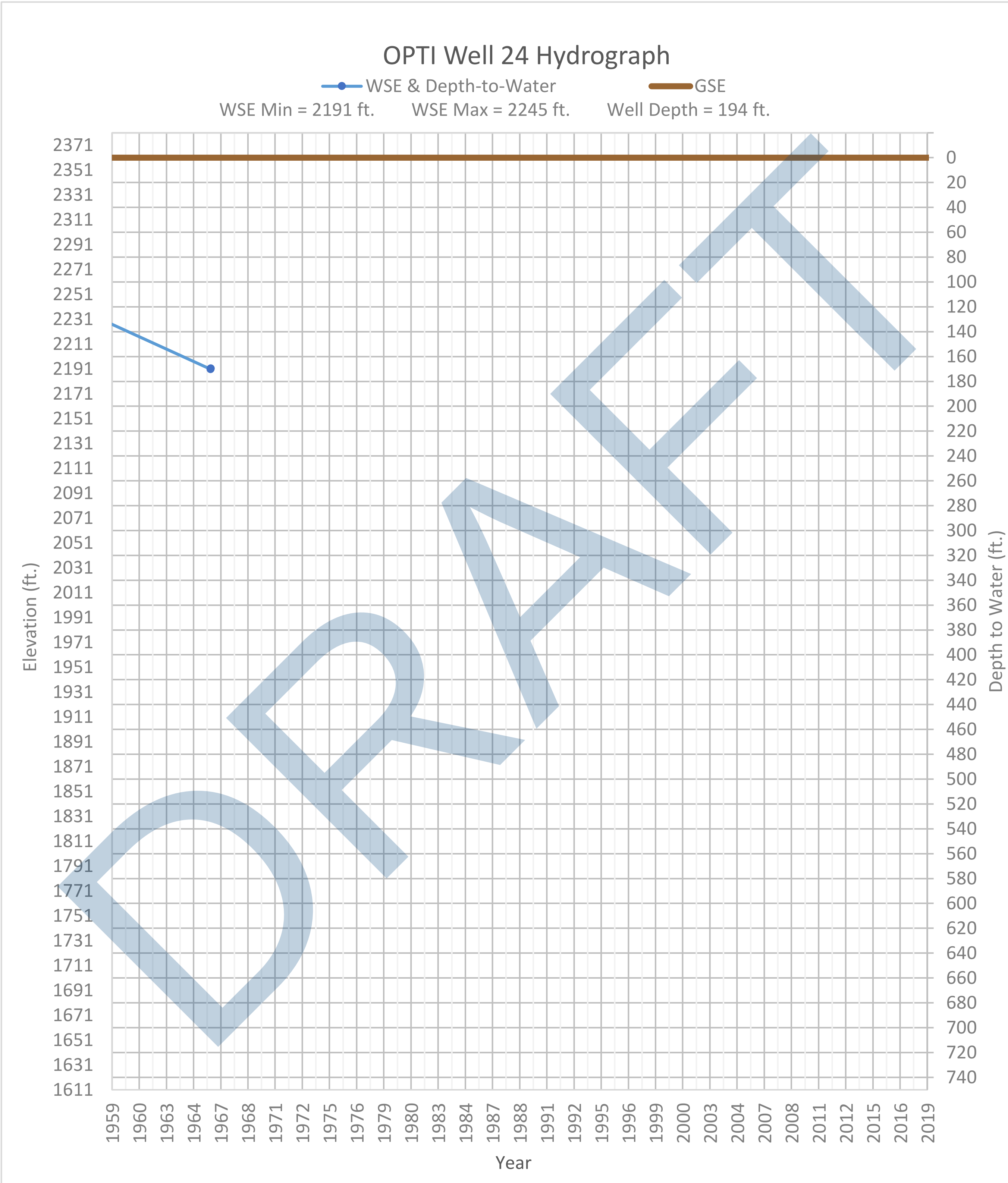


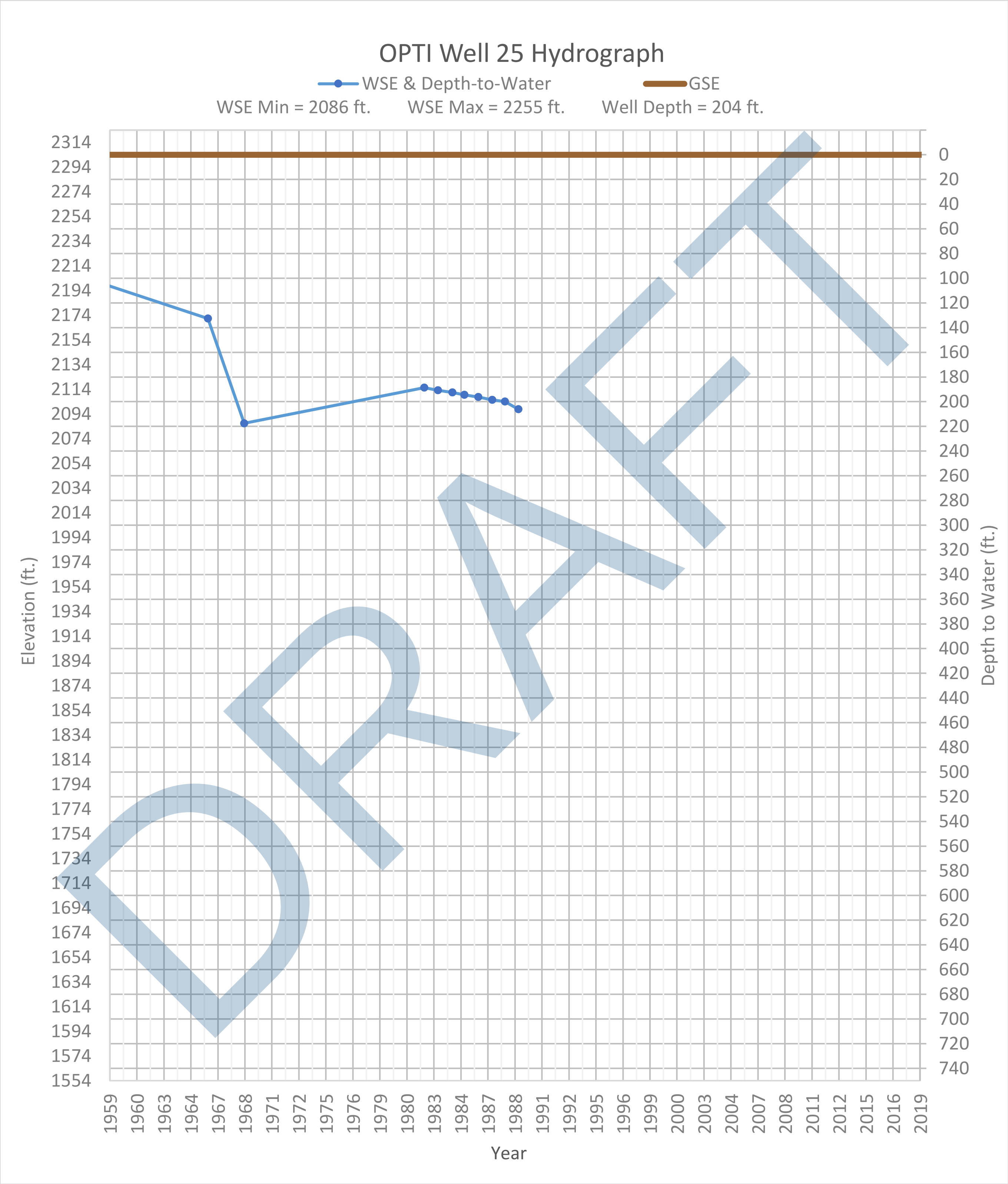
OPTI Well 21 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2795 ft.
WSE Max = 2796 ft.
Well Depth = 103 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



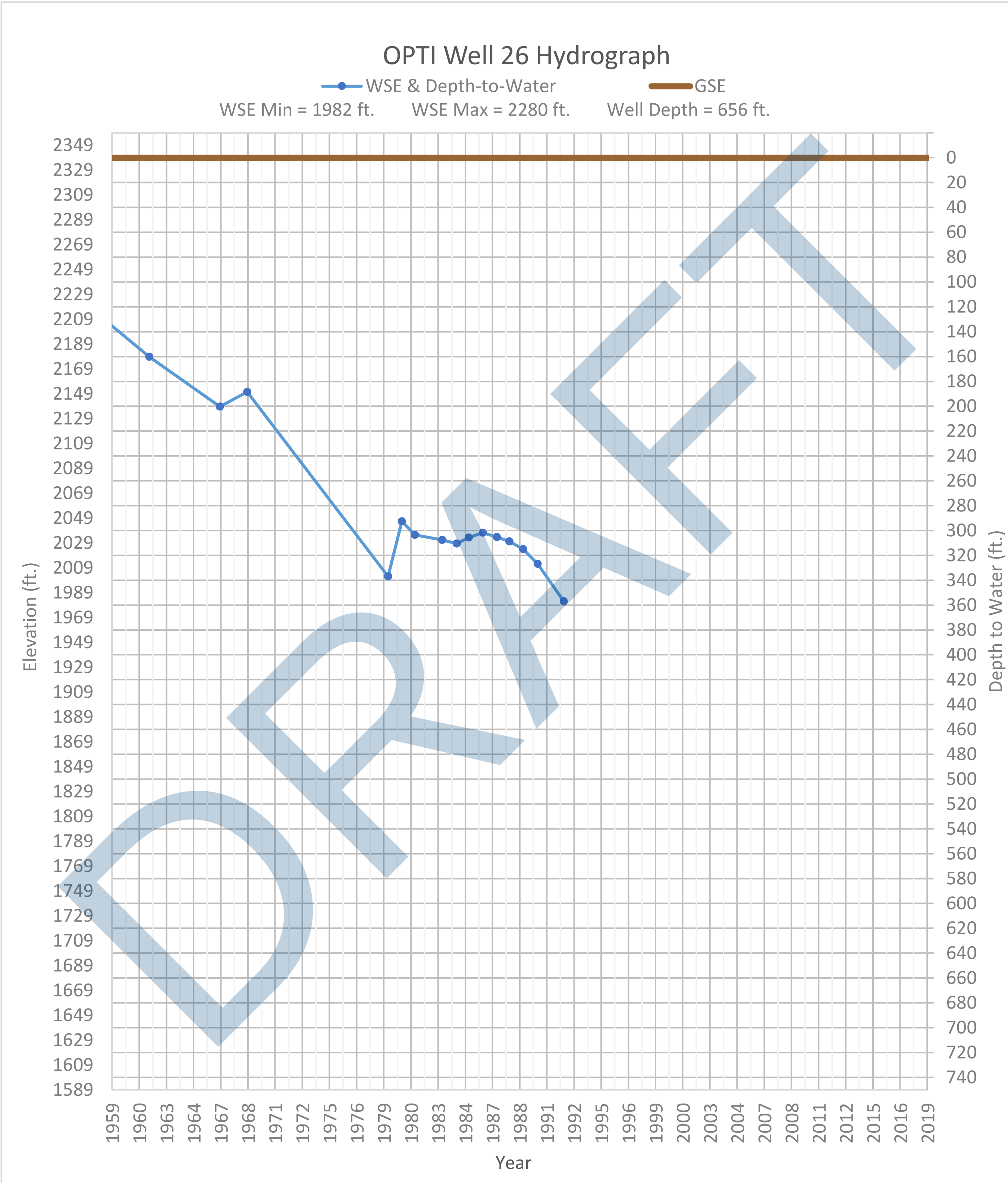
OPTI Well 22 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2796 ft.
WSE Max = 2797 ft.
Well Depth = 99 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

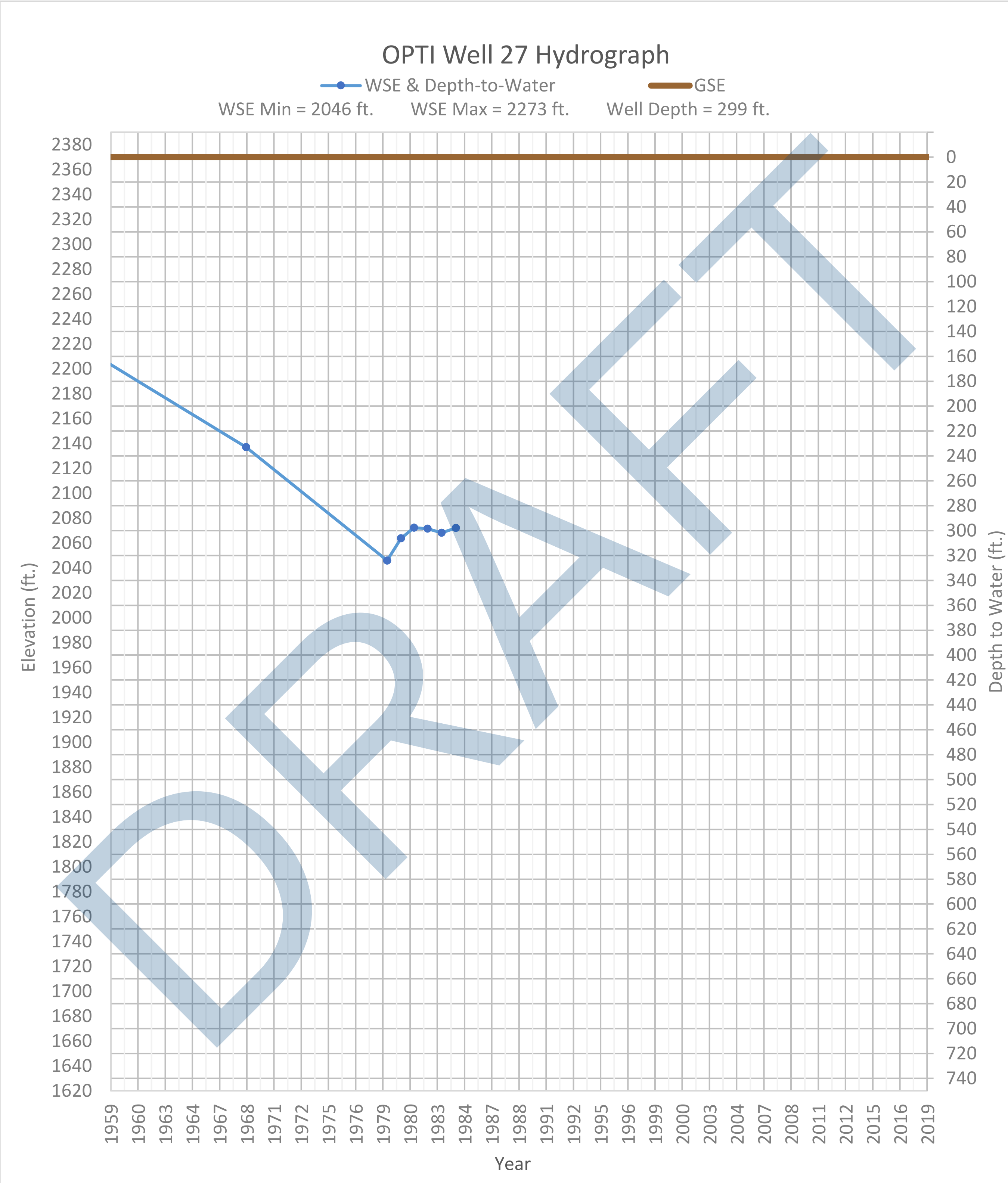

OPTI Well 23 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2214 ft.
WSE Max = 2256 ft.
Well Depth = 454 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 24 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2191 ft.
WSE Max = 2245 ft.
Well Depth = 194 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT
2371 2351 2331 2311 2291 2271 2251 2231 2211 2191 2171 2151 2131 2111 2091 2071 2051 2031 2011 1991 1971 1951 1931 1911 1891 1871 1851 1831 1811 1791 1771 1751 1731 1711 1691 1671 1651 1631 1611
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019

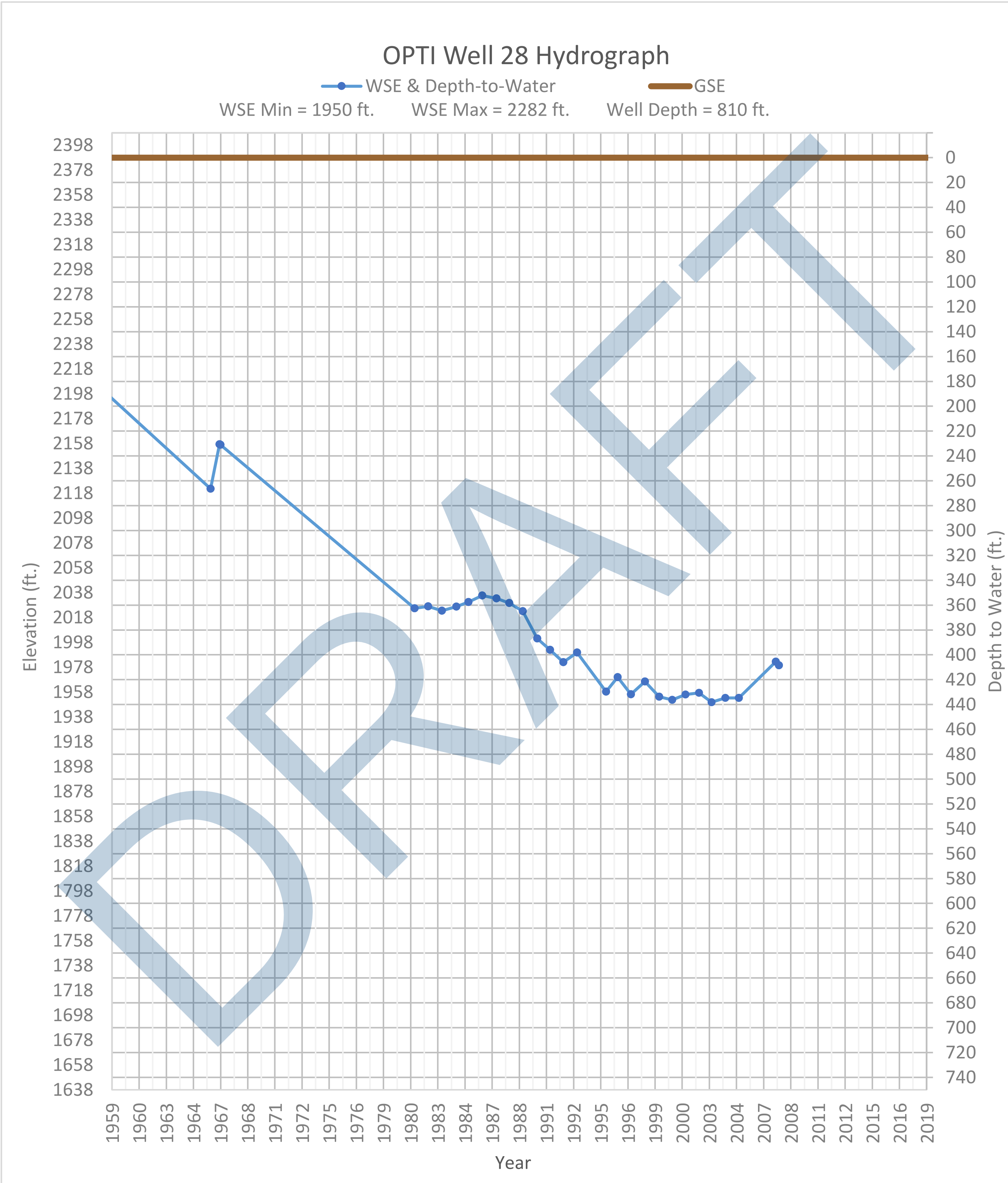


OPTI Well 25 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2086 ft.
WSE Max = 2255 ft.
Well Depth = 204 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

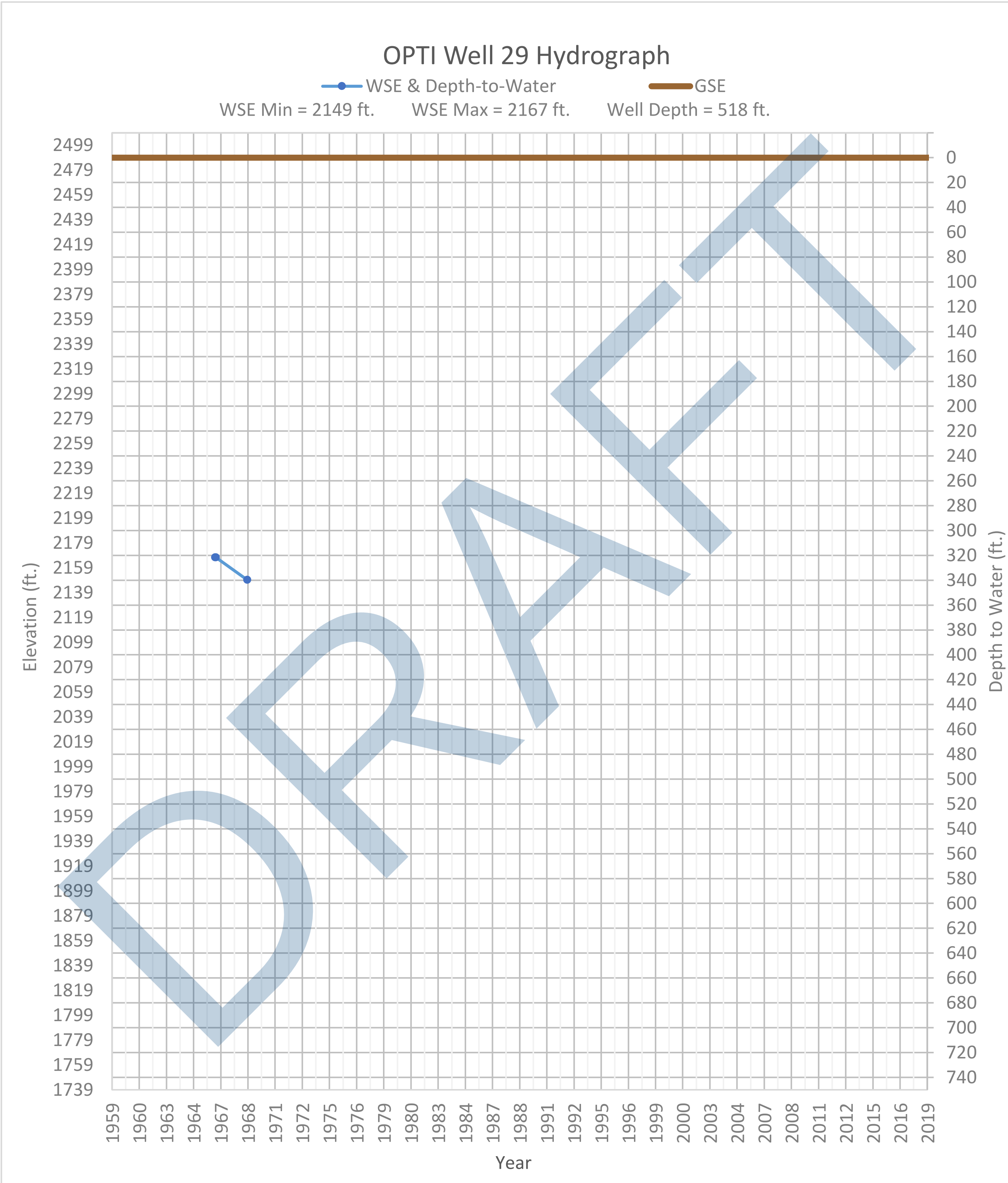

OPTI Well 26 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1982 ft.
WSE Max = 2280 ft.
Well Depth = 656 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



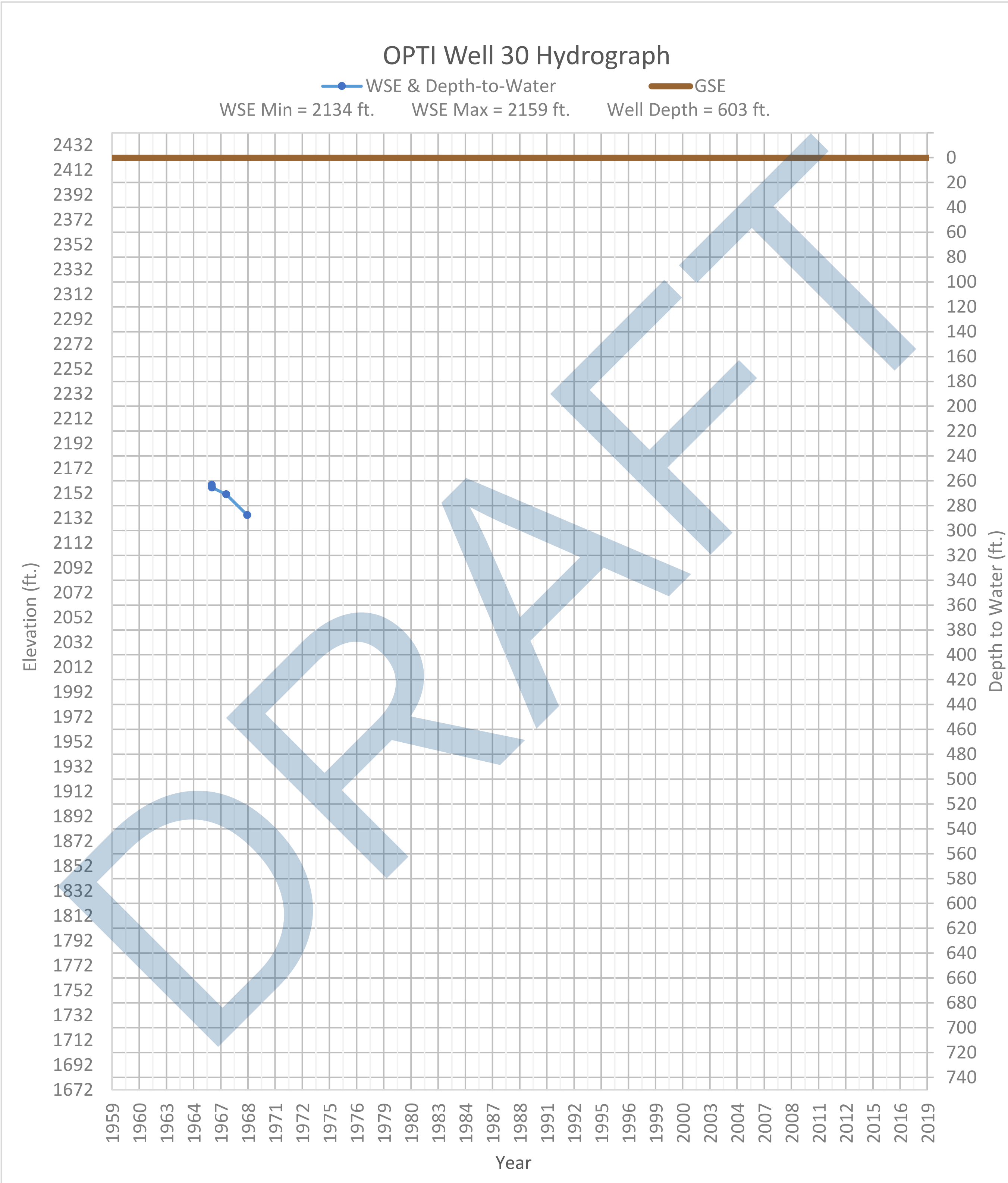
OPTI Well 27 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2046 ft.
WSE Max = 2273 ft.
Well Depth = 299 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



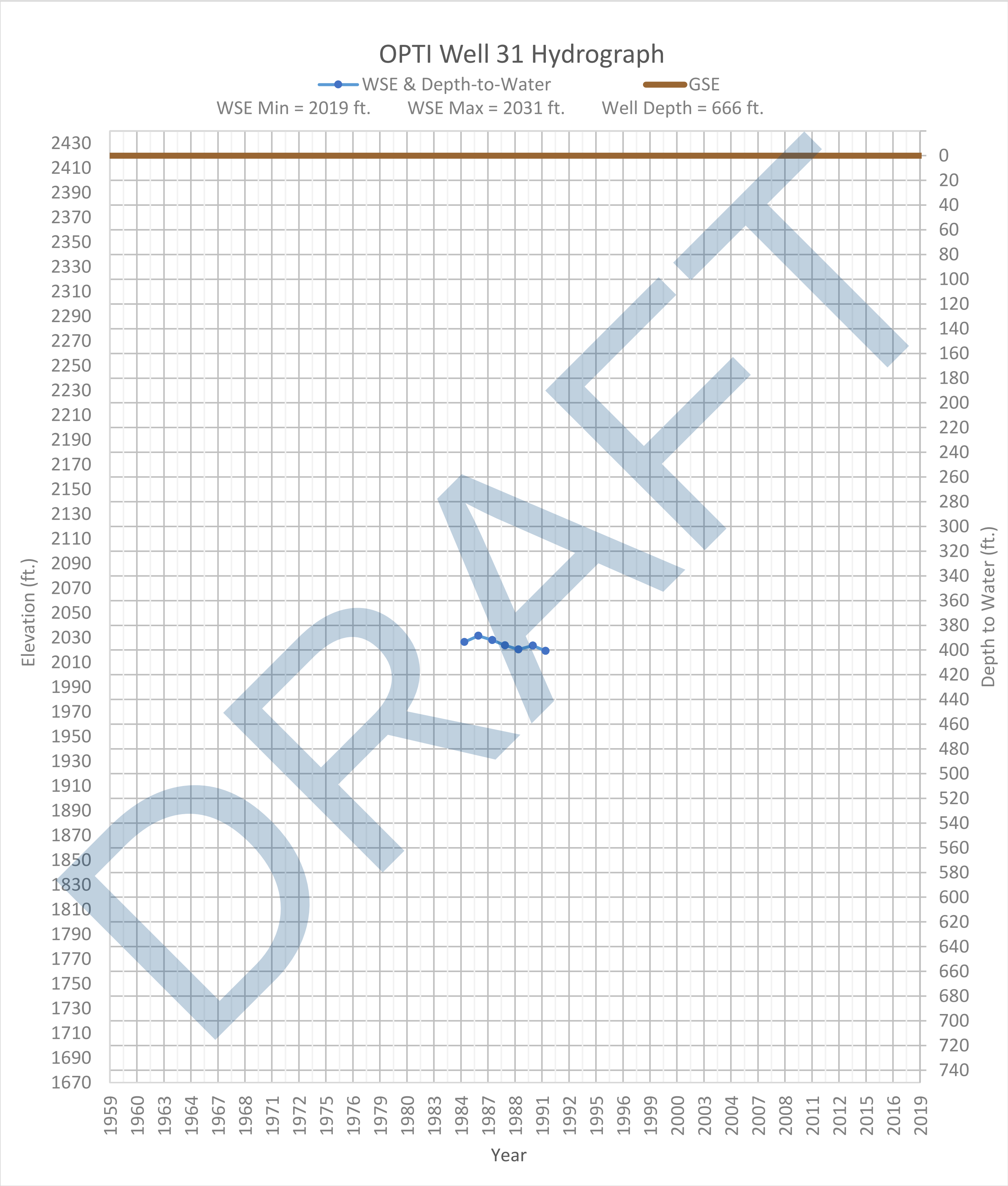
OPTI Well 28 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1950 ft.
WSE Max = 2282 ft.
Well Depth = 810 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



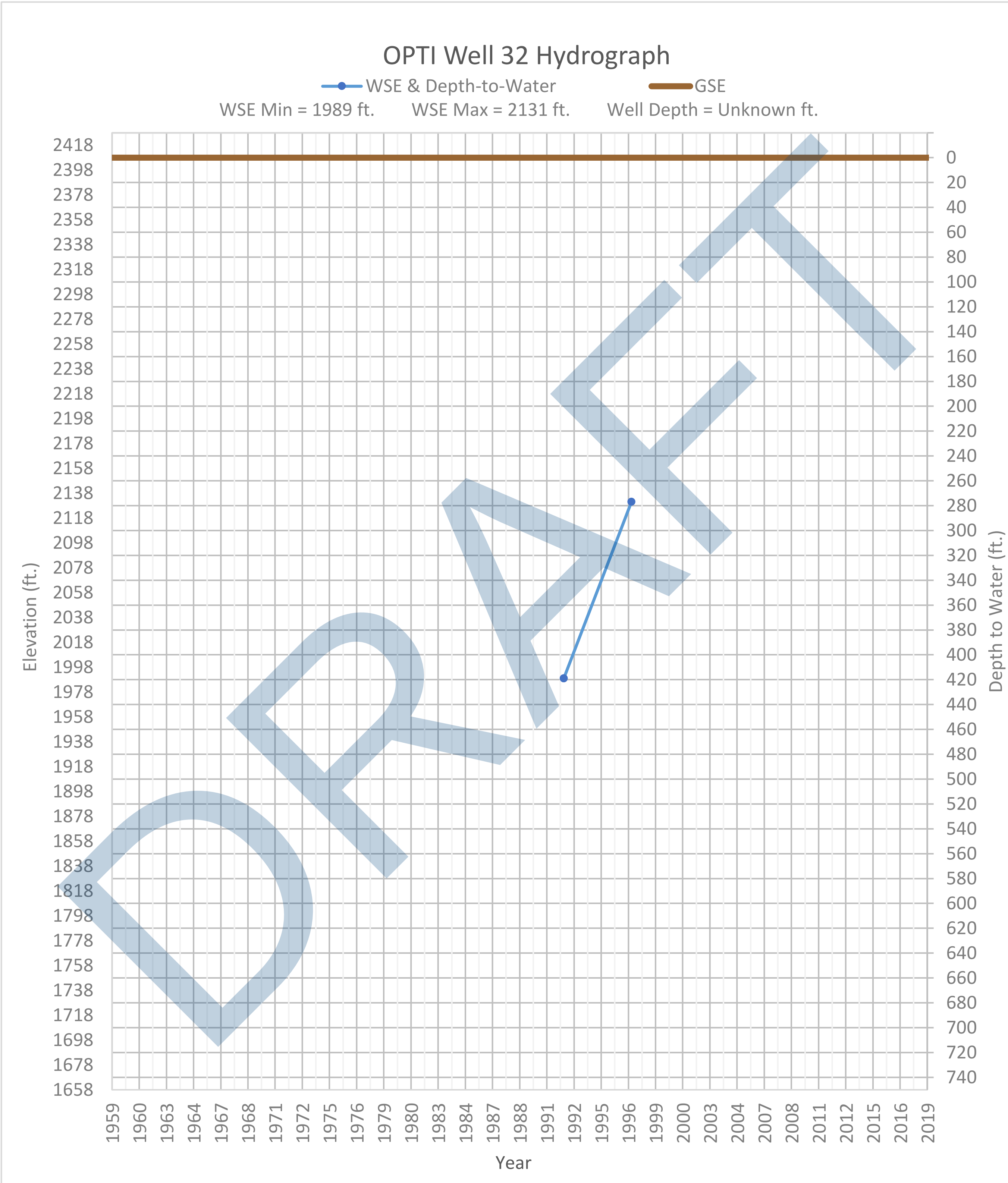
OPTI Well 29 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2149 ft.
WSE Max = 2167 ft.
Well Depth = 518 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



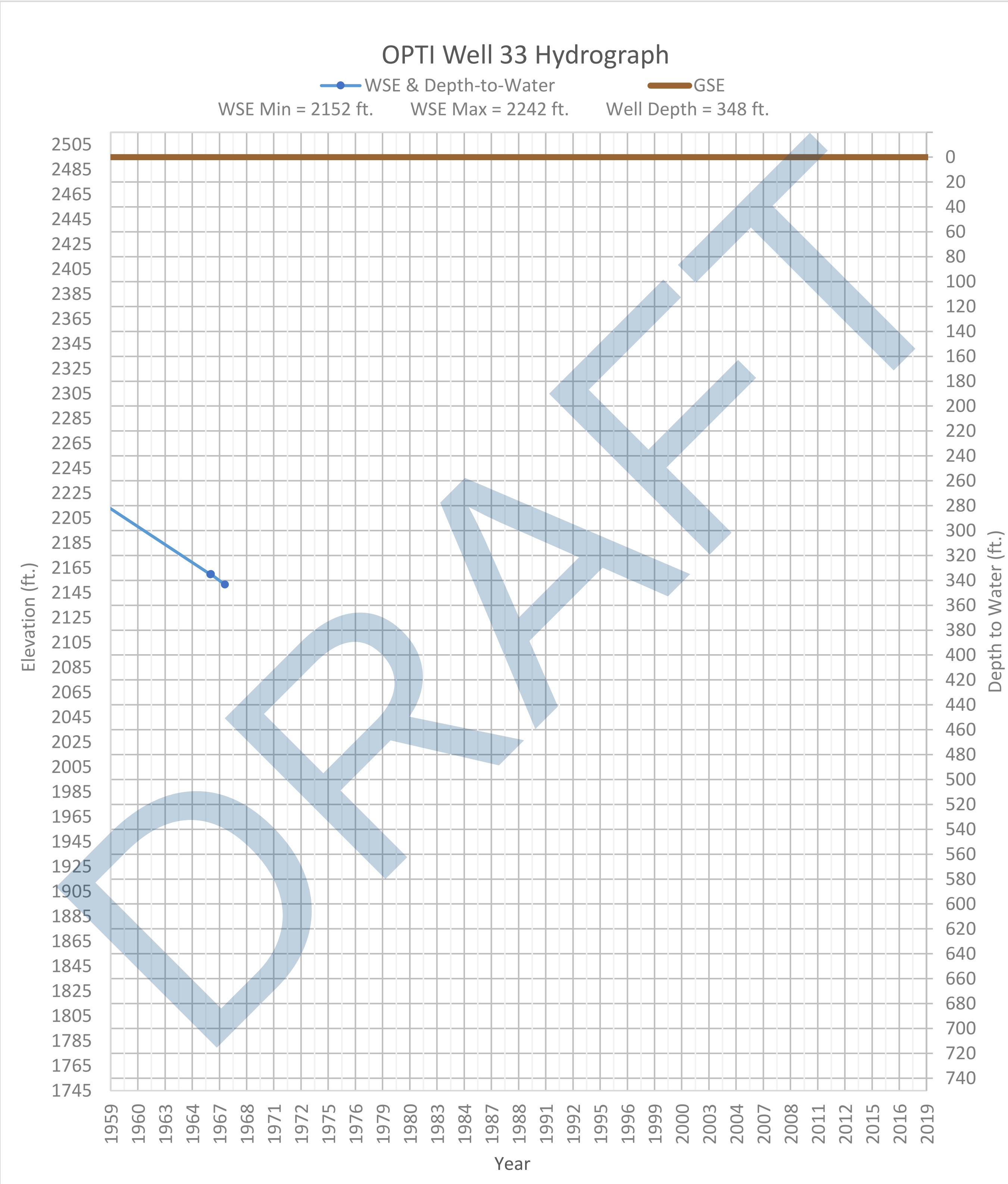
OPTI Well 30 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2134 ft.
WSE Max = 2159 ft.
Well Depth = 603 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



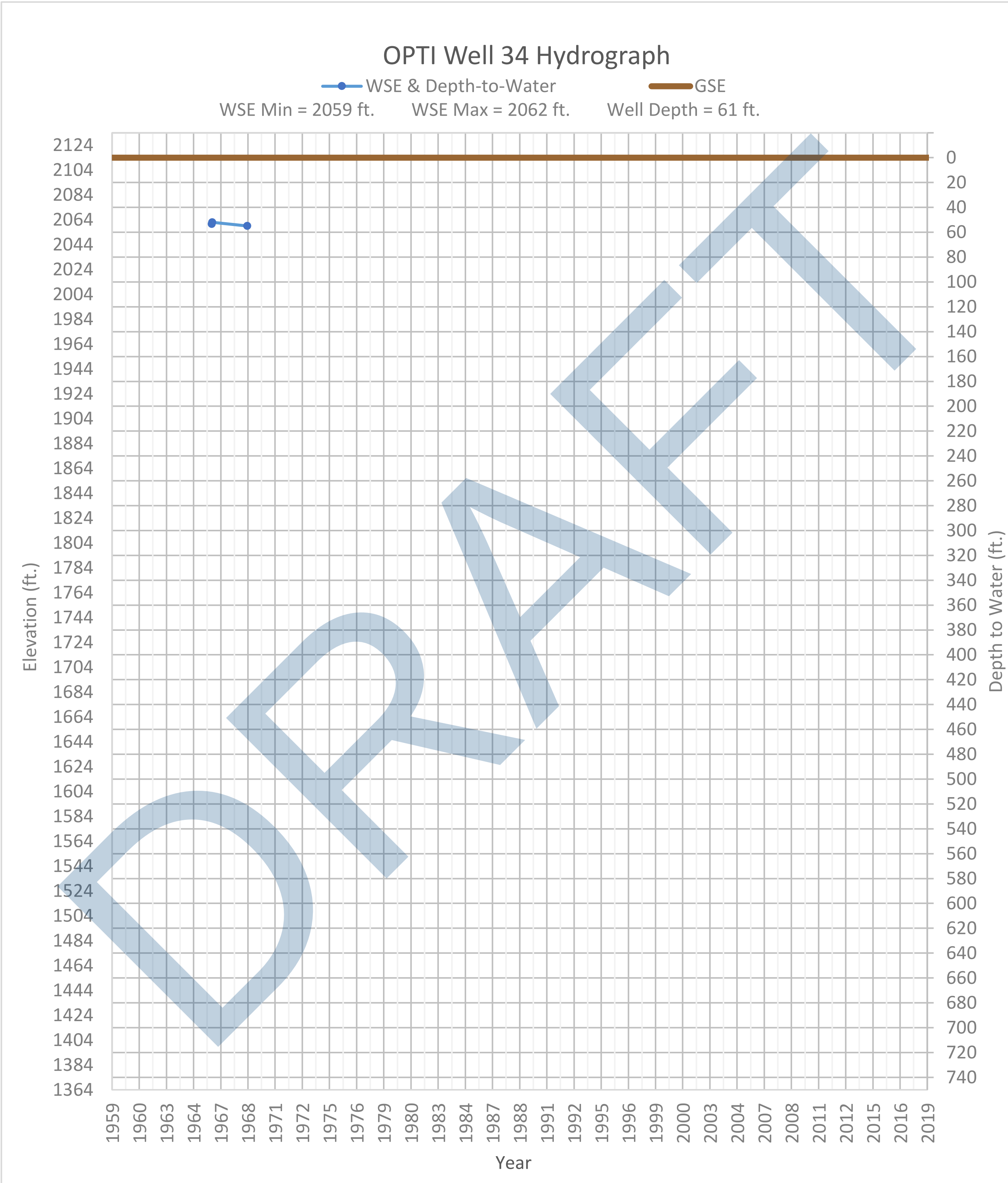
OPTI Well 31 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2019 ft.
WSE Max = 2031 ft.
Well Depth = 666 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

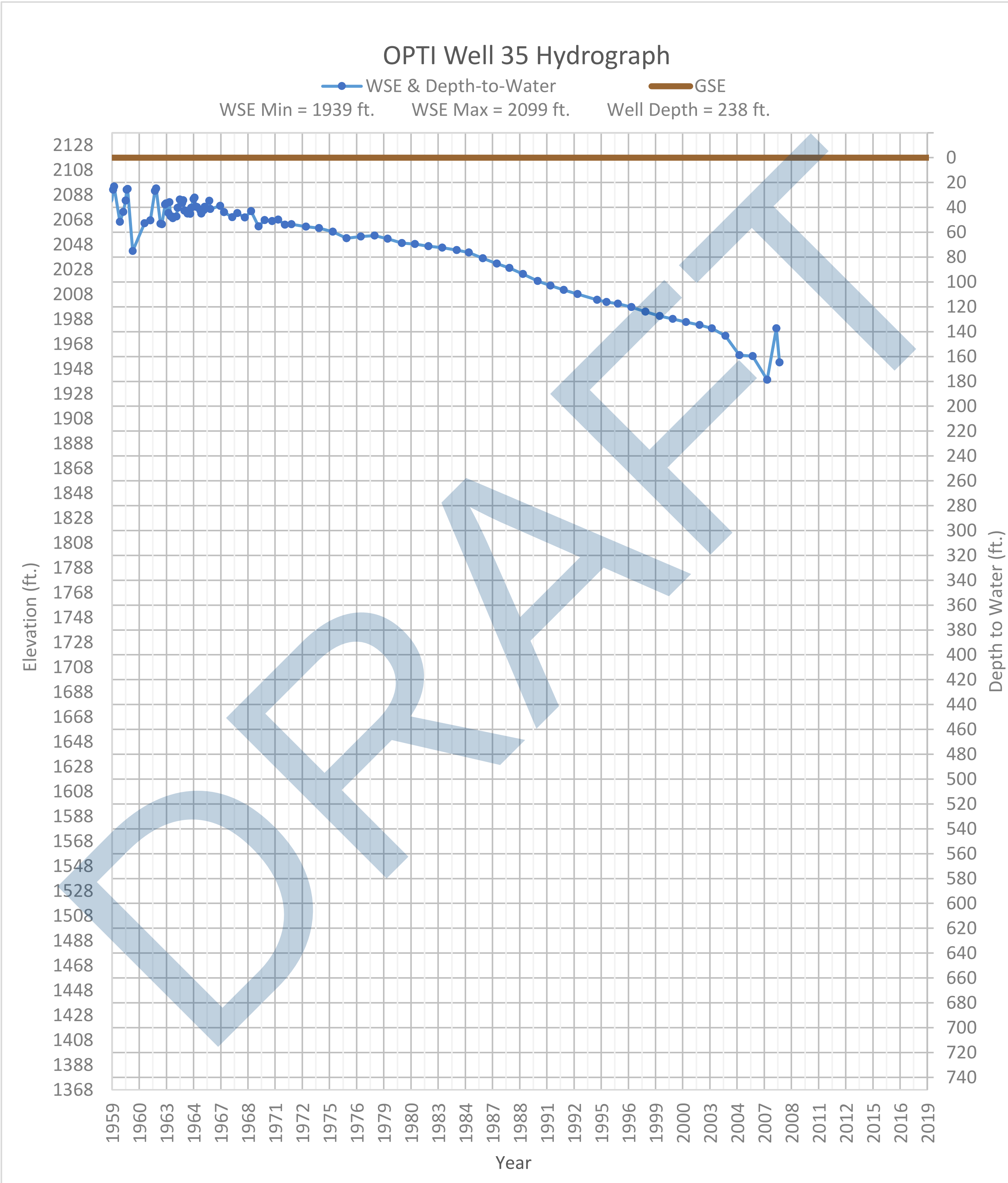


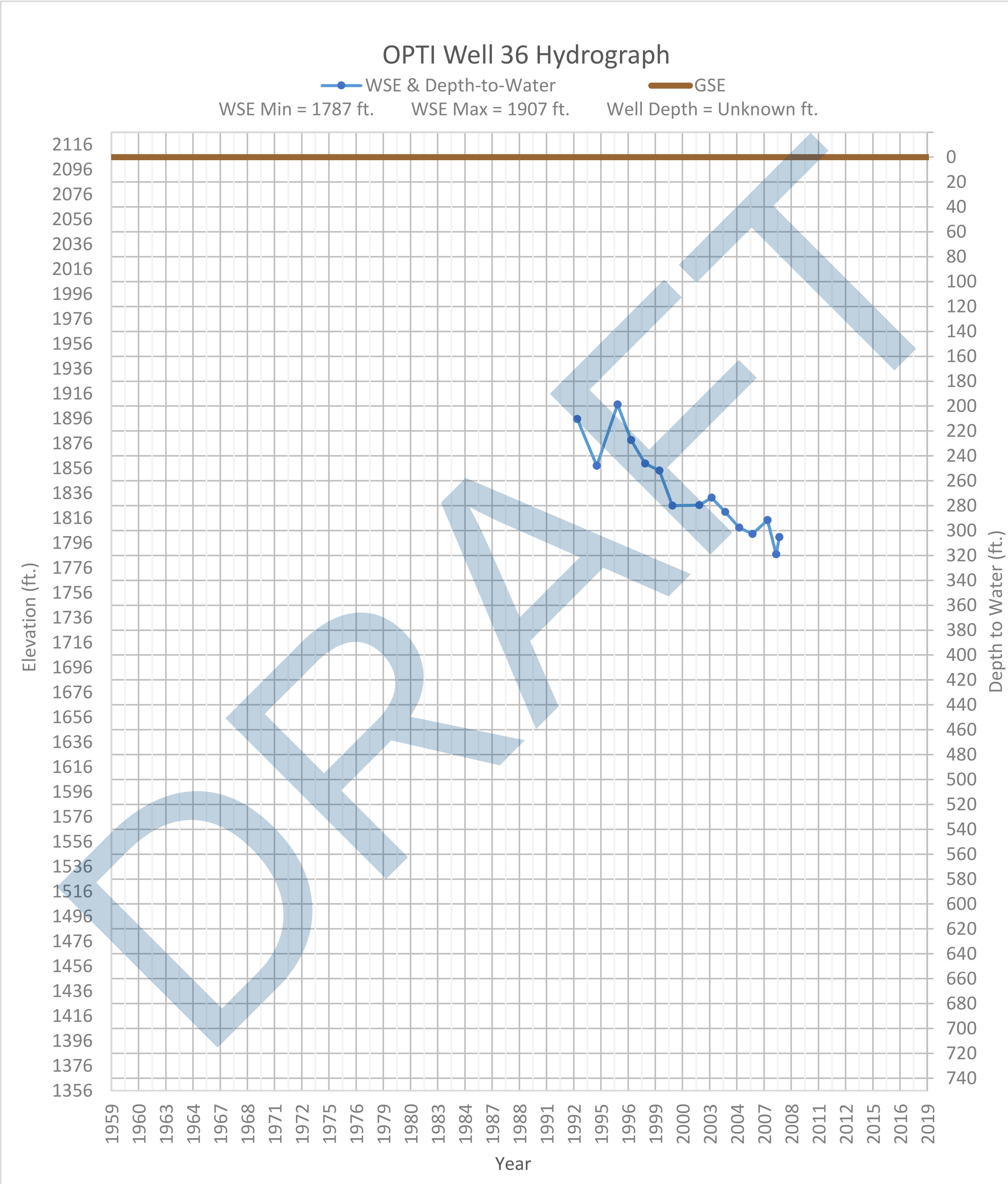
OPTI Well 32 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1989 ft.
WSE Max = 2131 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



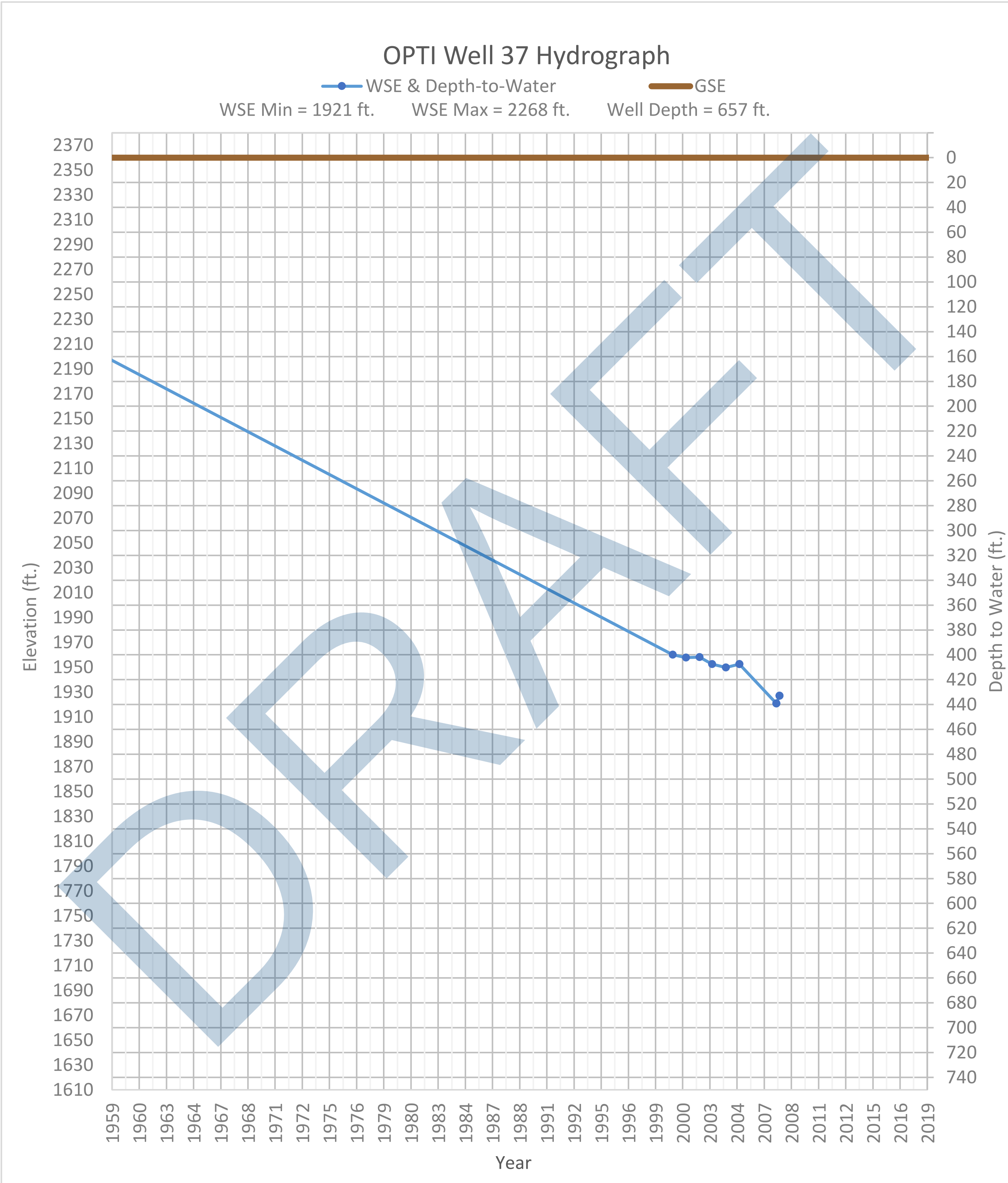
OPTI Well 33 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2152 ft.
WSE Max = 2242 ft.
Well Depth = 348 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 34 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2059 ft.
WSE Max = 2062 ft.
Well Depth = 61 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

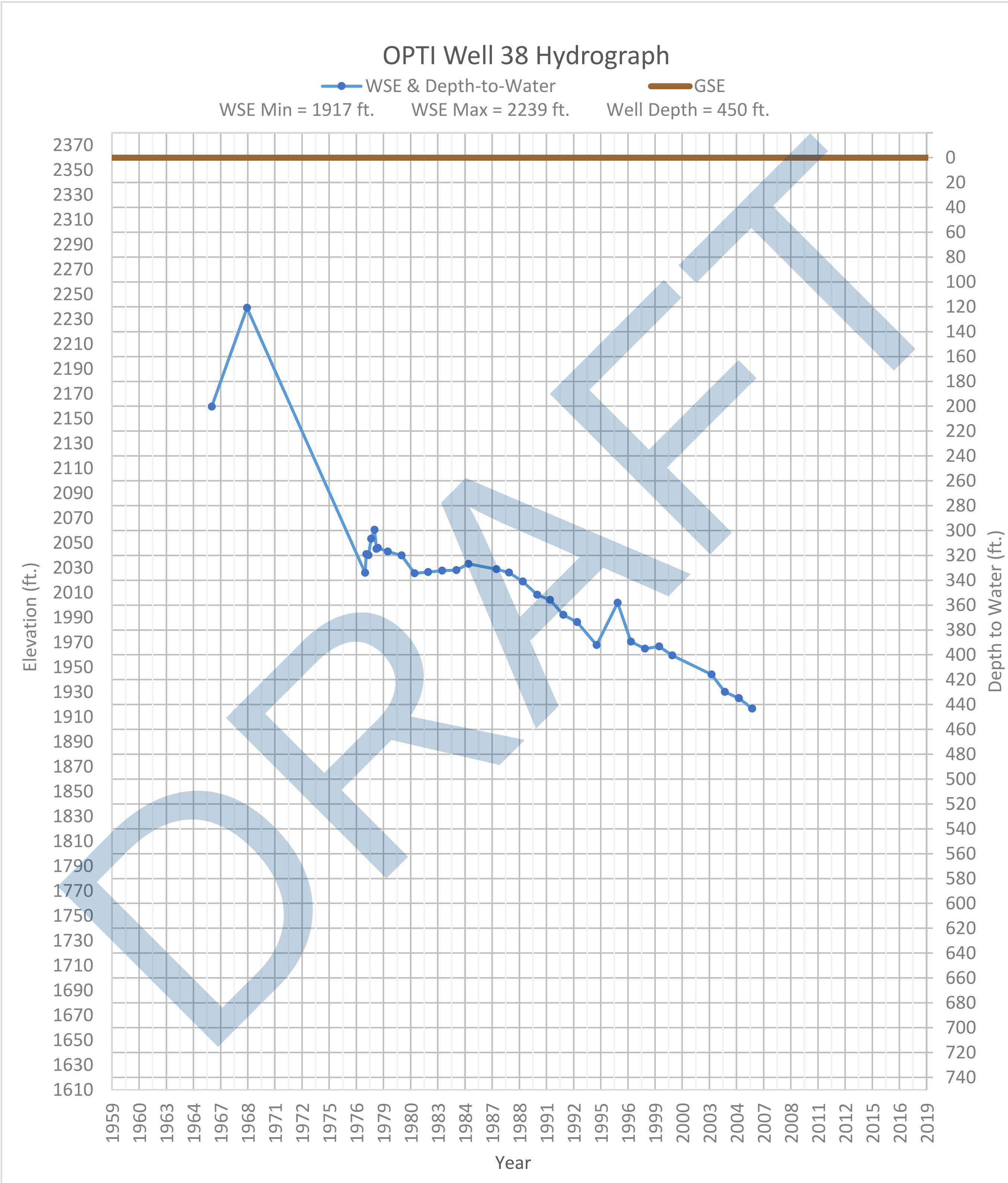

OPTI Well 35 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1939 ft.
WSE Max = 2099 ft.
Well Depth = 238 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



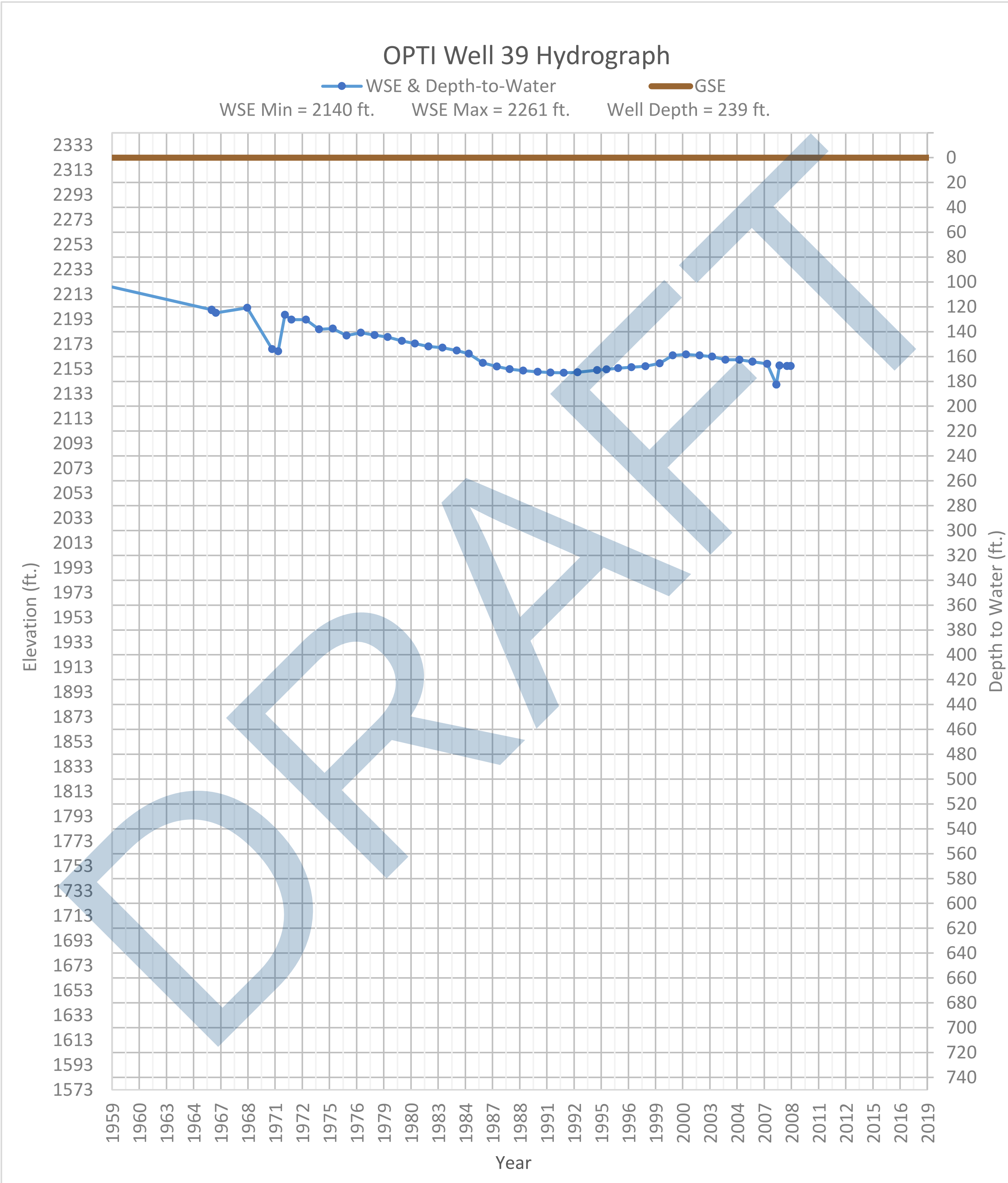
OPTI Well 36 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1787 ft.
WSE Max = 1907 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



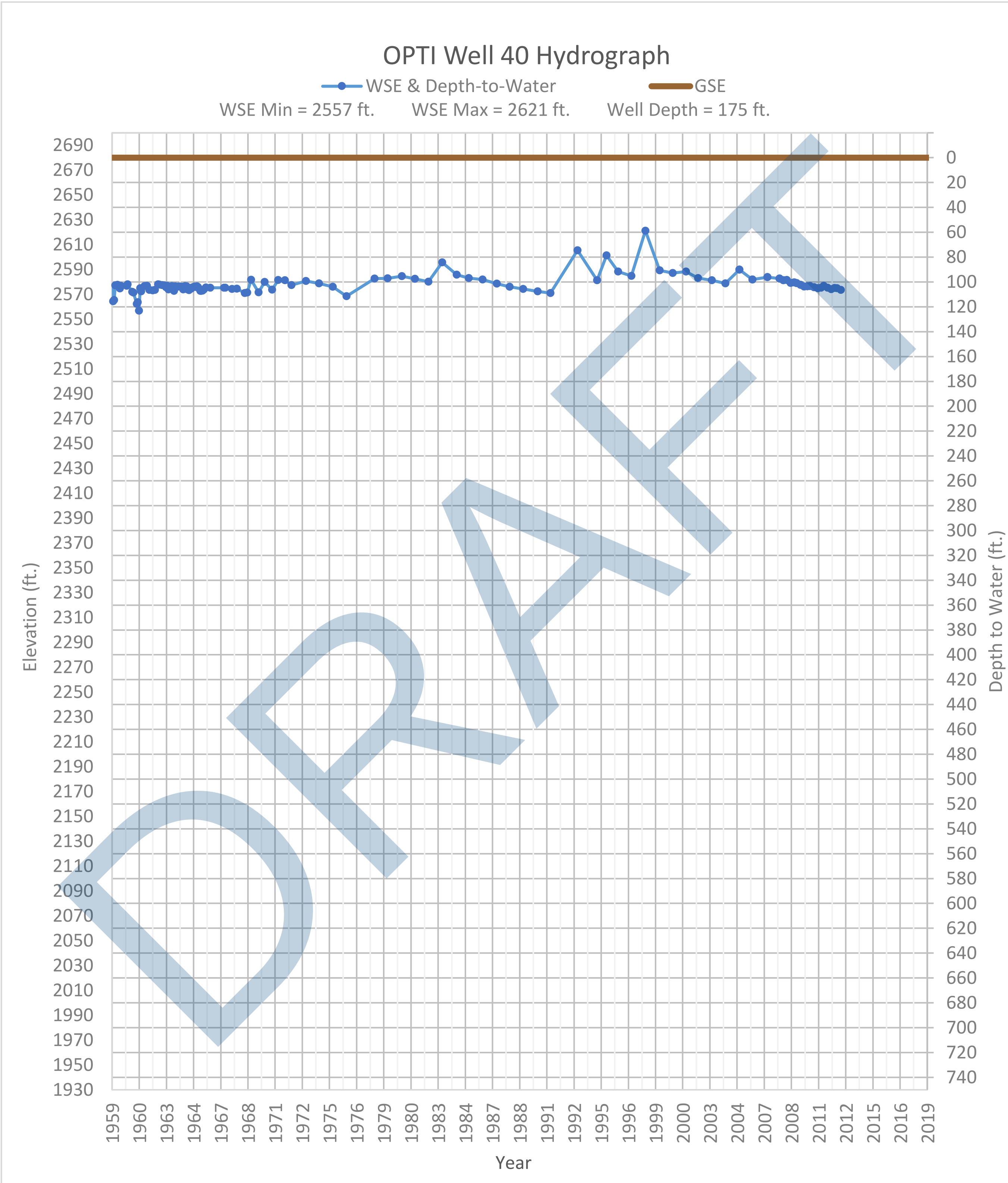
OPTI Well 37 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1921 ft.
WSE Max = 2268 ft.
Well Depth = 657 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



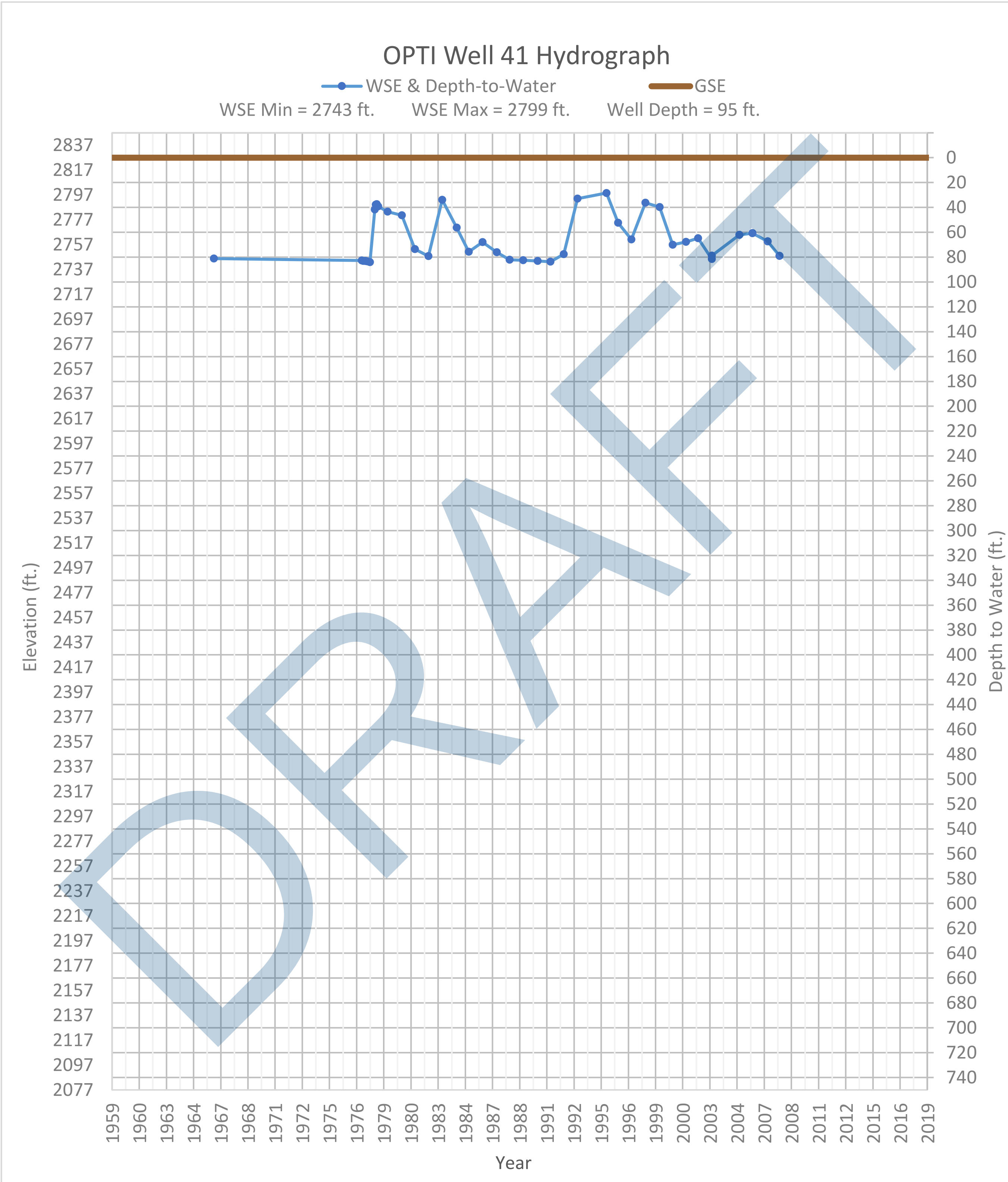
OPTI Well 38 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1917 ft.
WSE Max = 2239 ft.
Well Depth = 450 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



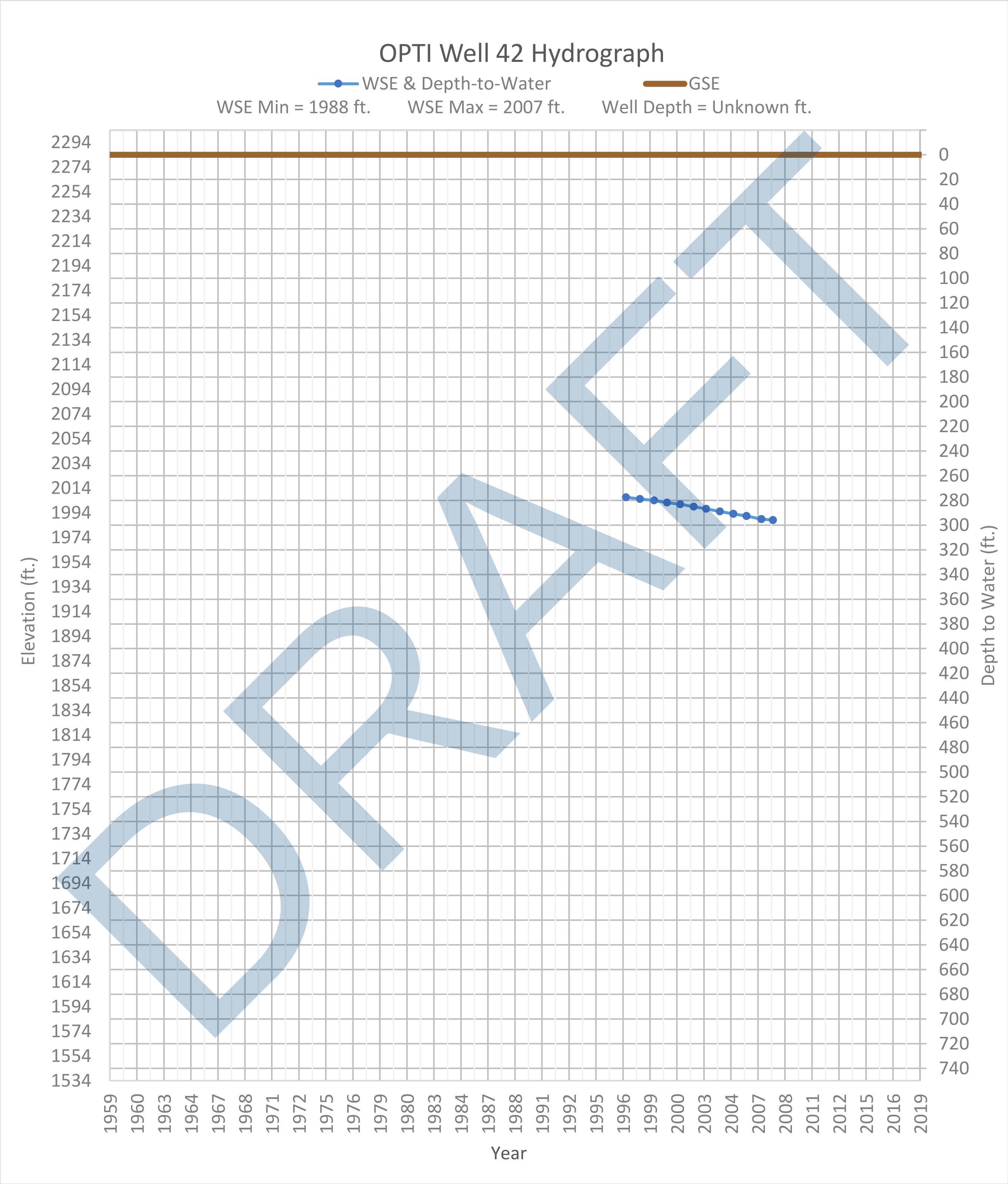
OPTI Well 39 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2140 ft.
WSE Max = 2261 ft.
Well Depth = 239 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



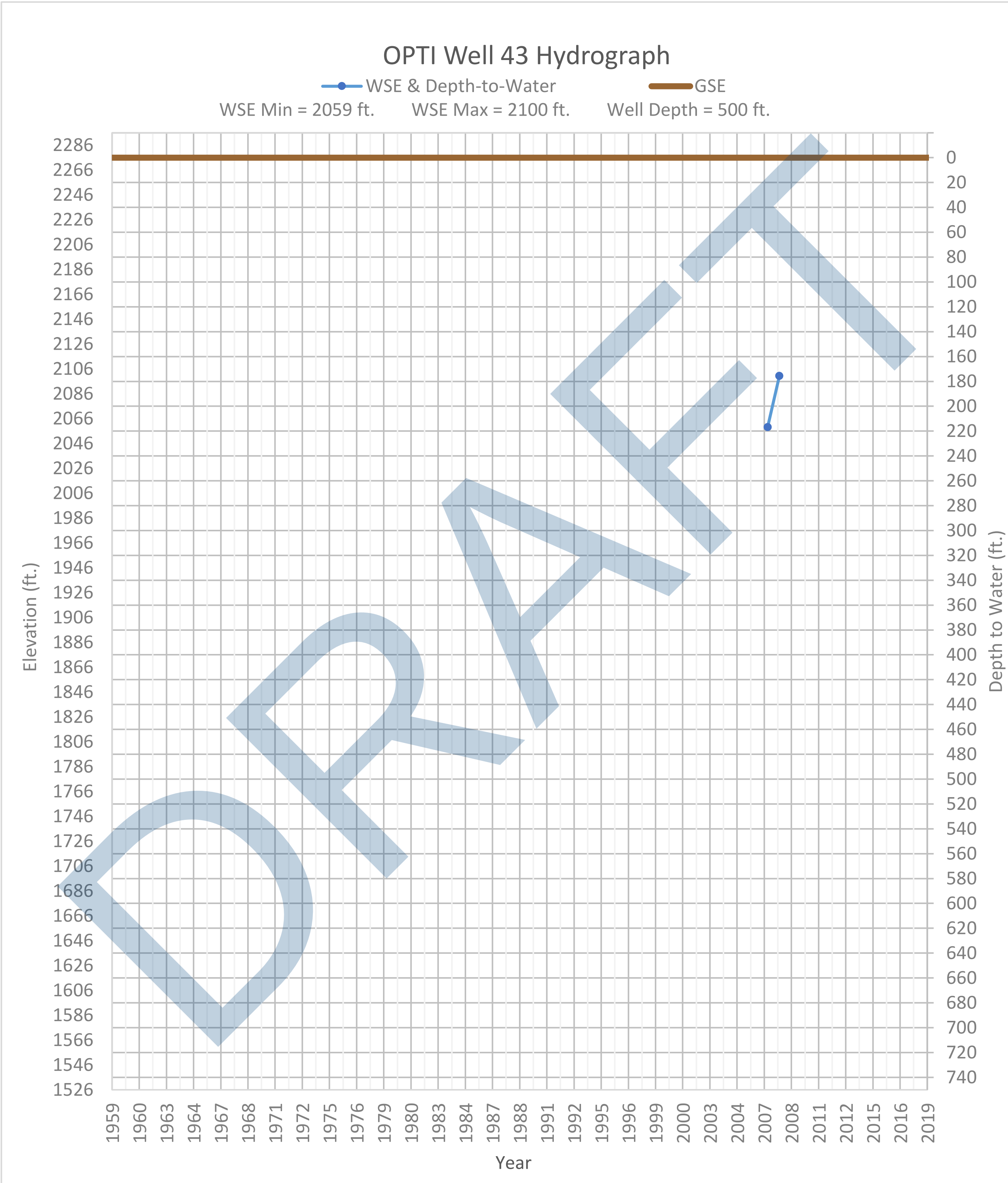
OPTI Well 40 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2557 ft.
WSE Max = 2621 ft.
Well Depth = 175 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



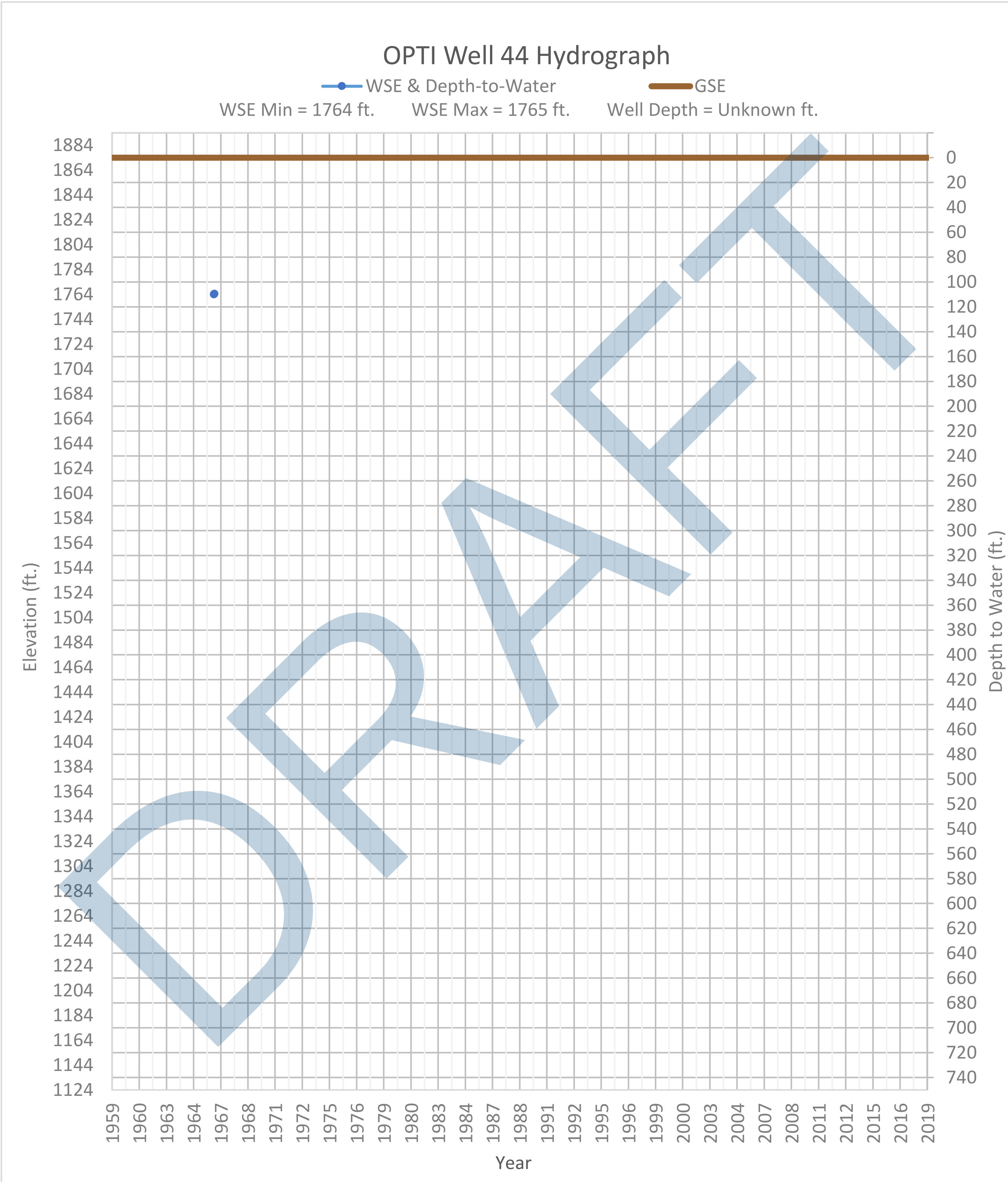
OPTI Well 41 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2743 ft.
WSE Max = 2799 ft.
Well Depth = 95 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



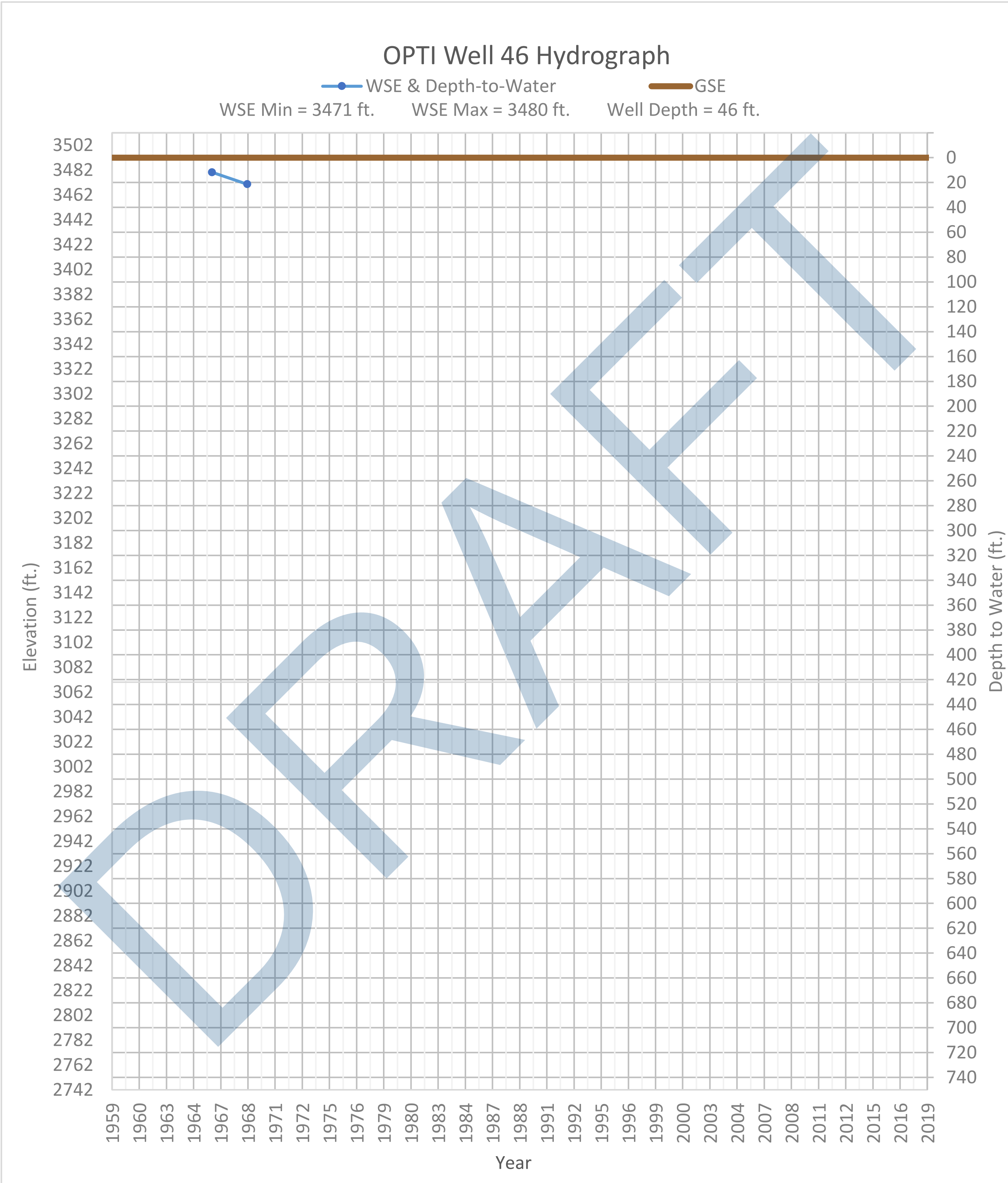
OPTI Well 42 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1988 ft.
WSE Max = 2007 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



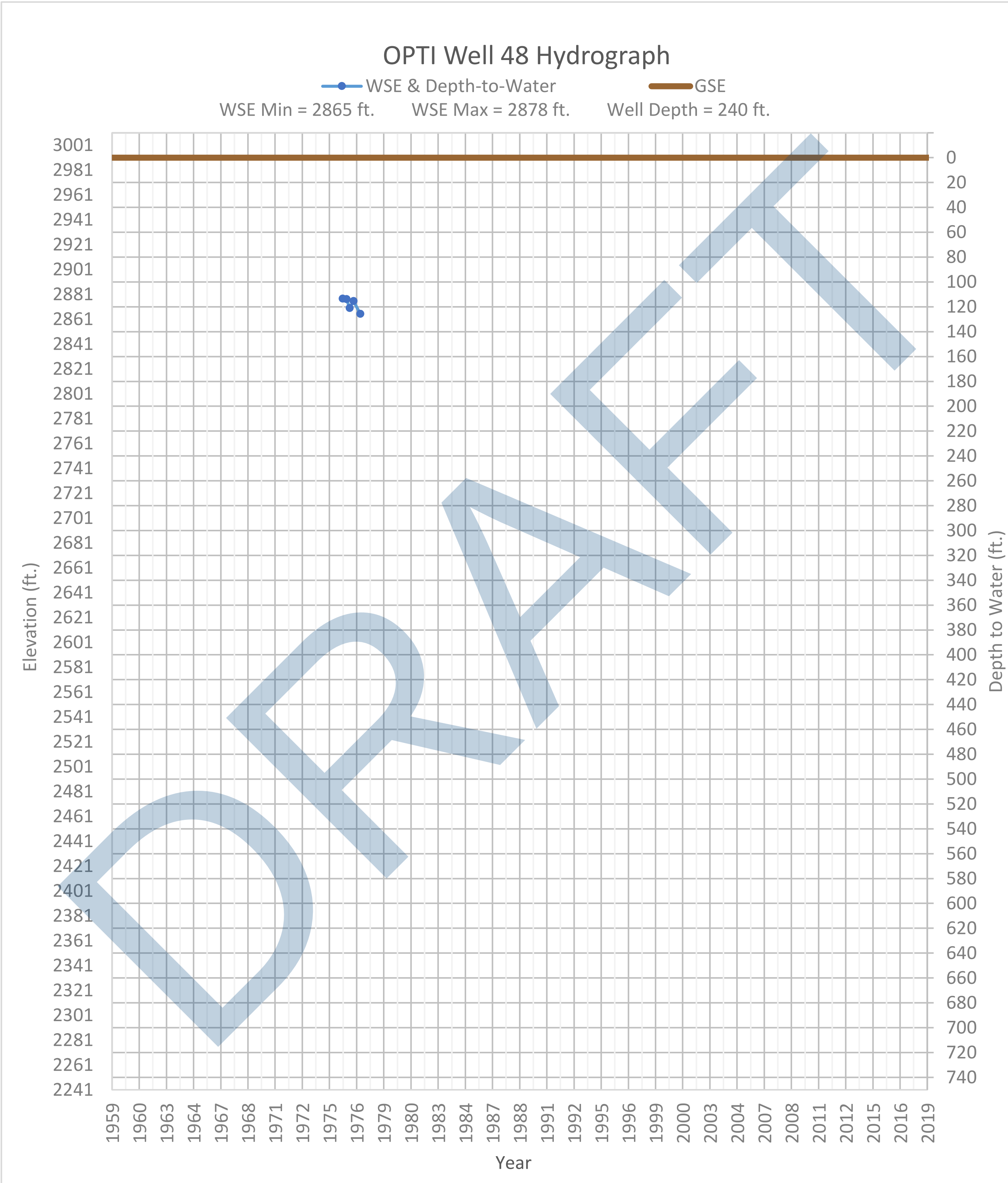
OPTI Well 43 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2059 ft.
WSE Max = 2100 ft.
Well Depth = 500 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

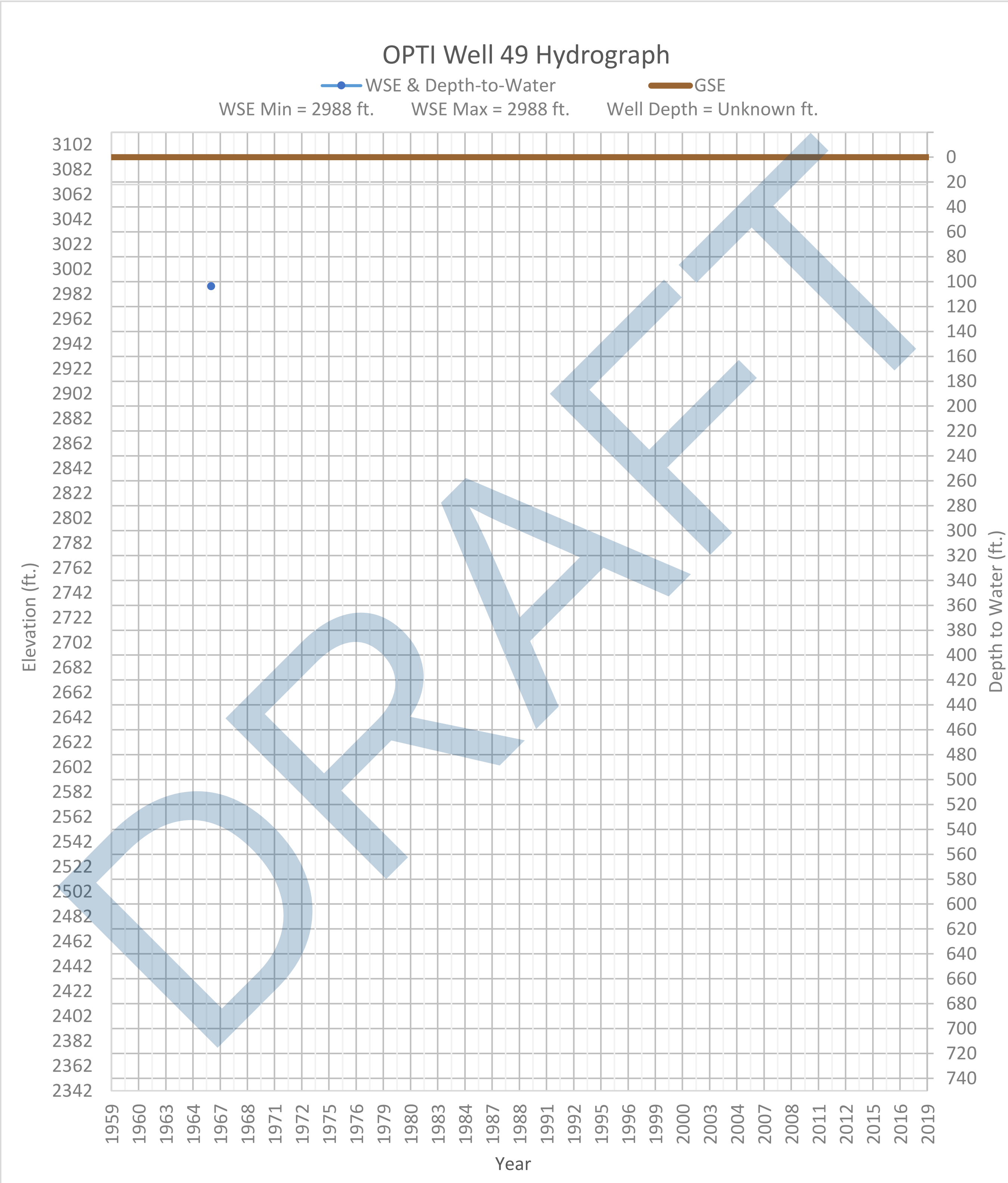


OPTI Well 44 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1764 ft.
WSE Max = 1765 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year

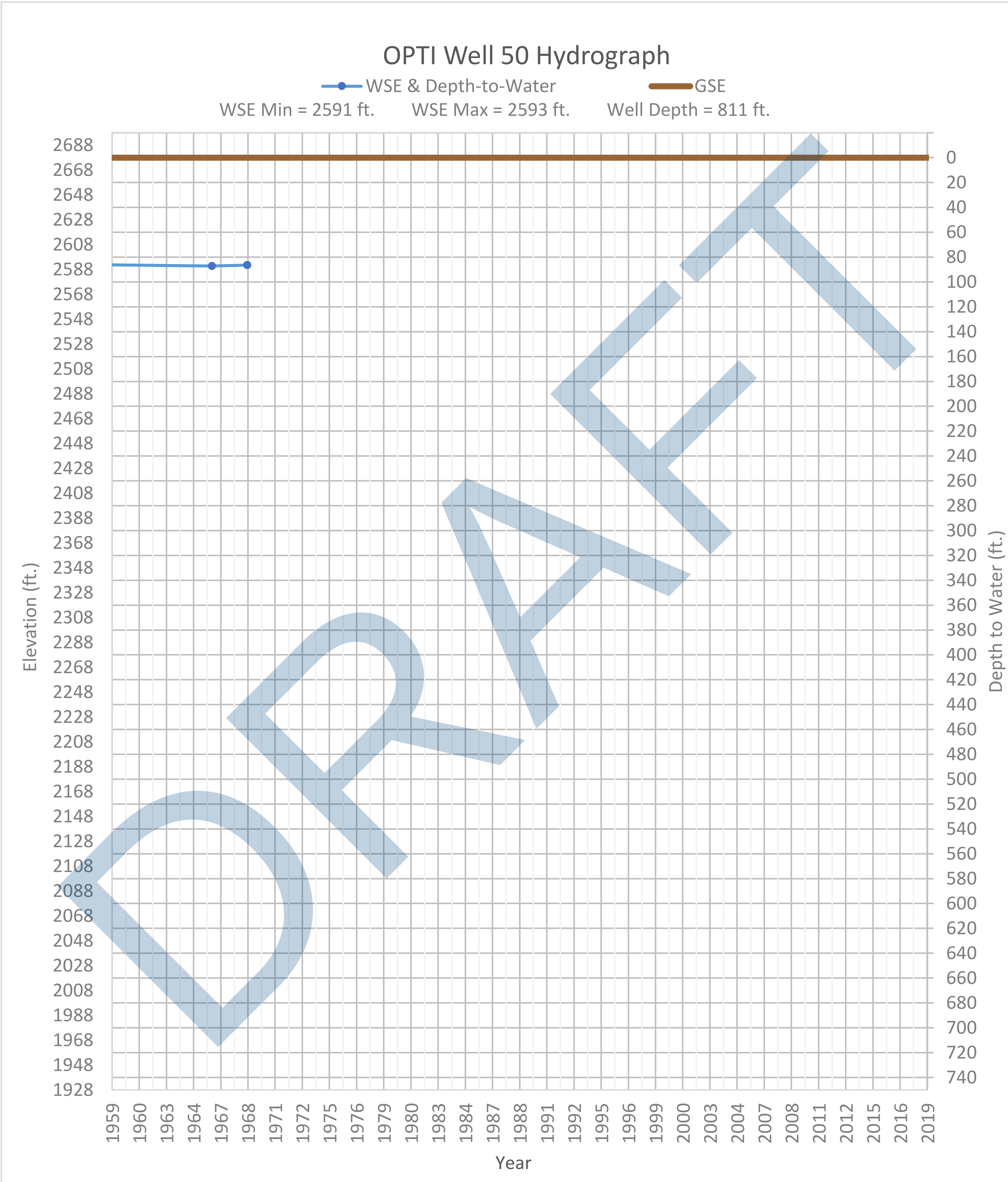


OPTI Well 46 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3471 ft.
WSE Max = 3480 ft.
Well Depth = 46 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

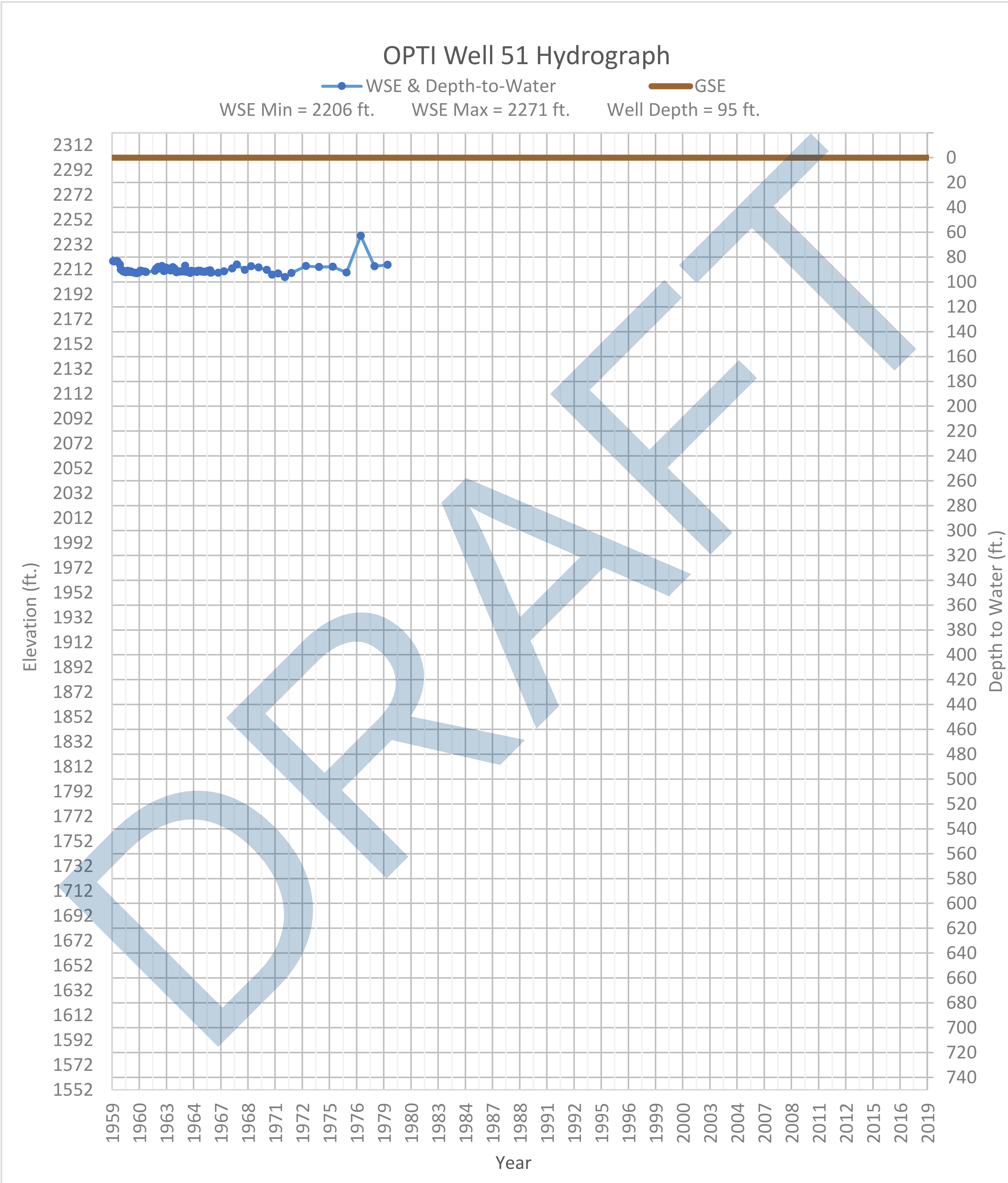

OPTI Well 48 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2865 ft.
WSE Max = 2878 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



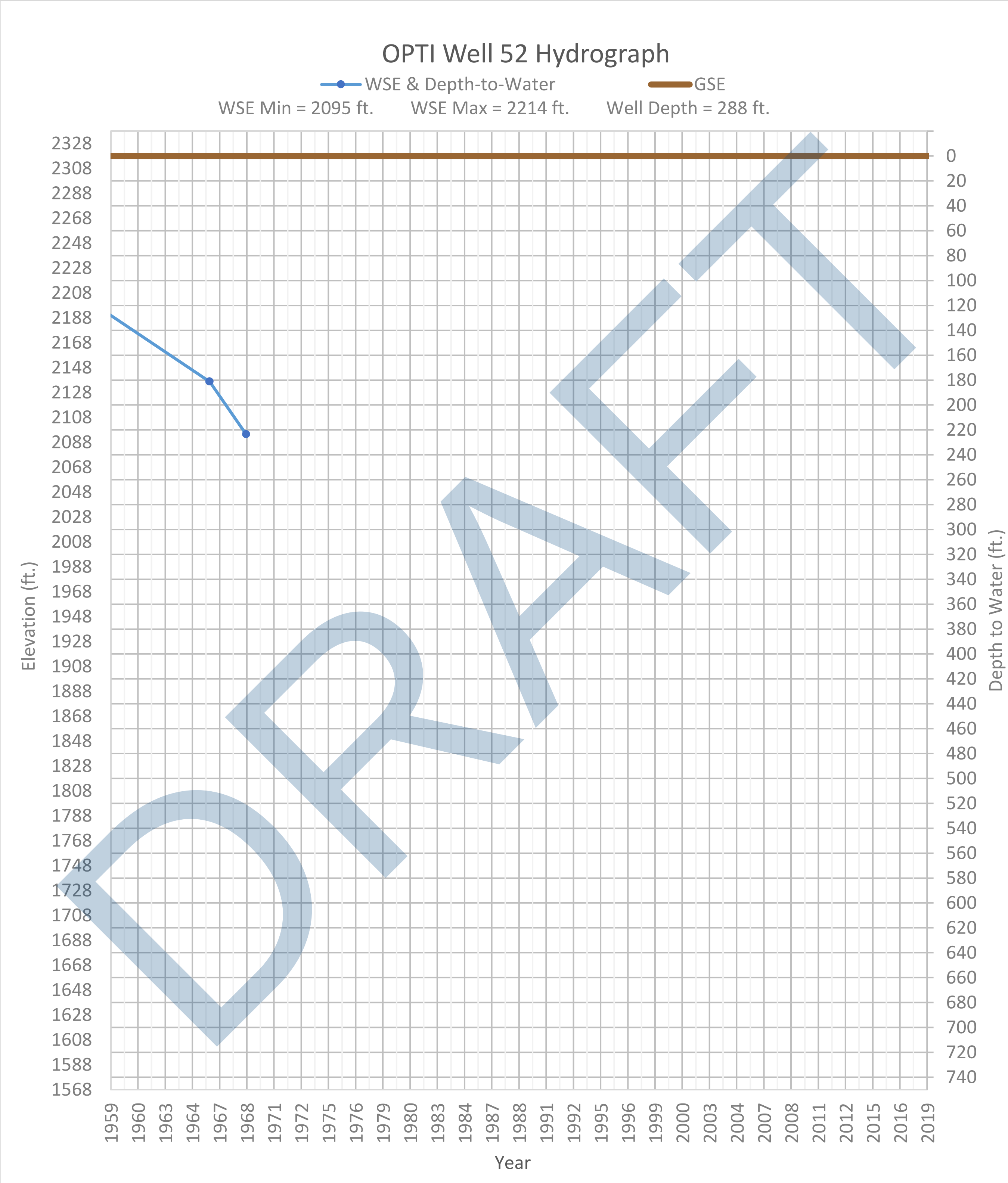
OPTI Well 49 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2988 ft.
WSE Max = 2988 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



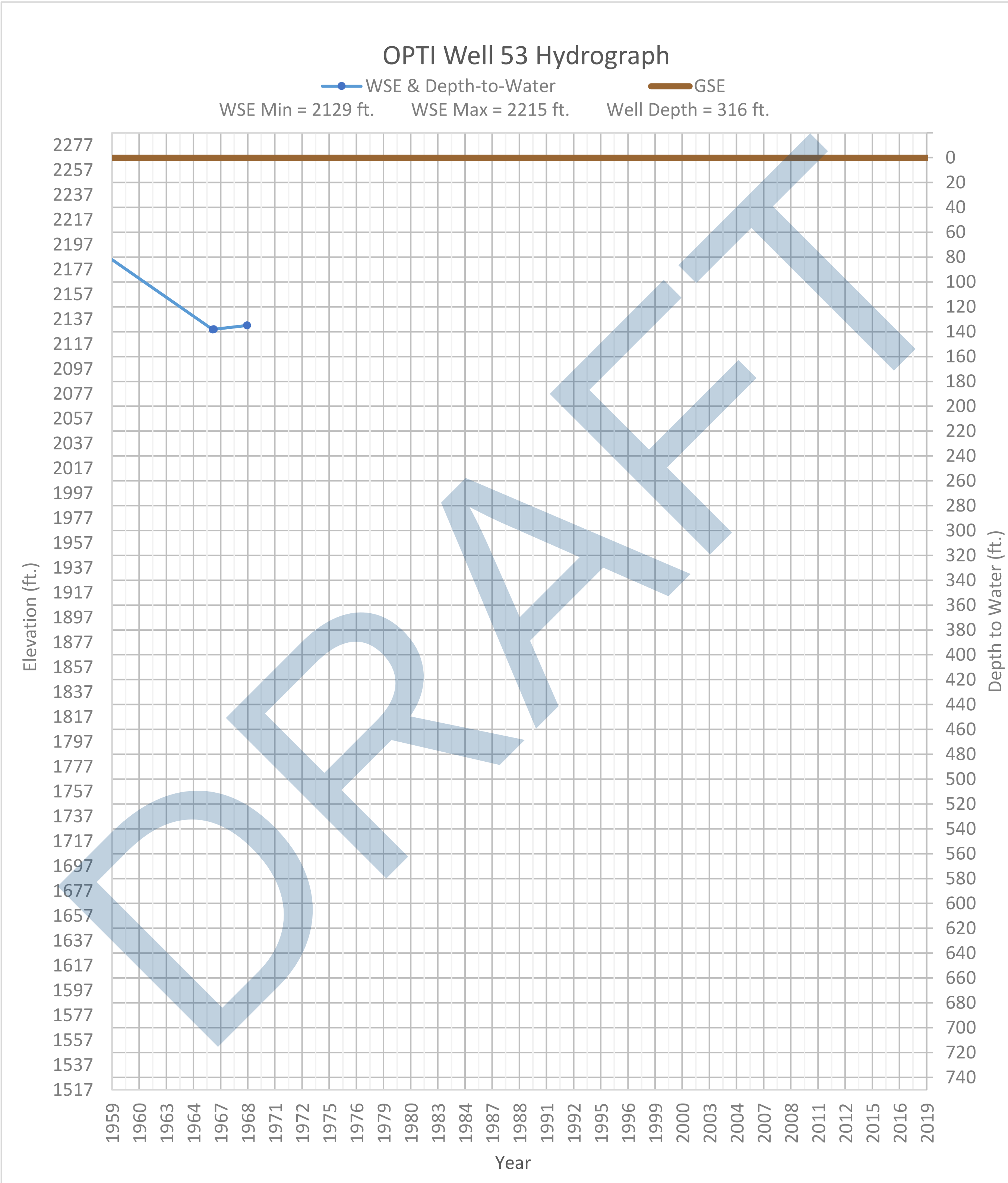
OPTI Well 50 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2591 ft.
WSE Max = 2593 ft.
Well Depth = 811 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



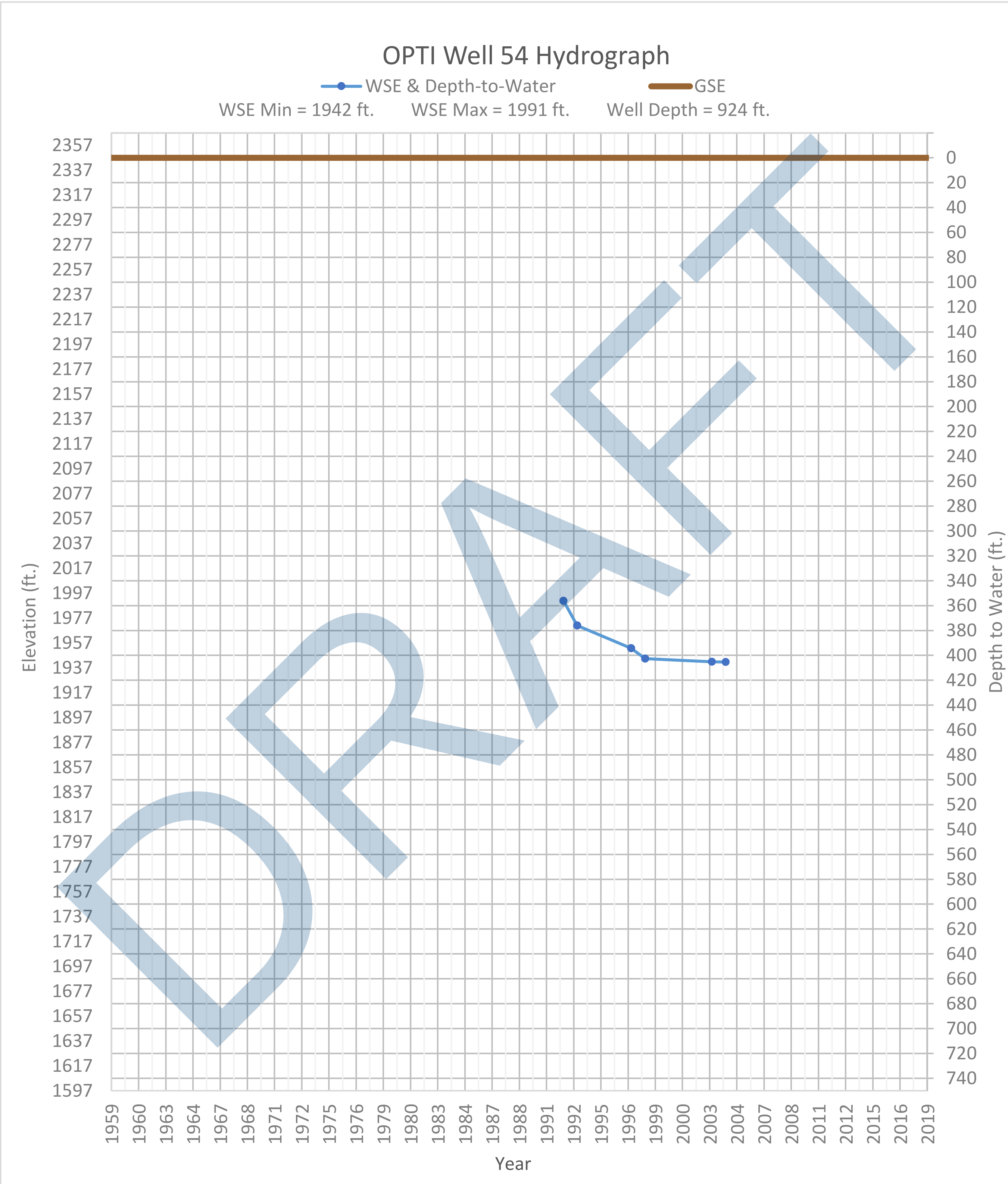
OPTI Well 51 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2206 ft.
WSE Max = 2271 ft.
Well Depth = 95 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

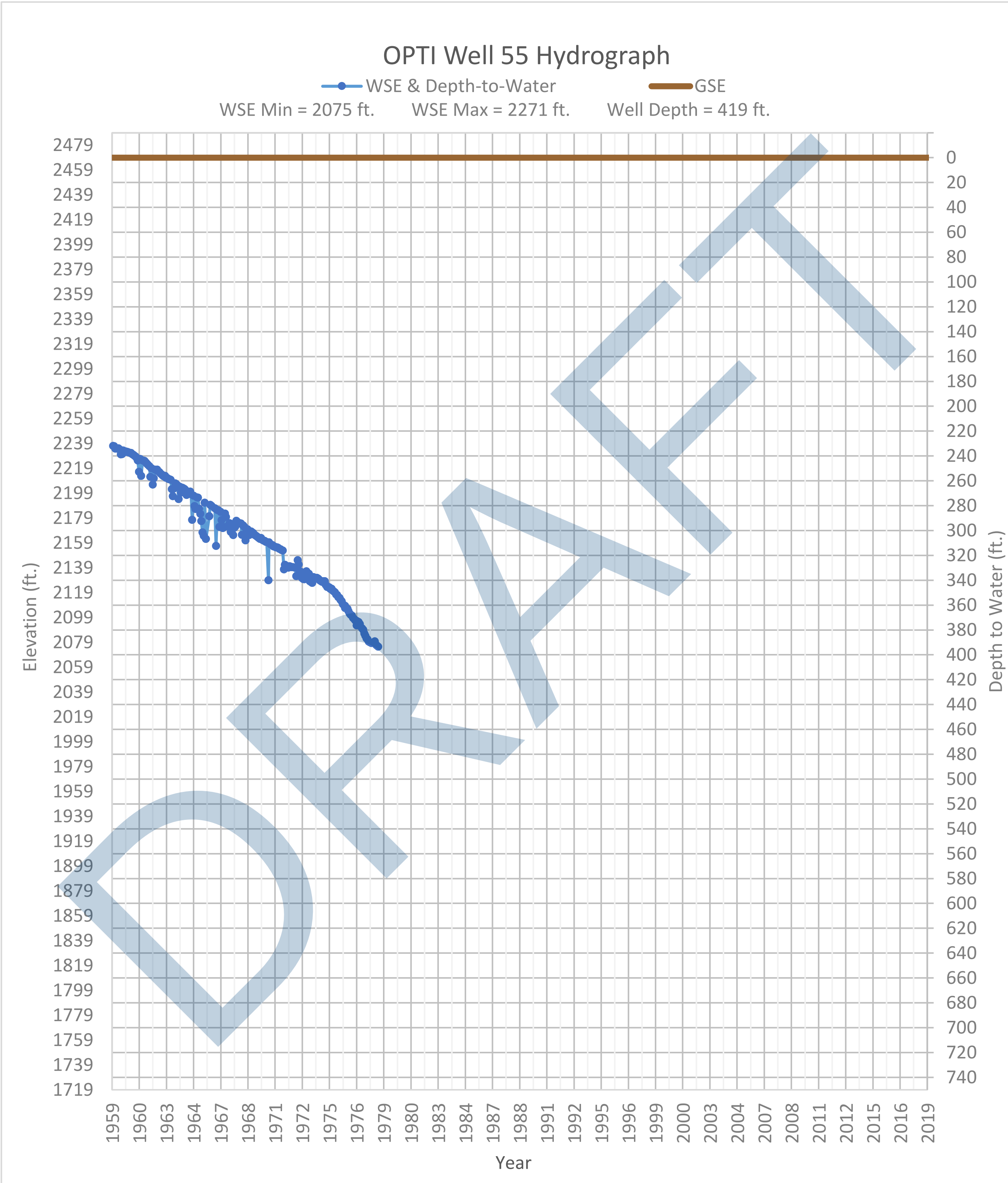


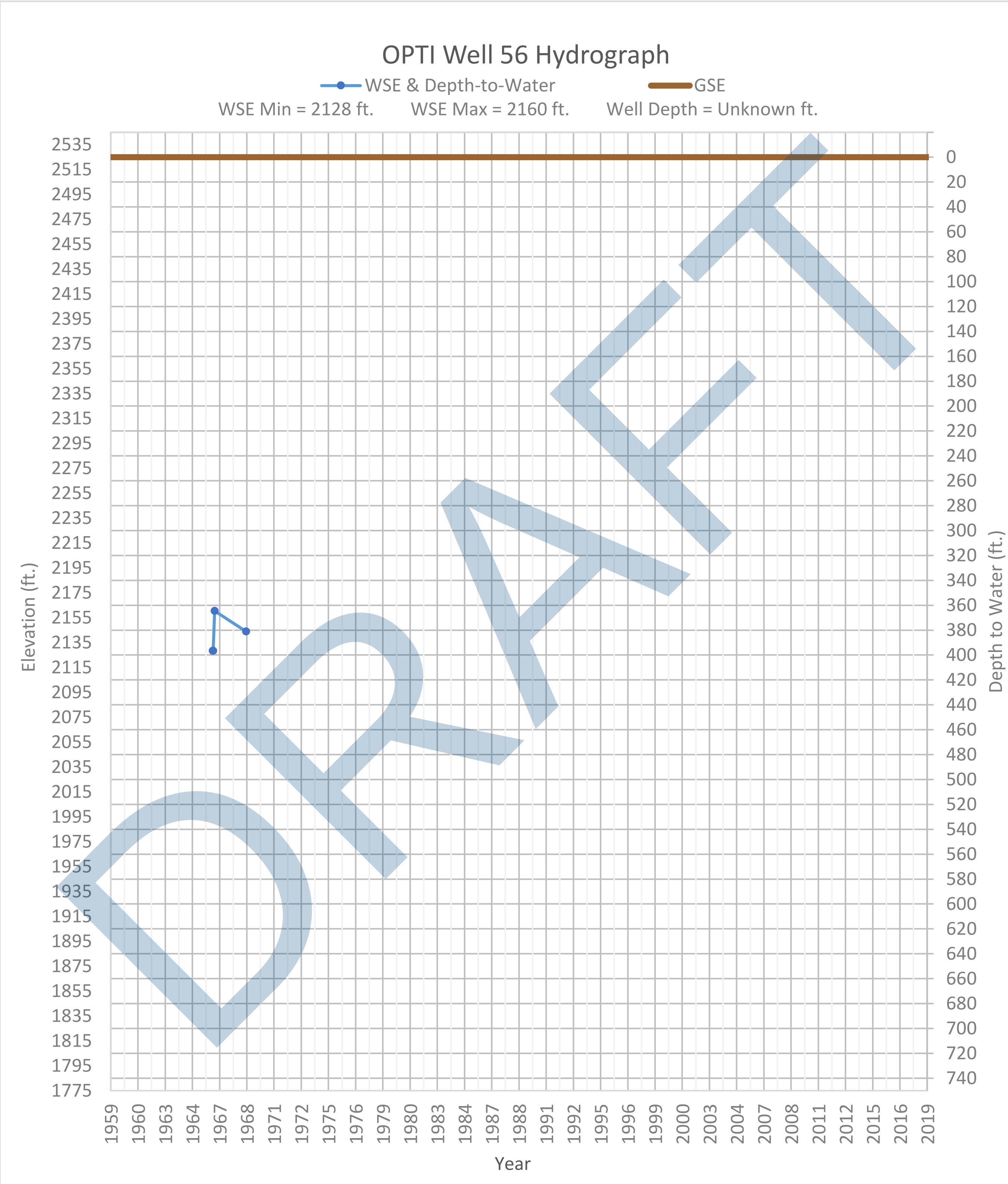
OPTI Well 52 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2095 ft.
WSE Max = 2214 ft.
Well Depth = 288 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

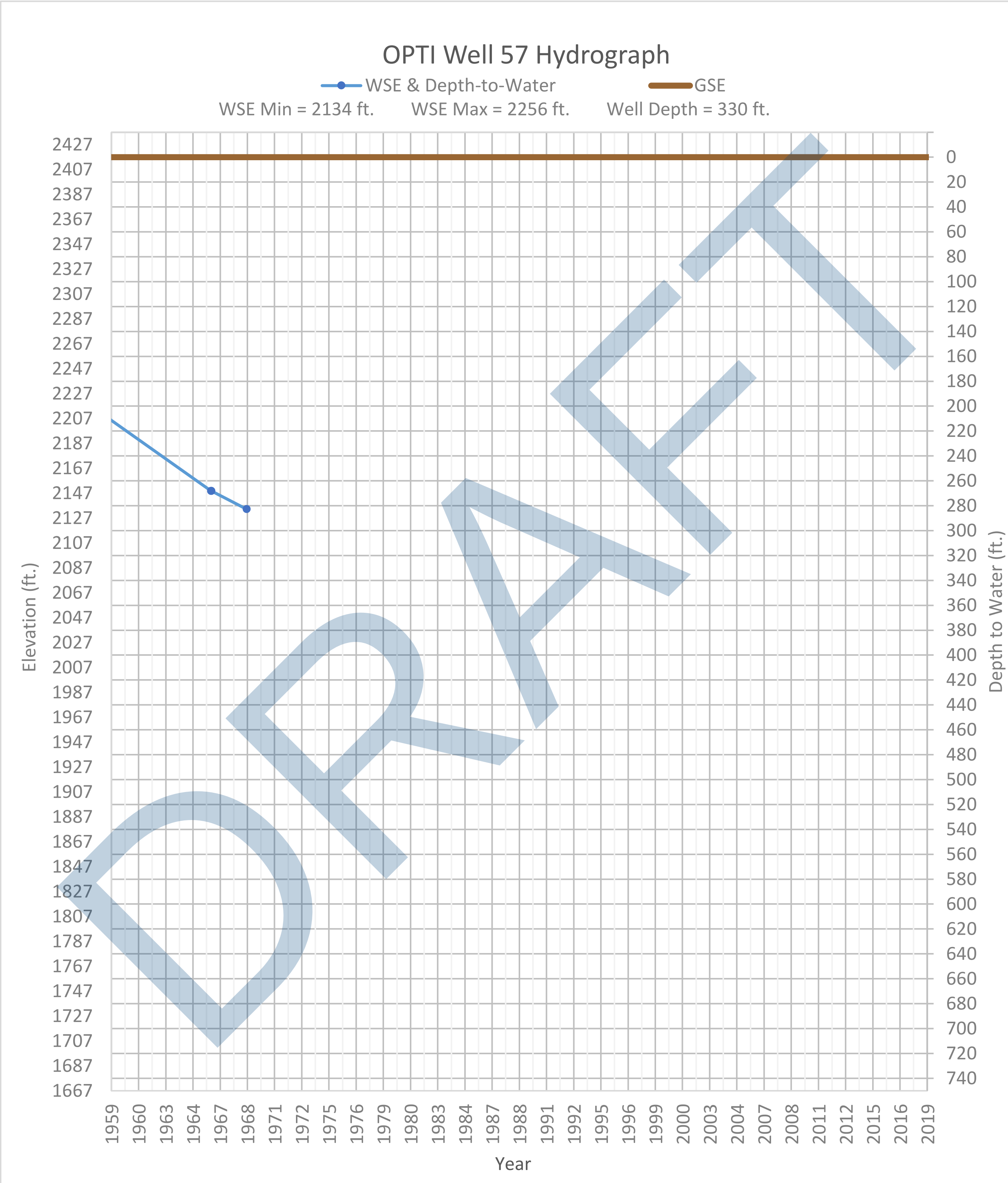


OPTI Well 53 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2129 ft.
WSE Max = 2215 ft.
Well Depth = 316 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 54 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1942 ft.
WSE Max = 1991 ft.
Well Depth = 924 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 55 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2075 ft.
WSE Max = 2271 ft.
Well Depth = 419 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 56 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2128 ft.
WSE Max = 2160 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 57 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2134 ft.
WSE Max = 2256 ft.
Well Depth = 330 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2427
2407
2387
2367
2347
2327
2307
2287
2267
2247
2227
2207
2187
2167
2147
2127
2107
2087
2067
2047
2027
2007
1987
1967
1947
1927
1907
1887
1867
1847
1827
1807
1787
1767
1747
1727
1707
1687
1667
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
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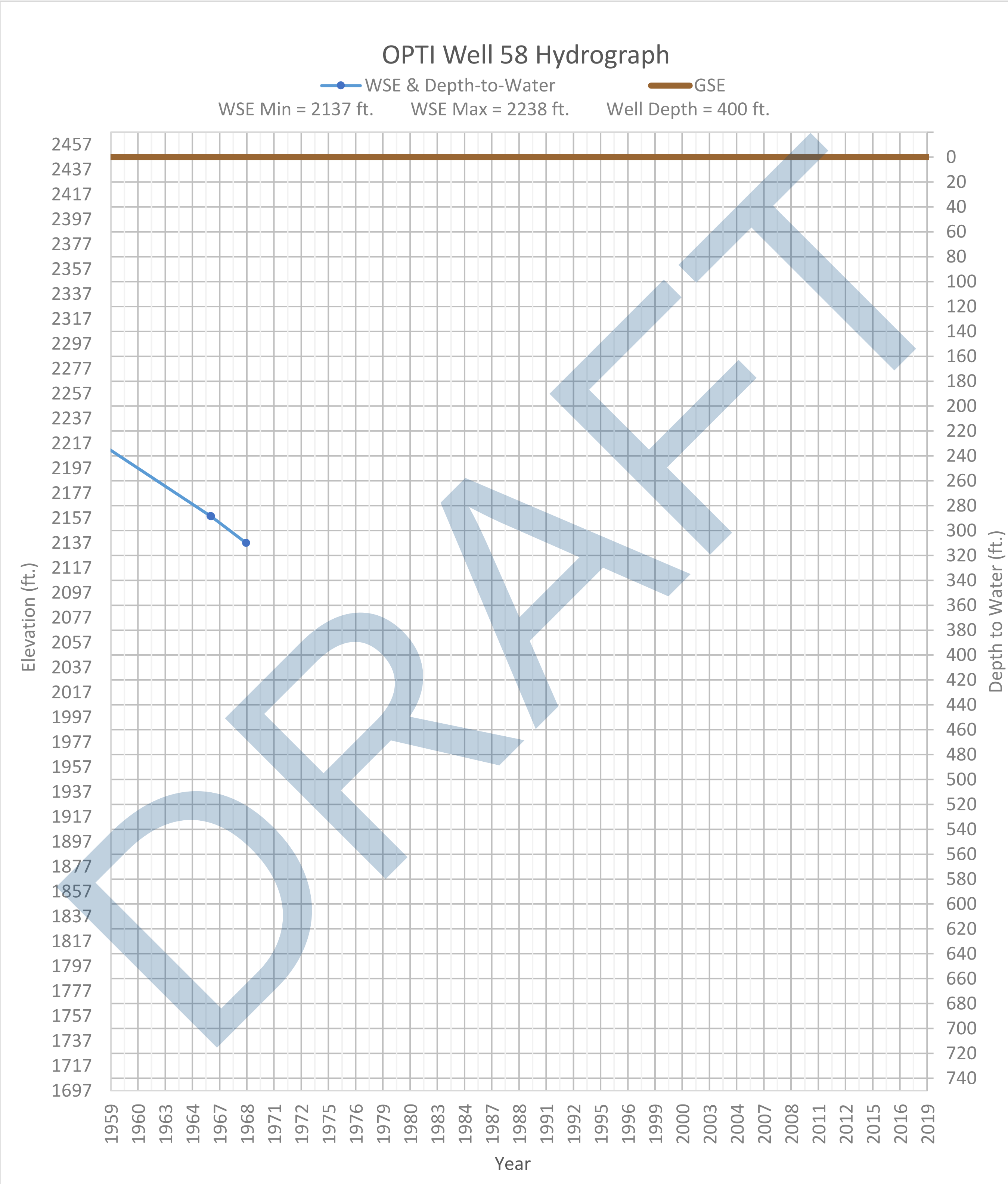
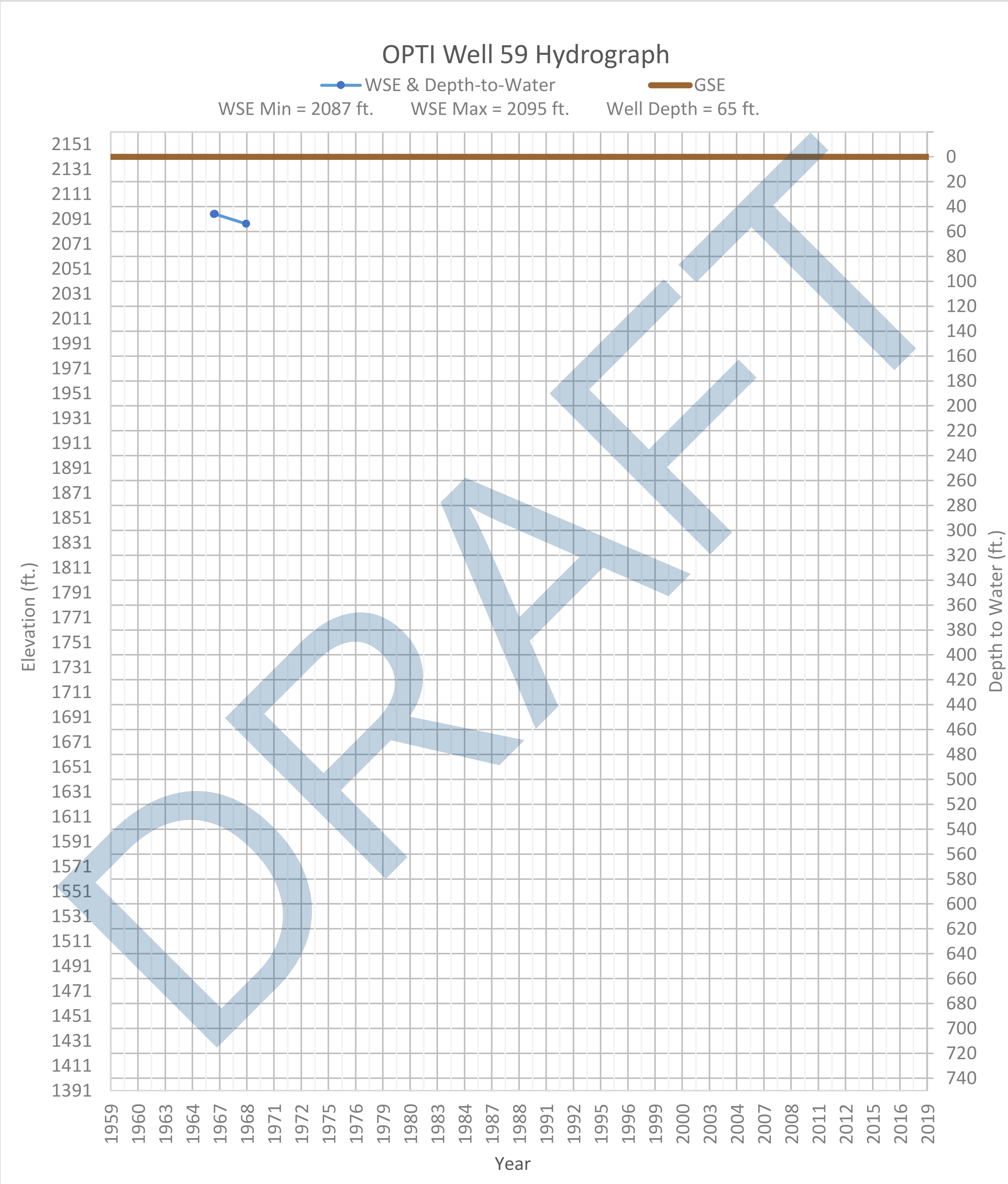
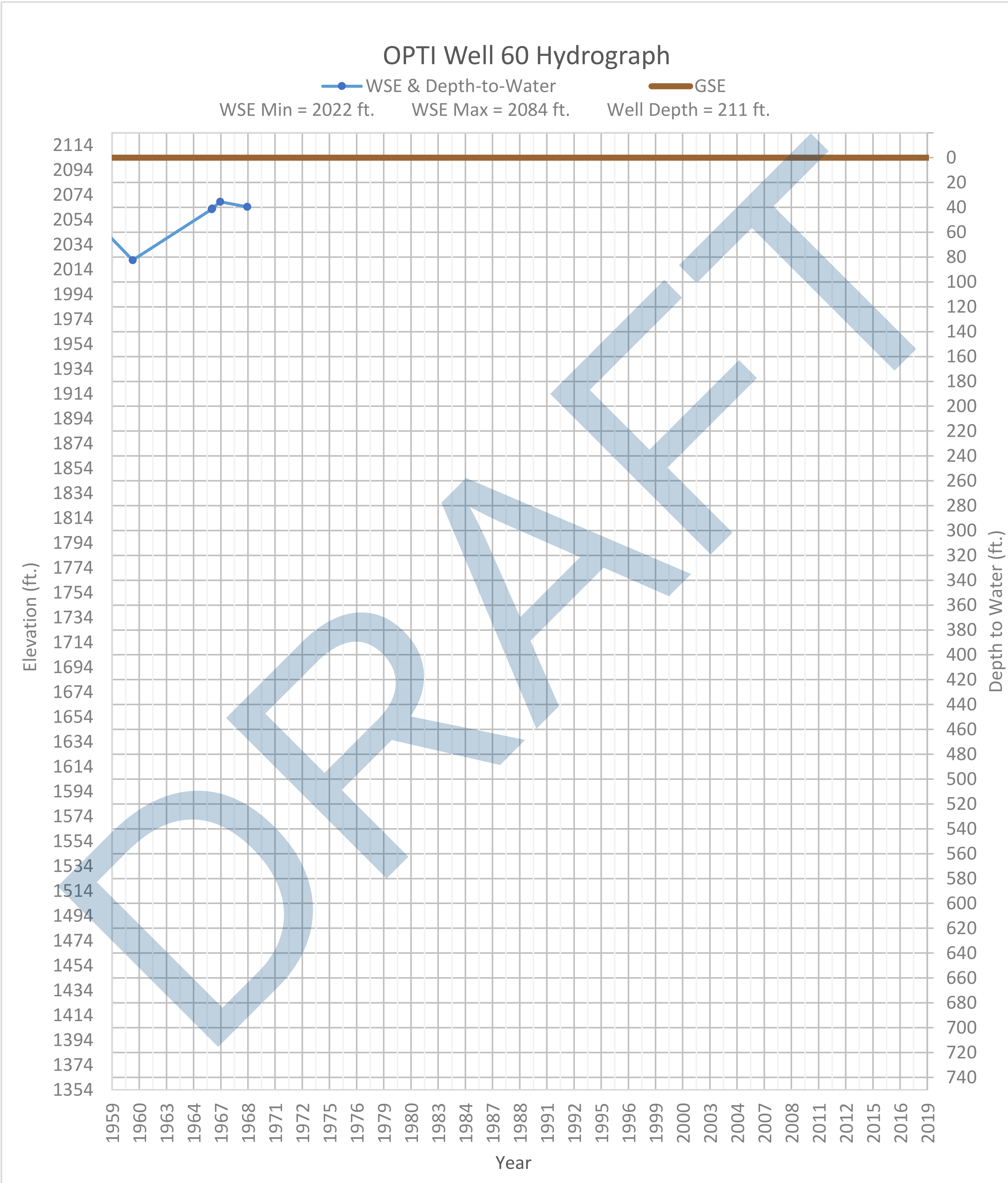
2016
2019
DRAFT



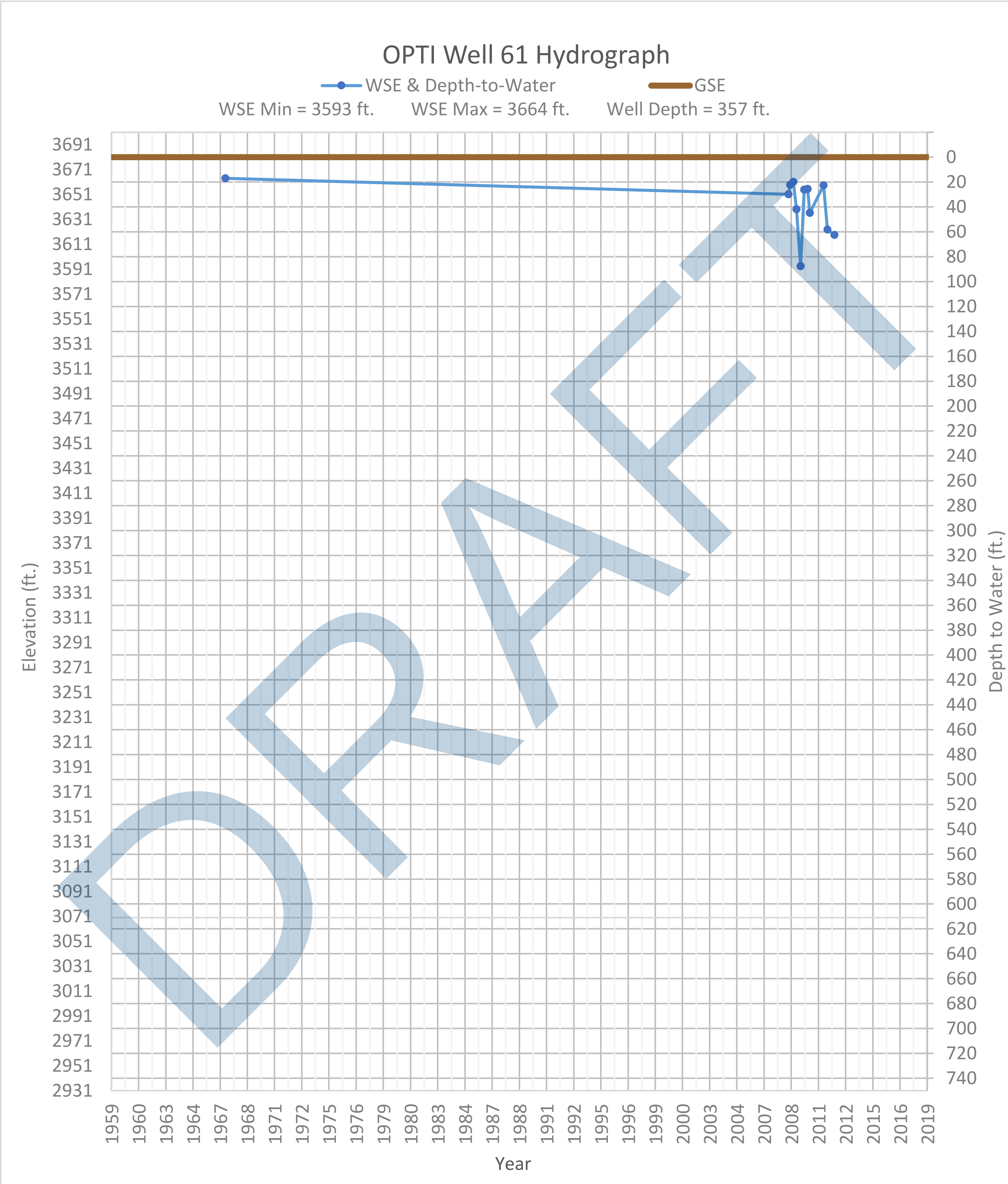
OPTI Well 58 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2137 ft.
WSE Max = 2238 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



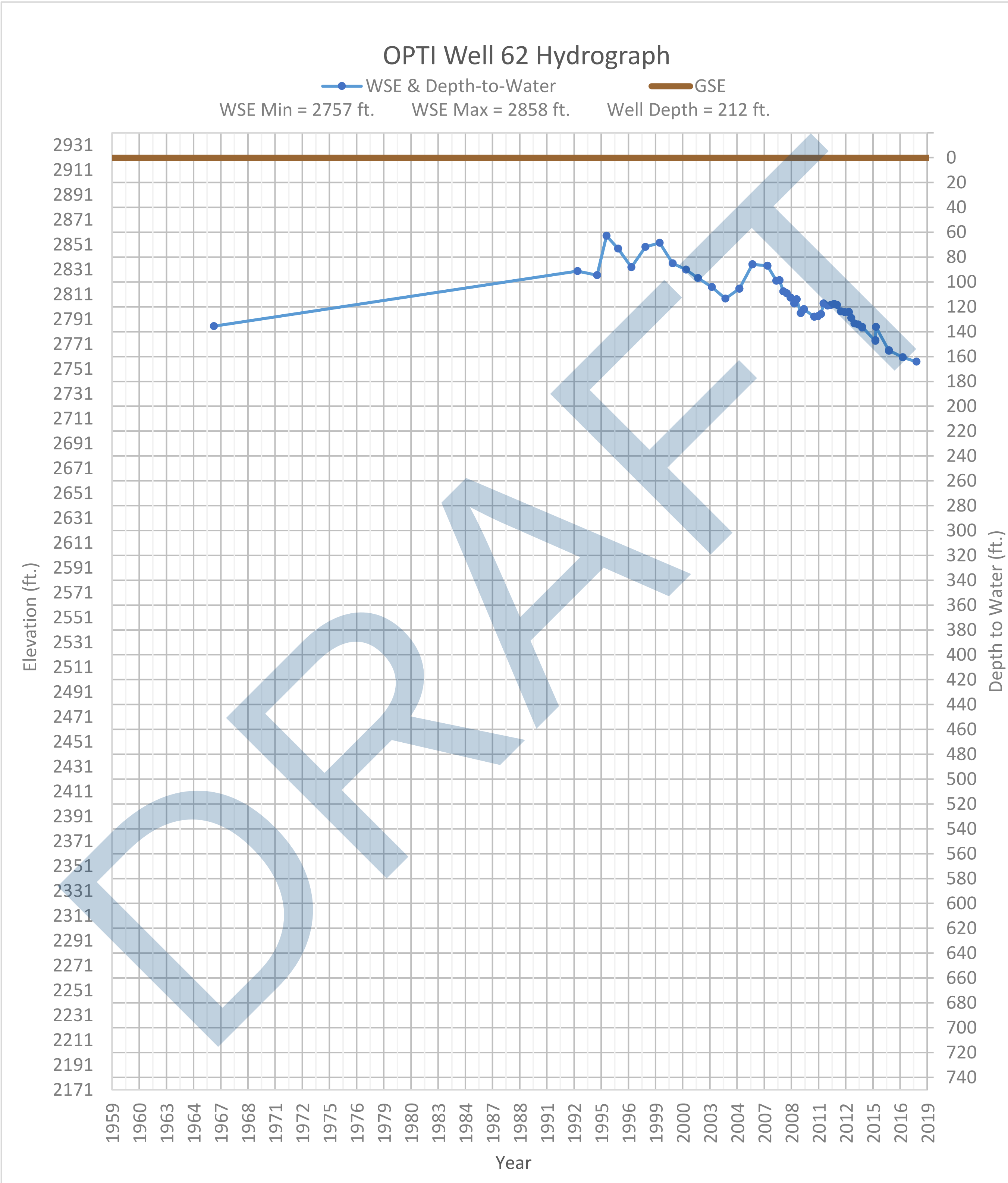
OPTI Well 59 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2087 ft.
WSE Max = 2095 ft.
Well Depth = 65 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



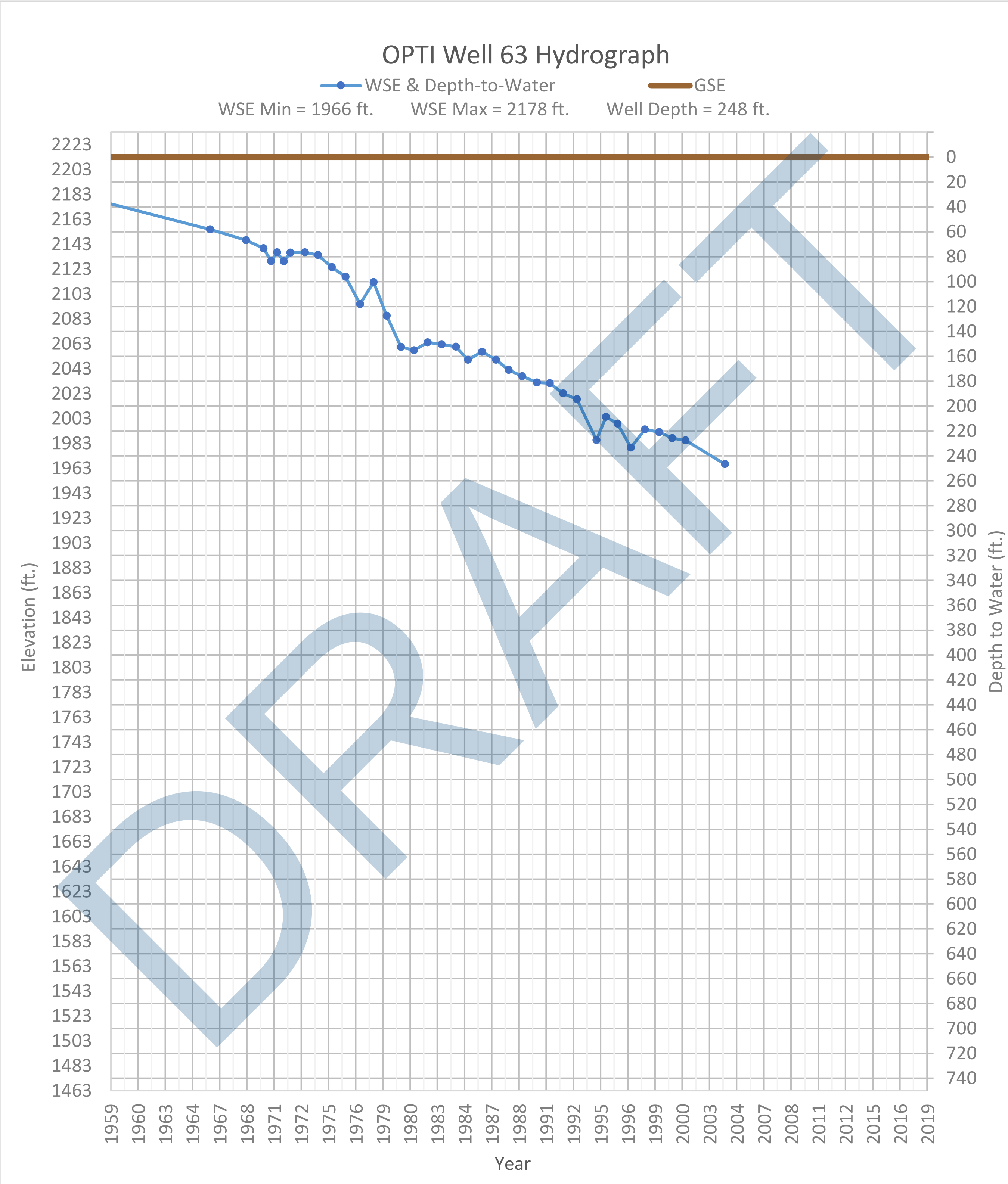
OPTI Well 60 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2022 ft.
WSE Max = 2084 ft.
Well Depth = 211 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



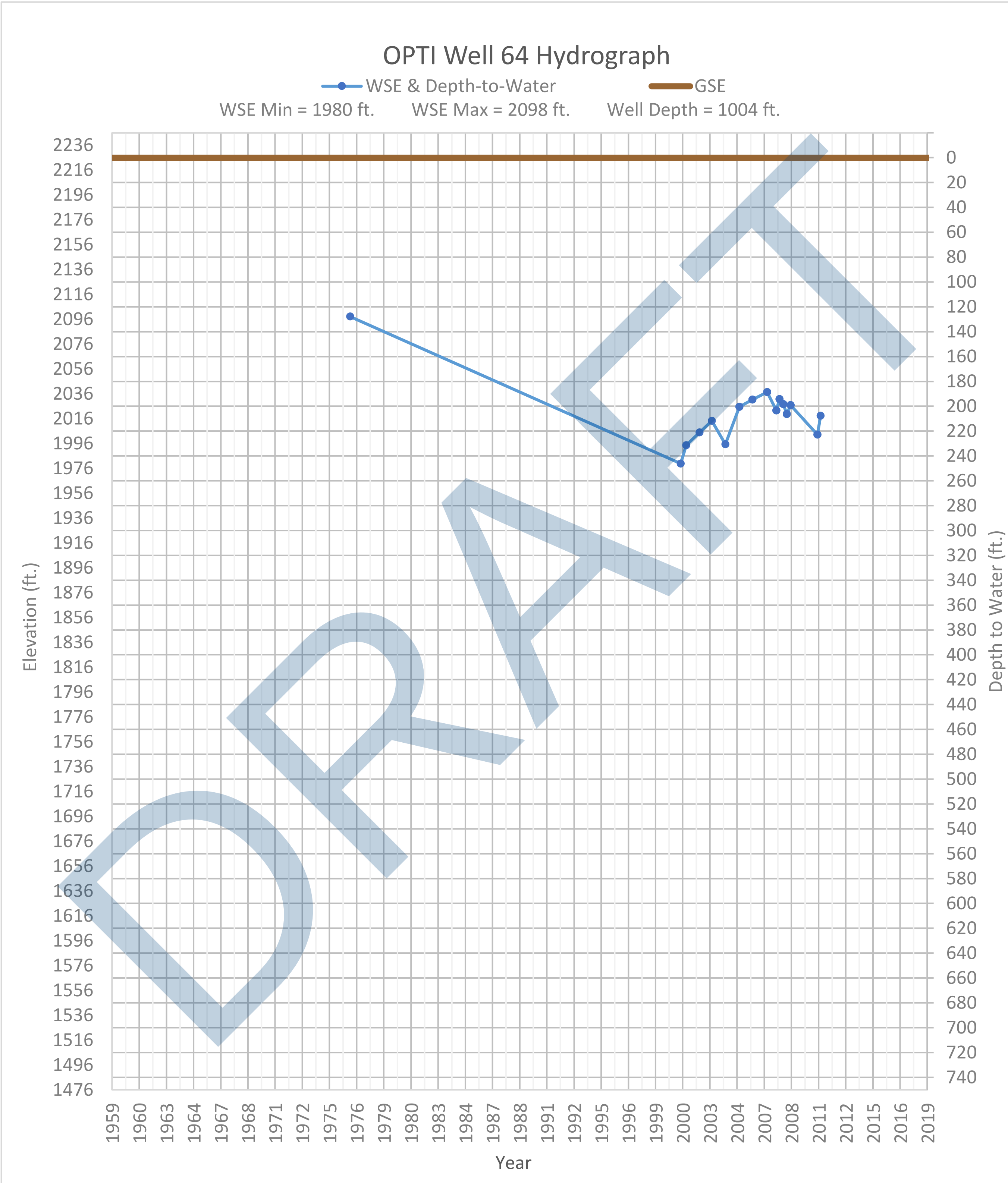
OPTI Well 61 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3593 ft.
WSE Max = 3664 ft.
Well Depth = 357 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

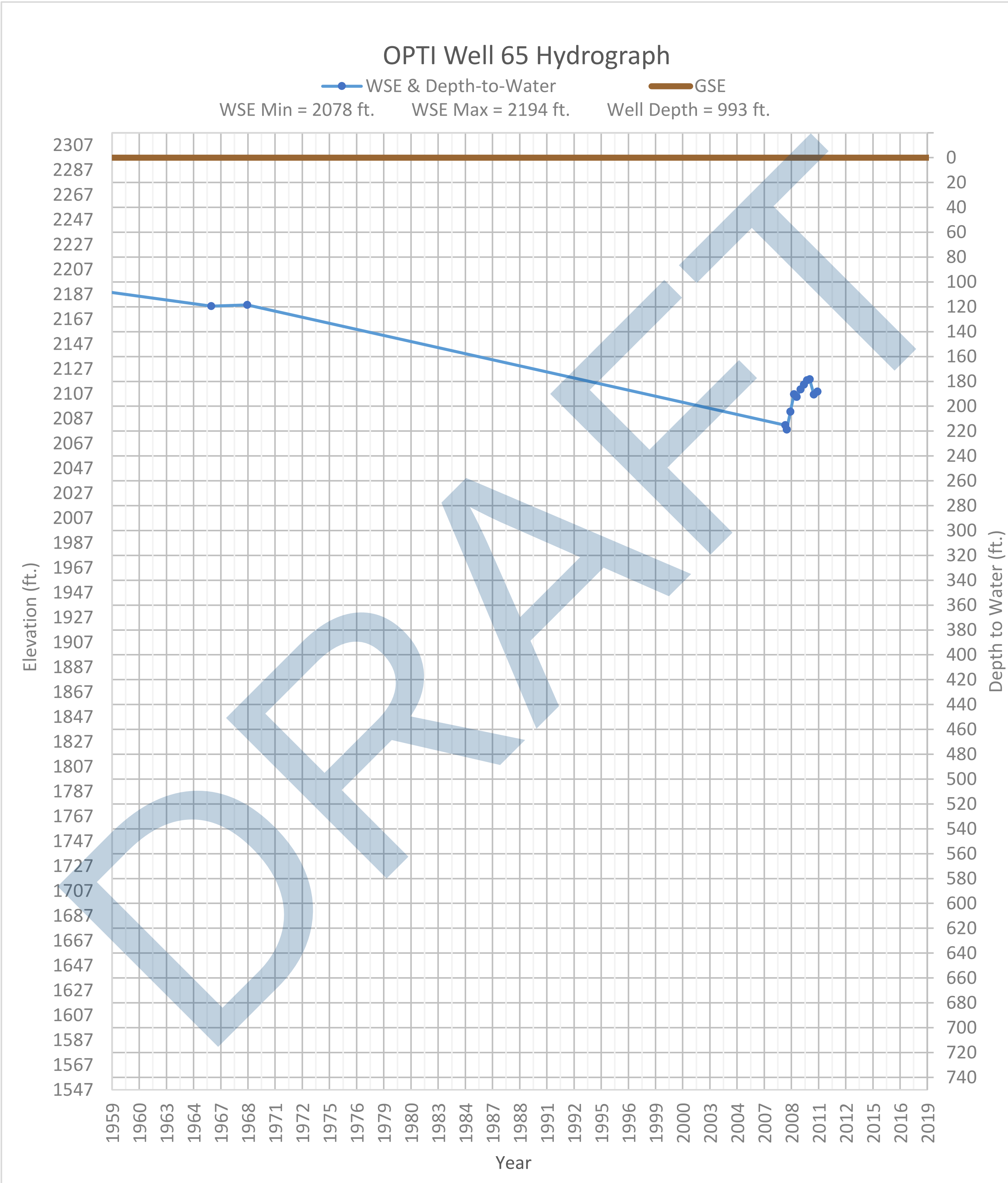


OPTI Well 62 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2757 ft.
WSE Max = 2858 ft.
Well Depth = 212 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

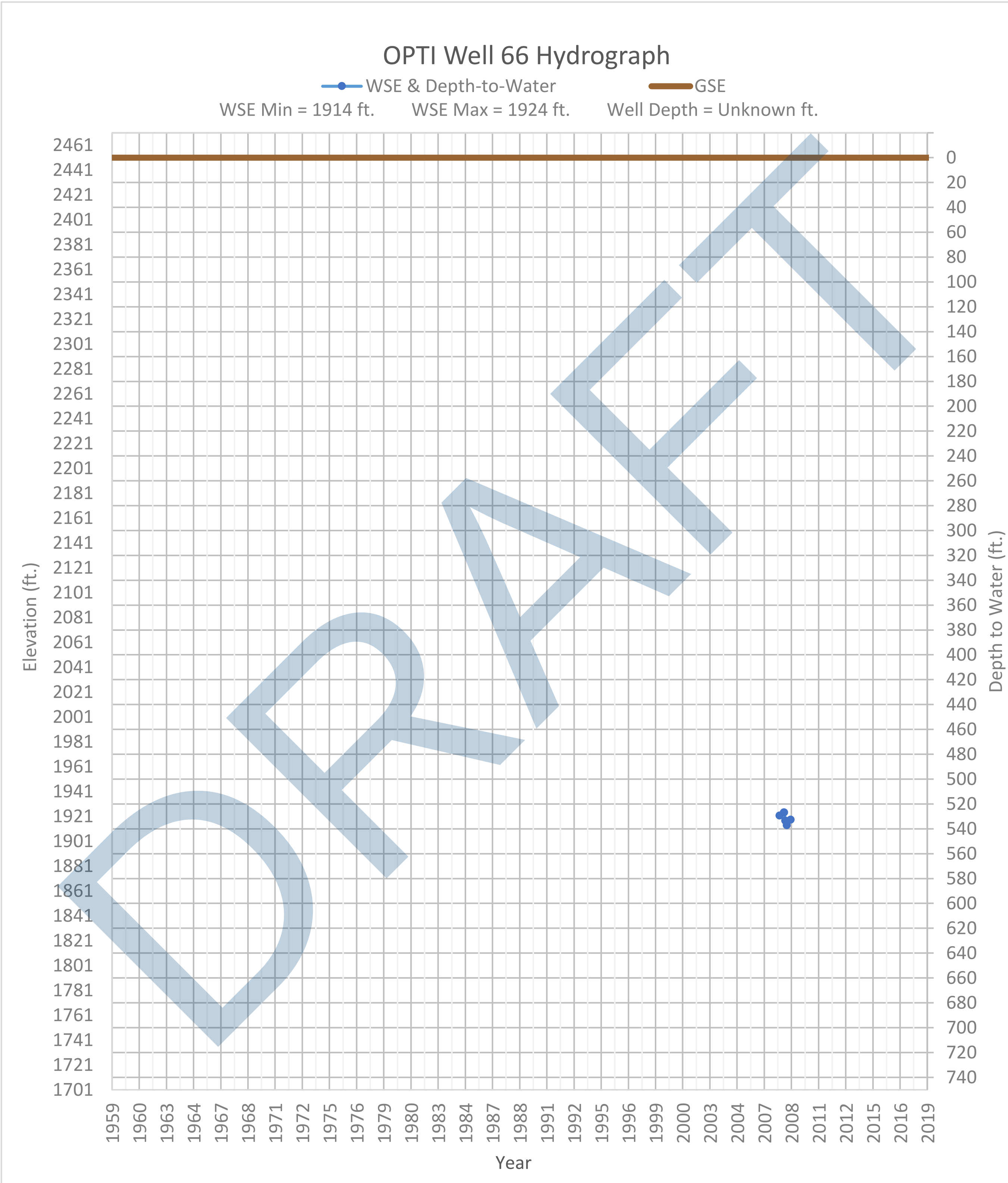


OPTI Well 63 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1966 ft.
WSE Max = 2178 ft.
Well Depth = 248 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

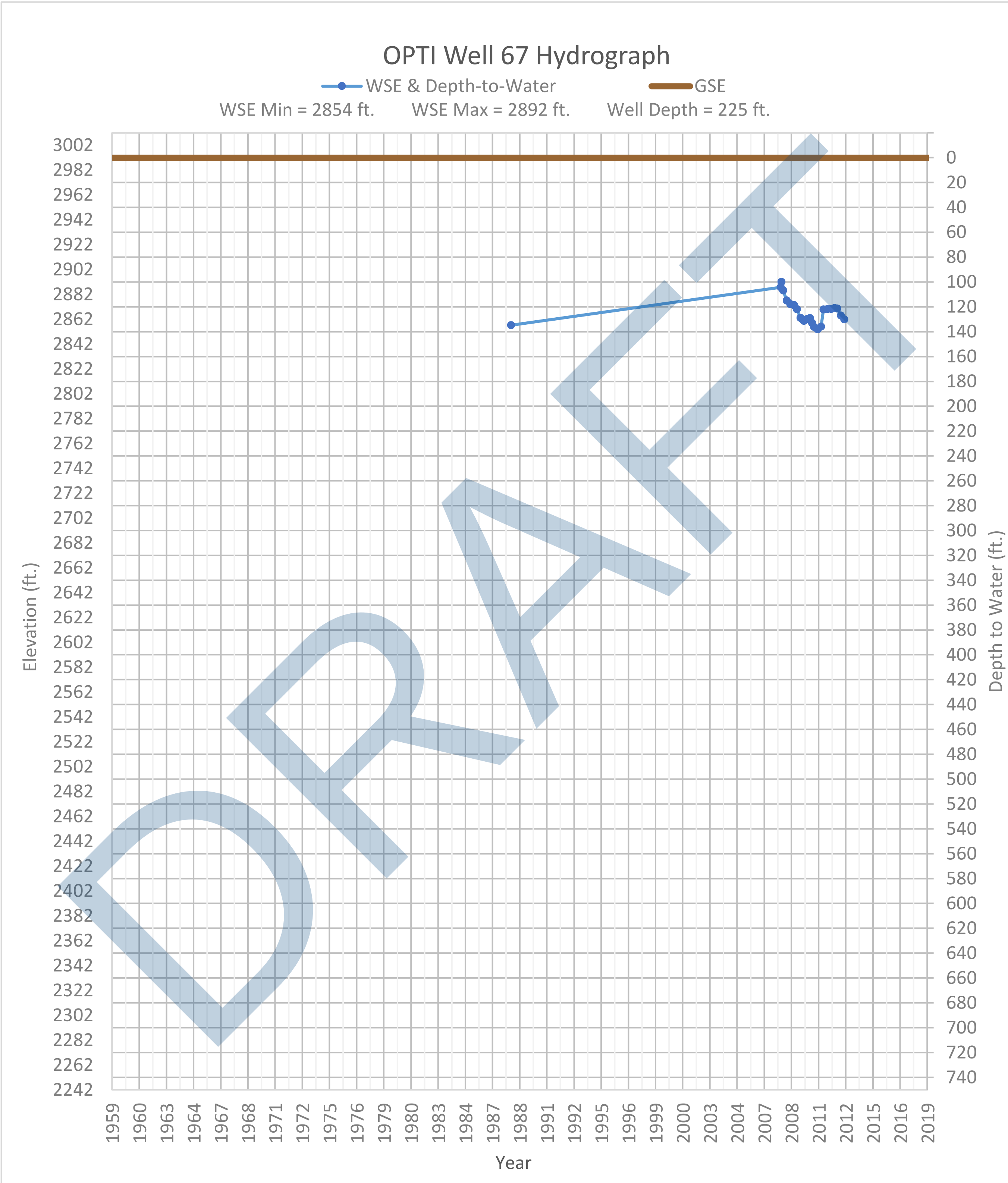

OPTI Well 64 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1980 ft.
WSE Max = 2098 ft.
Well Depth = 1004 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



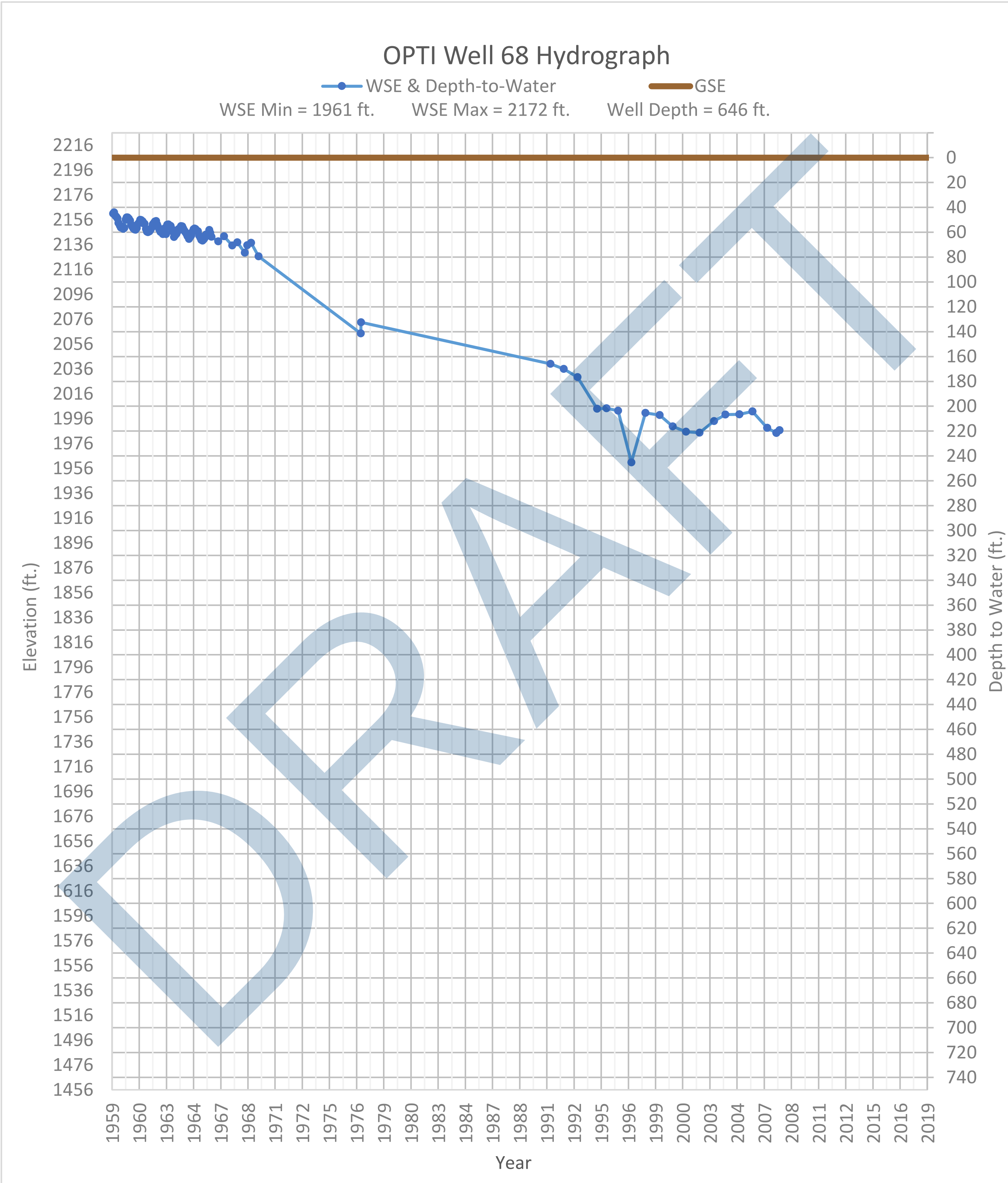
OPTI Well 65 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2078 ft.
WSE Max = 2194 ft.
Well Depth = 993 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



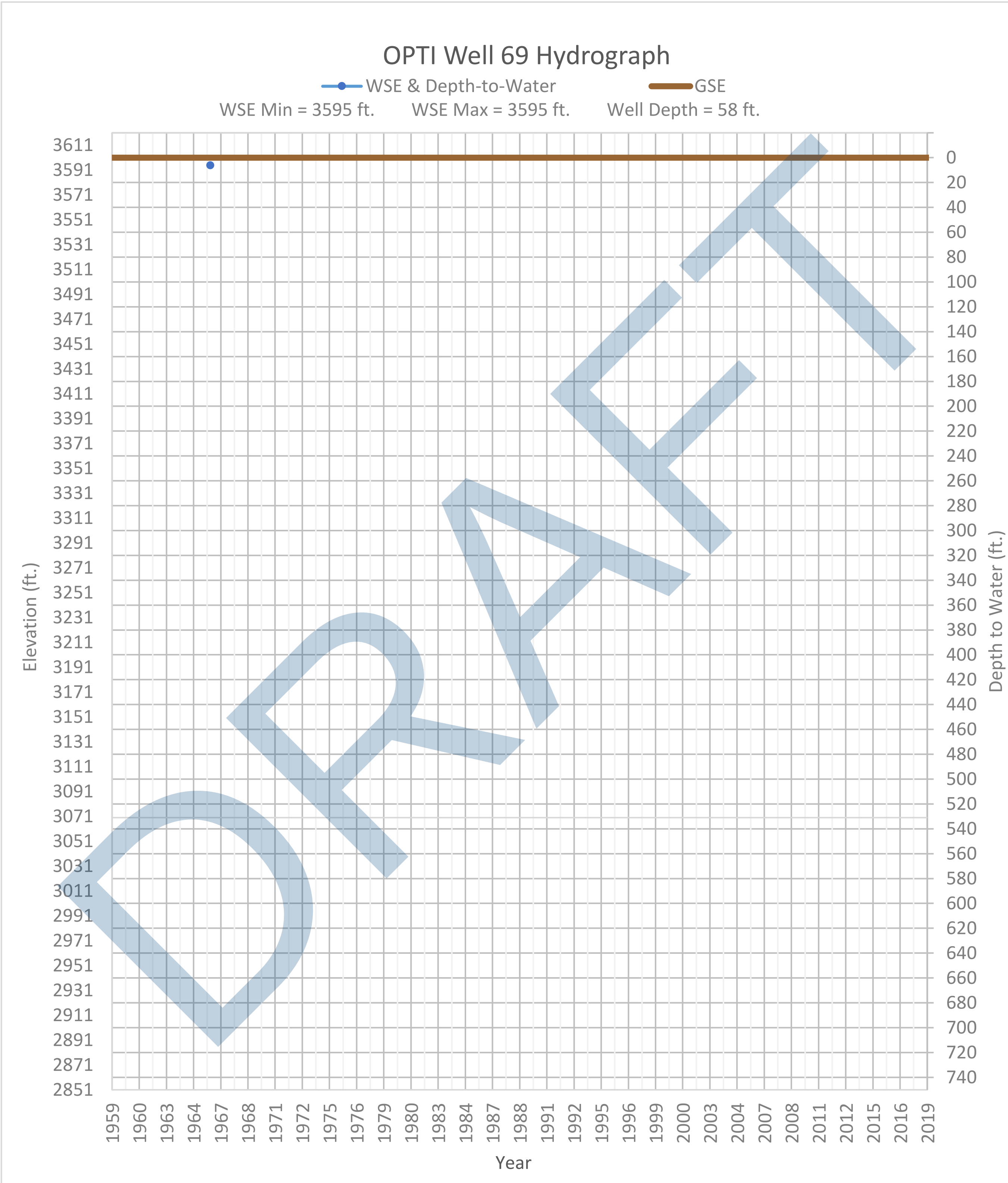
OPTI Well 66 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1914 ft.
WSE Max = 1924 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



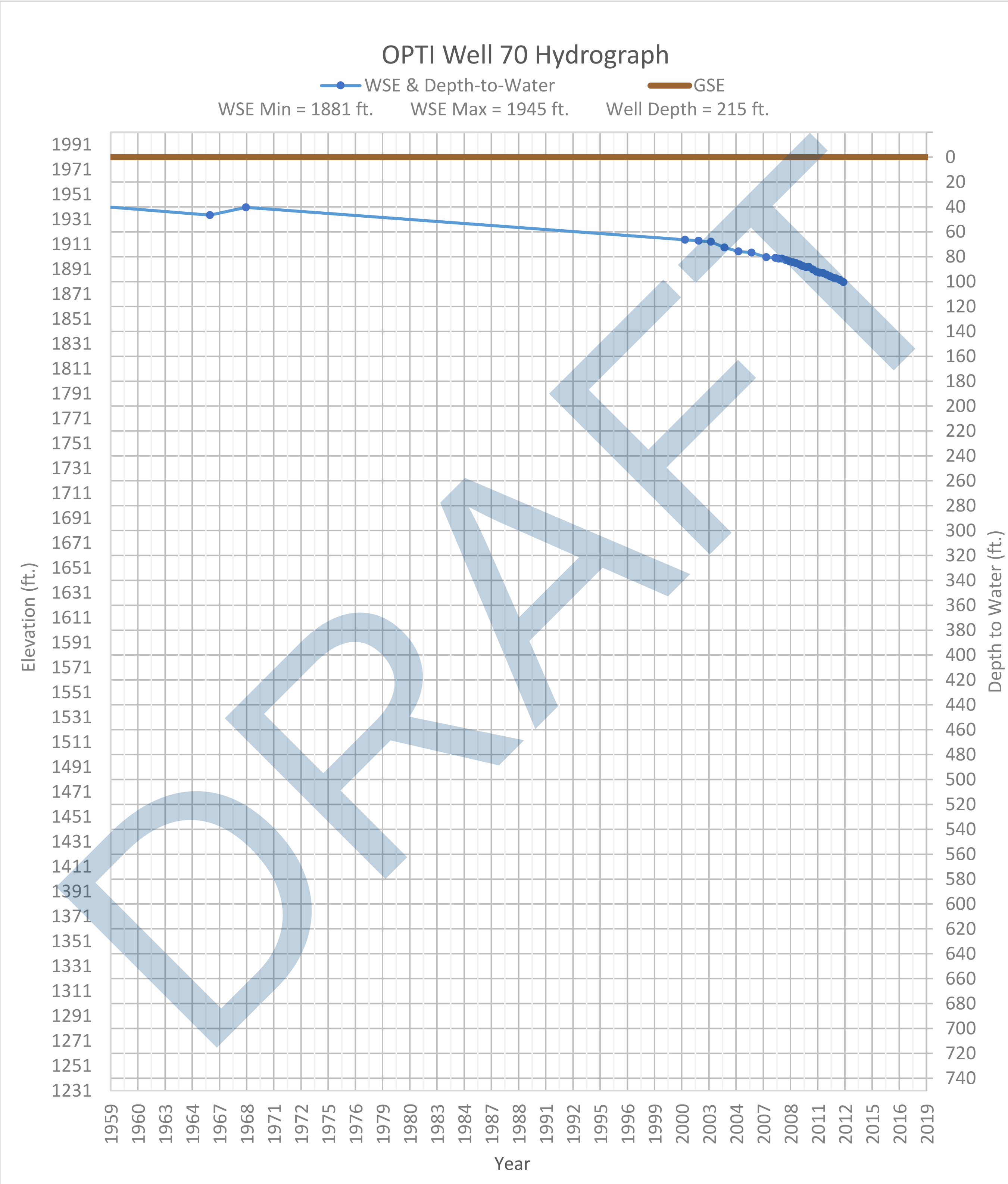
OPTI Well 67 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2854 ft.
WSE Max = 2892 ft.
Well Depth = 225 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



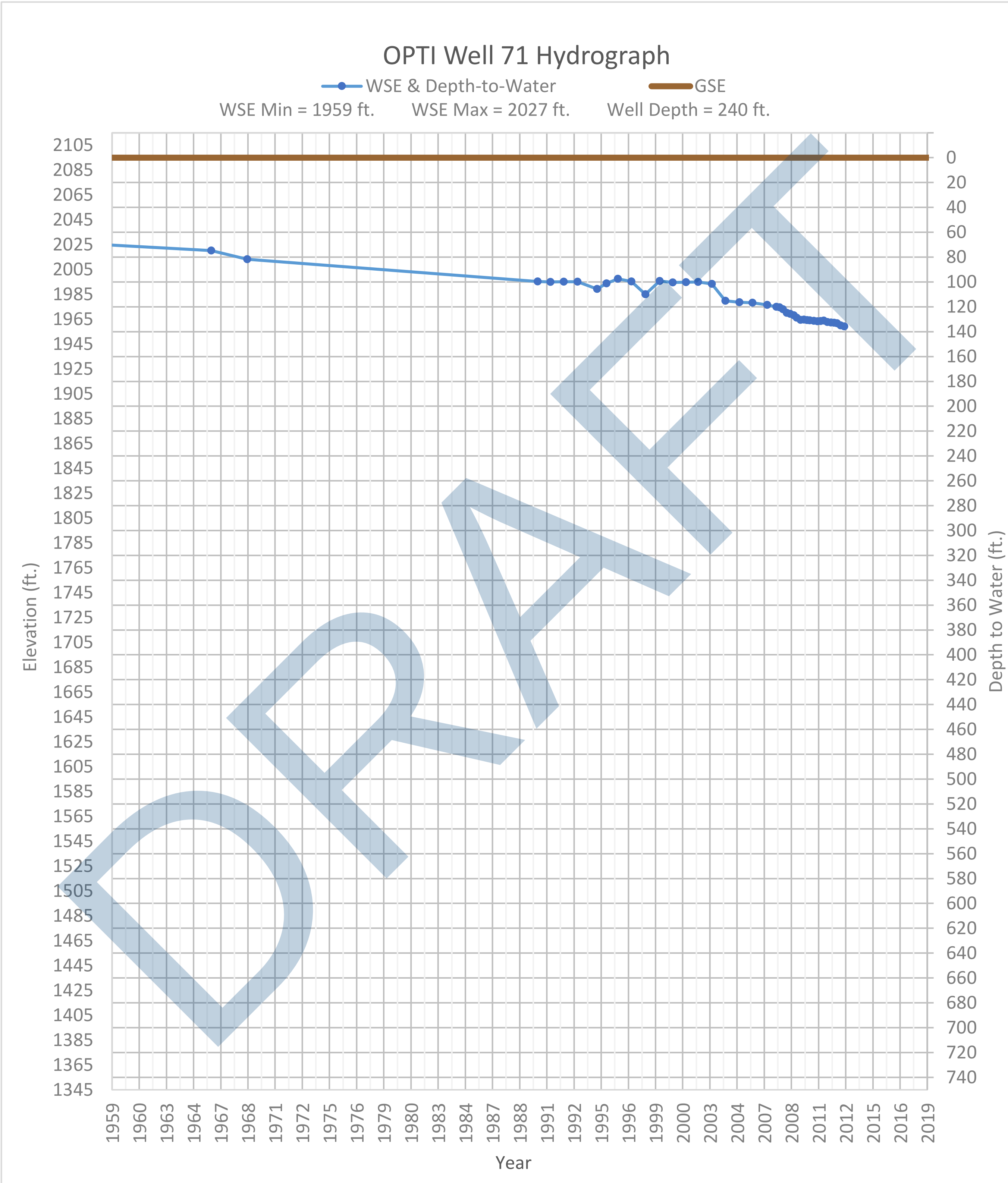
OPTI Well 68 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1961 ft.
WSE Max = 2172 ft.
Well Depth = 646 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



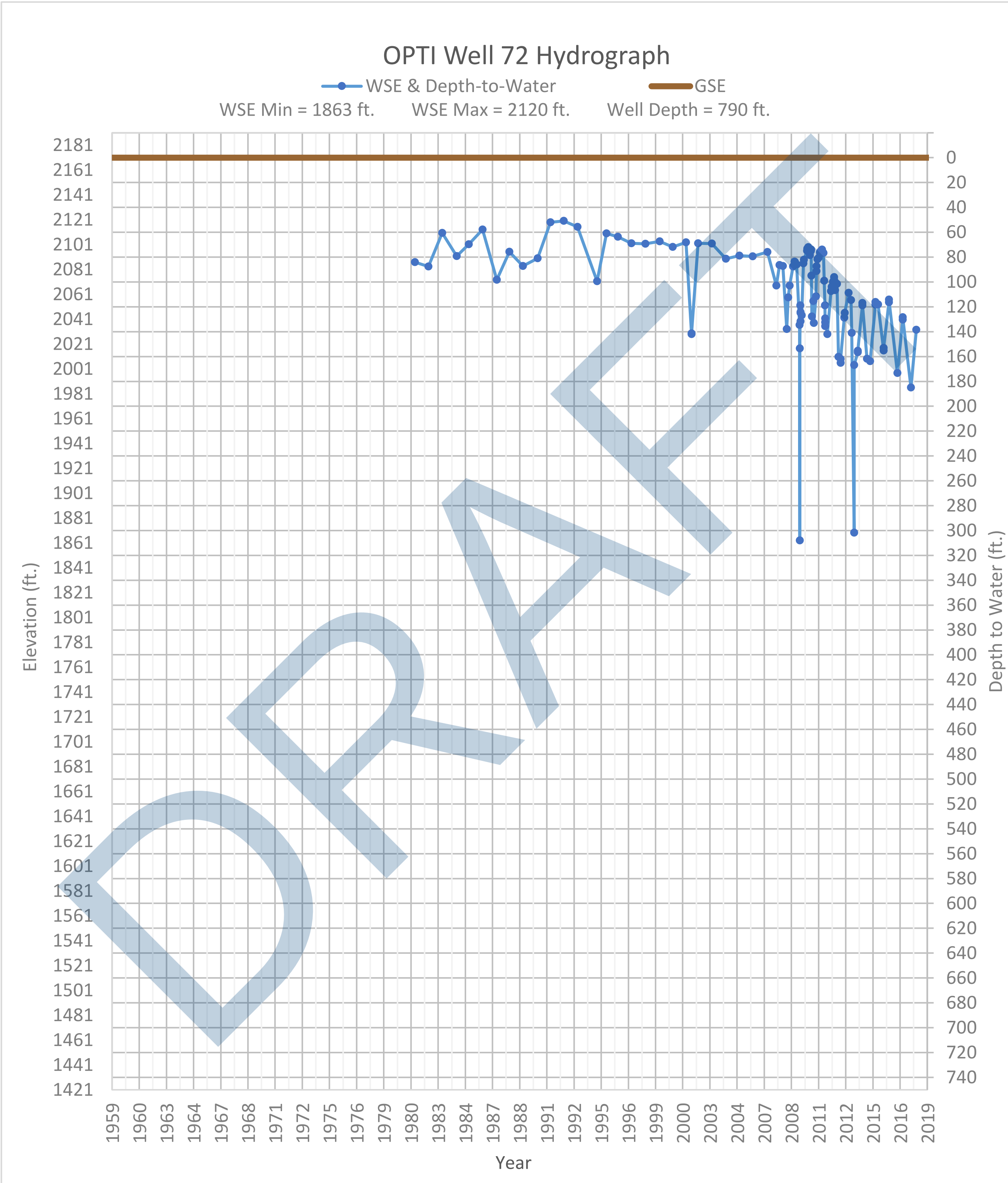
OPTI Well 69 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3595 ft.
WSE Max = 3595 ft.
Well Depth = 58 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



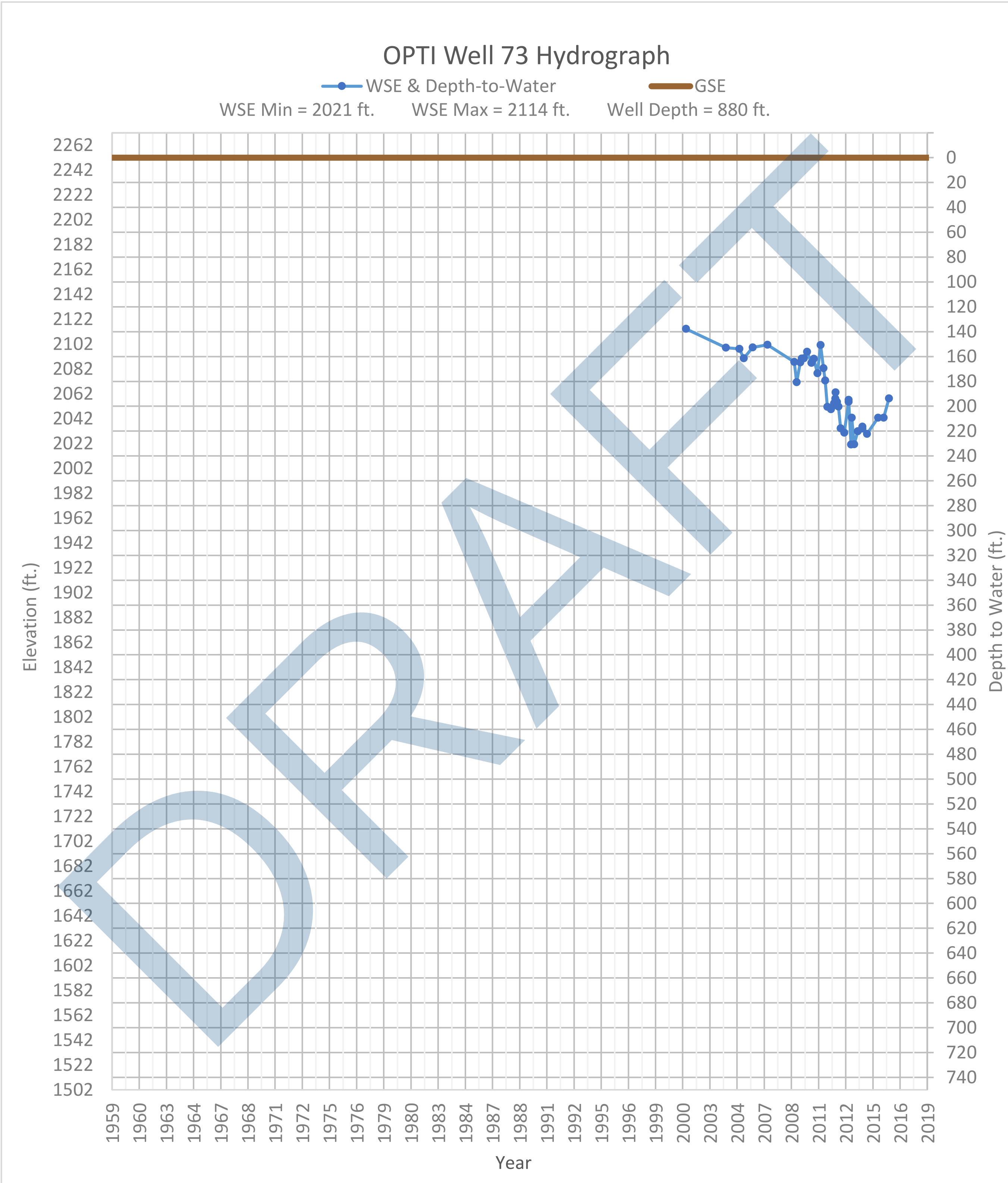
OPTI Well 70 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1881 ft.
WSE Max = 1945 ft.
Well Depth = 215 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



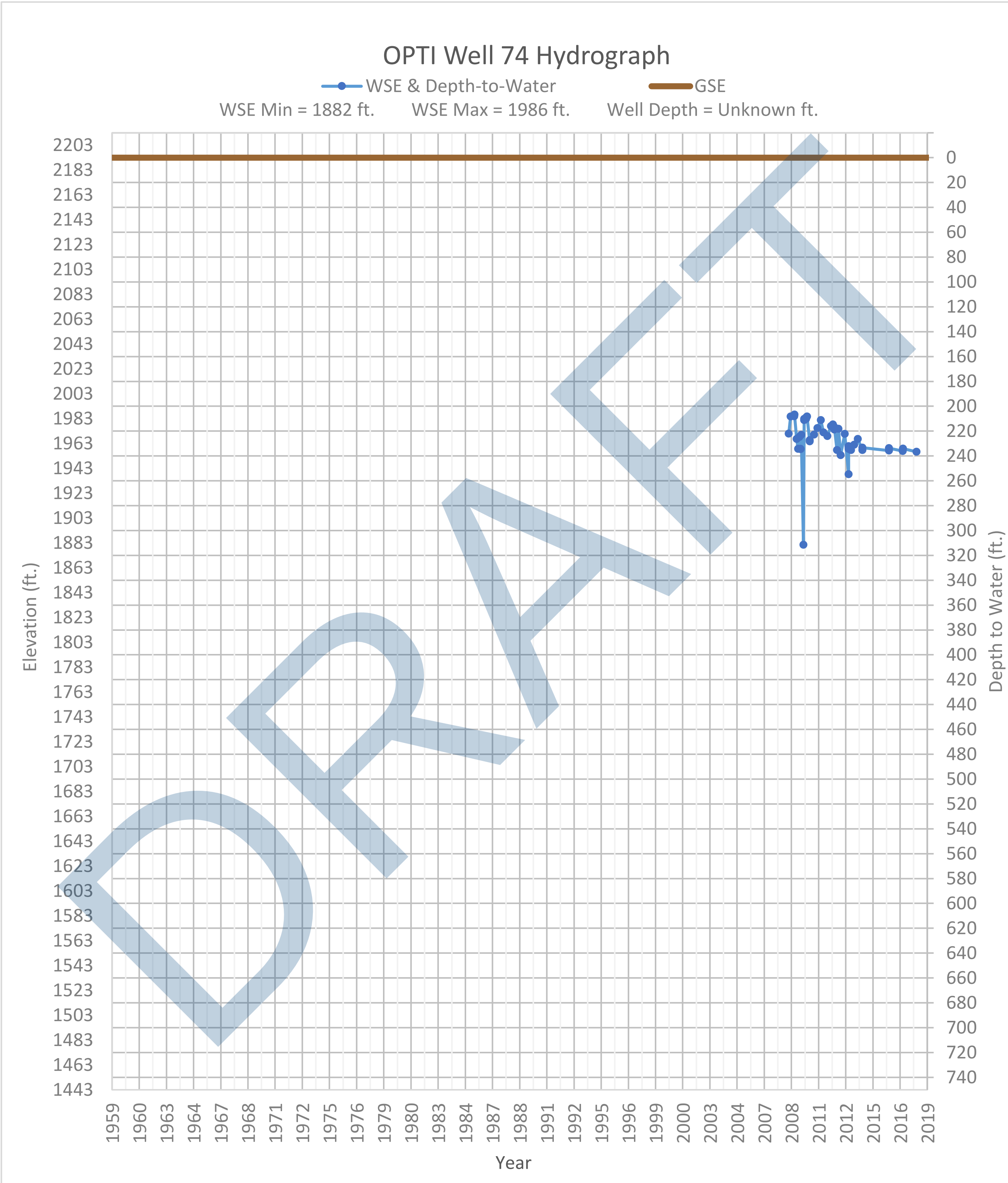
OPTI Well 71 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1959 ft.
WSE Max = 2027 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 72 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1863 ft.
WSE Max = 2120 ft.
Well Depth = 790 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

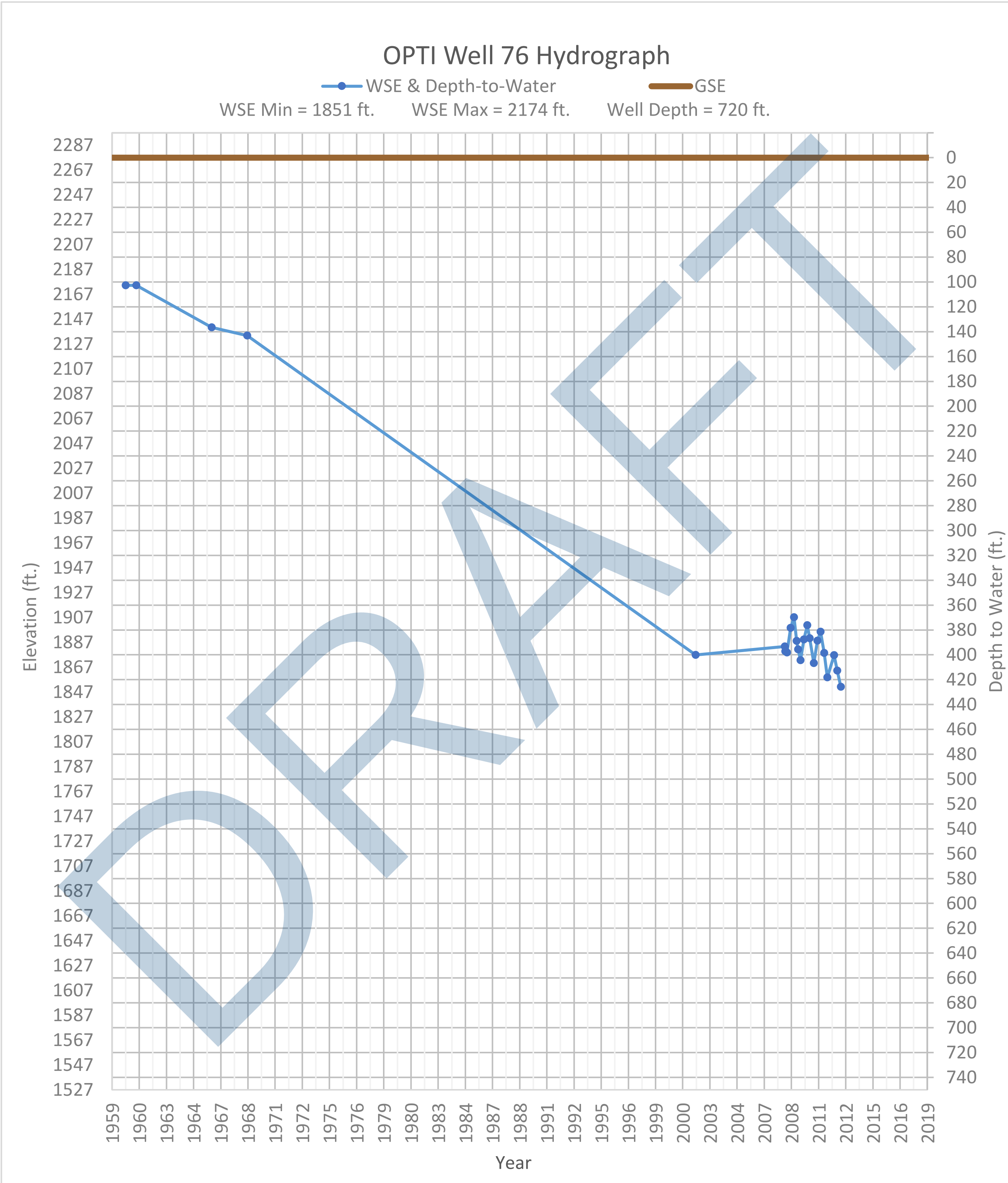


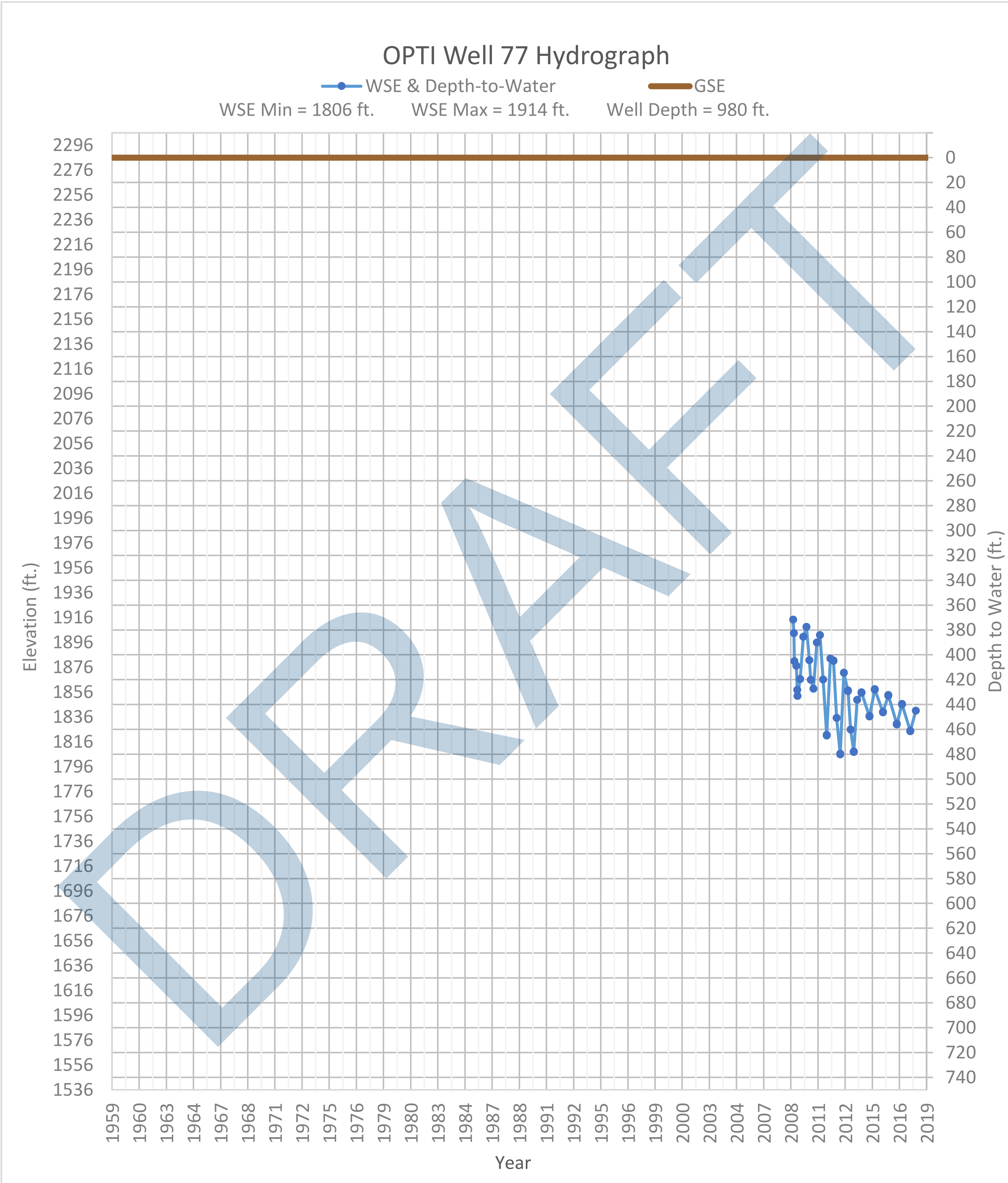
OPTI Well 73 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2021 ft.
WSE Max = 2114 ft.
Well Depth = 880 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



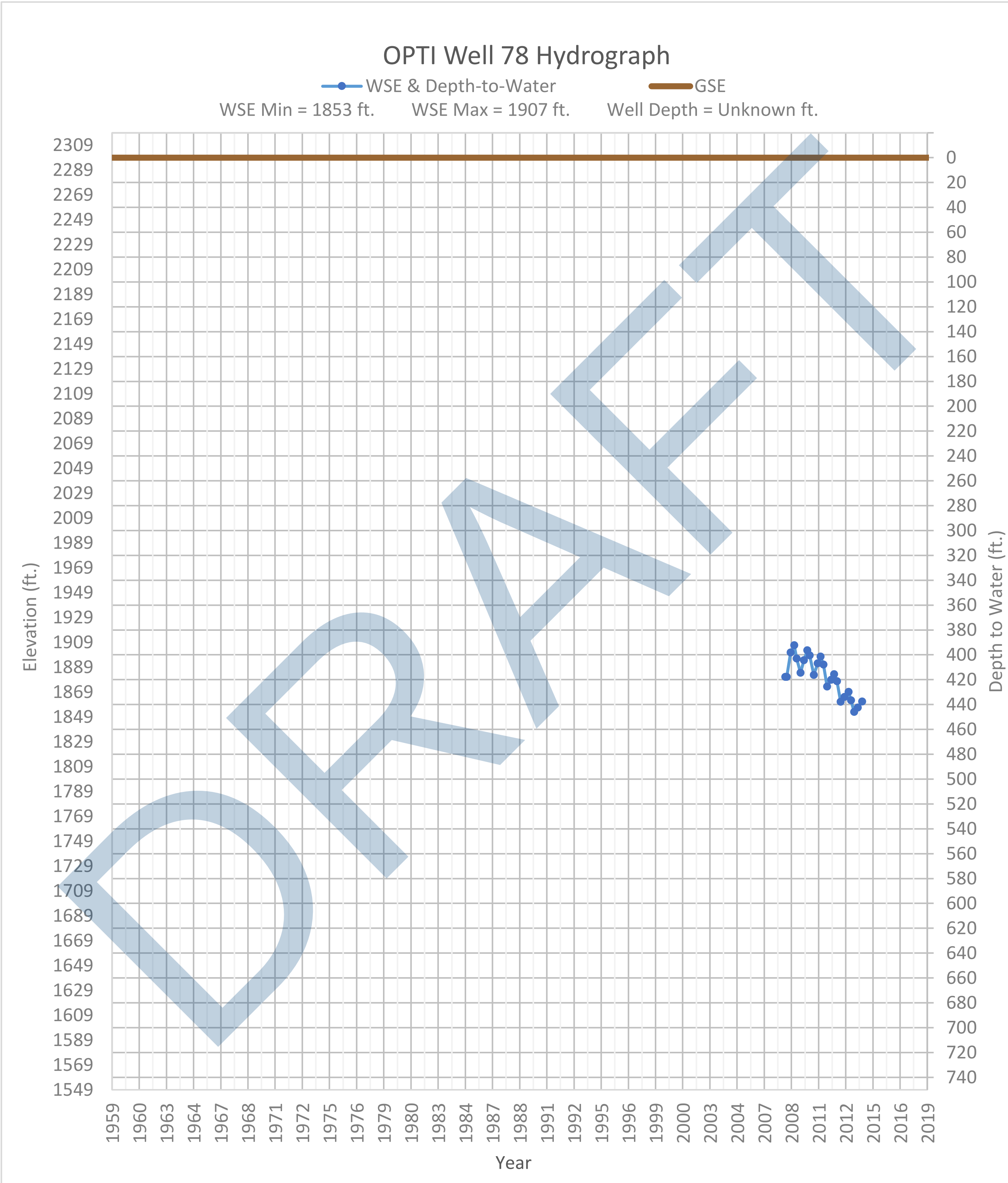
OPTI Well 74 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1882 ft.
WSE Max = 1986 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

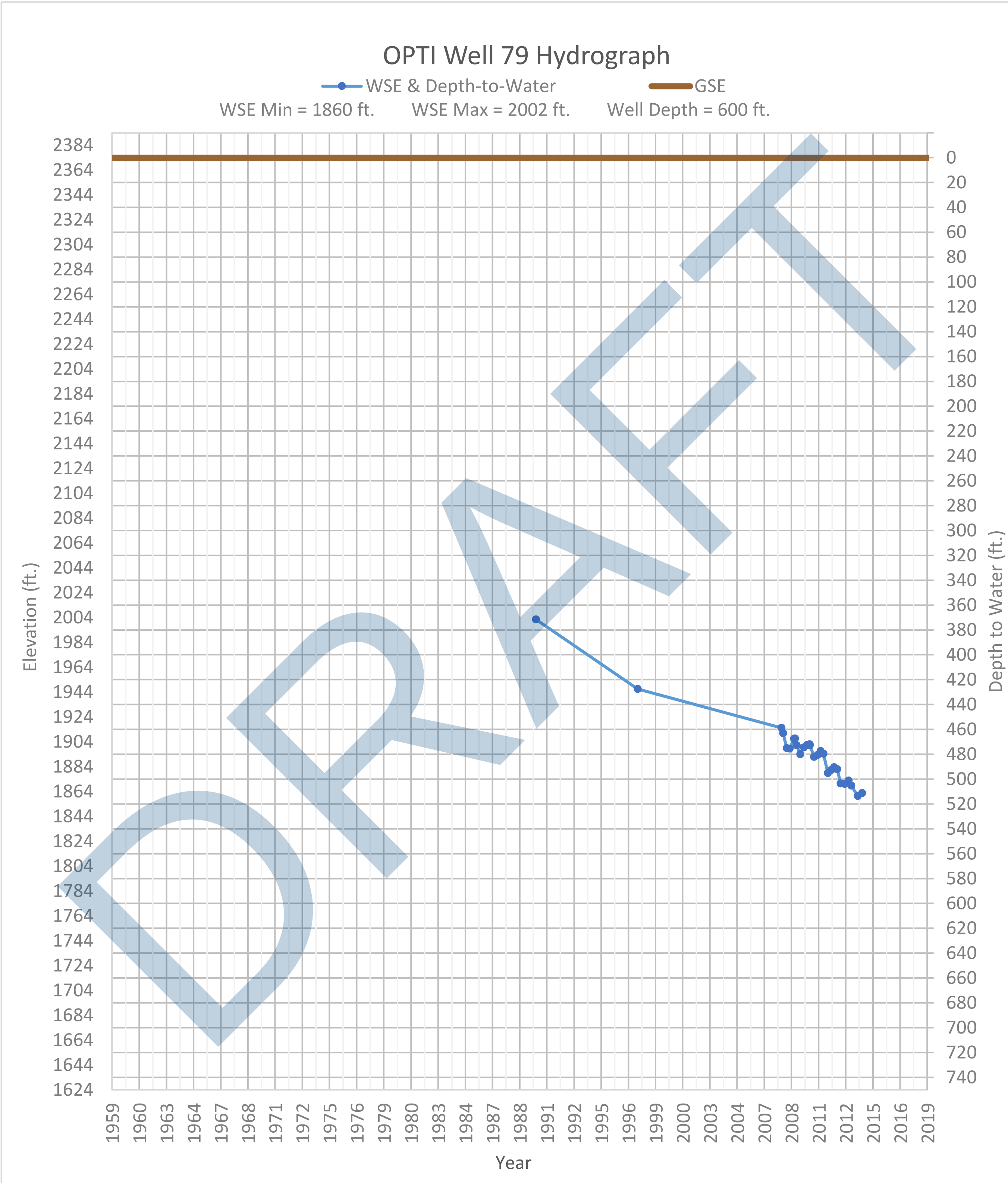
OPTI Well 75 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1912 ft.
WSE Max = 2089 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 76 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1851 ft.
WSE Max = 2174 ft.
Well Depth = 720 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

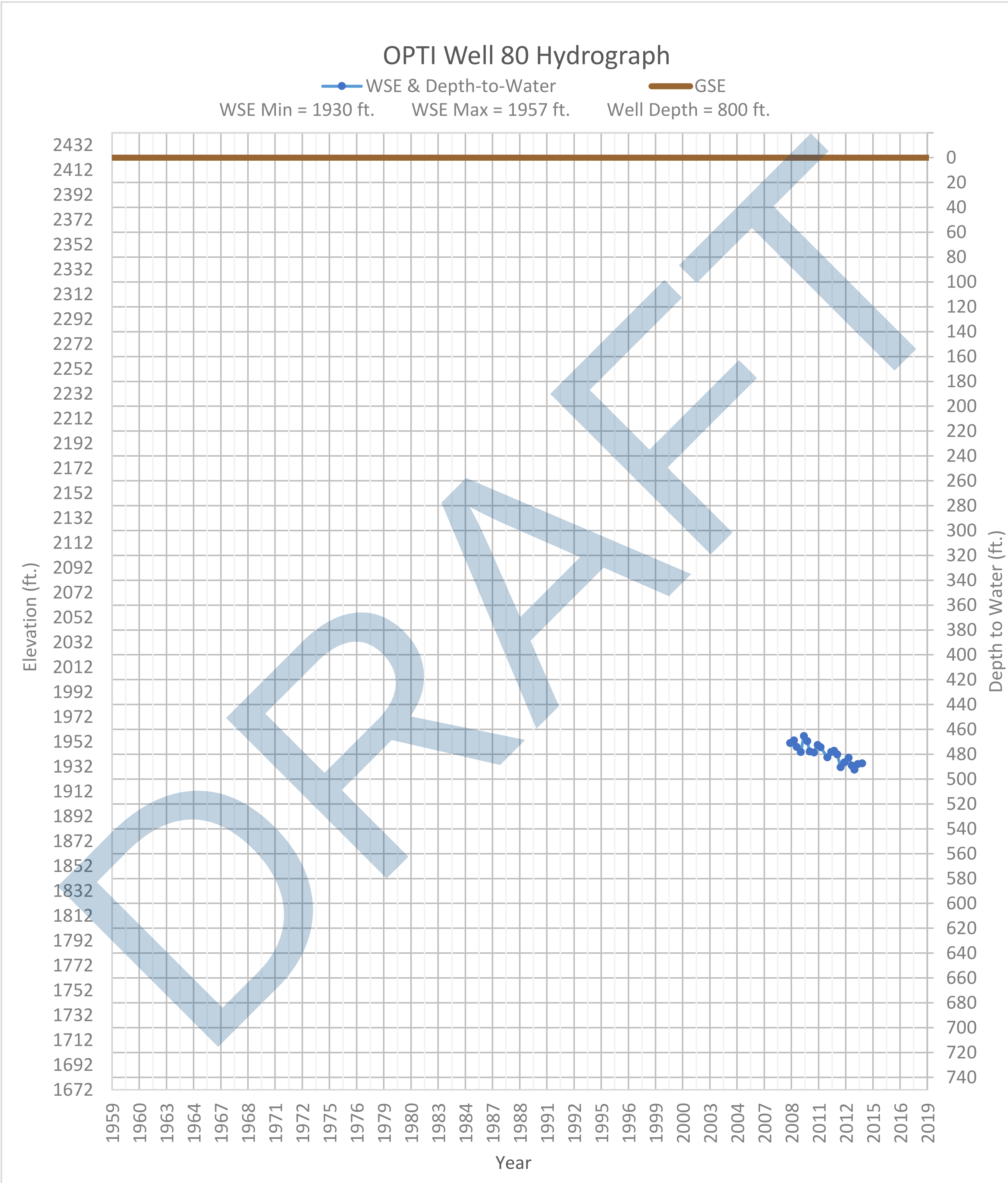


OPTI Well 77 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1806 ft.
WSE Max = 1914 ft.
Well Depth = 980 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

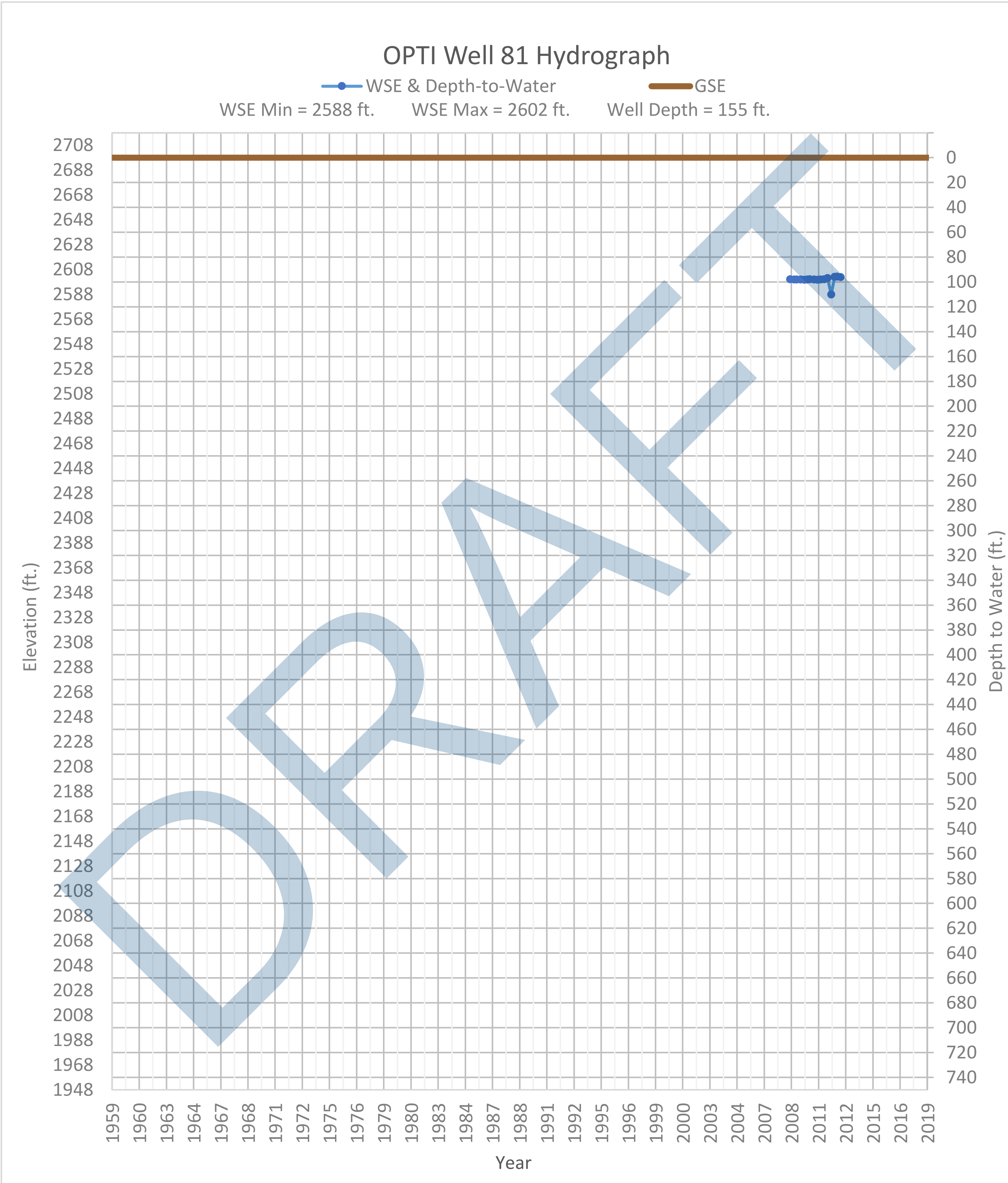

OPTI Well 78 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1853 ft.
WSE Max = 1907 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



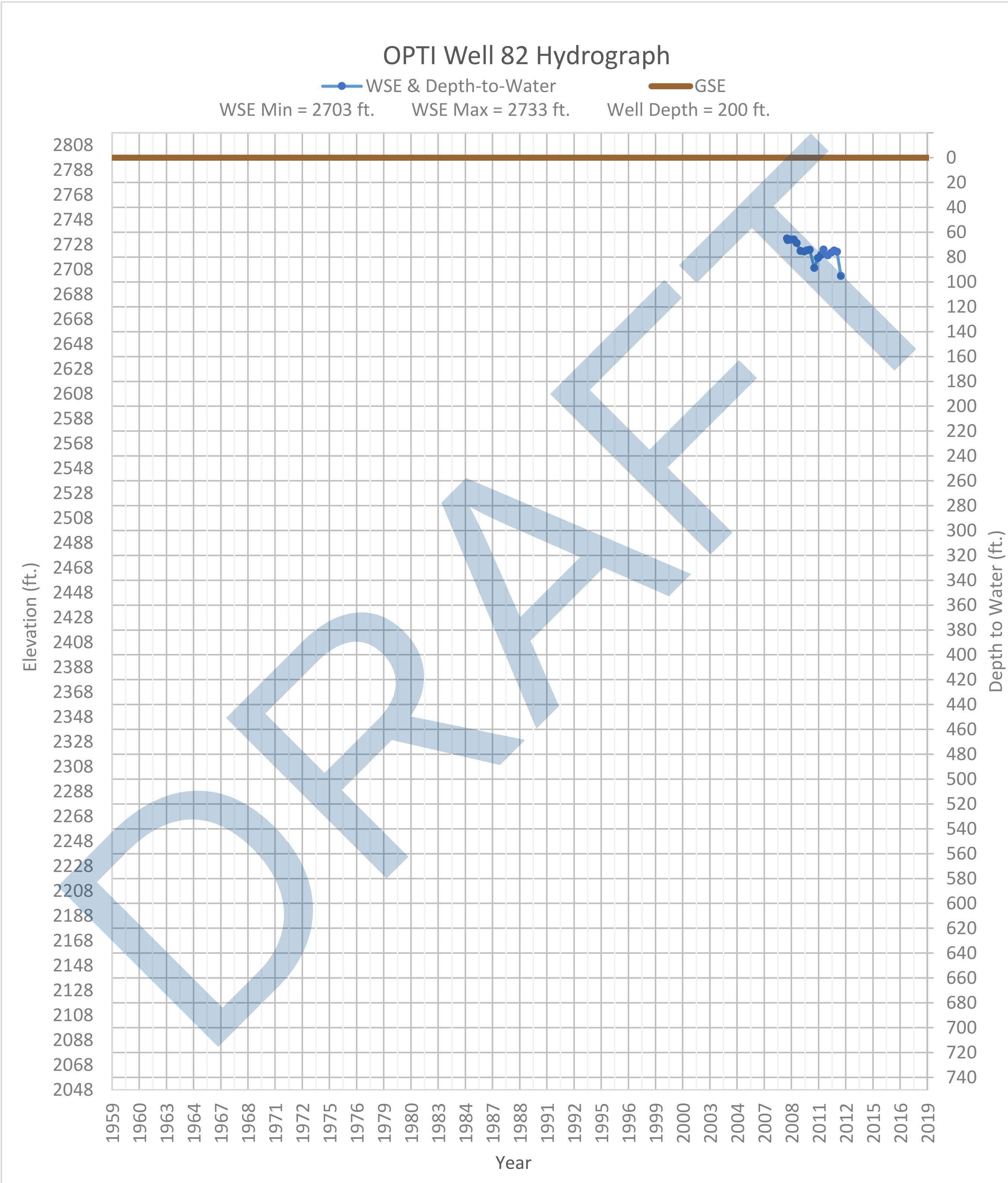
OPTI Well 79 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1860 ft.
WSE Max = 2002 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



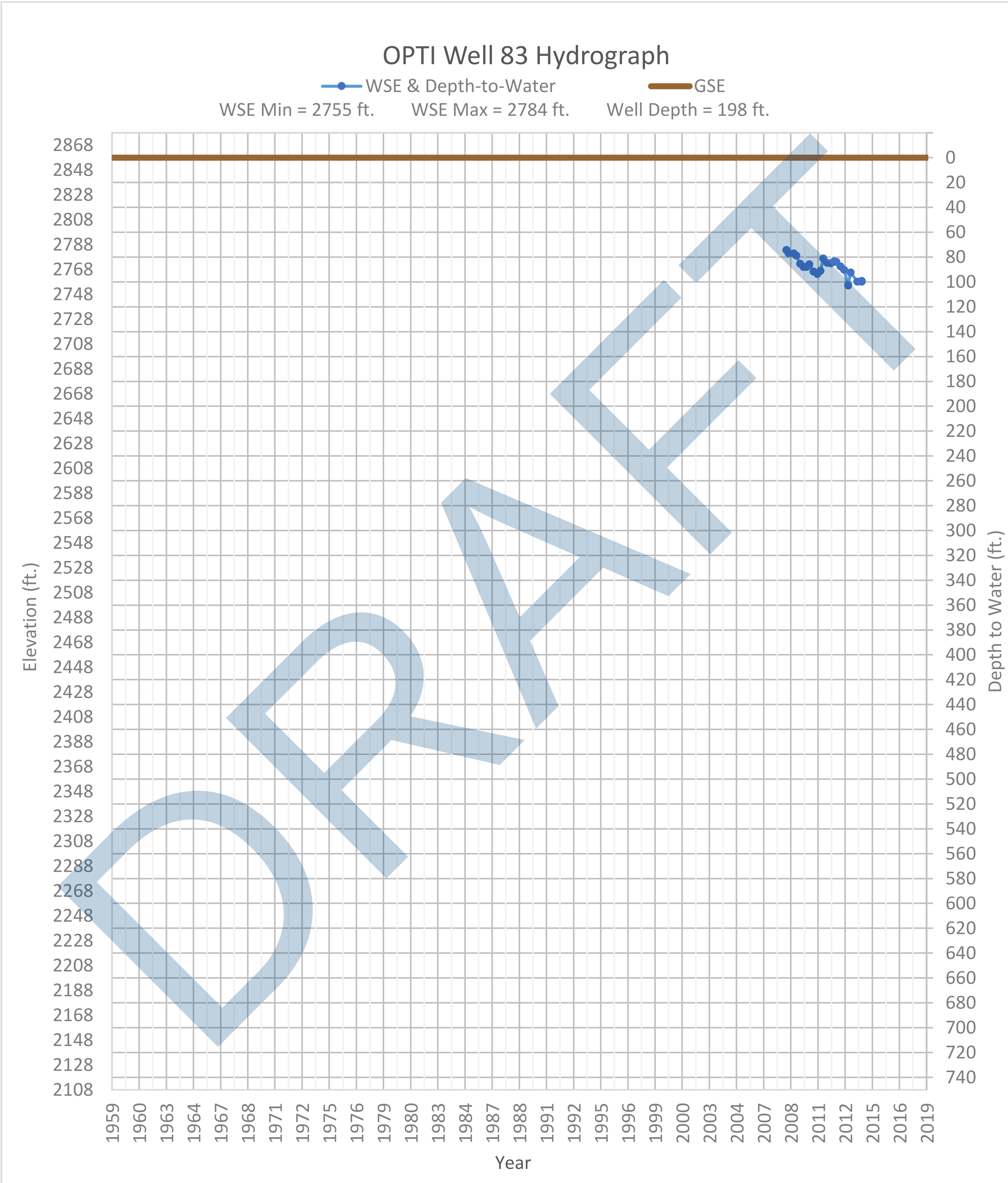
OPTI Well 80 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1930 ft.
WSE Max = 1957 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

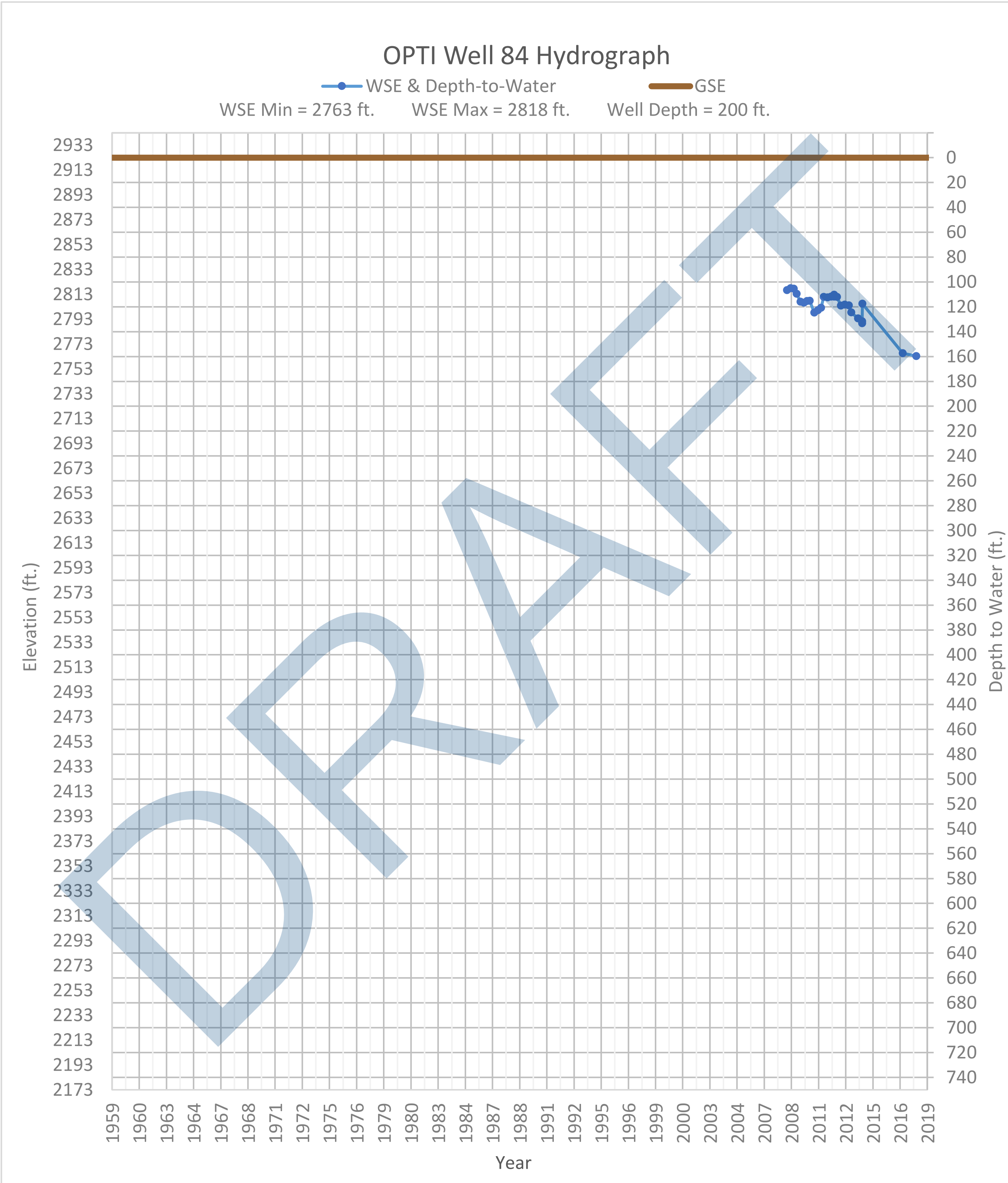


OPTI Well 81 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2588 ft.
WSE Max = 2602 ft.
Well Depth = 155 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

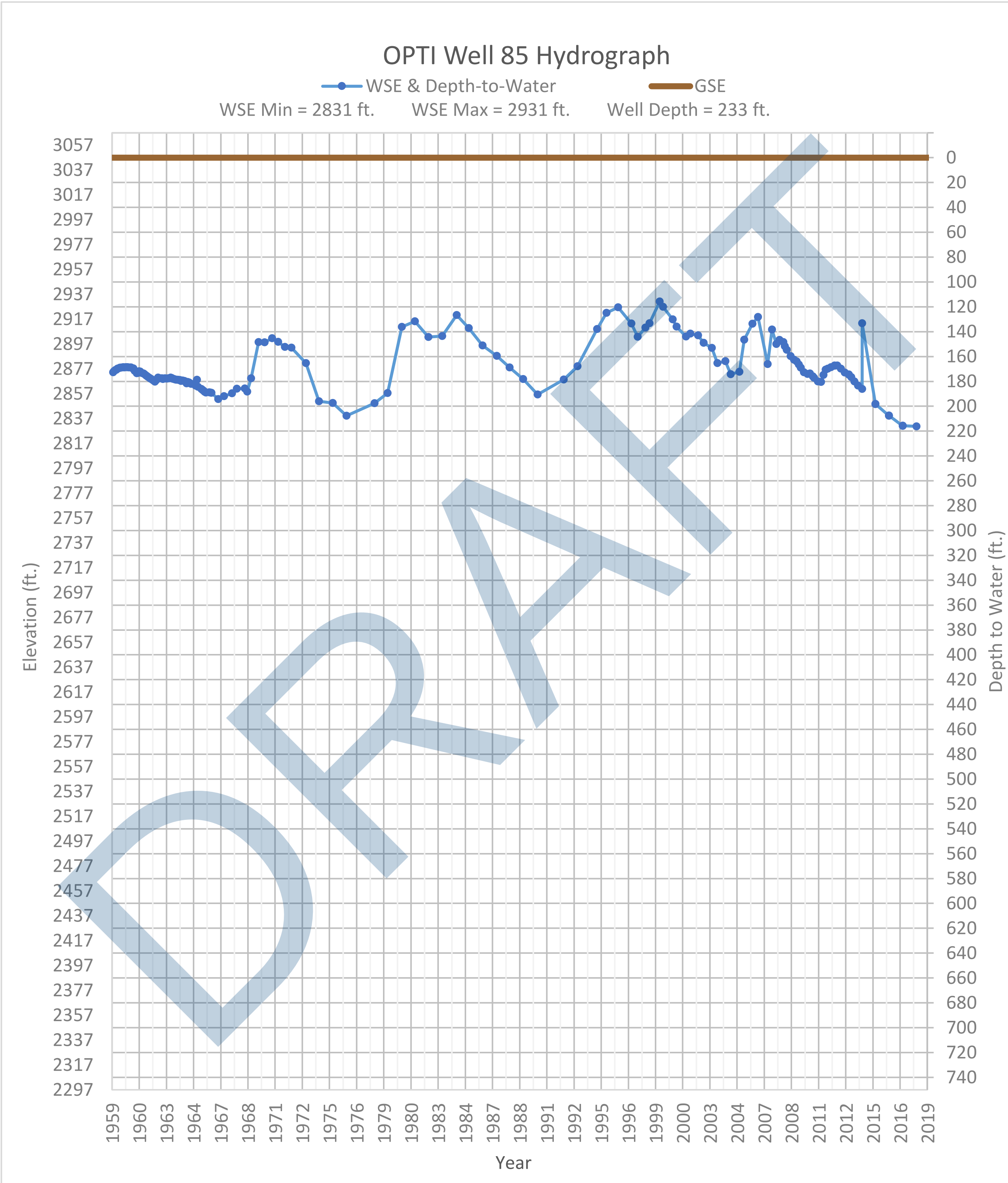


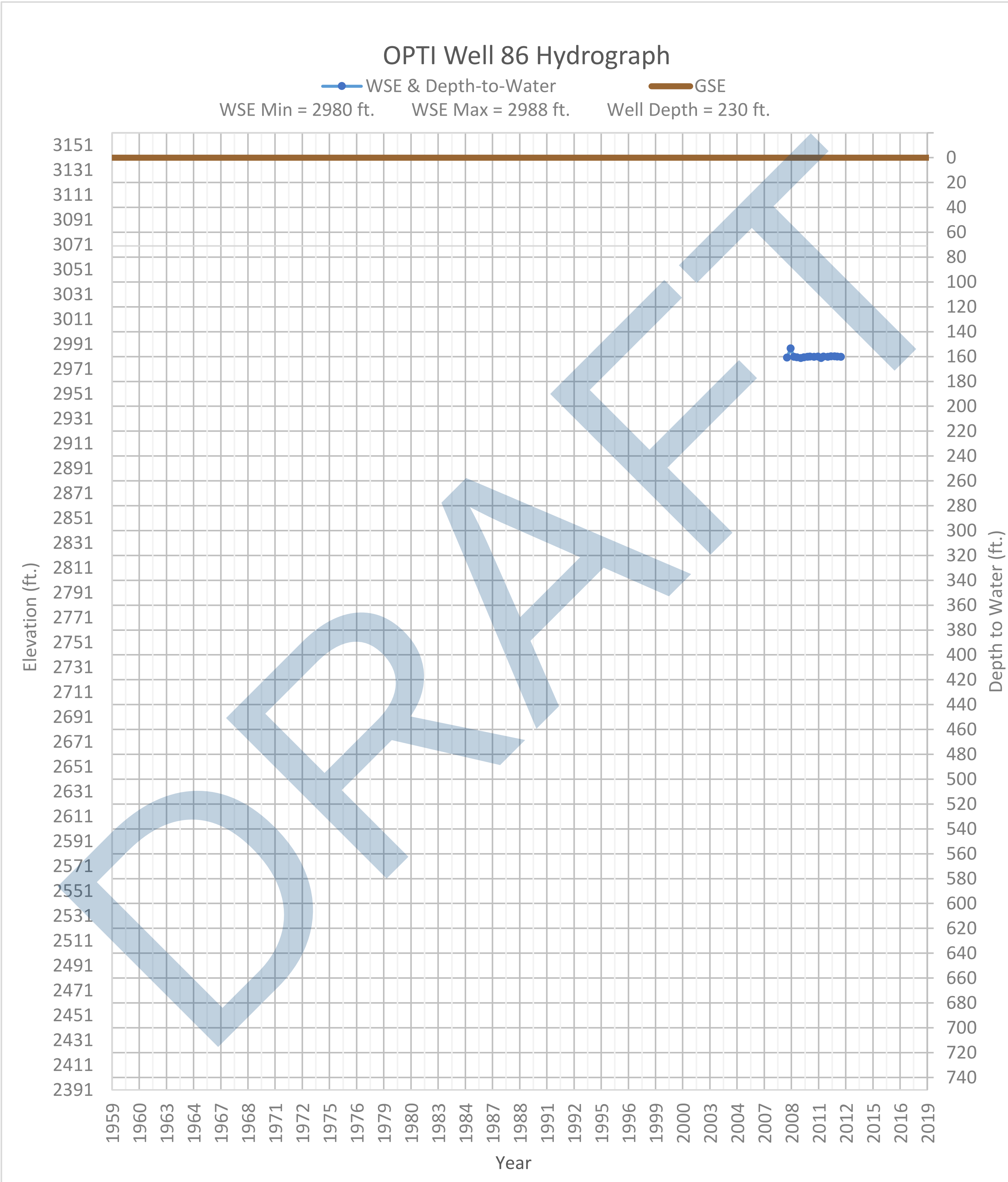
OPTI Well 82 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2703 ft.
WSE Max = 2733 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 83 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2755 ft.
WSE Max = 2784 ft.
Well Depth = 198 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 84 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2763 ft.
WSE Max = 2818 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 85 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2831 ft.
WSE Max = 2931 ft.
Well Depth = 233 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 86 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2980 ft.
WSE Max = 2988 ft.
Well Depth = 230 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
3151
3131
3111
3091
3071
3051
3031
3011
2991
2971
2951
2931
2911
2891
2871
2851
2831
2811
2791
2771
2751
2731
2711
2691
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2551
2531
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2471
2451
2431
2411
2391
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160
180
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220
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260
280
300
320
340
360
380
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520
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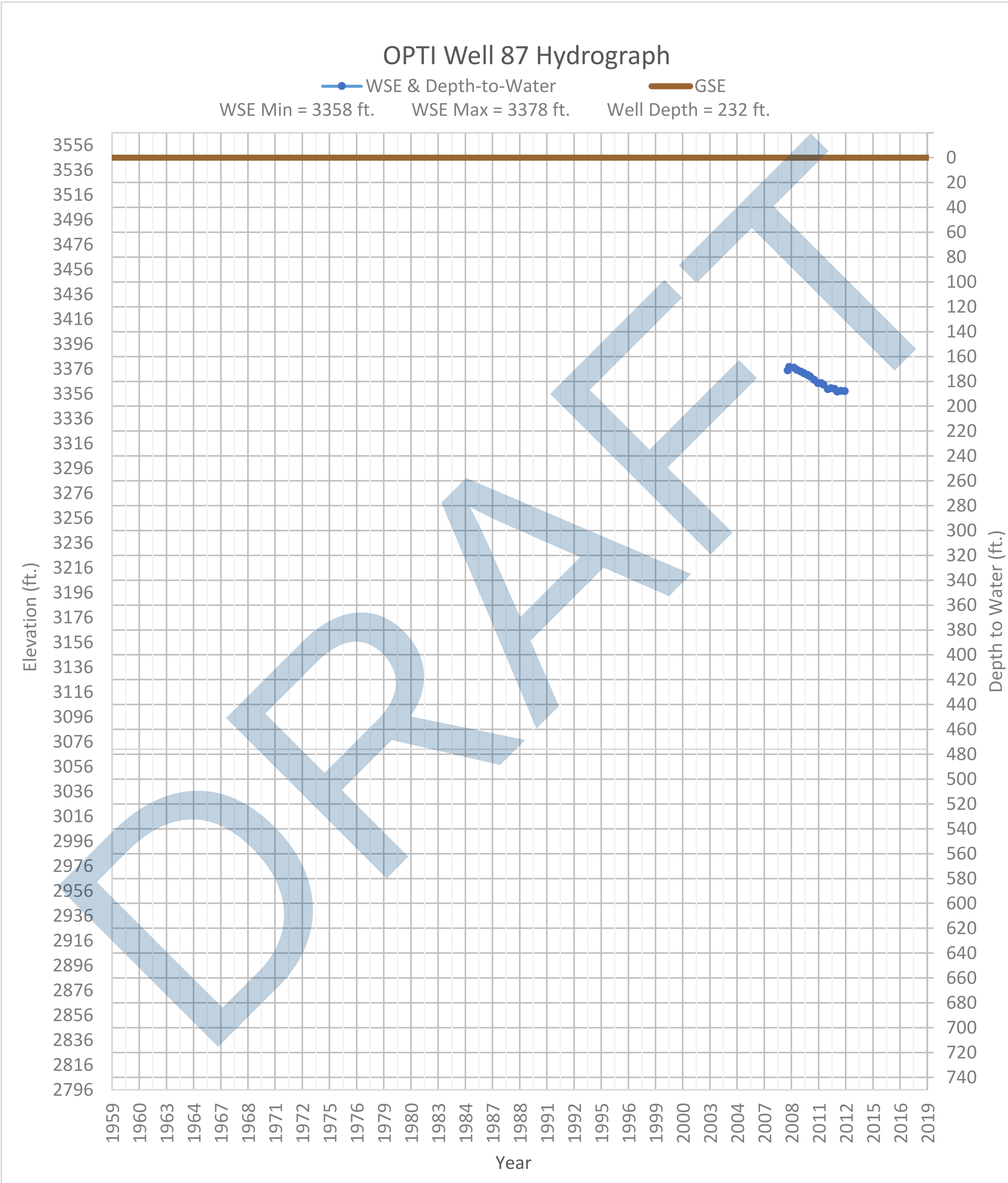
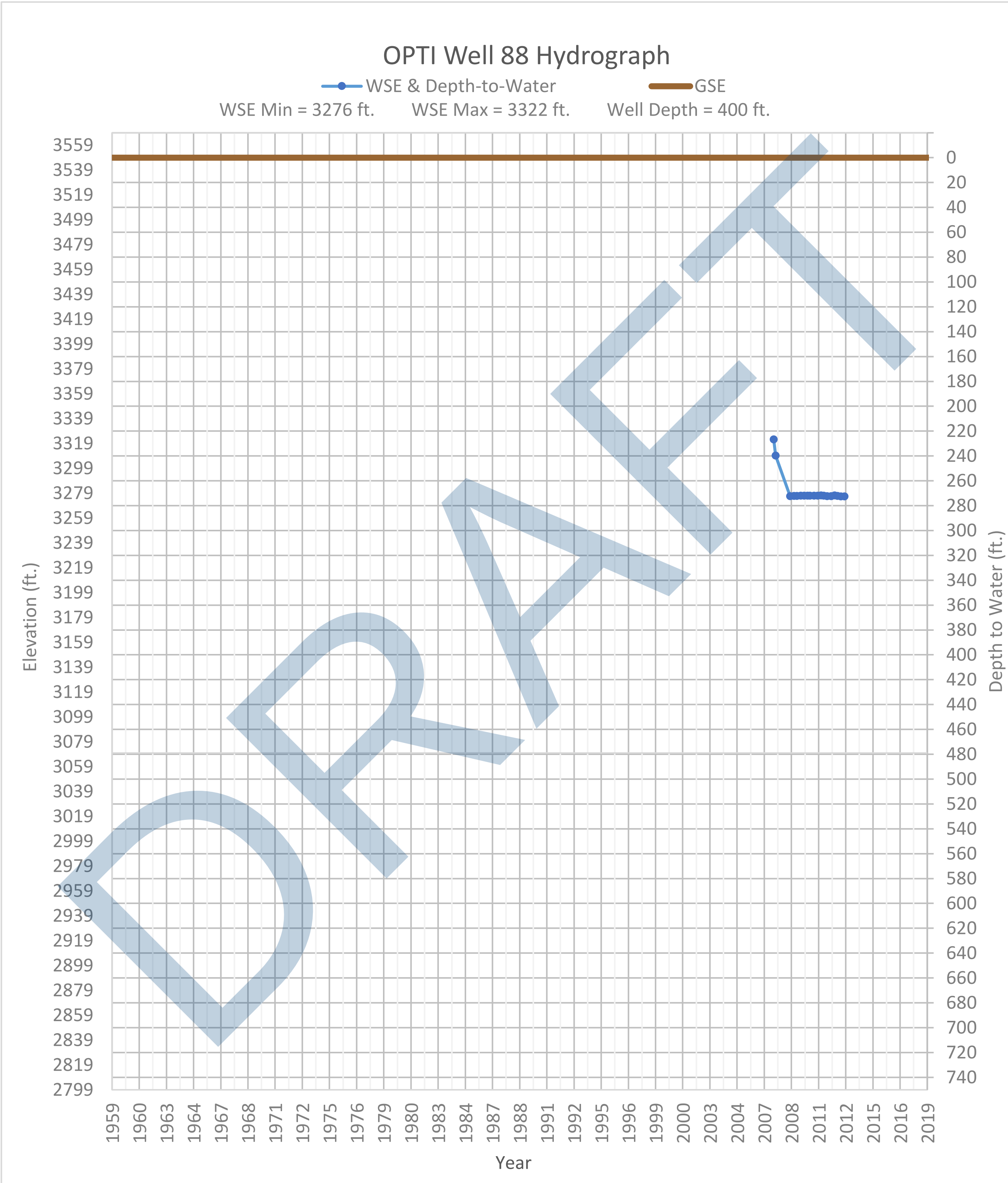
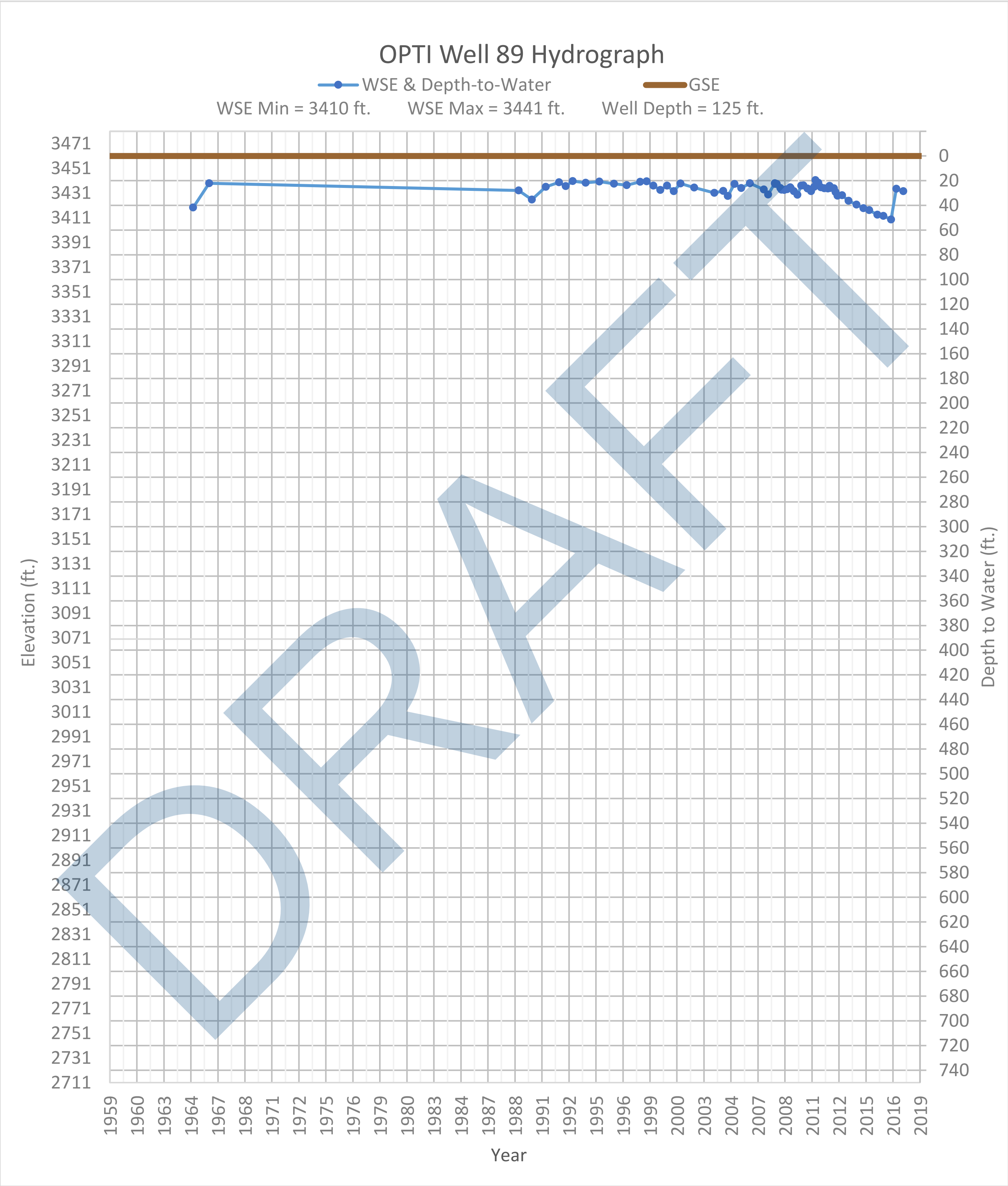
2019
DRAFT



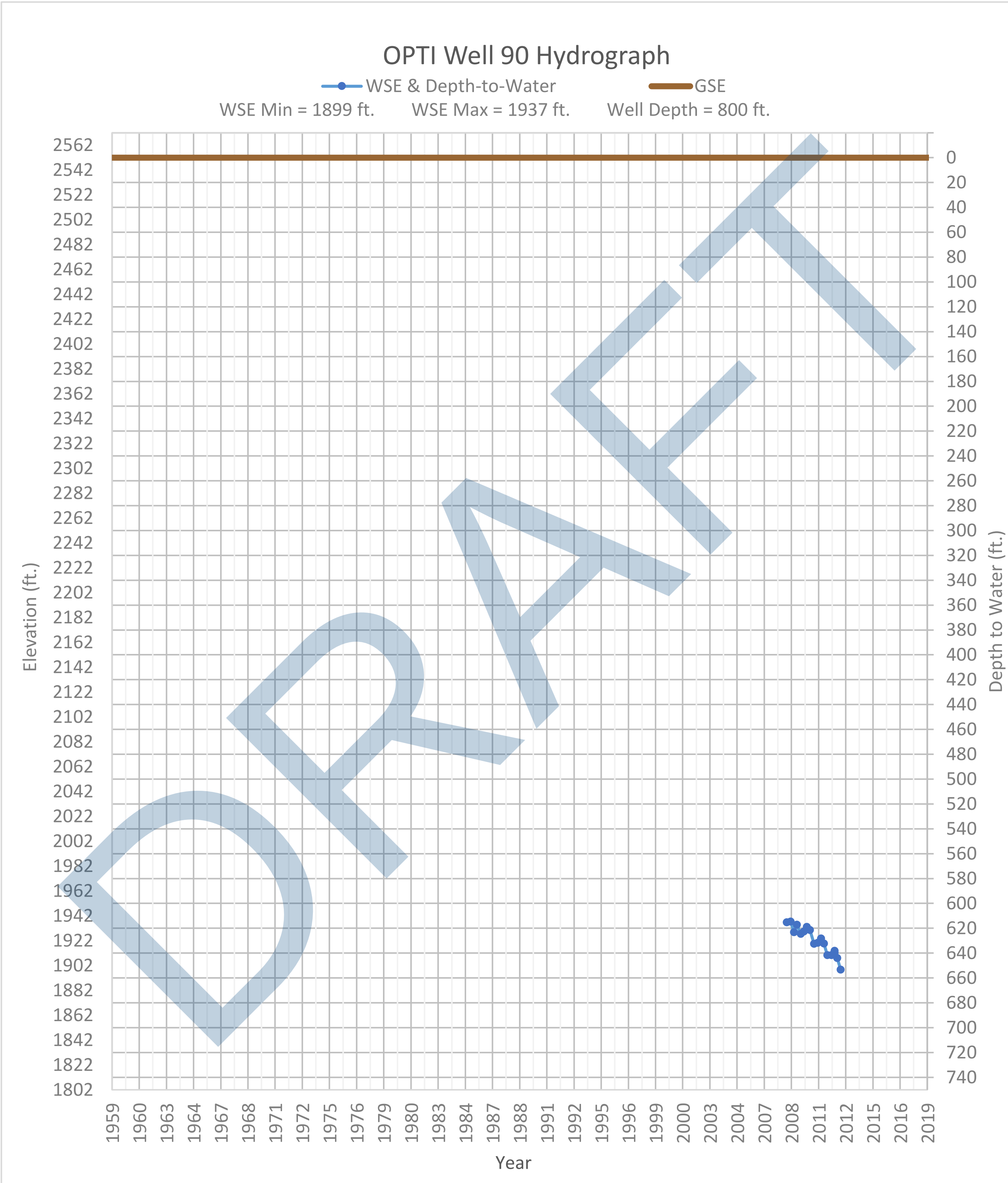
OPTI Well 87 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3358 ft.
WSE Max = 3378 ft.
Well Depth = 232 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



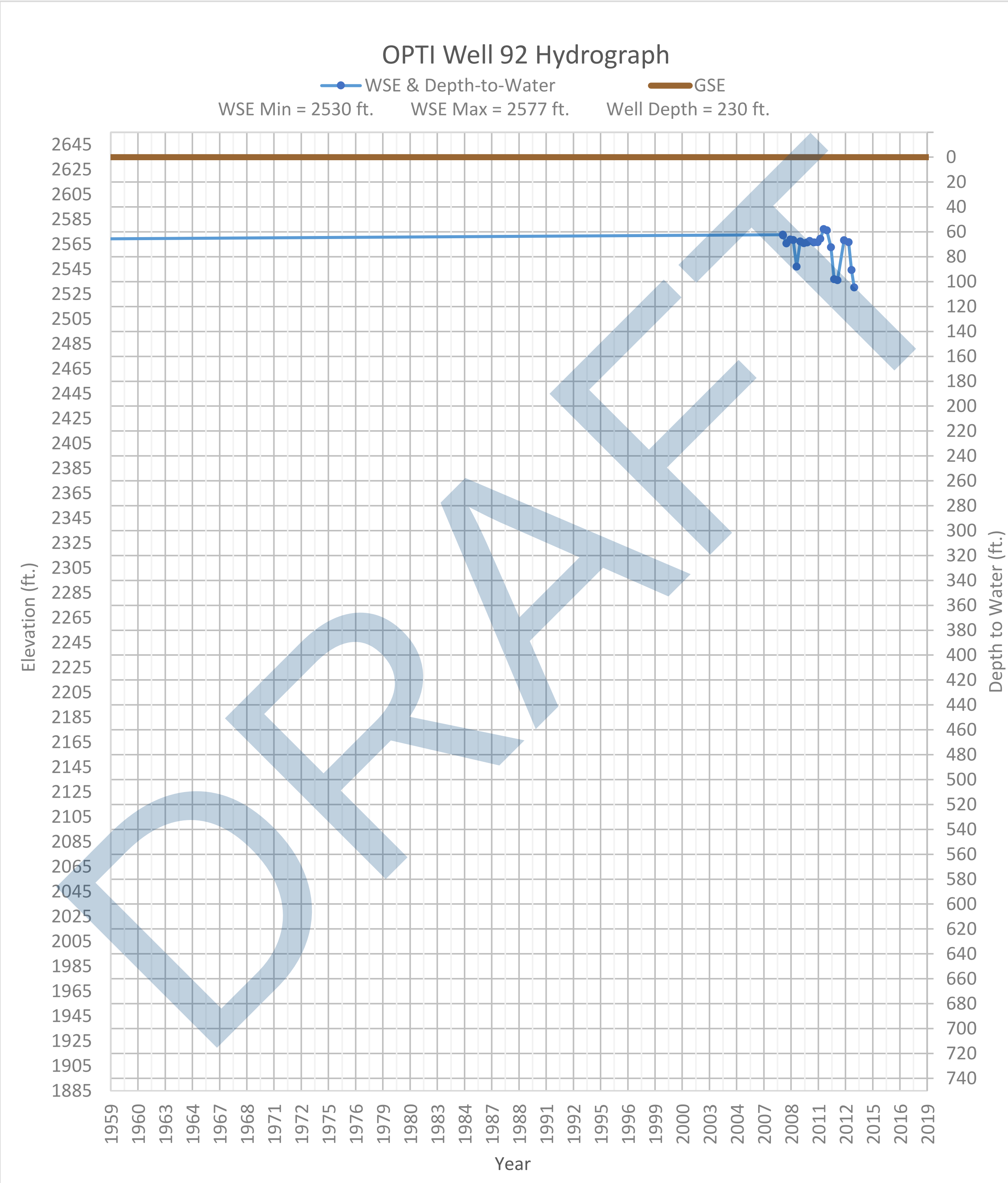
OPTI Well 88 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3276 ft.
WSE Max = 3322 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



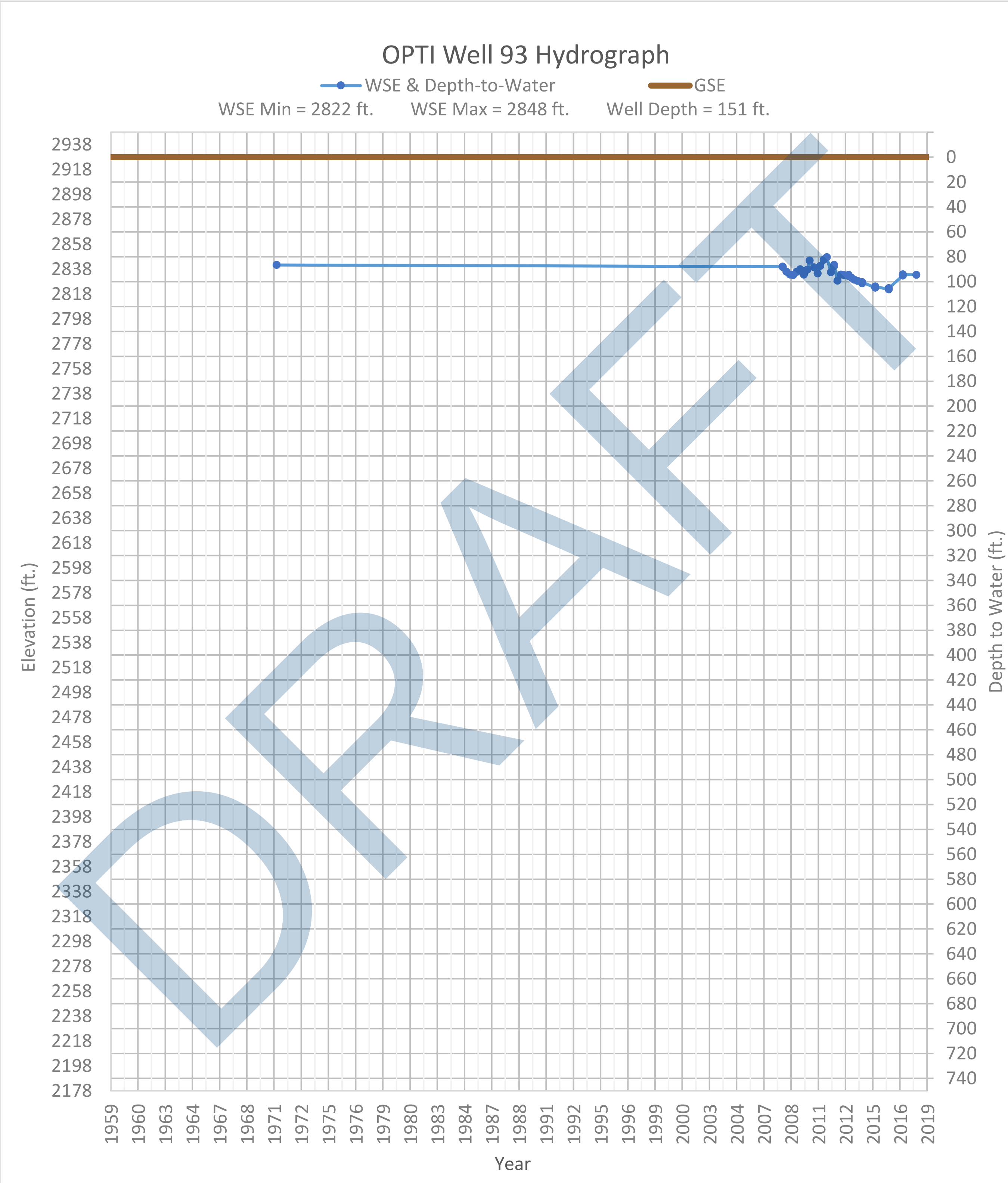
OPTI Well 89 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3410 ft.
WSE Max = 3441 ft.
Well Depth = 125 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 90 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1899 ft.
WSE Max = 1937 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

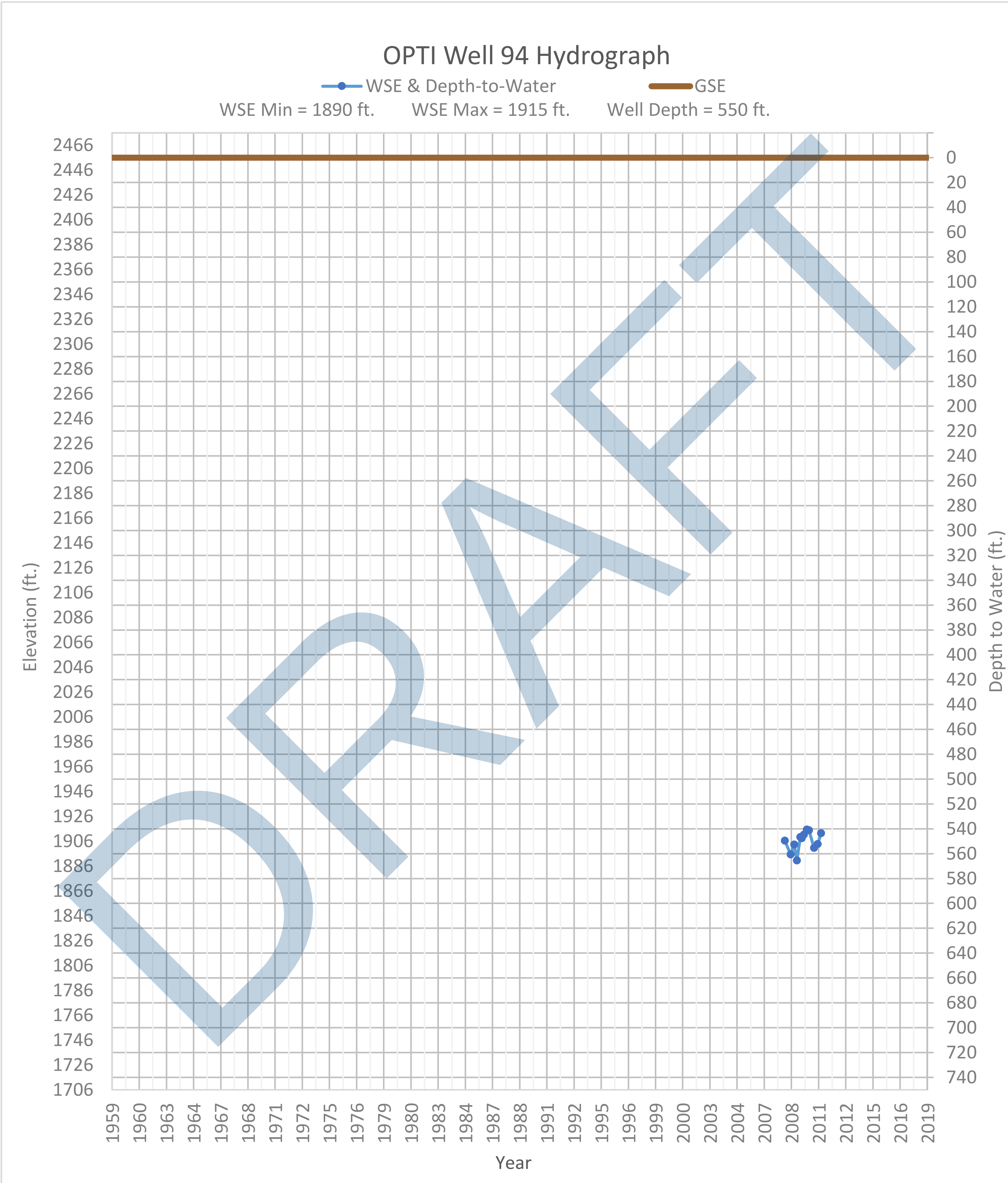
OPTI Well 91 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1837 ft.
WSE Max = 1915 ft.
Well Depth = 980 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

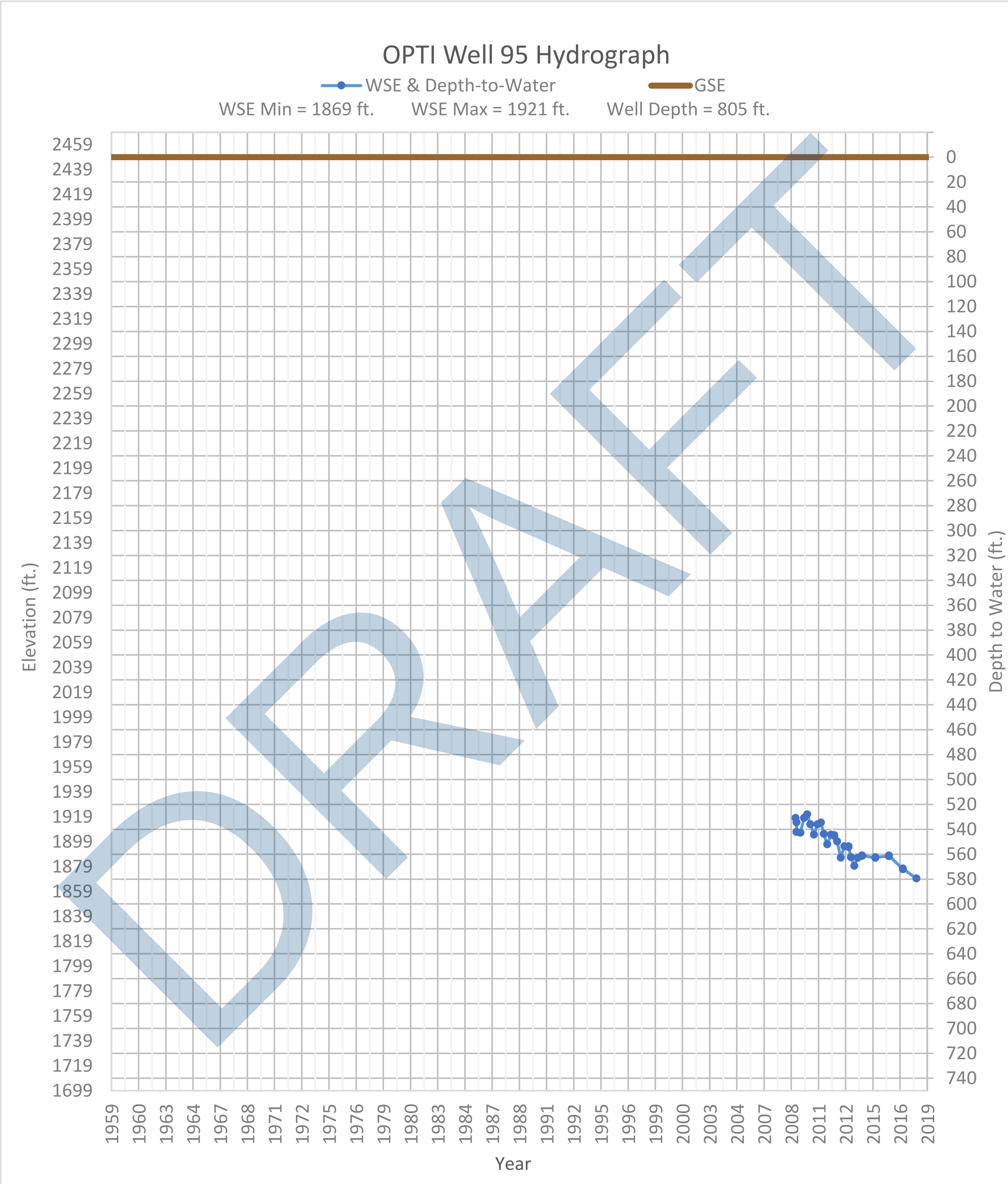


OPTI Well 92 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2530 ft.
WSE Max = 2577 ft.
Well Depth = 230 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

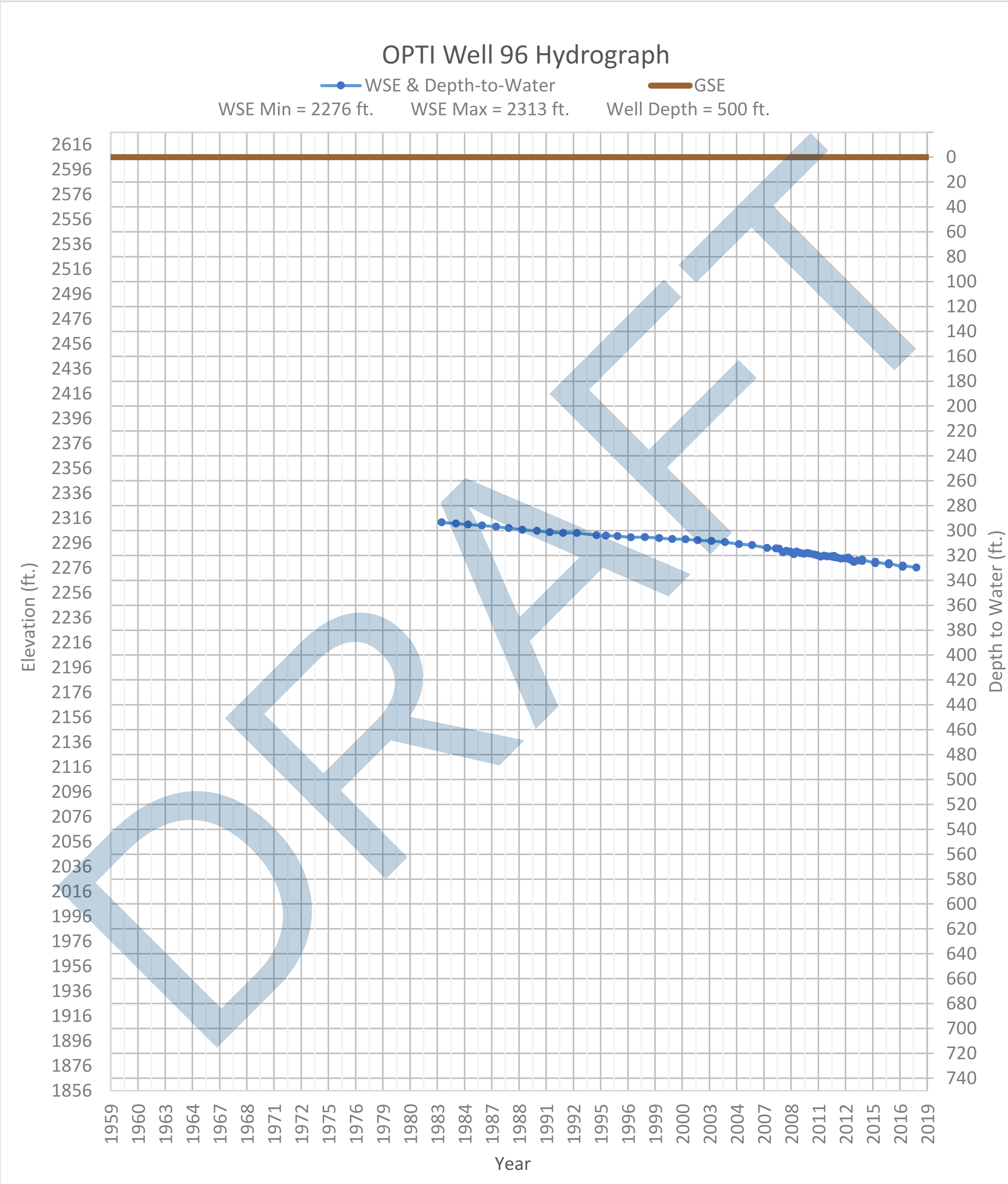


OPTI Well 93 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2822 ft.
WSE Max = 2848 ft.
Well Depth = 151 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 94 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1890 ft.
WSE Max = 1915 ft.
Well Depth = 550 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 95 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1869 ft.
WSE Max = 1921 ft.
Well Depth = 805 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 96 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2276 ft.
WSE Max = 2313 ft.
Well Depth = 500 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2616
2596
2576
2556
2536
2516
2496
2476
2456
2436
2416
2396
2376
2356
2336
2316
2296
2276
2256
2236
2216
2196
2176
2156
2136
2116
2096
2076
2056
2036
2016
1996
1976
1956
1936
1916
1896
1876
1856
0
20
40
60
80
100
120
140
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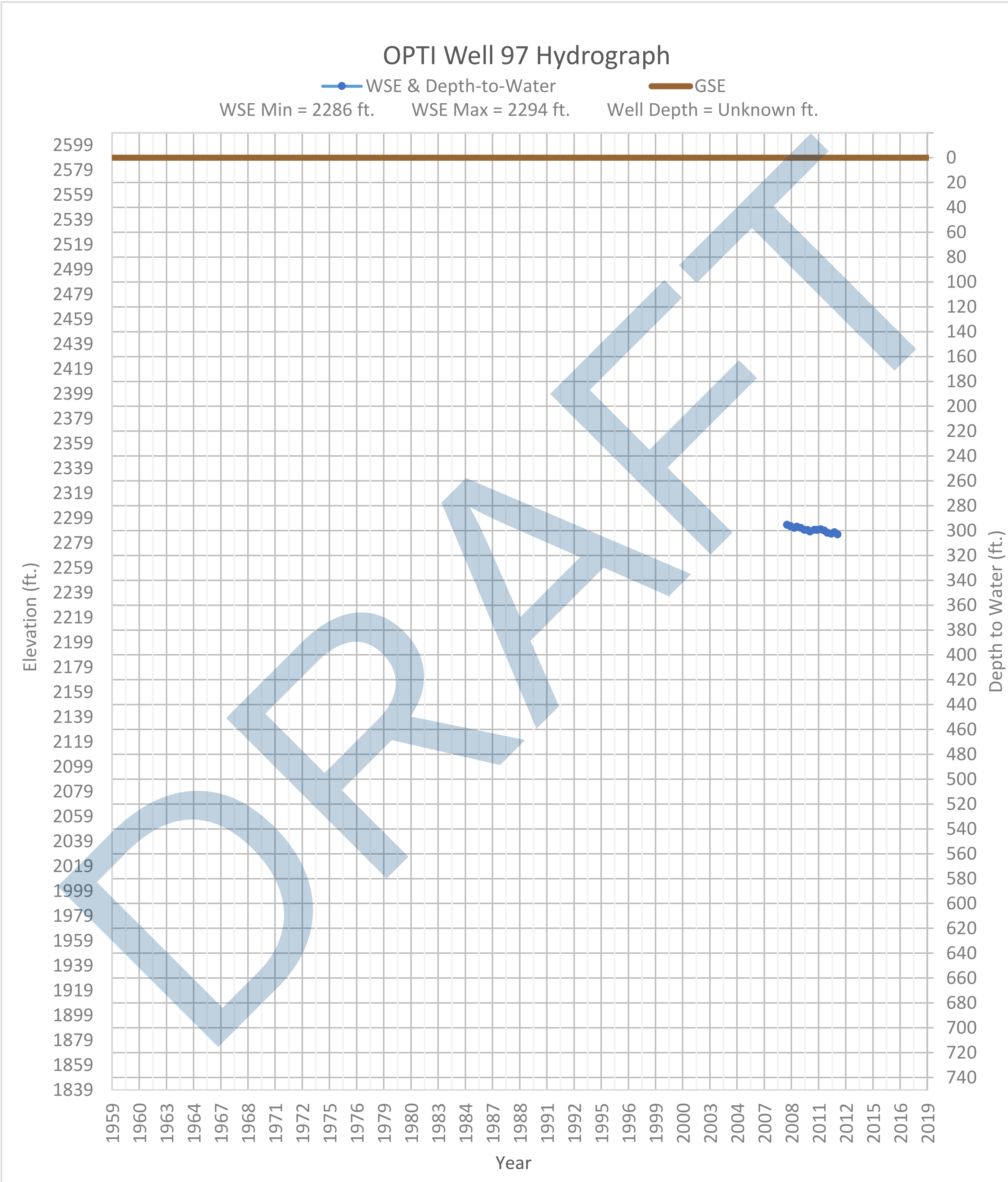
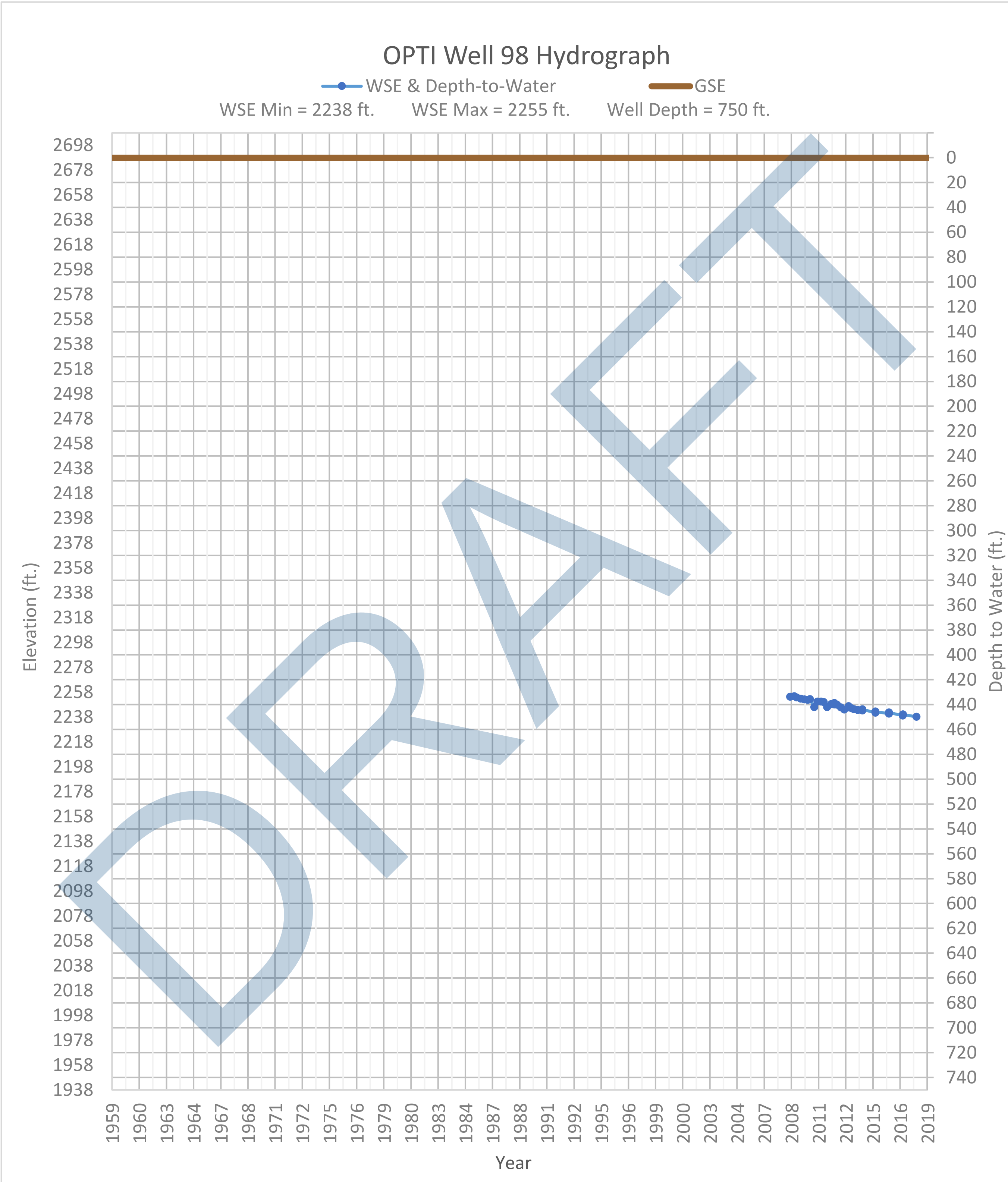
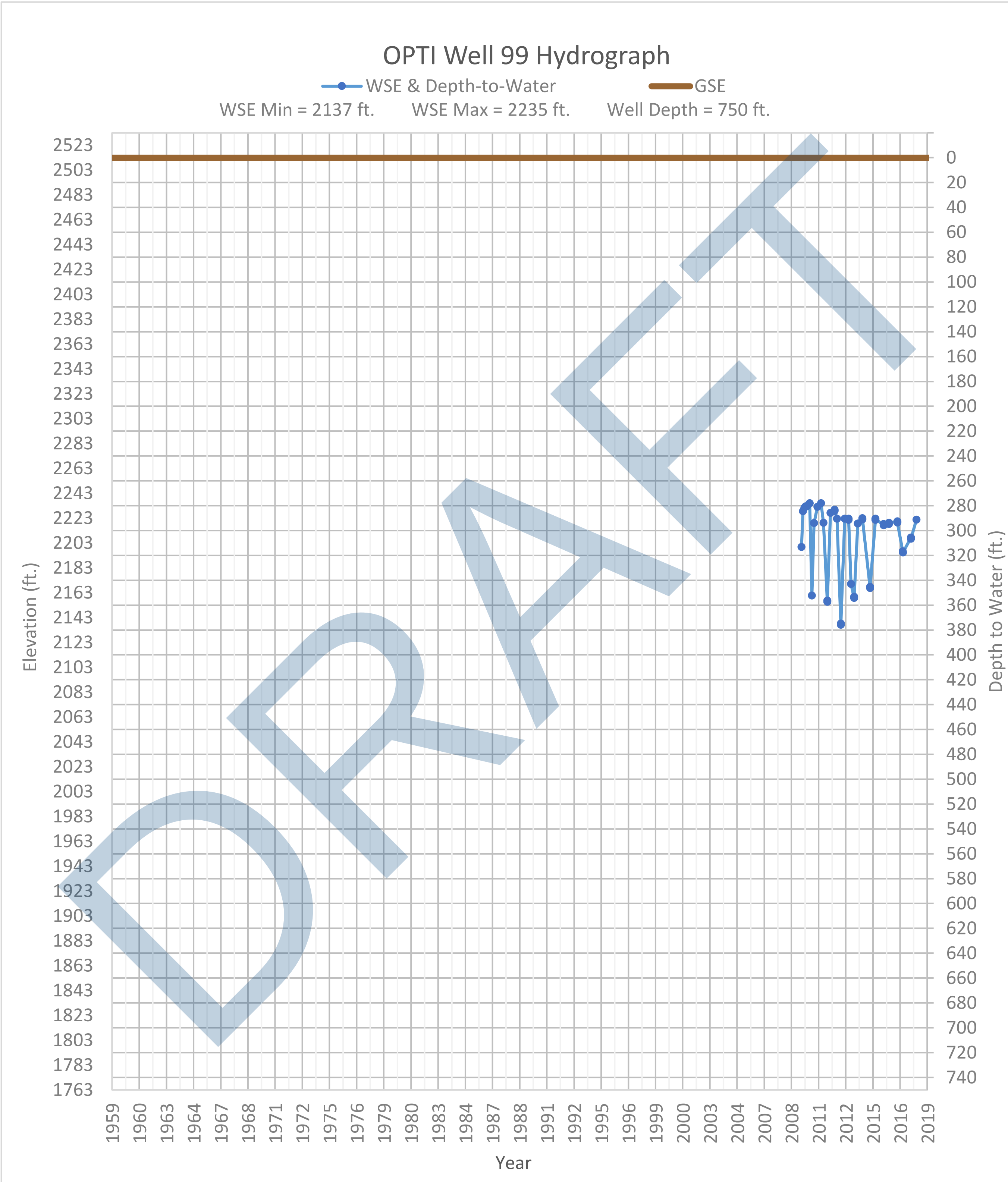


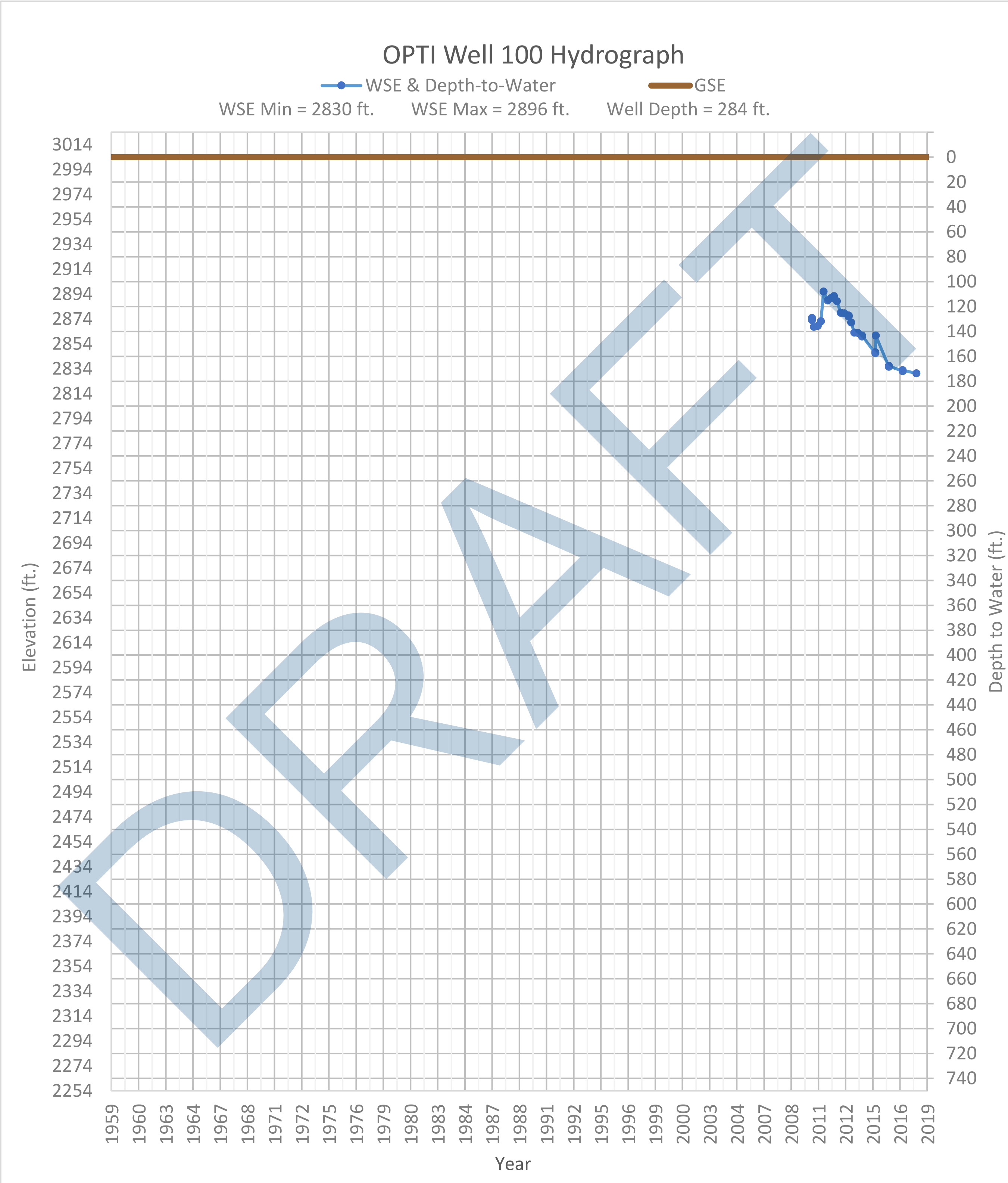
OPTI Well 97 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2286 ft.
WSE Max = 2294 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



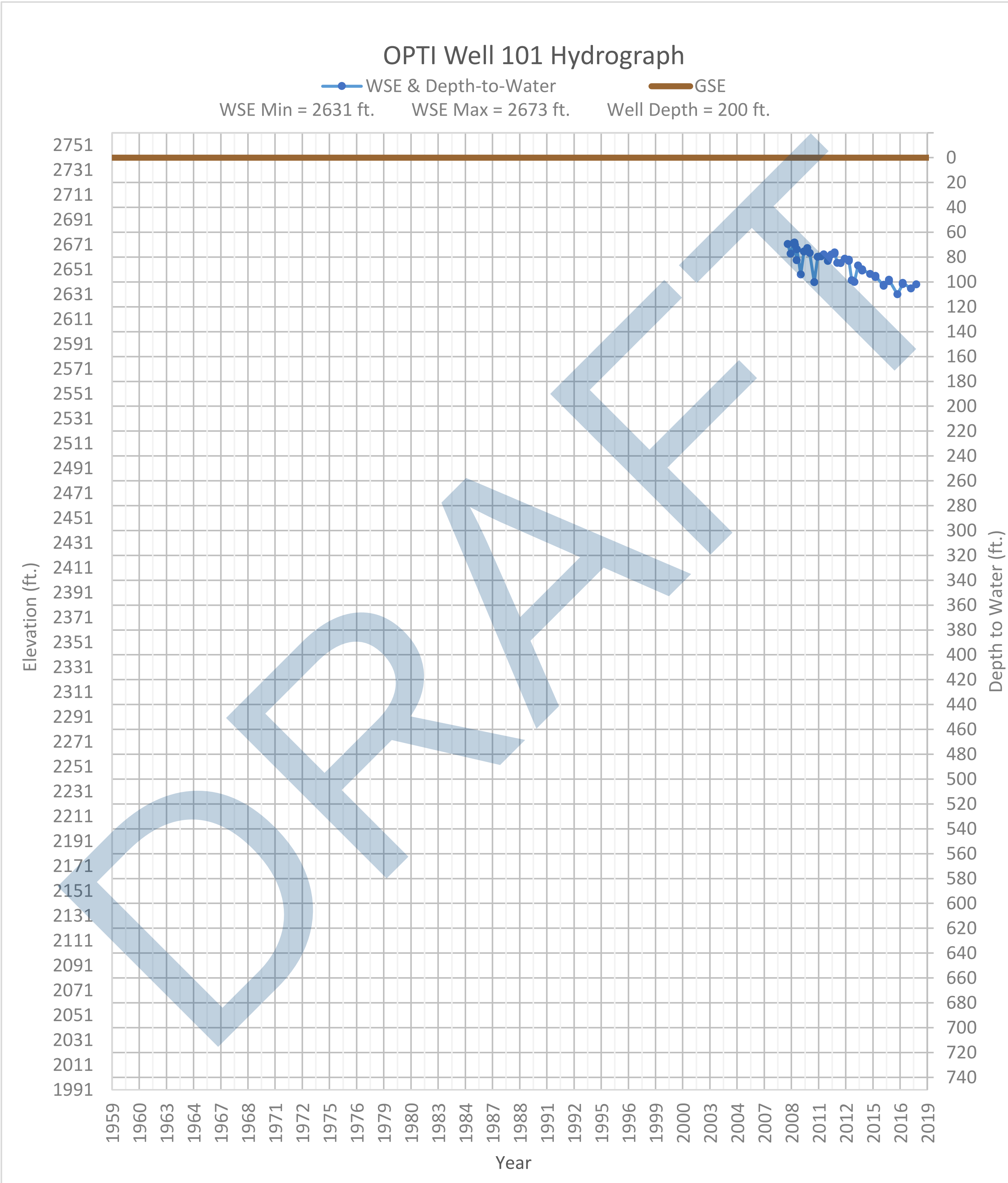
OPTI Well 98 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2238 ft.
WSE Max = 2255 ft.
Well Depth = 750 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



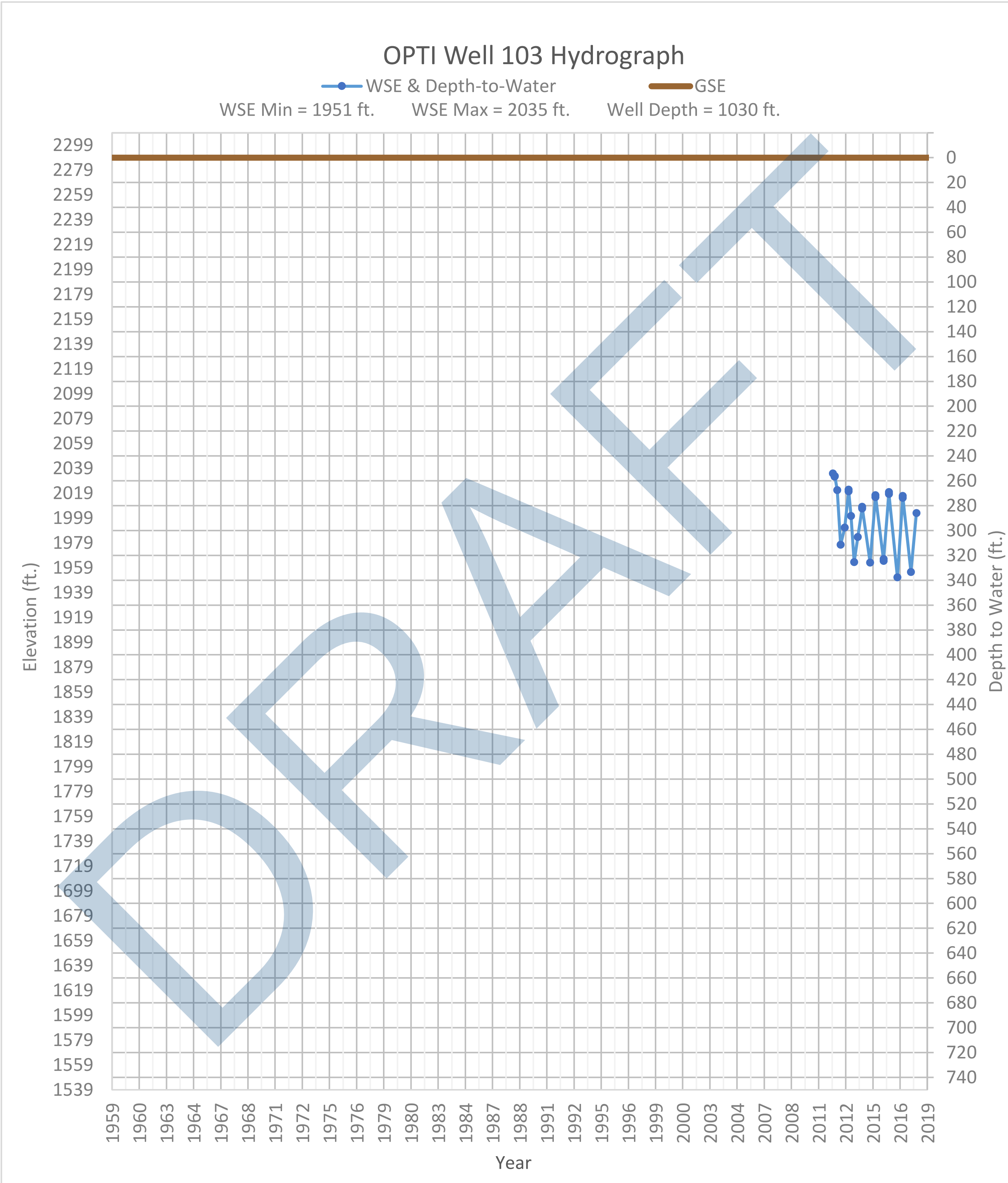
OPTI Well 99 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2137 ft.
WSE Max = 2235 ft.
Well Depth = 750 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



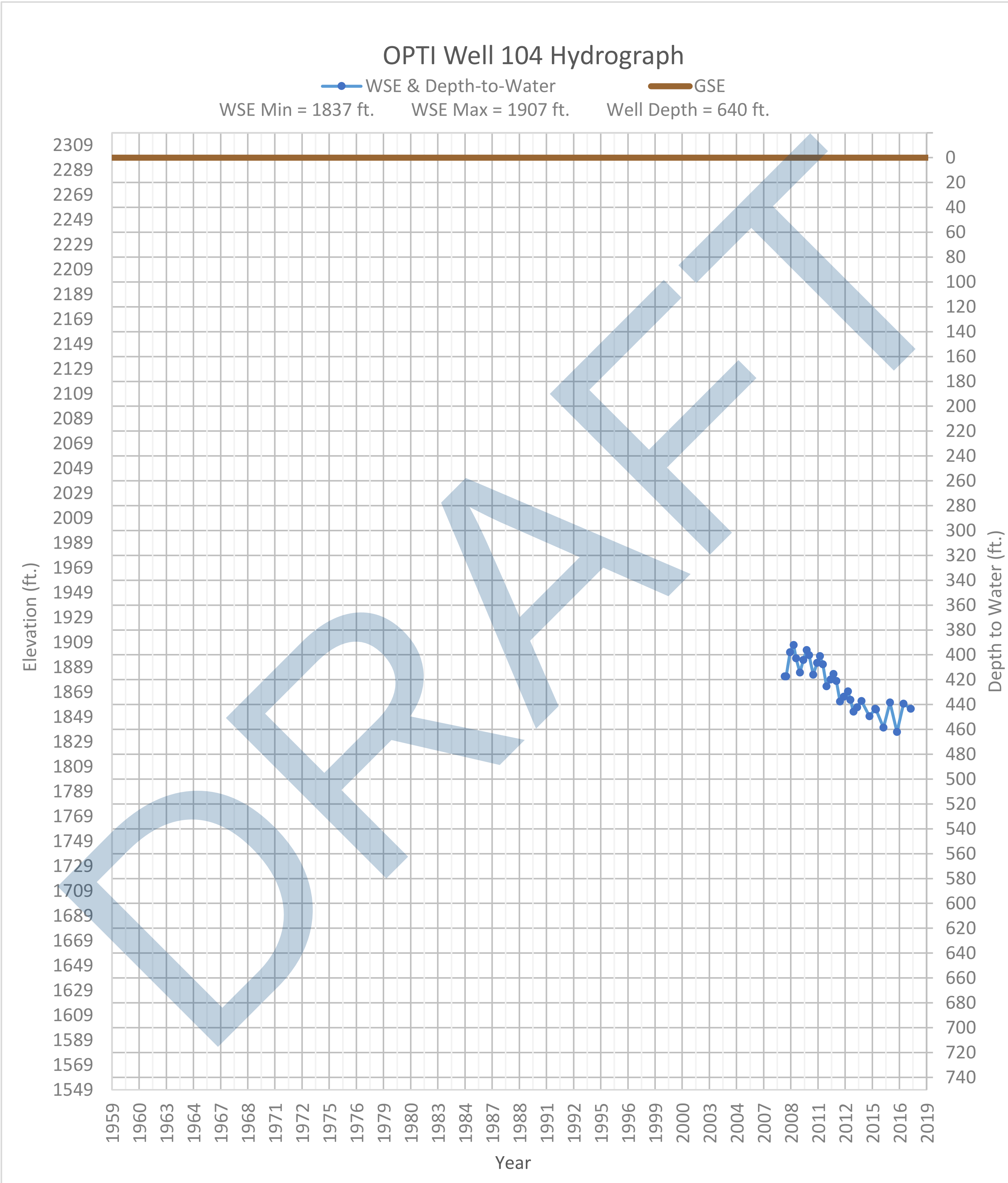
OPTI Well 100 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2830 ft.
WSE Max = 2896 ft.
Well Depth = 284 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 101 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2631 ft.
WSE Max = 2673 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

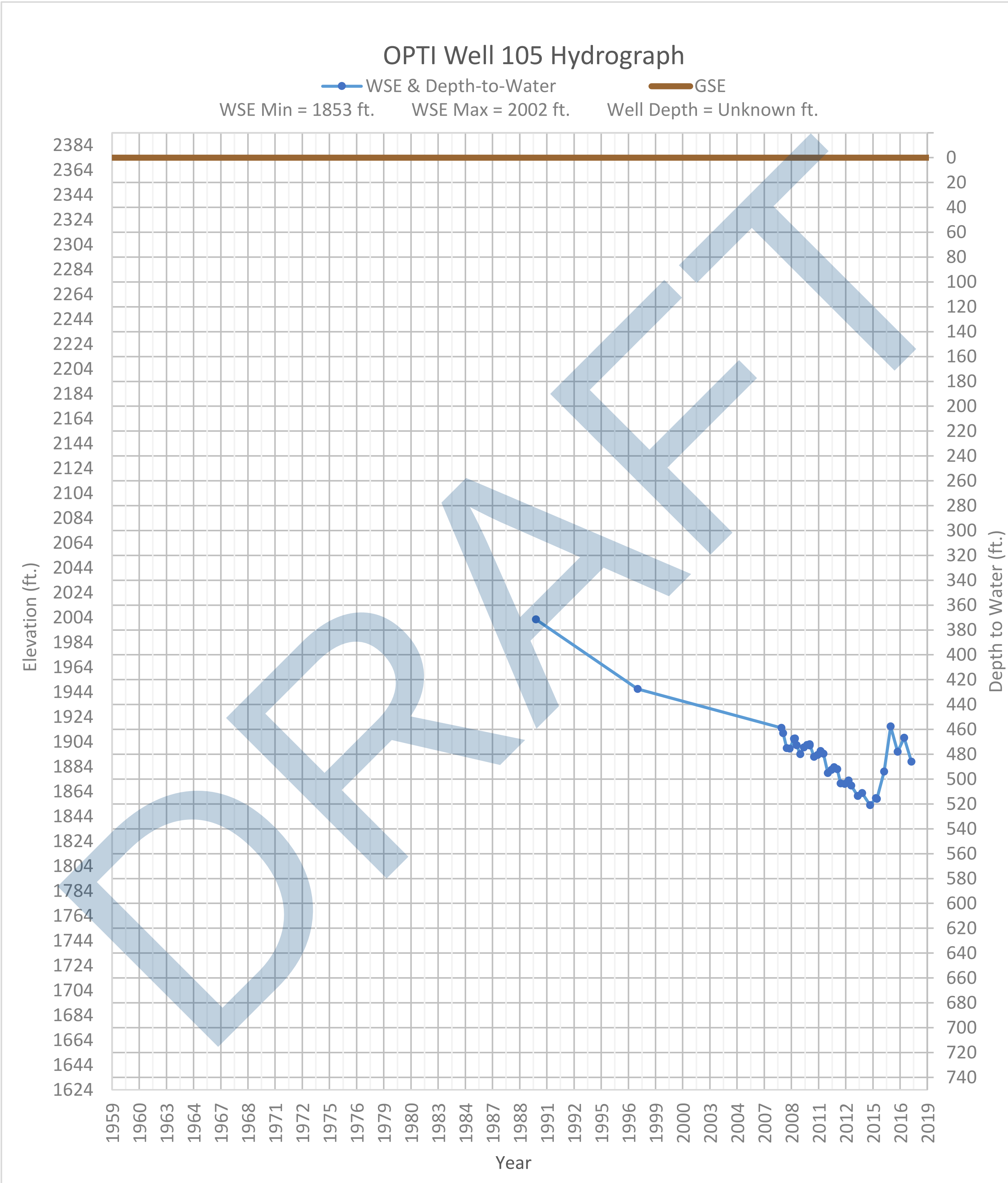
OPTI Well 102 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1802 ft.
WSE Max = 1861 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



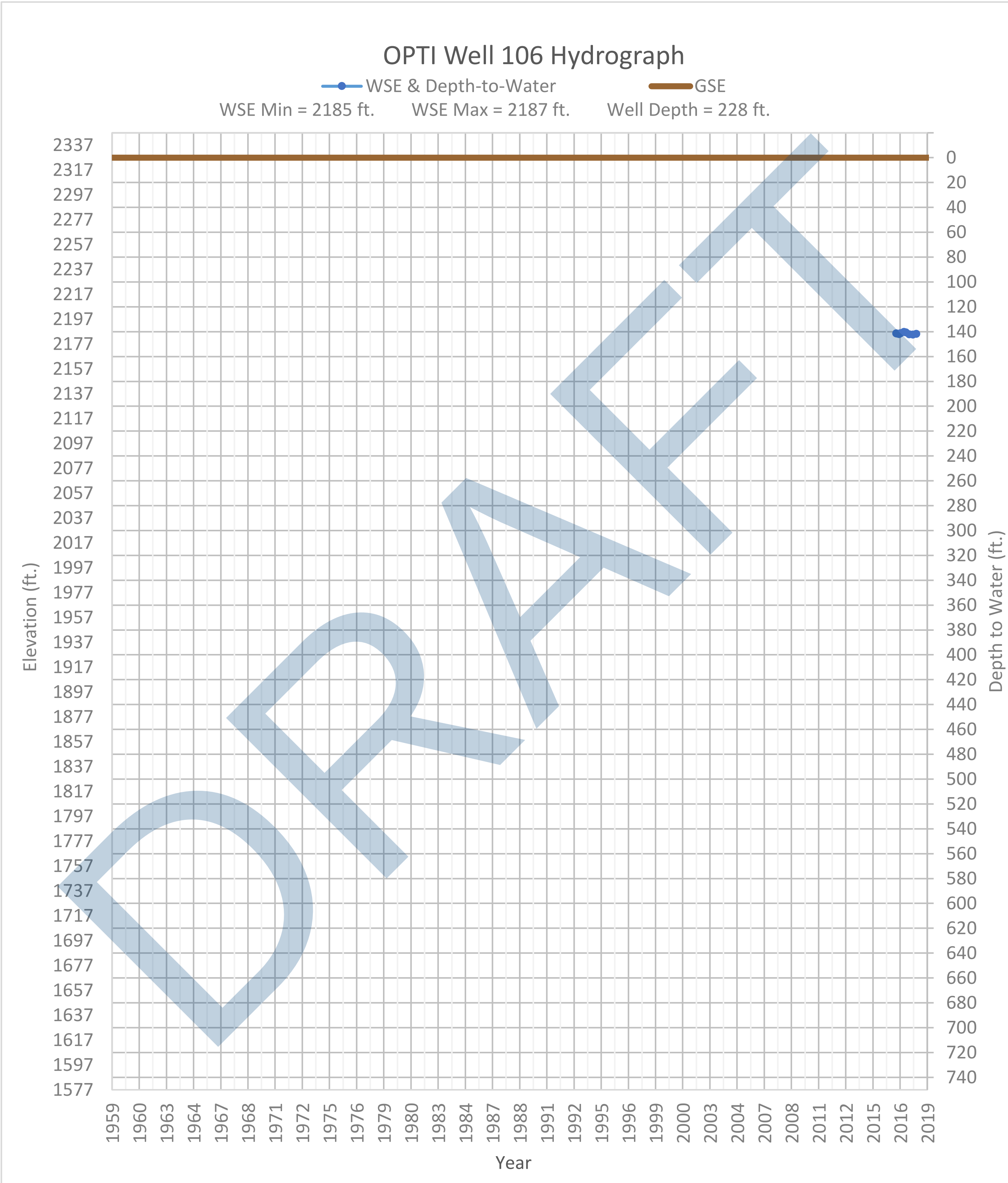
OPTI Well 103 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1951 ft.
WSE Max = 2035 ft.
Well Depth = 1030 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

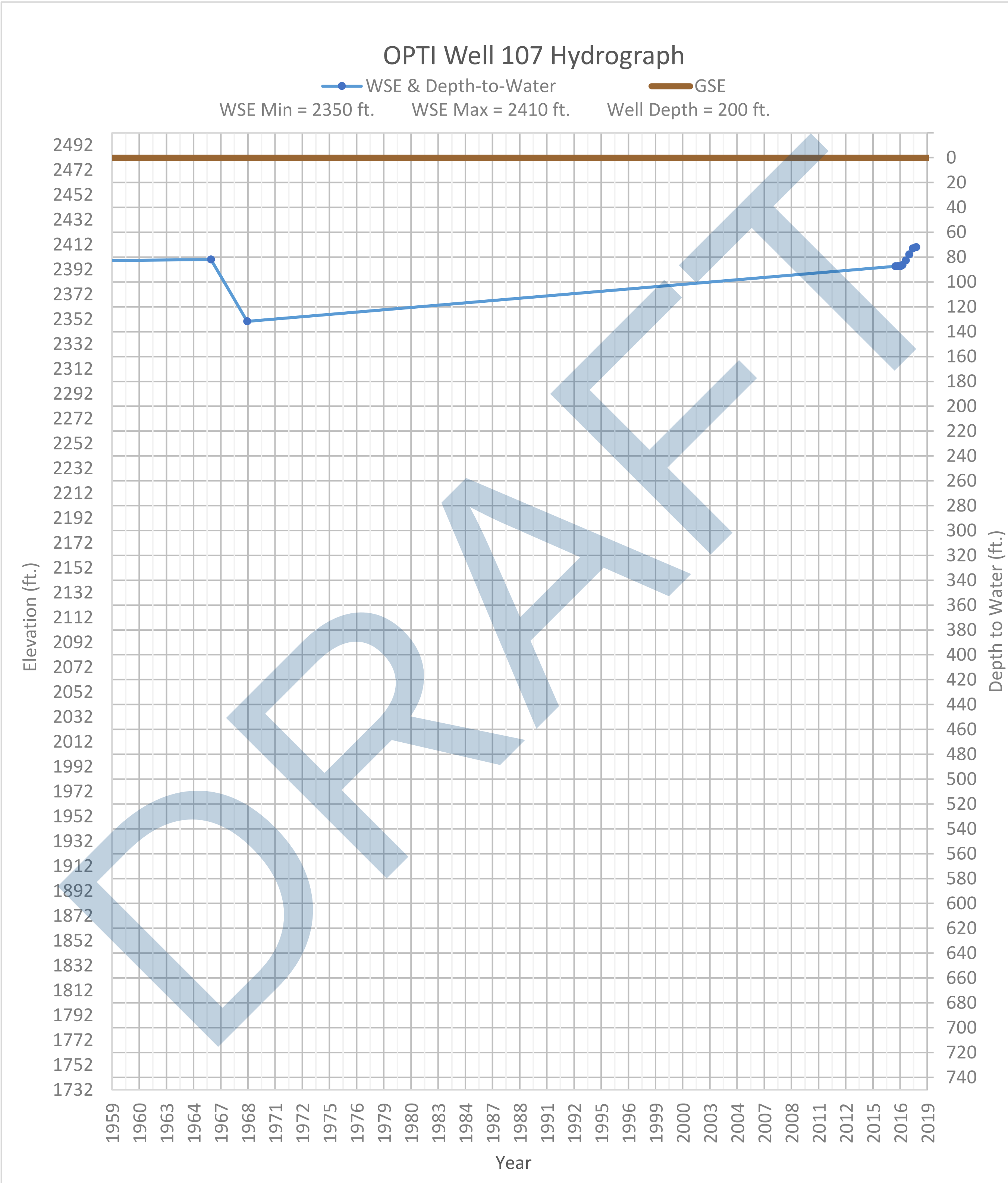


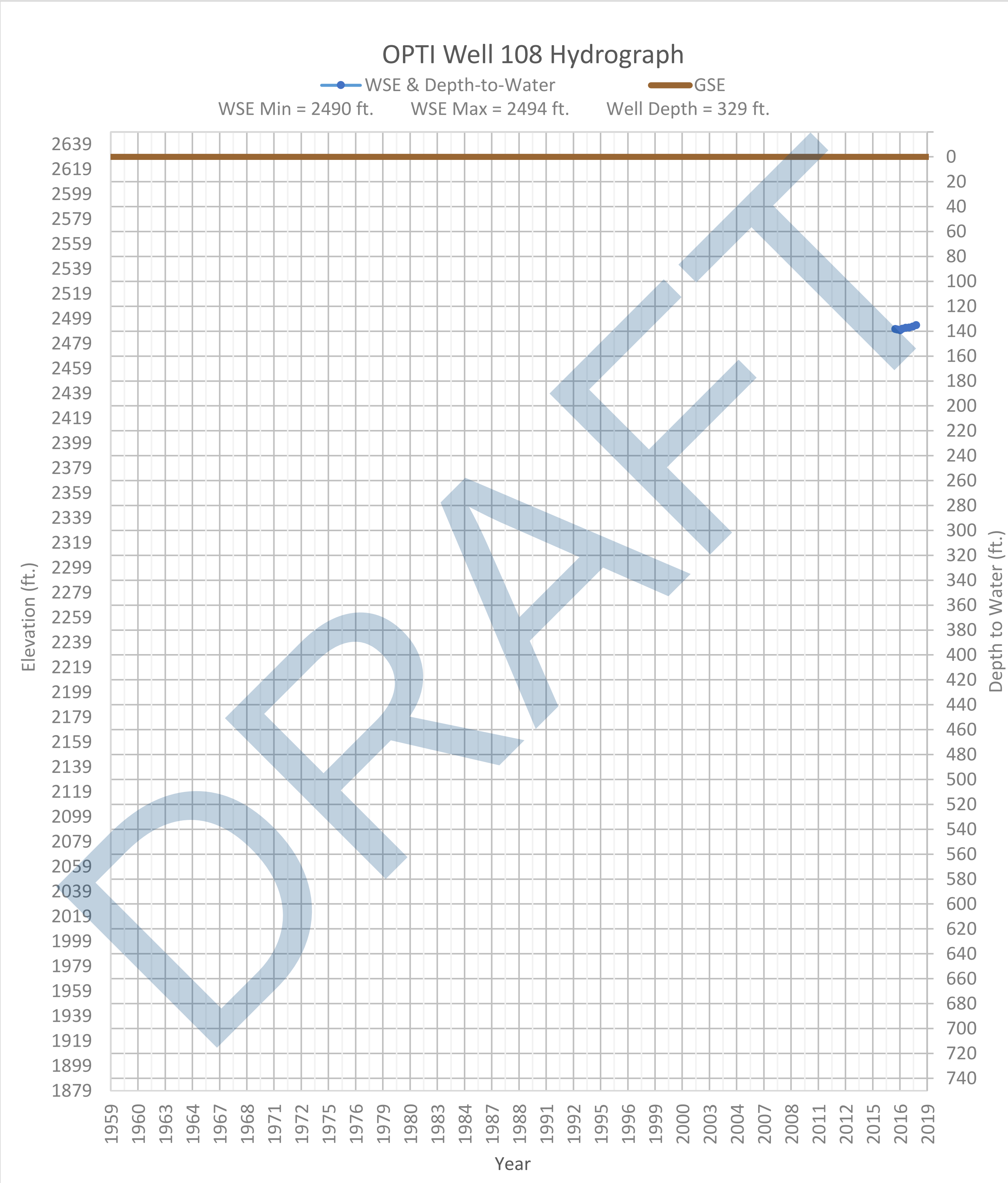
OPTI Well 104 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1837 ft.
WSE Max = 1907 ft.
Well Depth = 640 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2309 2289 2269 2249 2229 2209 2189 2169 2149 2129 2109 2089 2069 2049 2029 2009 1989 1969 1949 1929 1909 1889 1869 1849 1829 1809 1789 1769 1749 1729 1709 1689 1669 1649 1629 1609 1589 1569 1549
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT

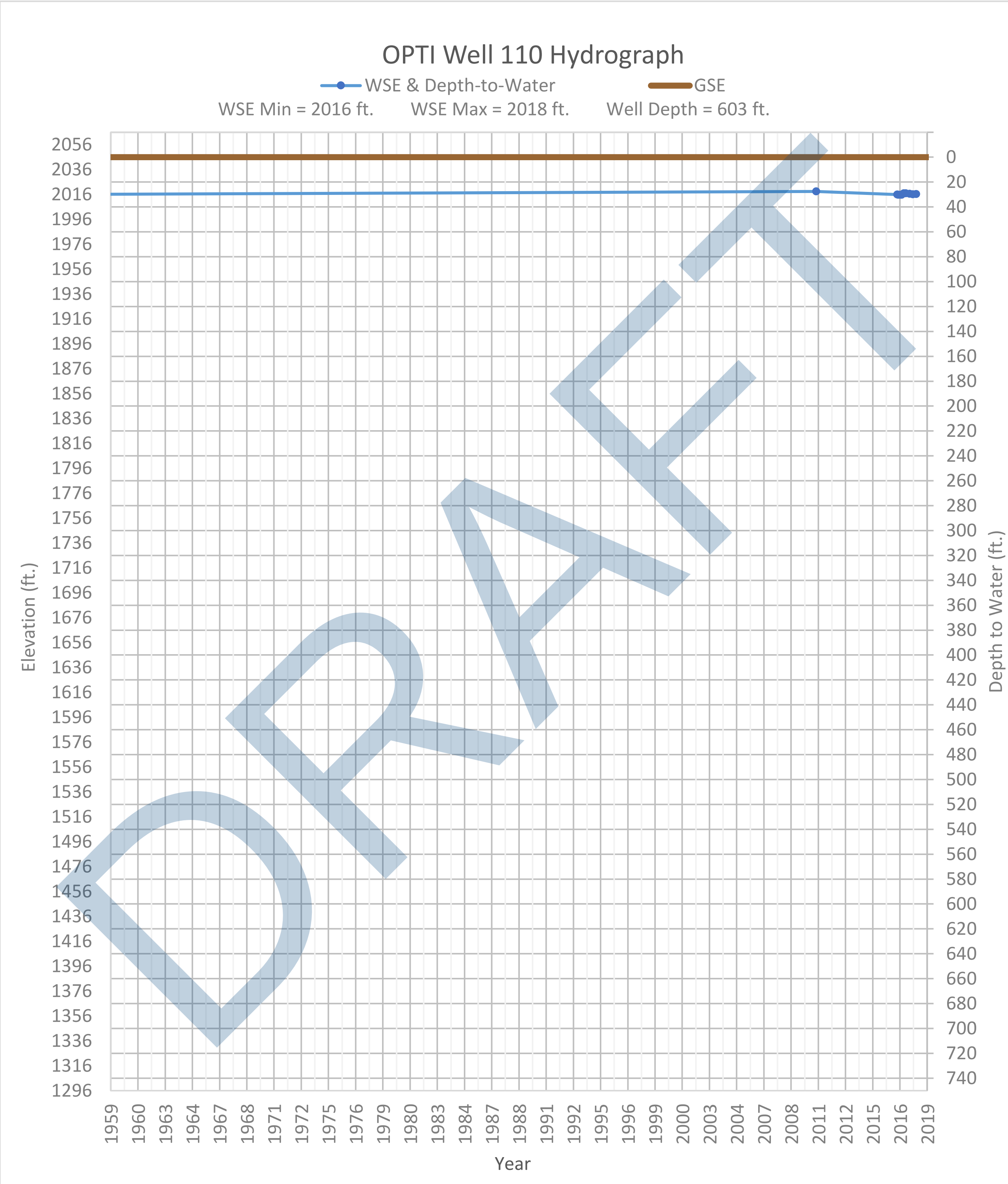


OPTI Well 105 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1853 ft.
WSE Max = 2002 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

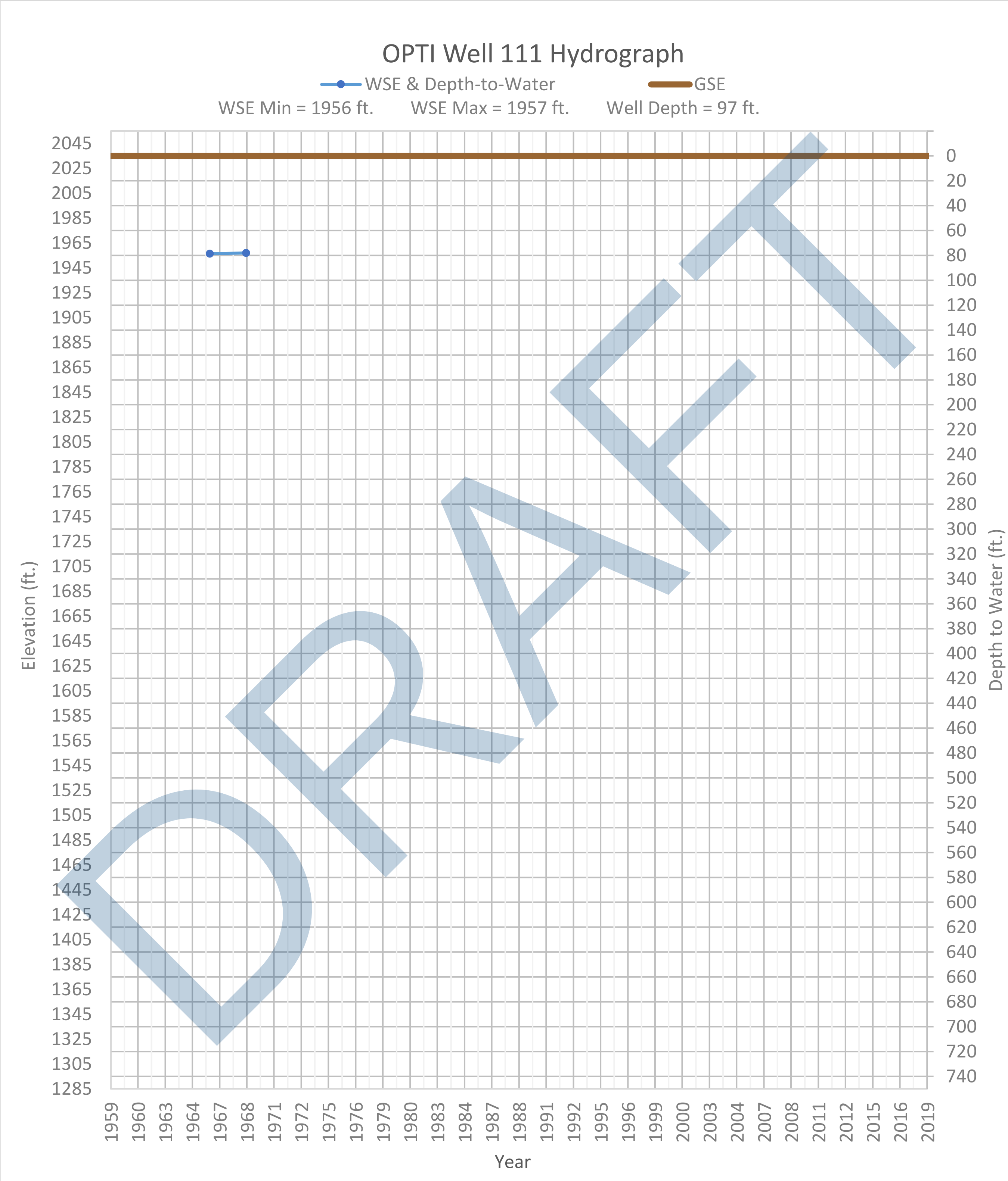

OPTI Well 106 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2185 ft.
WSE Max = 2187 ft.
Well Depth = 228 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

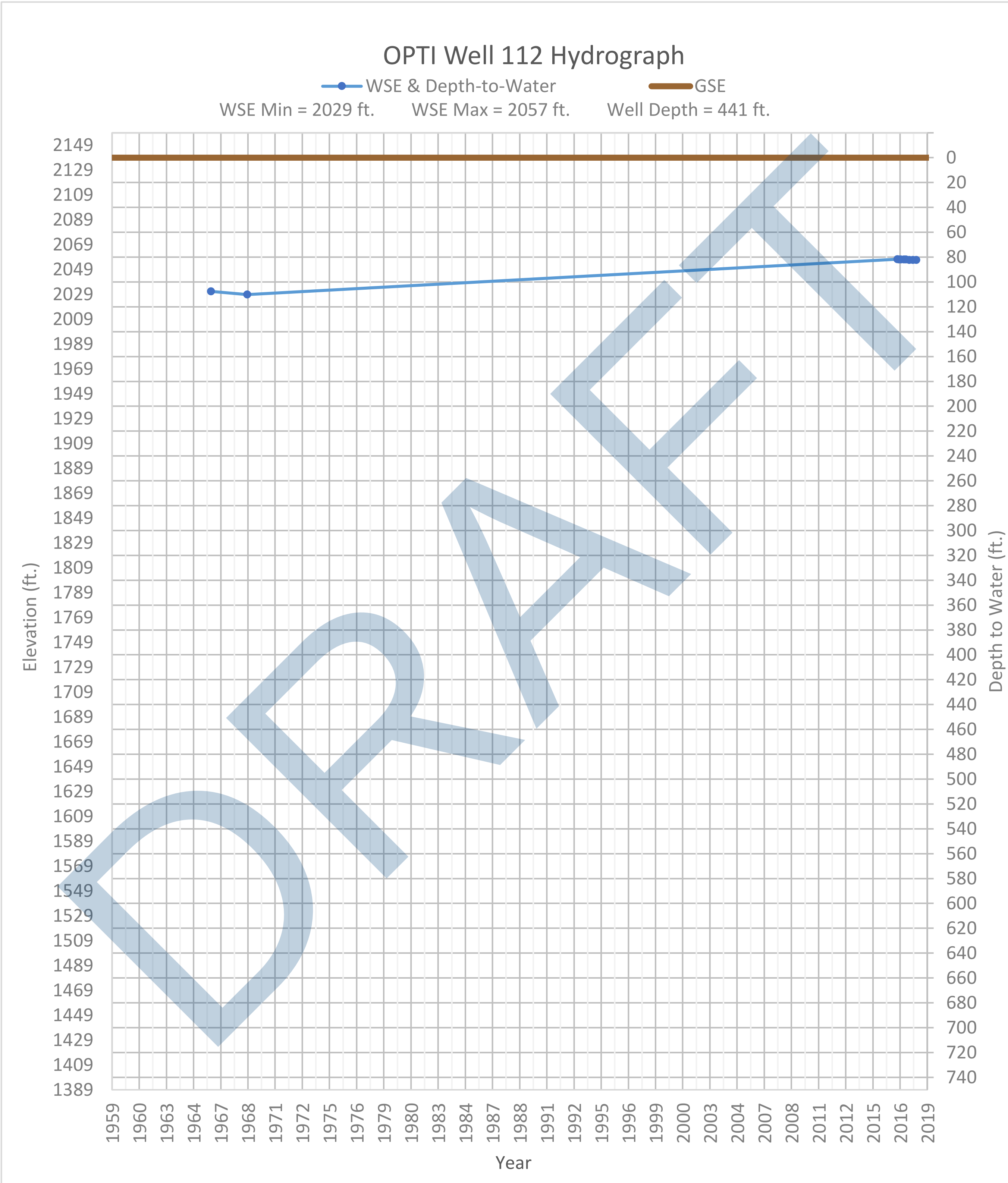

OPTI Well 107 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2350 ft.
WSE Max = 2410 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 108 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2490 ft.
WSE Max = 2494 ft.
Well Depth = 329 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

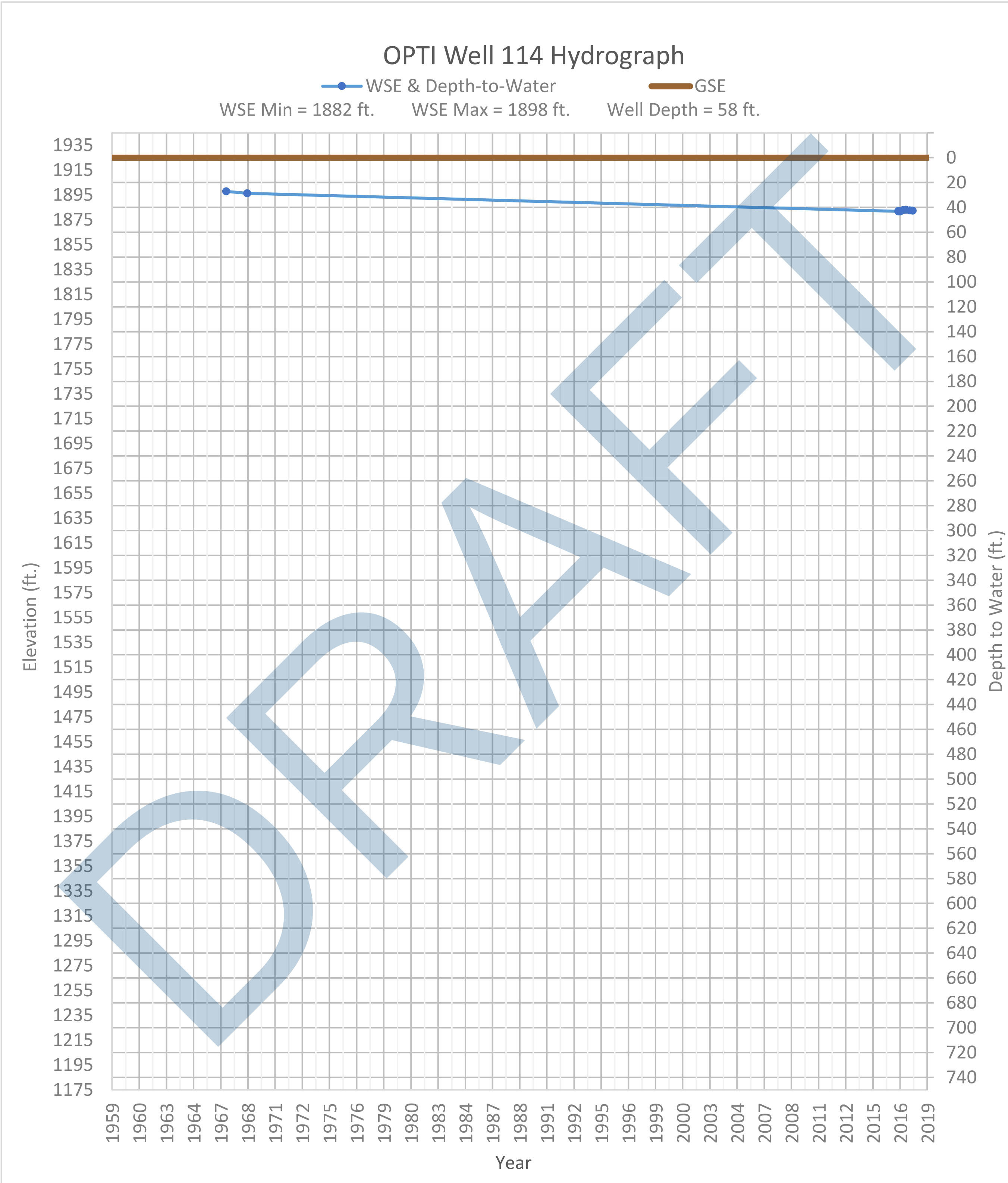


OPTI Well 110 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2016 ft.
WSE Max = 2018 ft.
Well Depth = 603 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

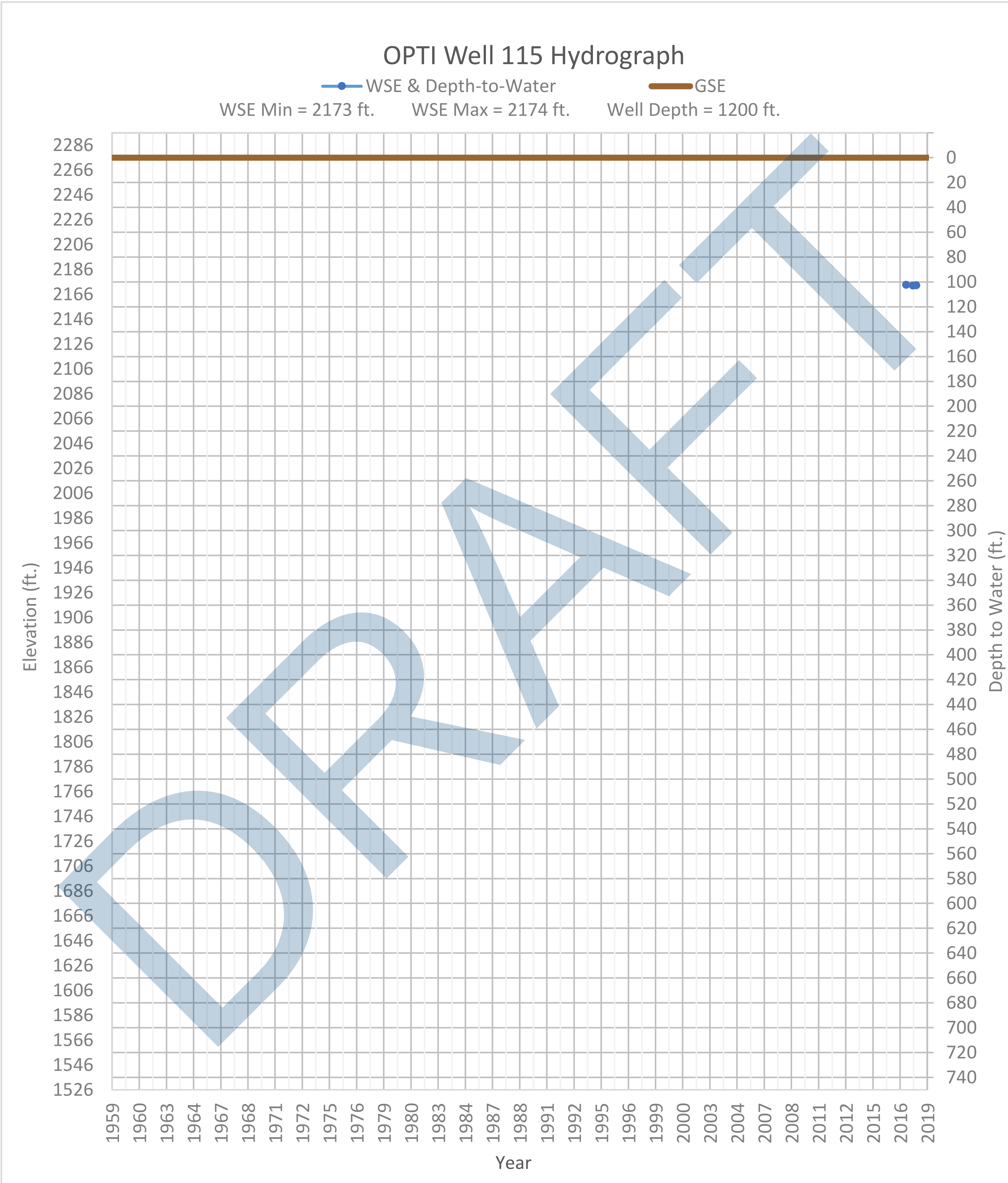

OPTI Well 111 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1956 ft.
WSE Max = 1957 ft.
Well Depth = 97 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



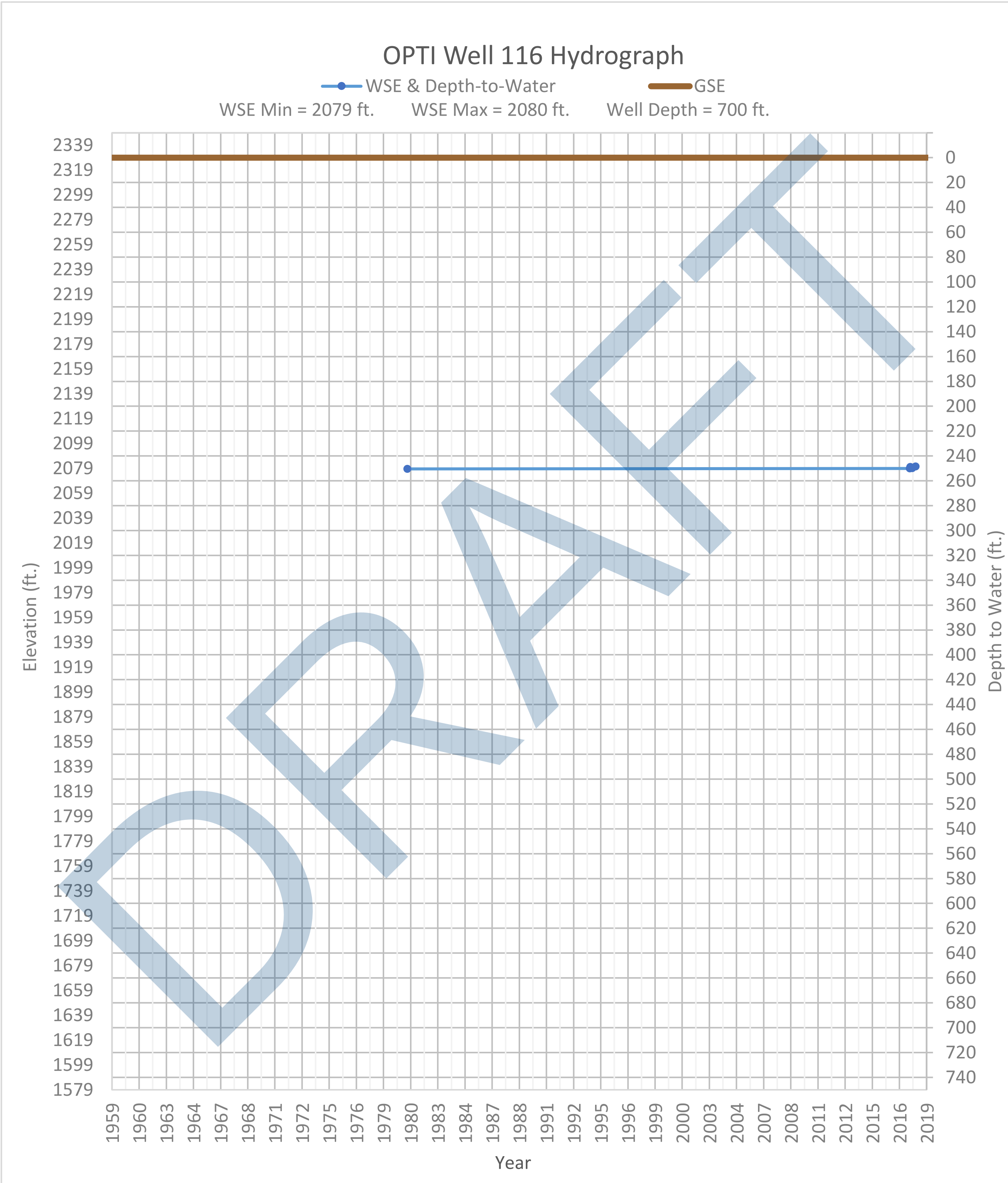
OPTI Well 112 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2029 ft.
WSE Max = 2057 ft.
Well Depth = 441 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



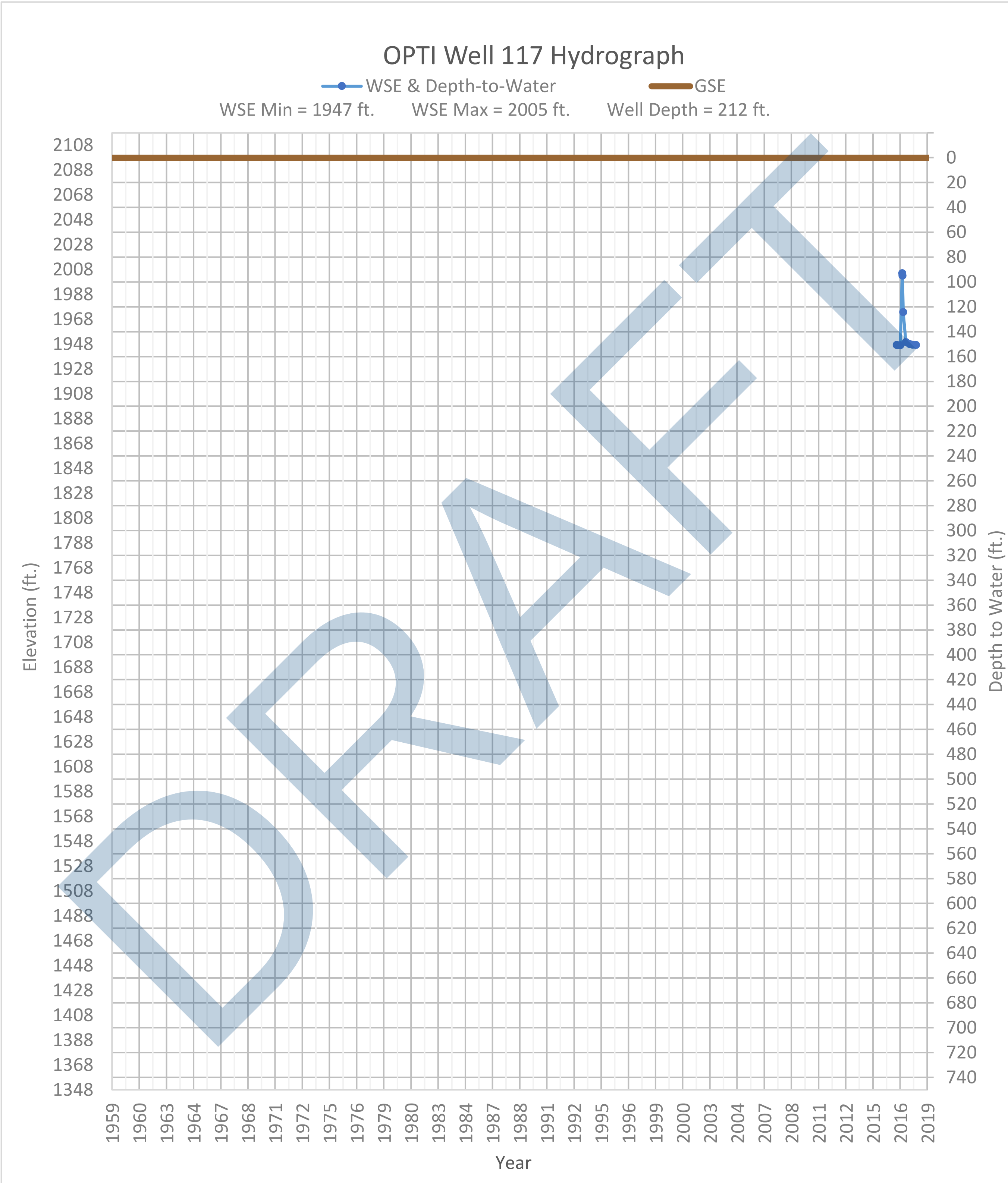
OPTI Well 114 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1882 ft.
WSE Max = 1898 ft.
Well Depth = 58 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



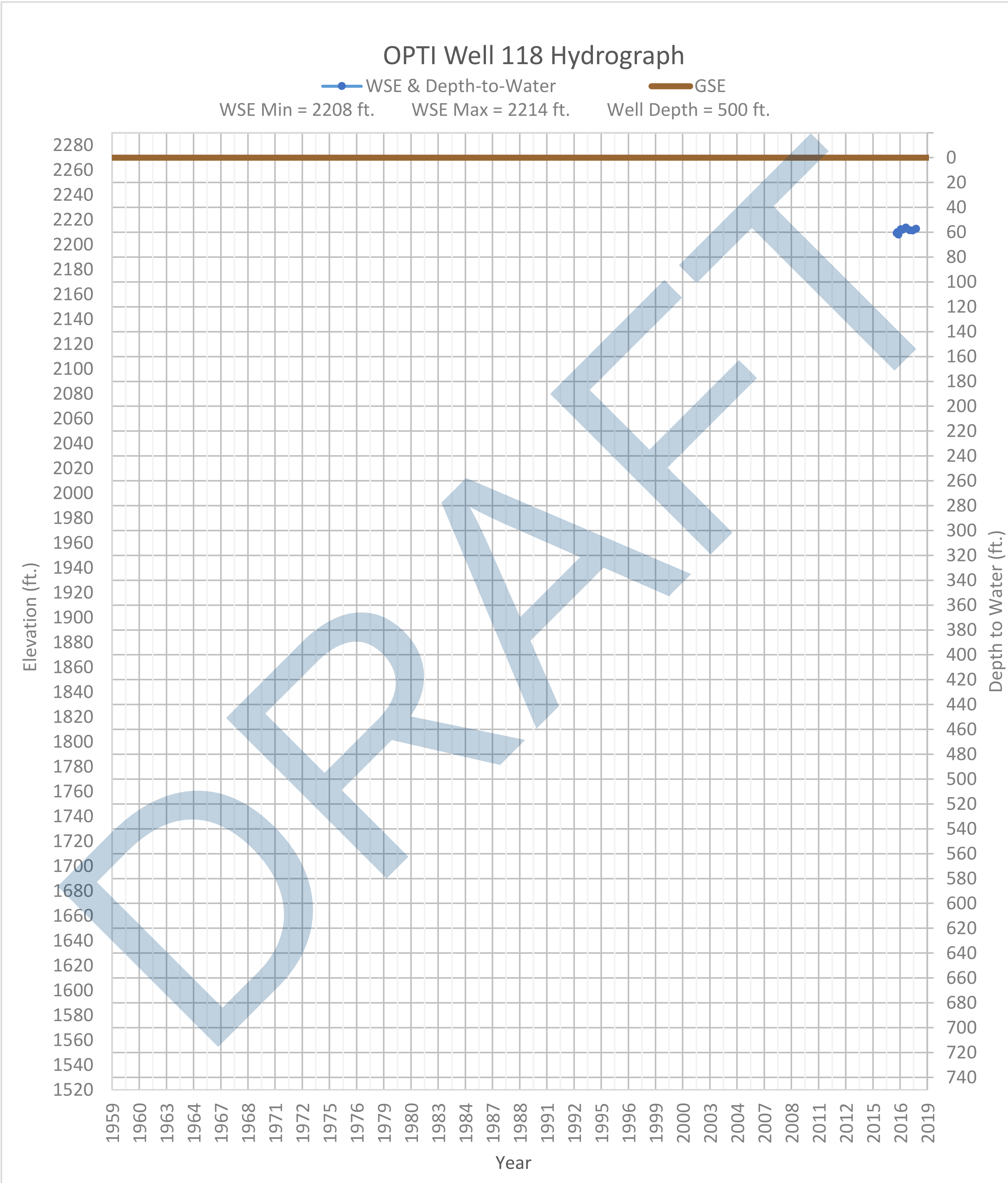
OPTI Well 115 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2173 ft.
WSE Max = 2174 ft.
Well Depth = 1200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



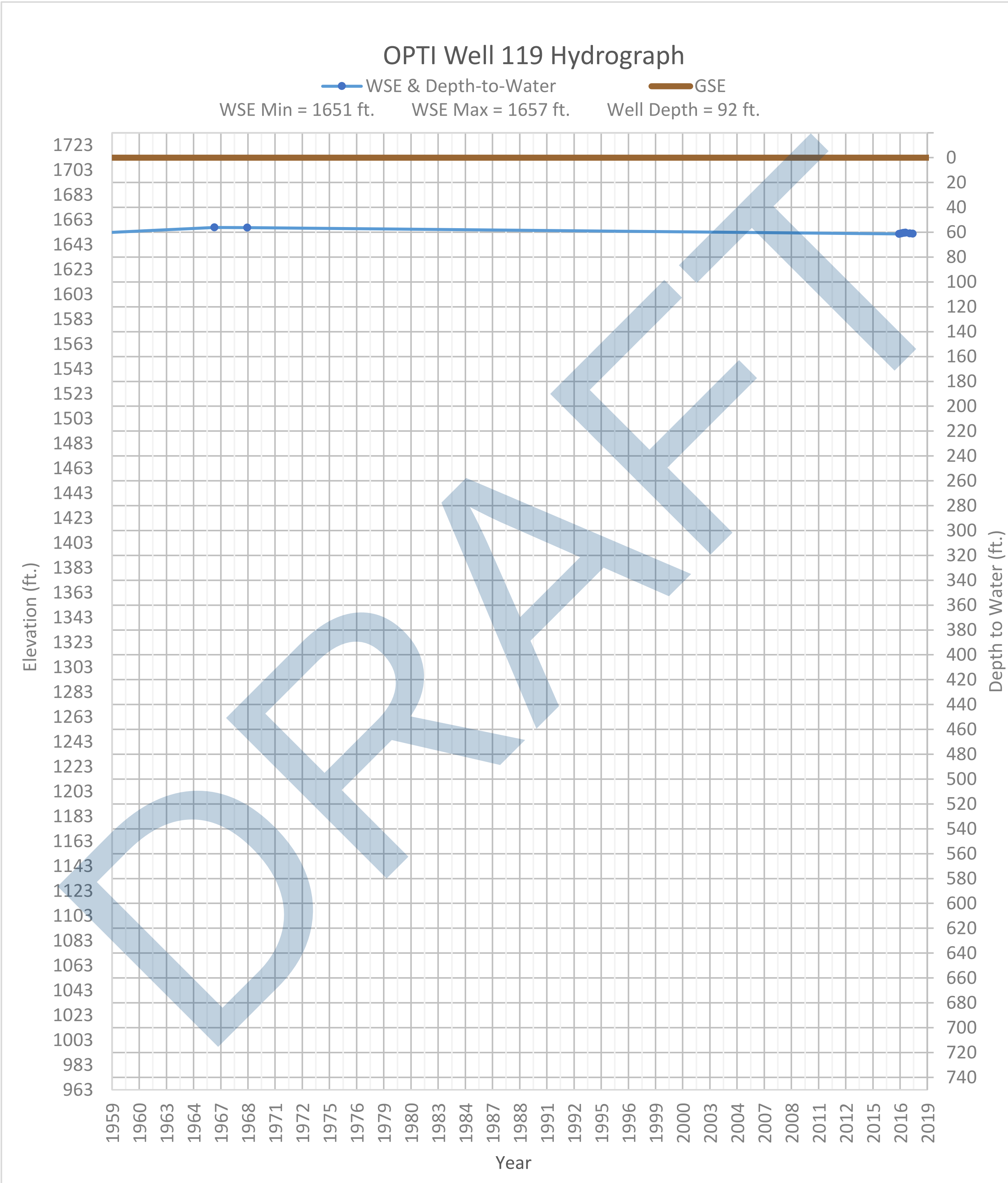
OPTI Well 116 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2079 ft.
WSE Max = 2080 ft.
Well Depth = 700 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



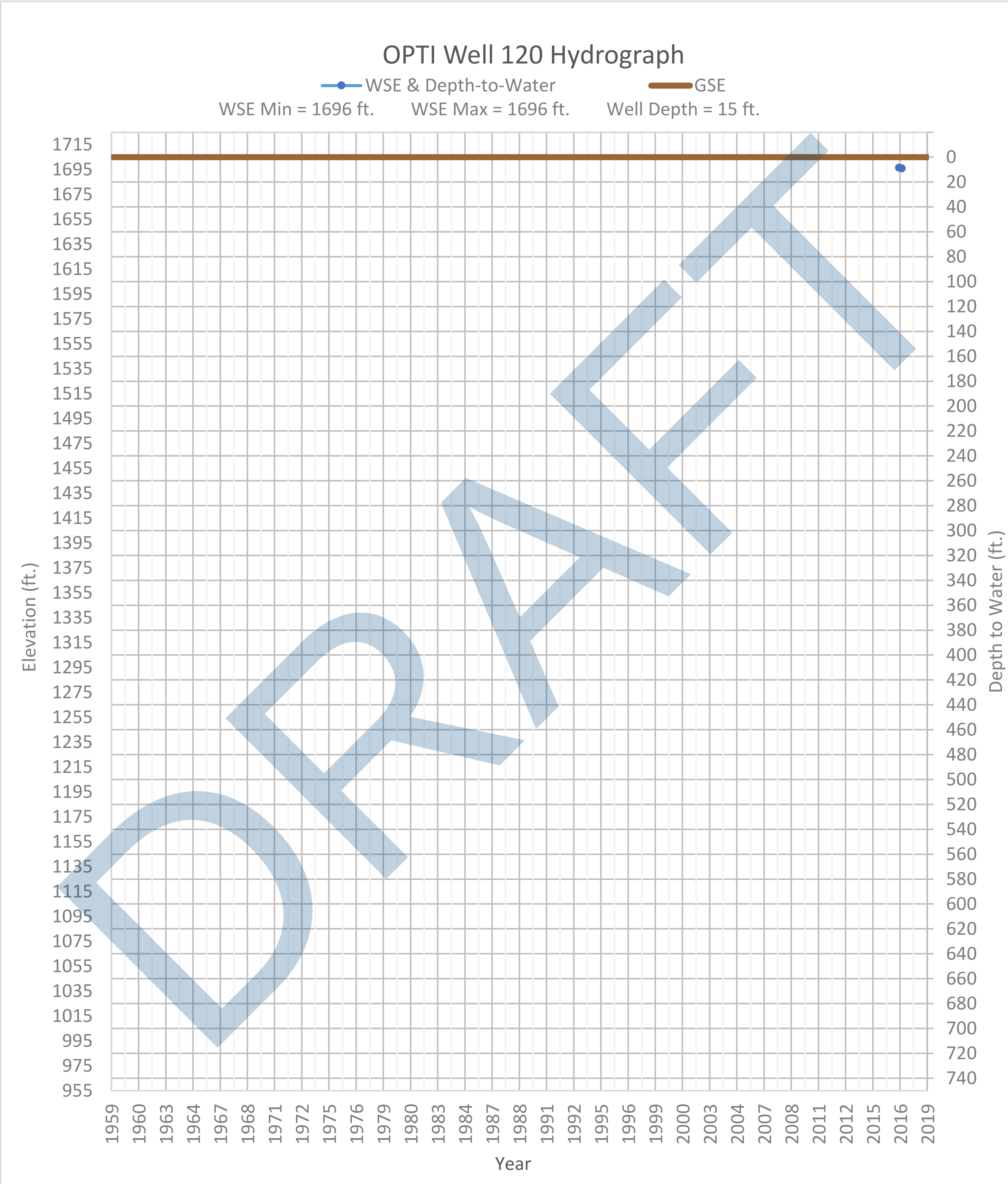
OPTI Well 117 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1947 ft.
WSE Max = 2005 ft.
Well Depth = 212 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

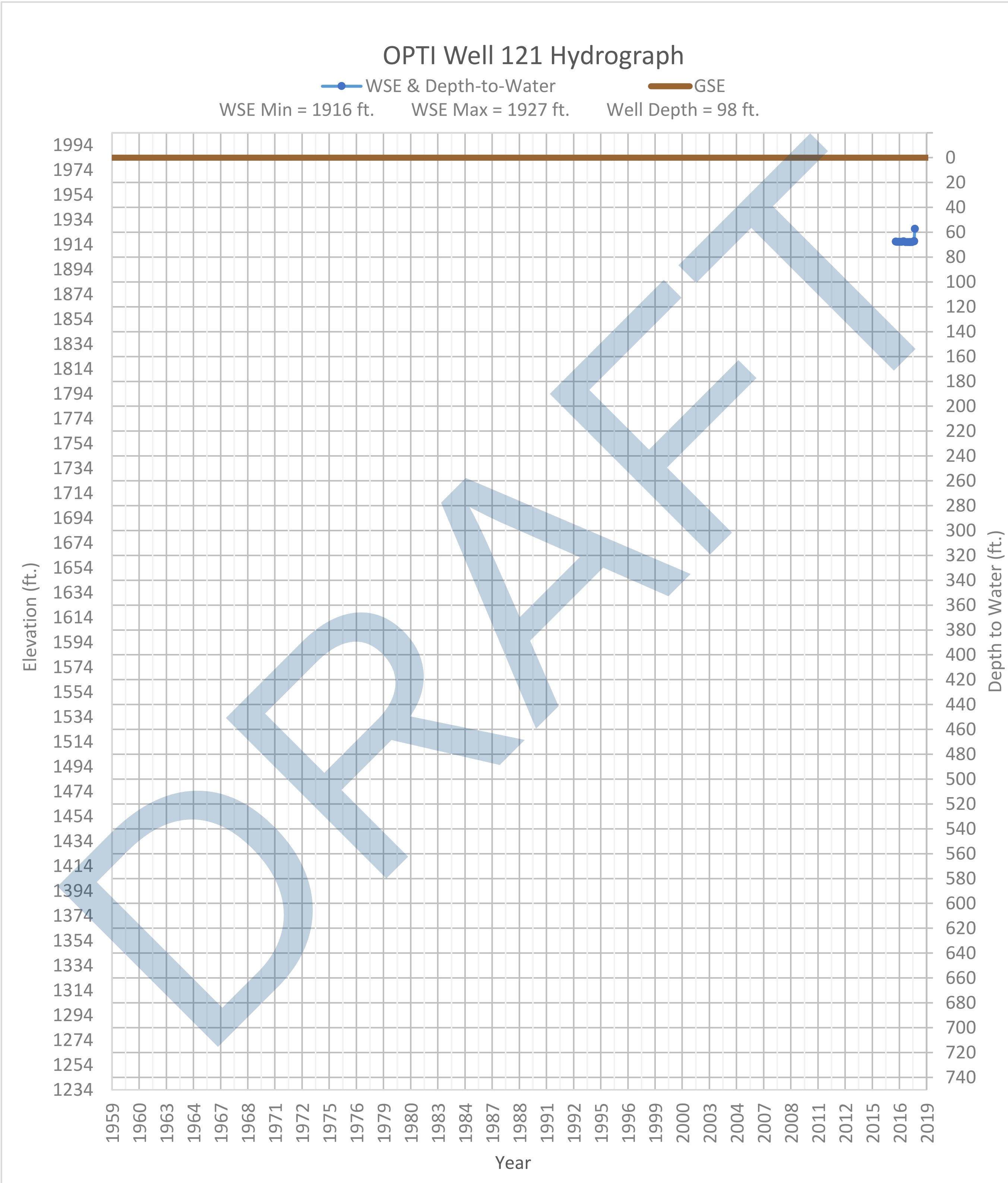


OPTI Well 118 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2208 ft.
WSE Max = 2214 ft.
Well Depth = 500 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

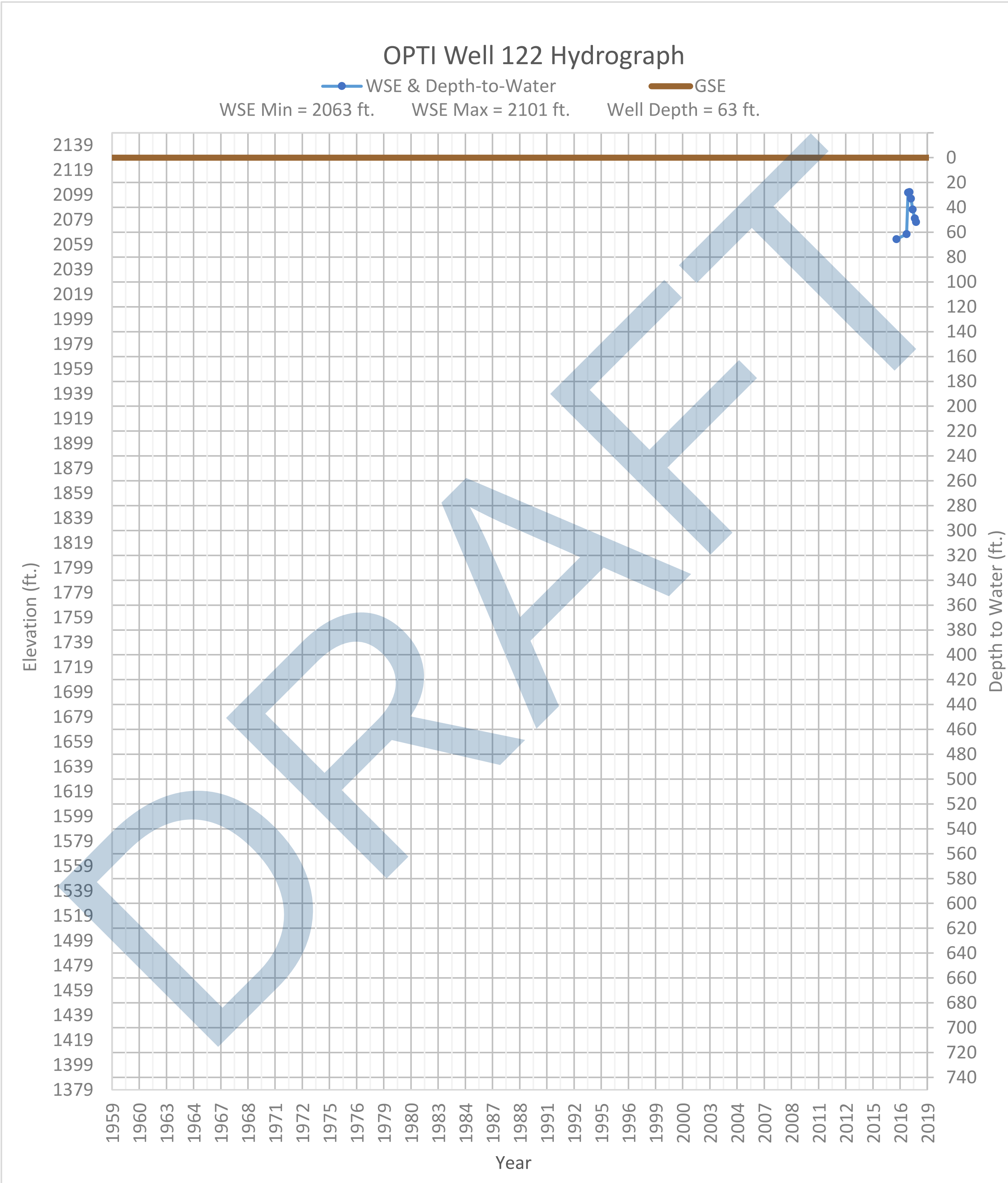


OPTI Well 119 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1651 ft.
WSE Max = 1657 ft.
Well Depth = 92 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

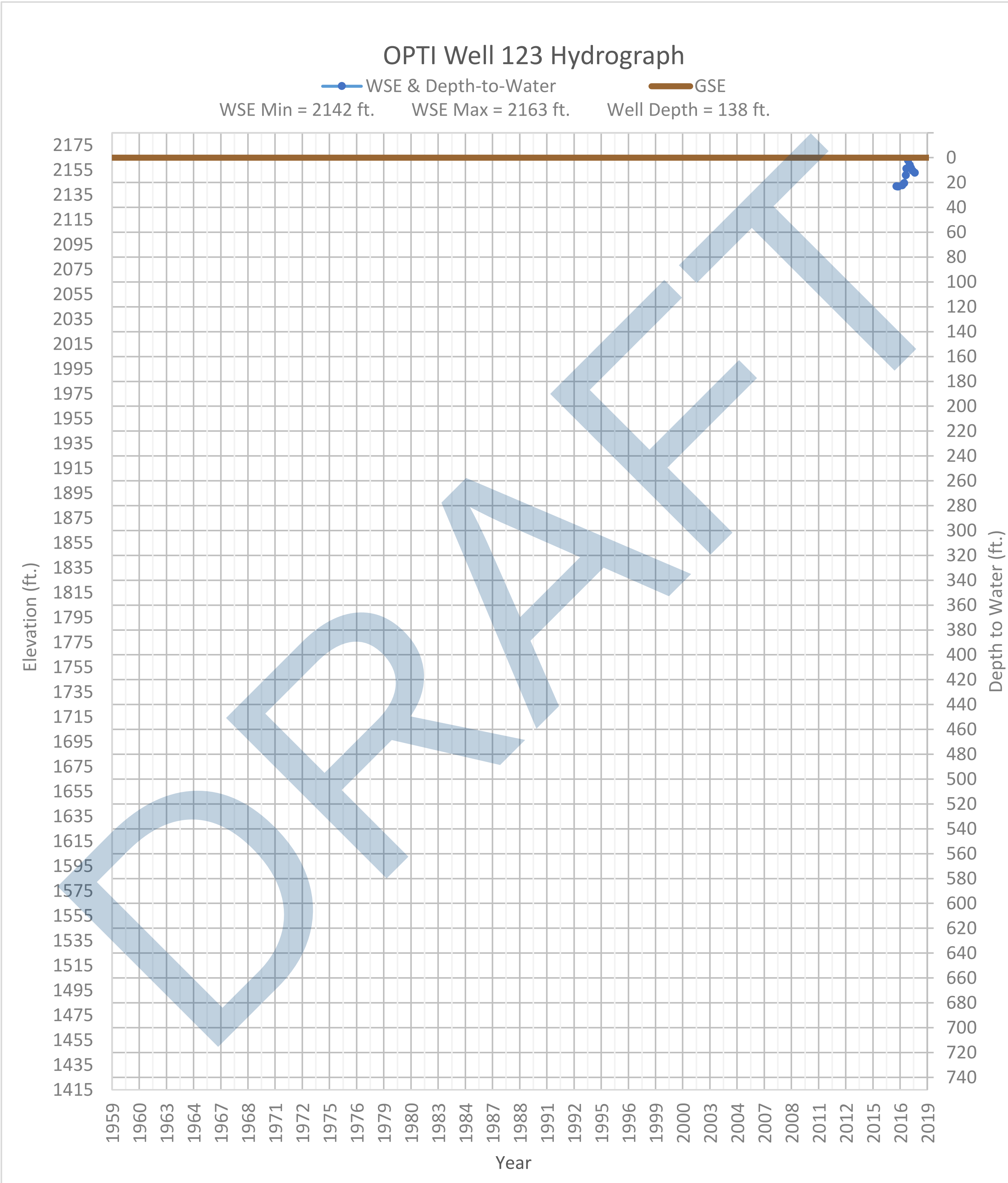

OPTI Well 120 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1696 ft.
WSE Max = 1696 ft.
Well Depth = 15 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



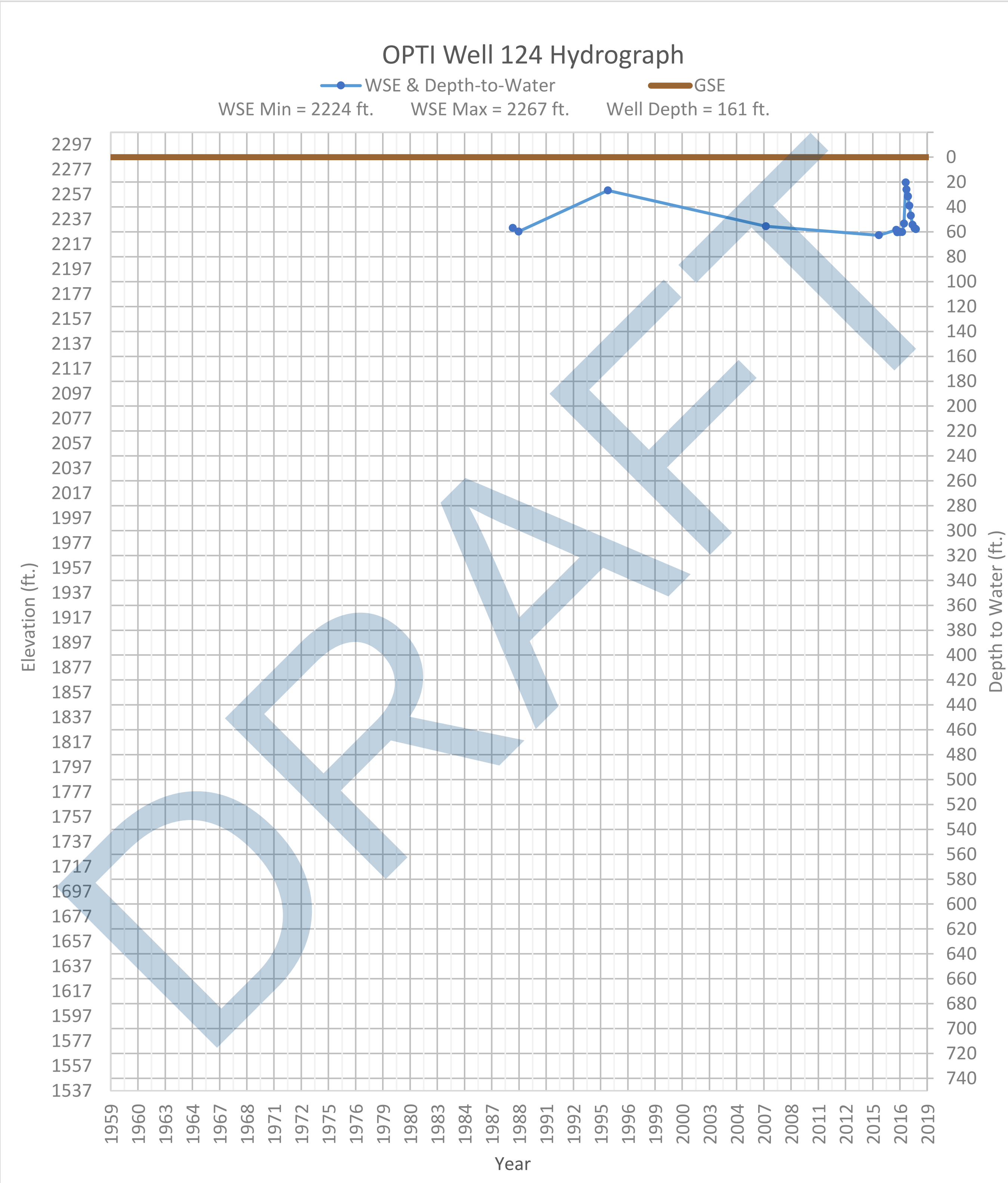
OPTI Well 121 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1916 ft.
WSE Max = 1927 ft.
Well Depth = 98 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



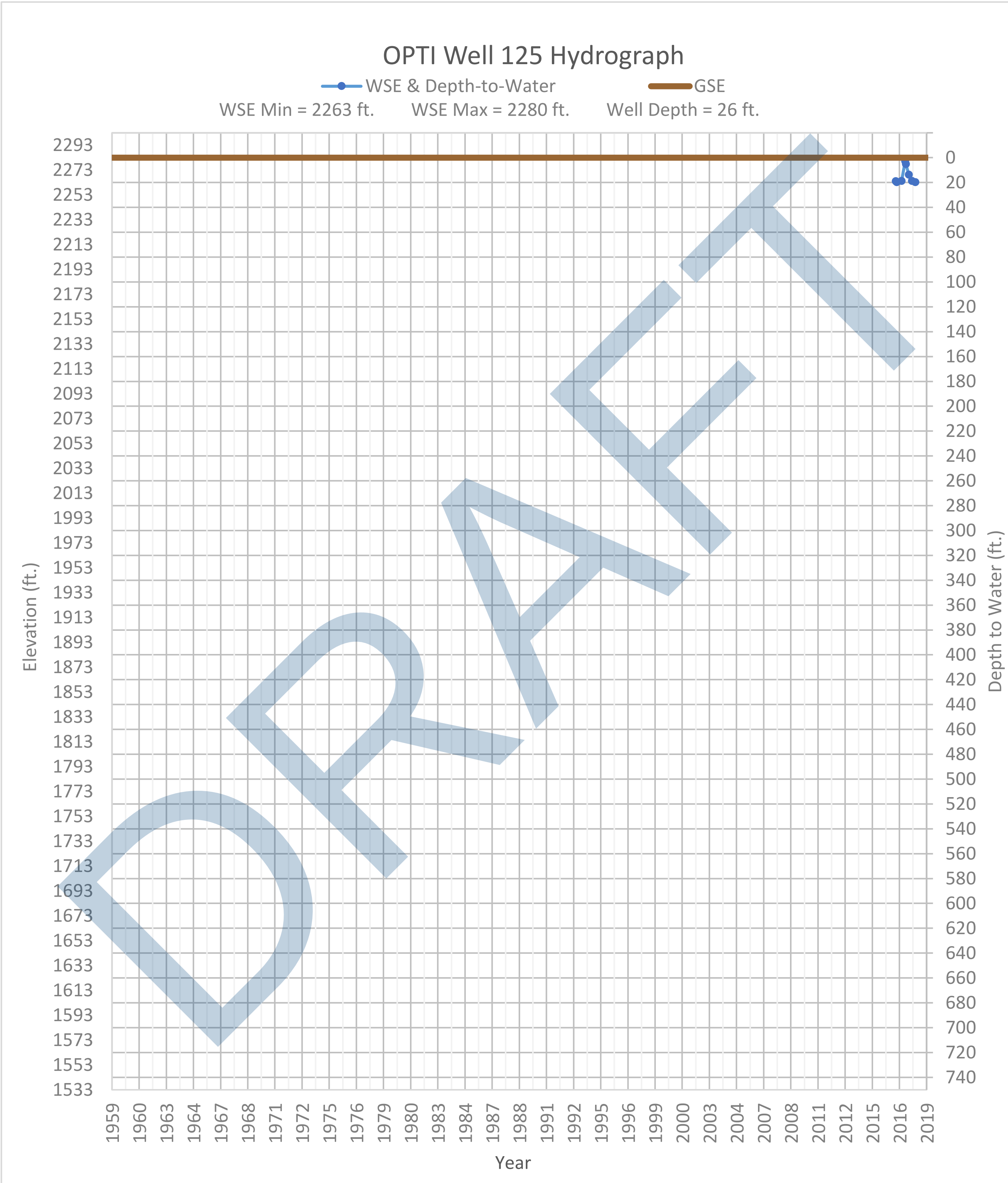
OPTI Well 122 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2063 ft.
WSE Max = 2101 ft.
Well Depth = 63 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



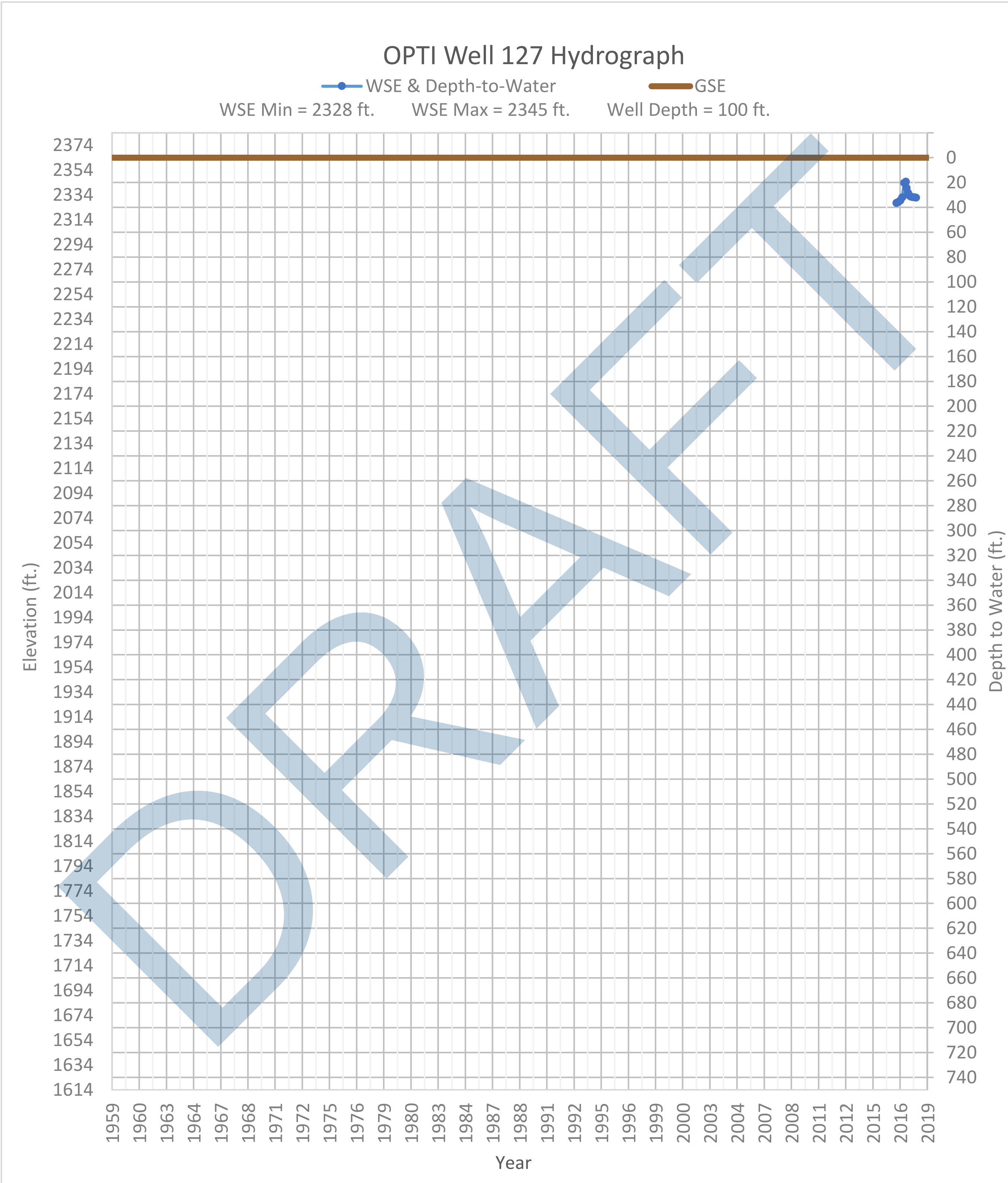
OPTI Well 123 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2142 ft.
WSE Max = 2163 ft.
Well Depth = 138 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 124 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2224 ft.
WSE Max = 2267 ft.
Well Depth = 161 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 125 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2263 ft.
WSE Max = 2280 ft.
Well Depth = 26 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 127 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2328 ft.
WSE Max = 2345 ft.
Well Depth = 100 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2374
2354
2334
2314
2294
2274
2254
2234
2214
2194
2174
2154
2134
2114
2094
2074
2054
2034
2014
1994
1974
1954
1934
1914
1894
1874
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1674
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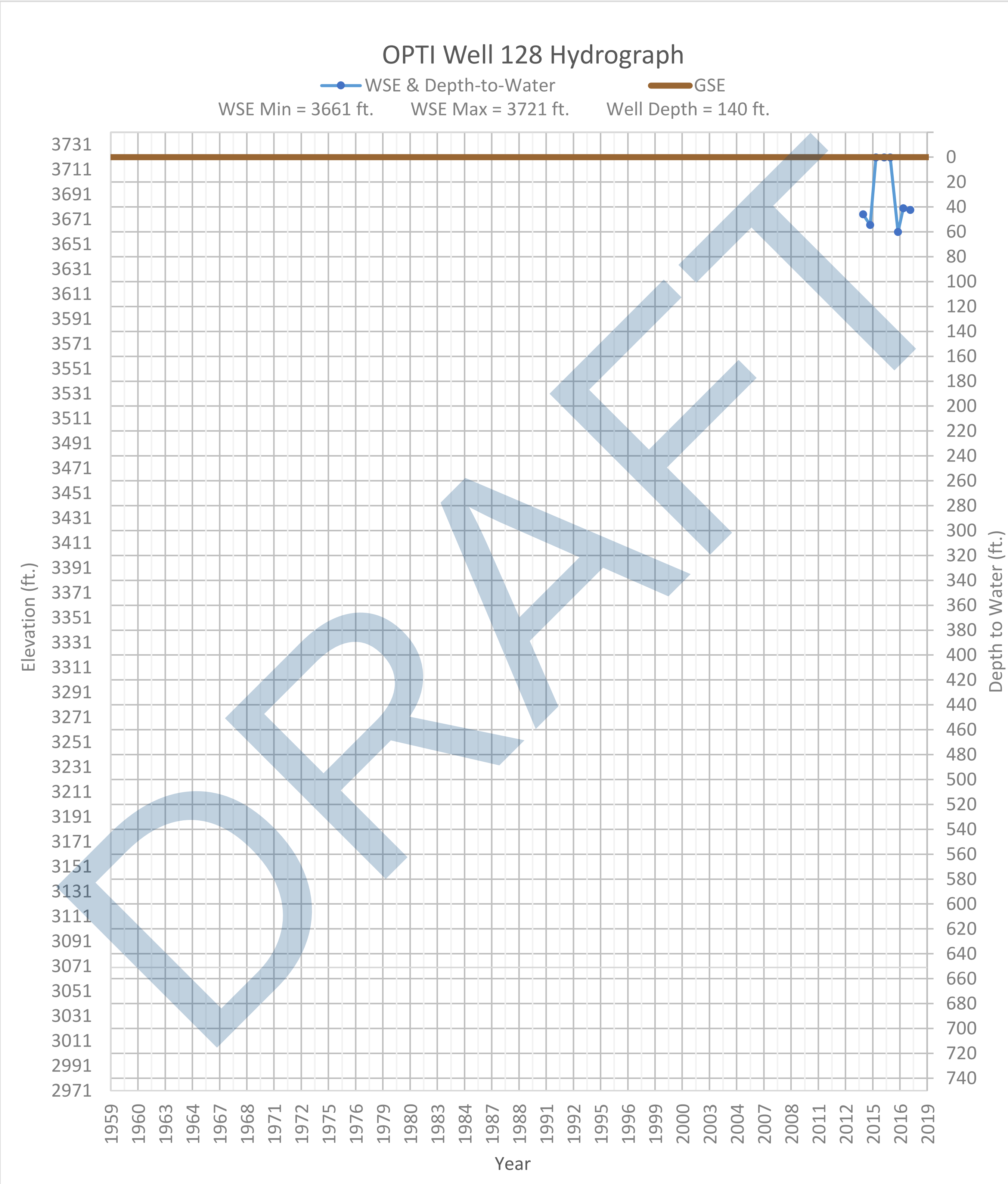
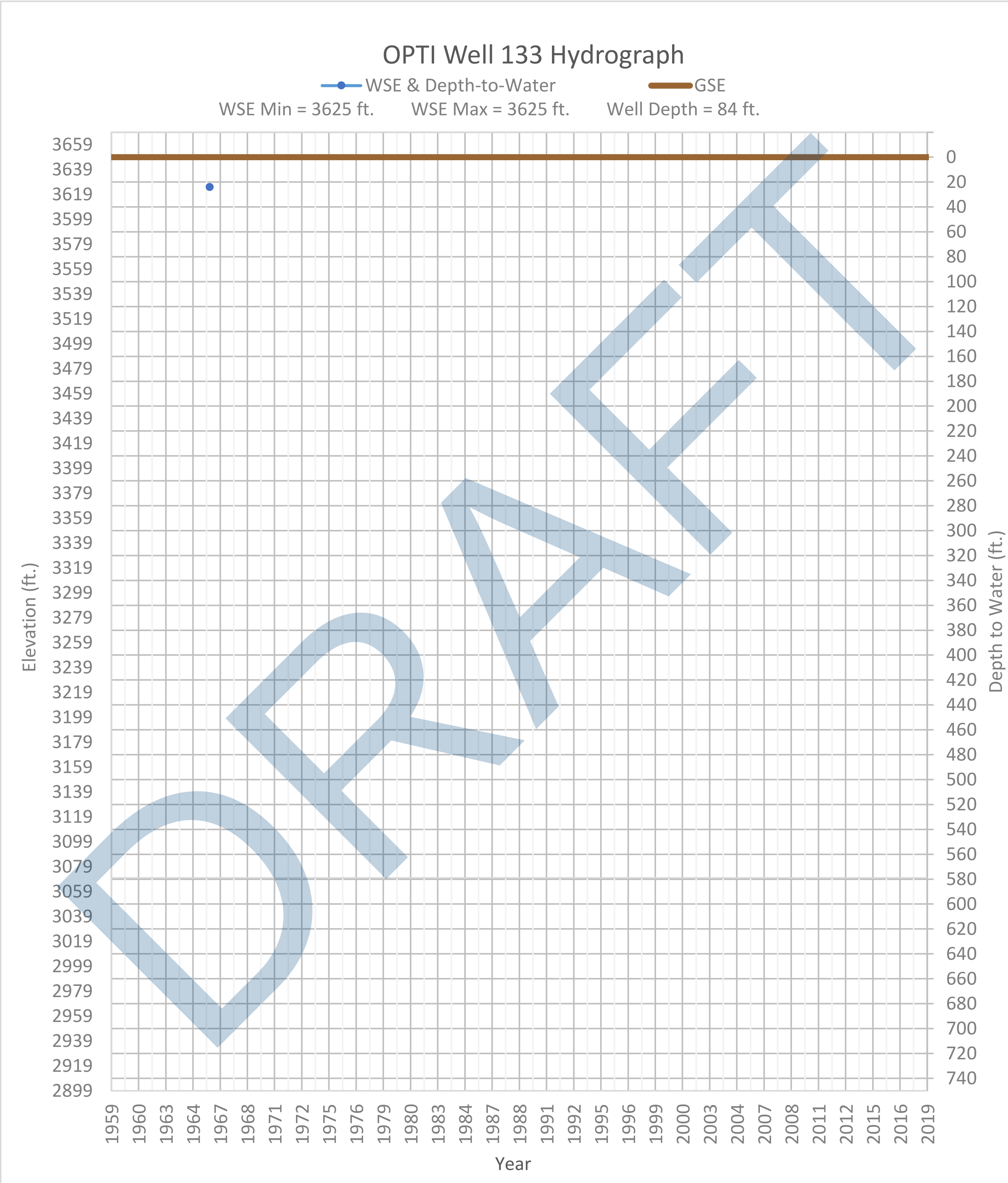
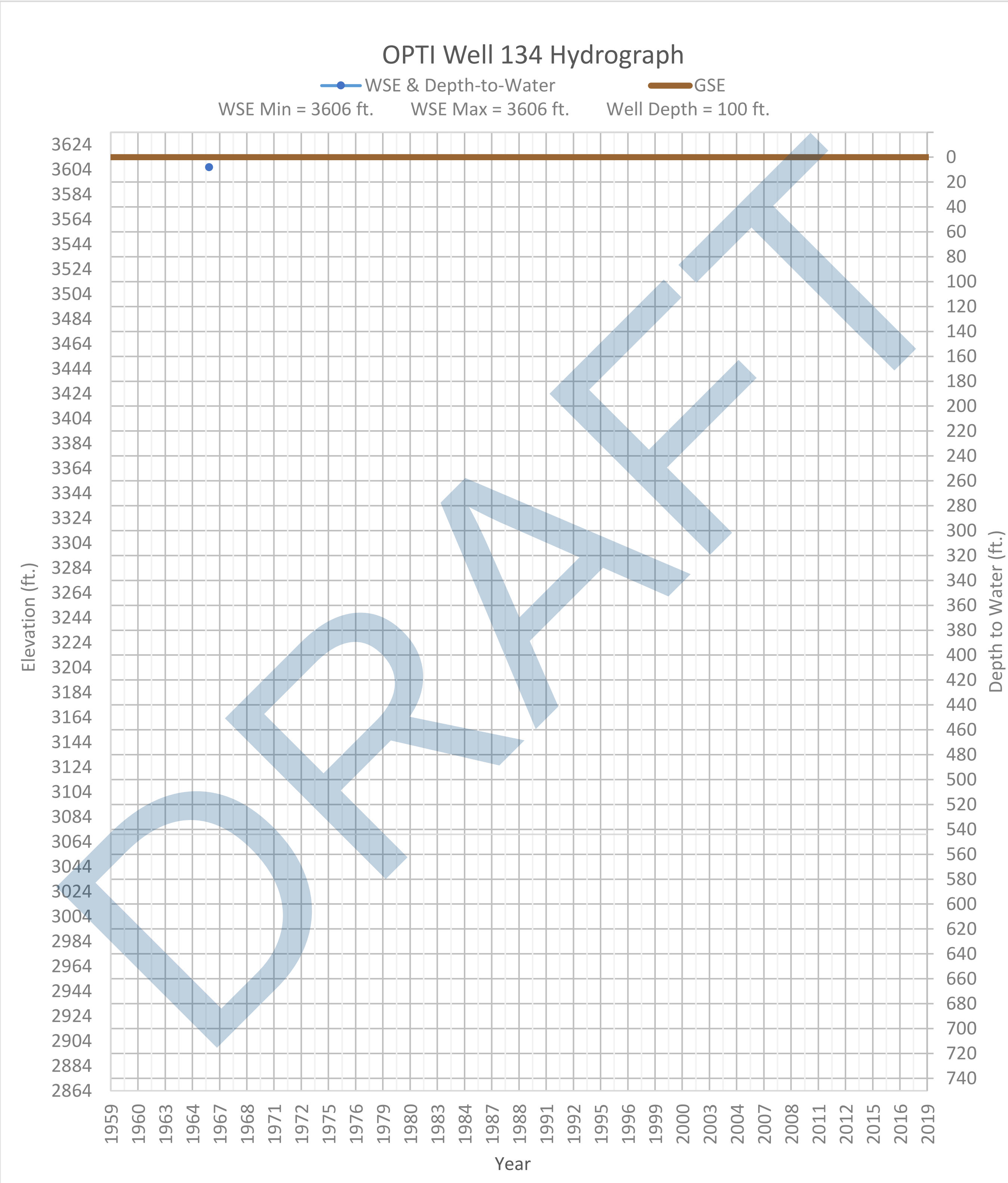


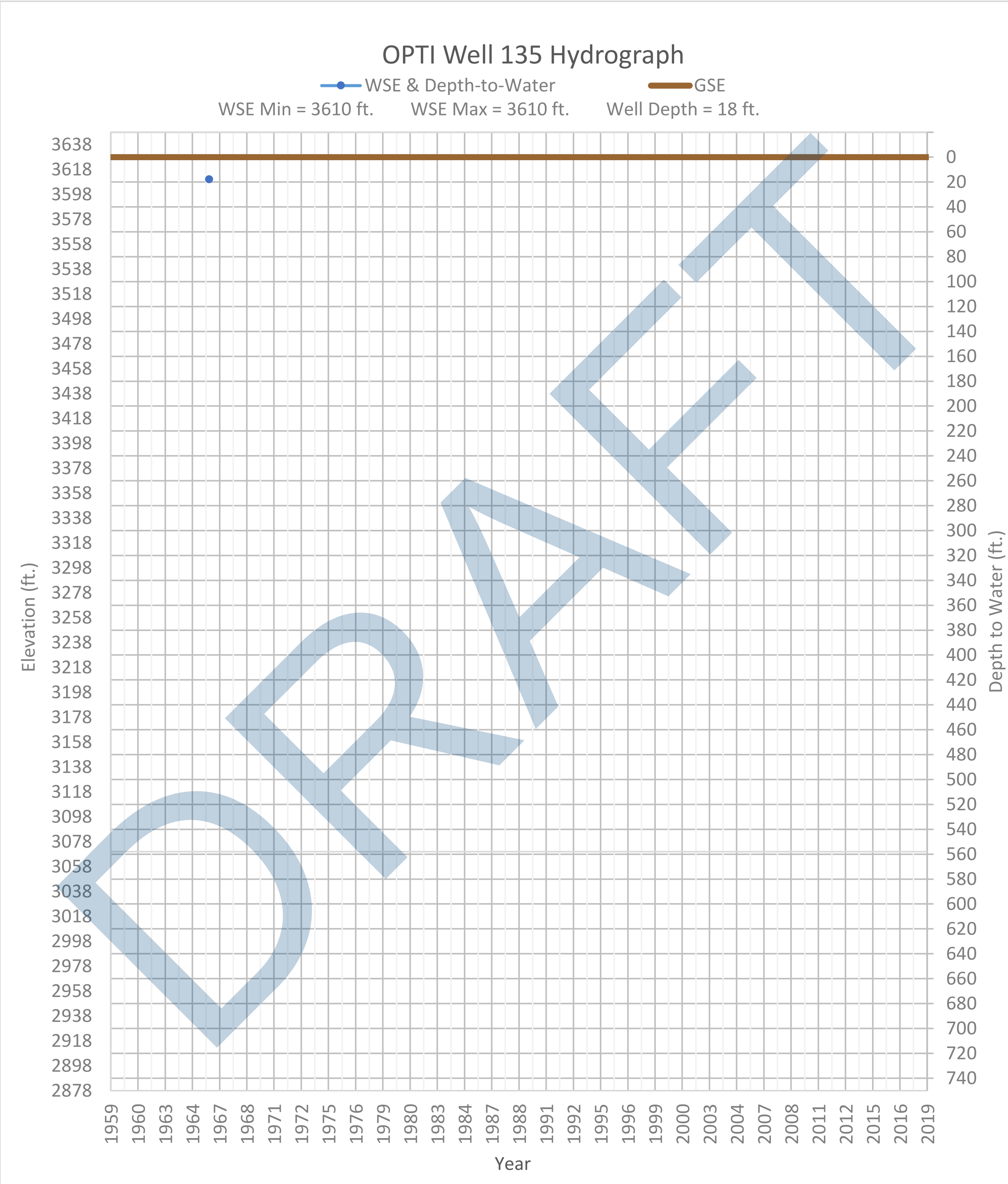
OPTI Well 128 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3661 ft.
WSE Max = 3721 ft.
Well Depth = 140 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



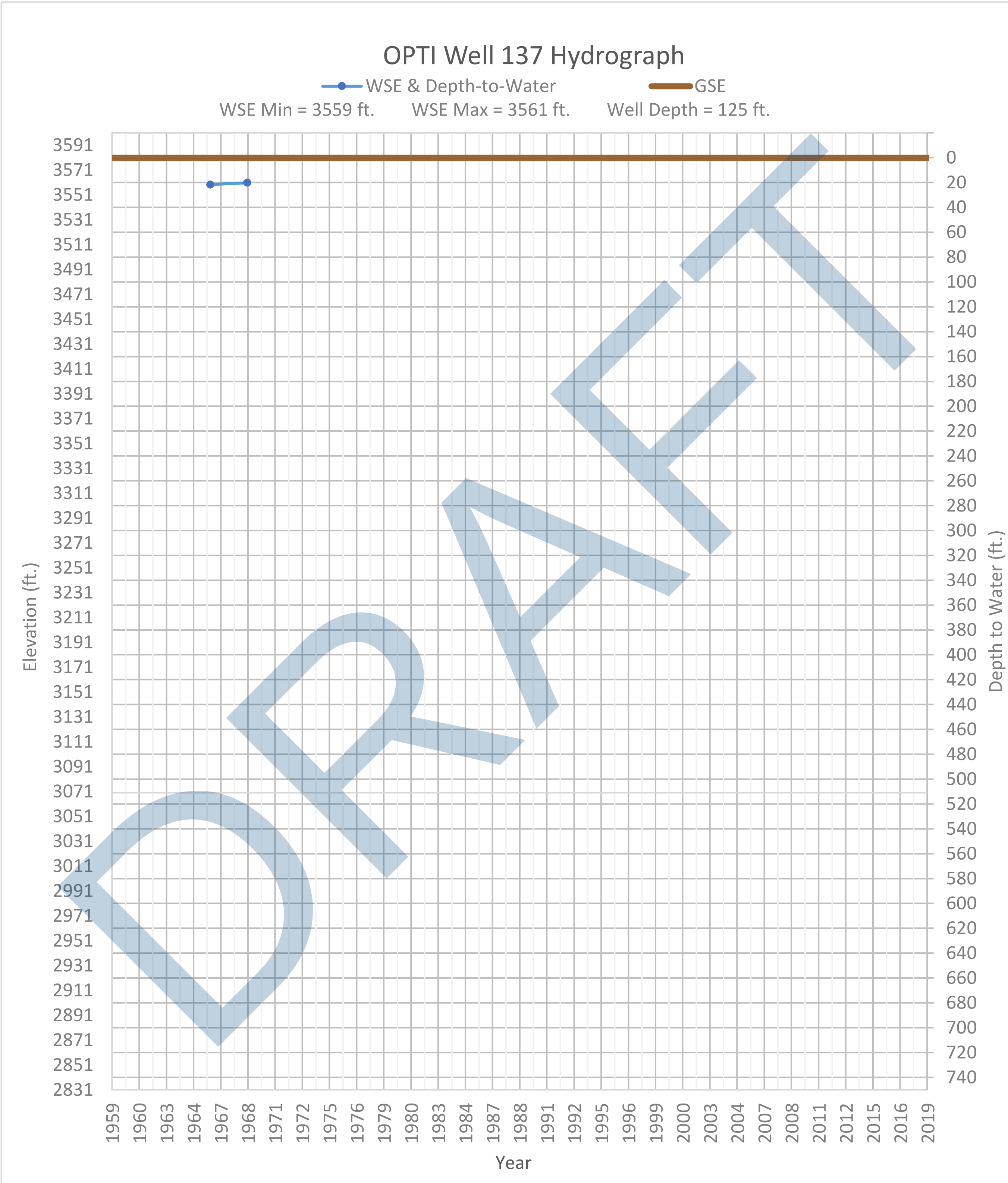
OPTI Well 133 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3625 ft.
WSE Max = 3625 ft.
Well Depth = 84 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



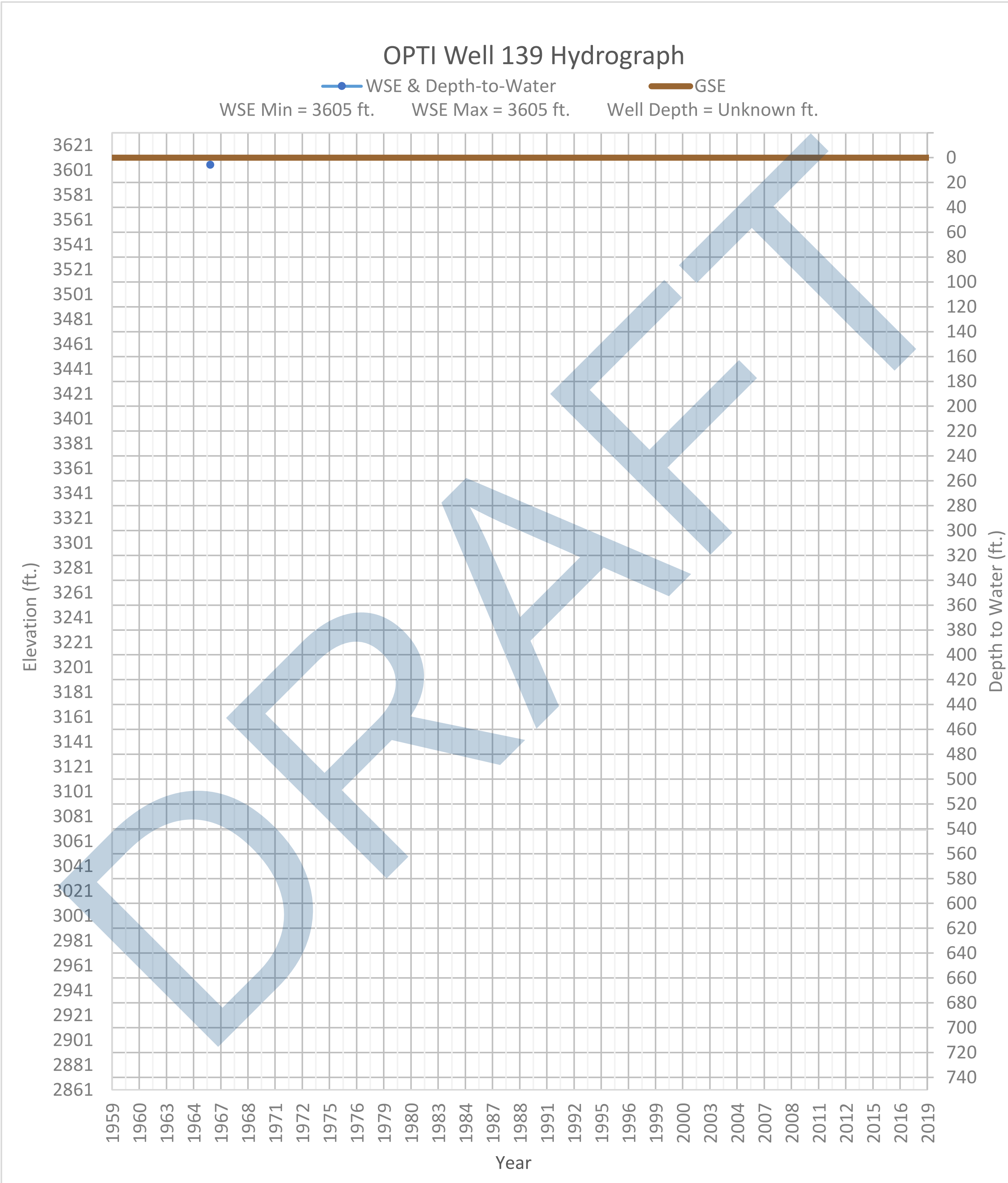
OPTI Well 134 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3606 ft.
WSE Max = 3606 ft.
Well Depth = 100 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



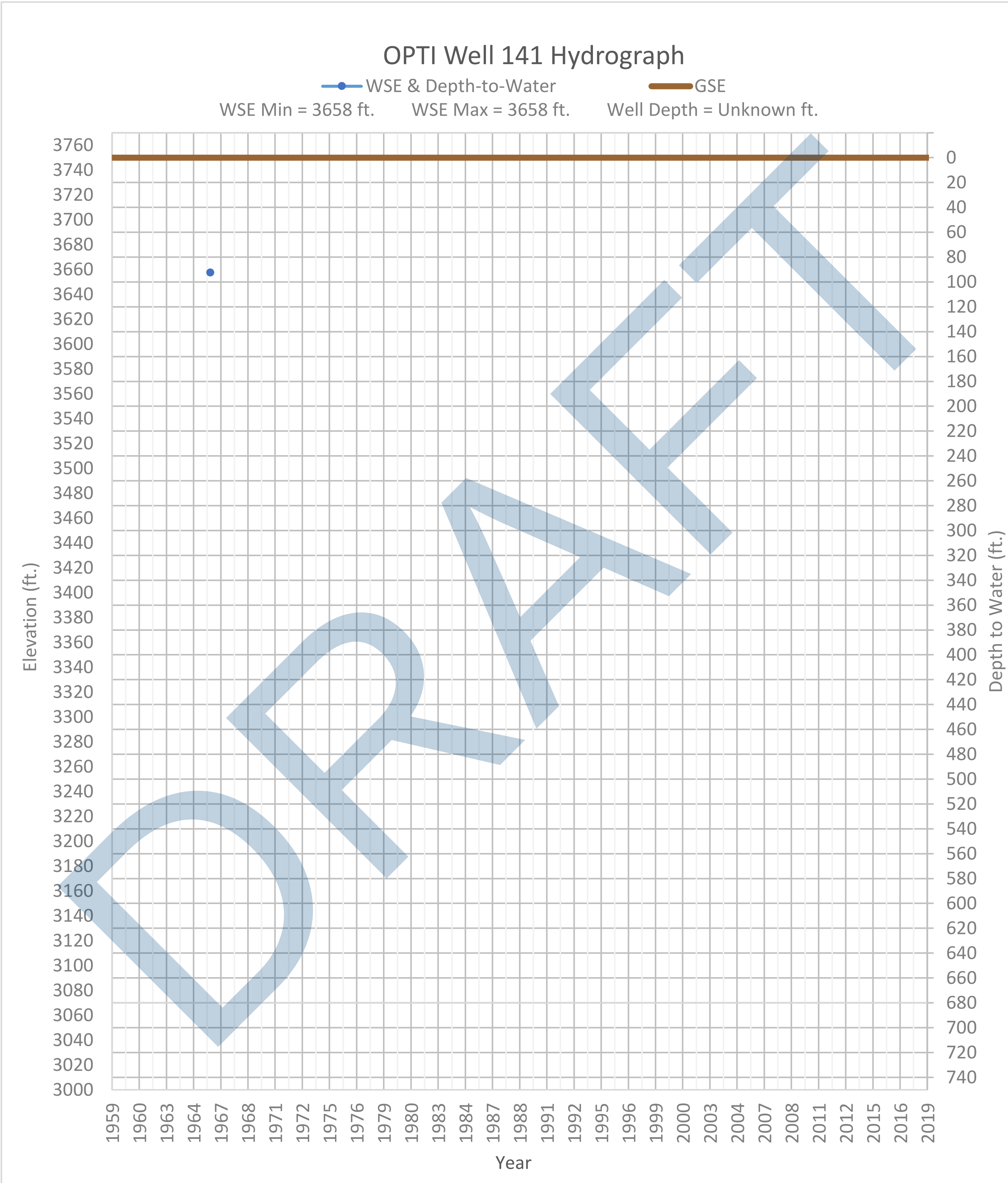
OPTI Well 135 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3610 ft.
WSE Max = 3610 ft.
Well Depth = 18 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



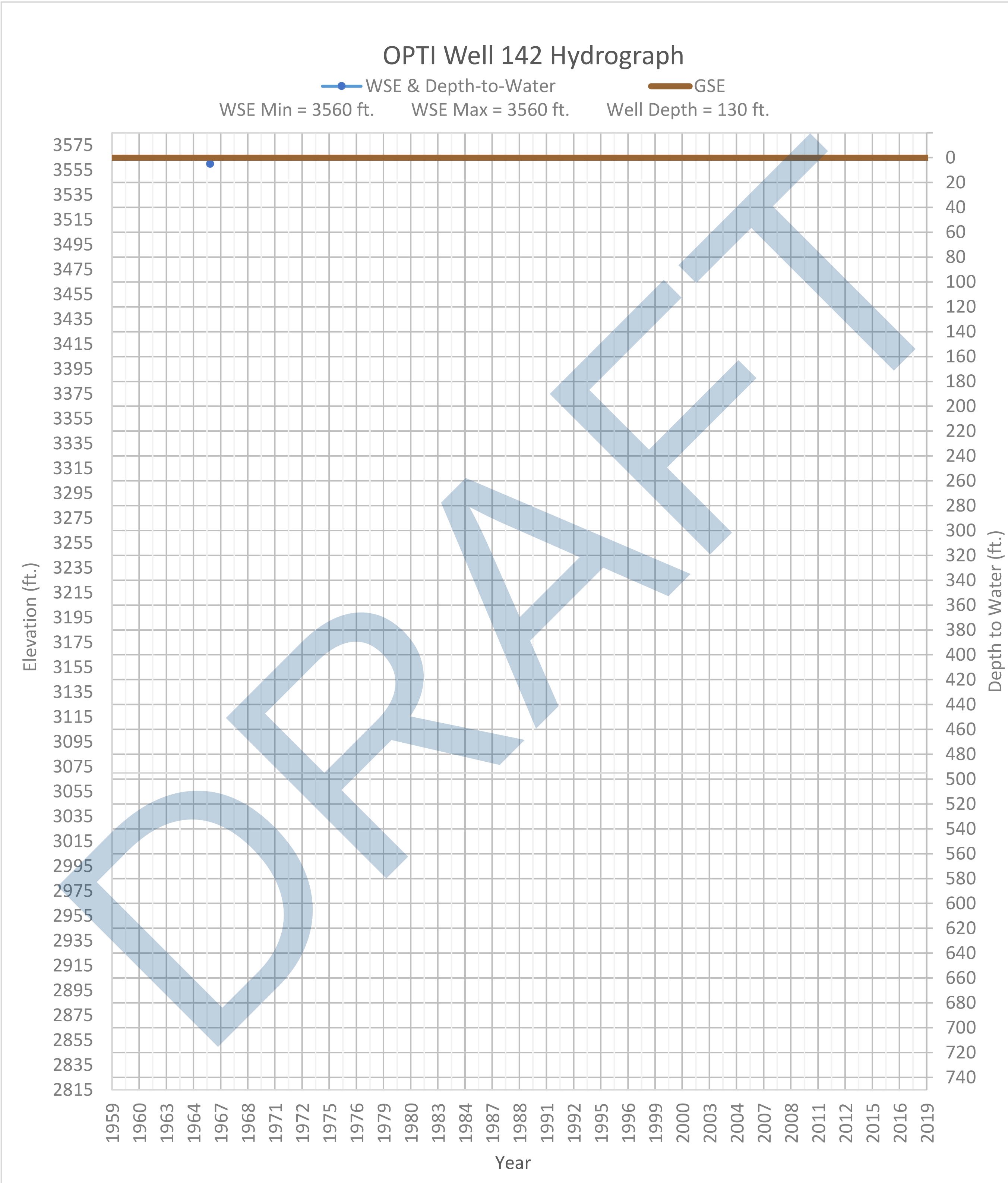
OPTI Well 137 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3559 ft.
WSE Max = 3561 ft.
Well Depth = 125 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

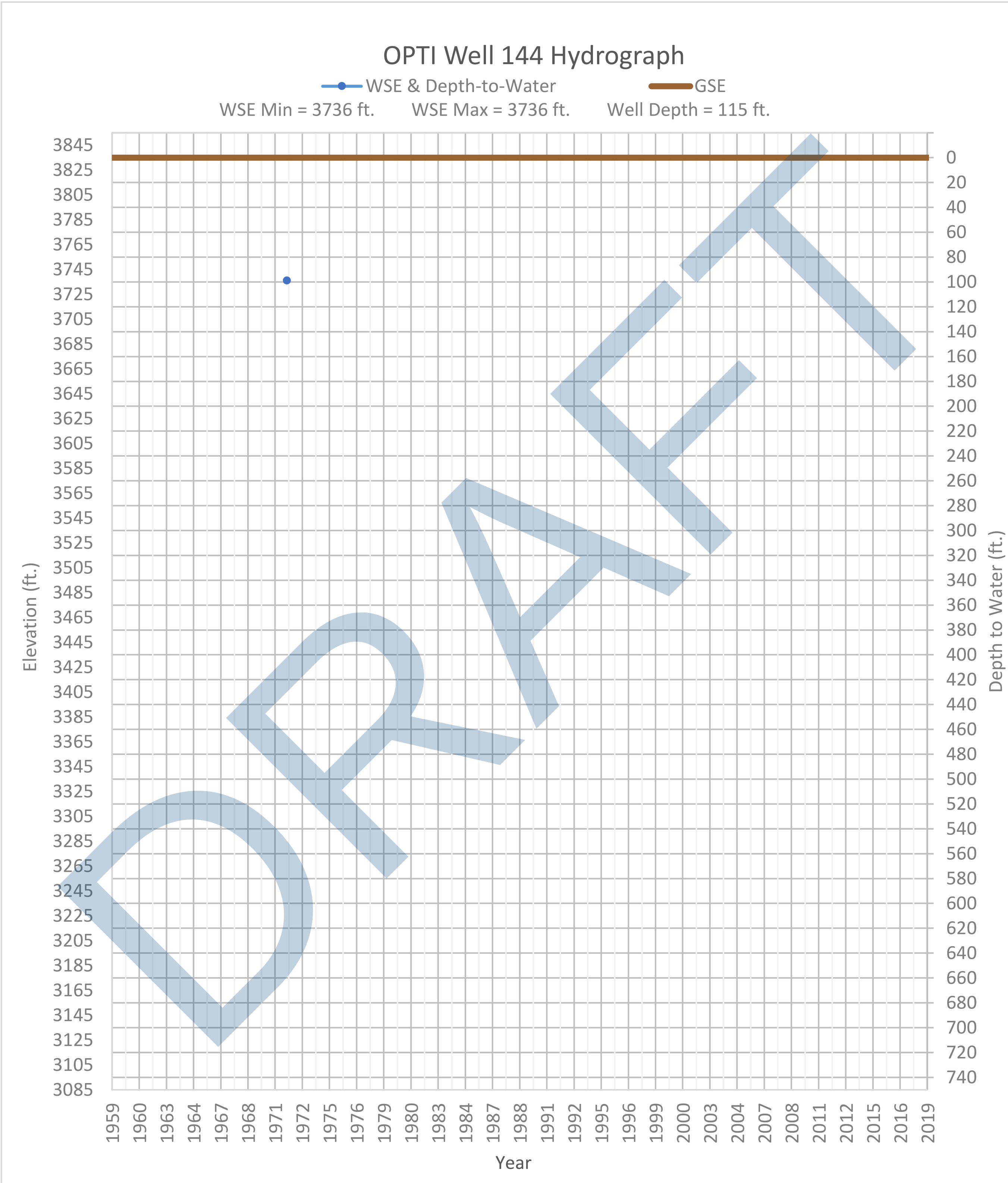


OPTI Well 139 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3605 ft.
WSE Max = 3605 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

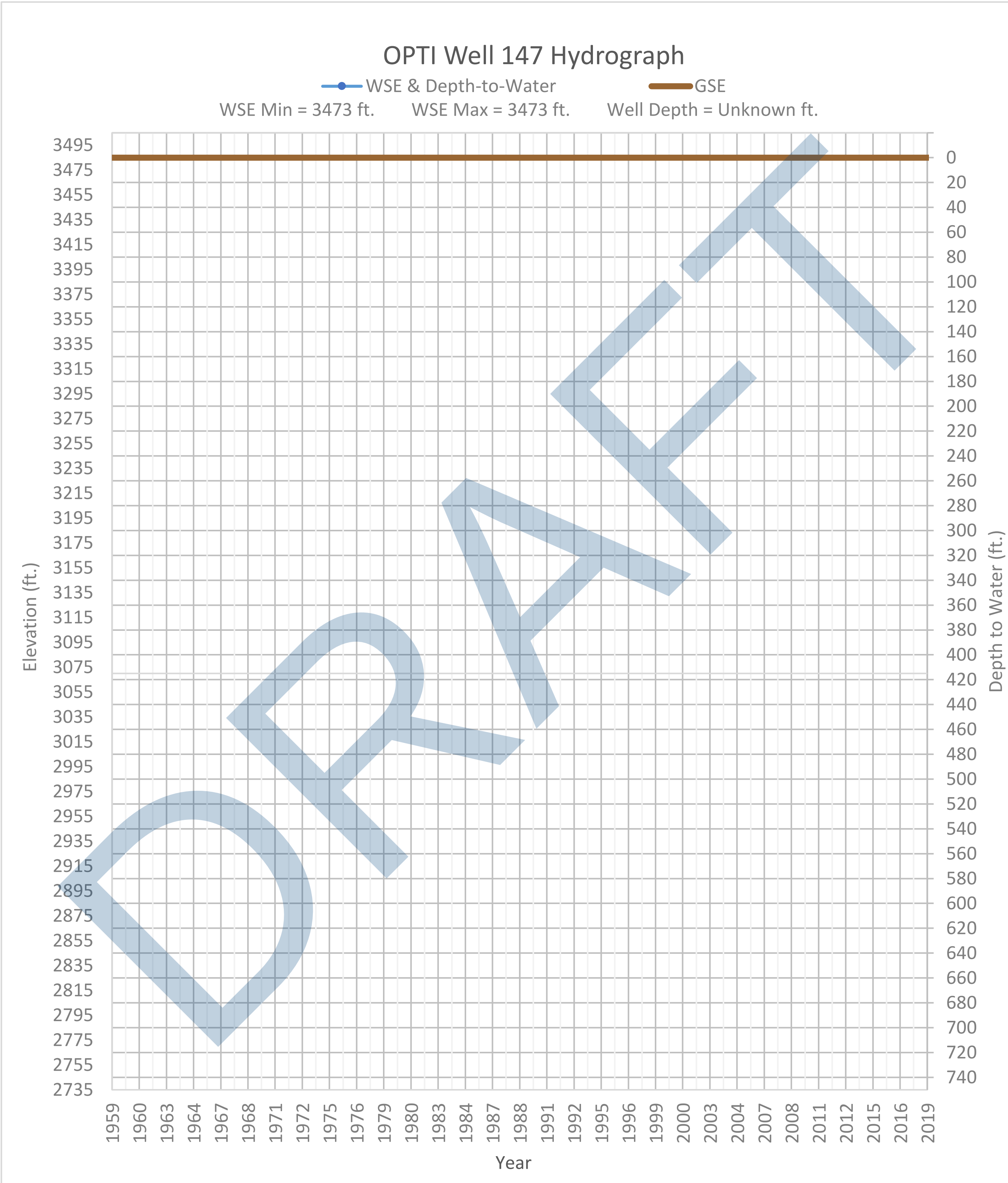


OPTI Well 141 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3658 ft.
WSE Max = 3658 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

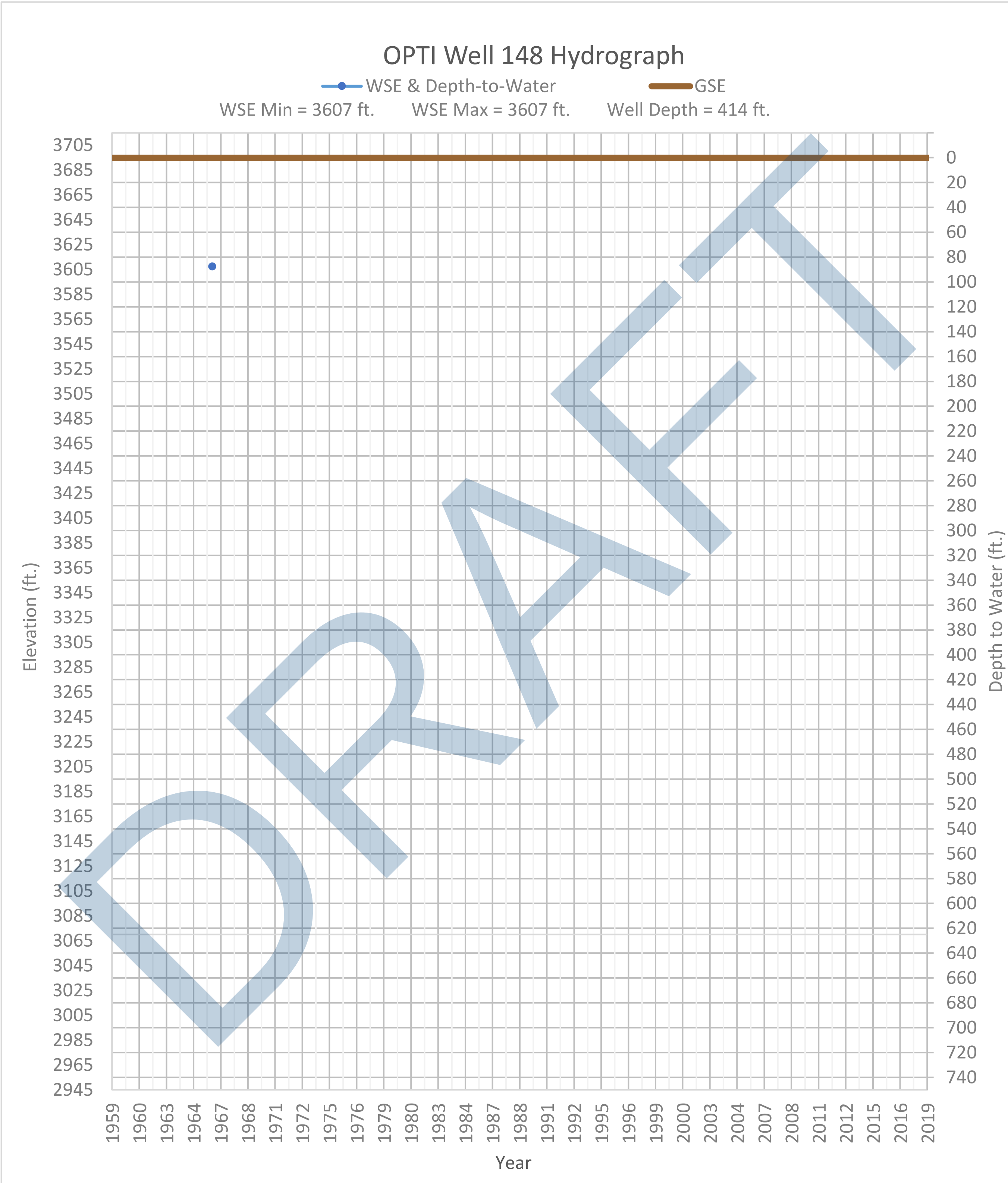

OPTI Well 142 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3560 ft.
WSE Max = 3560 ft.
Well Depth = 130 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



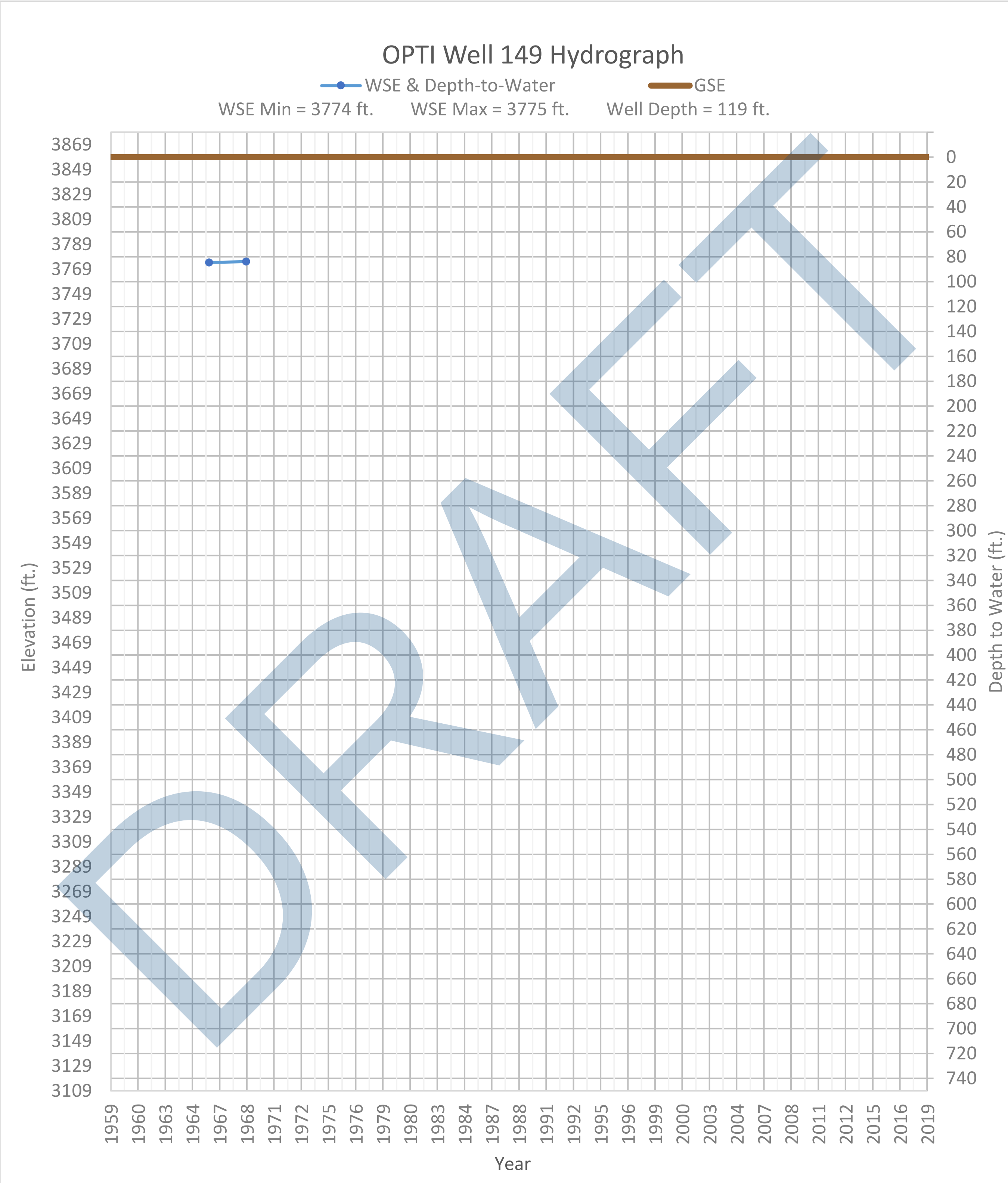
OPTI Well 144 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3736 ft.
WSE Max = 3736 ft.
Well Depth = 115 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



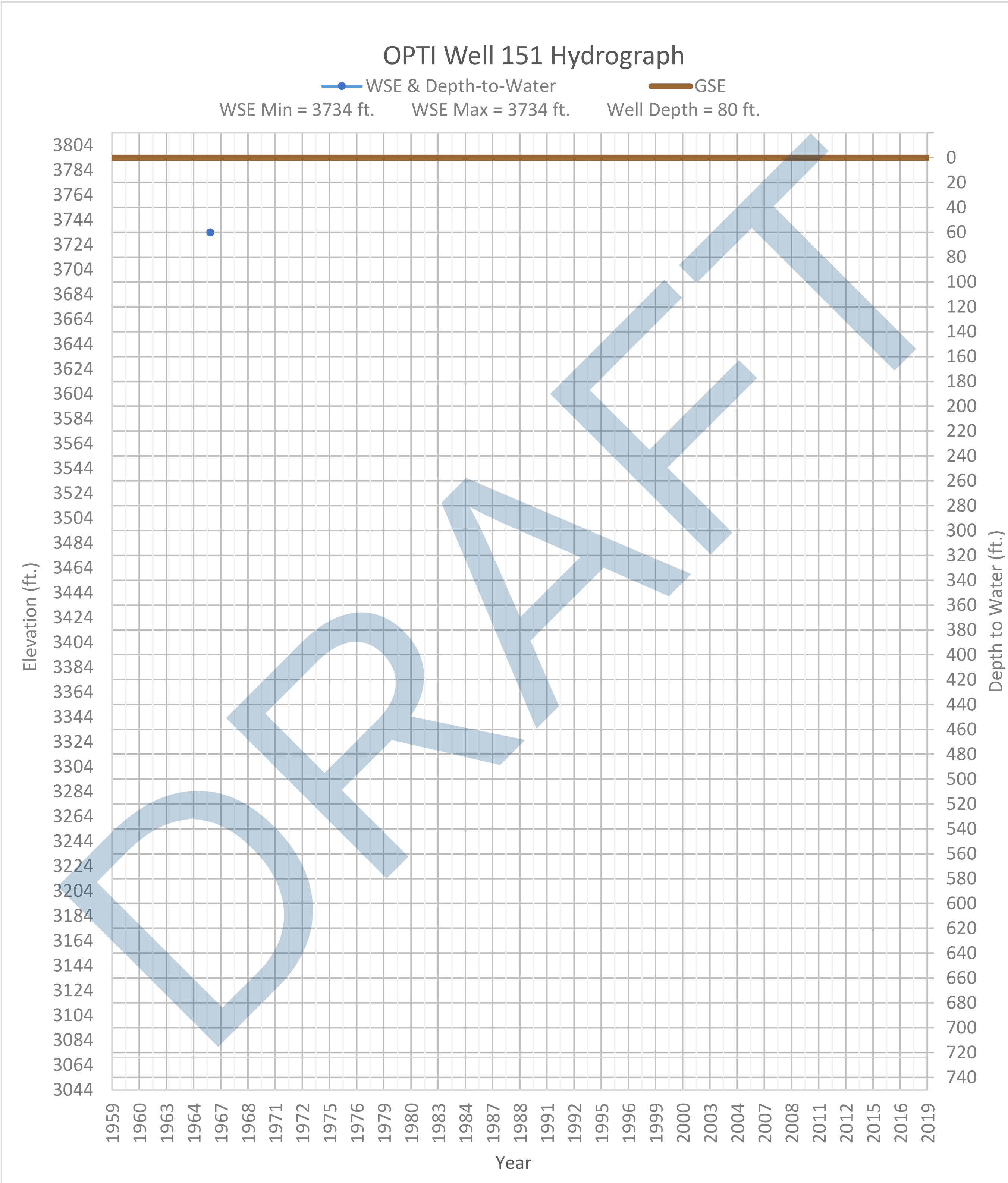
OPTI Well 147 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3473 ft.
WSE Max = 3473 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



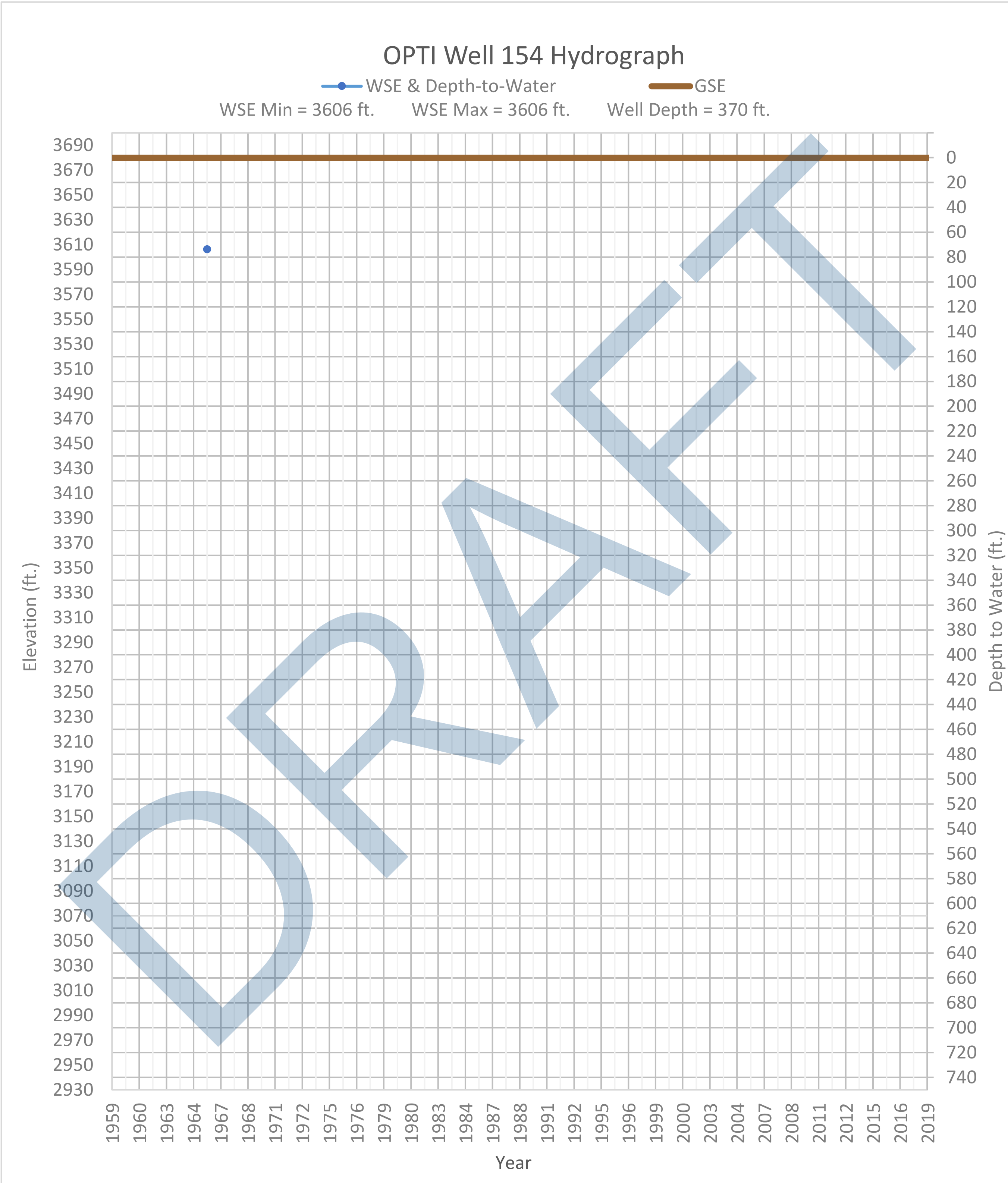
OPTI Well 148 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3607 ft.
WSE Max = 3607 ft.
Well Depth = 414 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



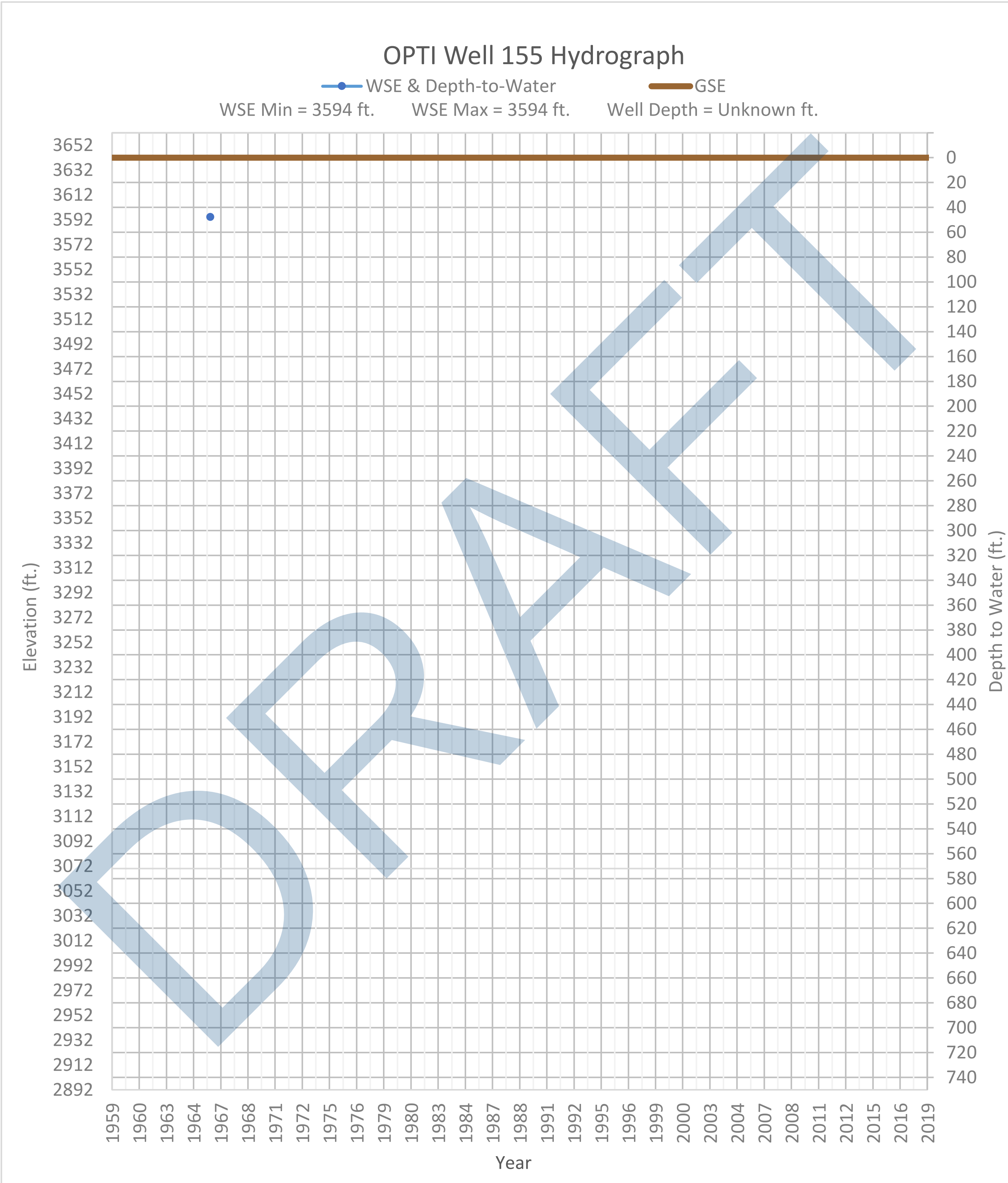
OPTI Well 149 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3774 ft.
WSE Max = 3775 ft.
Well Depth = 119 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



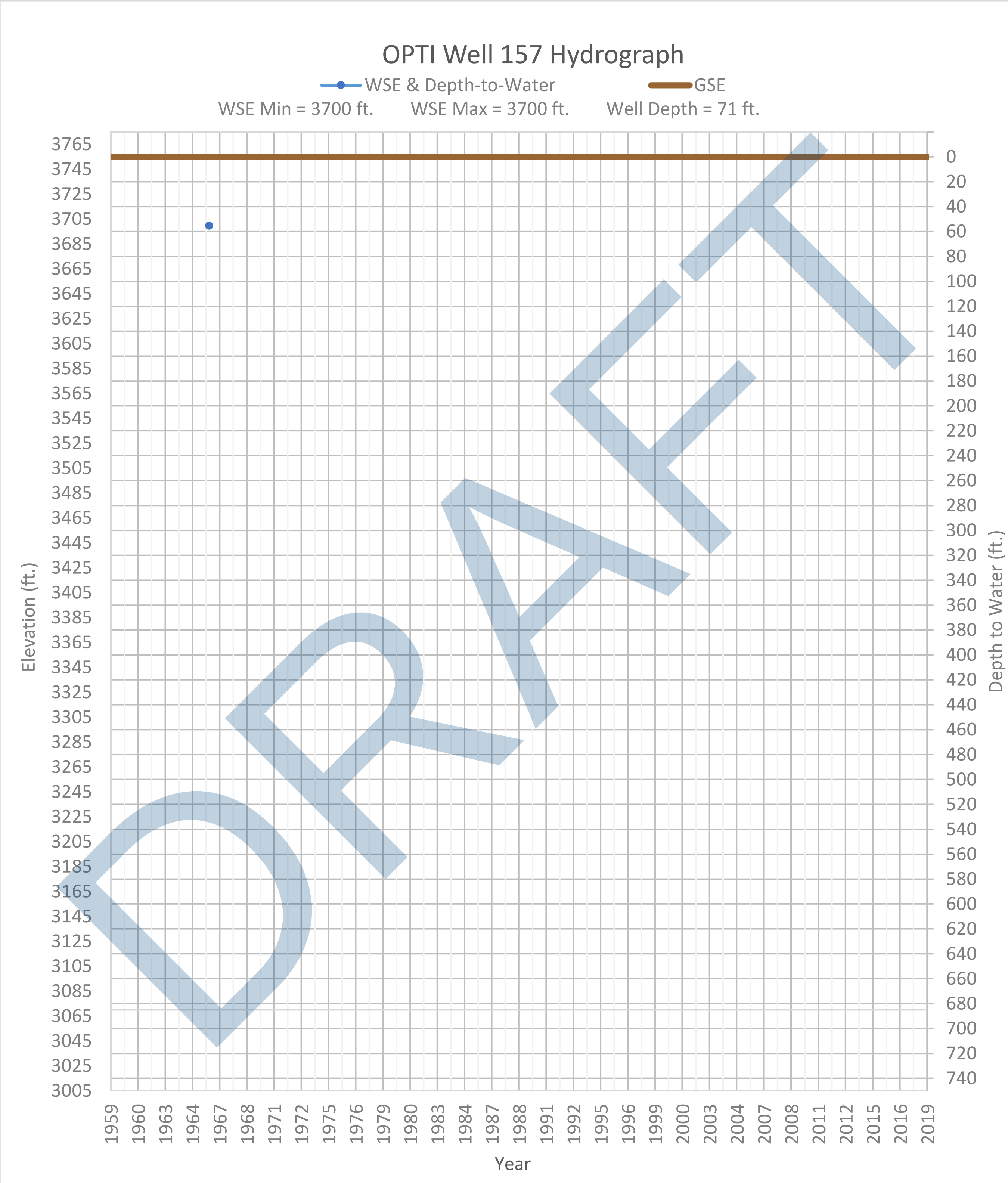
OPTI Well 151 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3734 ft.
WSE Max = 3734 ft.
Well Depth = 80 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



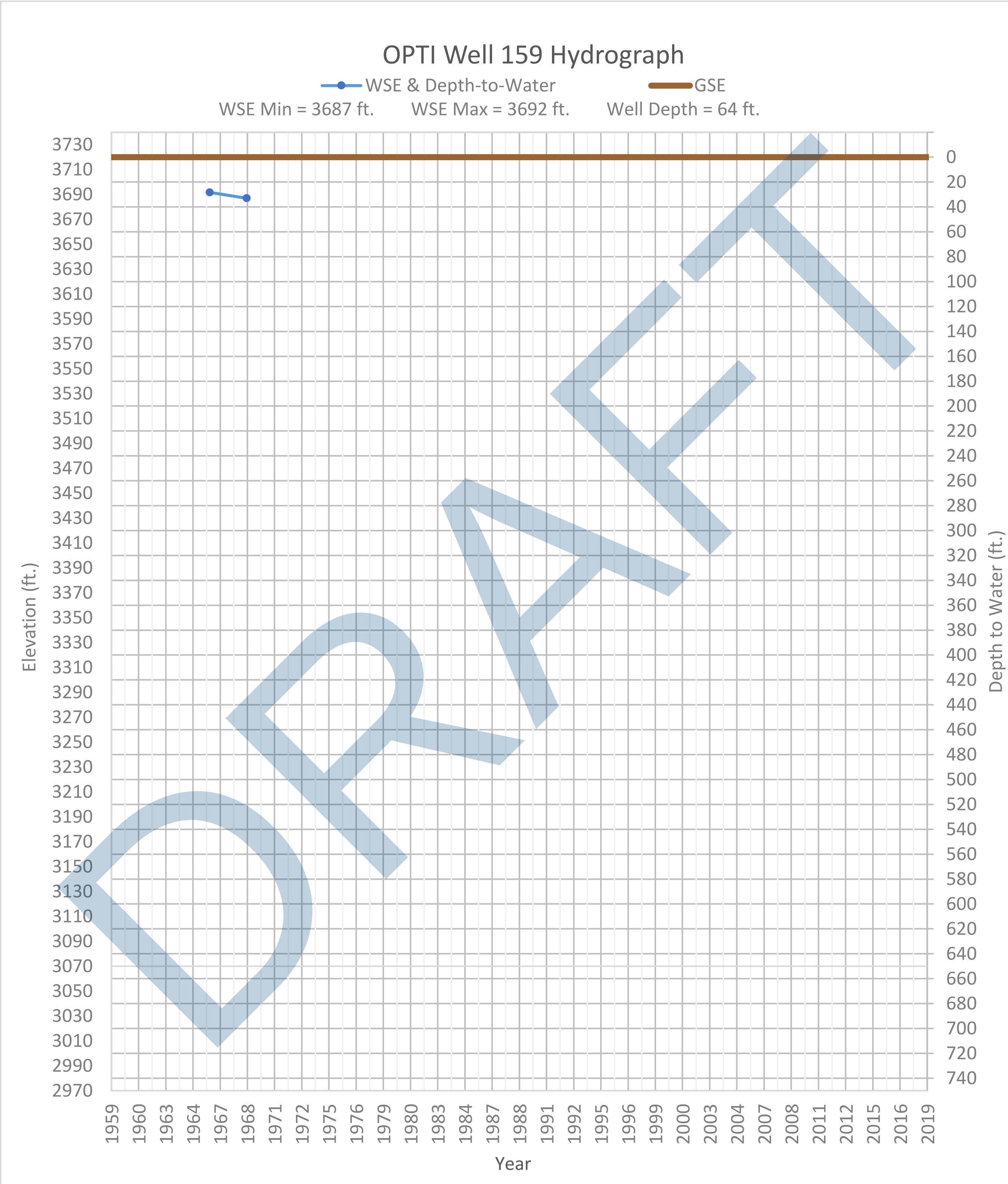
OPTI Well 154 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3606 ft.
WSE Max = 3606 ft.
Well Depth = 370 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



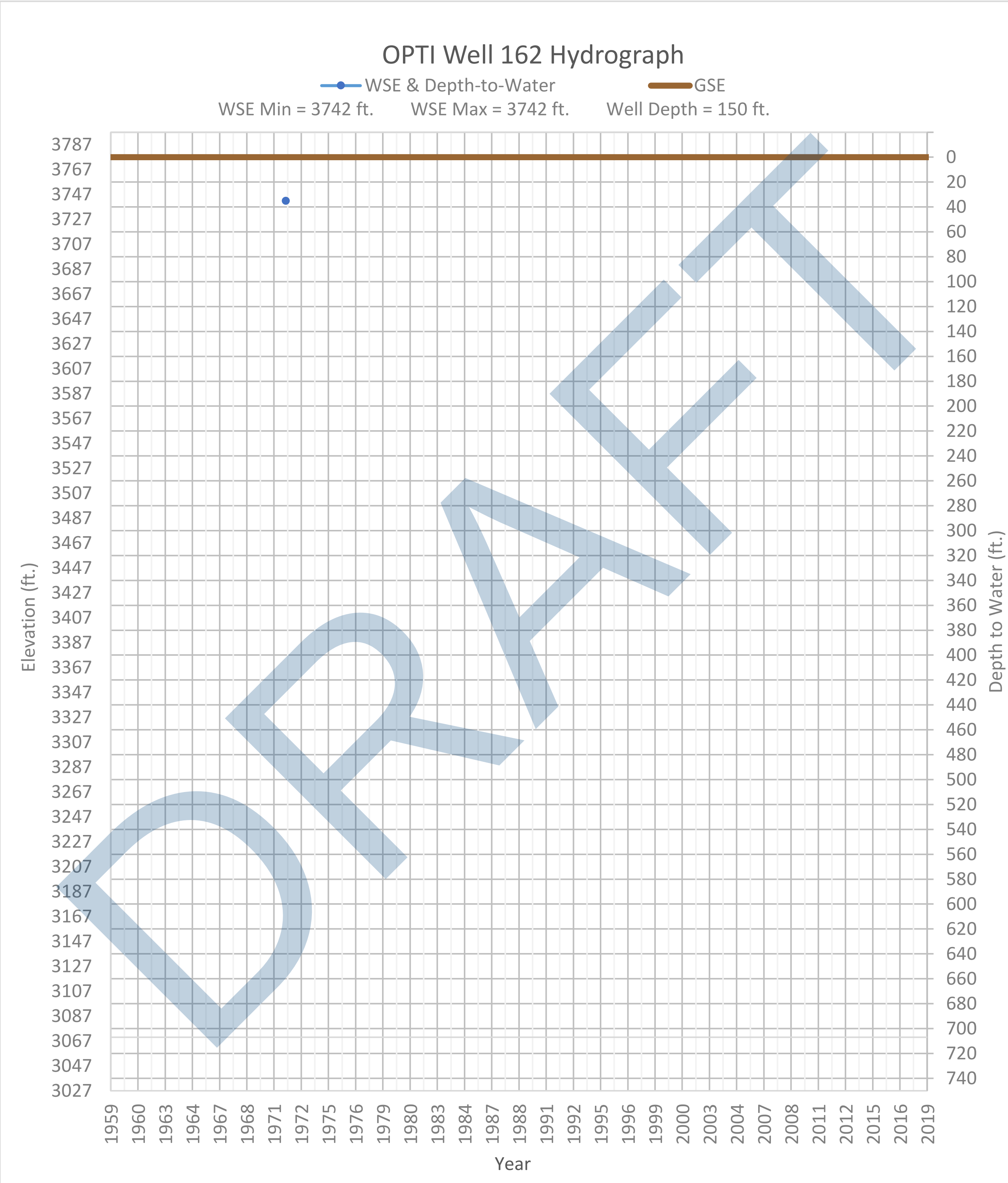
OPTI Well 155 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3594 ft.
WSE Max = 3594 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



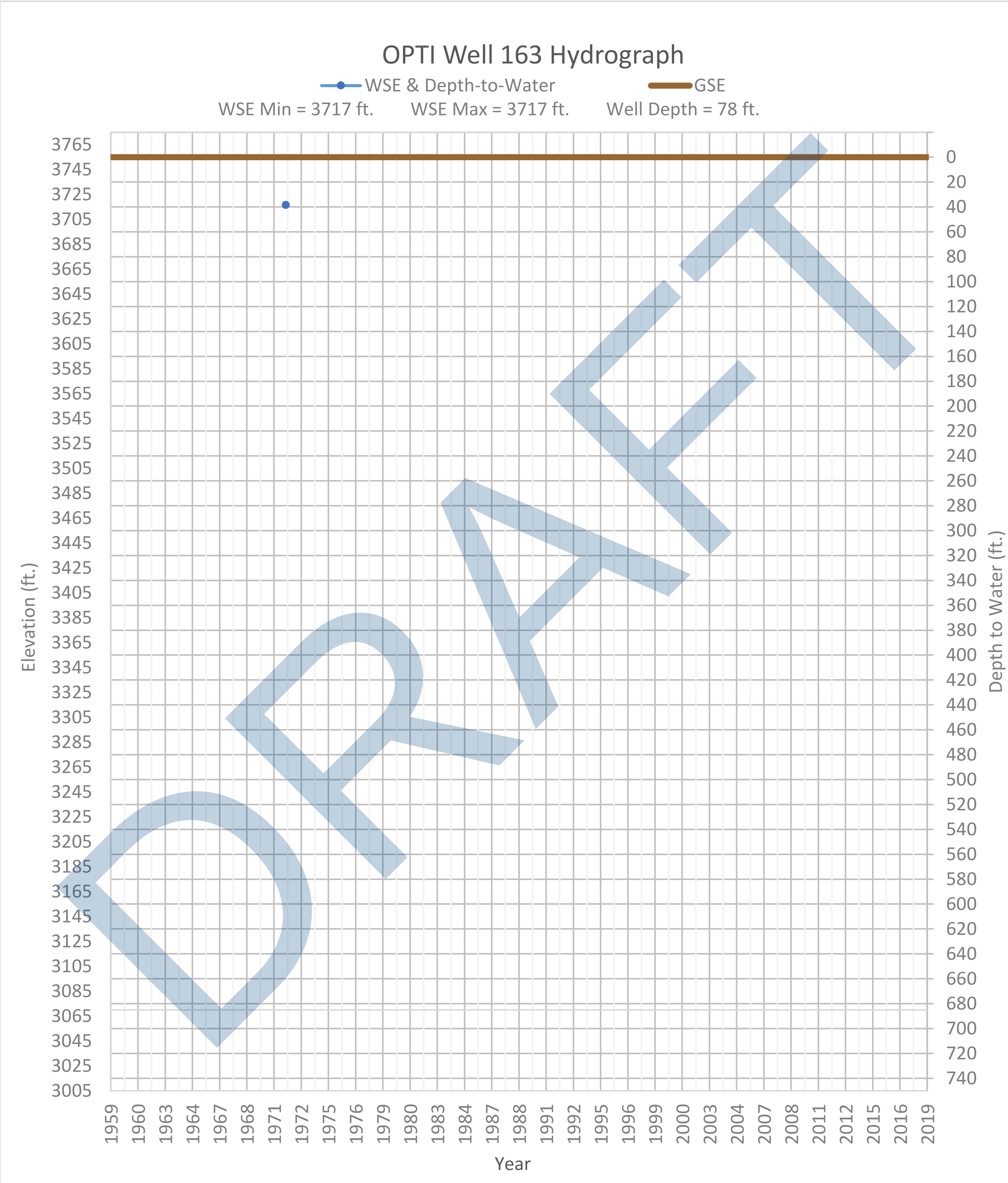
OPTI Well 157 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3700 ft.
WSE Max = 3700 ft.
Well Depth = 71 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

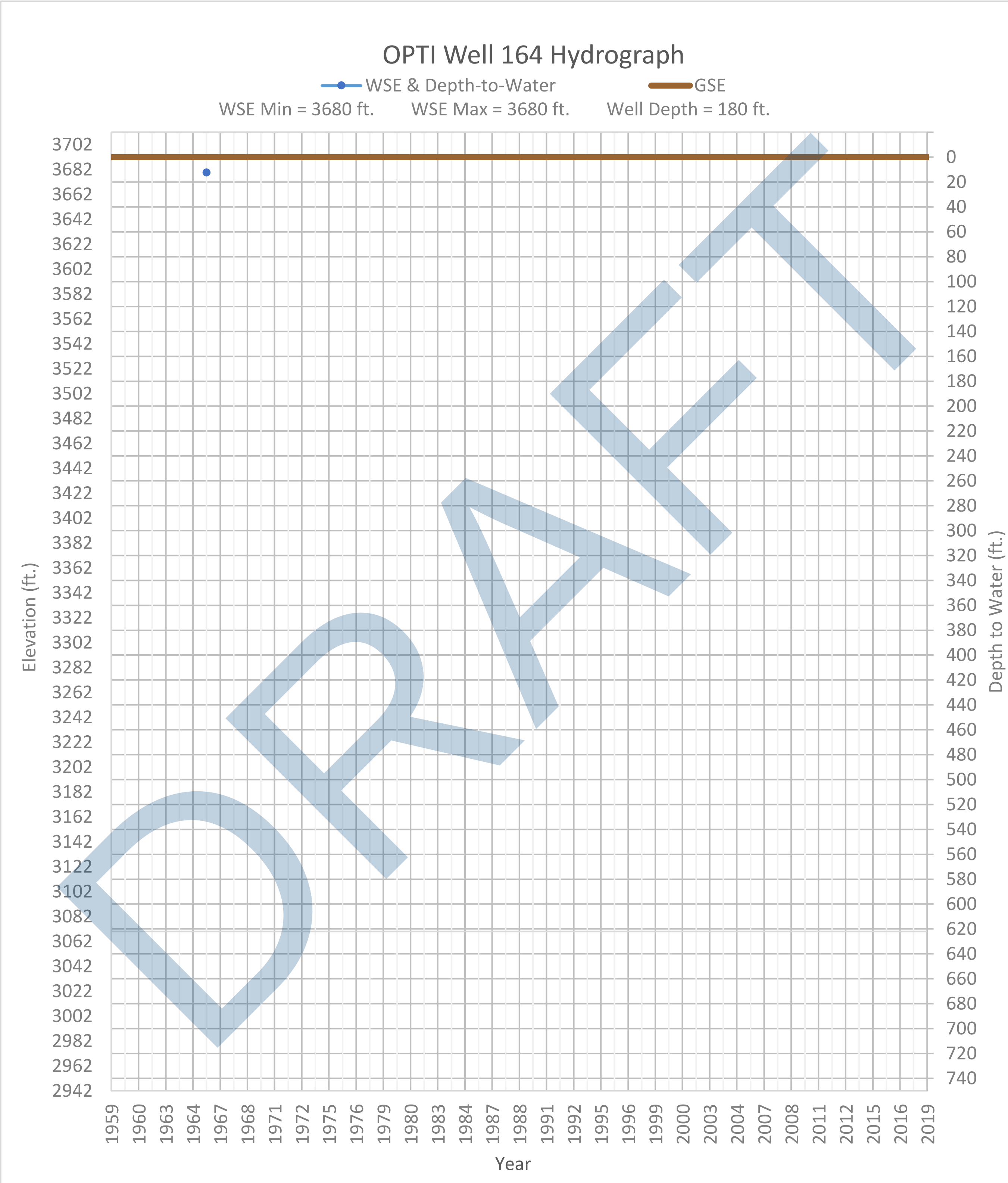


OPTI Well 159 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3687 ft.
WSE Max = 3692 ft.
Well Depth = 64 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

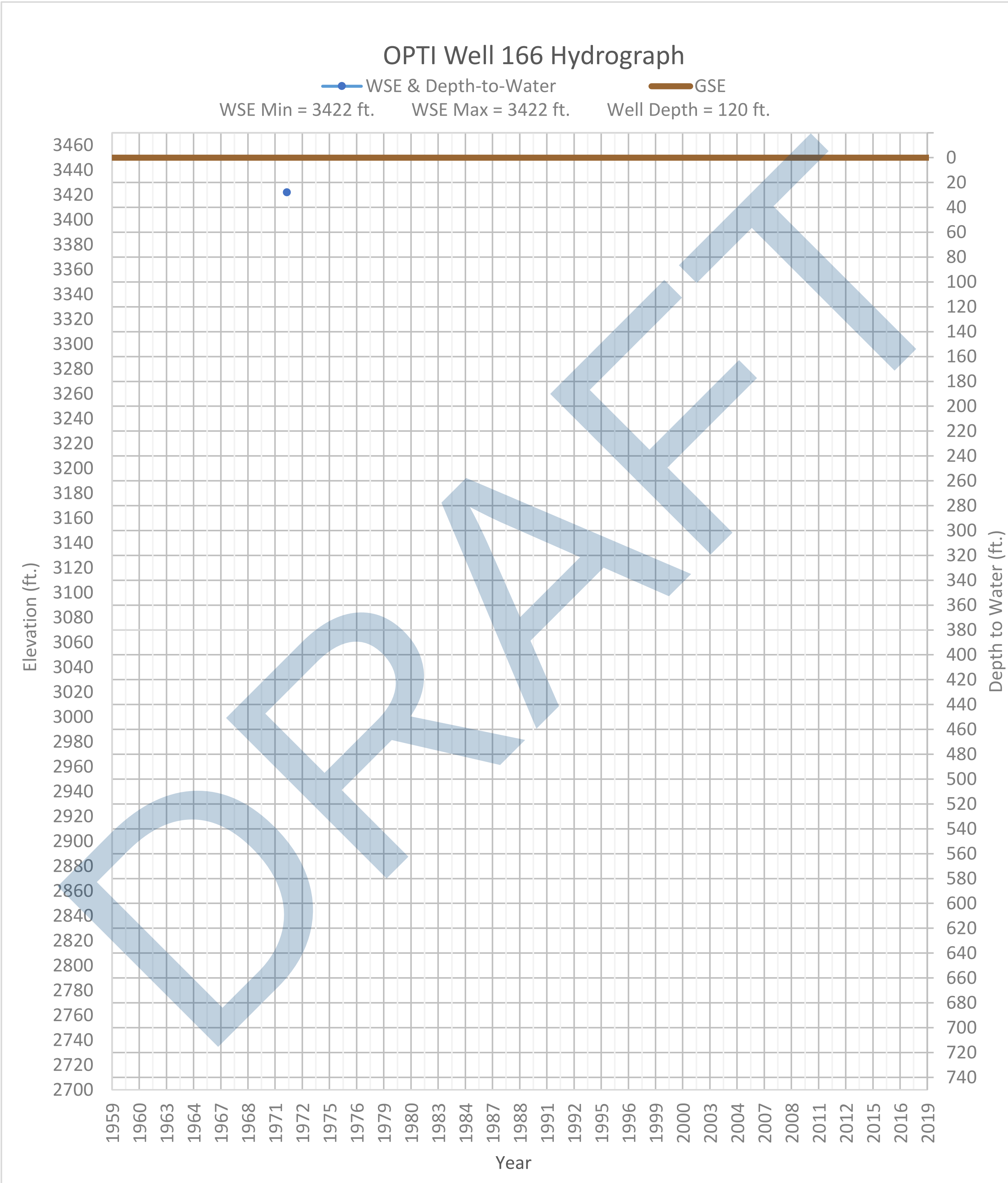


OPTI Well 162 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3742 ft.
WSE Max = 3742 ft.
Well Depth = 150 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

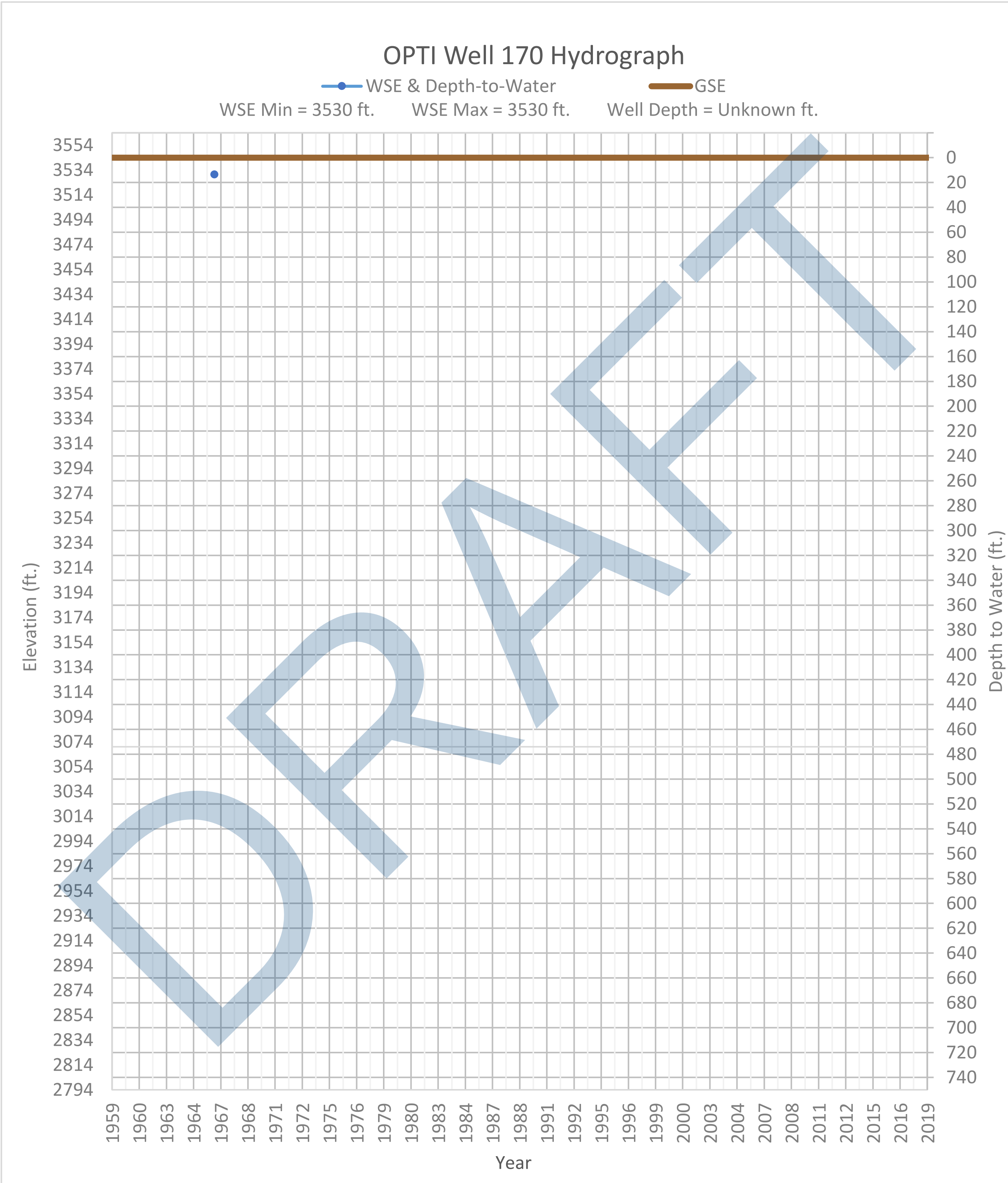

OPTI Well 163 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3717 ft.
WSE Max = 3717 ft.
Well Depth = 78 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



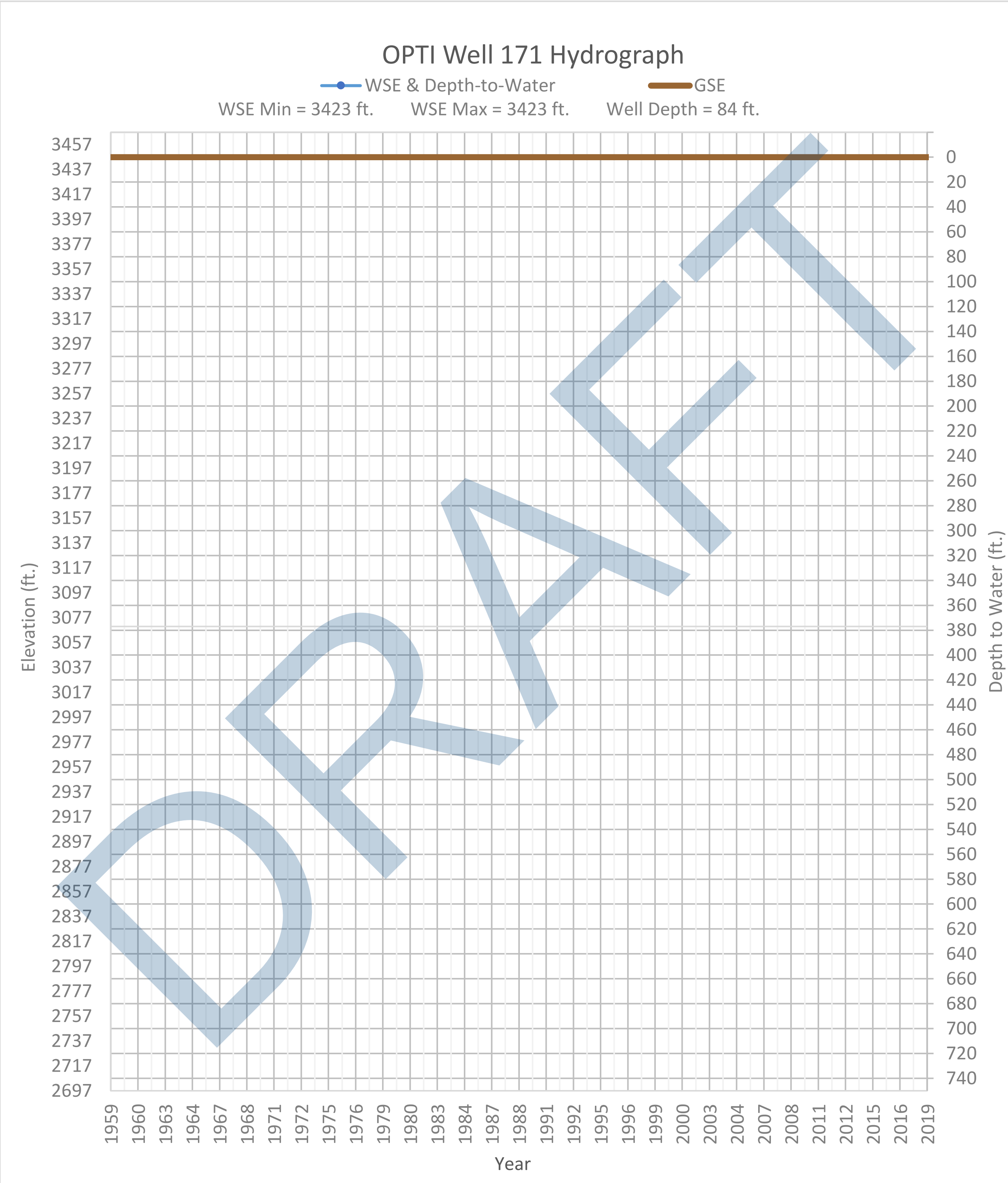
OPTI Well 164 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3680 ft.
WSE Max = 3680 ft.
Well Depth = 180 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



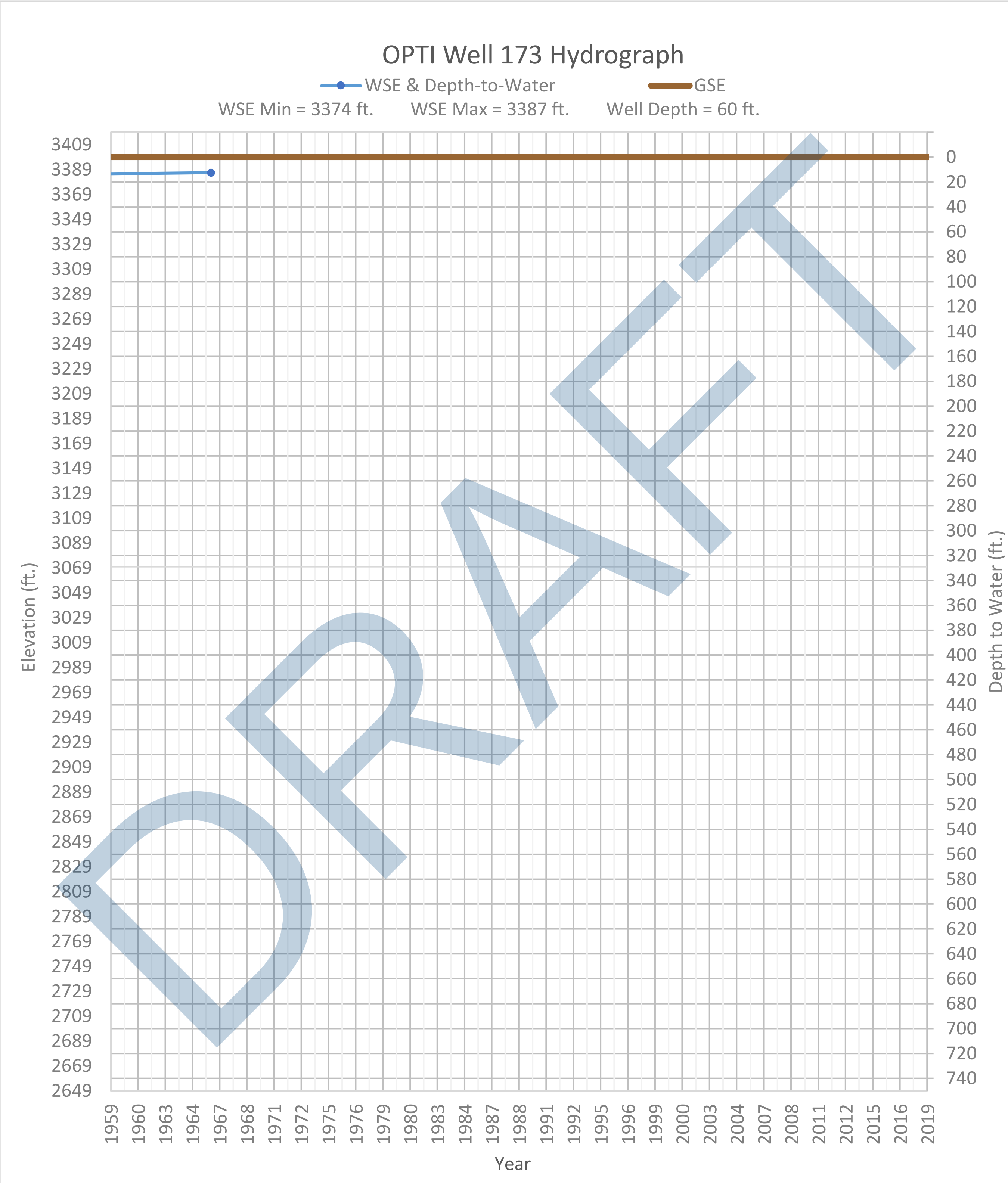
OPTI Well 166 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3422 ft.
WSE Max = 3422 ft.
Well Depth = 120 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



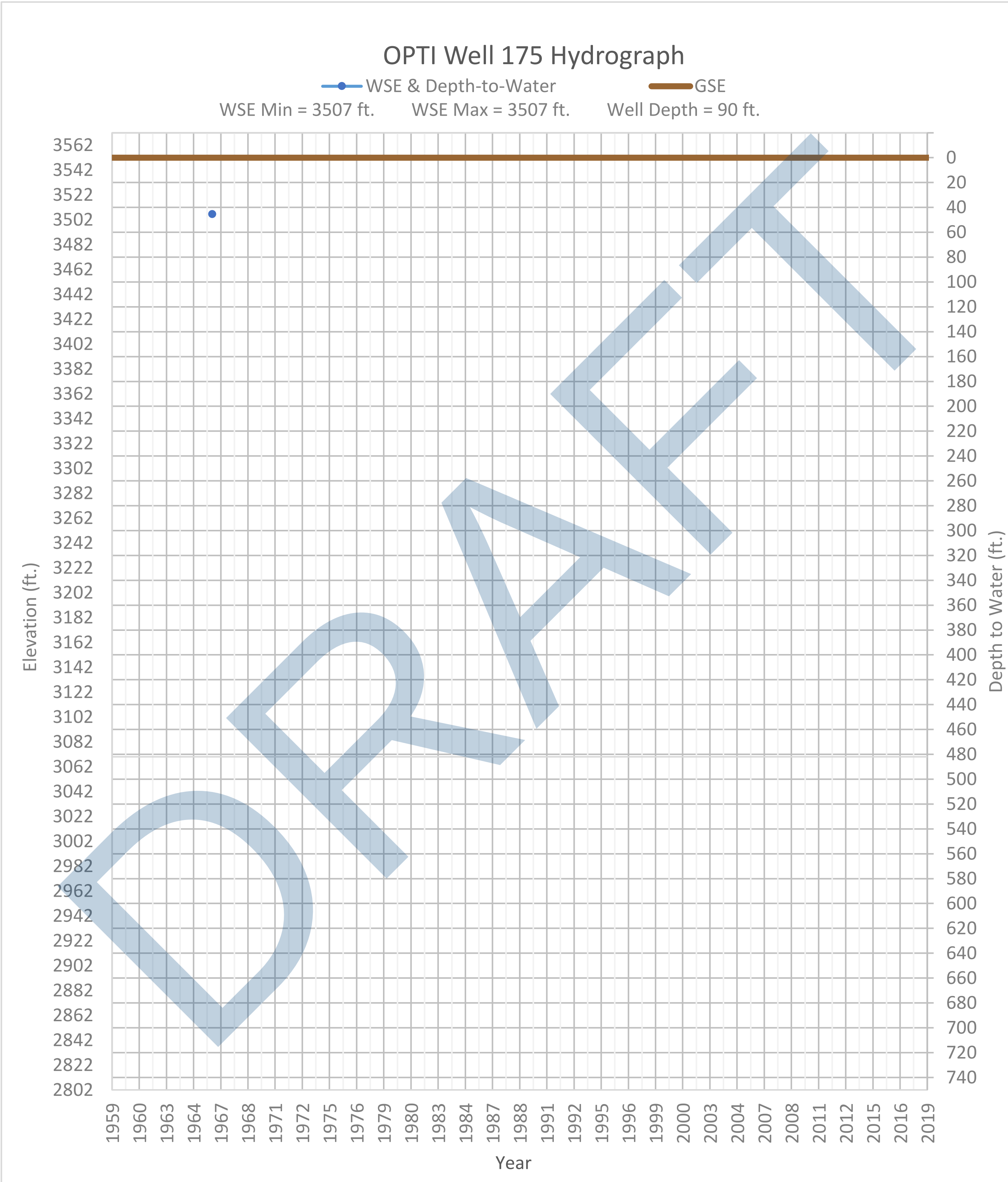
OPTI Well 170 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3530 ft.
WSE Max = 3530 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



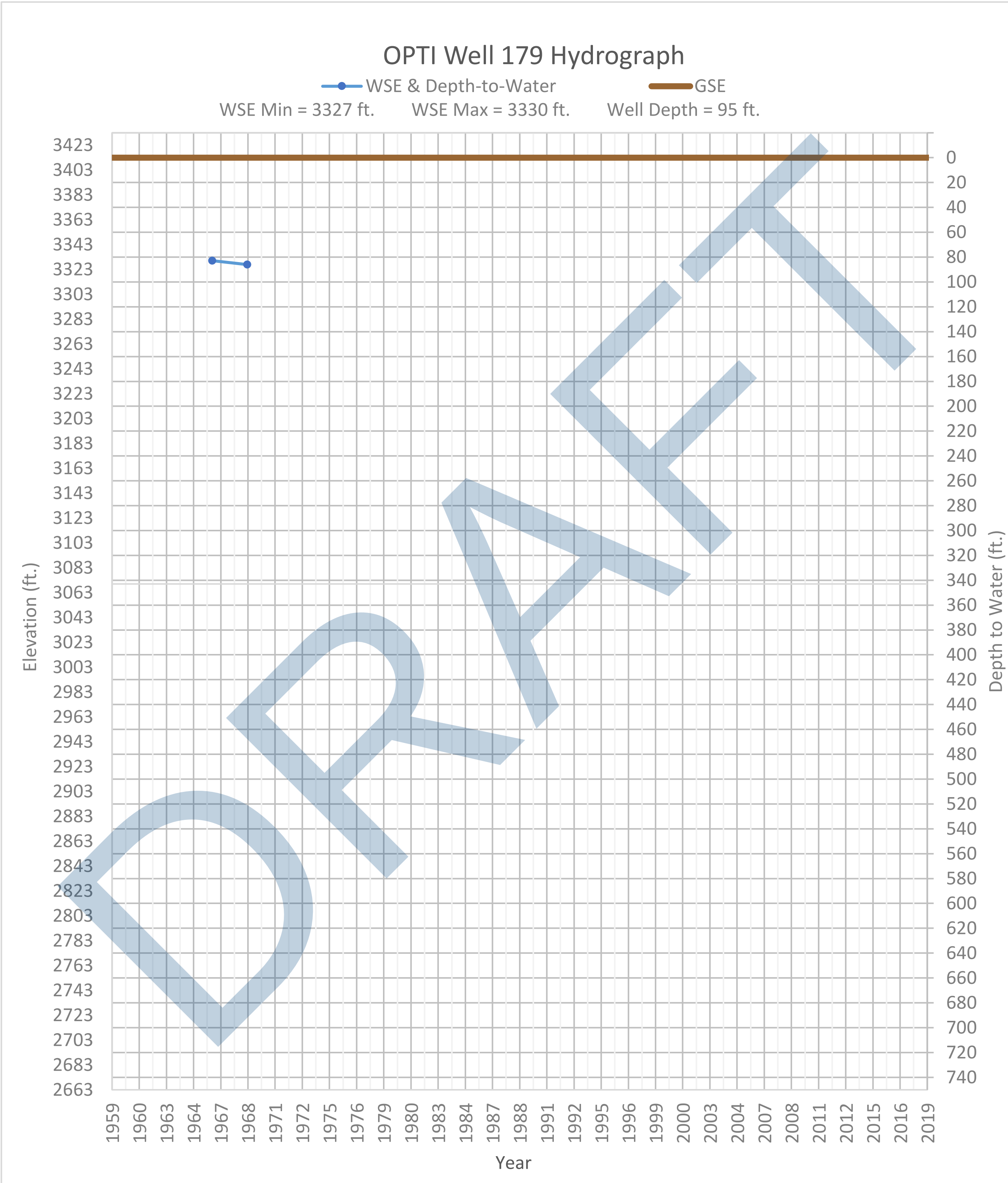
OPTI Well 171 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3423 ft.
WSE Max = 3423 ft.
Well Depth = 84 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



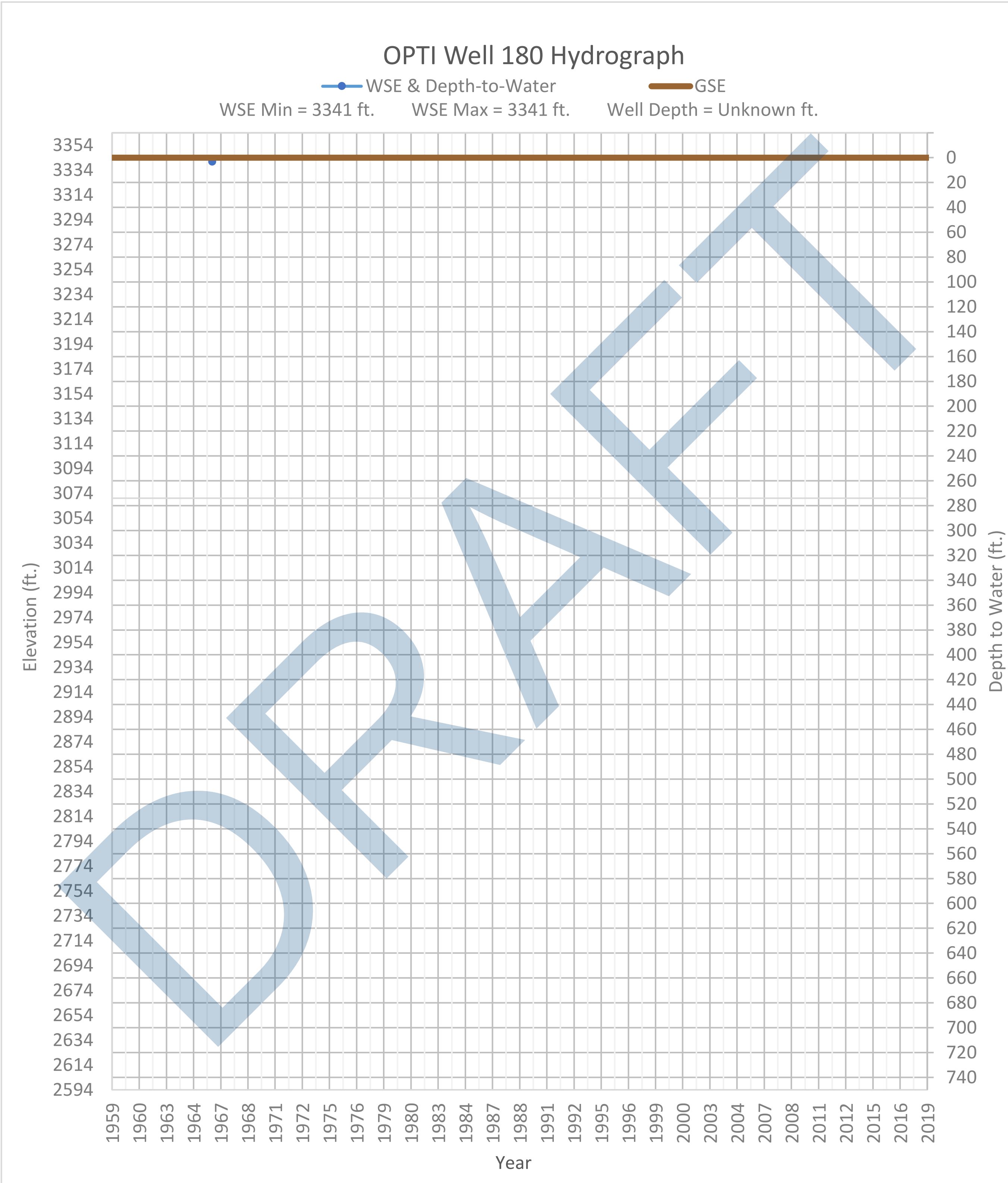
OPTI Well 173 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3374 ft.
WSE Max = 3387 ft.
Well Depth = 60 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



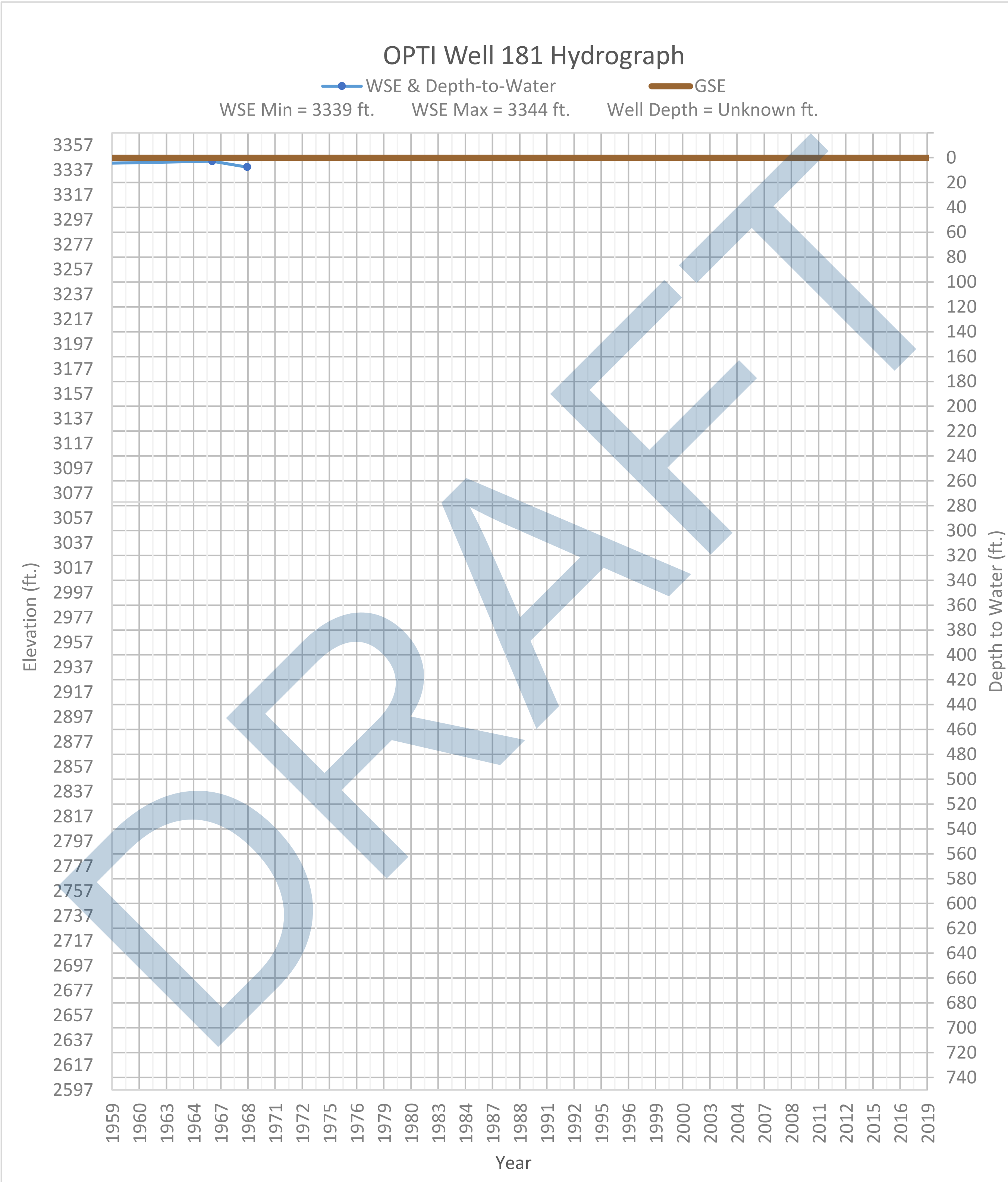
OPTI Well 175 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3507 ft.
WSE Max = 3507 ft.
Well Depth = 90 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 179 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3327 ft.
WSE Max = 3330 ft.
Well Depth = 95 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 180 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3341 ft.
WSE Max = 3341 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 181 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3339 ft.
WSE Max = 3344 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
3357
3337
3317
3297
3277
3257
3237
3217
3197
3177
3157
3137
3117
3097
3077
3057
3037
3017
2997
2977
2957
2937
2917
2897
2877
2857
2837
2817
2797
2777
2757
2737
2717
2697
2677
2657
2637
2617
2597
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
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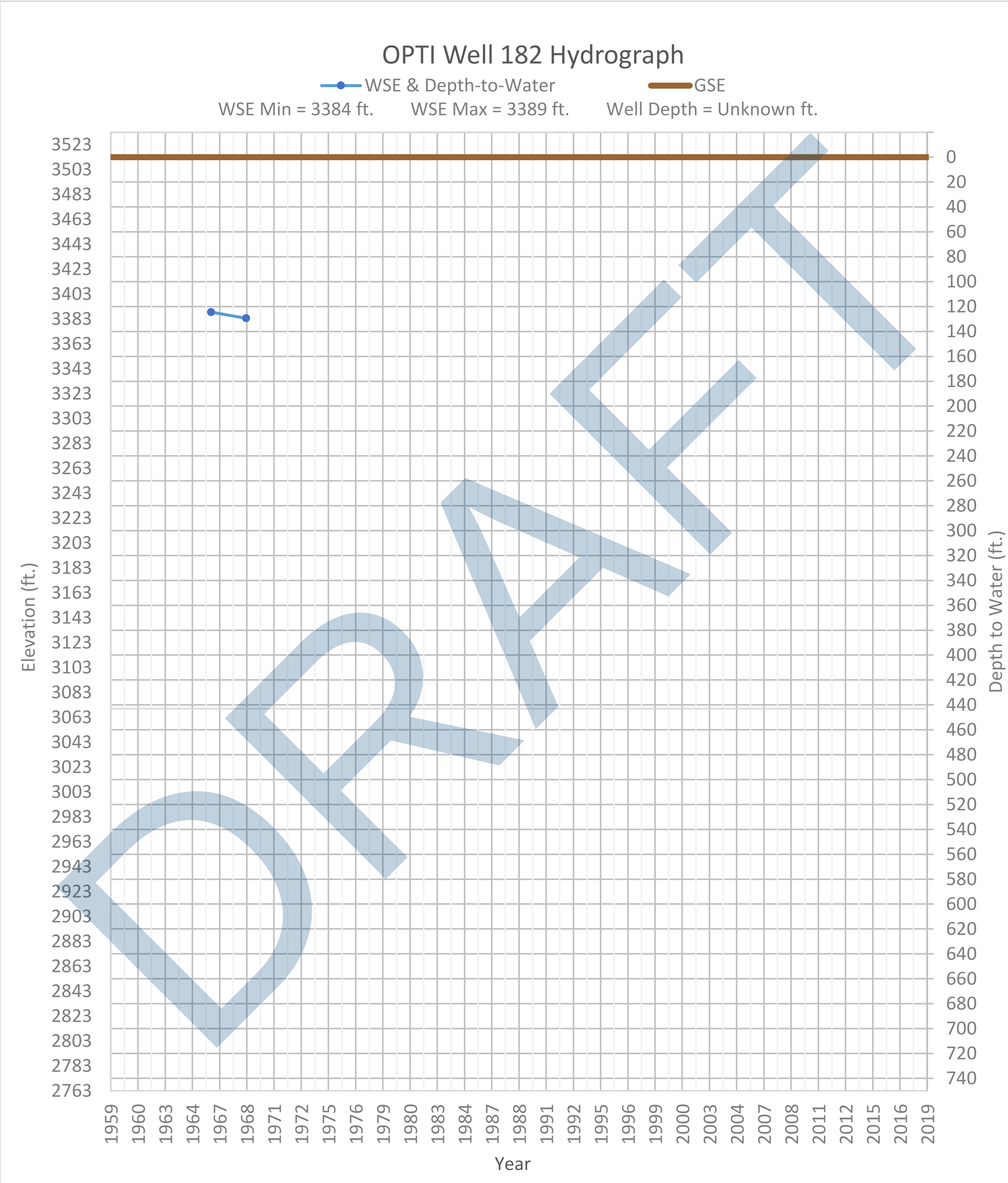
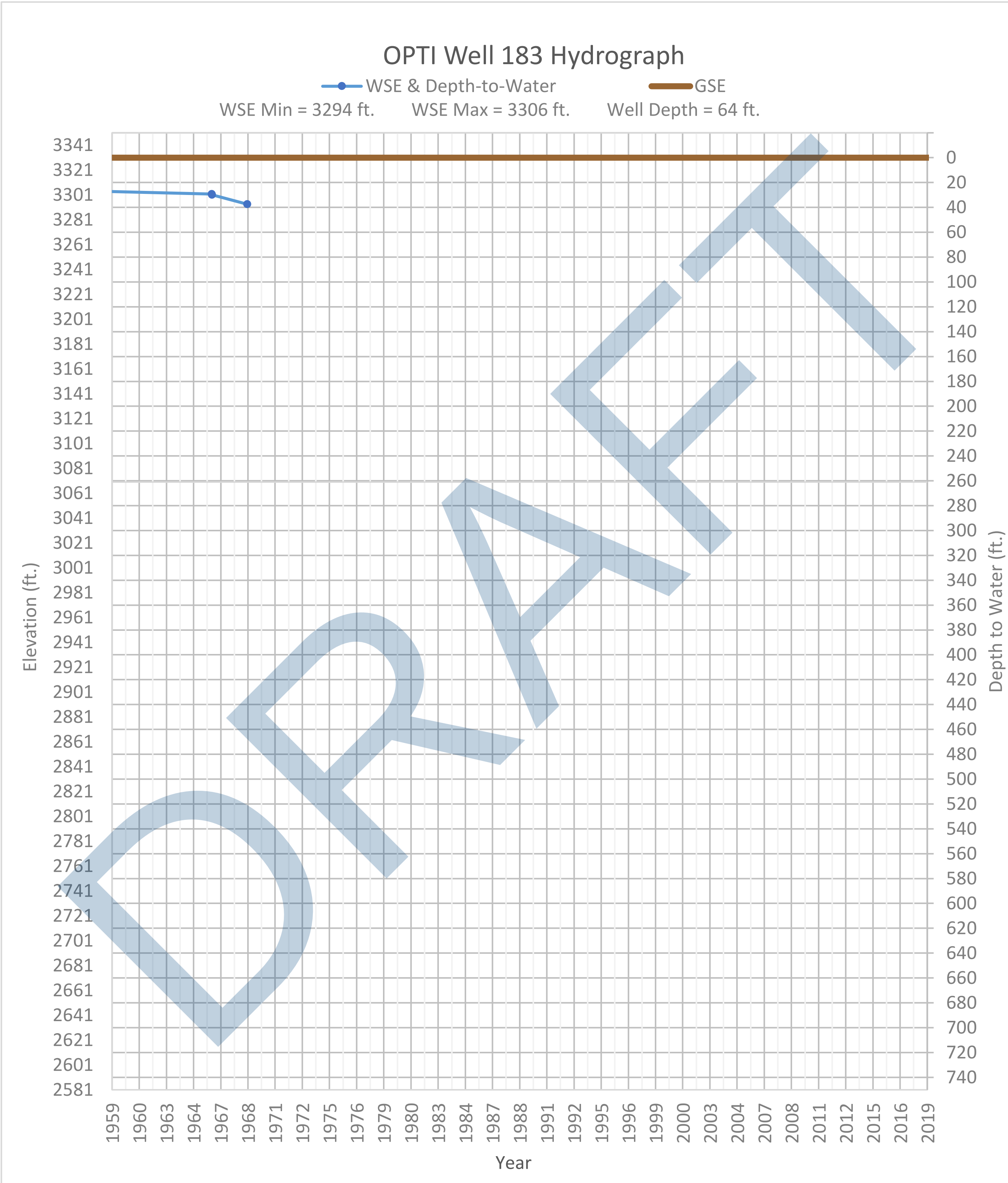
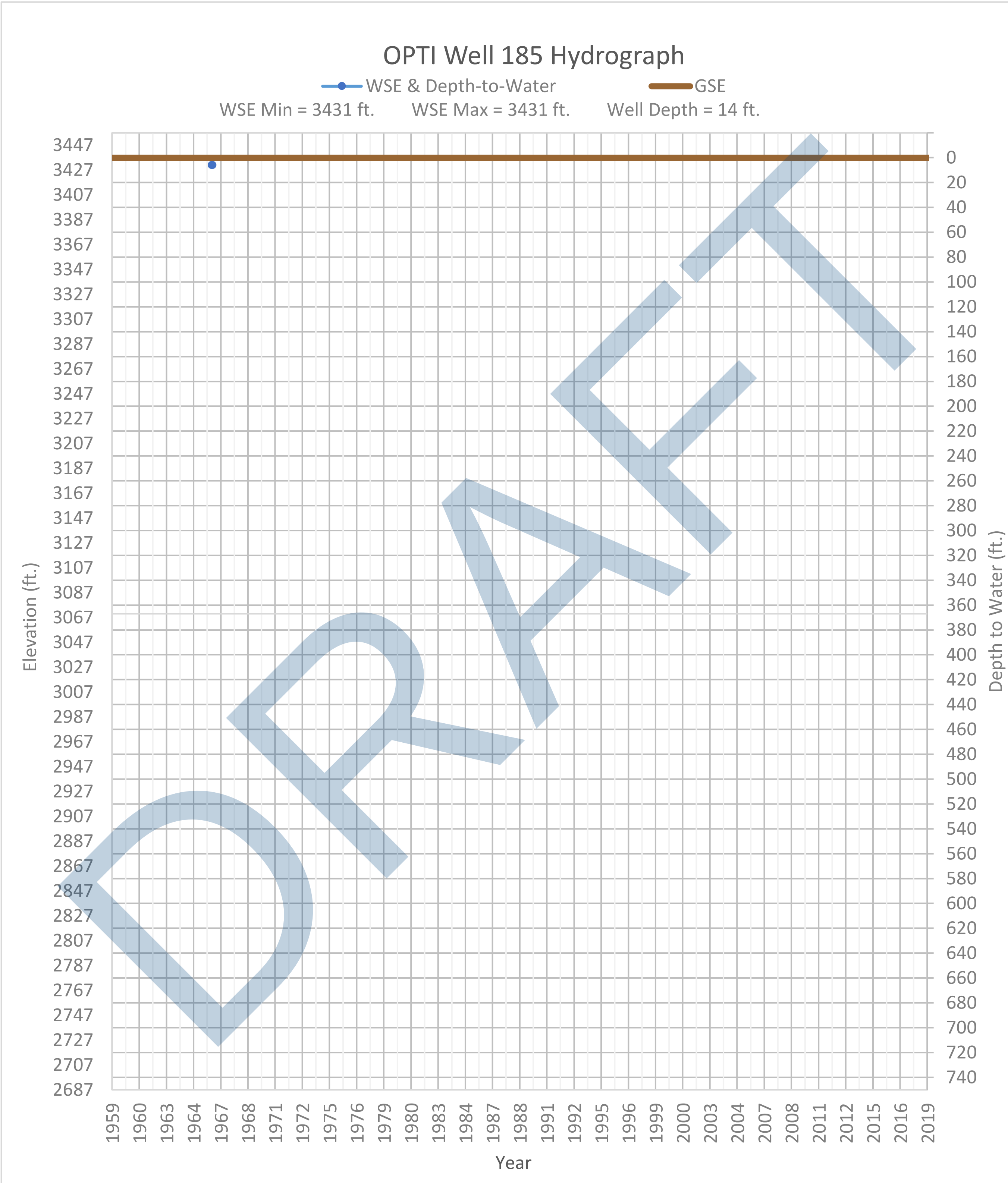
2011
2012
2015
2016
2019
DRAFT

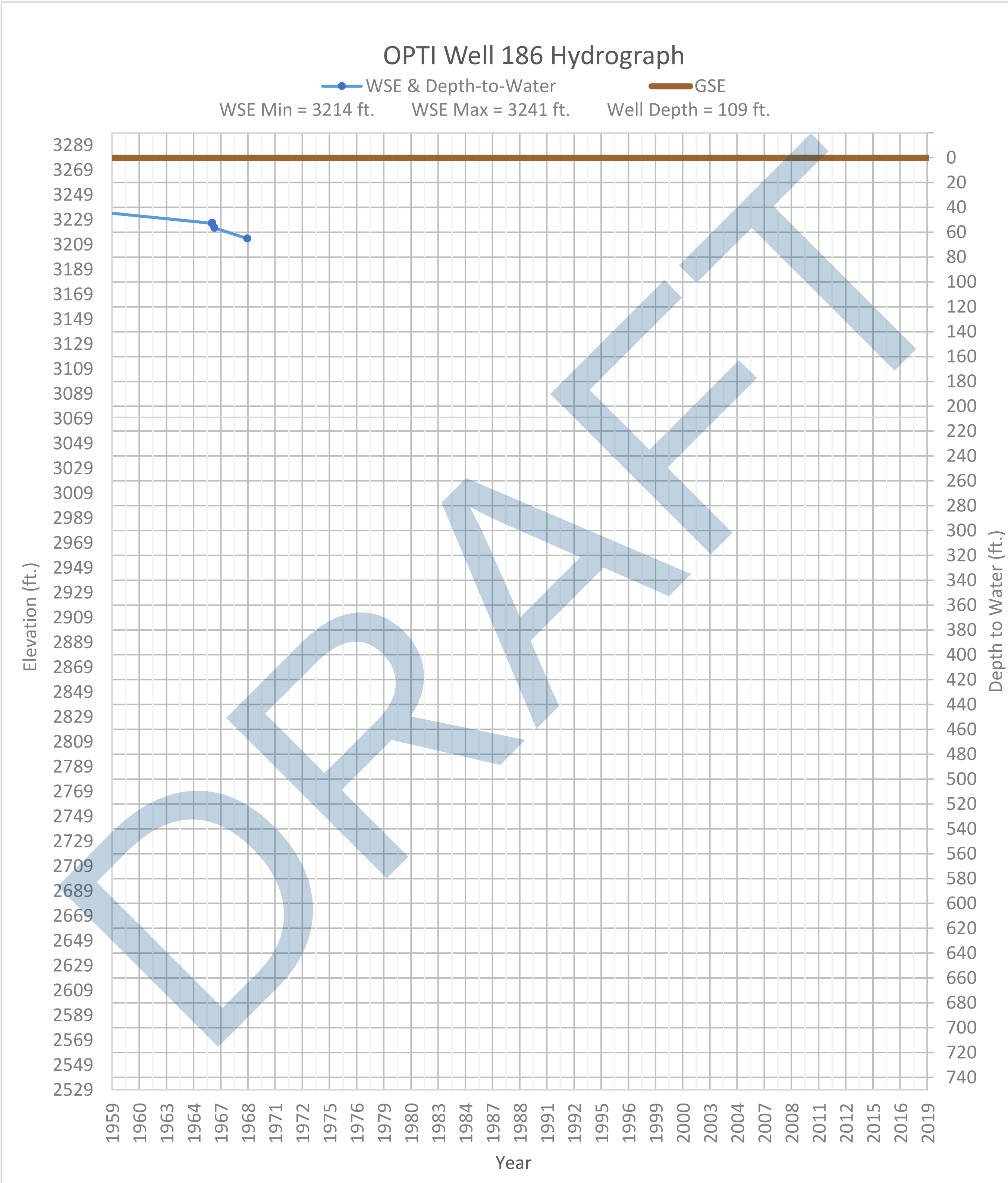


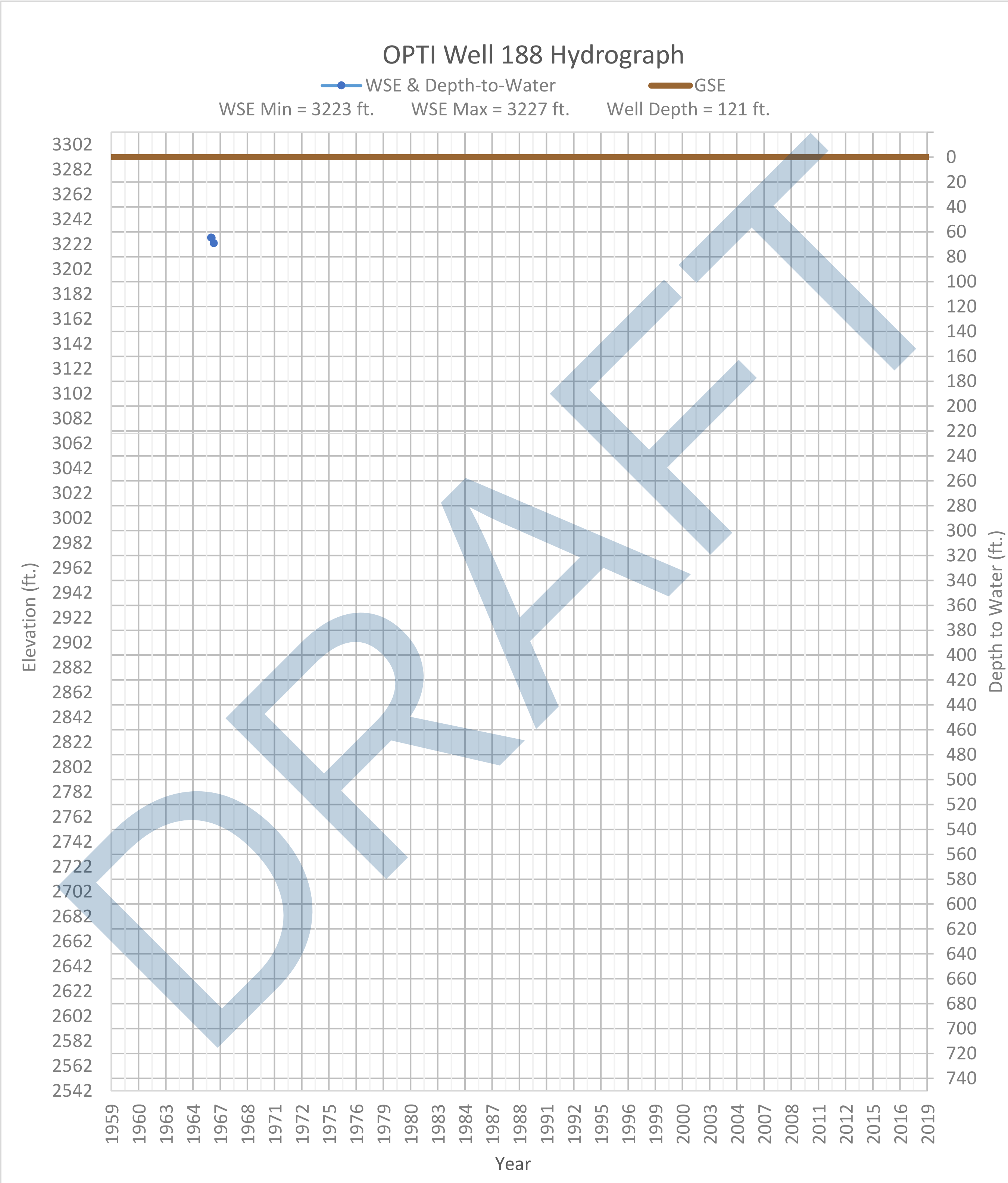
OPTI Well 182 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3384 ft.
WSE Max = 3389 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

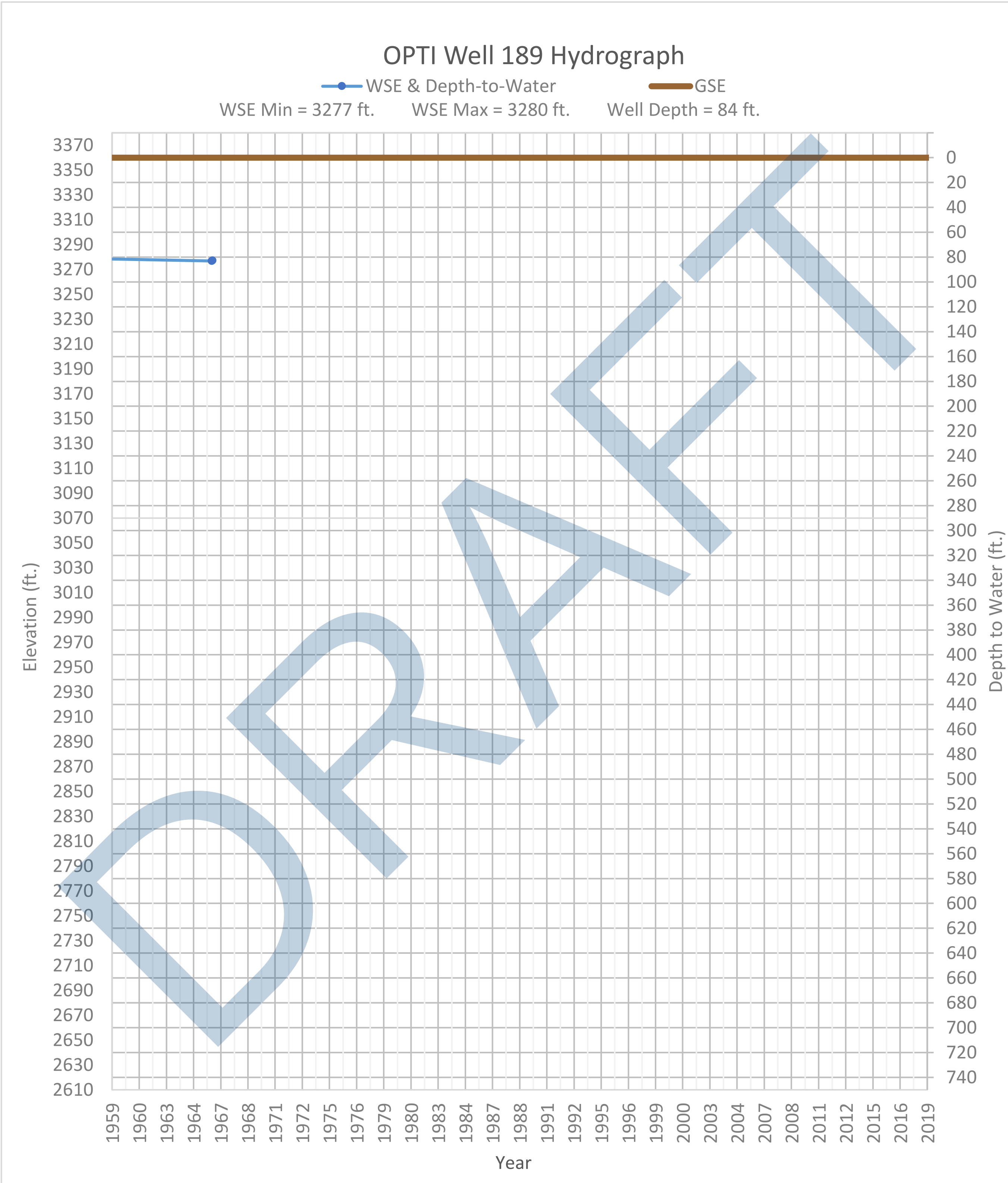


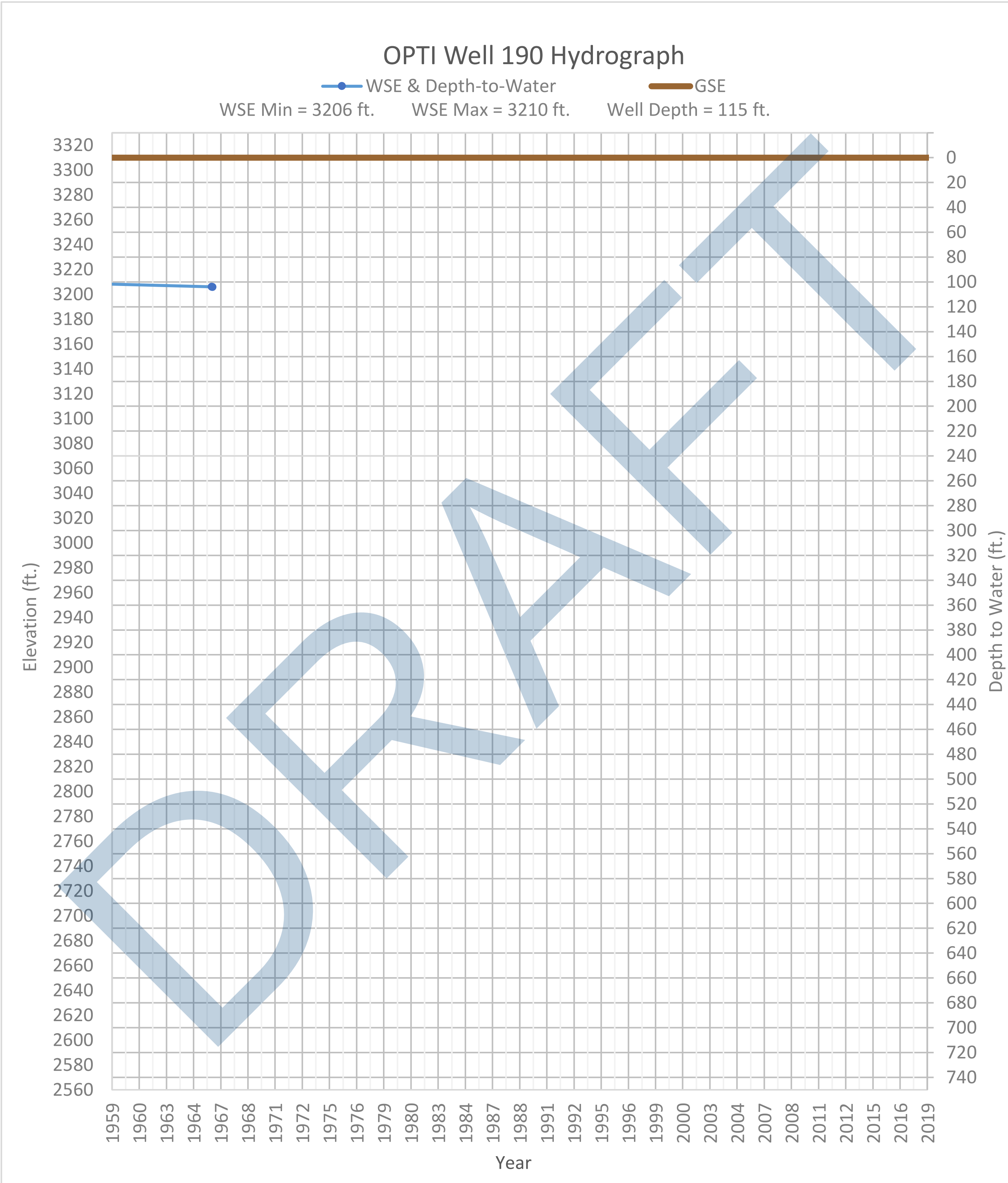
OPTI Well 183 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3294 ft.
WSE Max = 3306 ft.
Well Depth = 64 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 185 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3431 ft.
WSE Max = 3431 ft.
Well Depth = 14 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

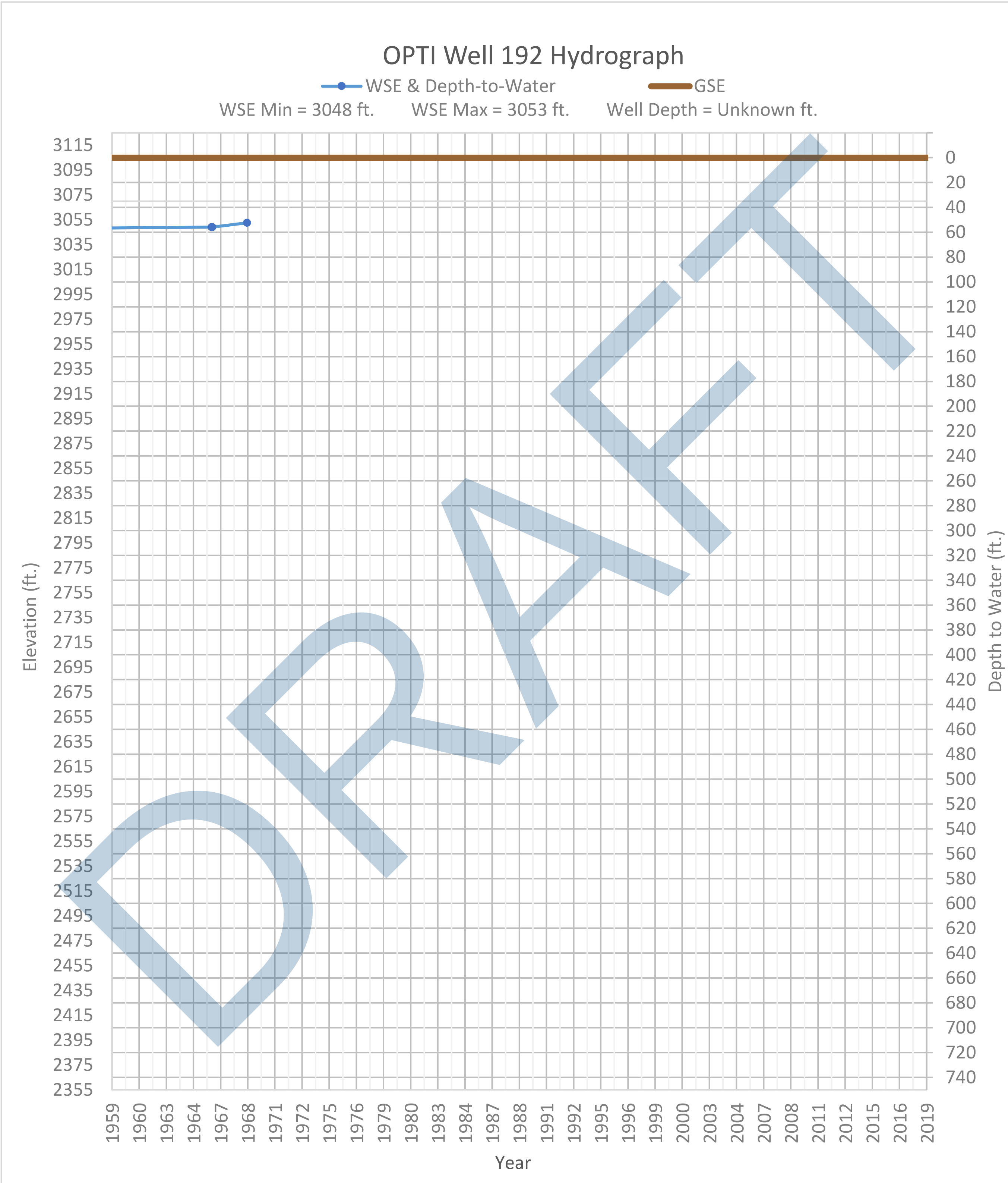

OPTI Well 186 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3214 ft.
WSE Max = 3241 ft.
Well Depth = 109 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 188 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3223 ft.
WSE Max = 3227 ft.
Well Depth = 121 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

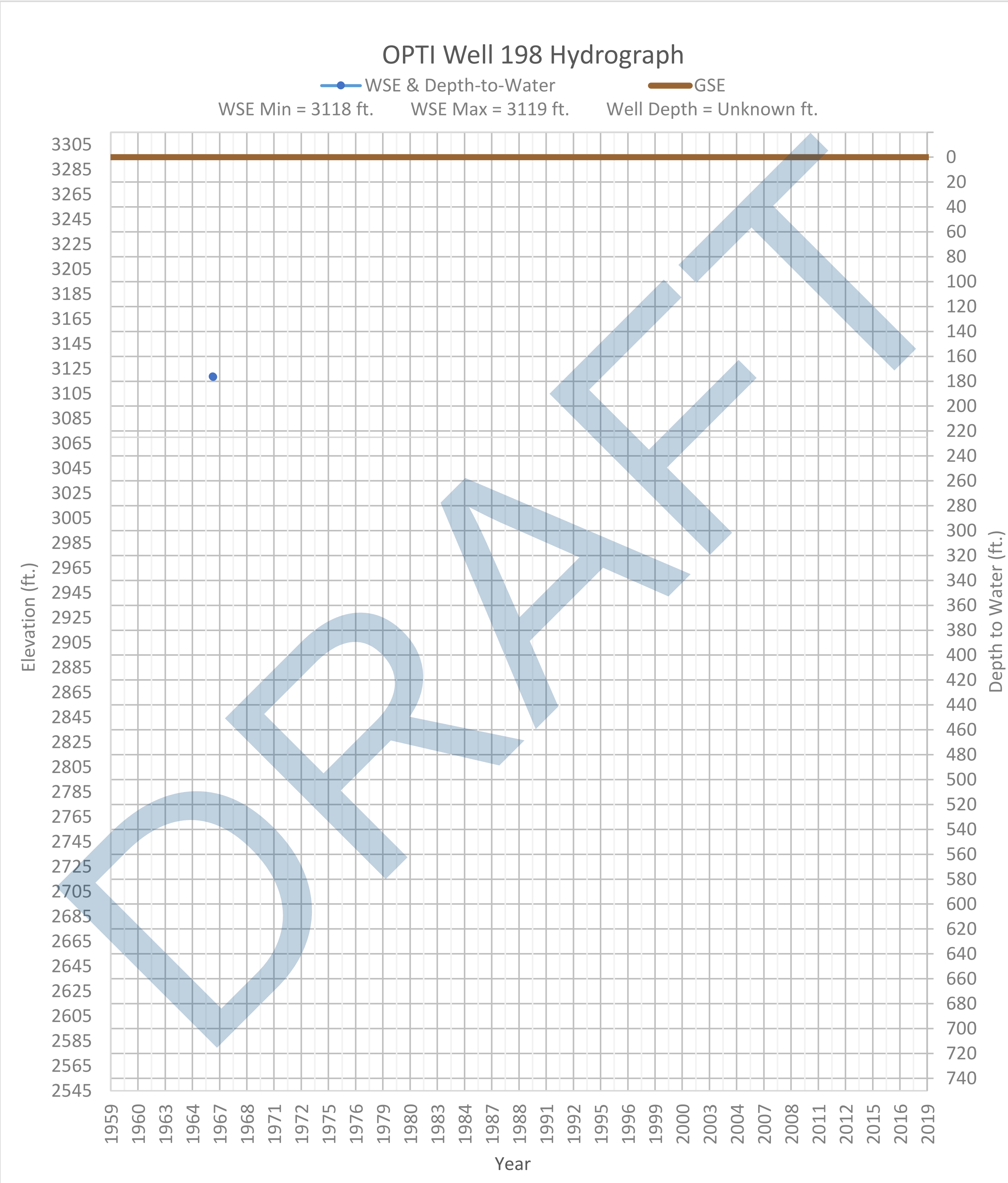

OPTI Well 189 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3277 ft.
WSE Max = 3280 ft.
Well Depth = 84 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



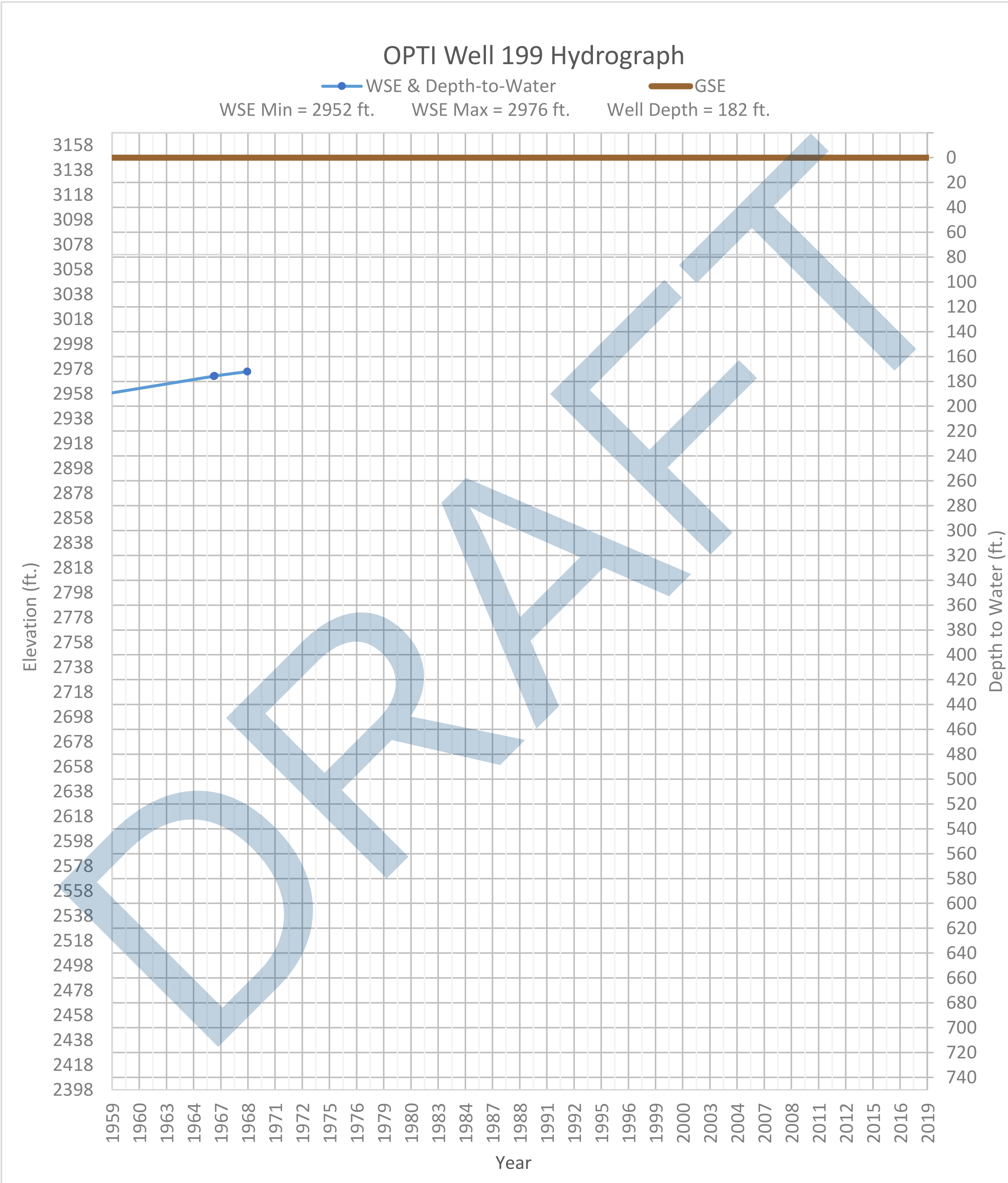
OPTI Well 190 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3206 ft.
WSE Max = 3210 ft.
Well Depth = 115 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



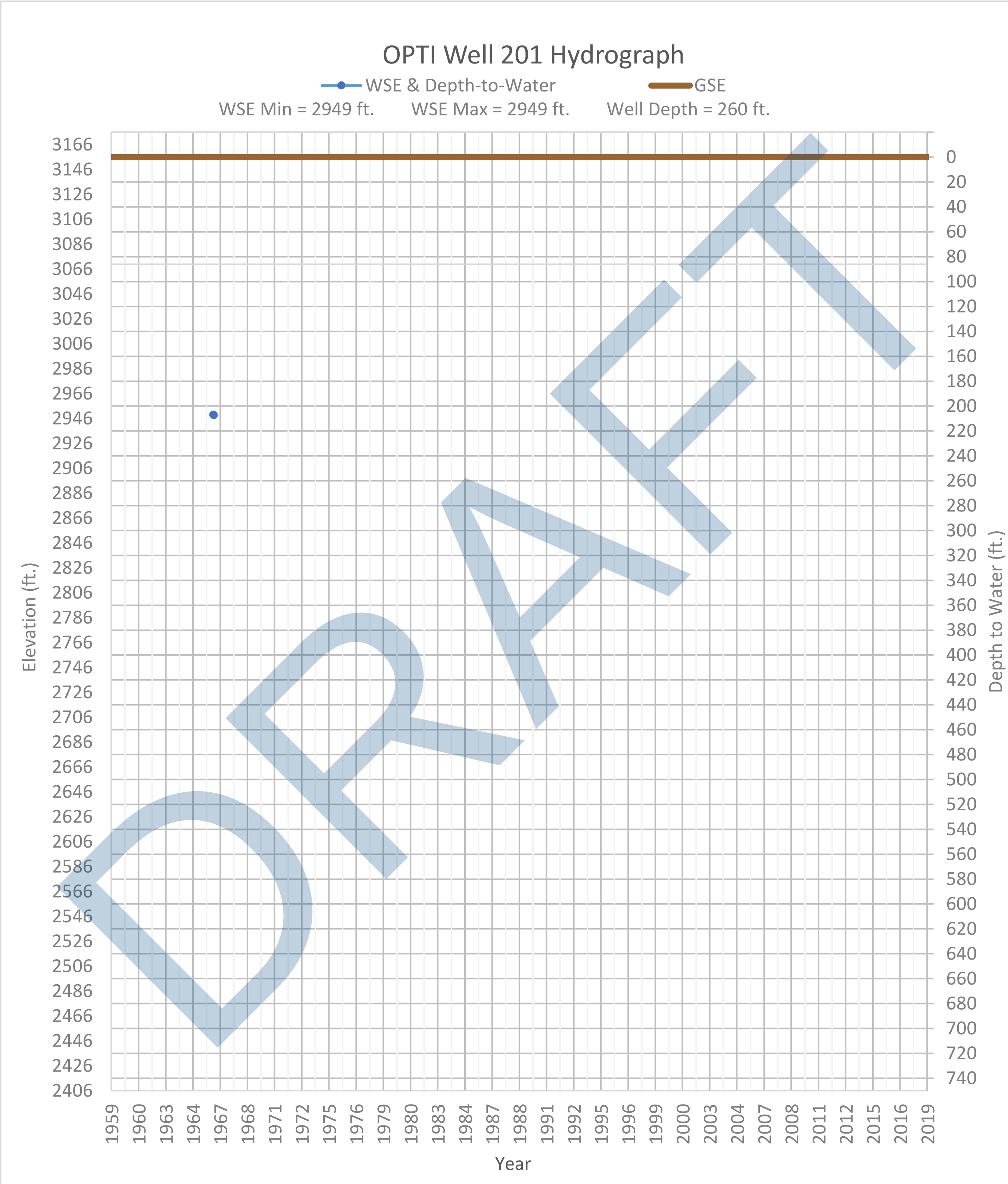
OPTI Well 192 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3048 ft.
WSE Max = 3053 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



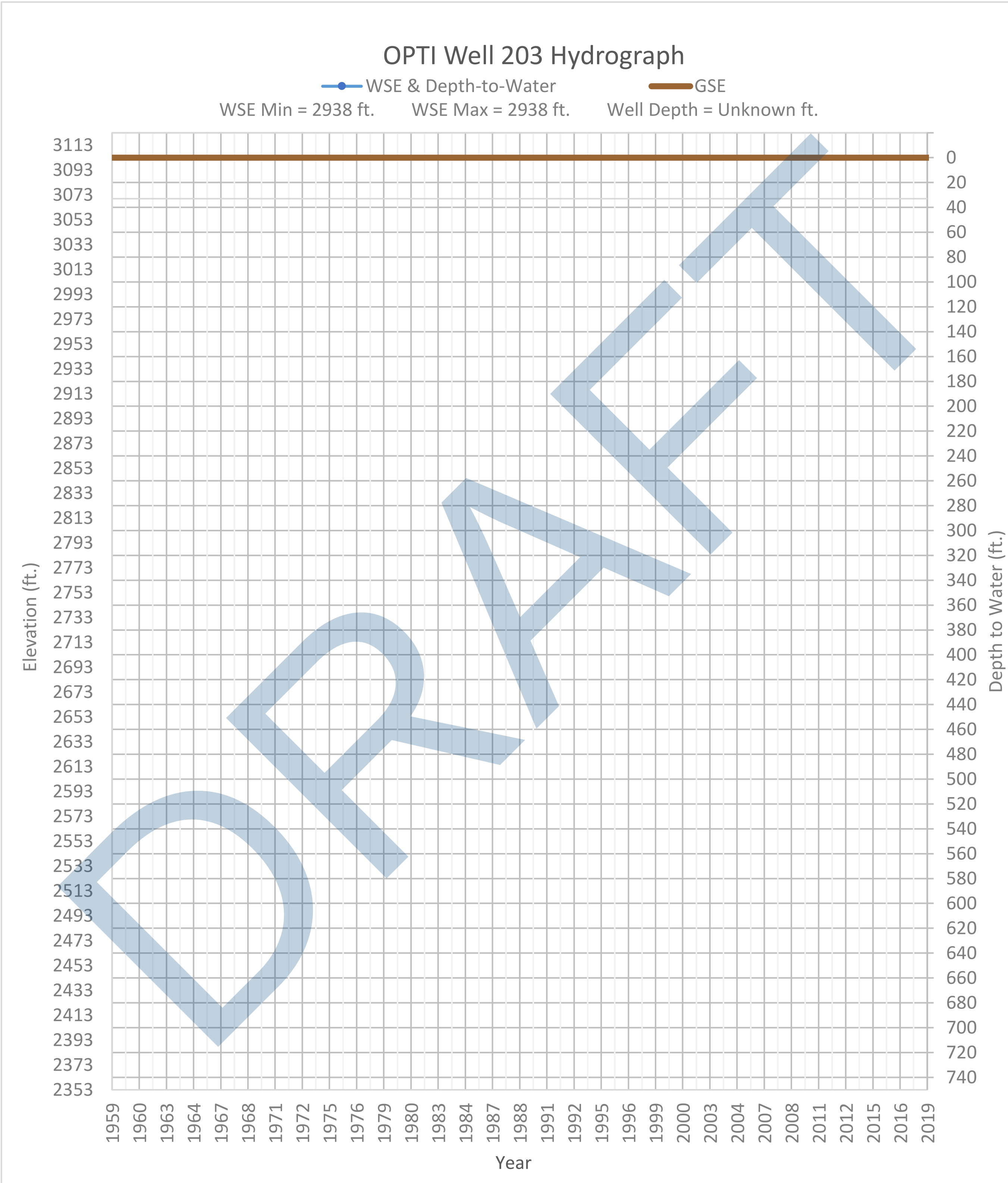
OPTI Well 198 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3118 ft.
WSE Max = 3119 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



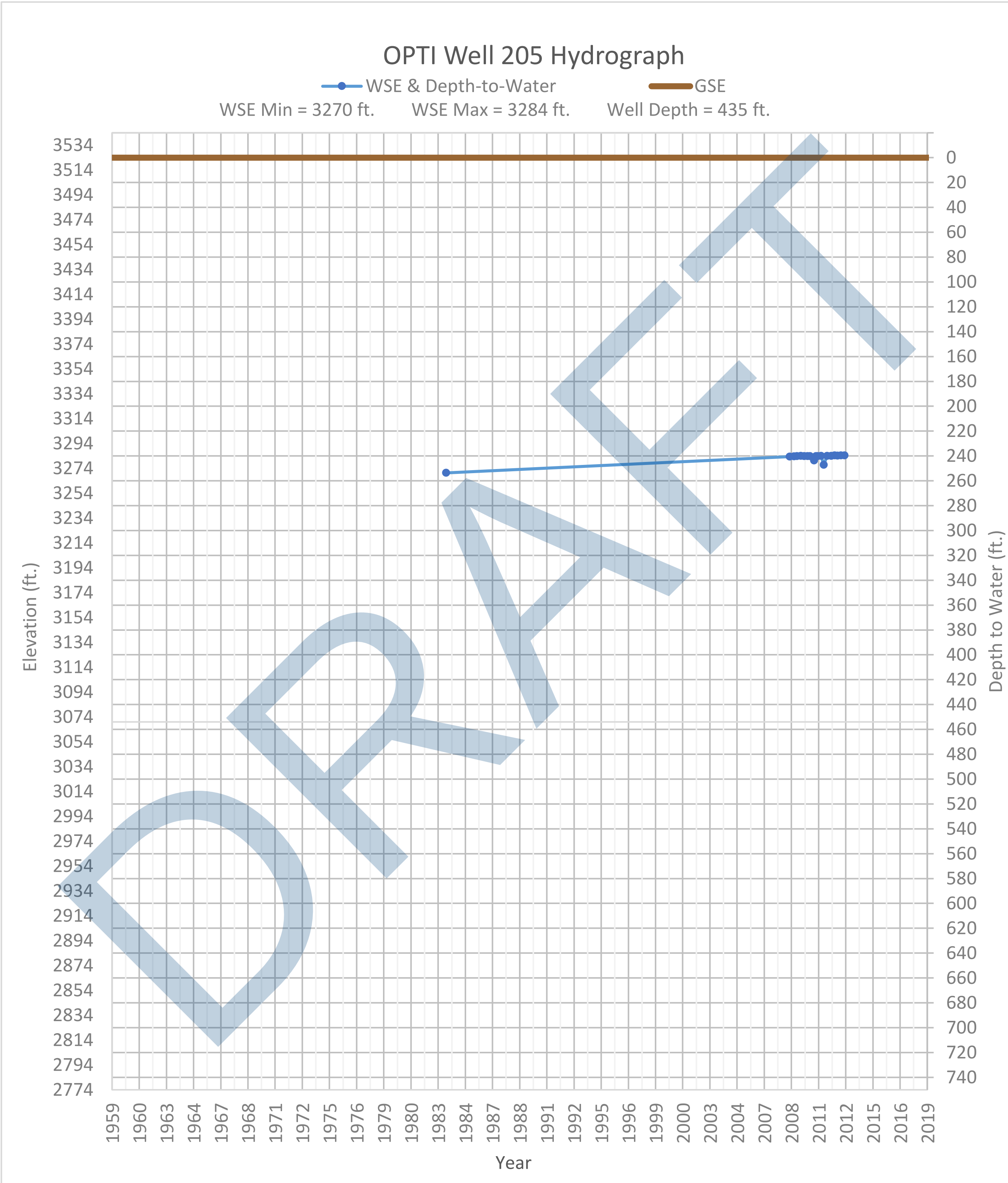
OPTI Well 199 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2952 ft.
WSE Max = 2976 ft.
Well Depth = 182 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



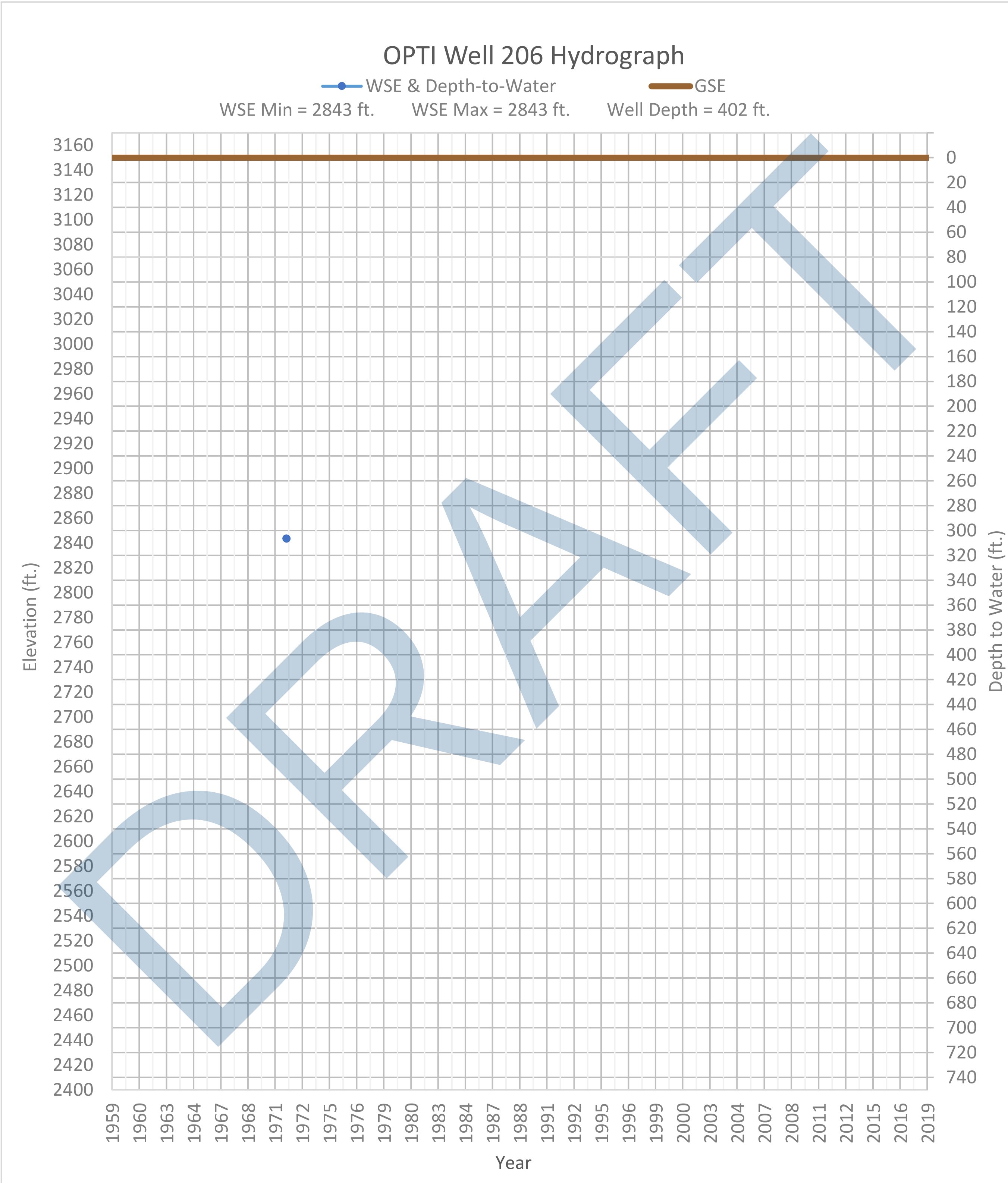
OPTI Well 201 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2949 ft.
WSE Max = 2949 ft.
Well Depth = 260 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



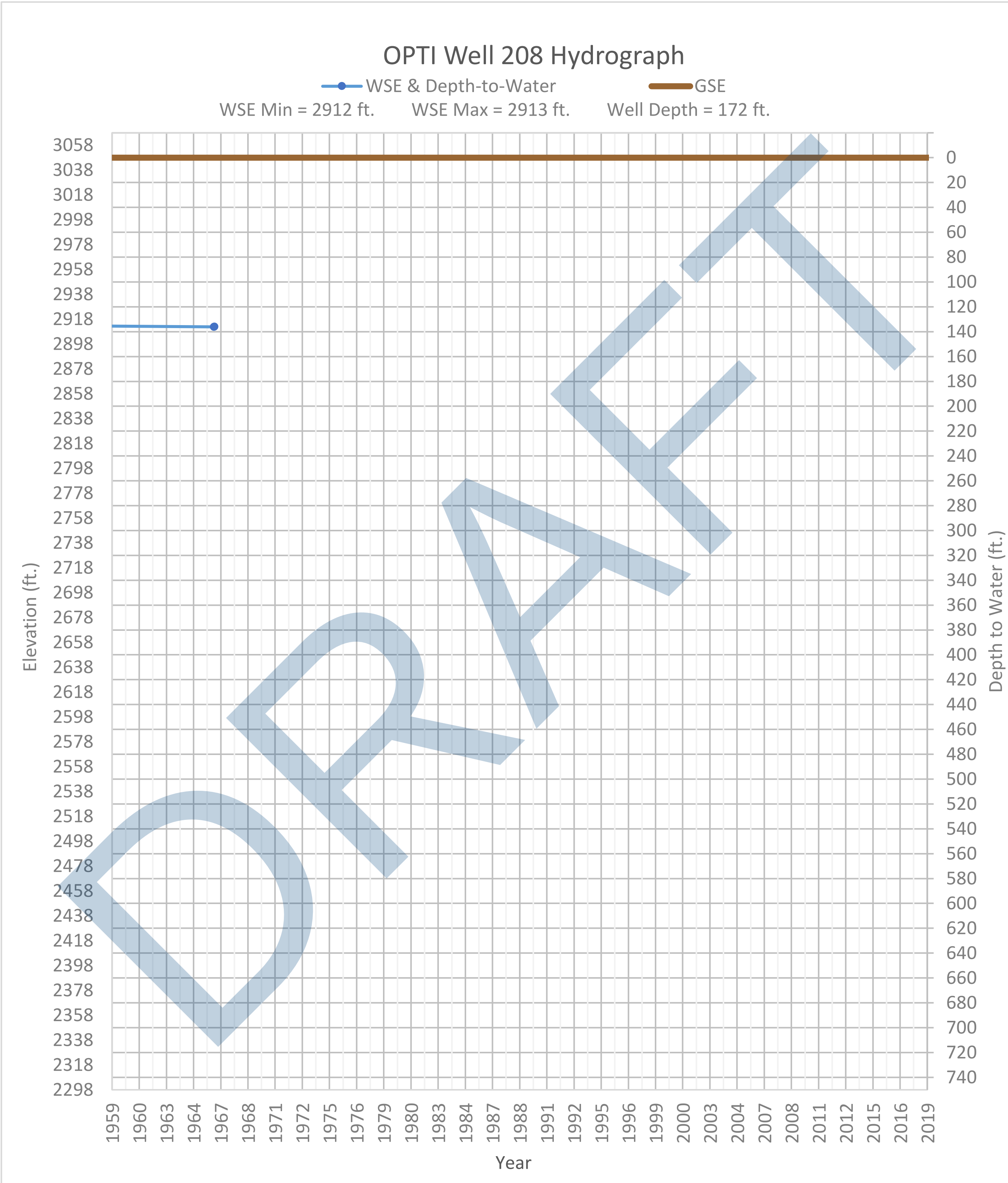
OPTI Well 203 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2938 ft.
WSE Max = 2938 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



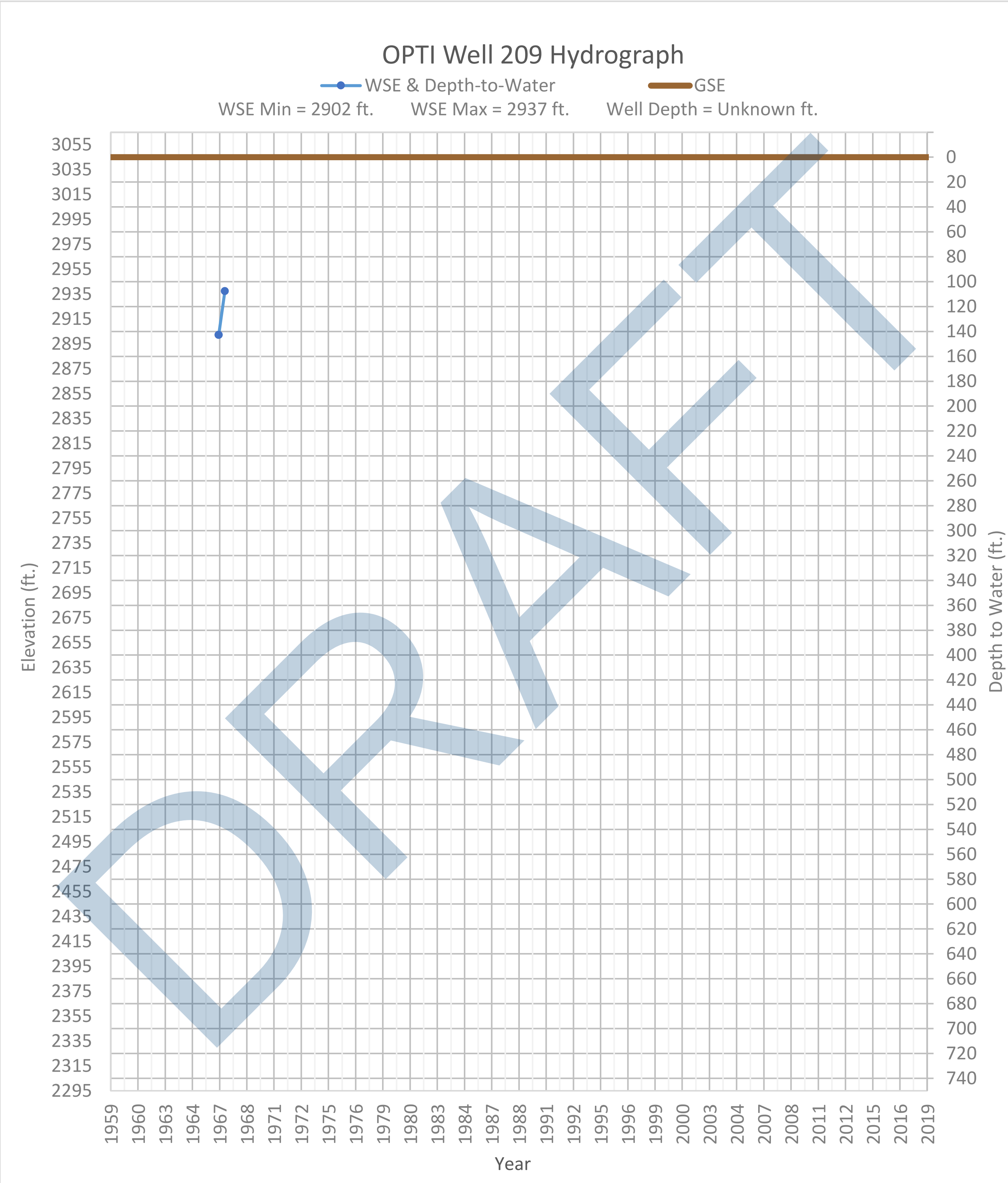
OPTI Well 205 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3270 ft.
WSE Max = 3284 ft.
Well Depth = 435 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



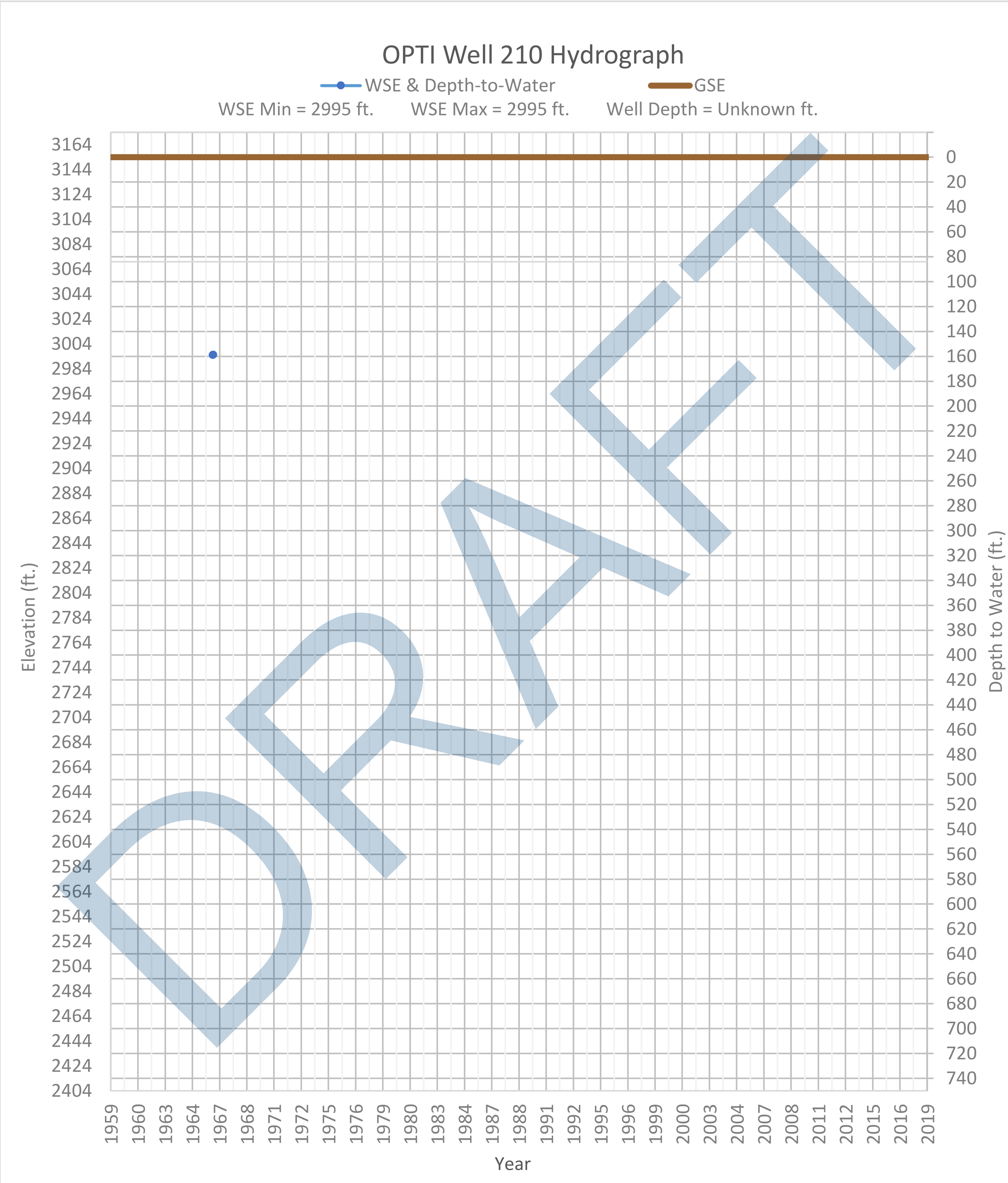
OPTI Well 206 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2843 ft.
WSE Max = 2843 ft.
Well Depth = 402 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



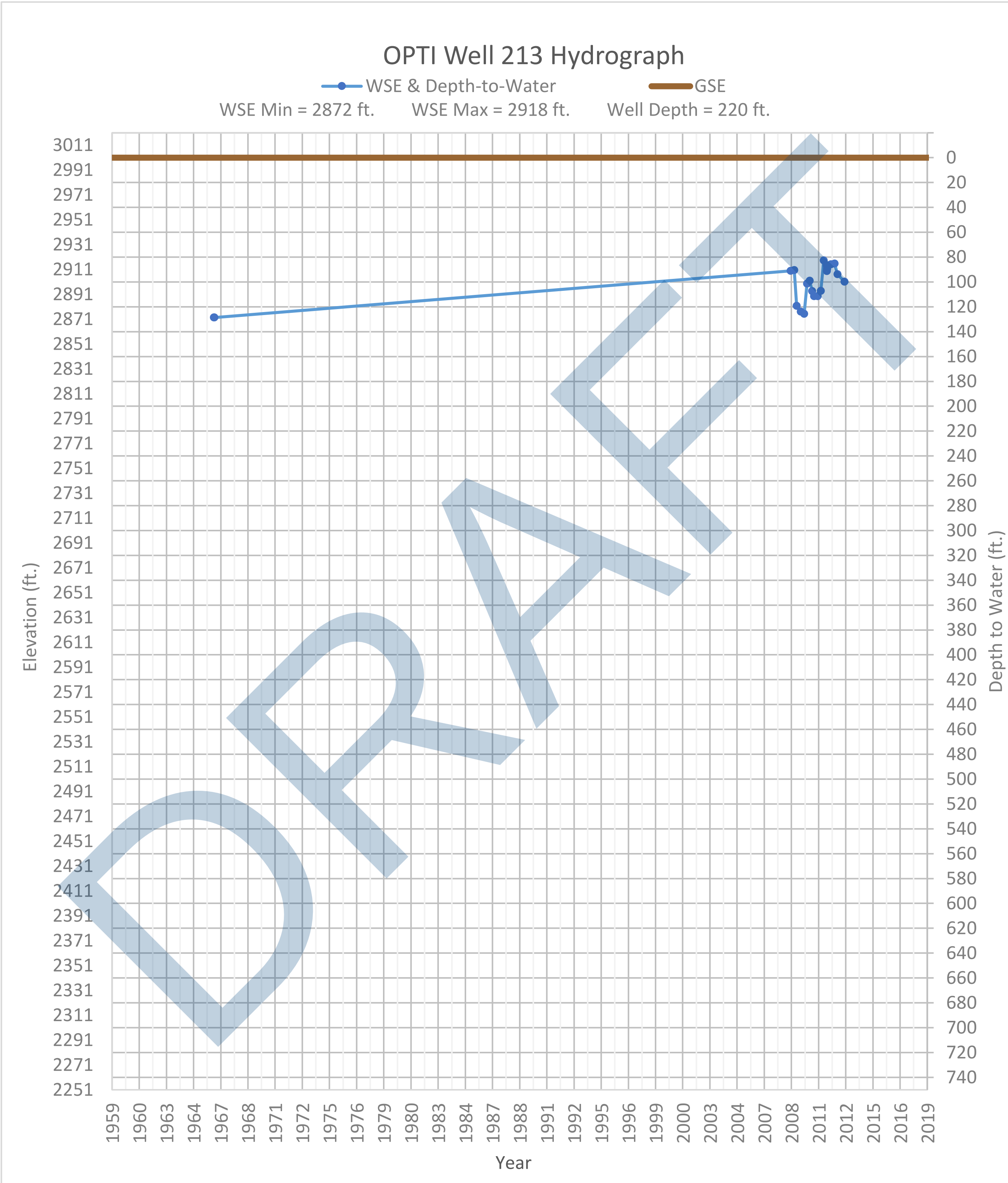
OPTI Well 208 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2912 ft.
WSE Max = 2913 ft.
Well Depth = 172 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



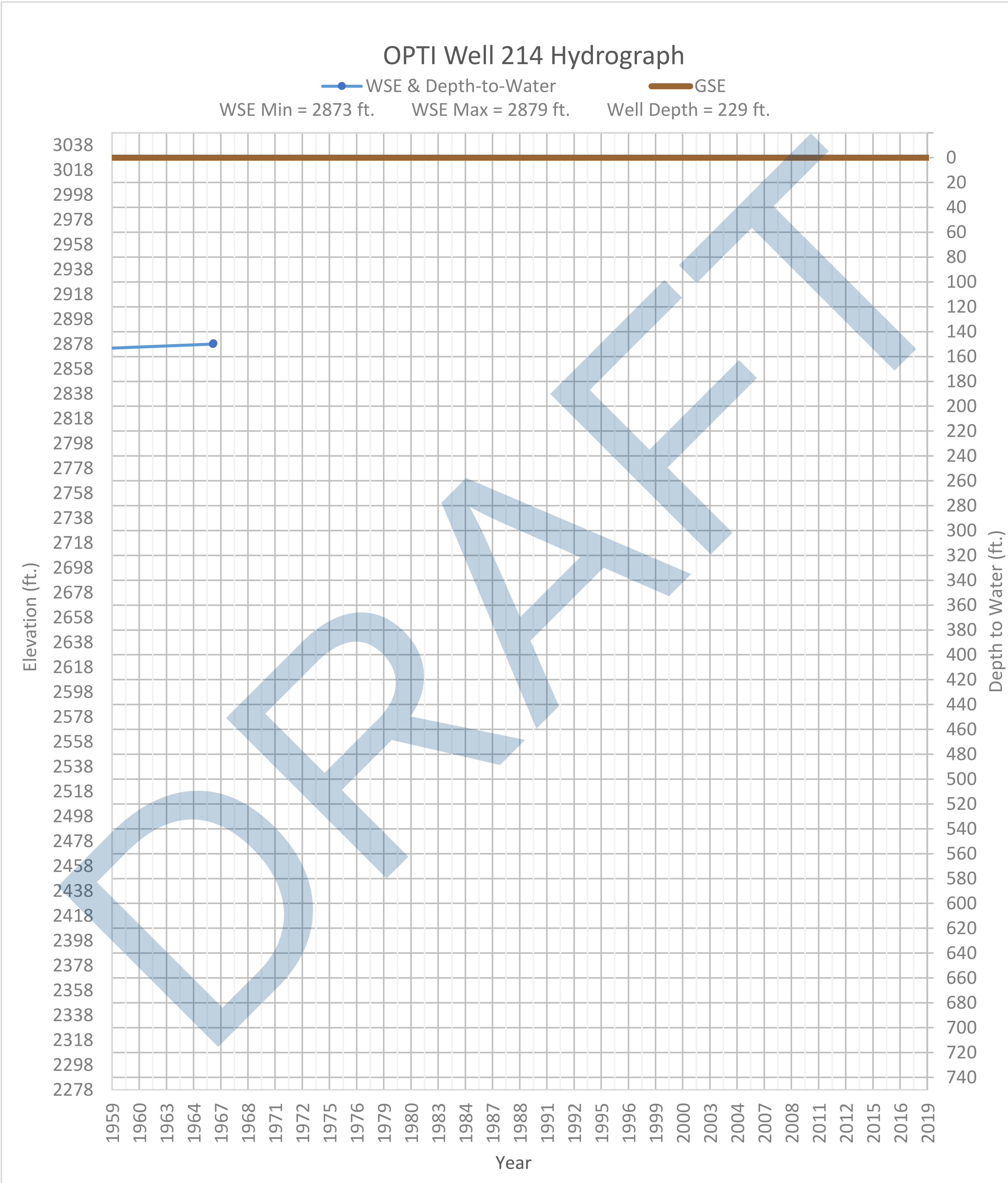
OPTI Well 209 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2902 ft.
WSE Max = 2937 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



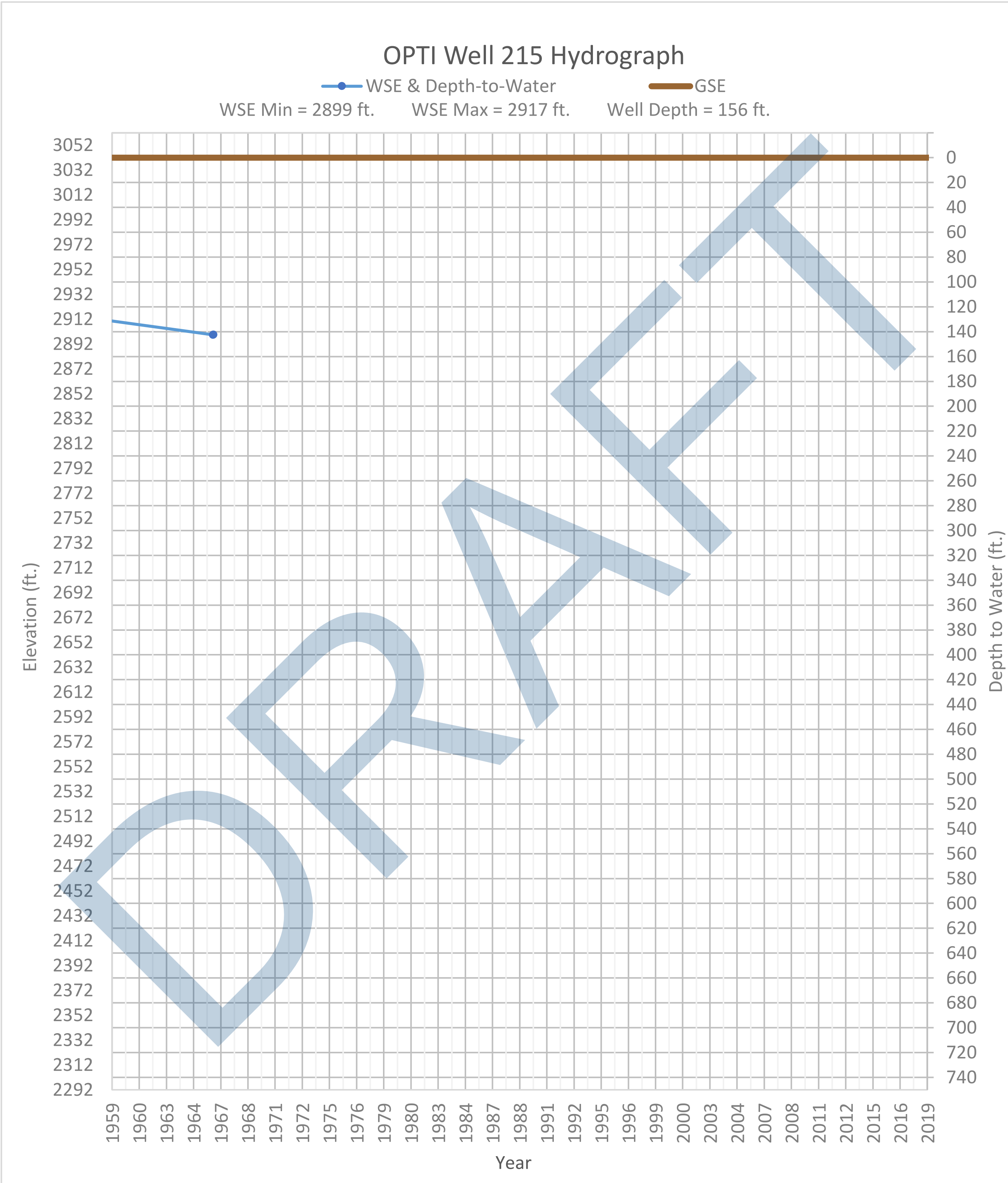
OPTI Well 210 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2995 ft.
WSE Max = 2995 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



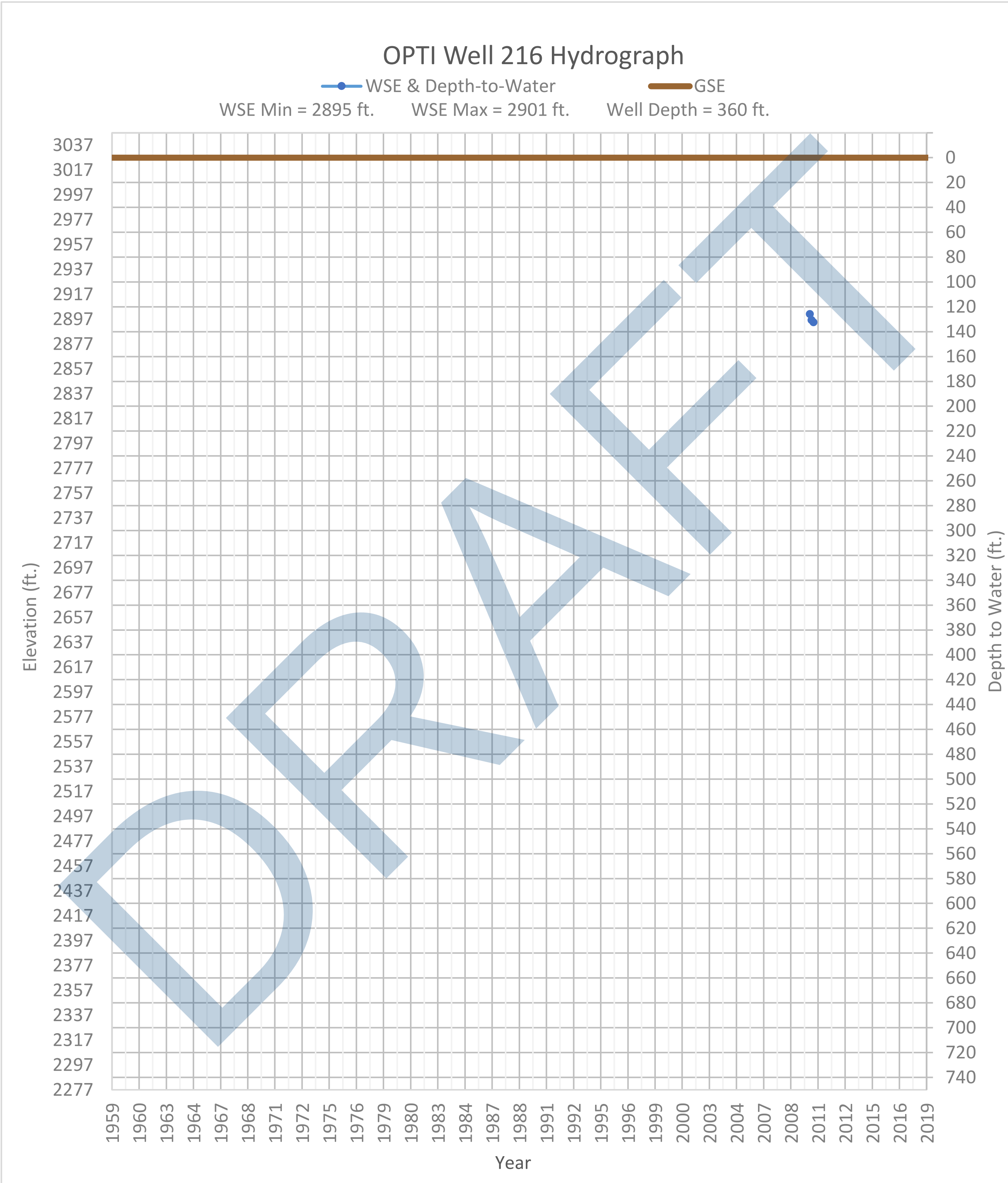
OPTI Well 213 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2872 ft.
WSE Max = 2918 ft.
Well Depth = 220 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



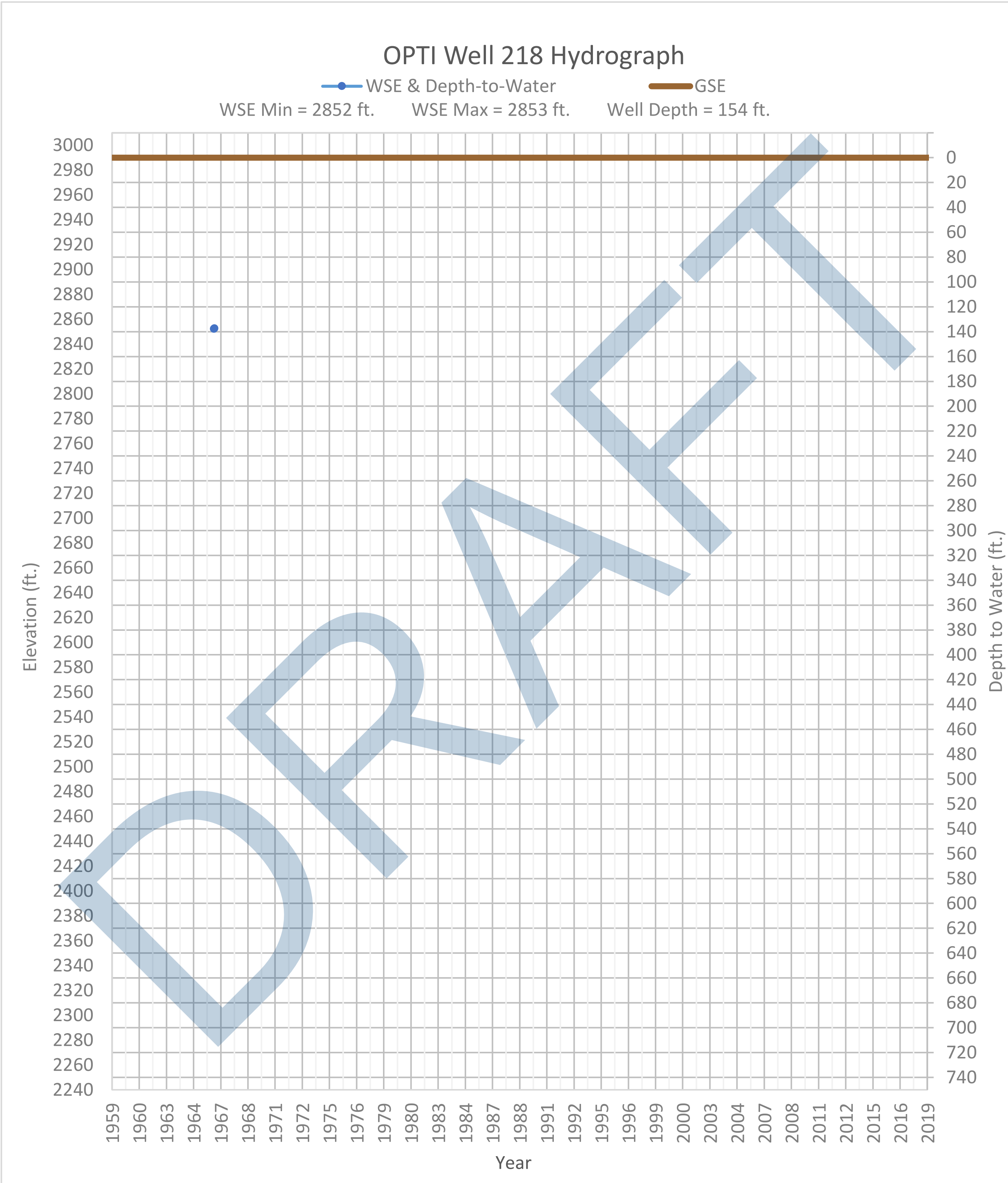
OPTI Well 214 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2873 ft.
WSE Max = 2879 ft.
Well Depth = 229 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



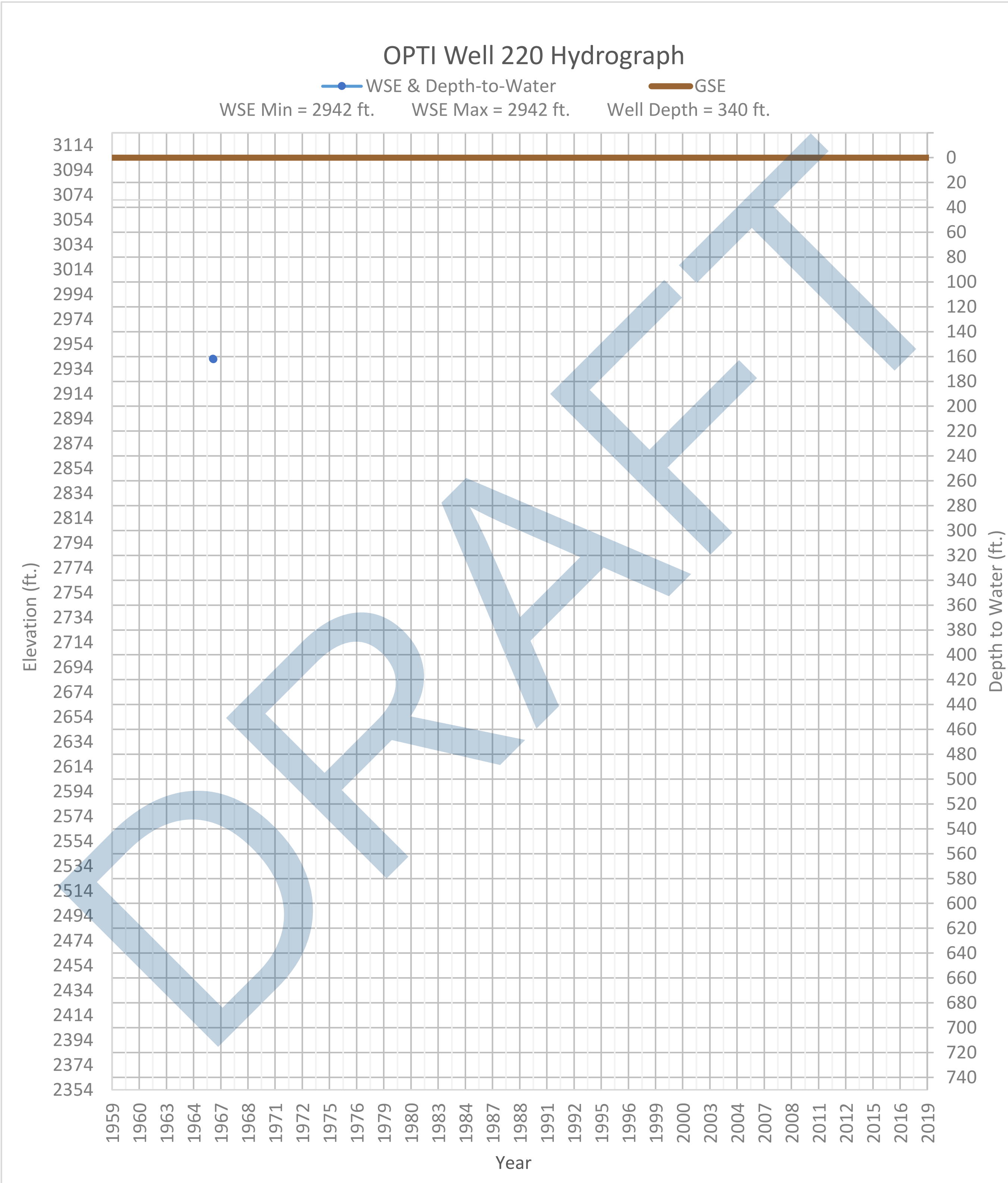
OPTI Well 215 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2899 ft.
WSE Max = 2917 ft.
Well Depth = 156 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



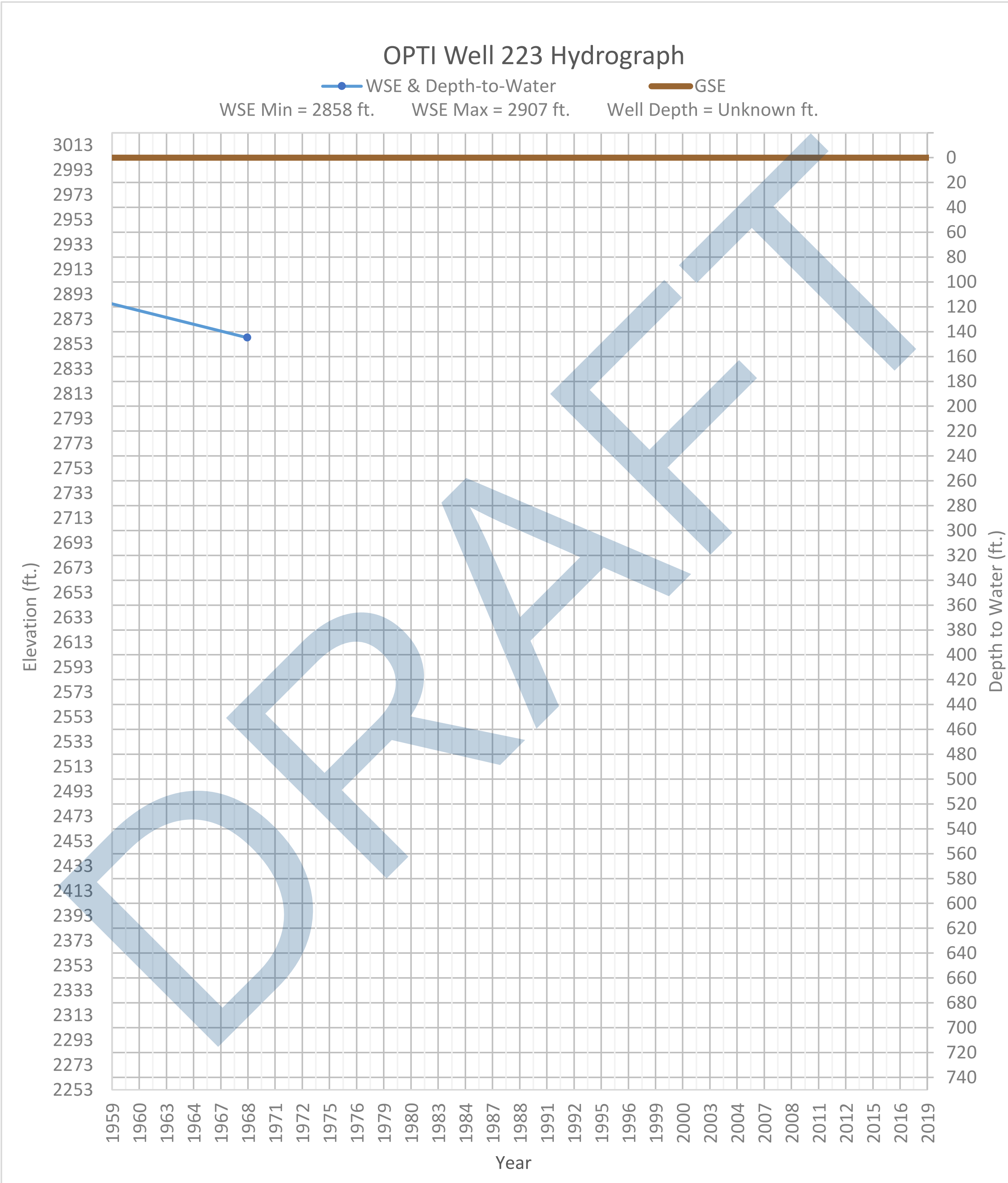
OPTI Well 216 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2895 ft.
WSE Max = 2901 ft.
Well Depth = 360 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



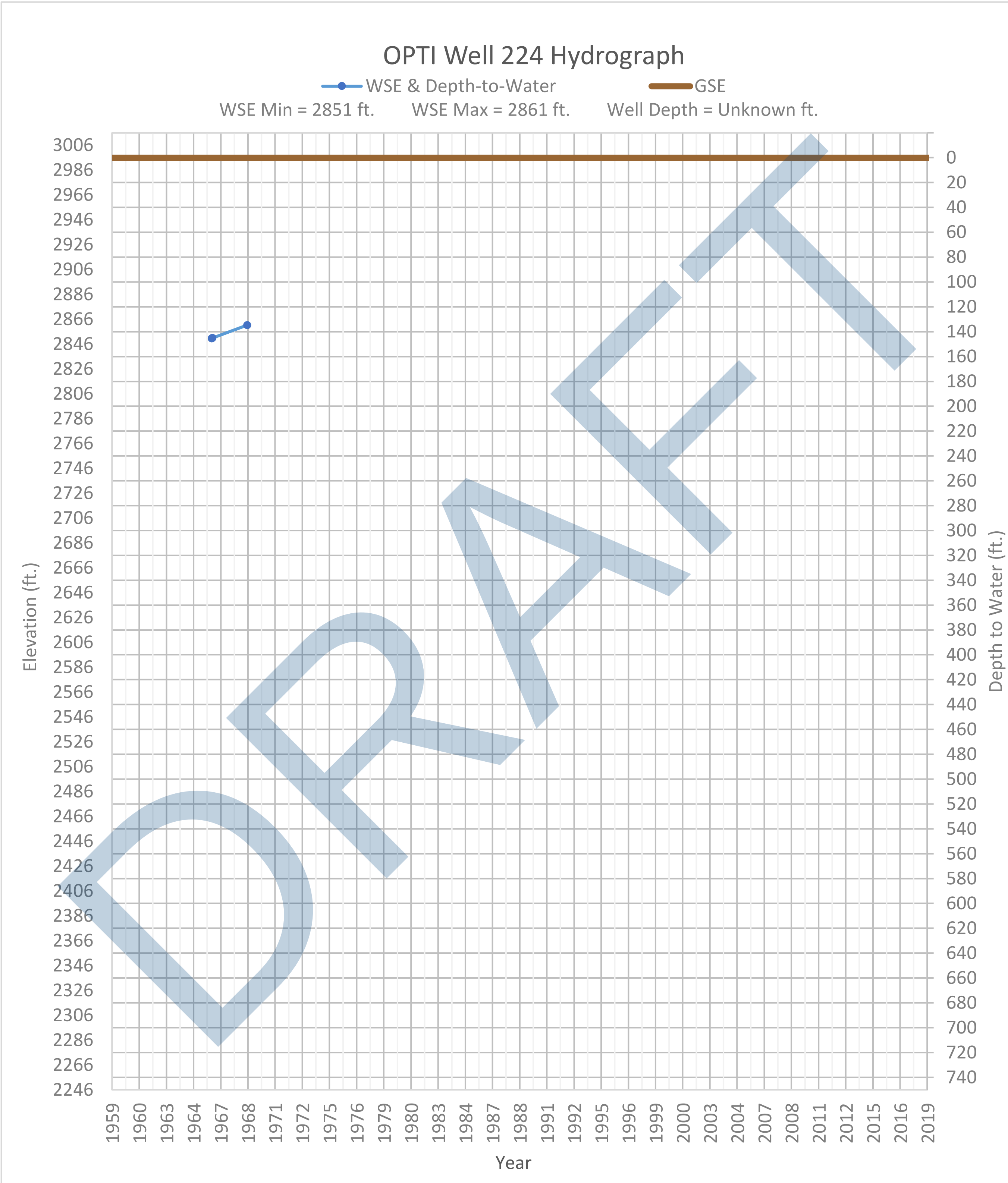
OPTI Well 218 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2852 ft.
WSE Max = 2853 ft.
Well Depth = 154 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



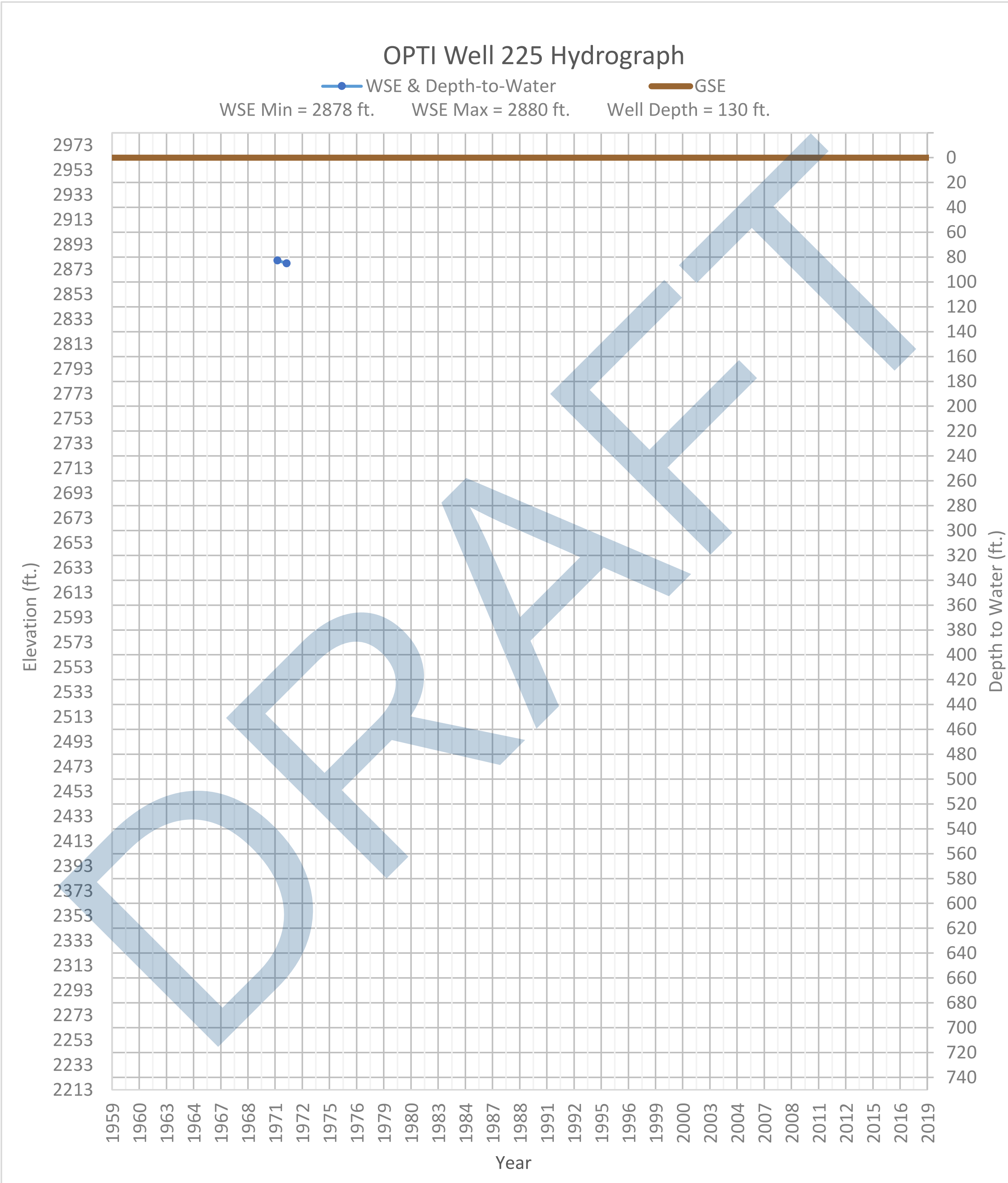
OPTI Well 220 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2942 ft.
WSE Max = 2942 ft.
Well Depth = 340 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



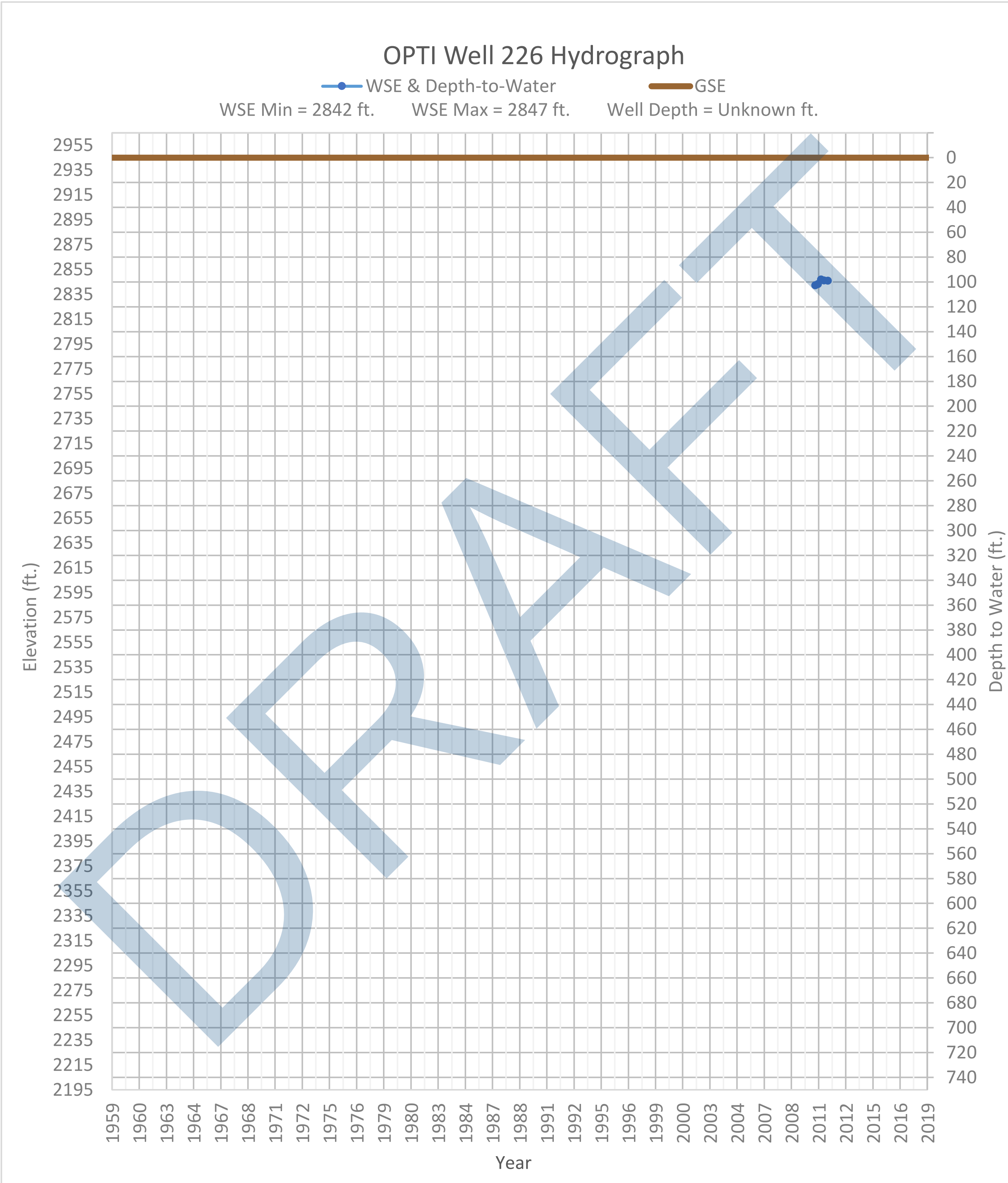
OPTI Well 223 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2858 ft.
WSE Max = 2907 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

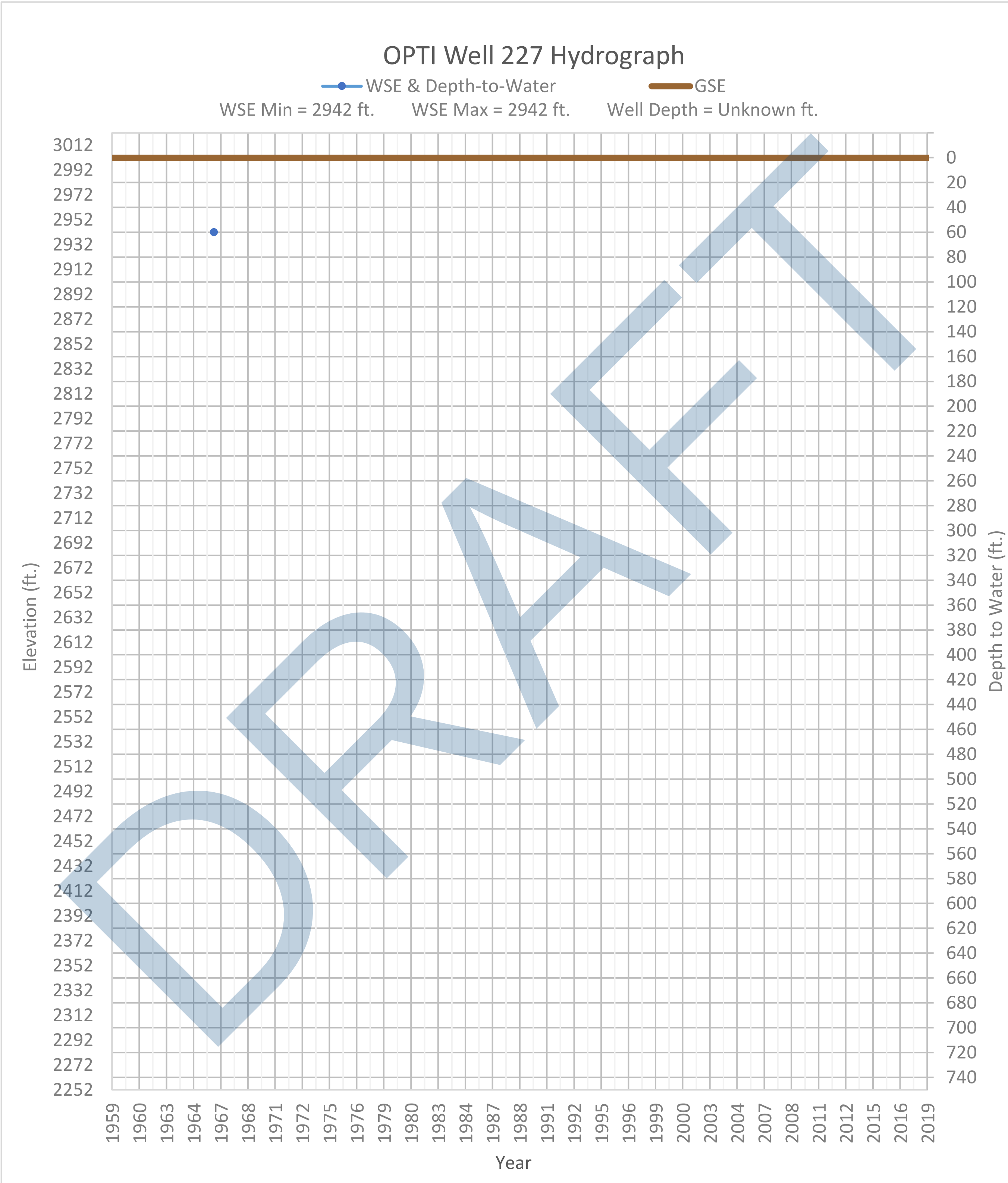


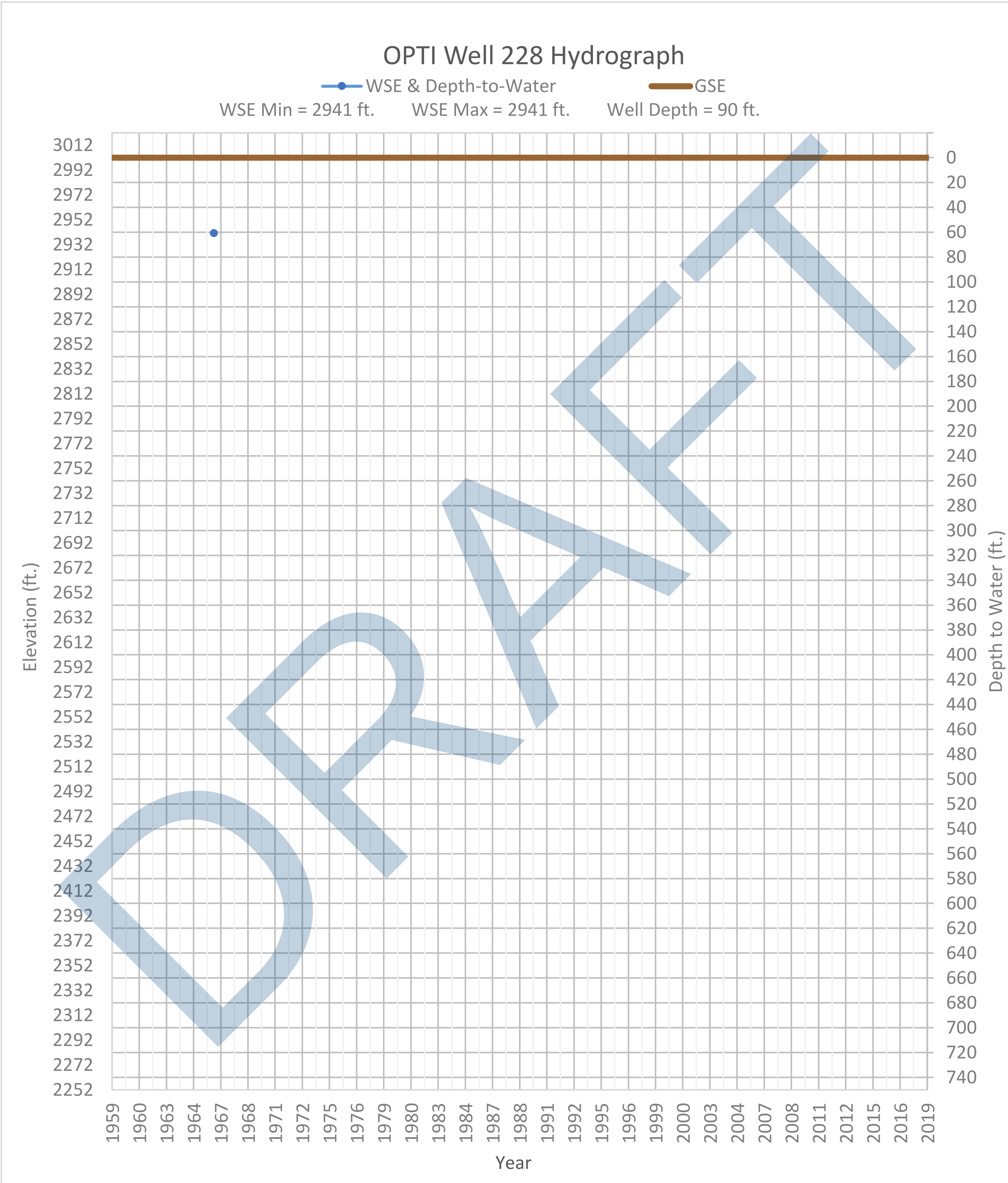
OPTI Well 224 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2851 ft.
WSE Max = 2861 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



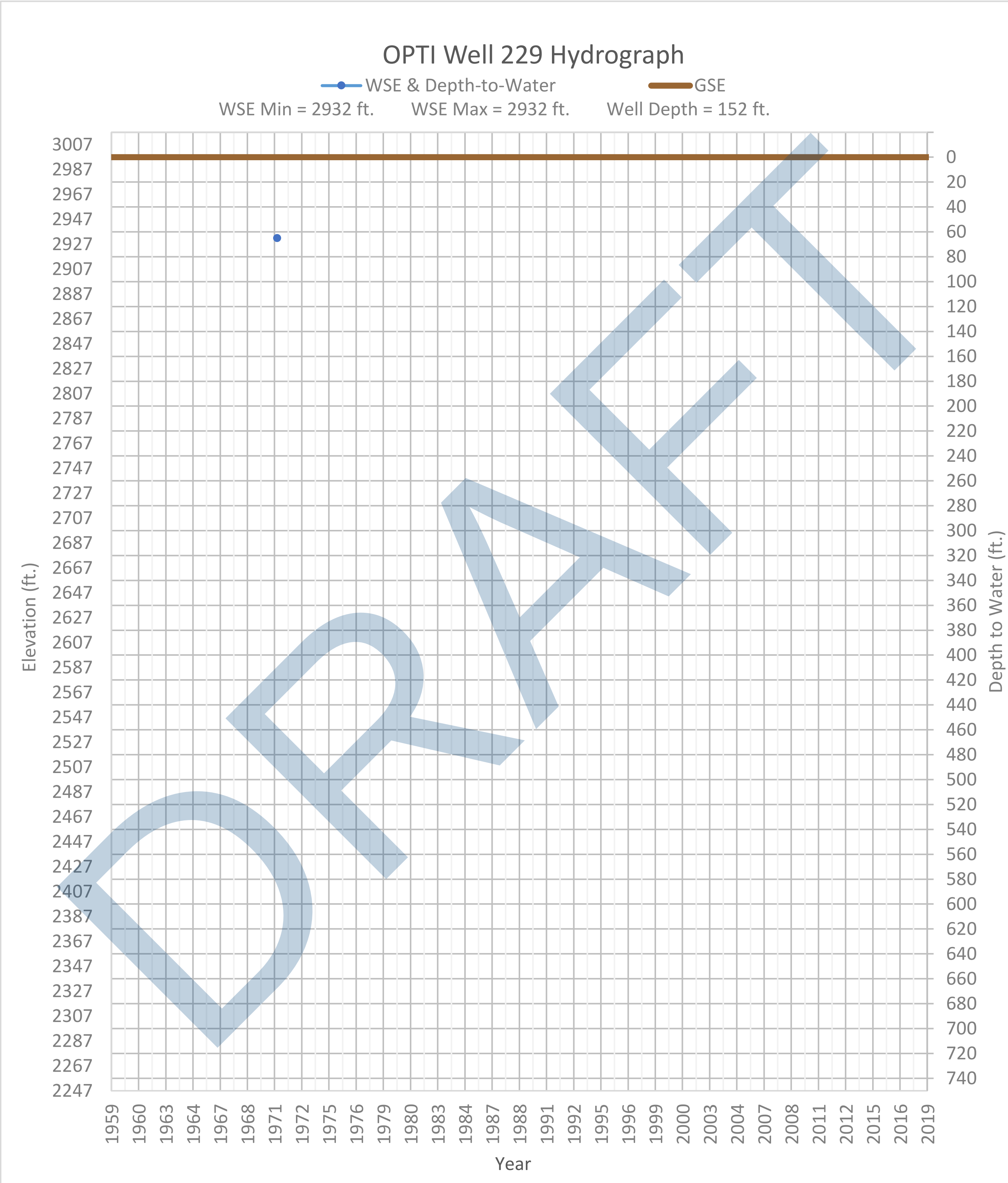
OPTI Well 225 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2878 ft.
WSE Max = 2880 ft.
Well Depth = 130 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 226 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2842 ft.
WSE Max = 2847 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

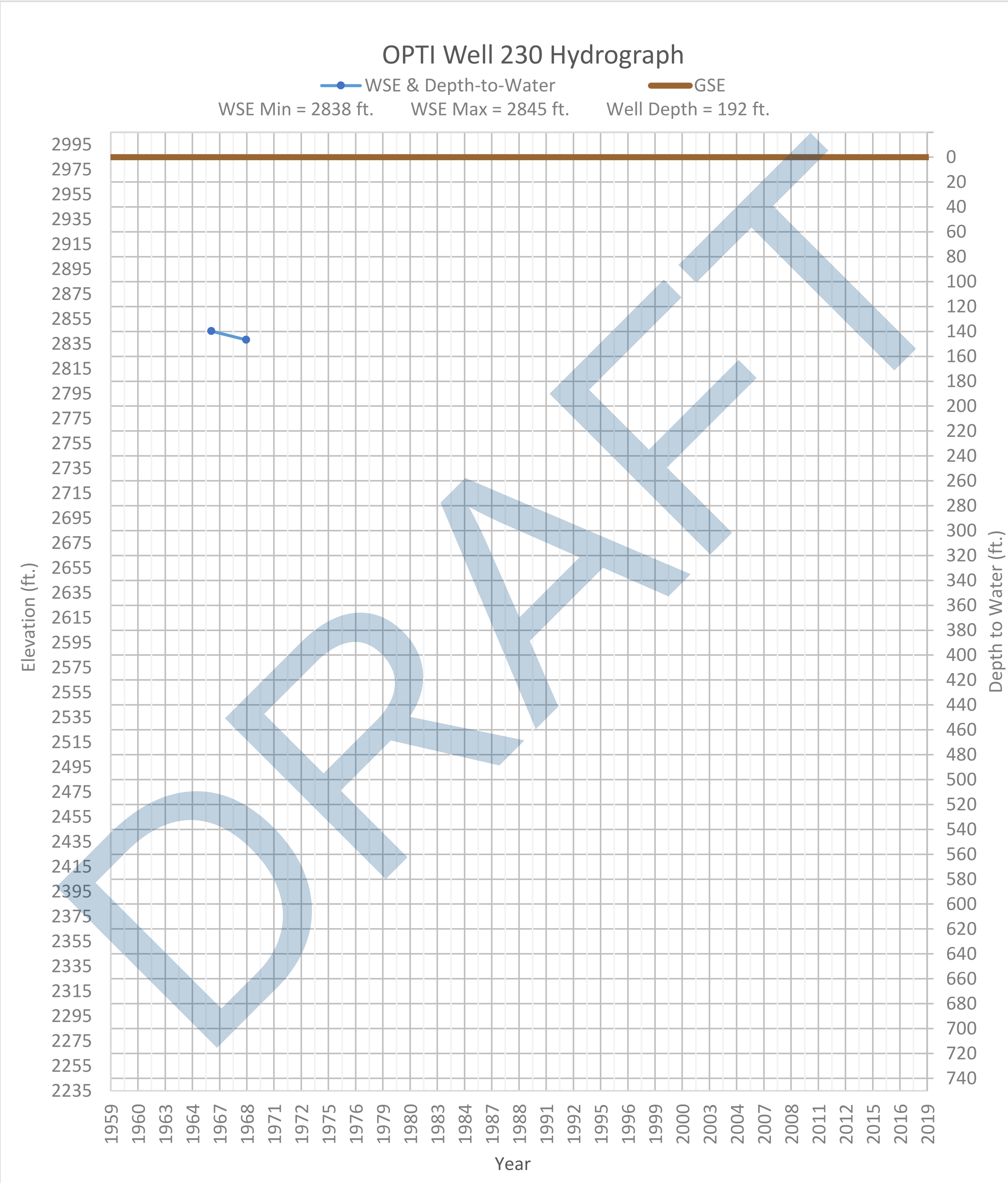

OPTI Well 227 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2942 ft.
WSE Max = 2942 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 228 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2941 ft.
WSE Max = 2941 ft.
Well Depth = 90 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 229 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2932 ft.
WSE Max = 2932 ft.
Well Depth = 152 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 230 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2838 ft.
WSE Max = 2845 ft.
Well Depth = 192 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2995
2975
2955
2935
2915
2895
2875
2855
2835
2815
2795
2775
2755
2735
2715
2695
2675
2655
2635
2615
2595
2575
2555
2535
2515
2495
2475
2455
2435
2415
2395
2375
2355
2335
2315
2295
2275
2255
2235
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
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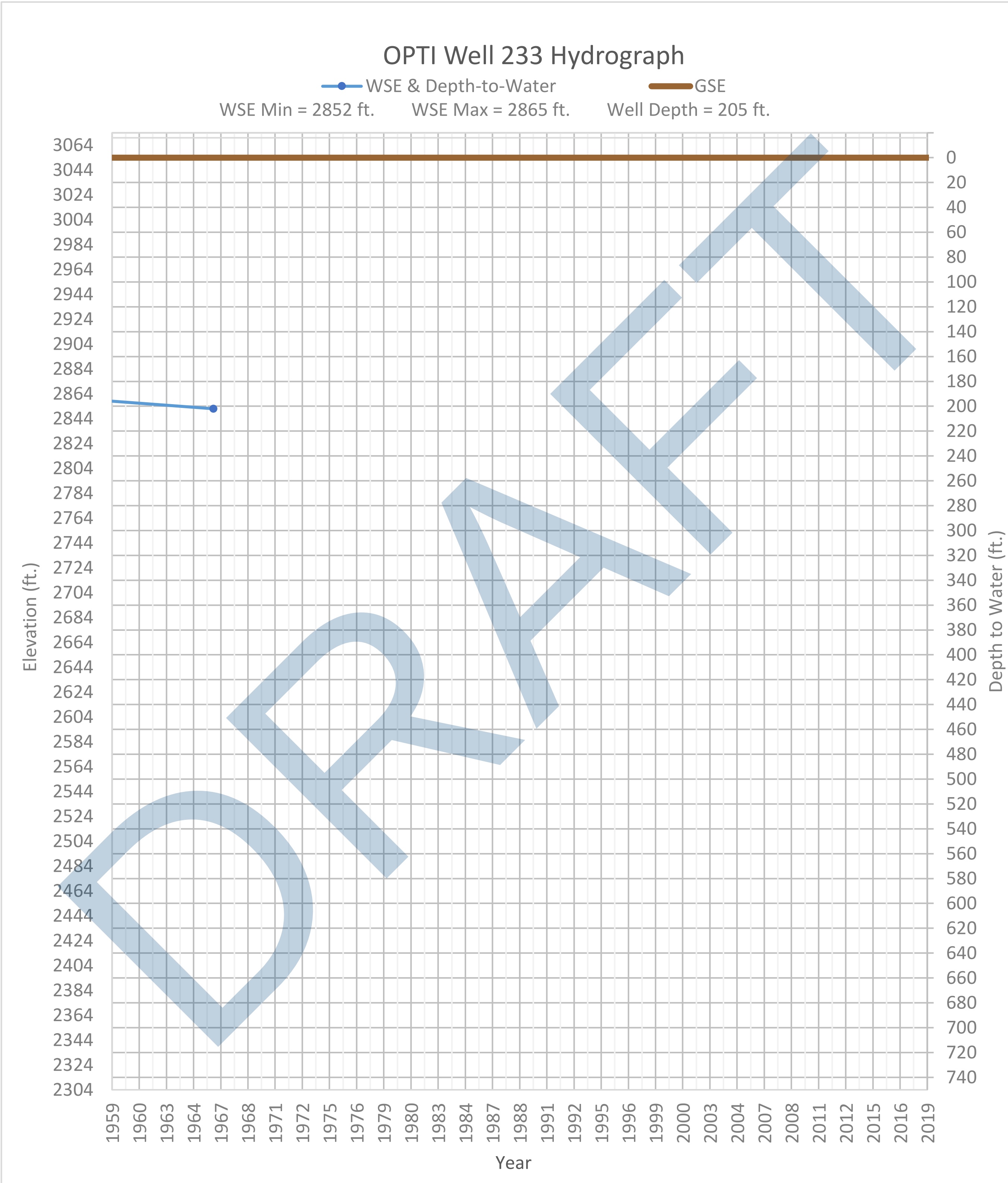
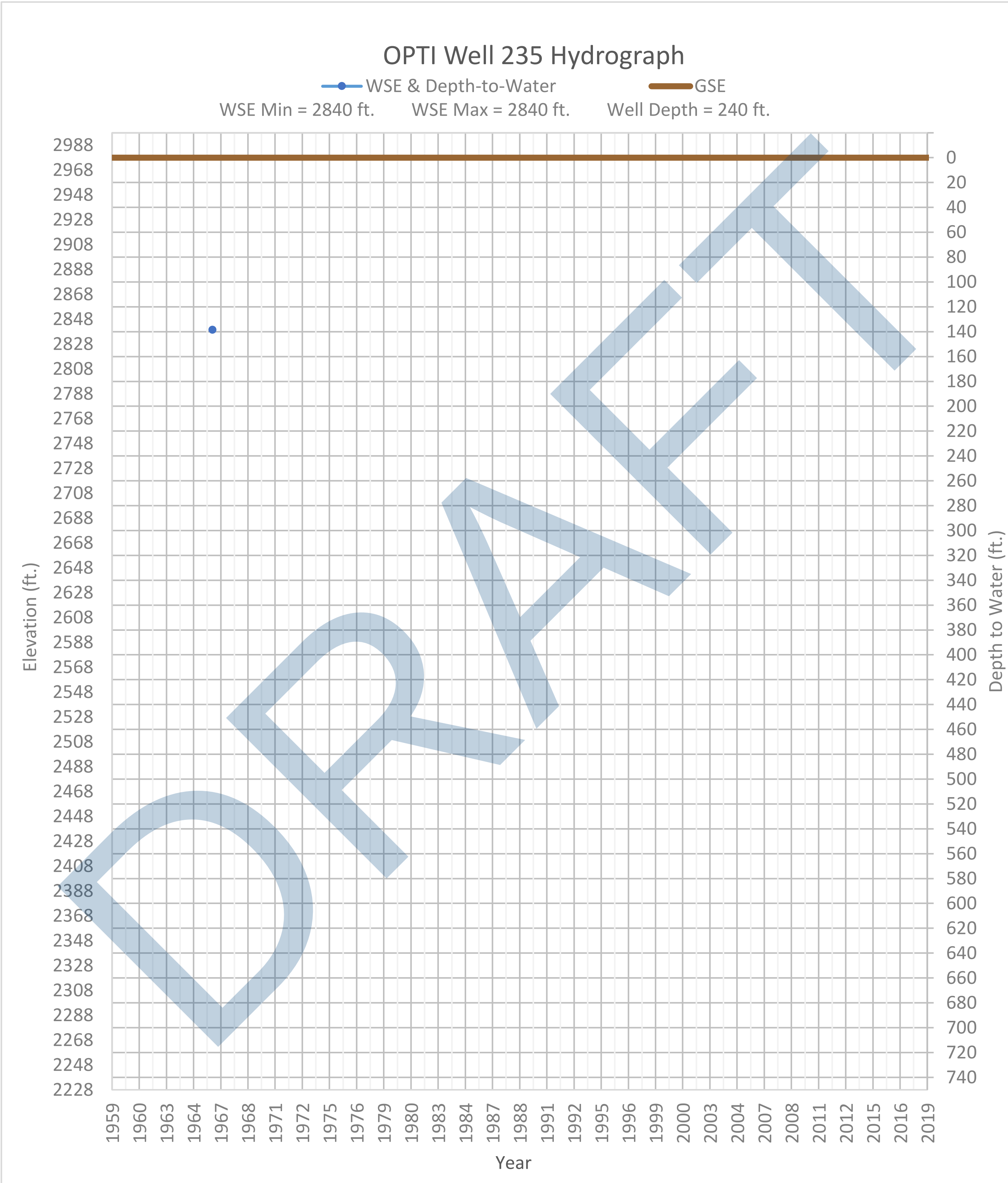
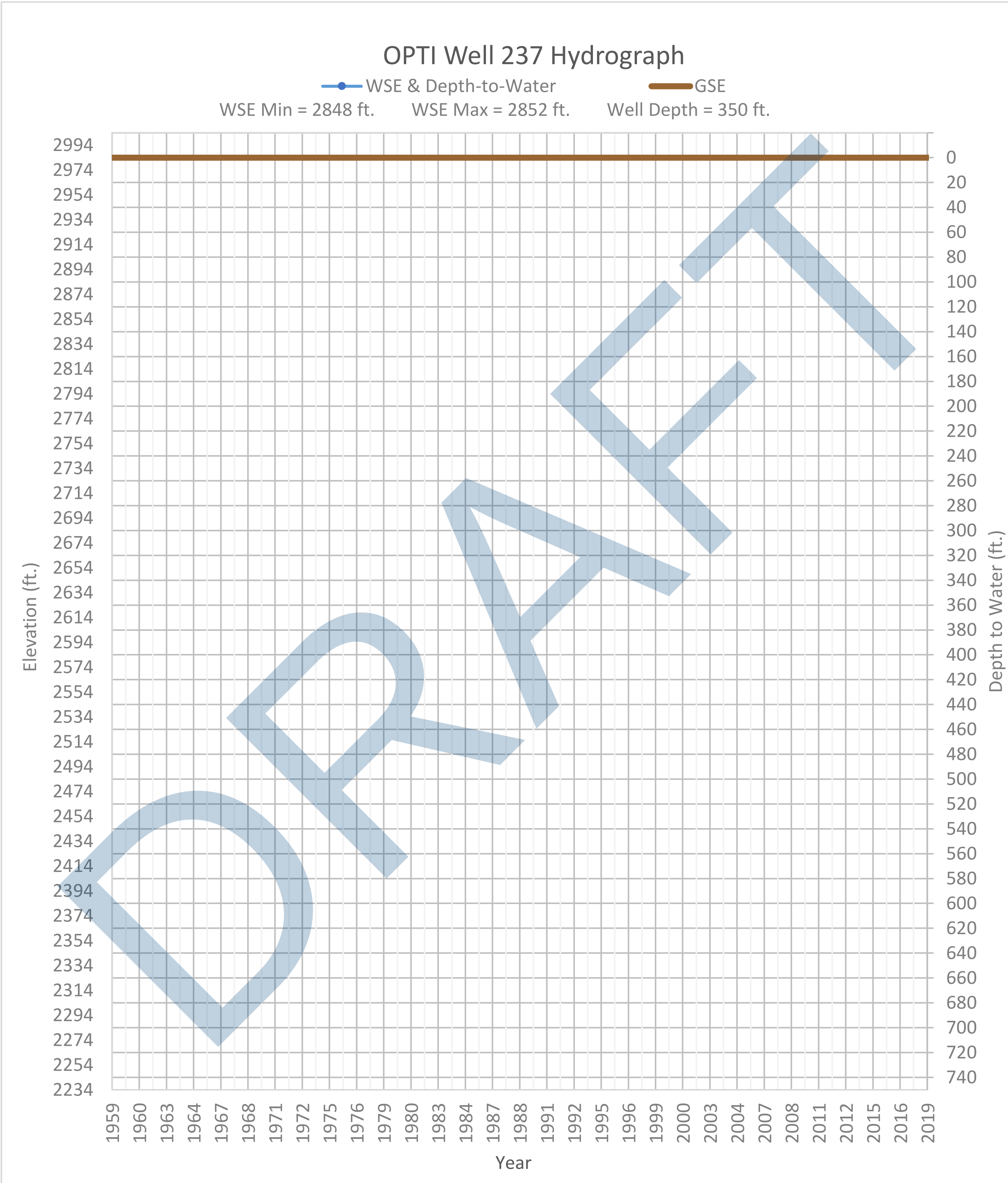
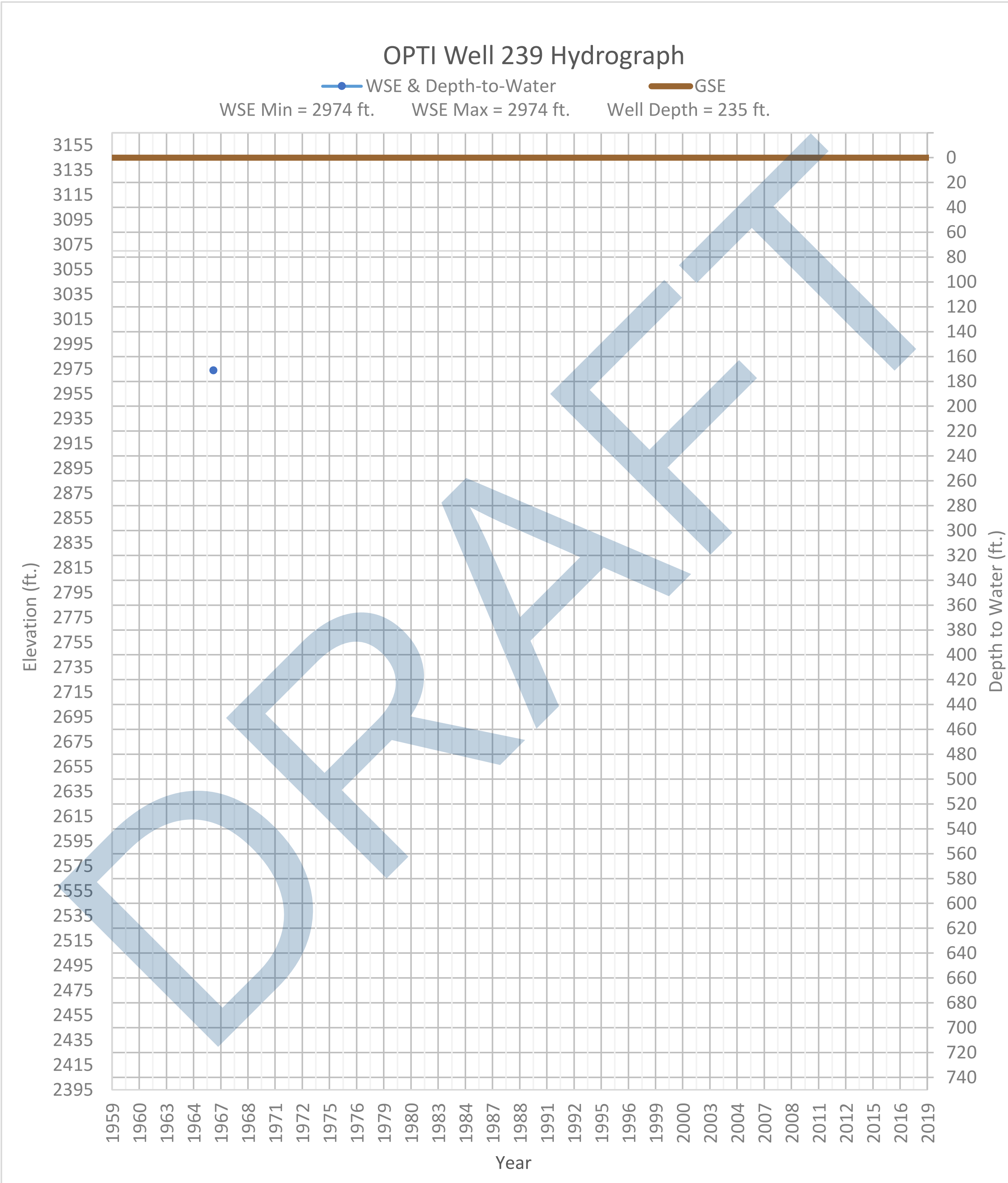


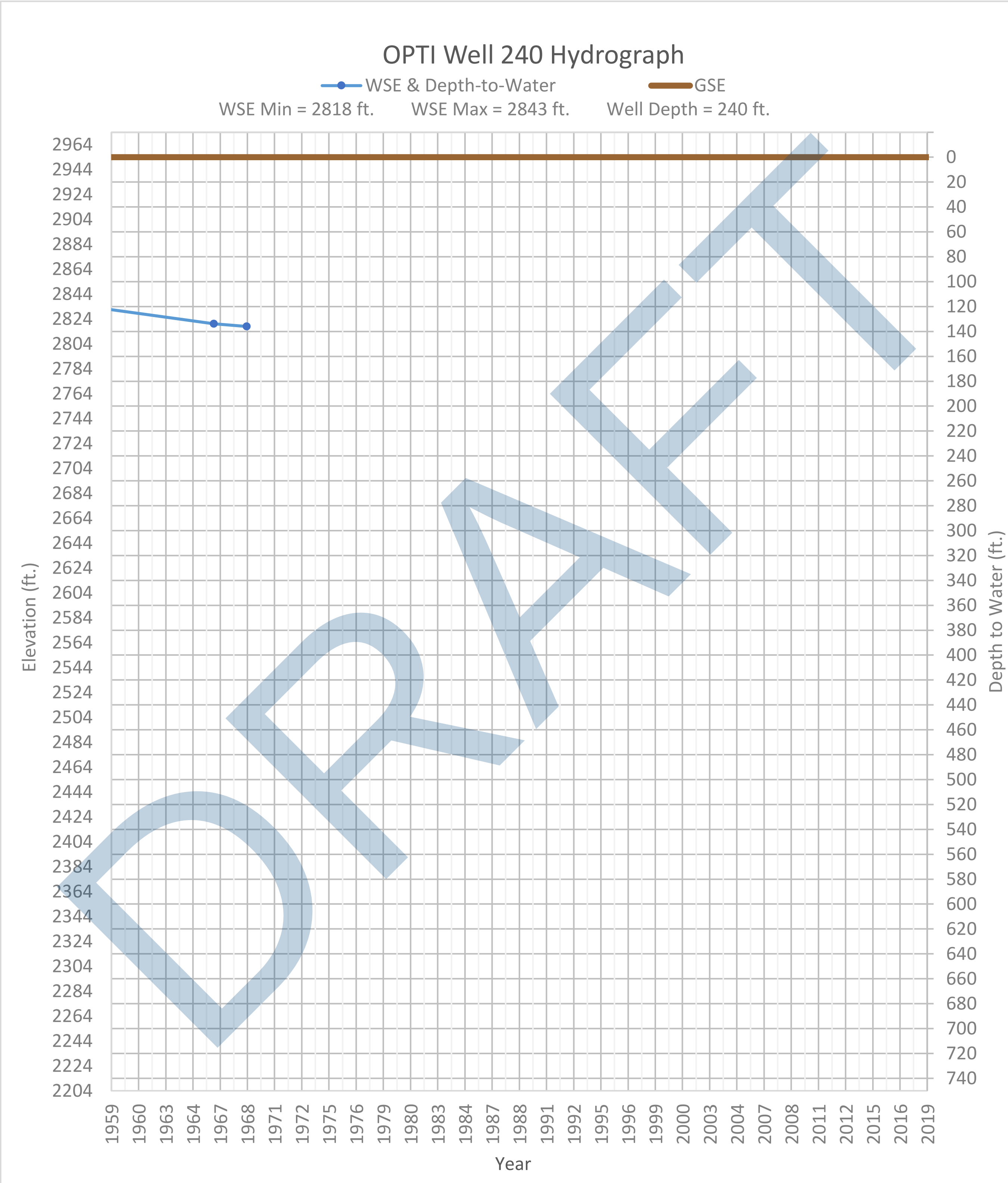
OPTI Well 233 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2852 ft.
WSE Max = 2865 ft.
Well Depth = 205 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



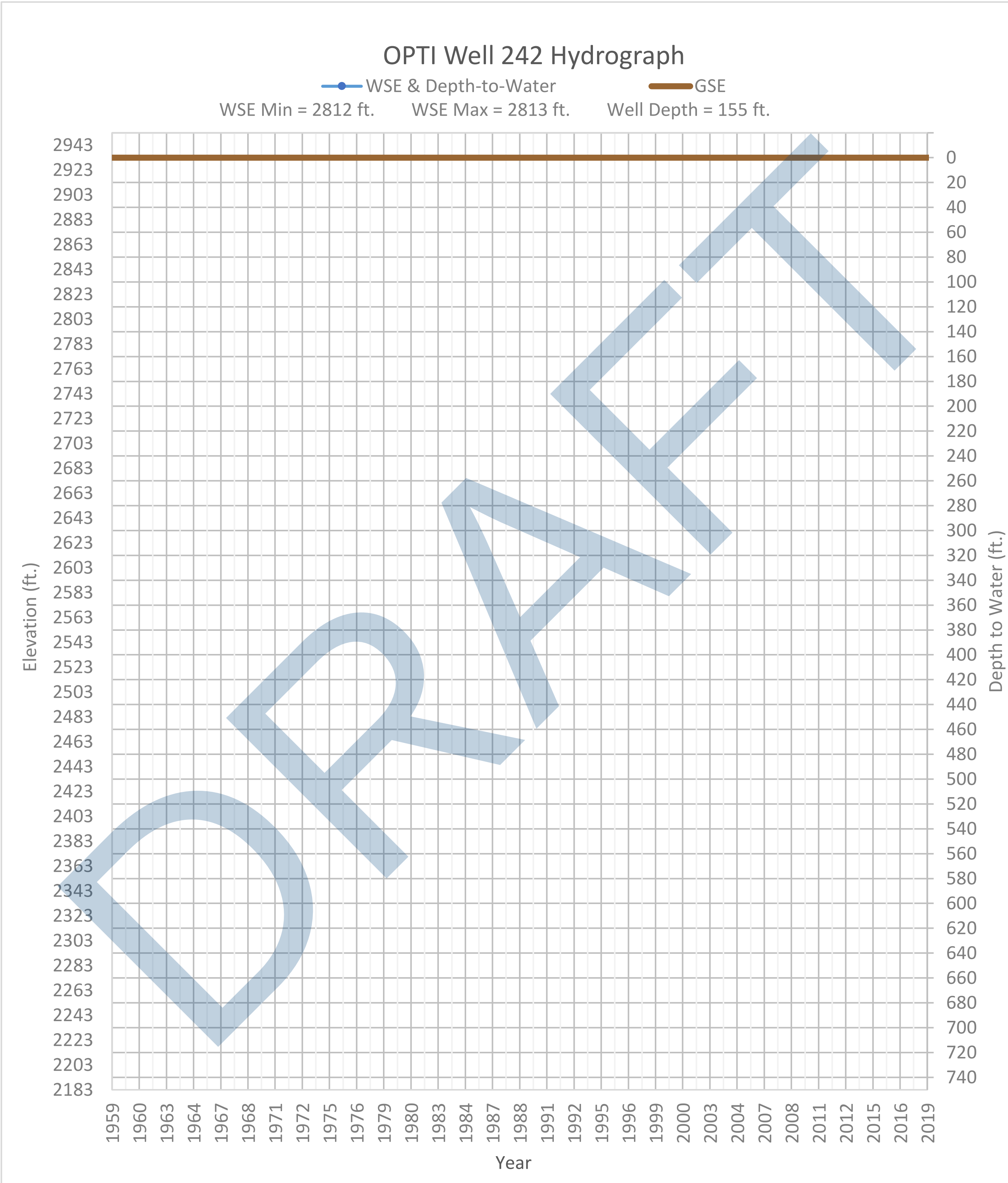
OPTI Well 235 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2840 ft.
WSE Max = 2840 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

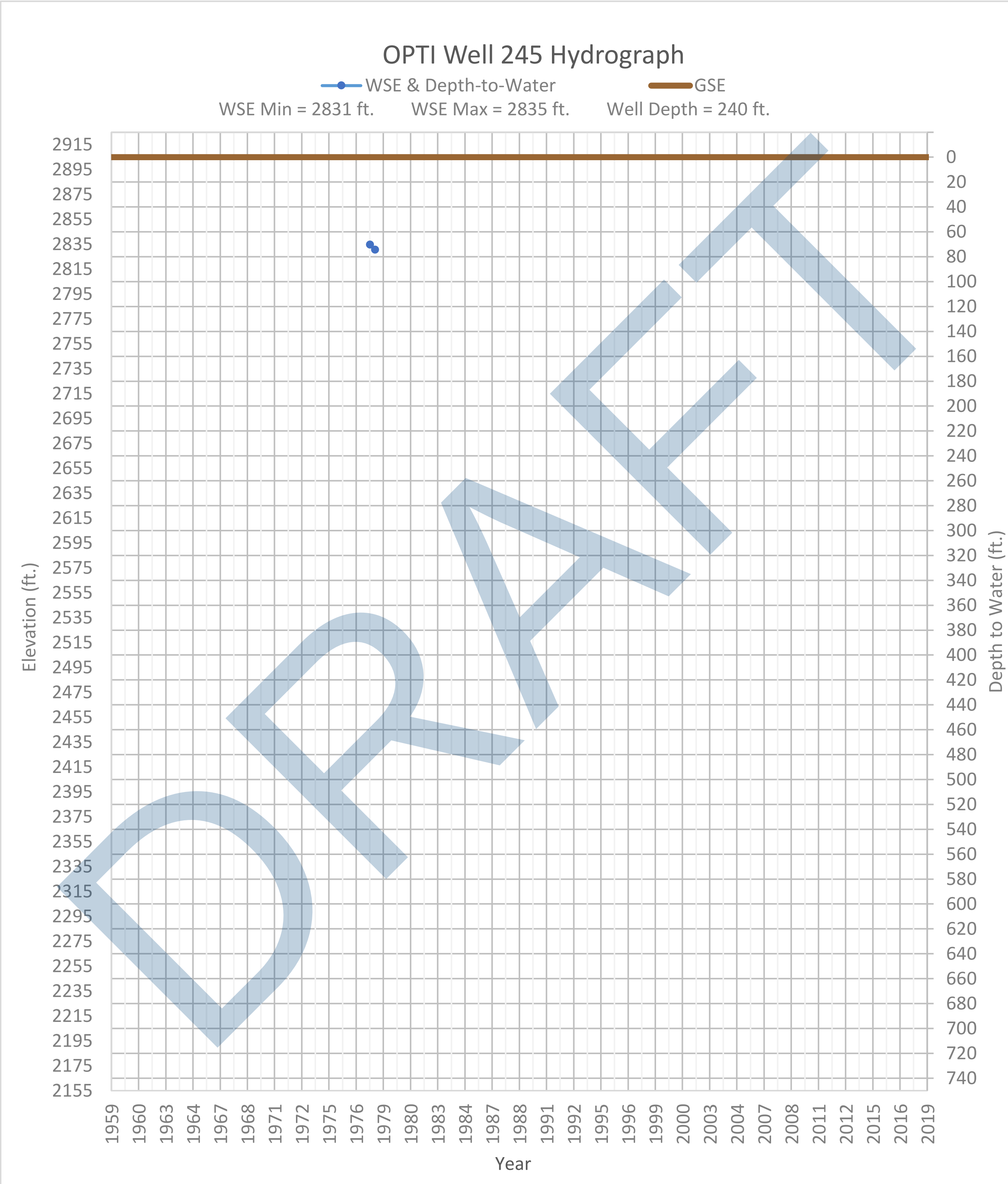

OPTI Well 237 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2848 ft.
WSE Max = 2852 ft.
Well Depth = 350 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 239 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2974 ft.
WSE Max = 2974 ft.
Well Depth = 235 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

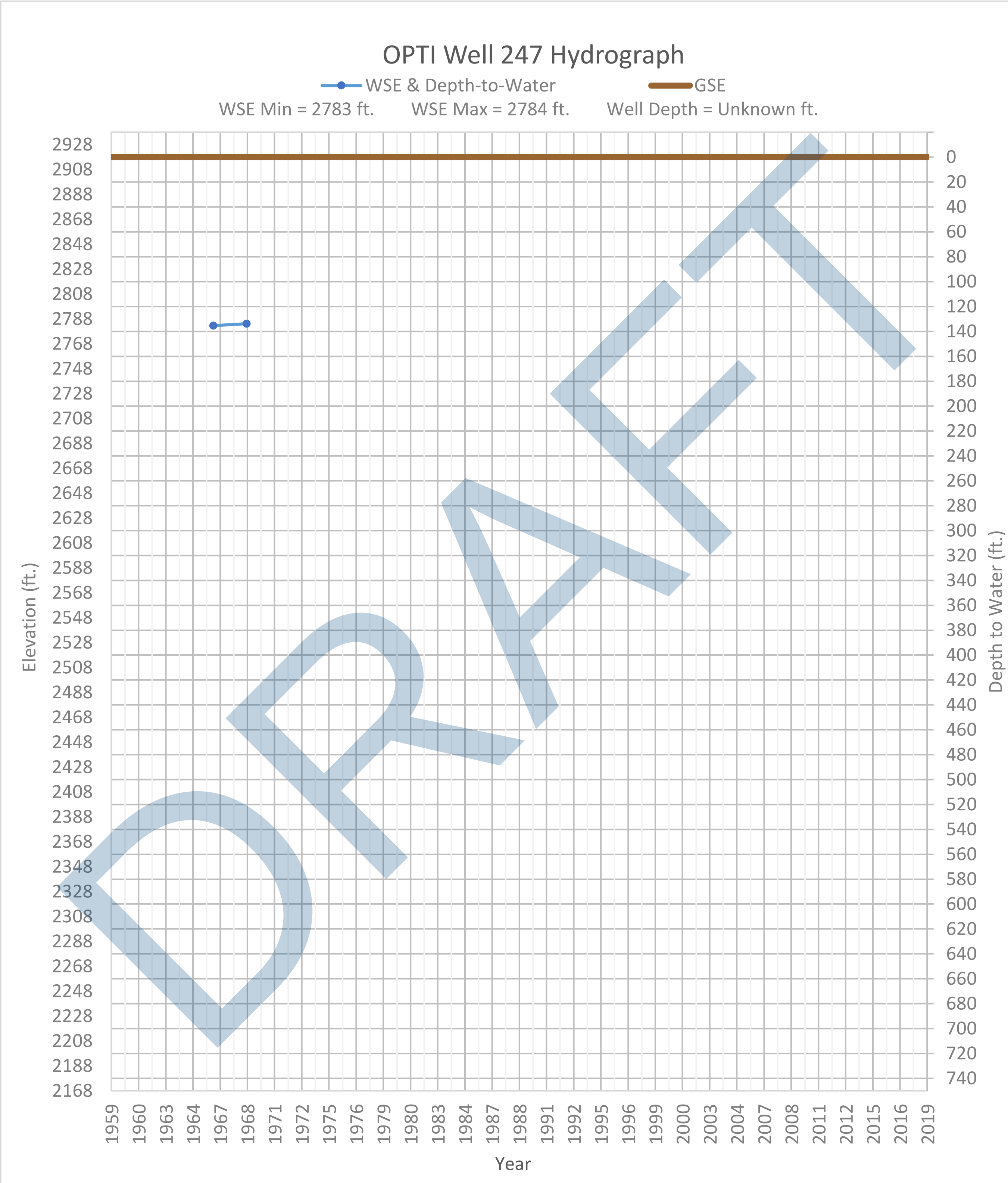


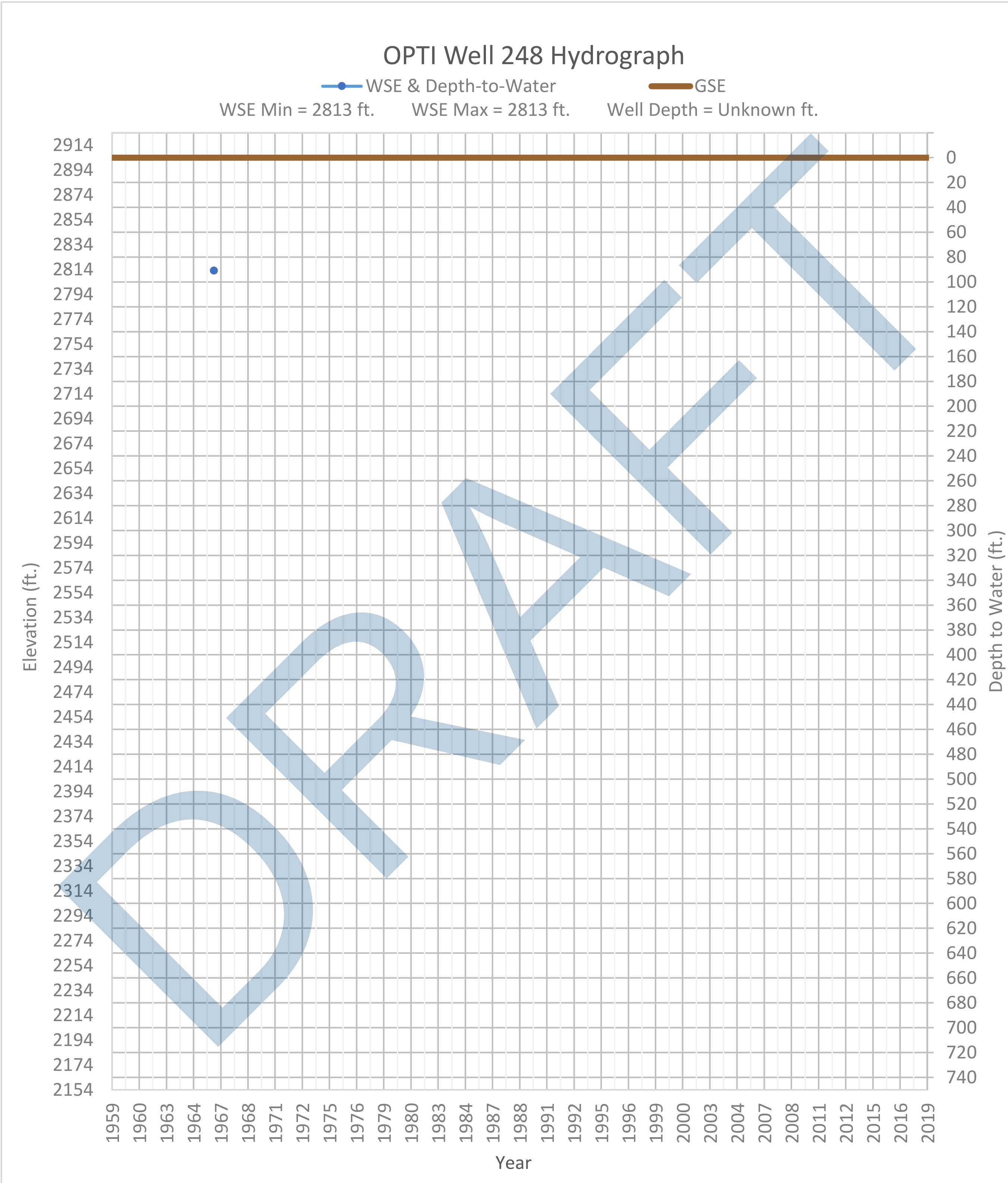
OPTI Well 240 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2818 ft.
WSE Max = 2843 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 242 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2812 ft.
WSE Max = 2813 ft.
Well Depth = 155 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

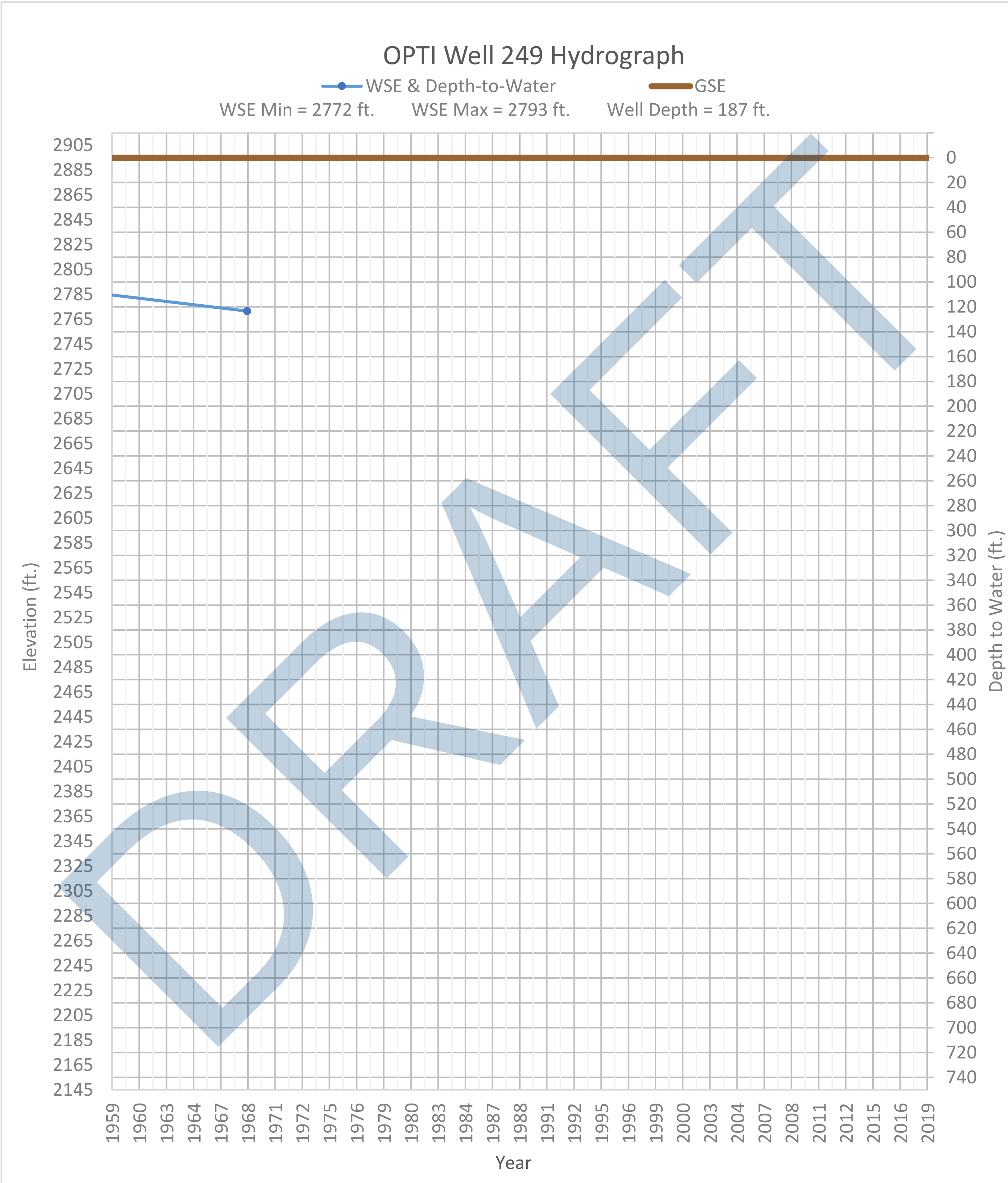


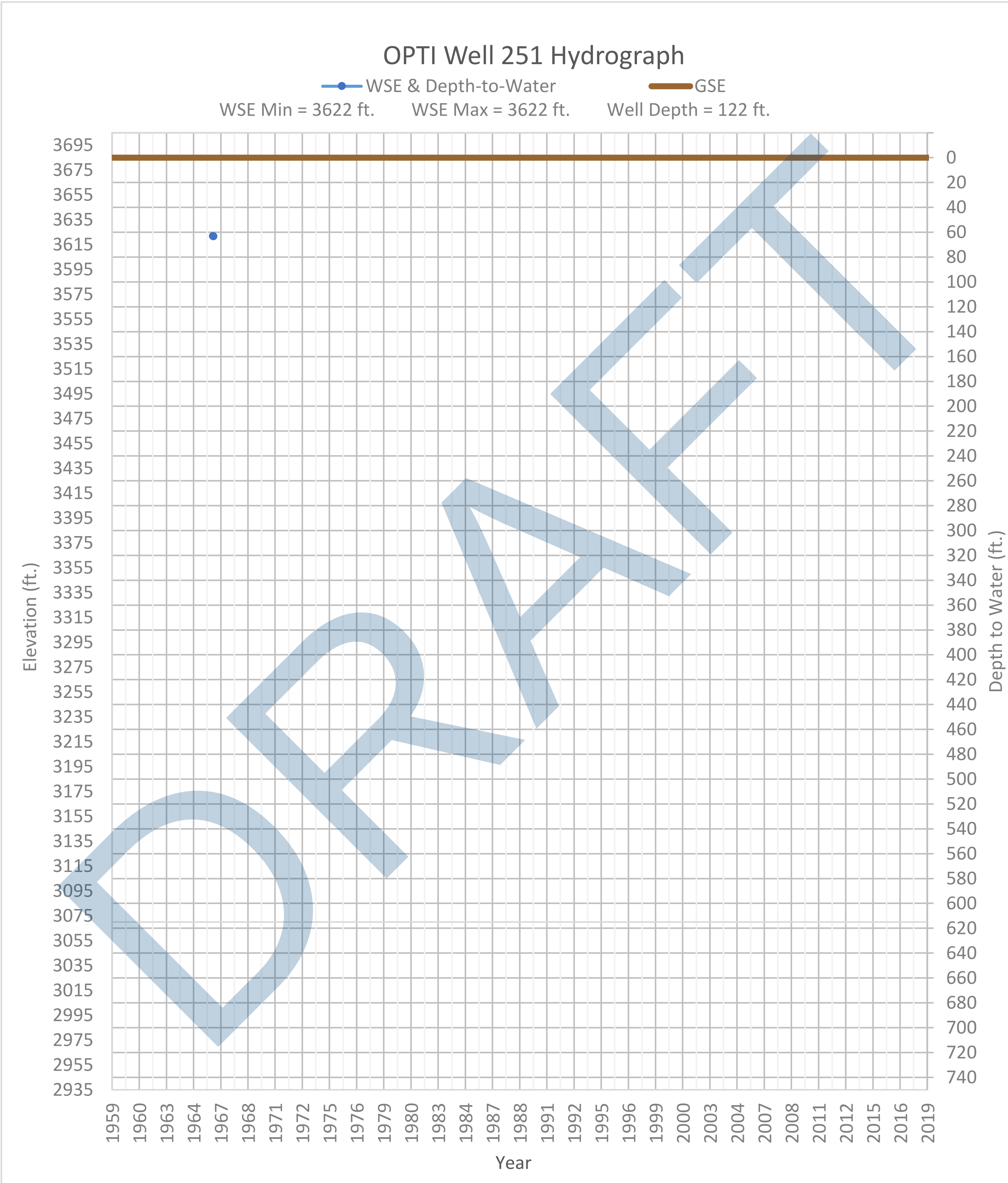
OPTI Well 245 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2831 ft.
WSE Max = 2835 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

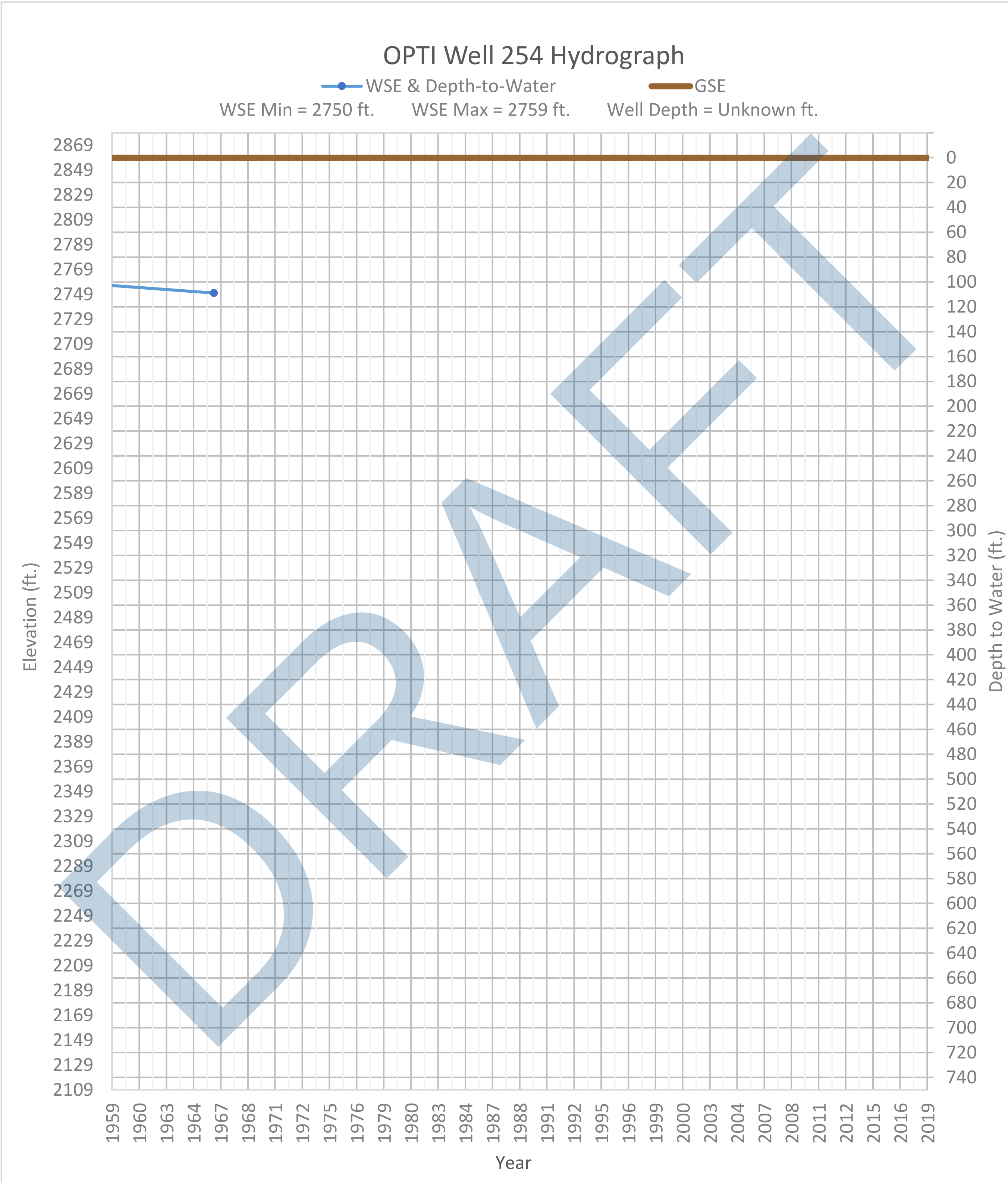

OPTI Well 247 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2783 ft.
WSE Max = 2784 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



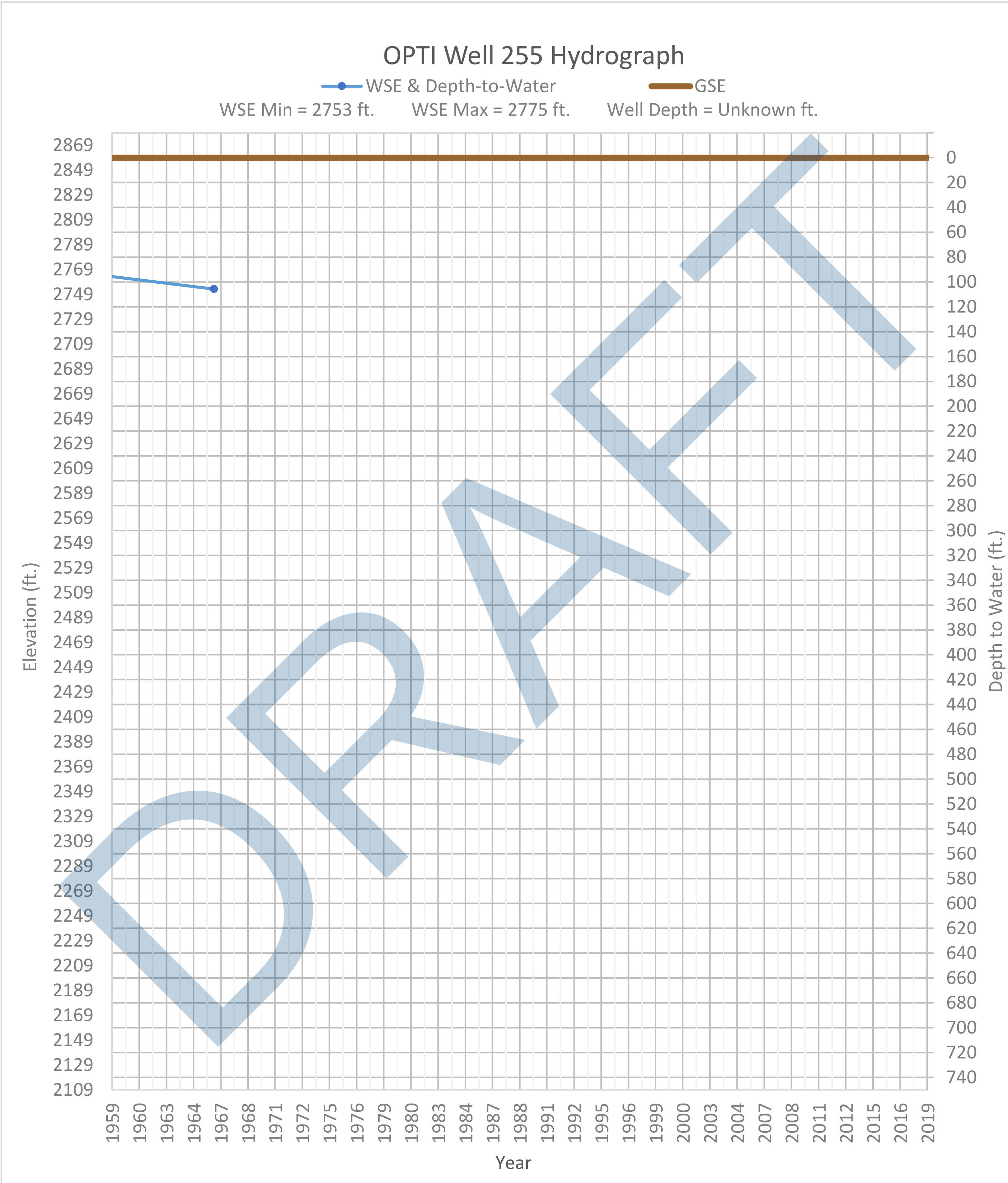
OPTI Well 248 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2813 ft.
WSE Max = 2813 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 249 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2772 ft.
WSE Max = 2793 ft.
Well Depth = 187 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

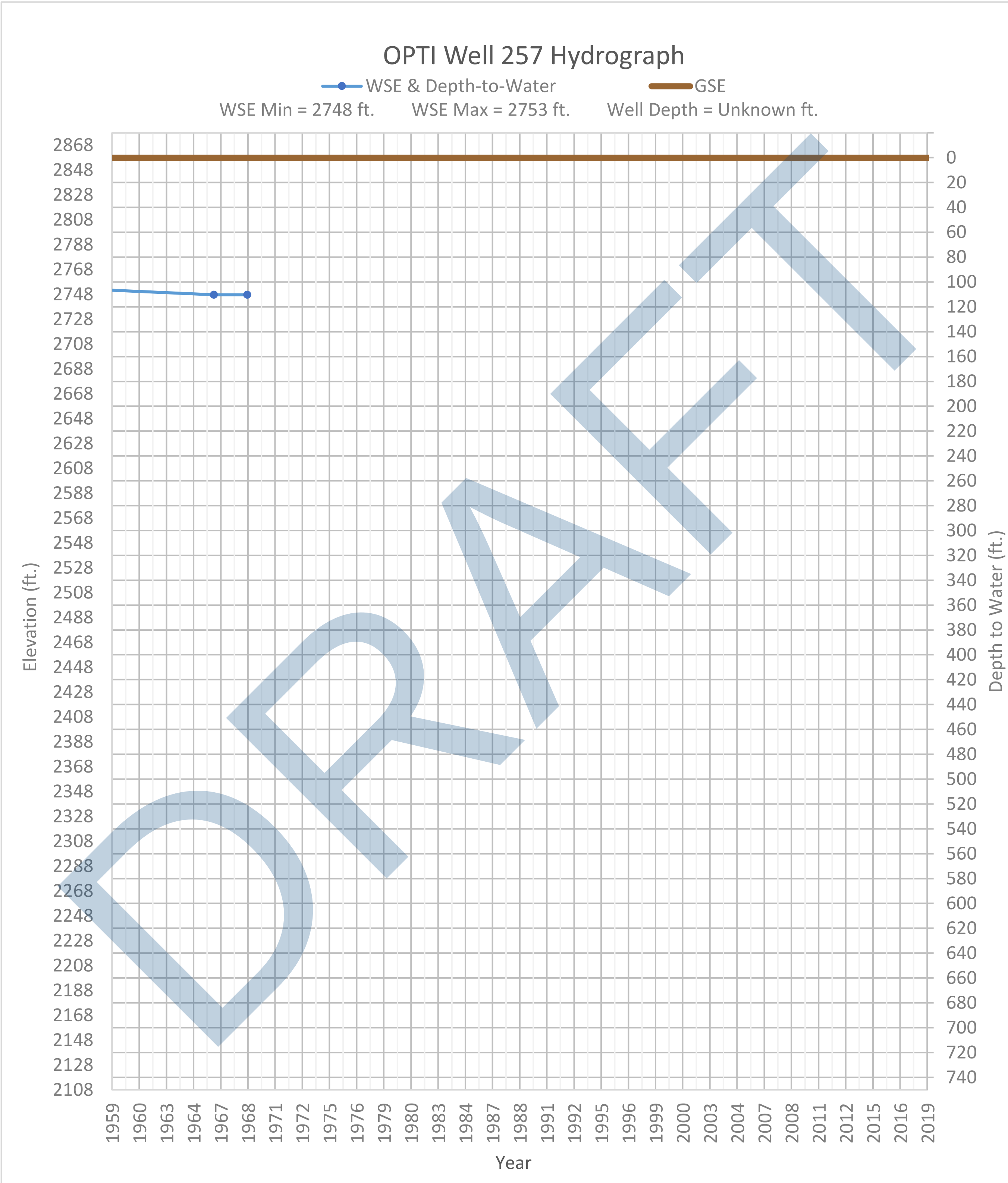

OPTI Well 251 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3622 ft.
WSE Max = 3622 ft.
Well Depth = 122 ft.
Elevation (ft.)
3695 3675 3655 3635 3615 3595 3575 3555 3535 3515 3495 3475 3455 3435 3415 3395 3375 3355 3335 3315 3295 3275 3255 3235 3215 3195 3175 3155 3135 3115 3095 3075 3055 3035 3015 2995 2975 2955 2935
Depth to Water (ft.)
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
Year
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019



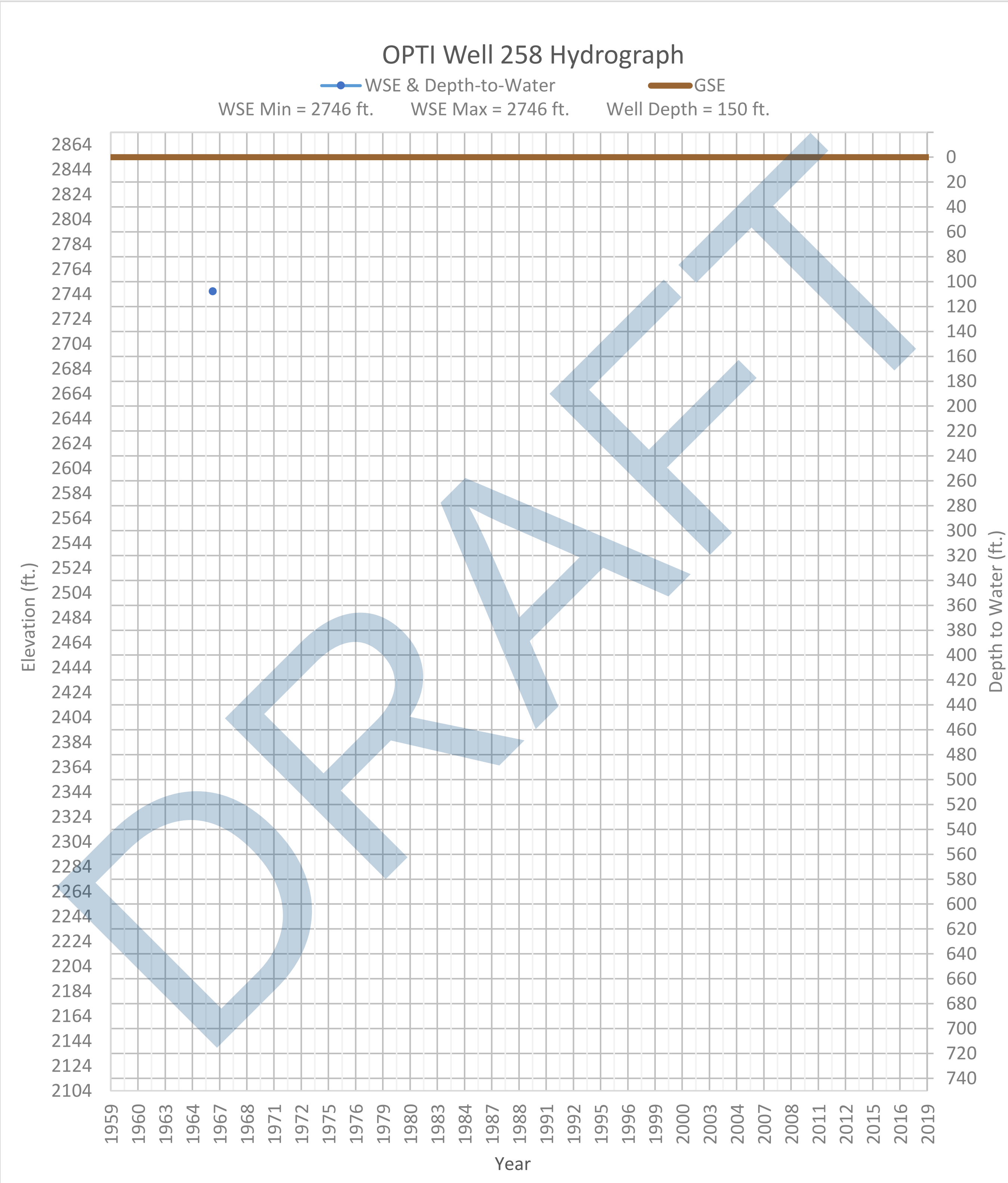
OPTI Well 254 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2750 ft.
WSE Max = 2759 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



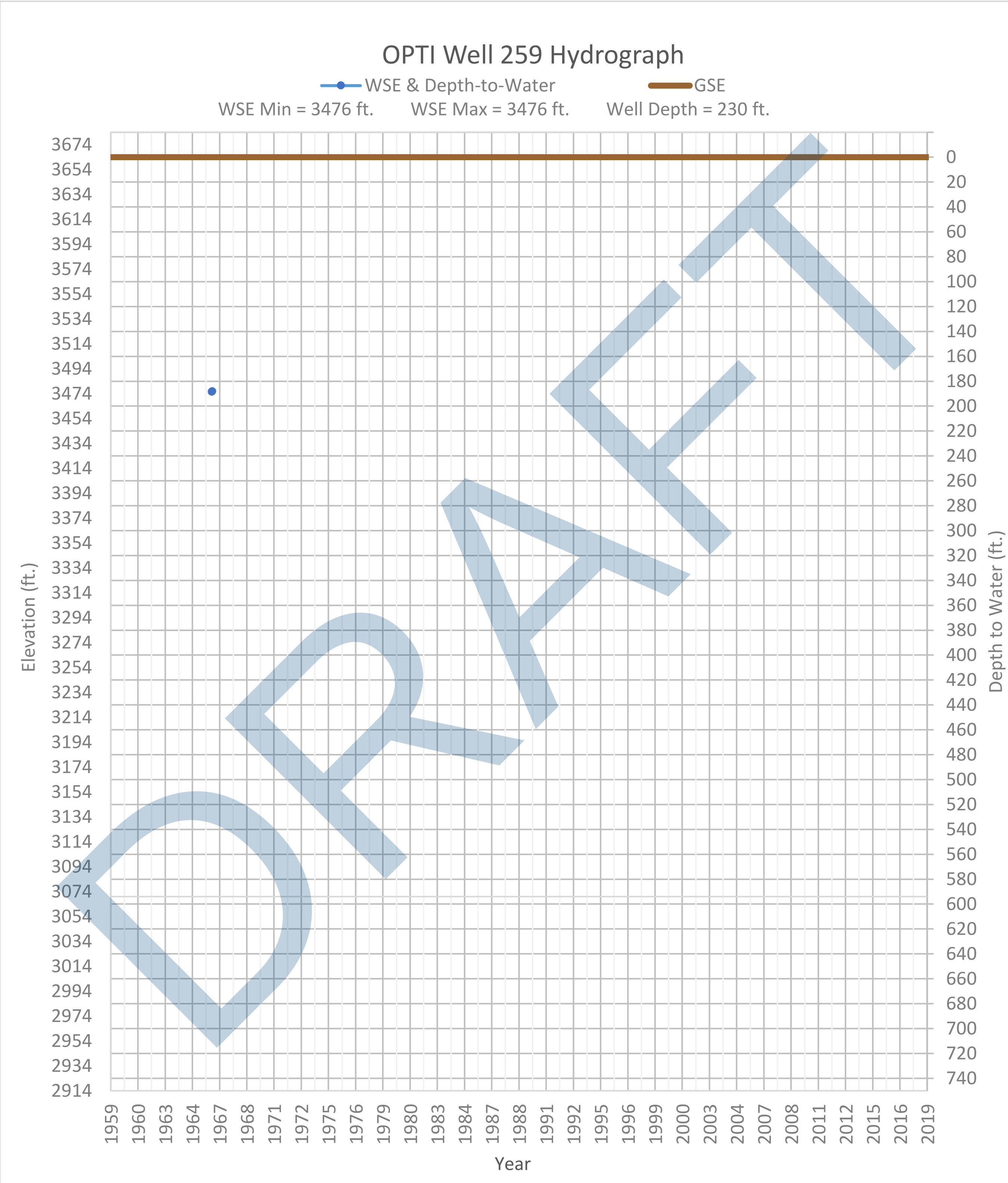
OPTI Well 255 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2753 ft.
WSE Max = 2775 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



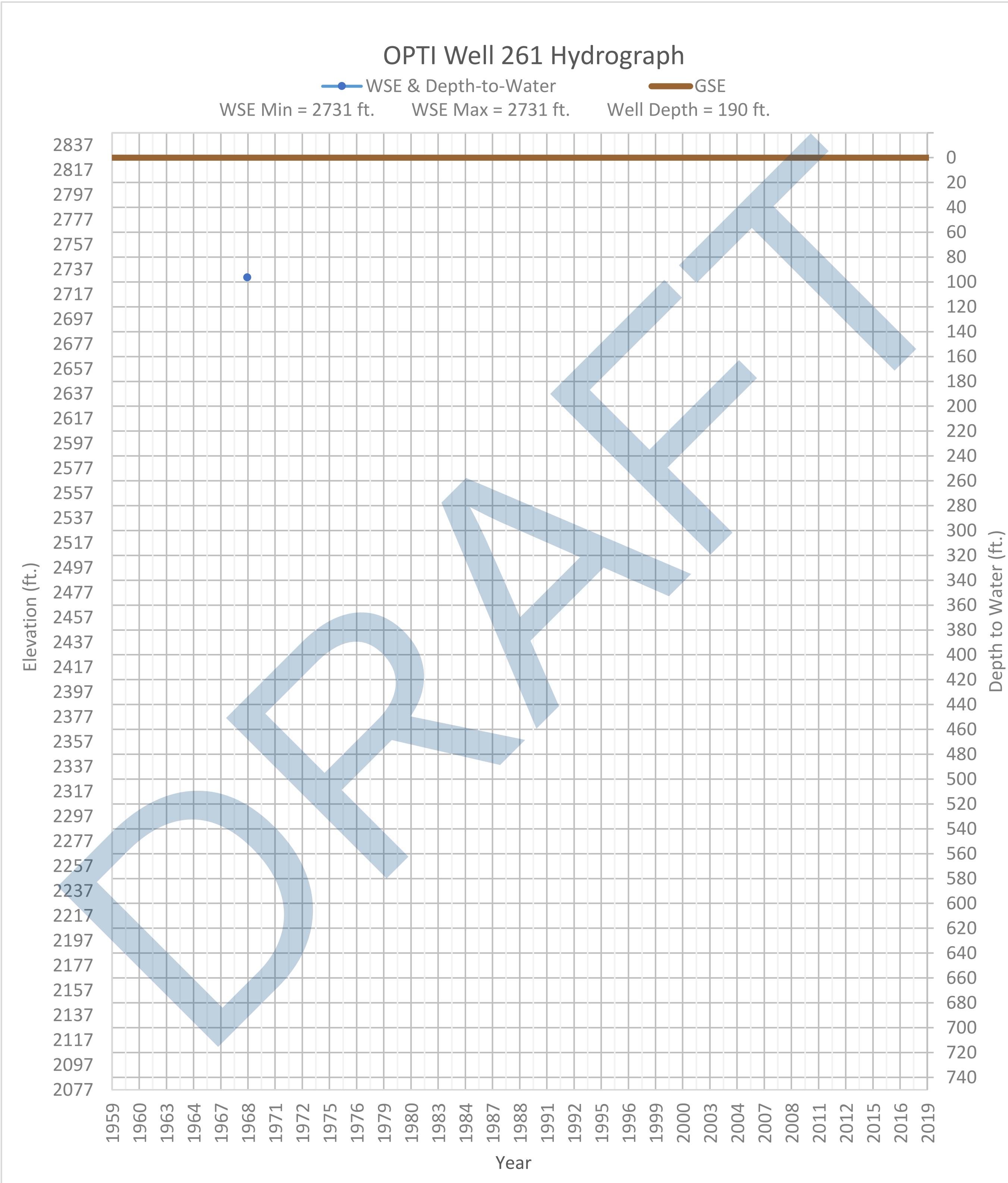
OPTI Well 257 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2748 ft.
WSE Max = 2753 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

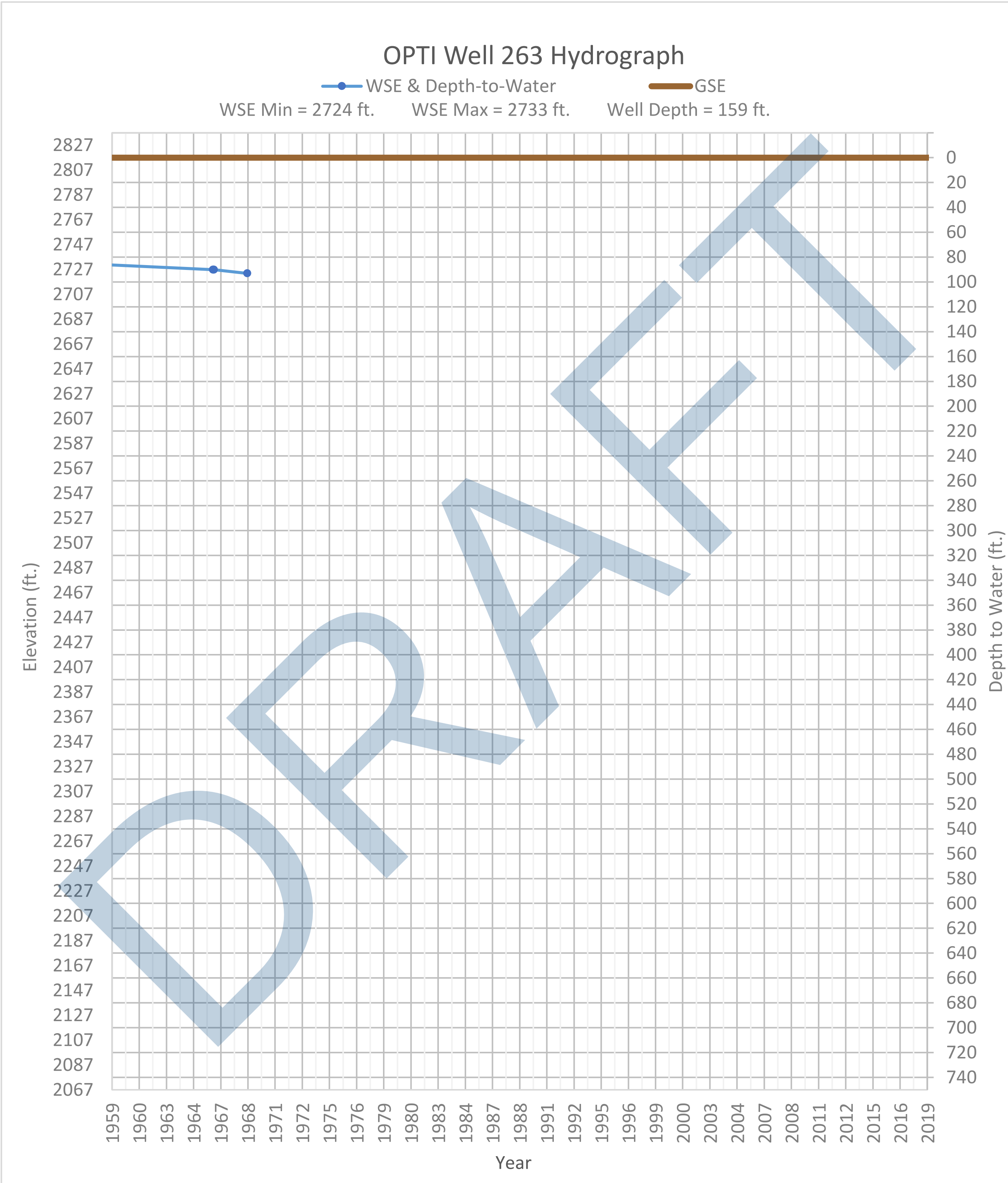


OPTI Well 258 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2746 ft.
WSE Max = 2746 ft.
Well Depth = 150 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

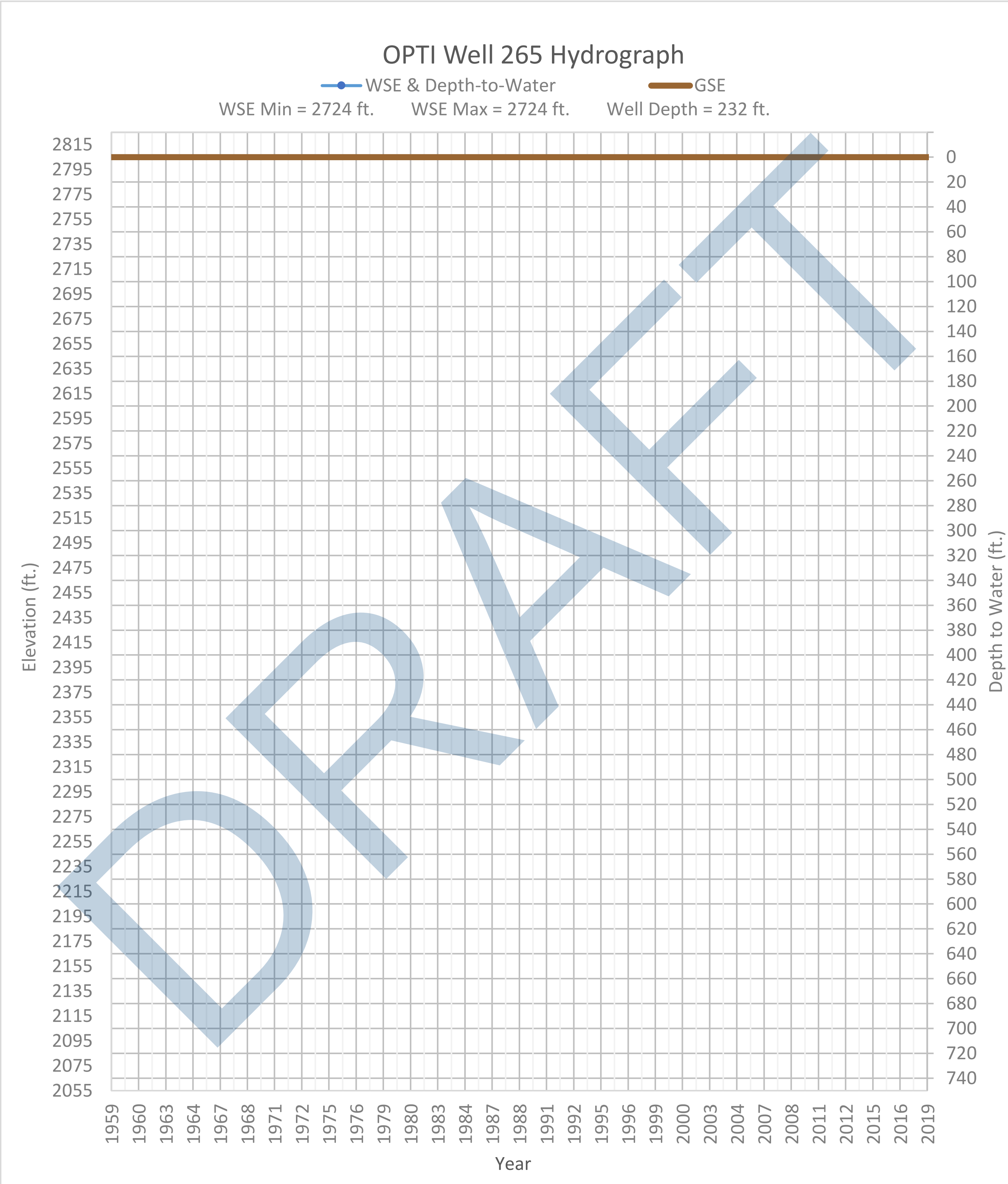


OPTI Well 259 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3476 ft.
WSE Max = 3476 ft.
Well Depth = 230 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

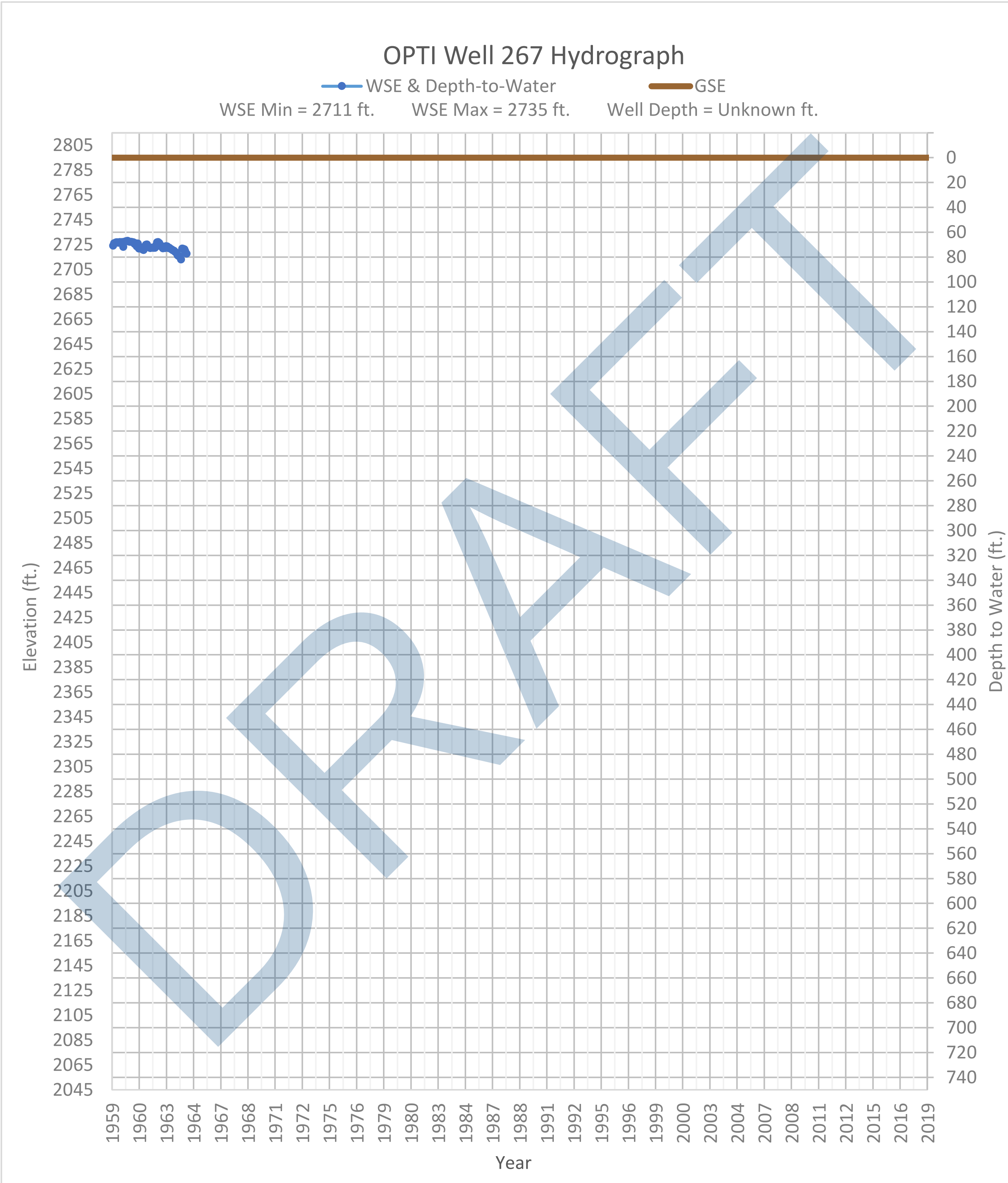

OPTI Well 261 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2731 ft.
WSE Max = 2731 ft.
Well Depth = 190 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

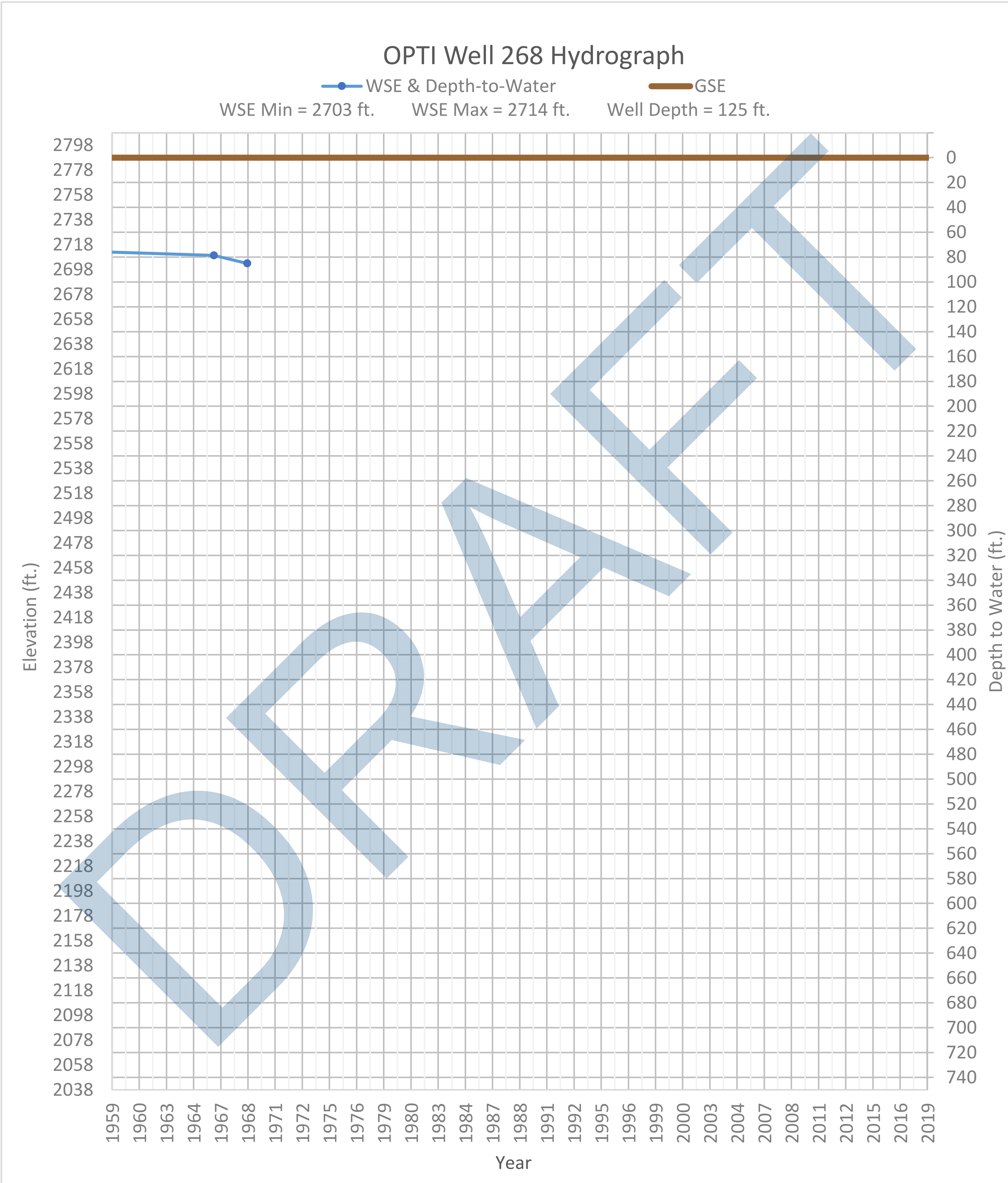


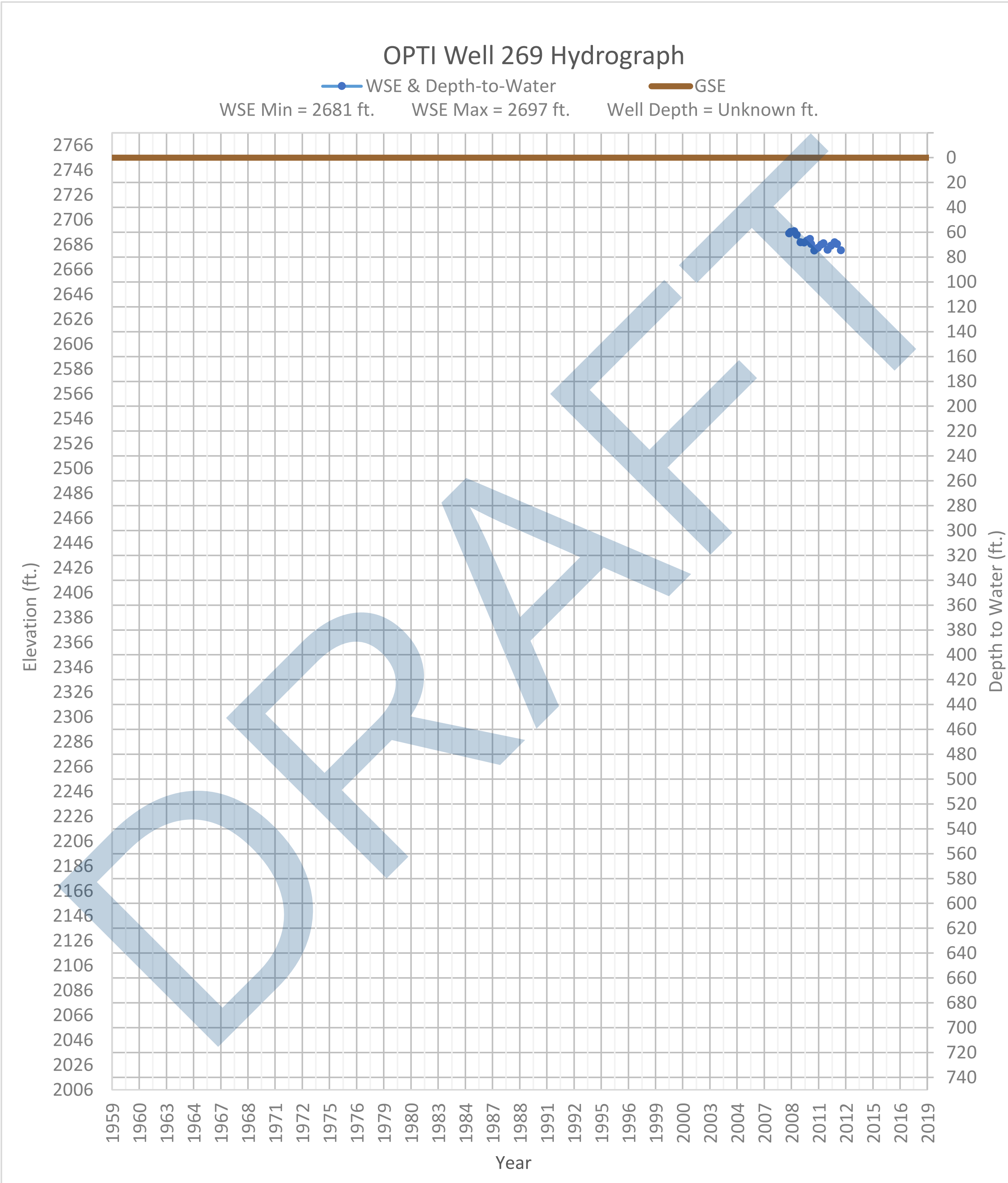
OPTI Well 263 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2724 ft.
WSE Max = 2733 ft.
Well Depth = 159 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



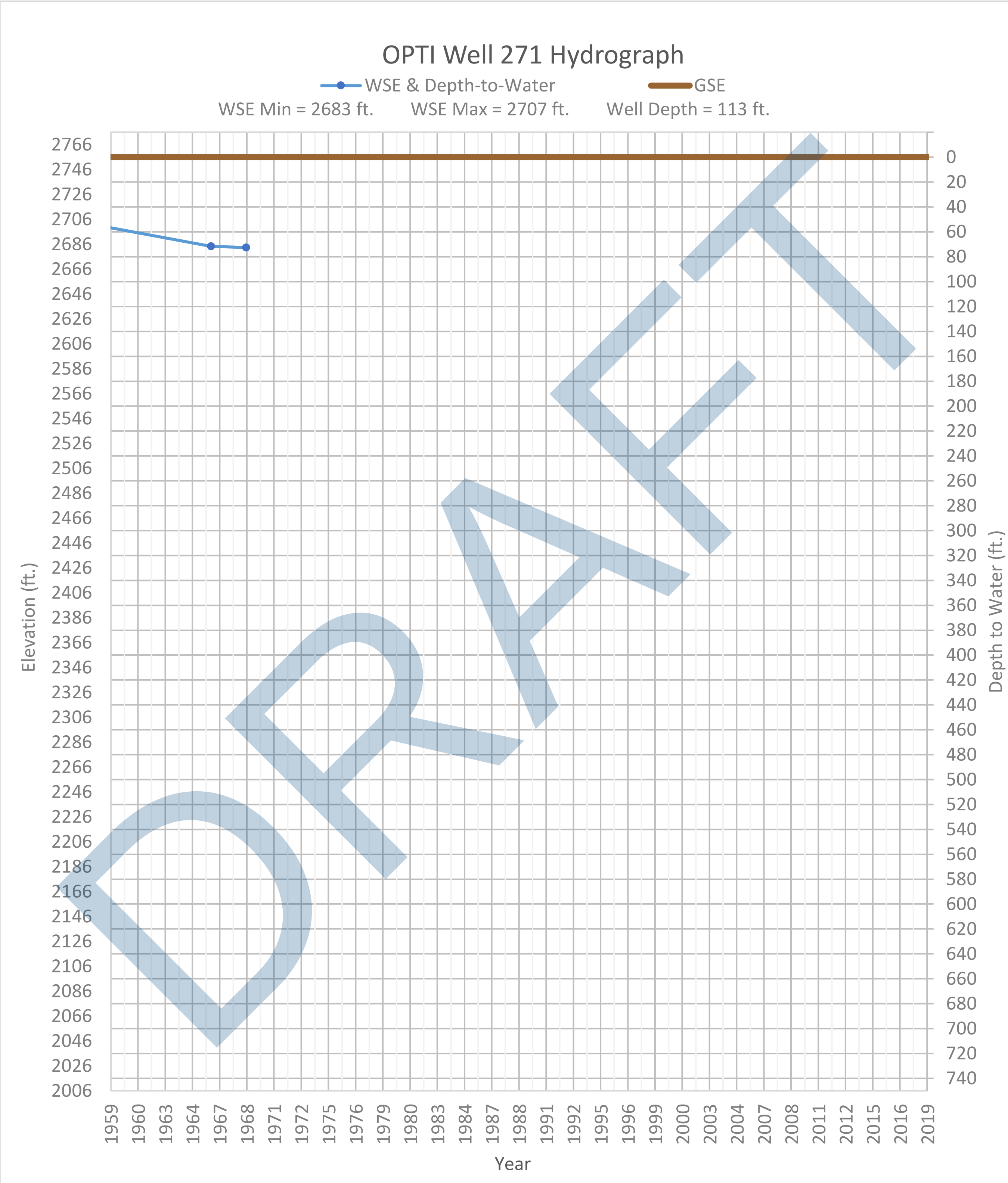
OPTI Well 265 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2724 ft.
WSE Max = 2724 ft.
Well Depth = 232 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

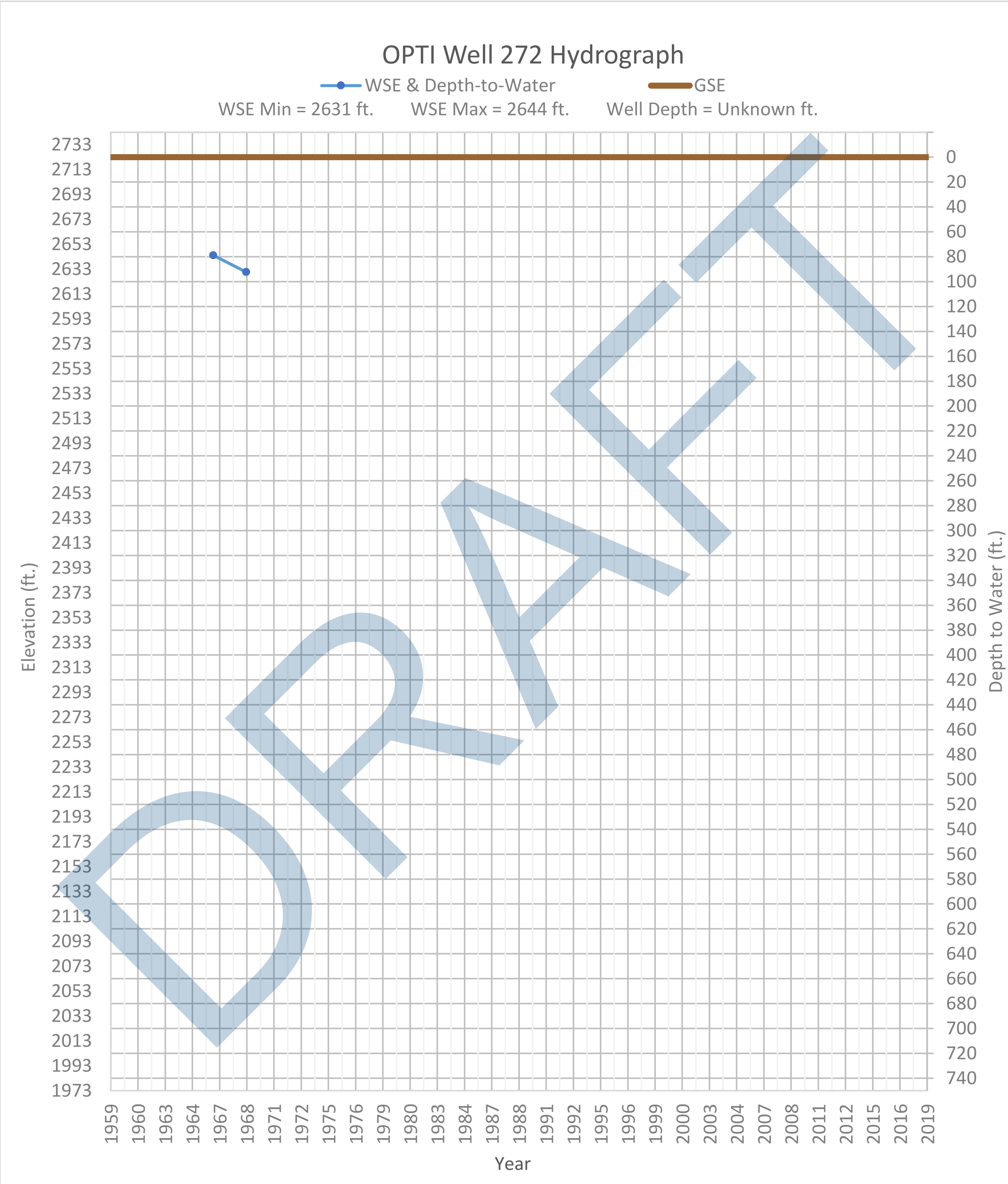

OPTI Well 267 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2711 ft.
WSE Max = 2735 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 268 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2703 ft.
WSE Max = 2714 ft.
Well Depth = 125 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

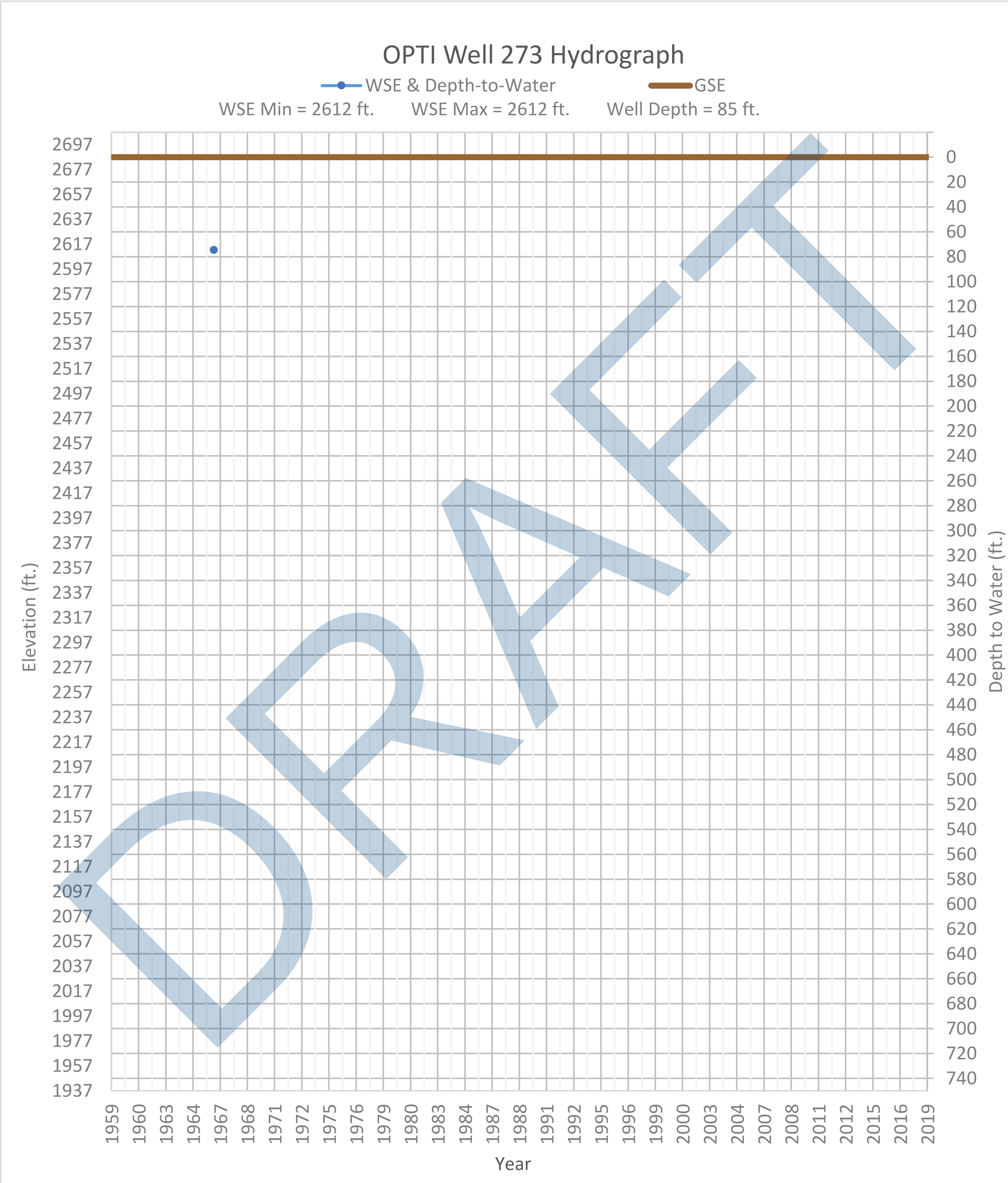


OPTI Well 269 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2681 ft.
WSE Max = 2697 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

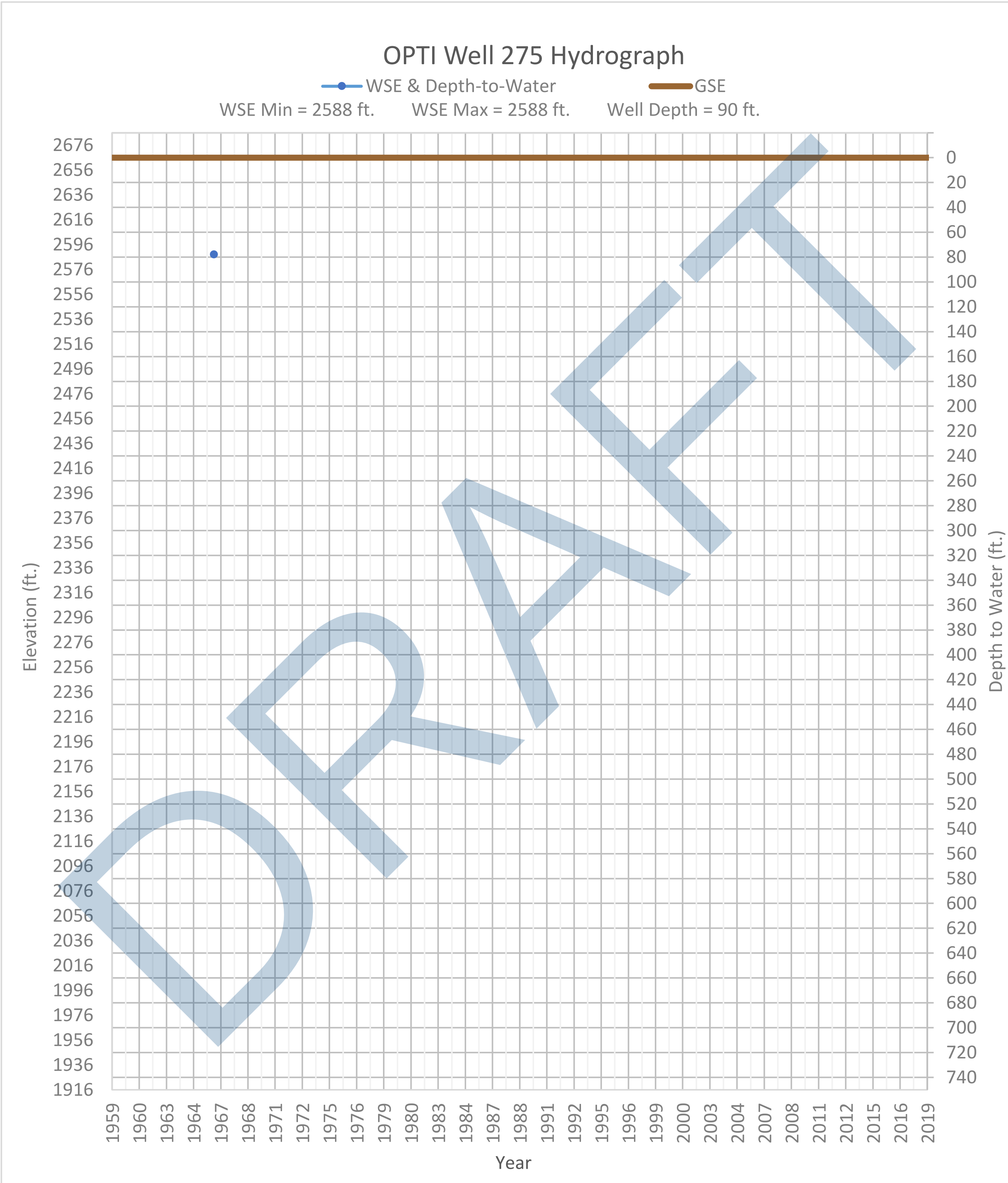

OPTI Well 271 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2683 ft.
WSE Max = 2707 ft.
Well Depth = 113 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



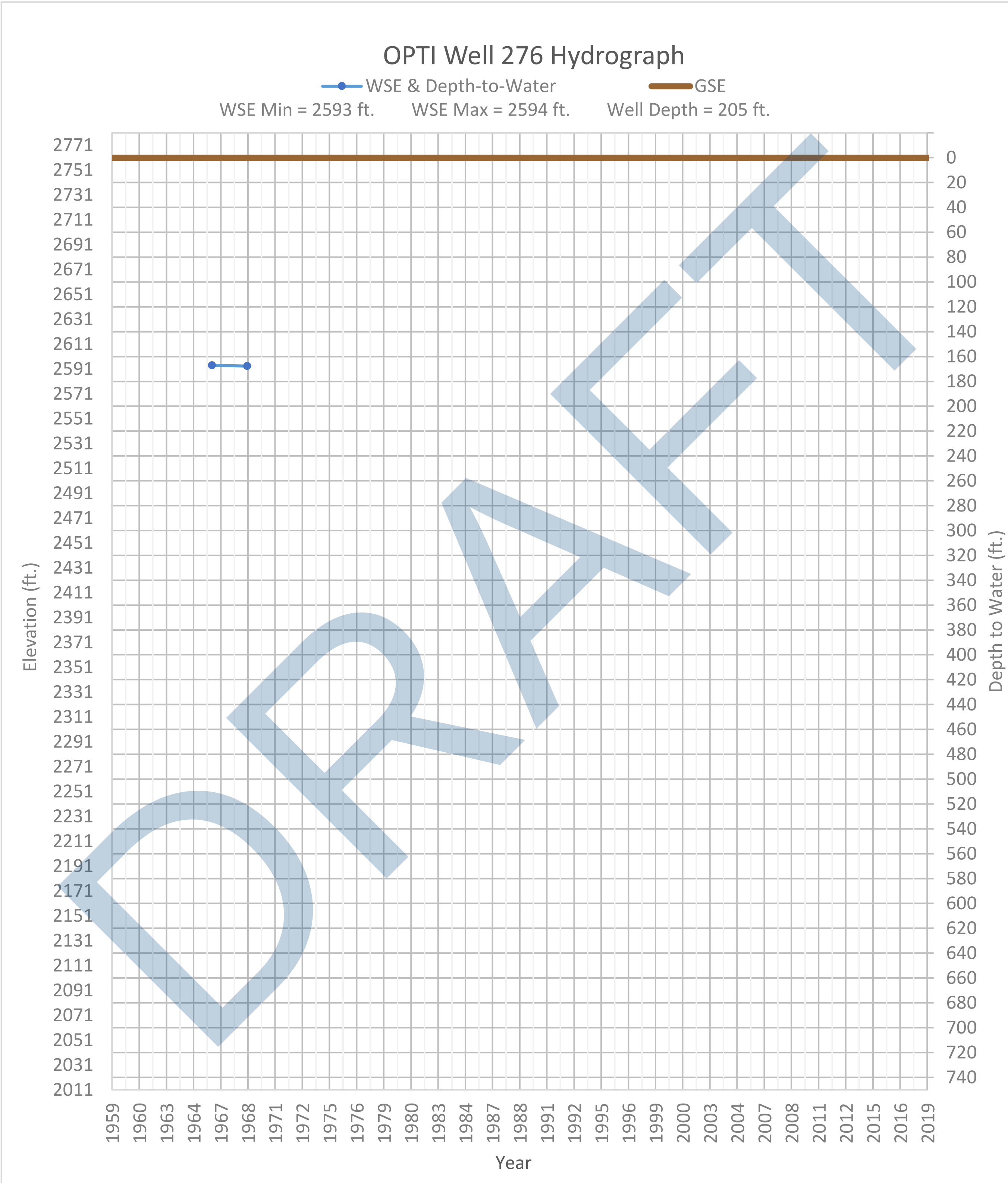
OPTI Well 272 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2631 ft.
WSE Max = 2644 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



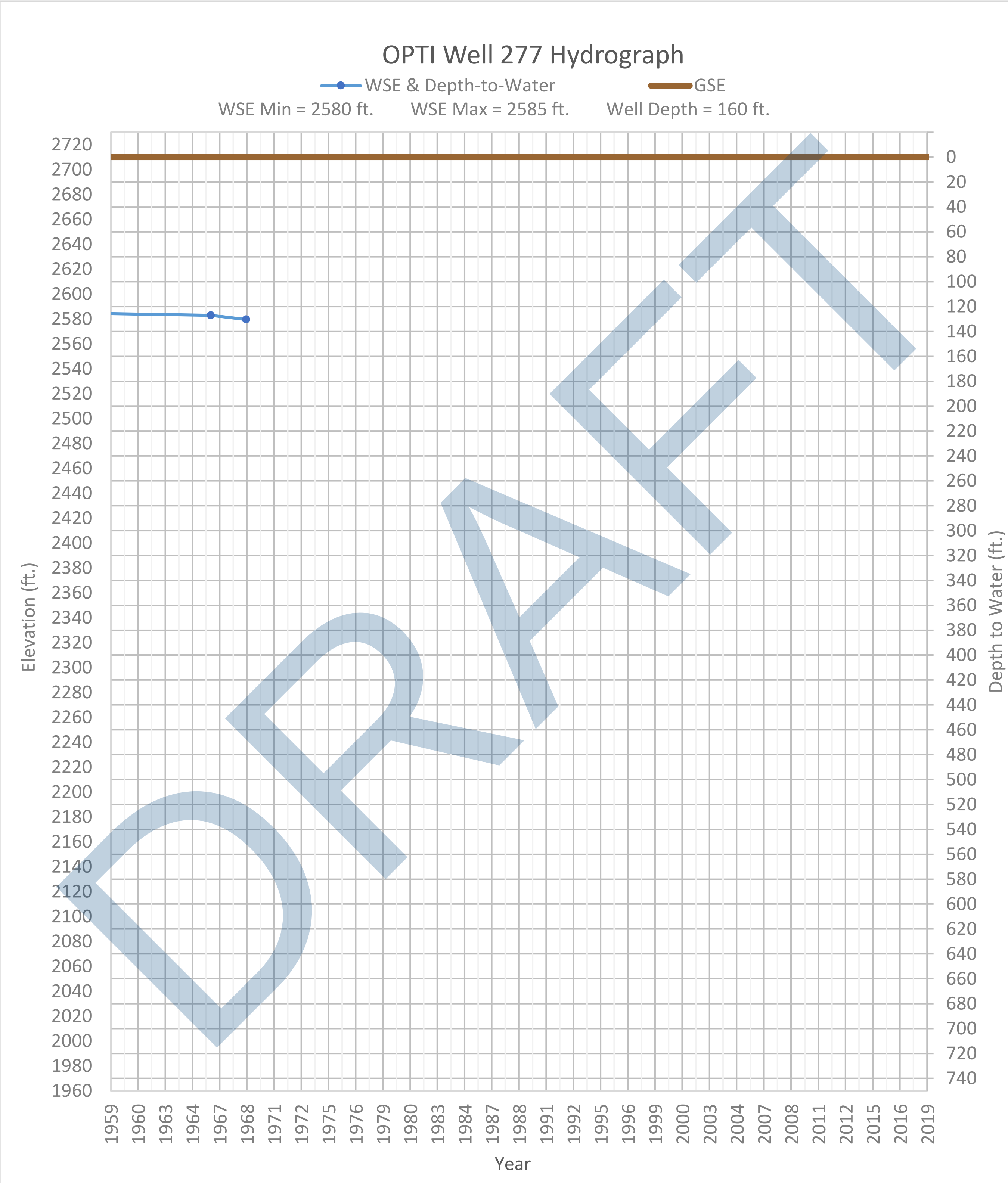
OPTI Well 273 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2612 ft.
WSE Max = 2612 ft.
Well Depth = 85 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

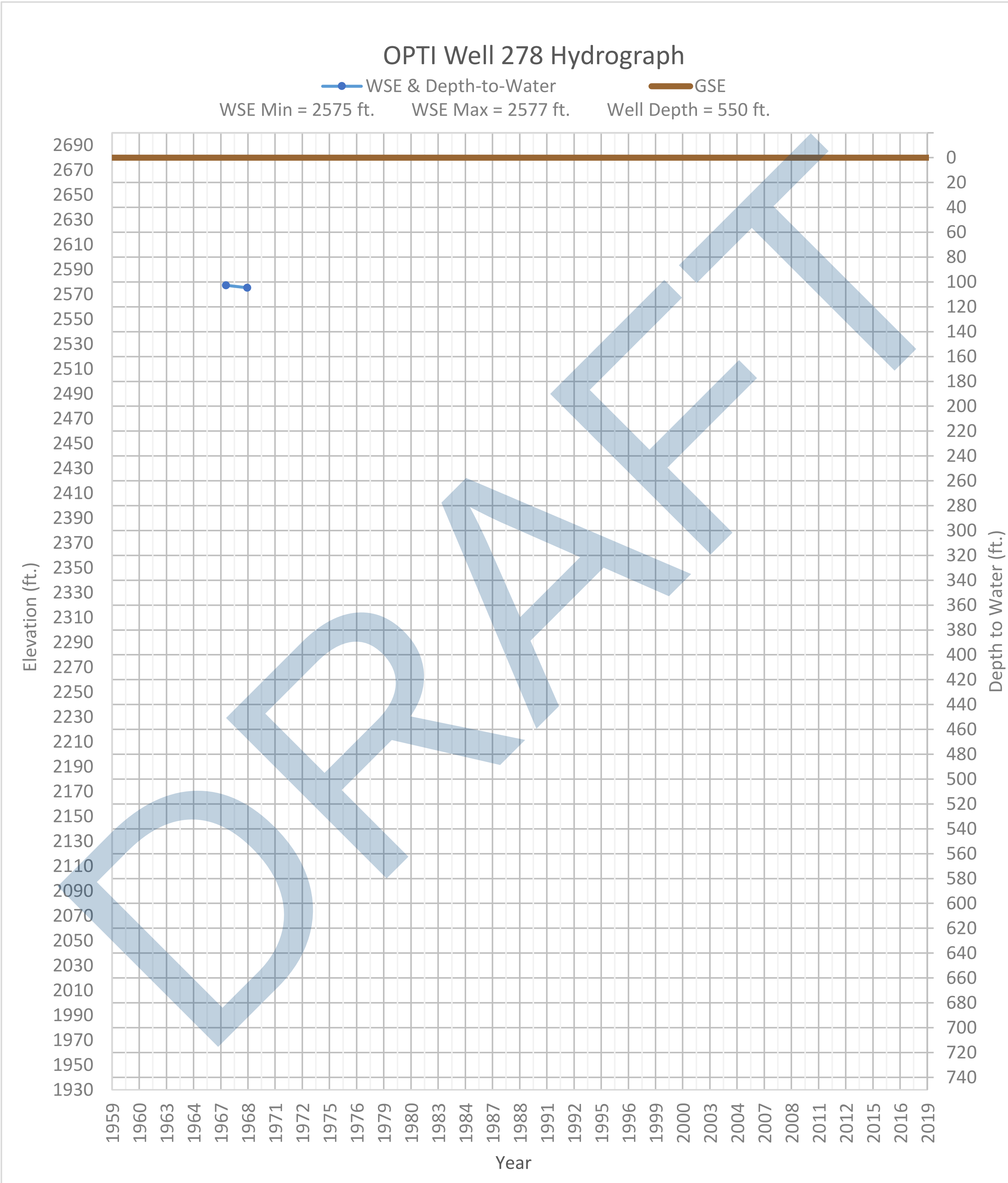


OPTI Well 275 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2588 ft.
WSE Max = 2588 ft.
Well Depth = 90 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

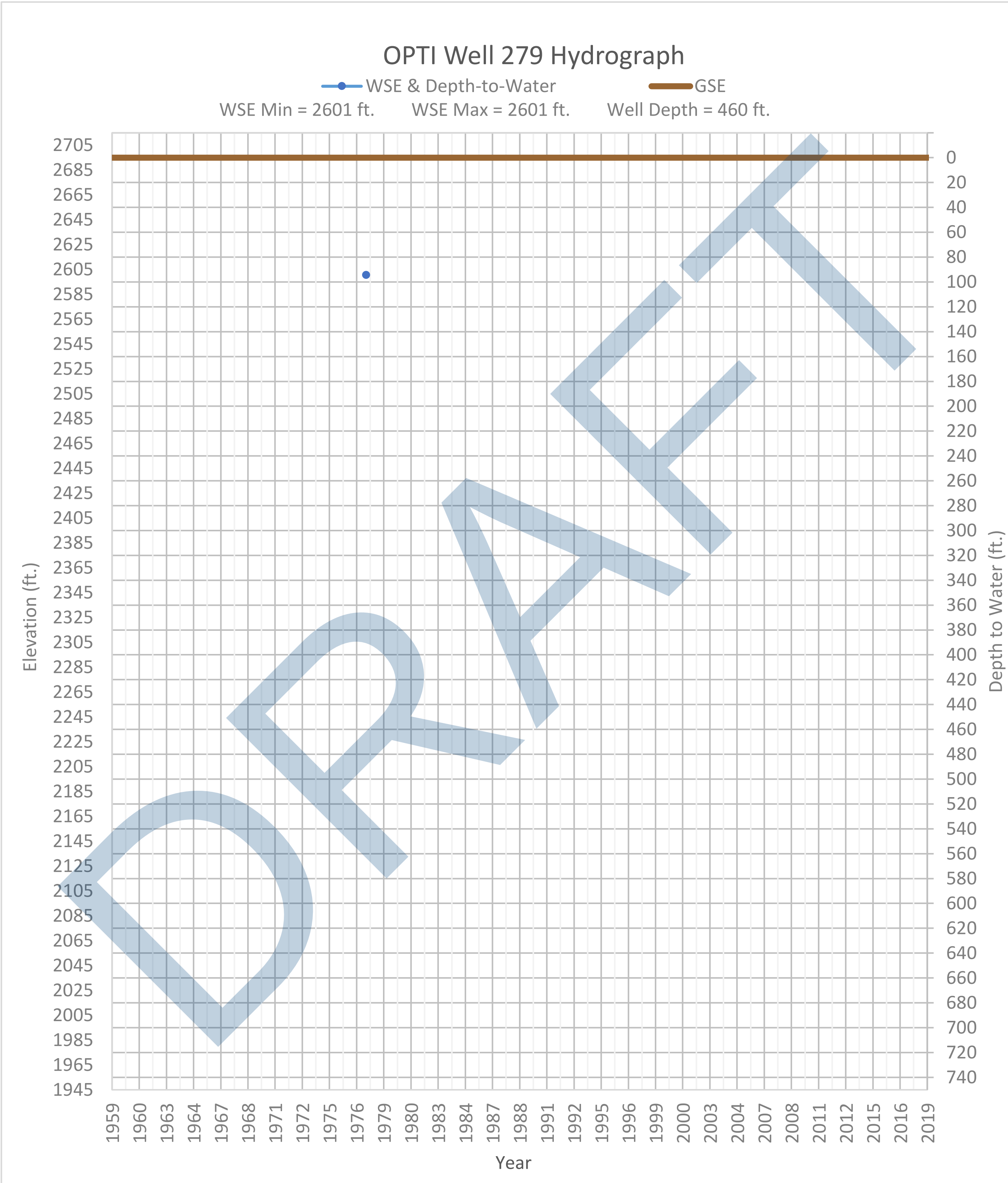


OPTI Well 276 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2593 ft.
WSE Max = 2594 ft.
Well Depth = 205 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

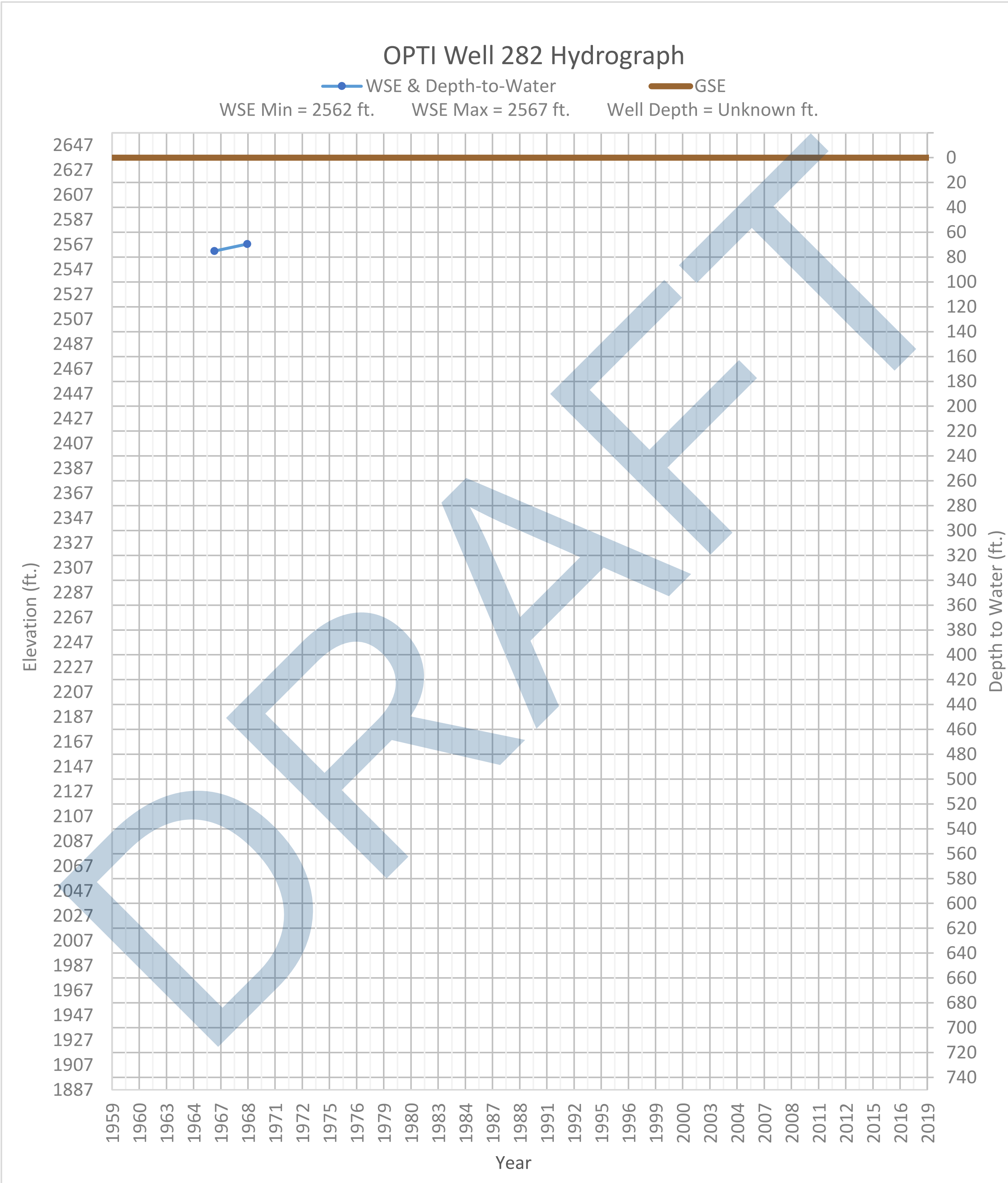

OPTI Well 277 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2580 ft.
WSE Max = 2585 ft.
Well Depth = 160 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



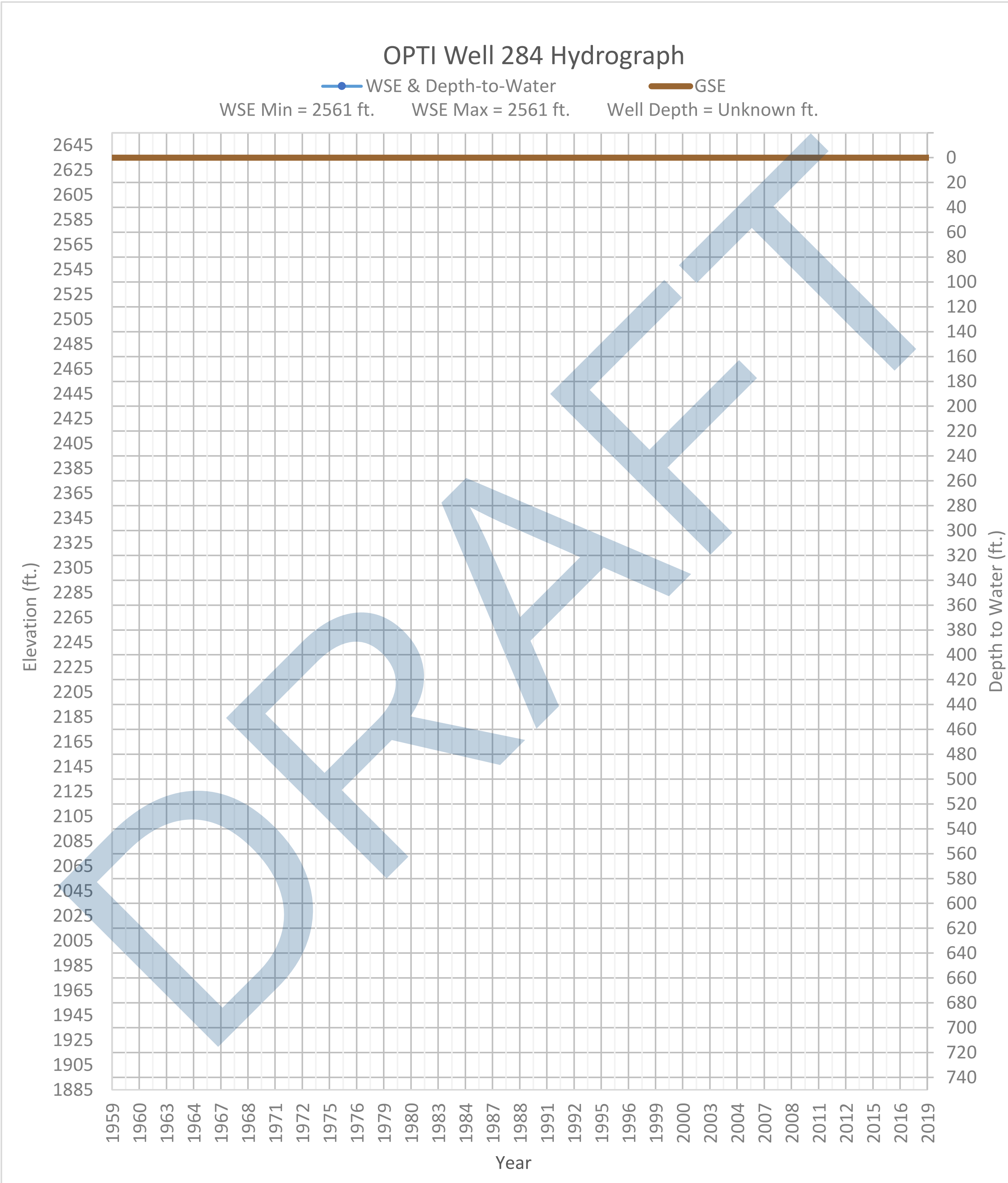
OPTI Well 278 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2575 ft.
WSE Max = 2577 ft.
Well Depth = 550 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



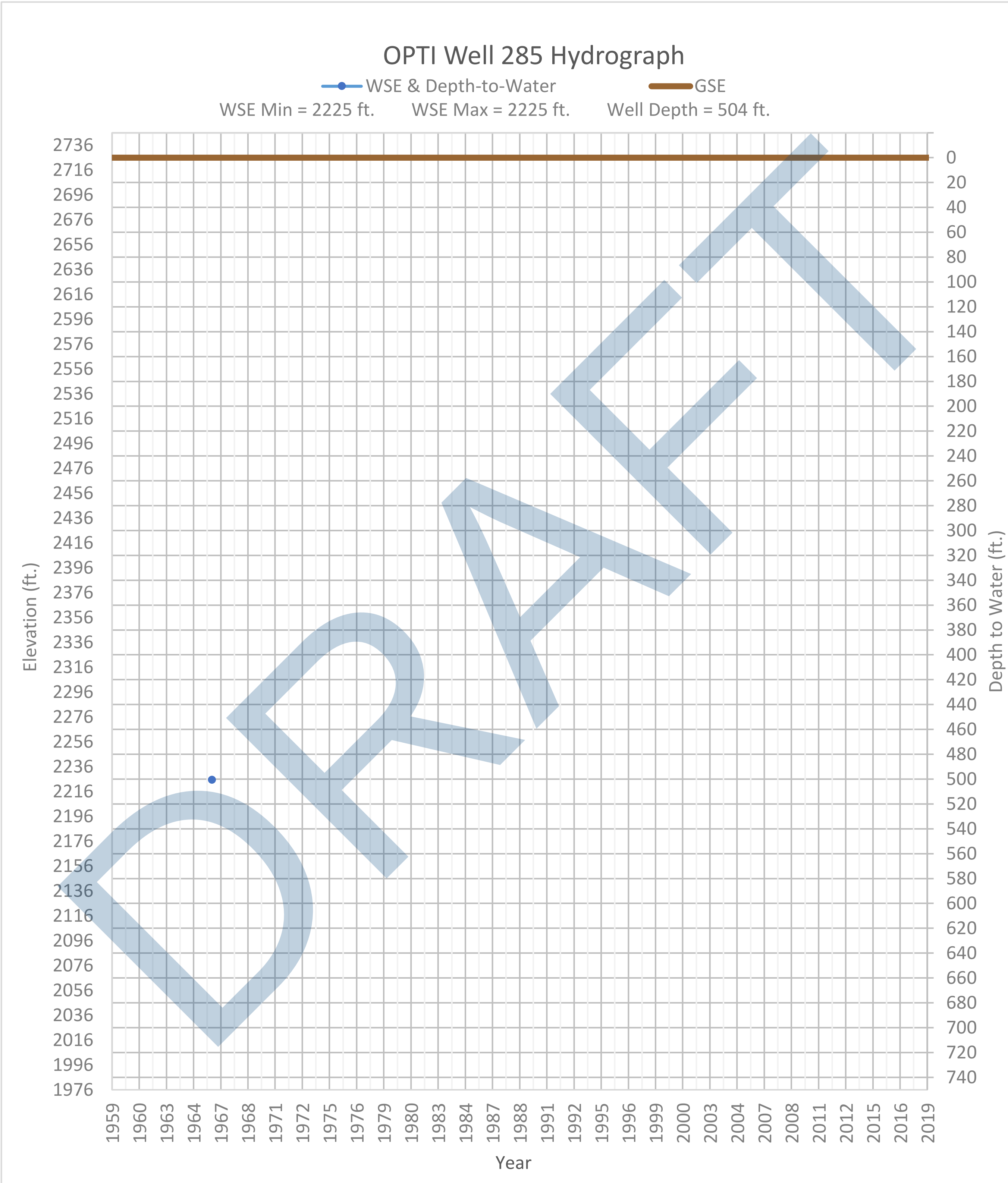
OPTI Well 279 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2601 ft.
WSE Max = 2601 ft.
Well Depth = 460 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



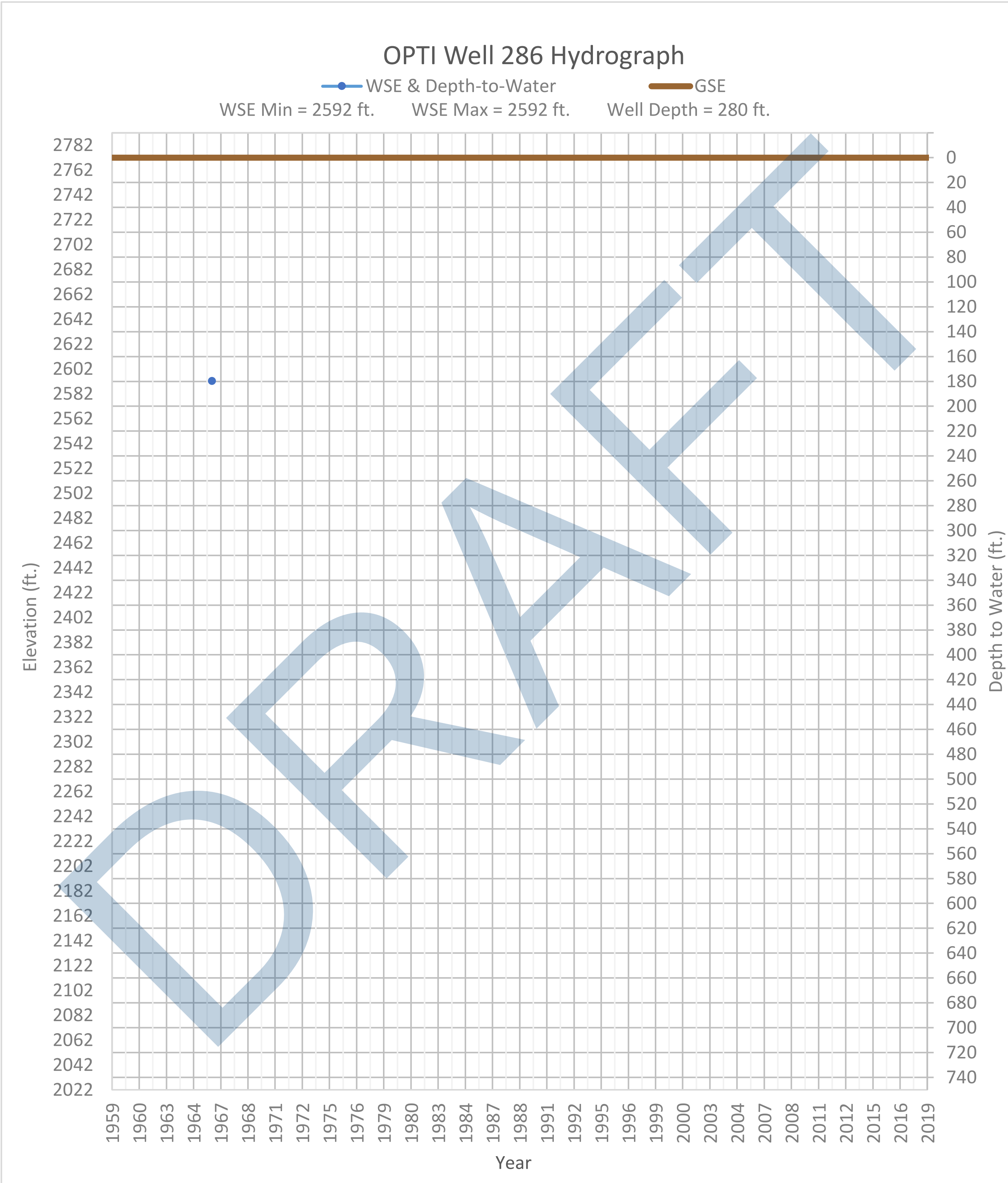
OPTI Well 282 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2562 ft.
WSE Max = 2567 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



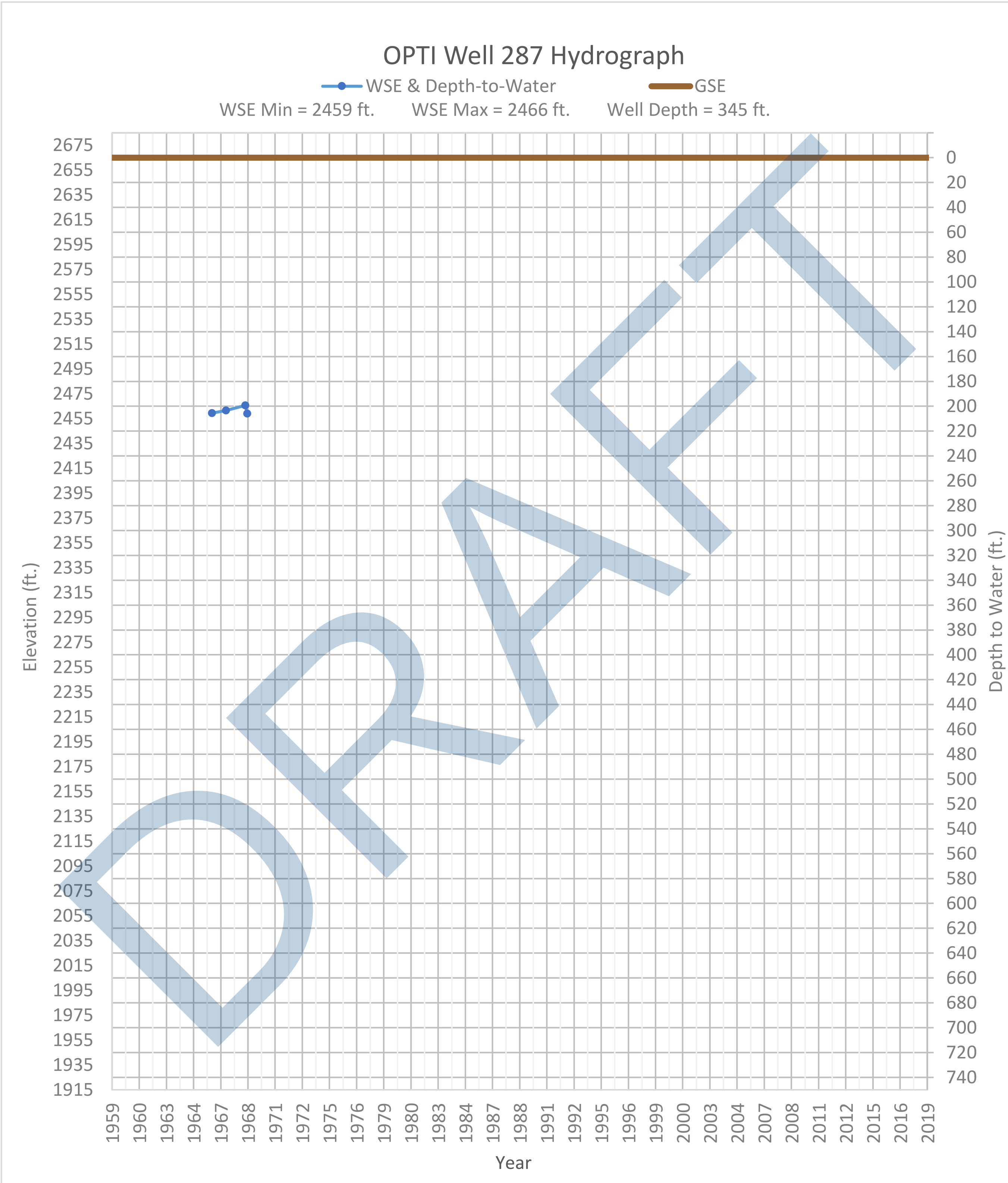
OPTI Well 284 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2561 ft.
WSE Max = 2561 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



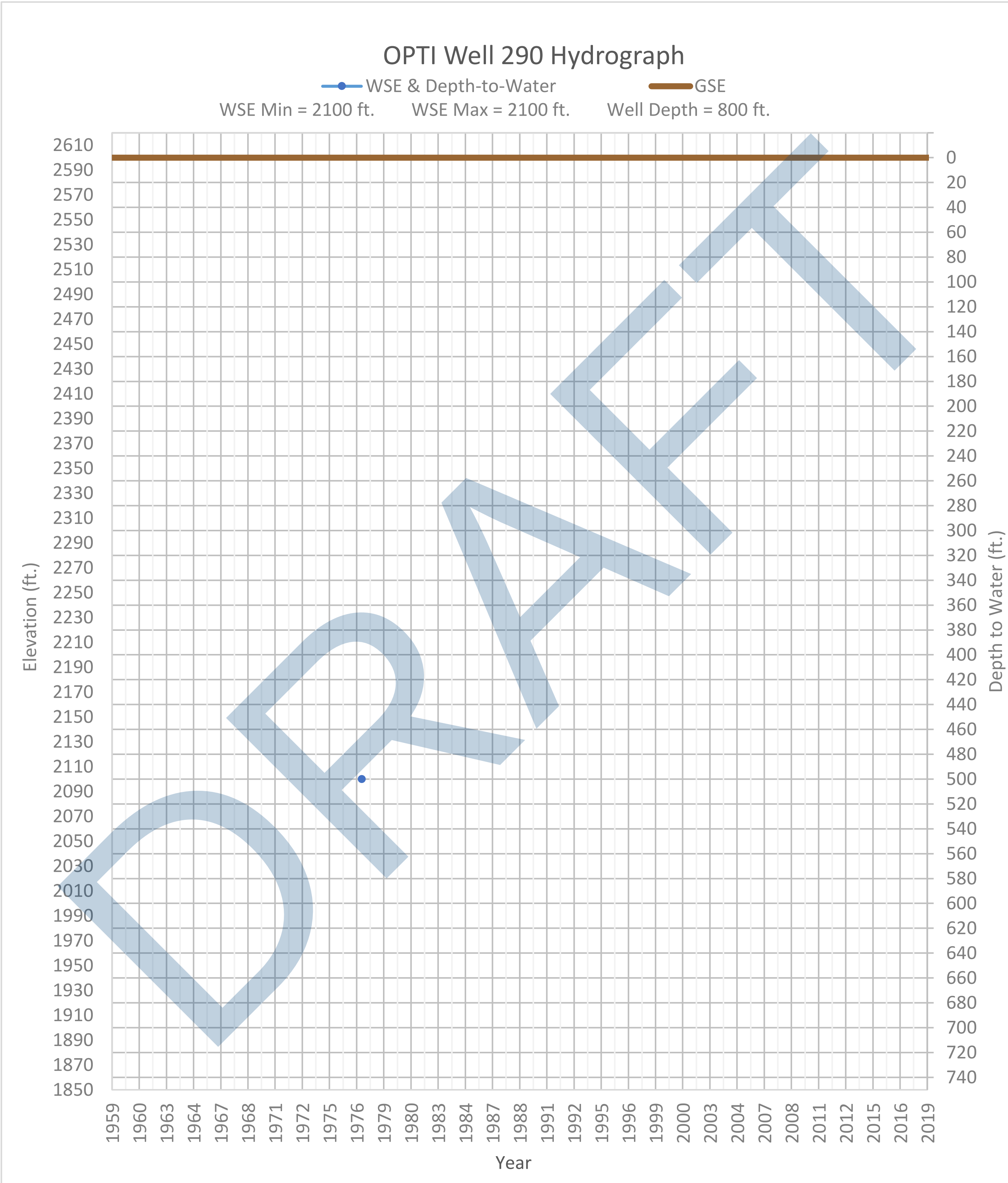
OPTI Well 285 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2225 ft.
WSE Max = 2225 ft.
Well Depth = 504 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 286 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2592 ft.
WSE Max = 2592 ft.
Well Depth = 280 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 287 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2459 ft.
WSE Max = 2466 ft.
Well Depth = 345 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 290 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2100 ft.
WSE Max = 2100 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2610
2590
2570
2550
2530
2510
2490
2470
2450
2430
2410
2390
2370
2350
2330
2310
2290
2270
2250
2230
2210
2190
2170
2150
2130
2110
2090
2070
2050
2030
2010
1990
1970
1950
1930
1910
1890
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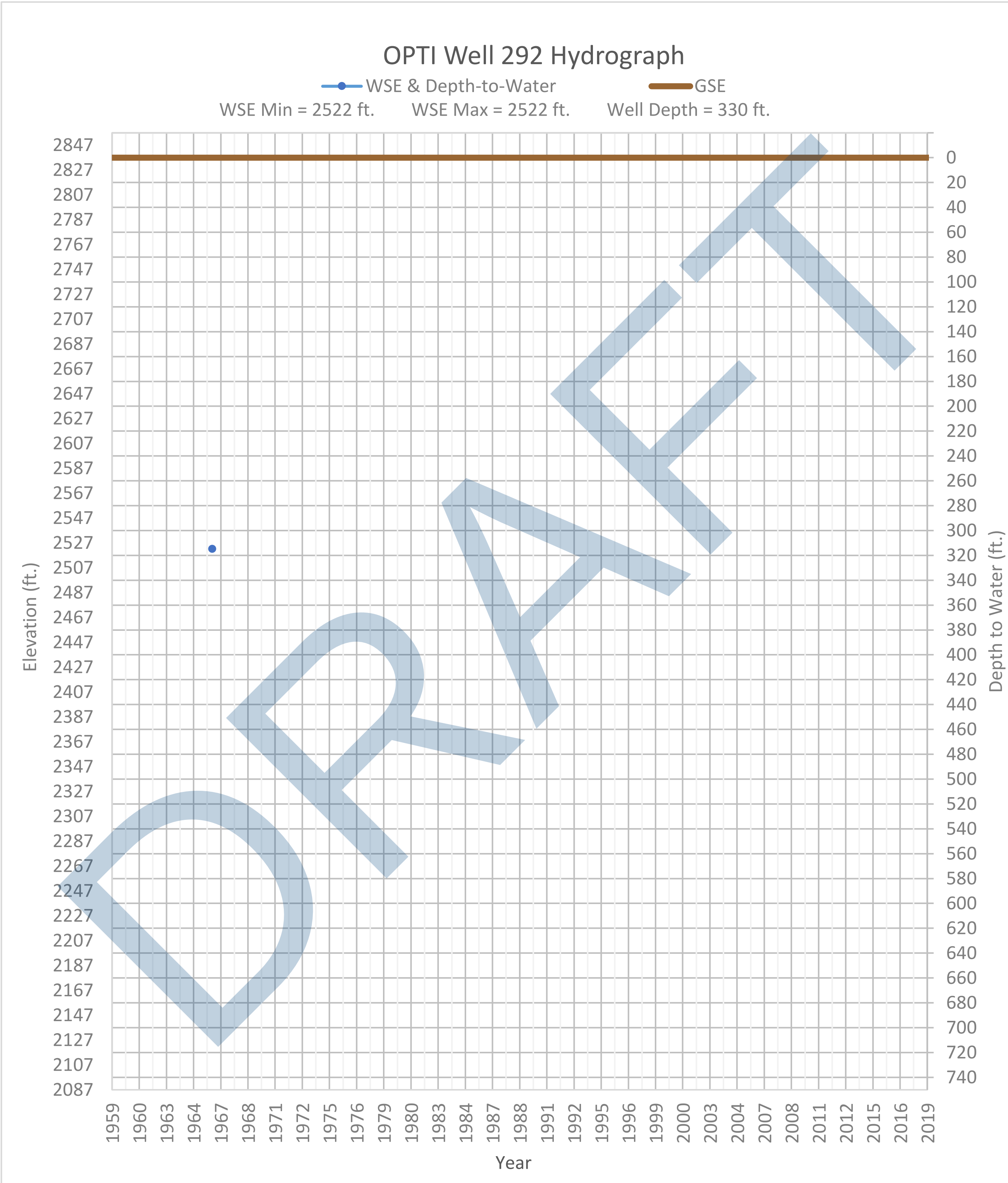
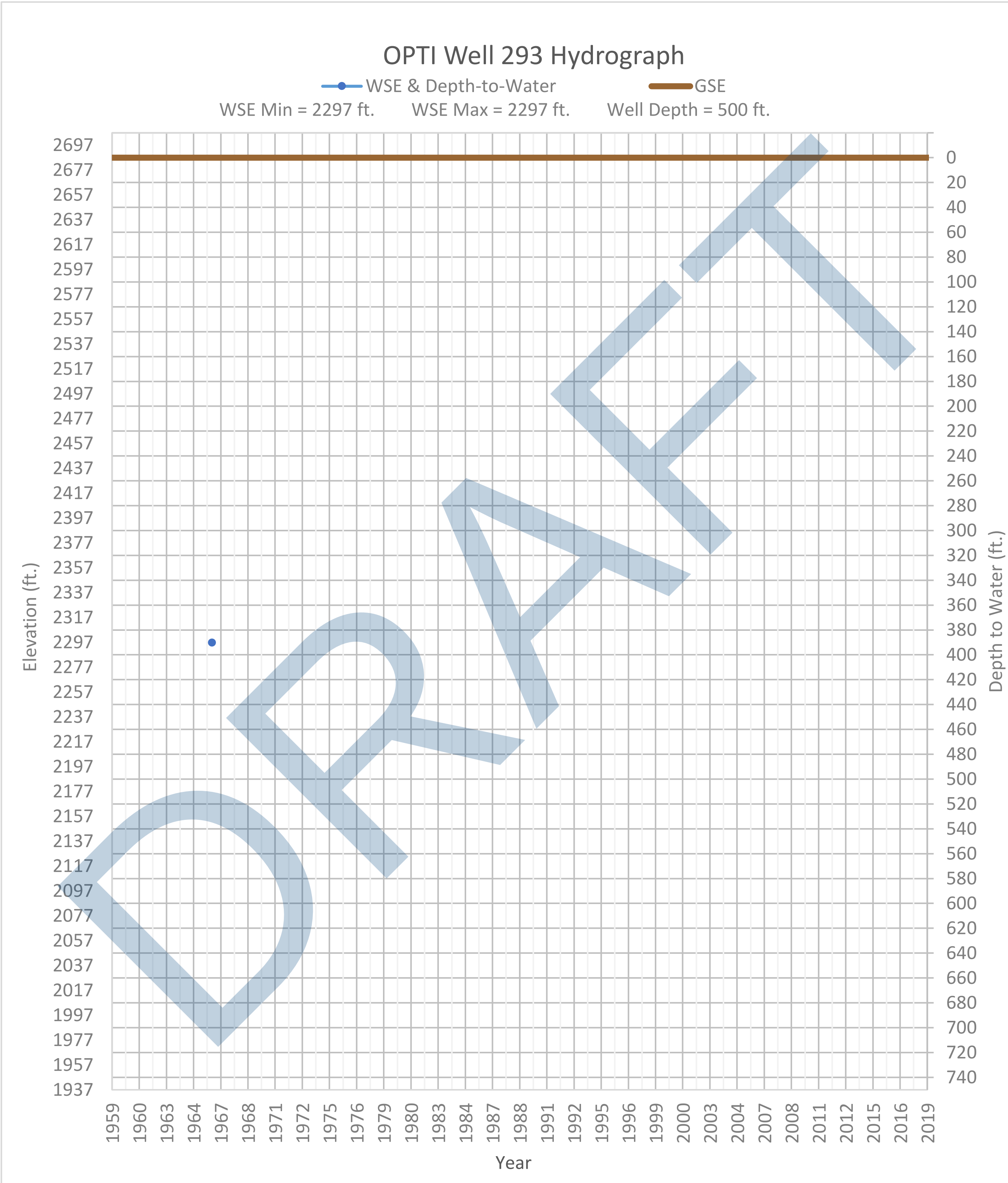
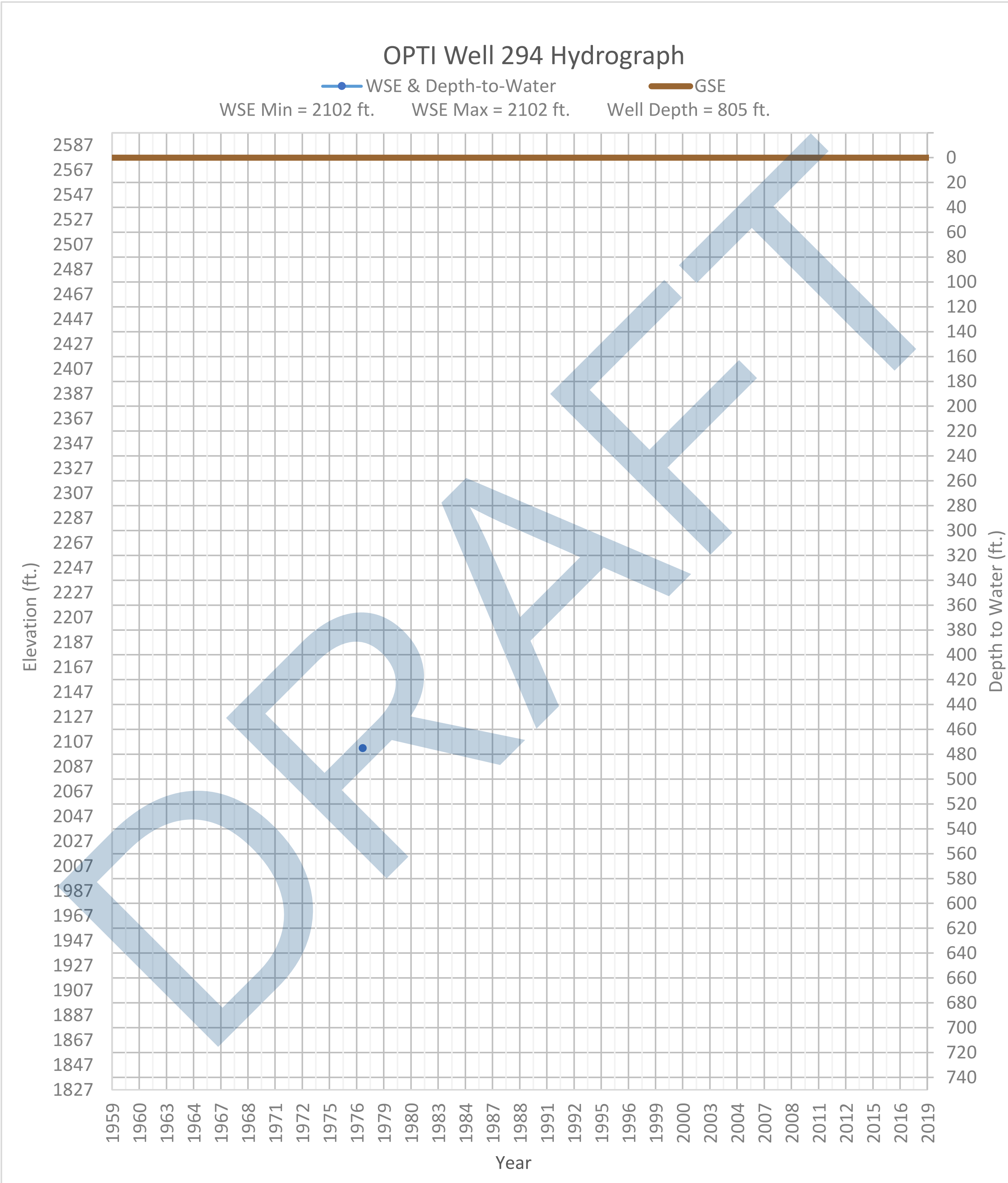
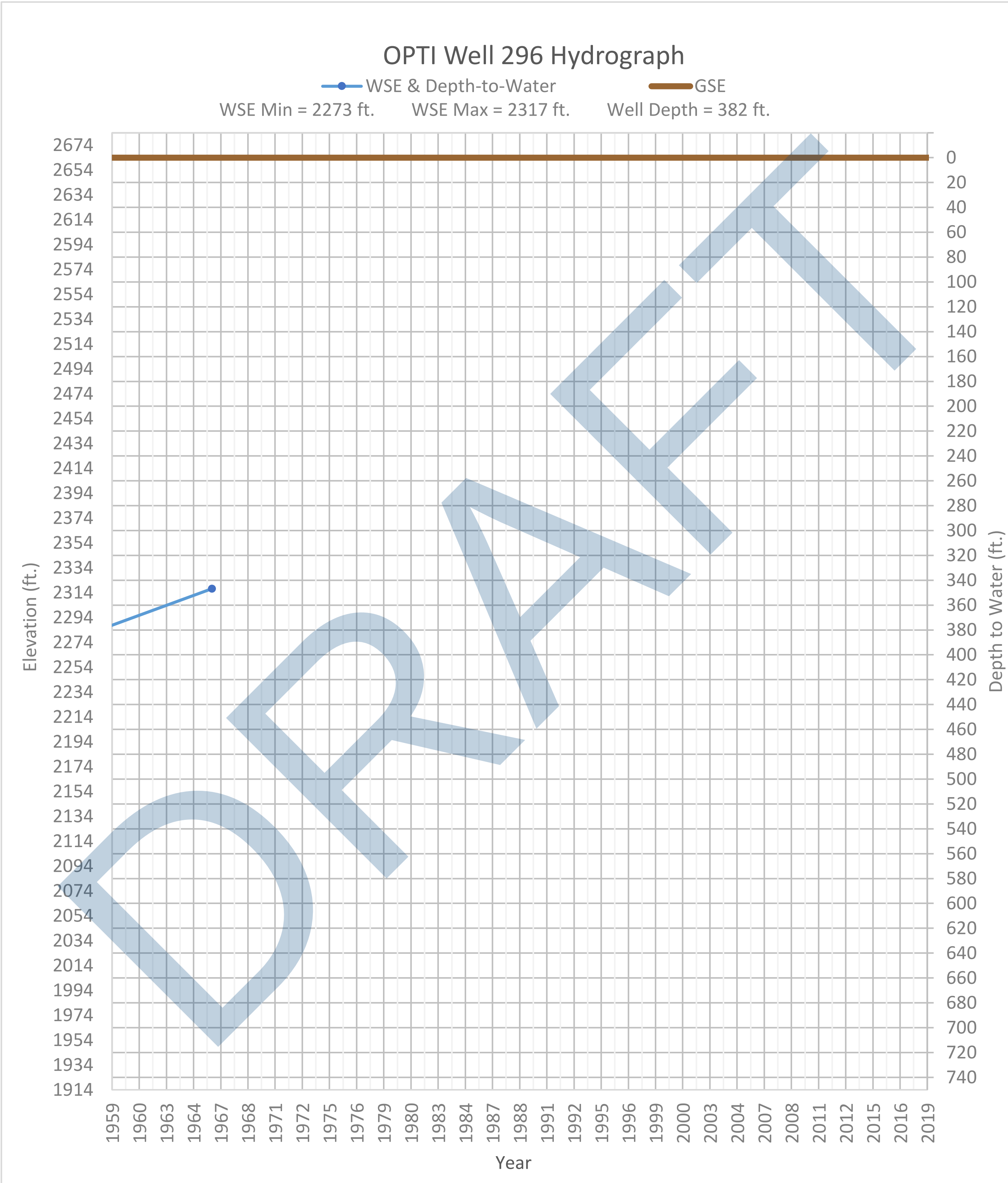

OPTI Well 292 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2522 ft.
WSE Max = 2522 ft.
Well Depth = 330 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 293 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2297 ft.
WSE Max = 2297 ft.
Well Depth = 500 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 294 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2102 ft.
WSE Max = 2102 ft.
Well Depth = 805 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 296 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2273 ft.
WSE Max = 2317 ft.
Well Depth = 382 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2674
2654
2634
2614
2594
2574
2554
2534
2514
2494
2474
2454
2434
2414
2394
2374
2354
2334
2314
2294
2274
2254
2234
2214
2194
2174
2154
2134
2114
2094
2074
2054
2034
2014
1994
1974
1954
1934
1914
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
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1971
1972
1975
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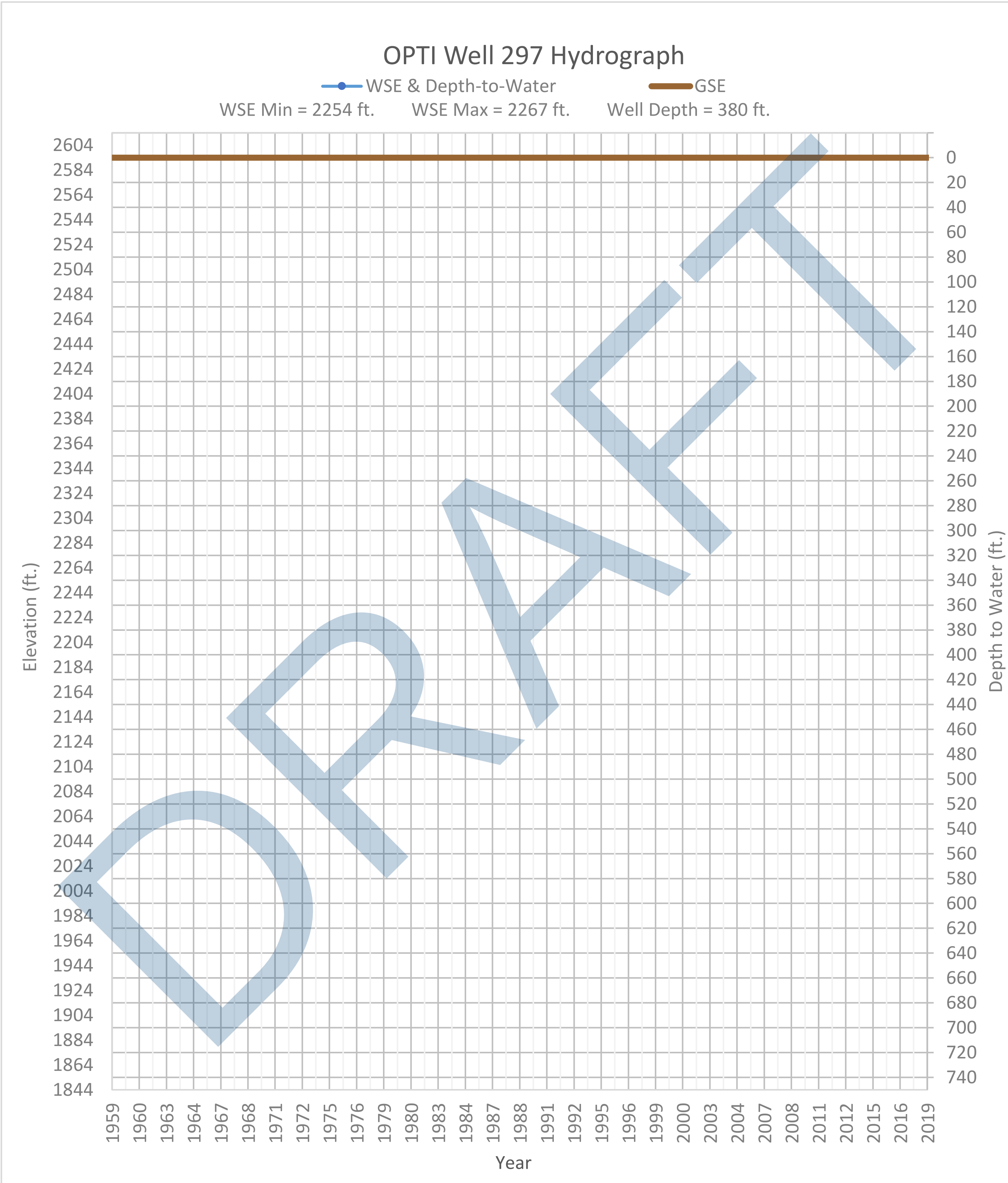
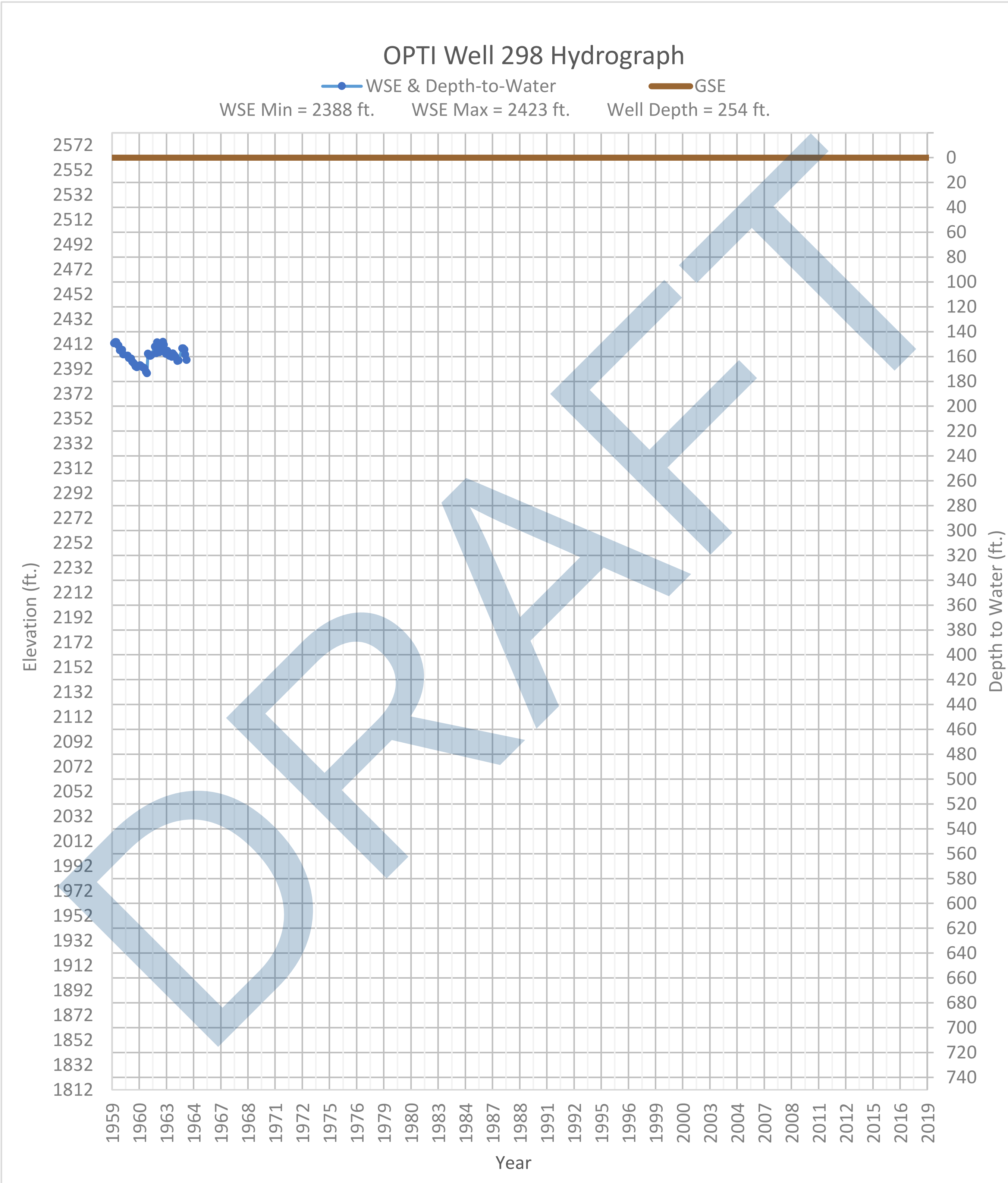
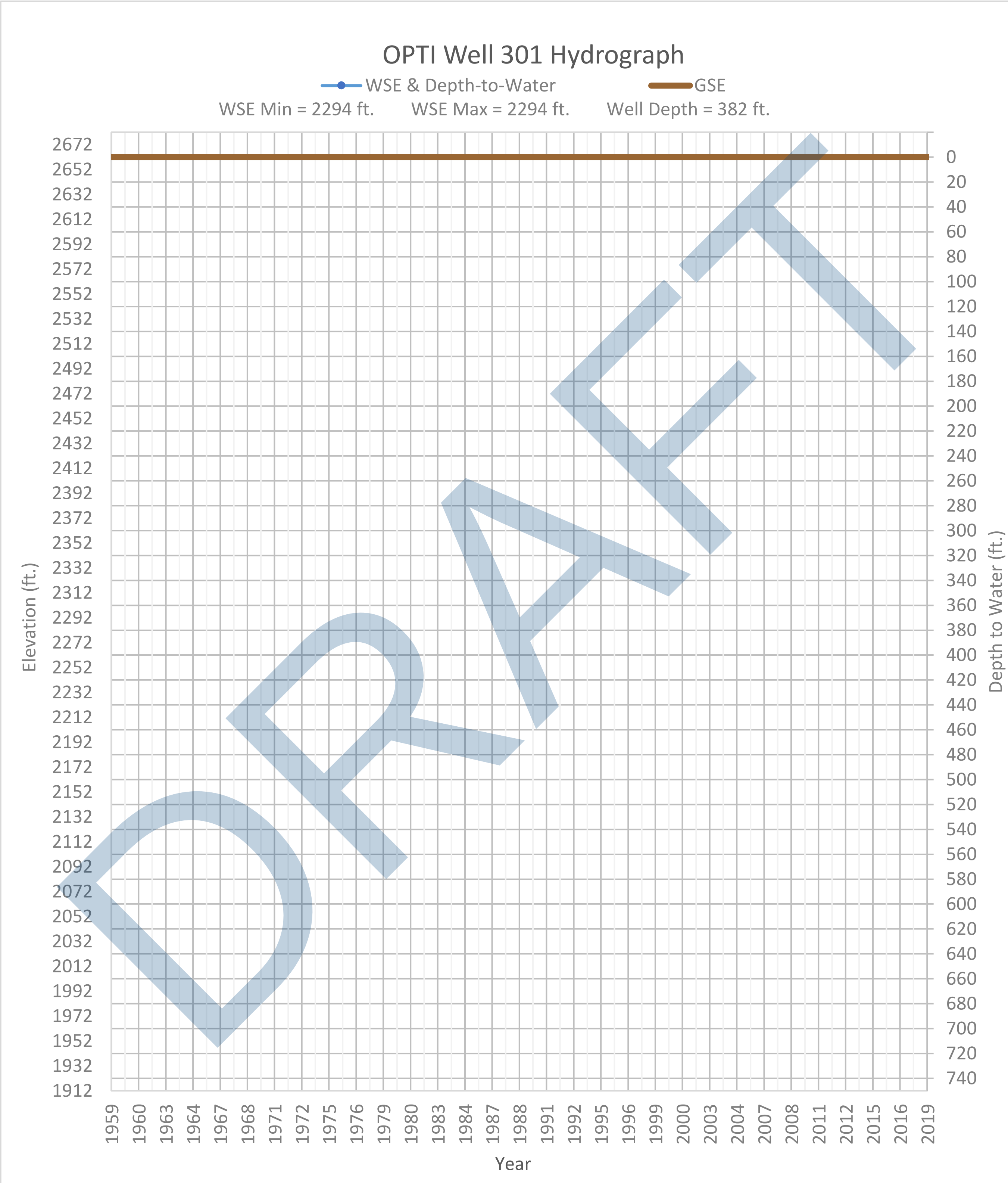
2011
2012
2015
2016
2019
DRAFT



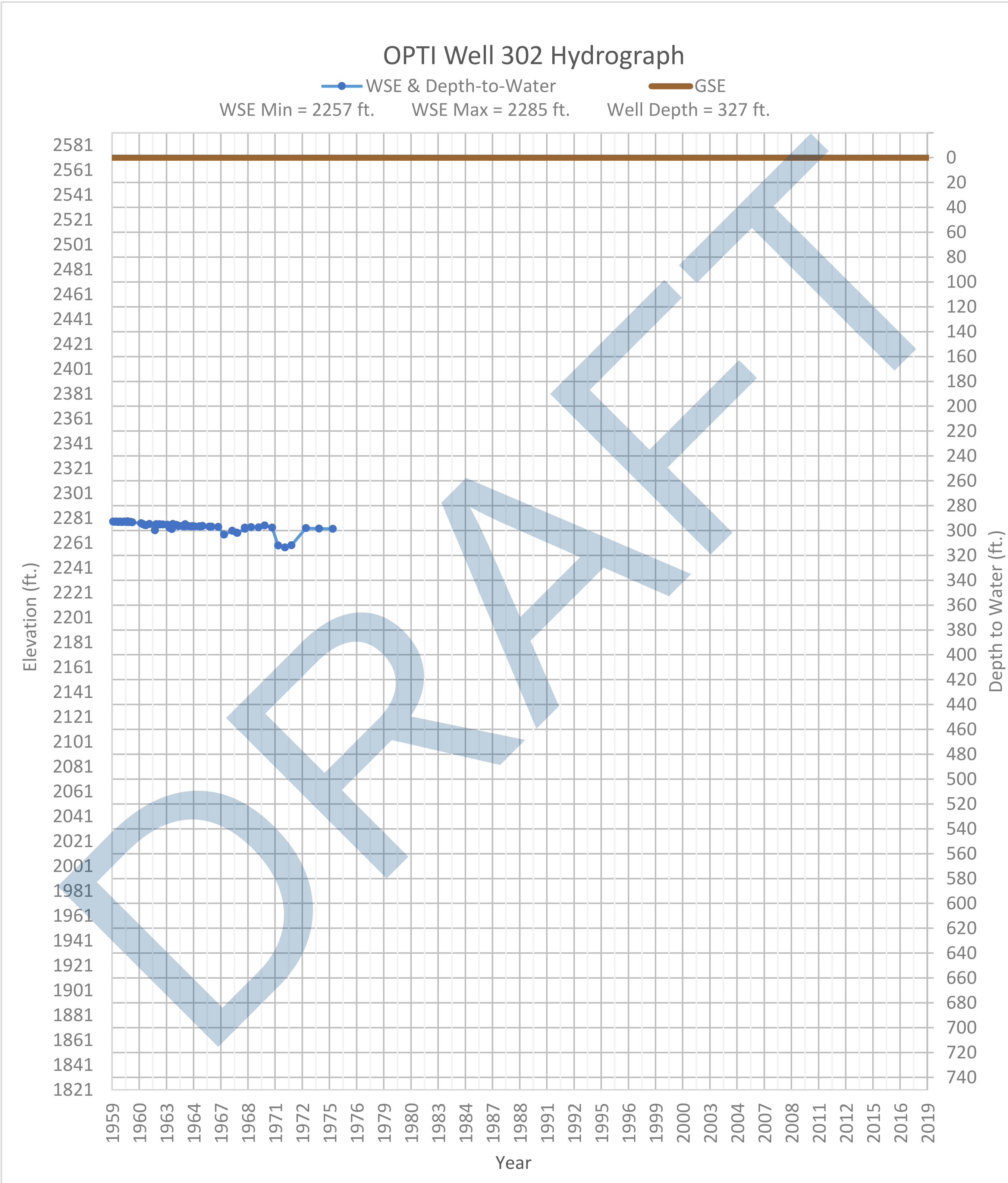
OPTI Well 297 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2254 ft.
WSE Max = 2267 ft.
Well Depth = 380 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 298 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2388 ft.
WSE Max = 2423 ft.
Well Depth = 254 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 301 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2294 ft.
WSE Max = 2294 ft.
Well Depth = 382 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 302 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2257 ft.
WSE Max = 2285 ft.
Well Depth = 327 ft.
Elevation (ft.)
2581
2561
2541
2521
2501
2481
2461
2441
2421
2401
2381
2361
2341
2321
2301
2281
2261
2241
2221
2201
2181
2161
2141
2121
2101
2081
2061
2041
2021
2001
1981
1961
1941
1921
1901
1881
1861
1841
1821
Depth to Water (ft.)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
Year
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
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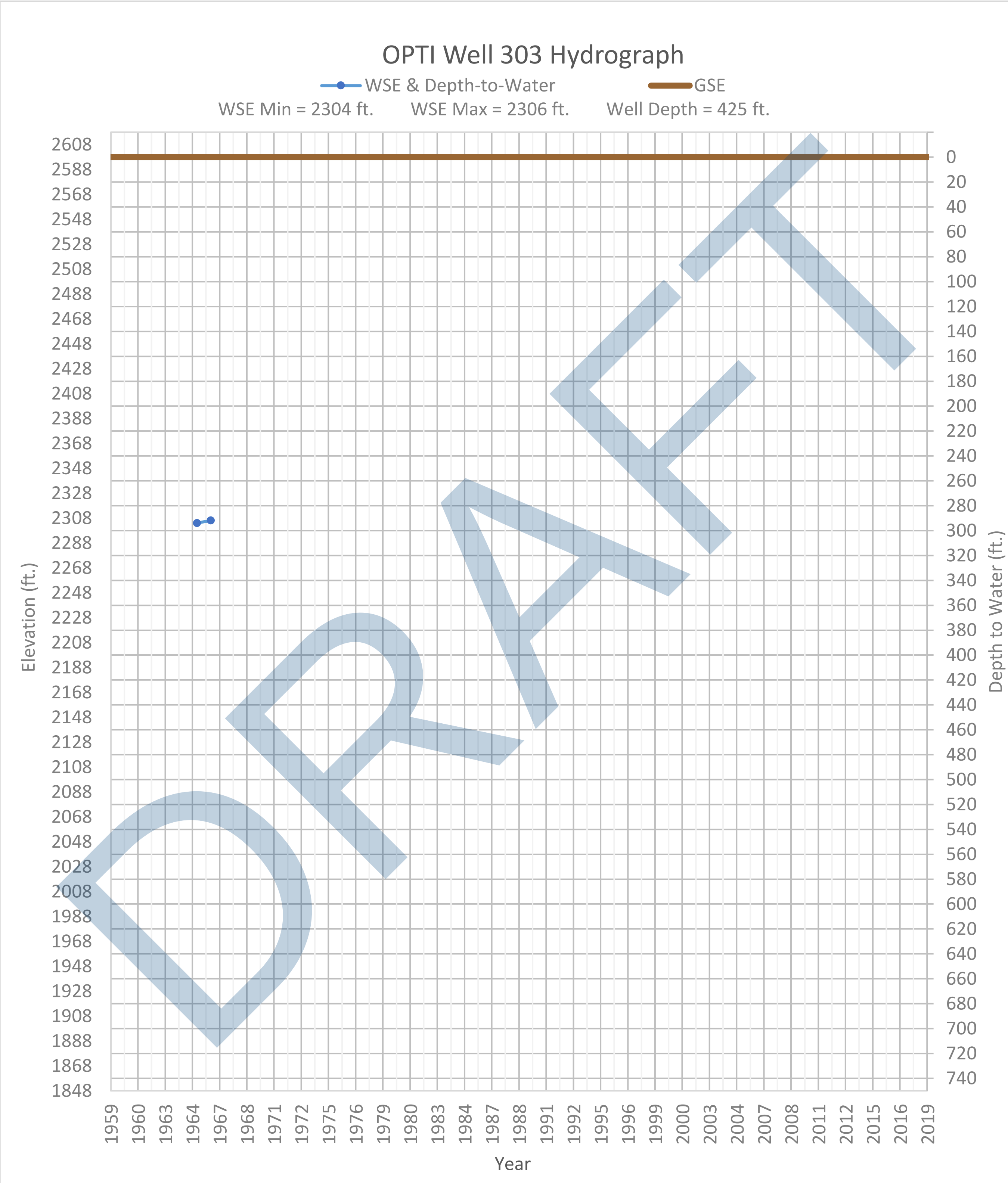
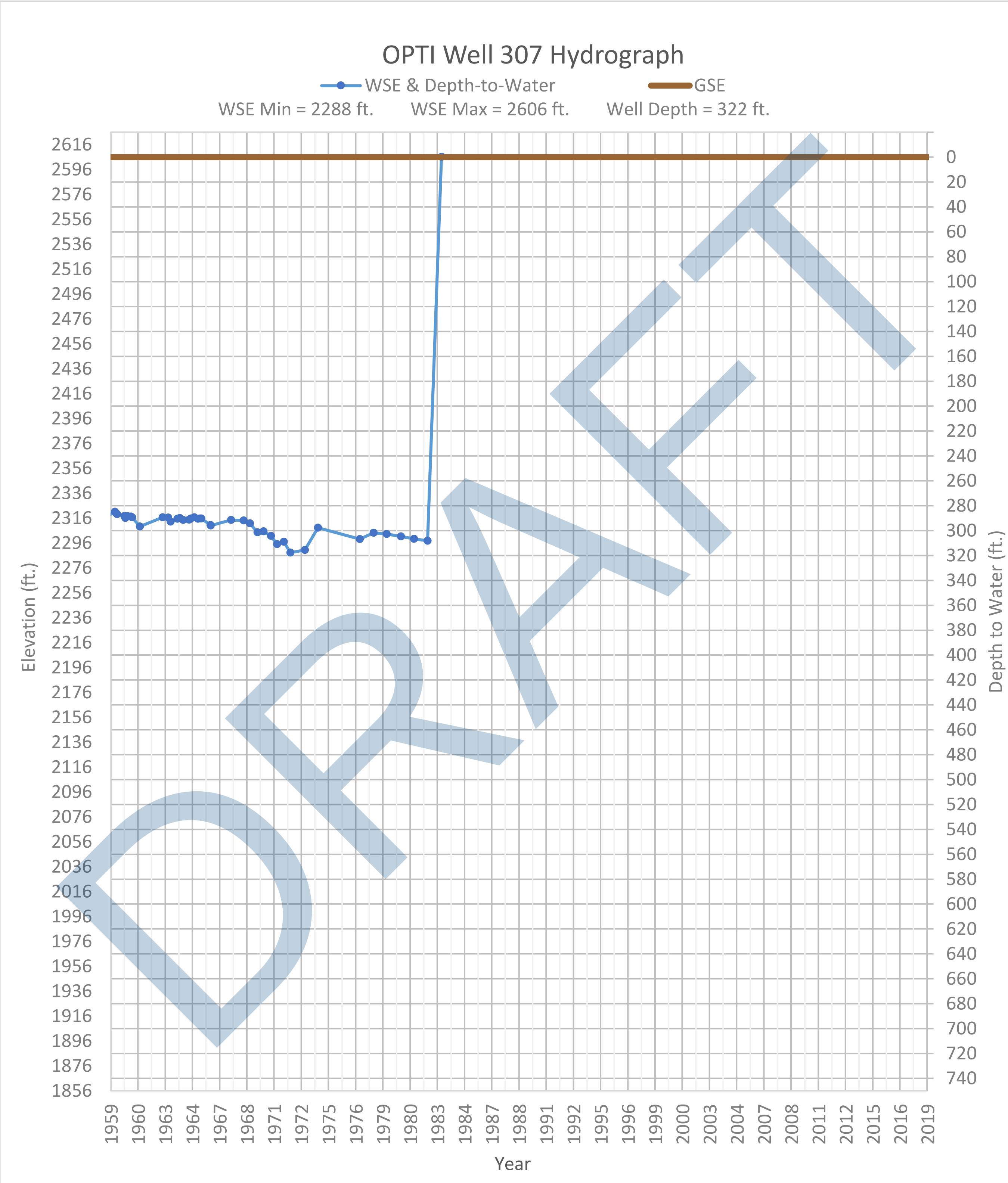
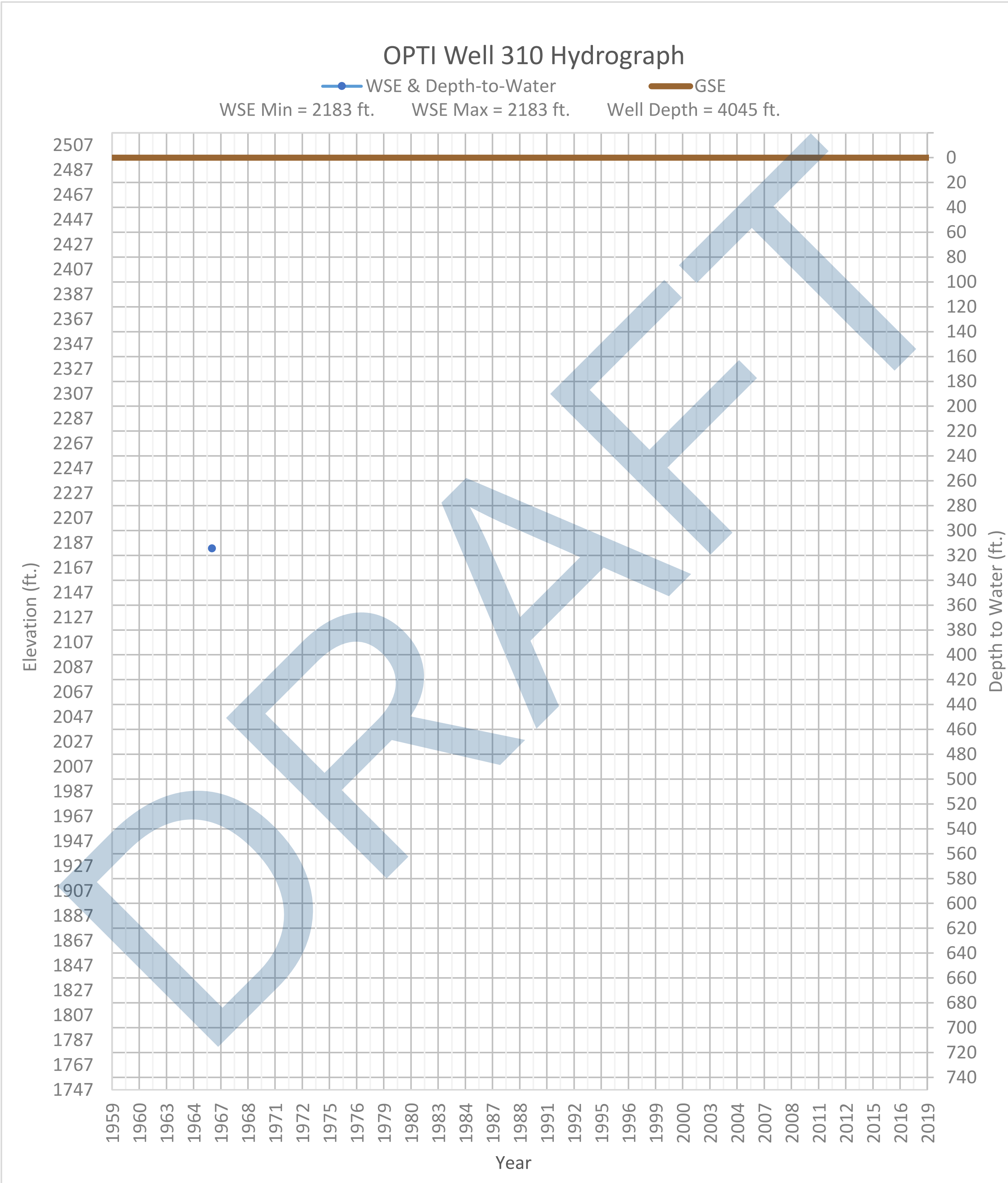
2012
2015
2016
2019
DRAFT


OPTI Well 303 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2304 ft.
WSE Max = 2306 ft.
Well Depth = 425 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 307 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2288 ft.
WSE Max = 2606 ft.
Well Depth = 322 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 310 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2183 ft.
WSE Max = 2183 ft.
Well Depth = 4045 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2507
2487
2467
2447
2427
2407
2387
2367
2347
2327
2307
2287
2267
2247
2227
2207
2187
2167
2147
2127
2107
2087
2067
2047
2027
2007
1987
1967
1947
1927
1907
1887
1867
1847
1827
1807
1787
1767
1747
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
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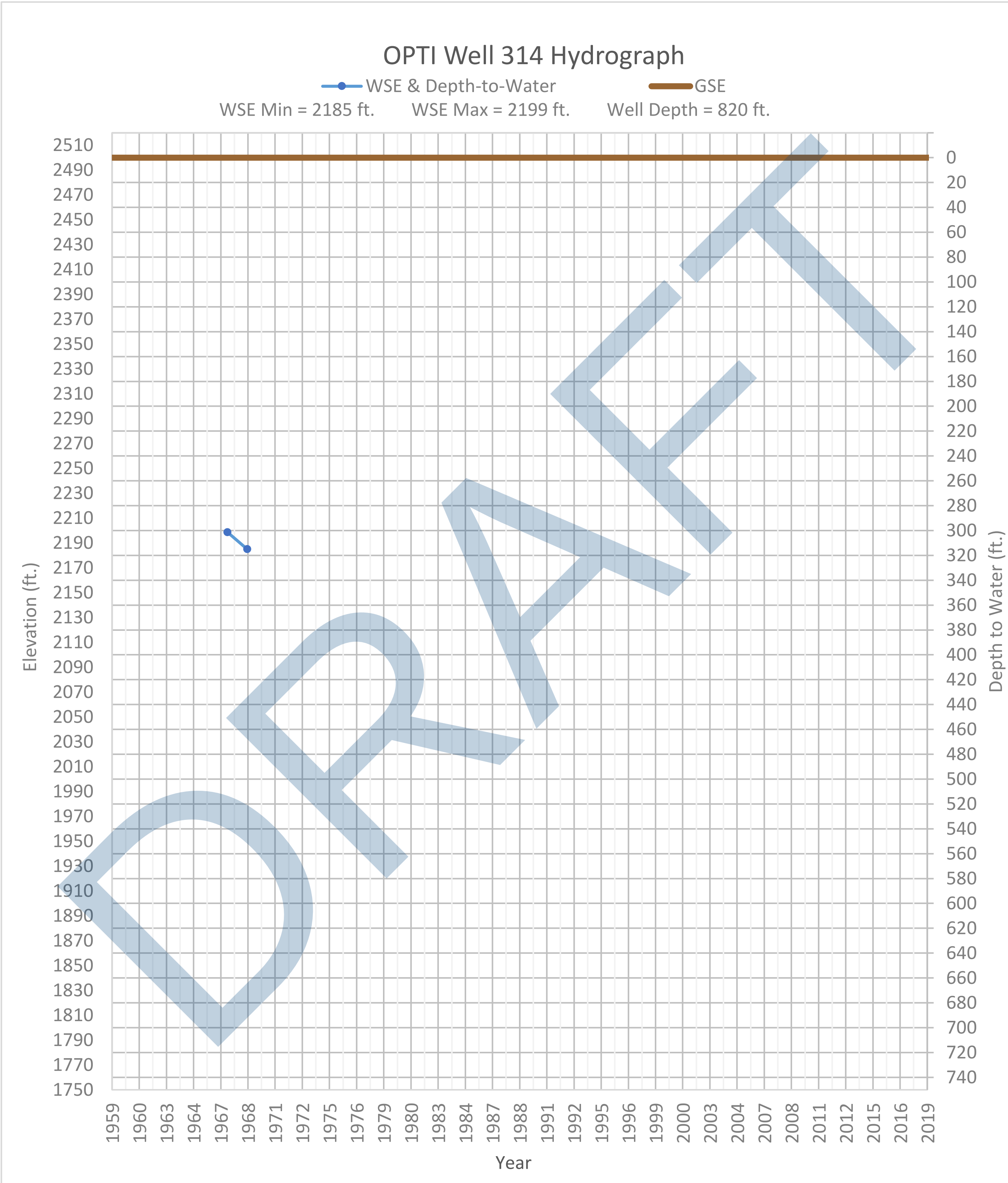
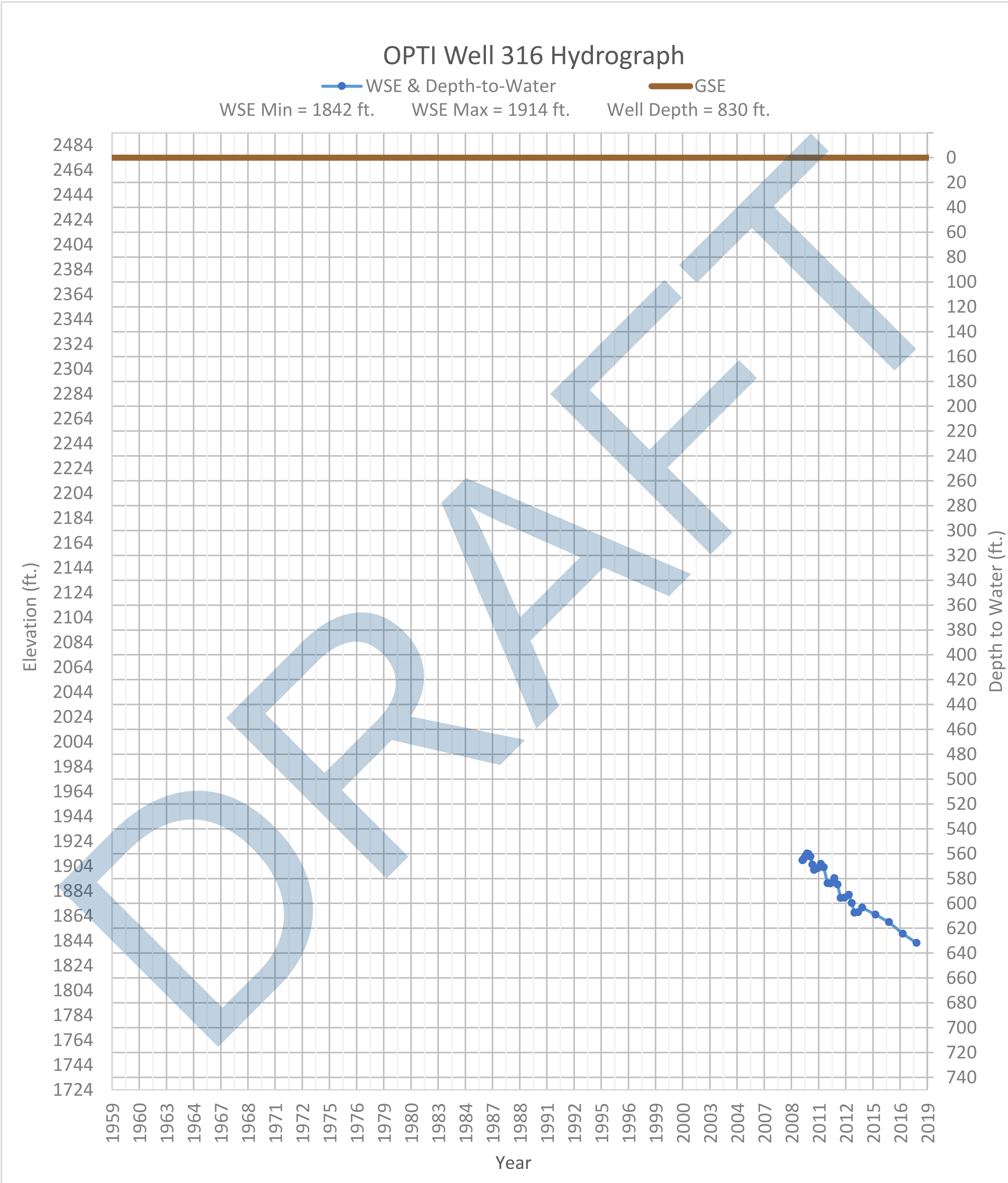
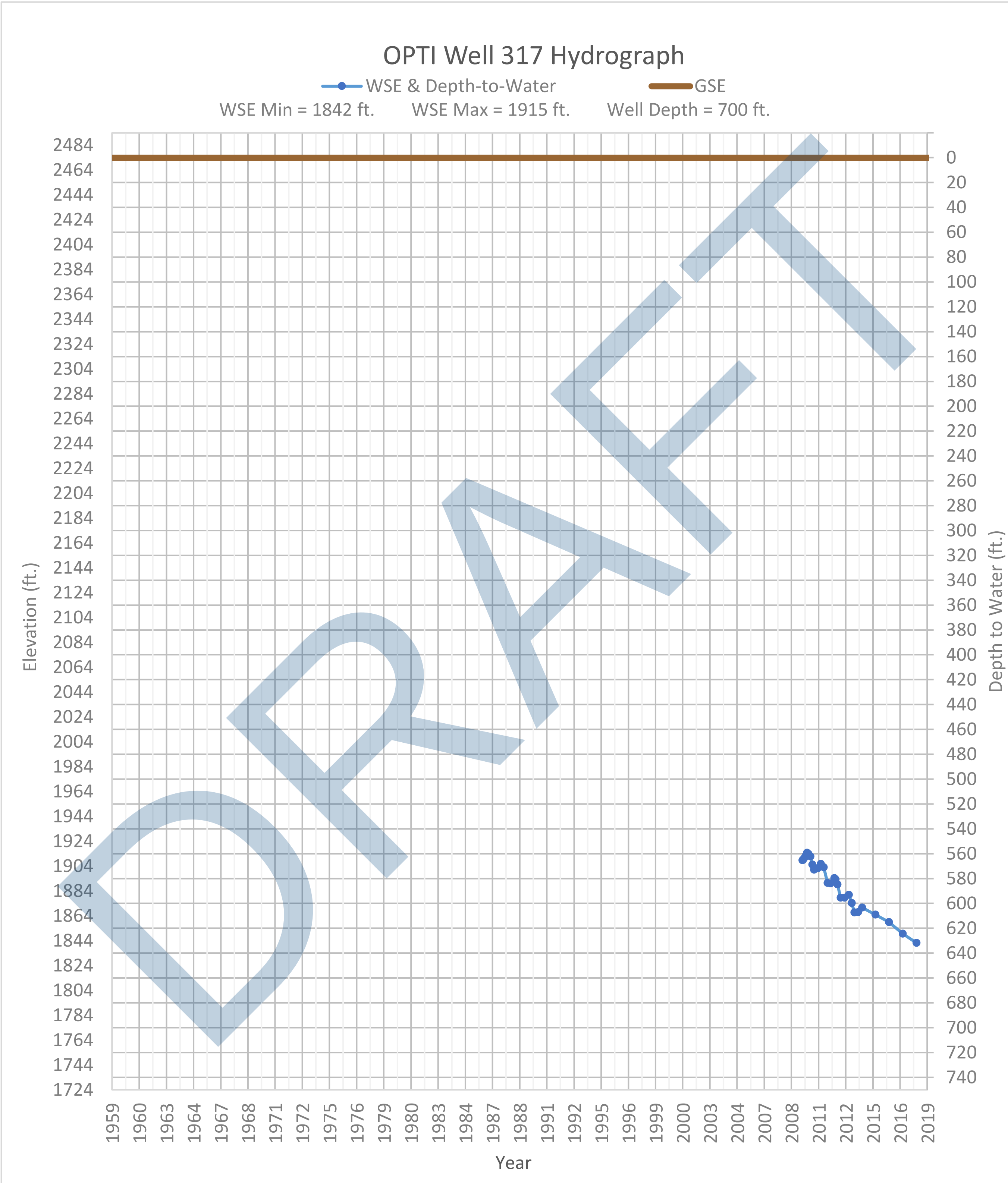
2016
2019
DRAFT



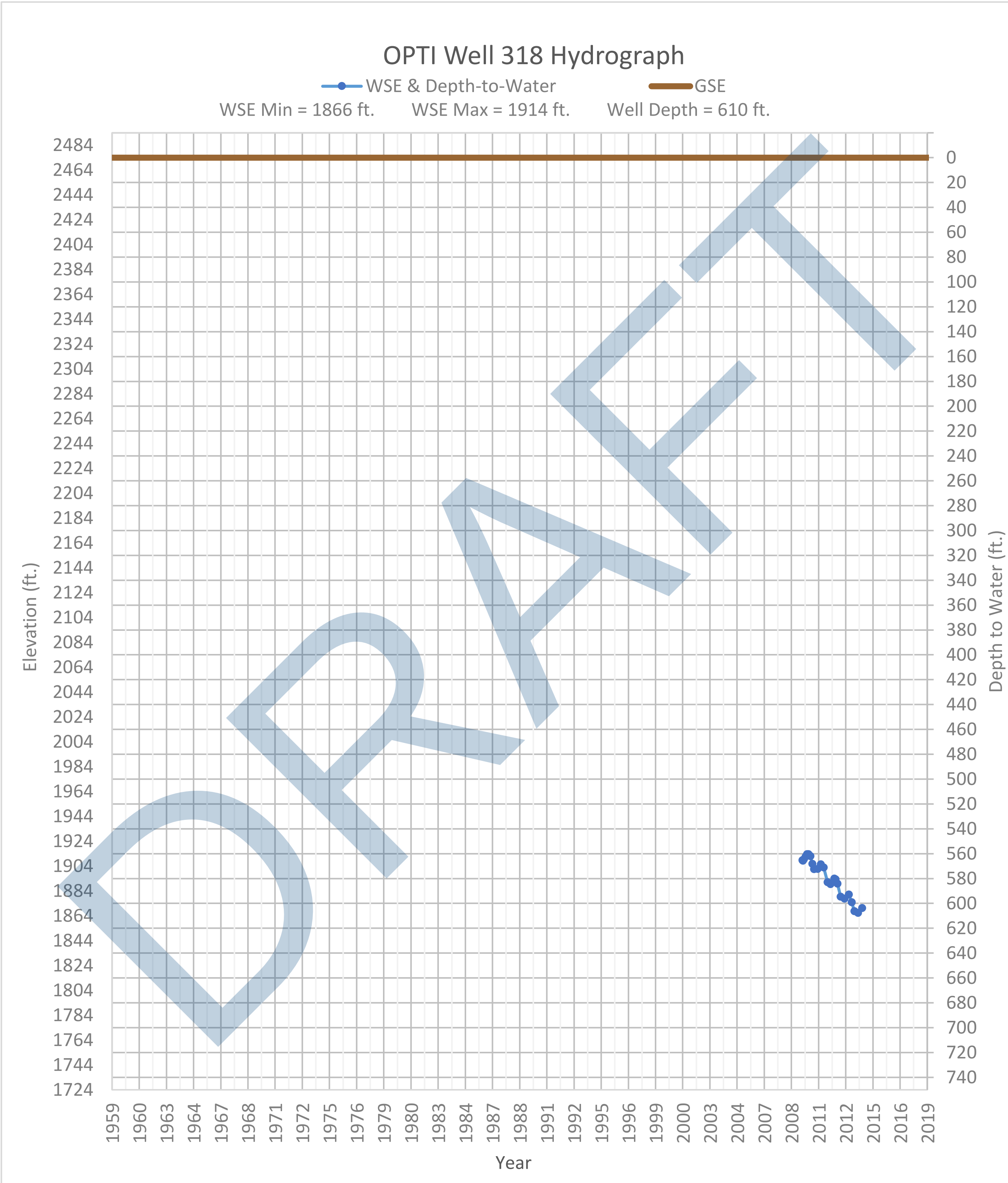
OPTI Well 314 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2185 ft.
WSE Max = 2199 ft.
Well Depth = 820 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



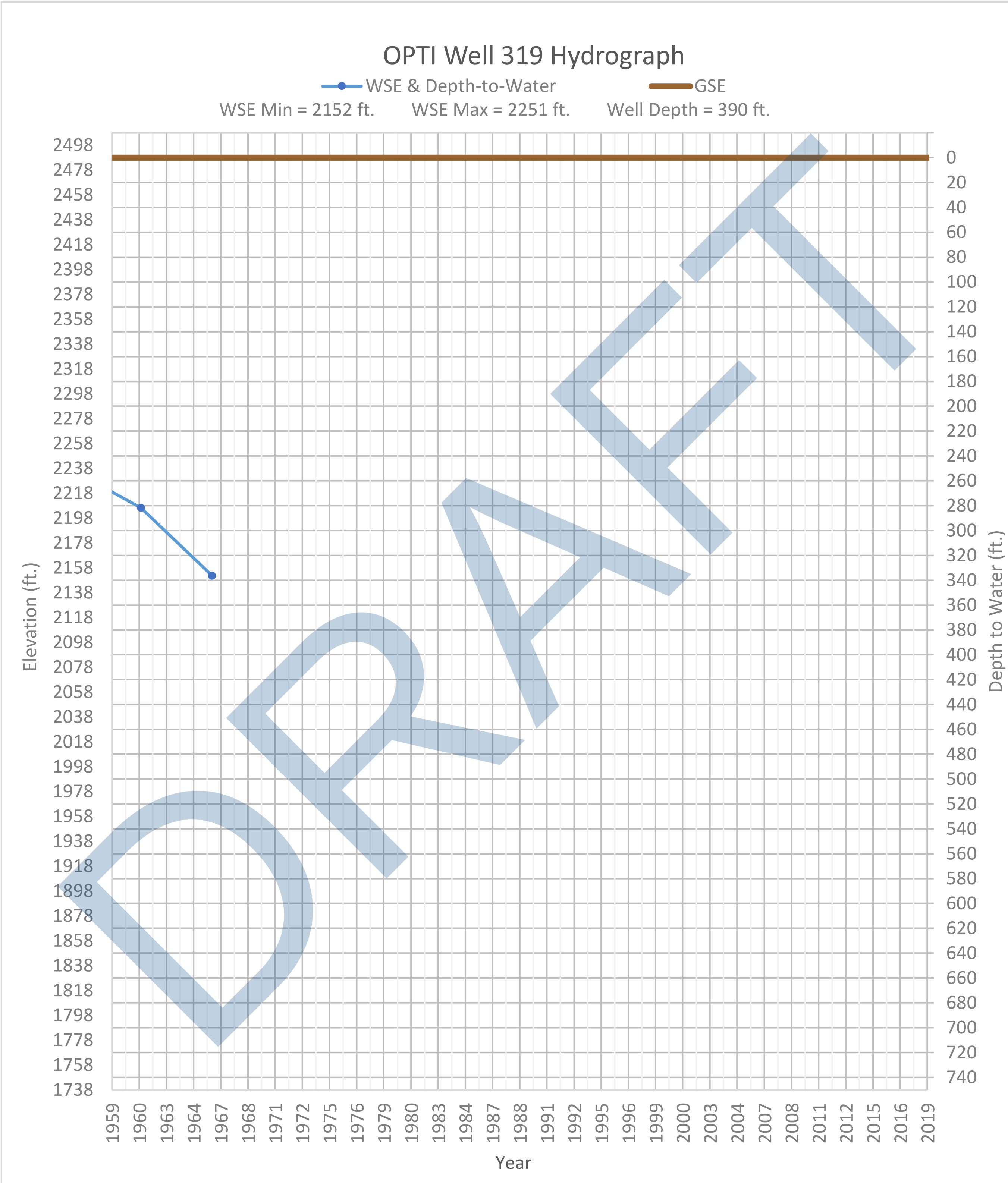
OPTI Well 316 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1842 ft.
WSE Max = 1914 ft.
Well Depth = 830 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



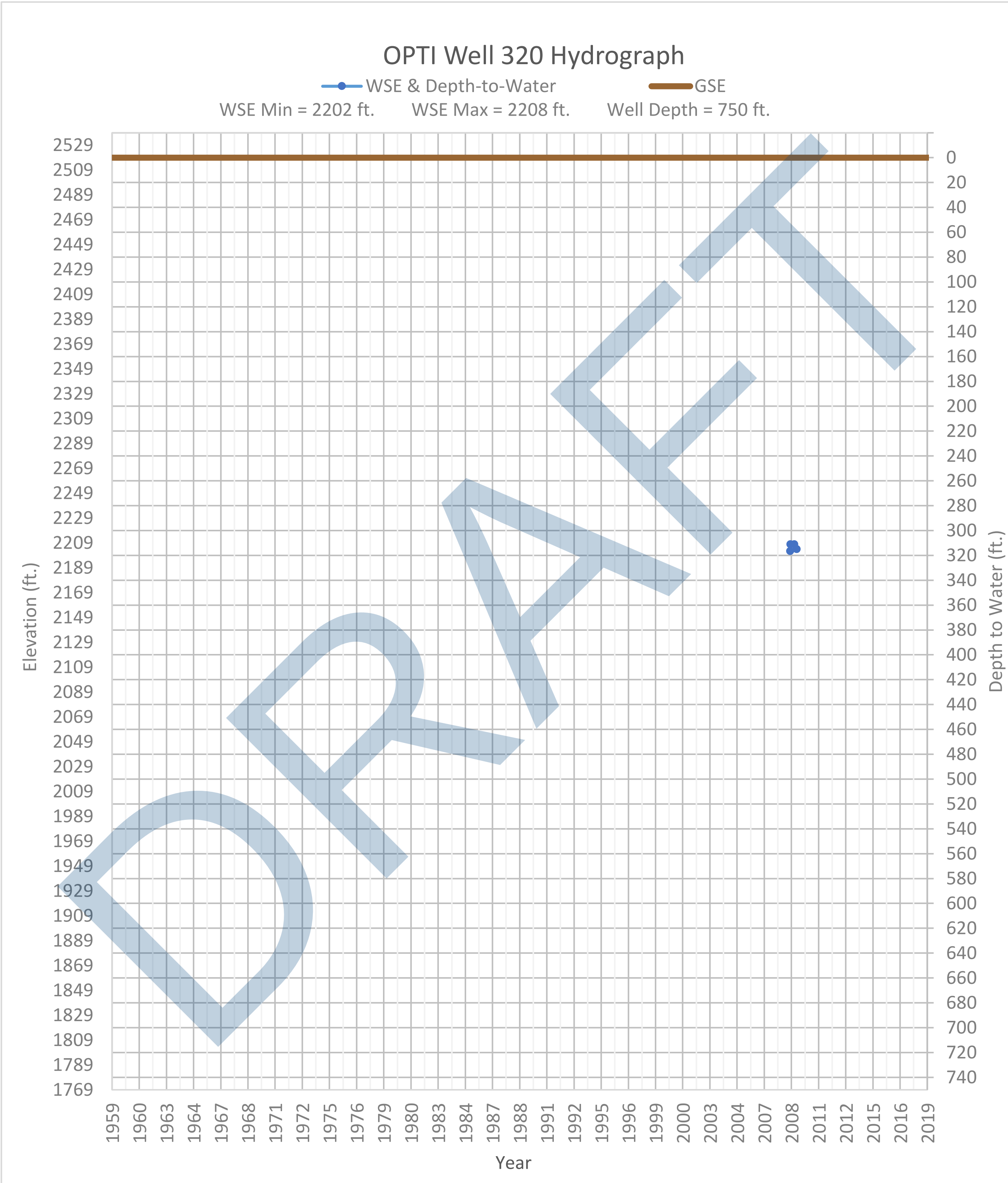
OPTI Well 317 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1842 ft.
WSE Max = 1915 ft.
Well Depth = 700 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



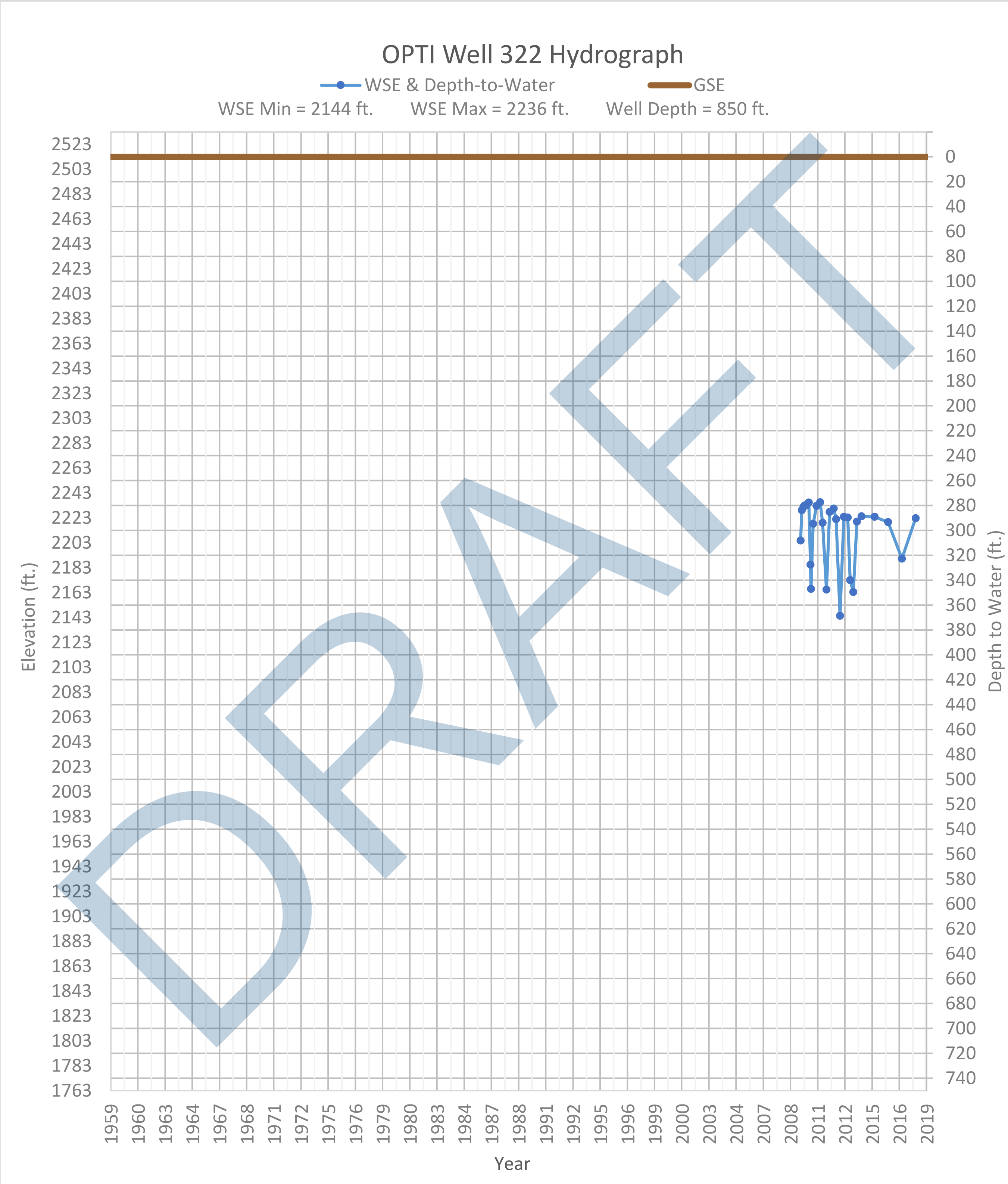
OPTI Well 318 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1866 ft.
WSE Max = 1914 ft.
Well Depth = 610 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



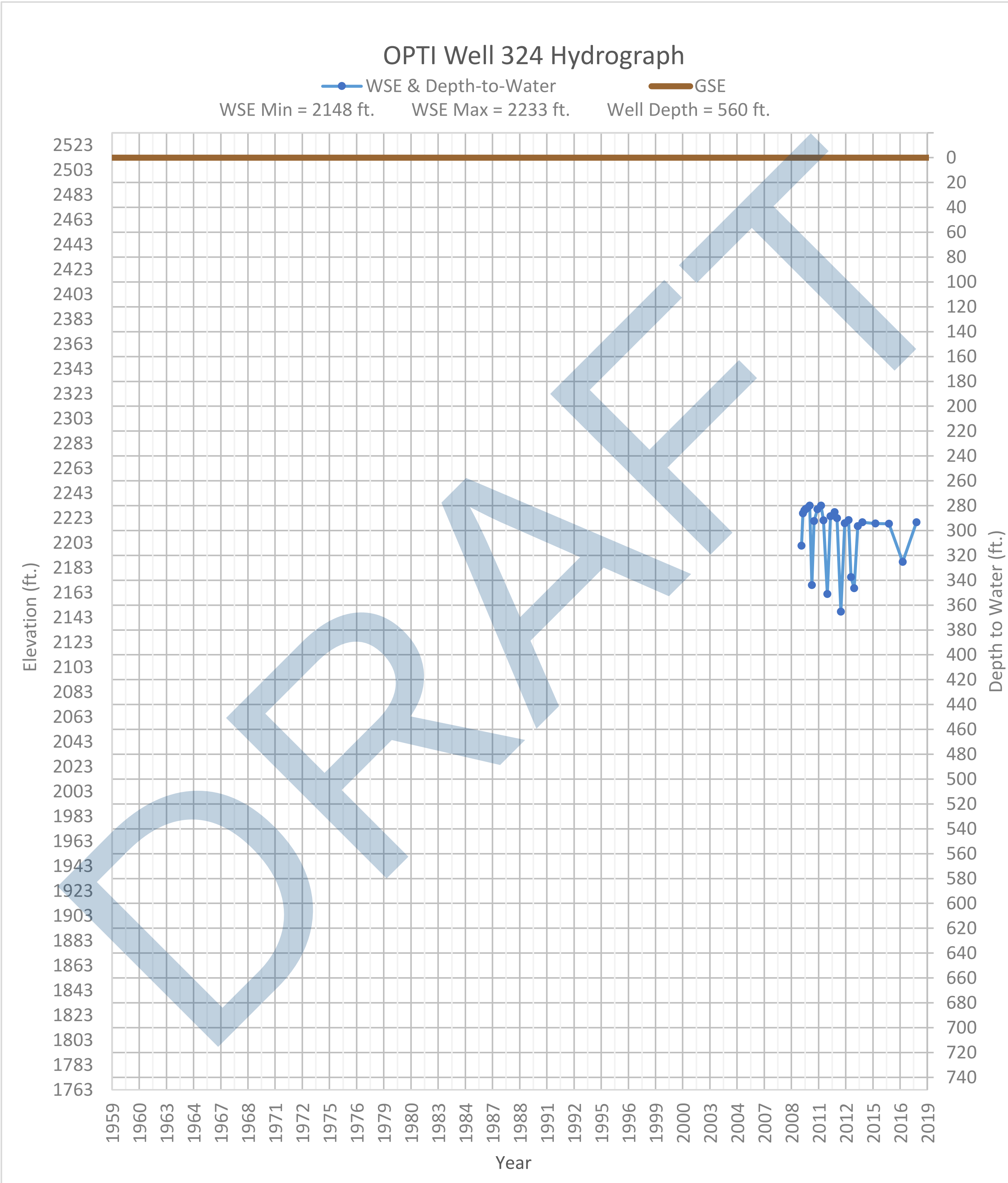
OPTI Well 319 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2152 ft.
WSE Max = 2251 ft.
Well Depth = 390 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



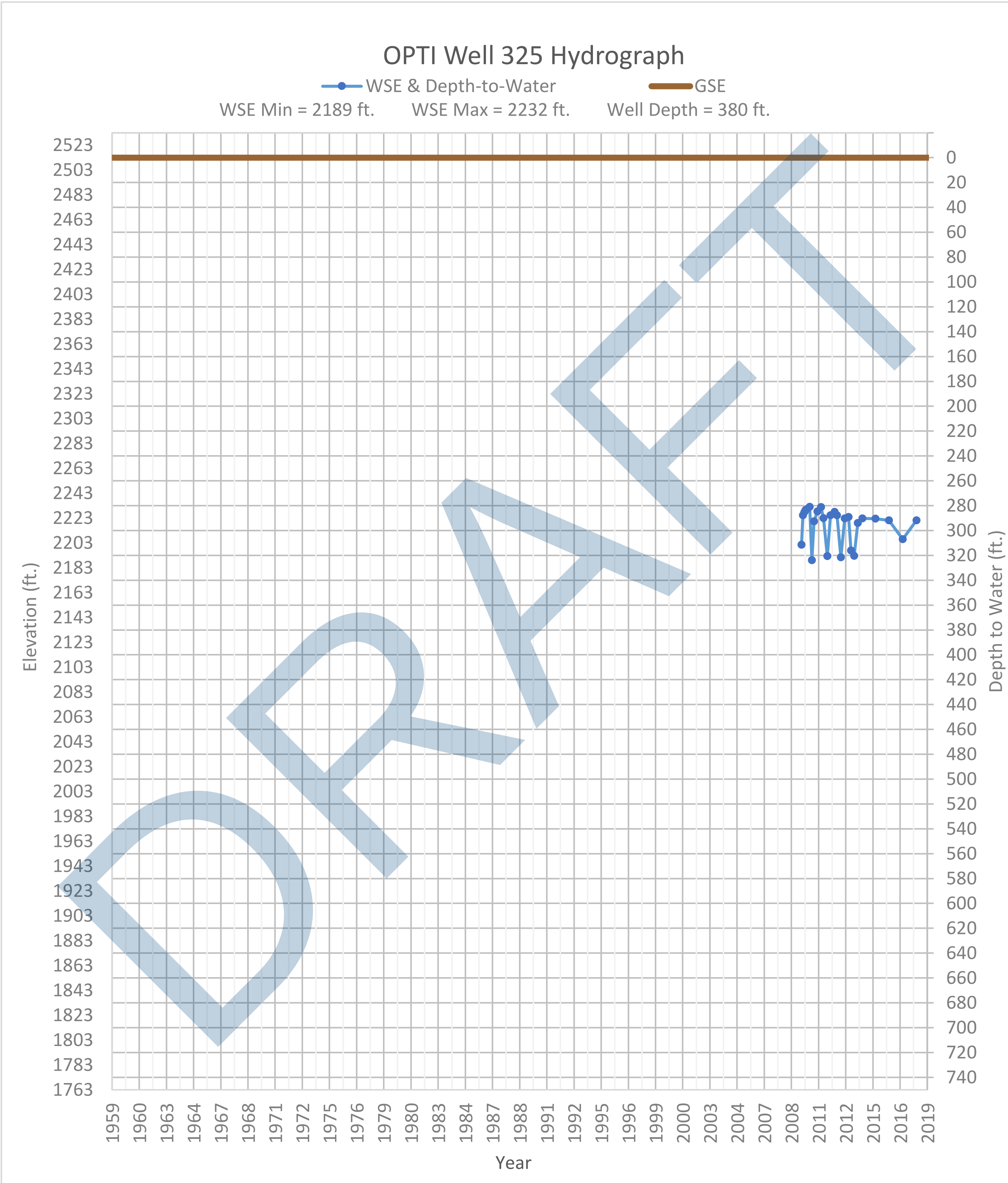
OPTI Well 320 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2202 ft.
WSE Max = 2208 ft.
Well Depth = 750 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

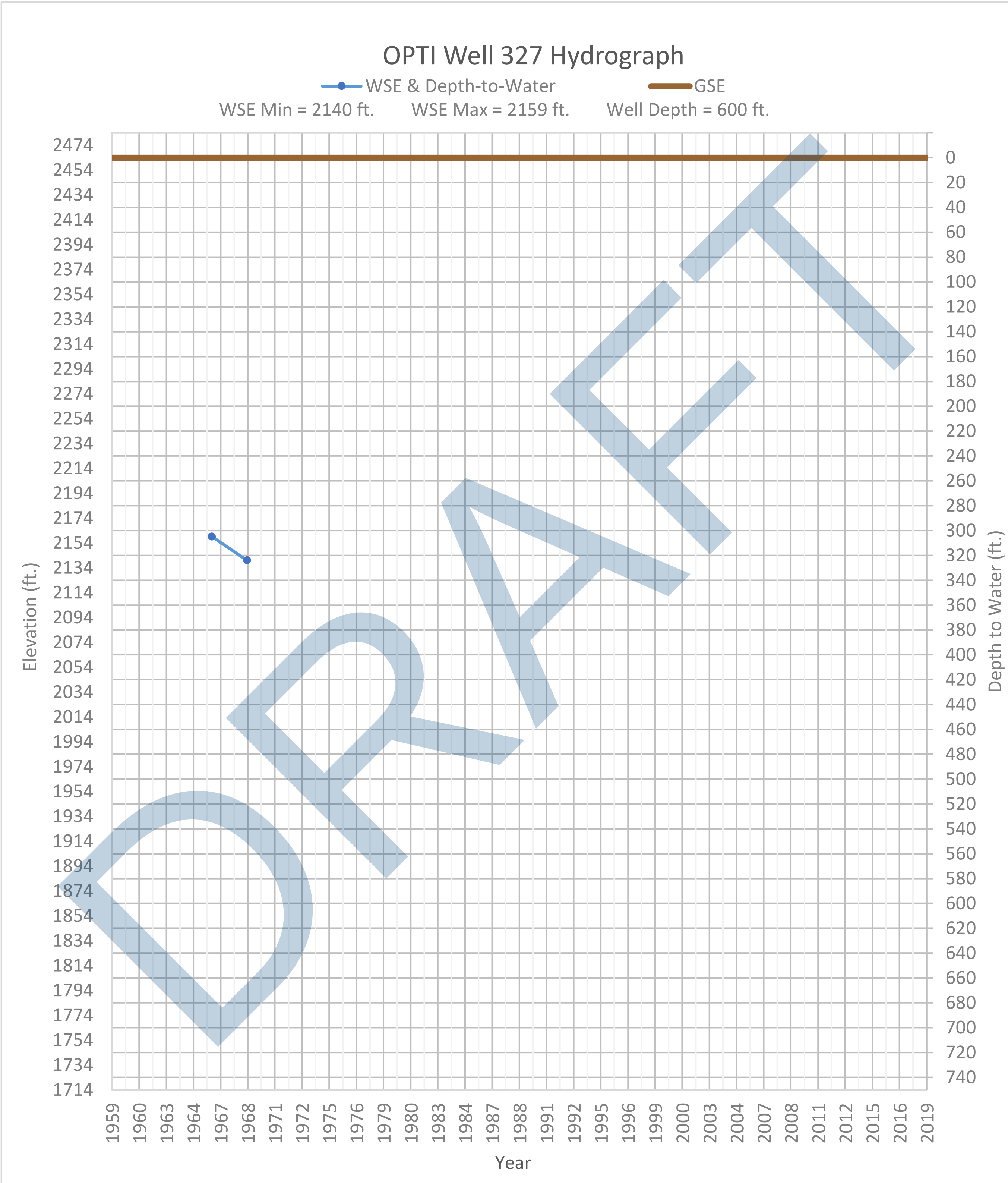


OPTI Well 322 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2144 ft.
WSE Max = 2236 ft.
Well Depth = 850 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

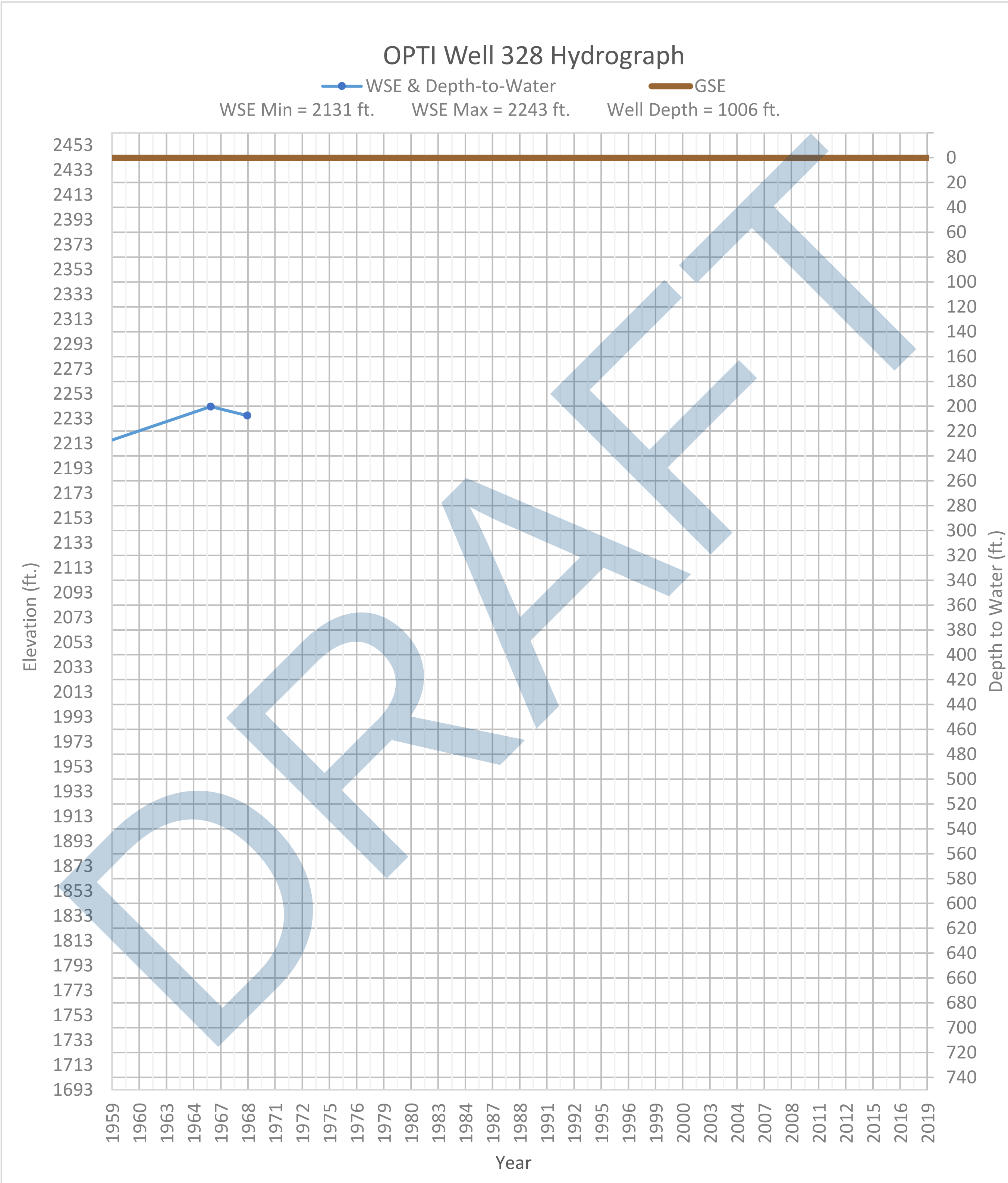


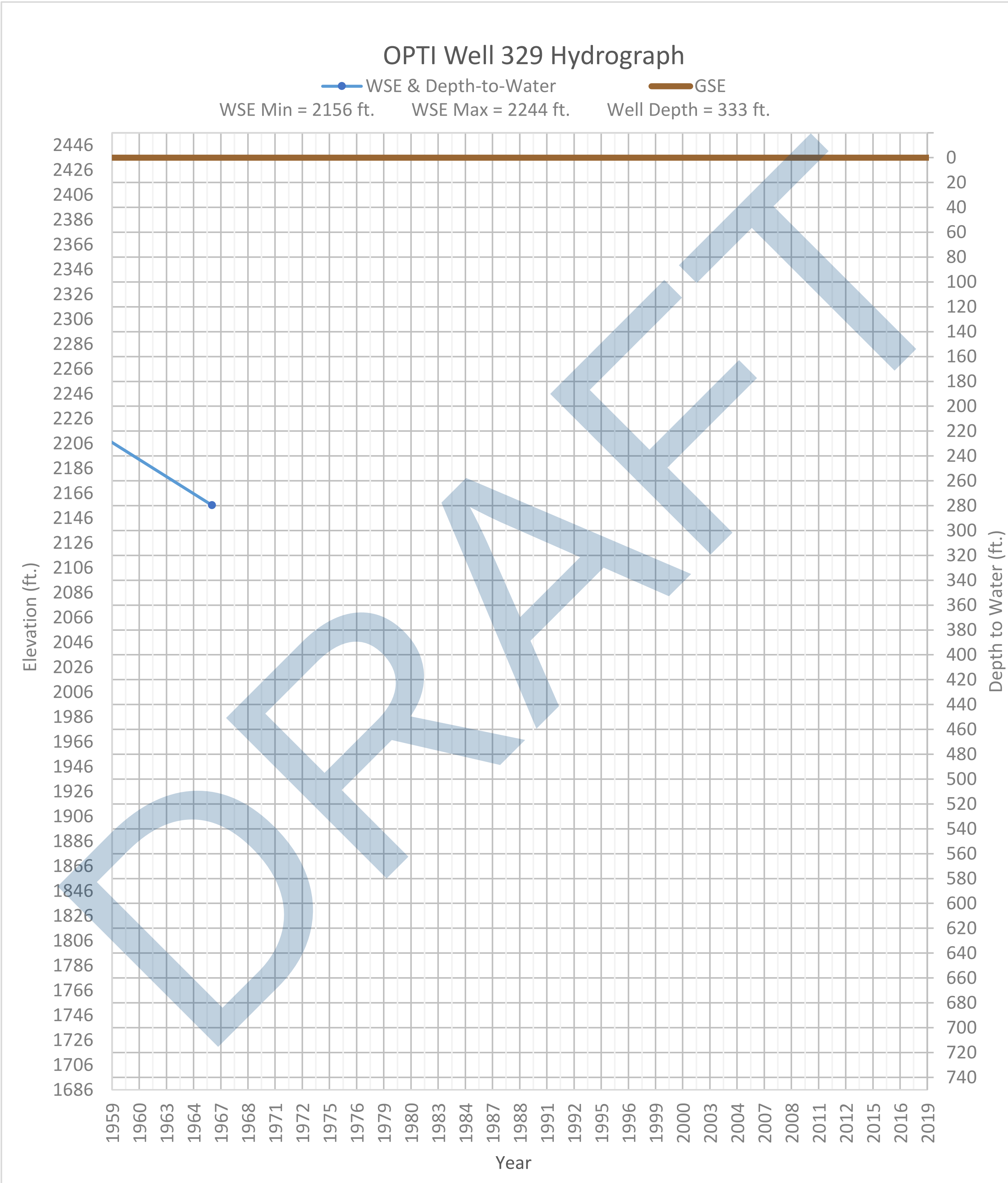
OPTI Well 324 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2148 ft.
WSE Max = 2233 ft.
Well Depth = 560 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 325 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2189 ft.
WSE Max = 2232 ft.
Well Depth = 380 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

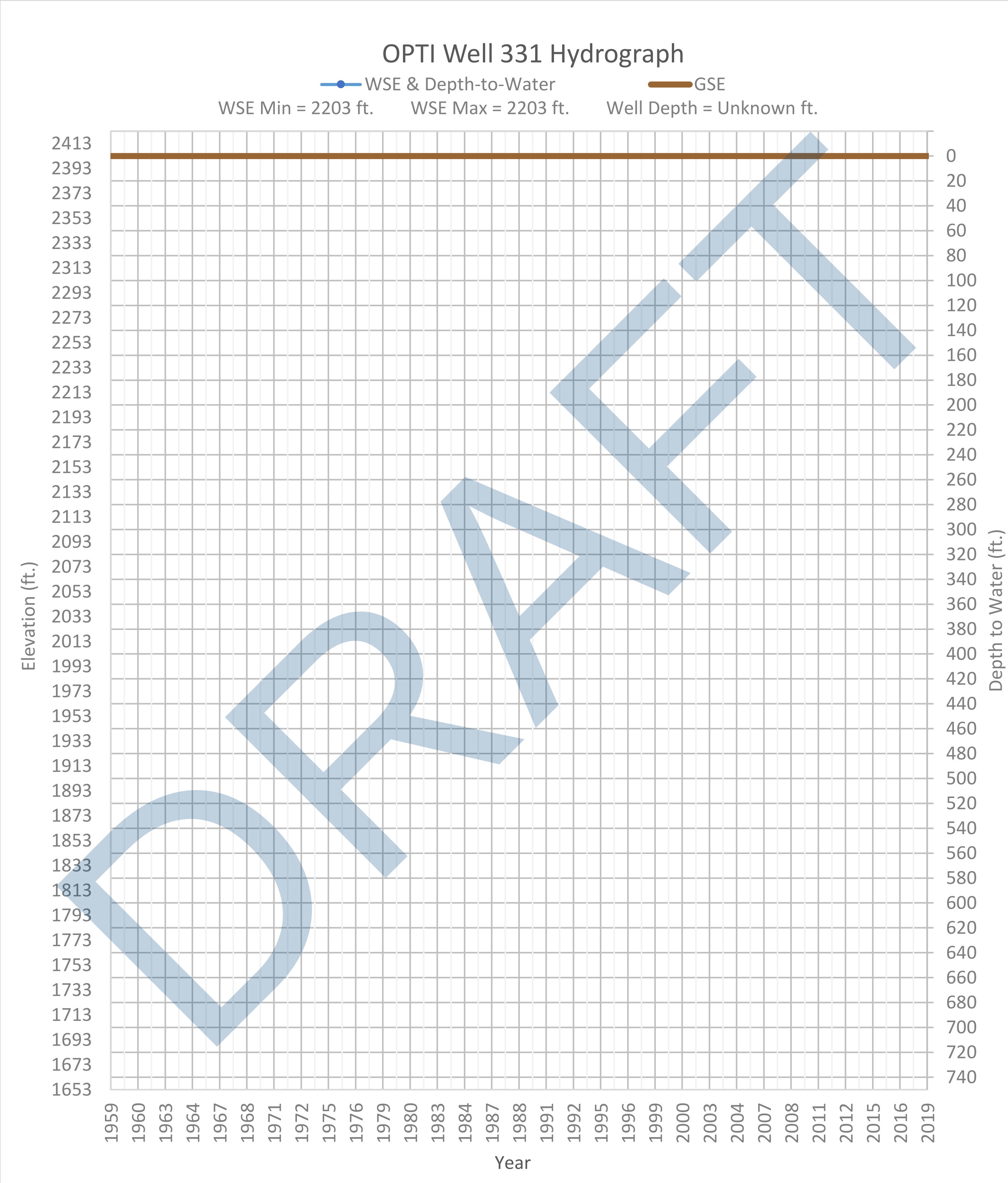


OPTI Well 327 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2140 ft.
WSE Max = 2159 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

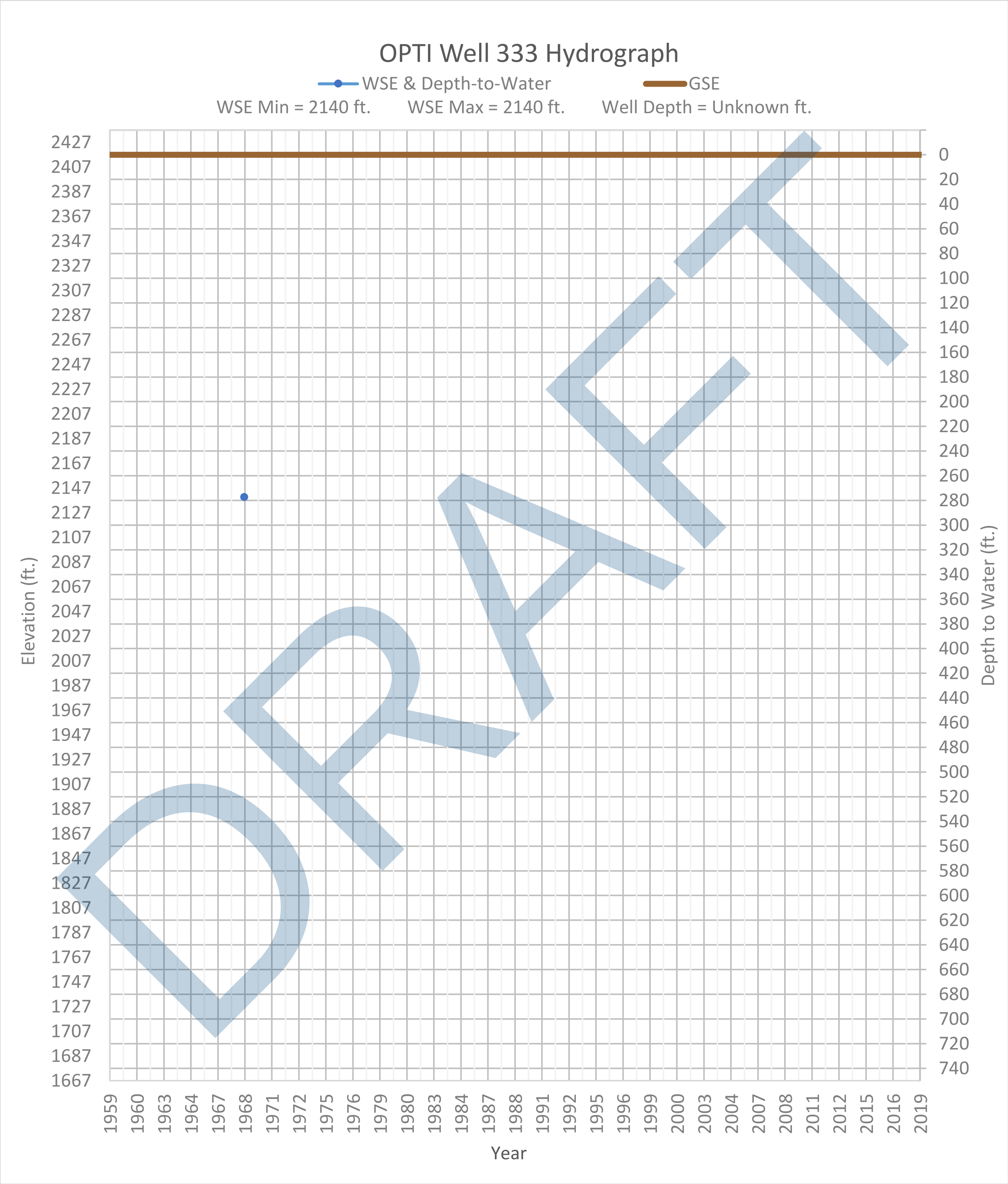

OPTI Well 328 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2131 ft.
WSE Max = 2243 ft.
Well Depth = 1006 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



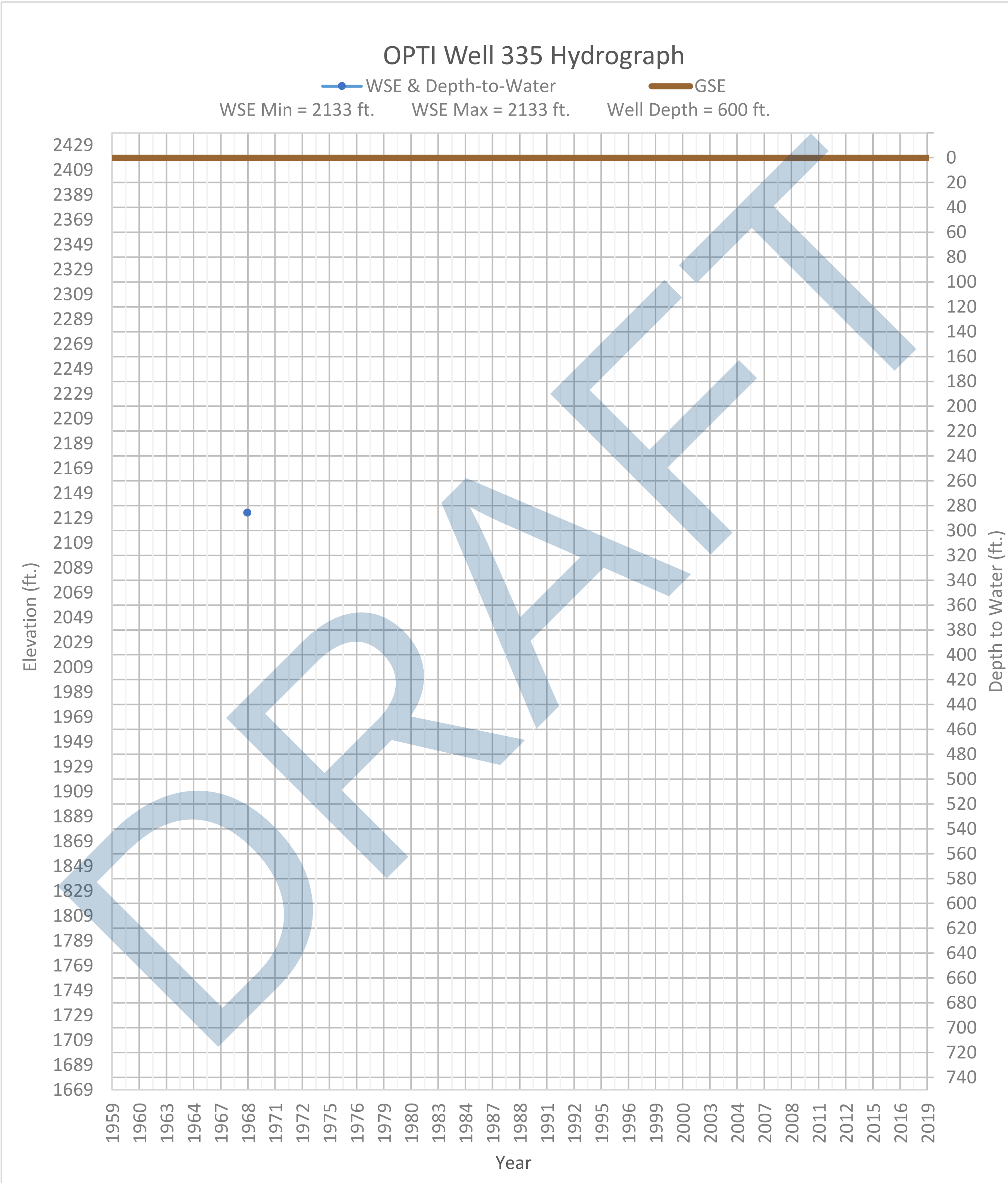
OPTI Well 329 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2156 ft.
WSE Max = 2244 ft.
Well Depth = 333 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



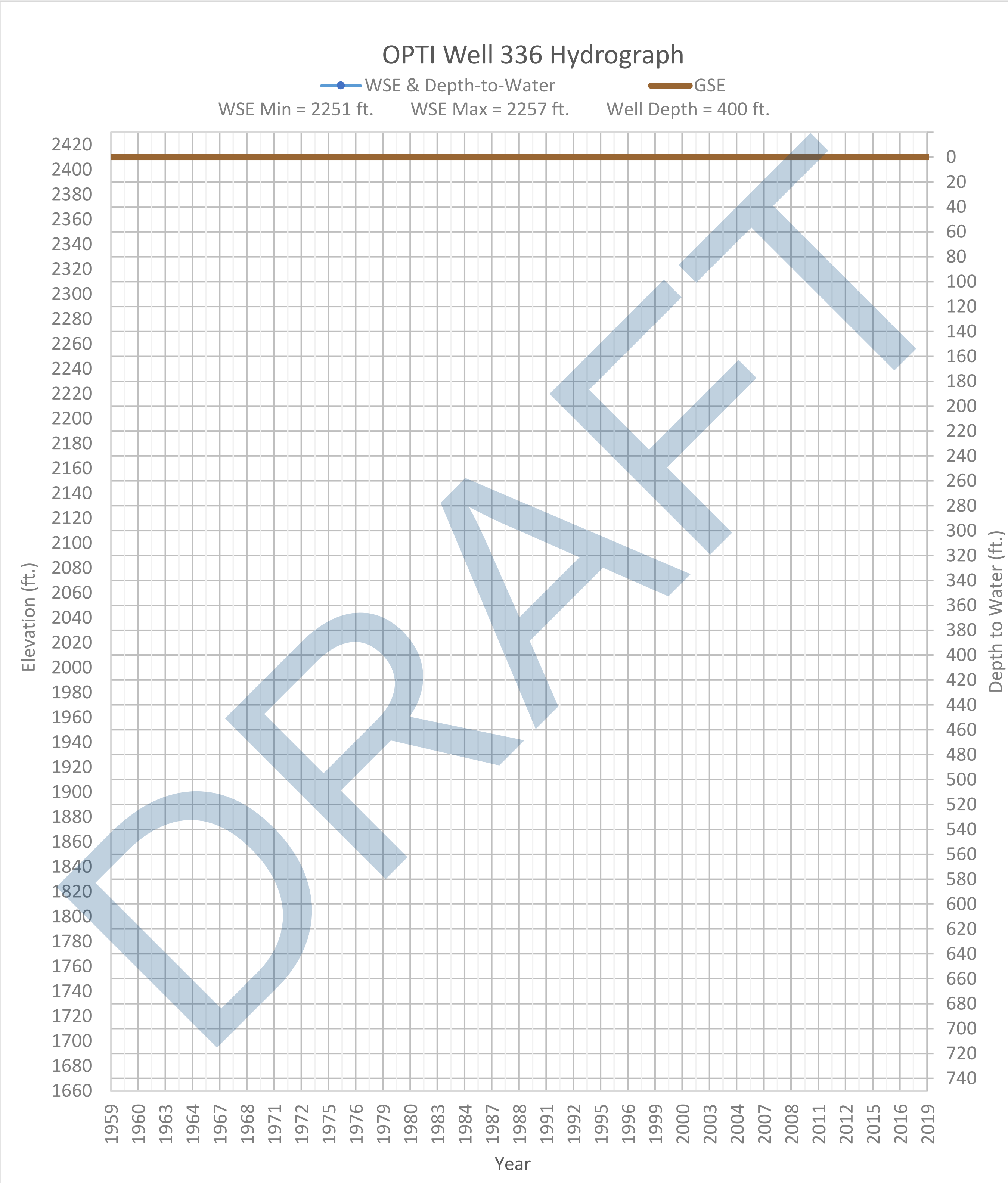
OPTI Well 331 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2203 ft.
WSE Max = 2203 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2413 2393 2373 2353 2333 2313 2293 2273 2253 2233 2213 2193 2173 2153 2133 2113 2093 2073 2053 2033 2013 1993 1973 1953 1933 1913 1893 1873 1853 1833 1813 1793 1773 1753 1733 1713 1693 1673 1653
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT



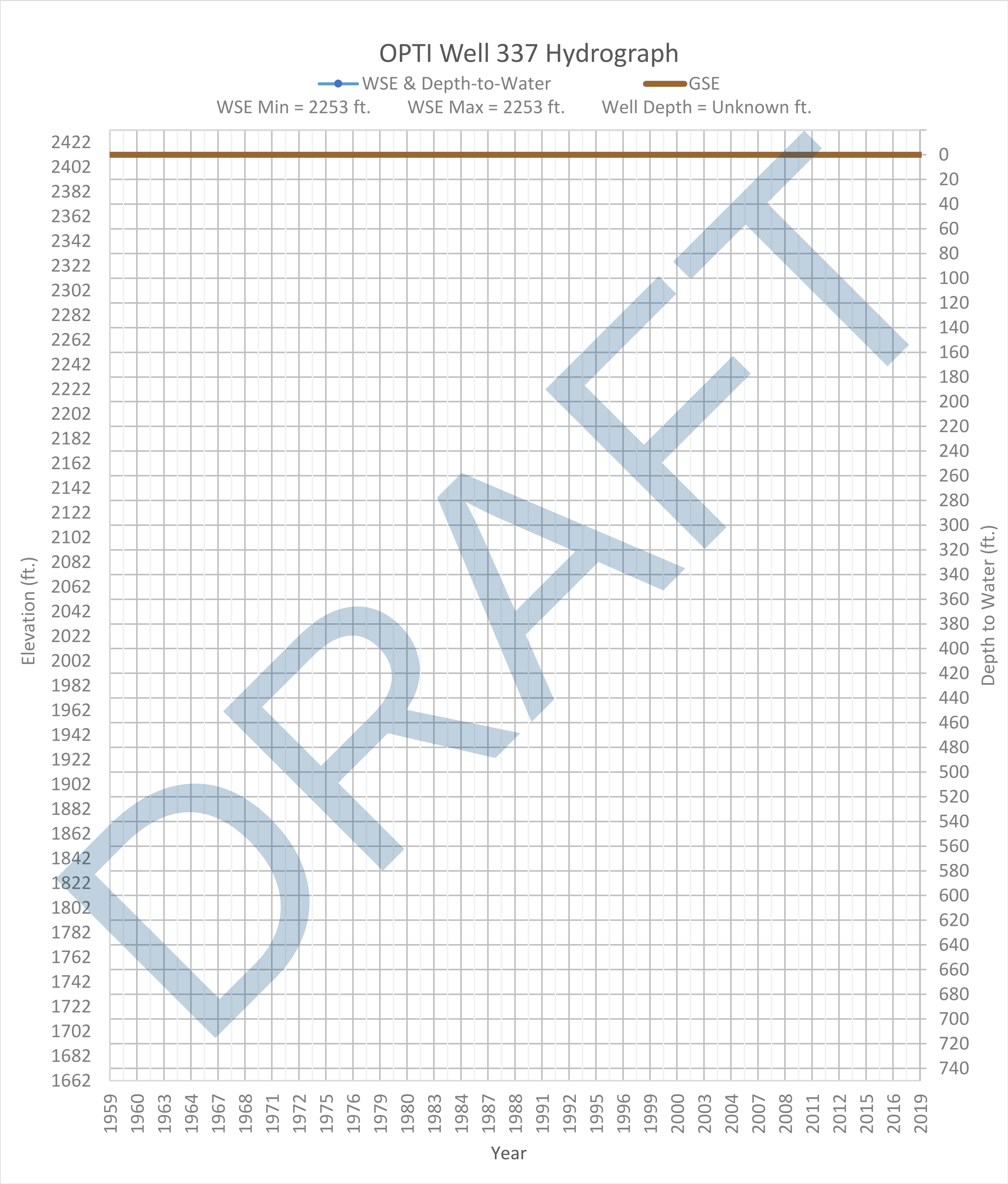
OPTI Well 333 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2140 ft.
WSE Max = 2140 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



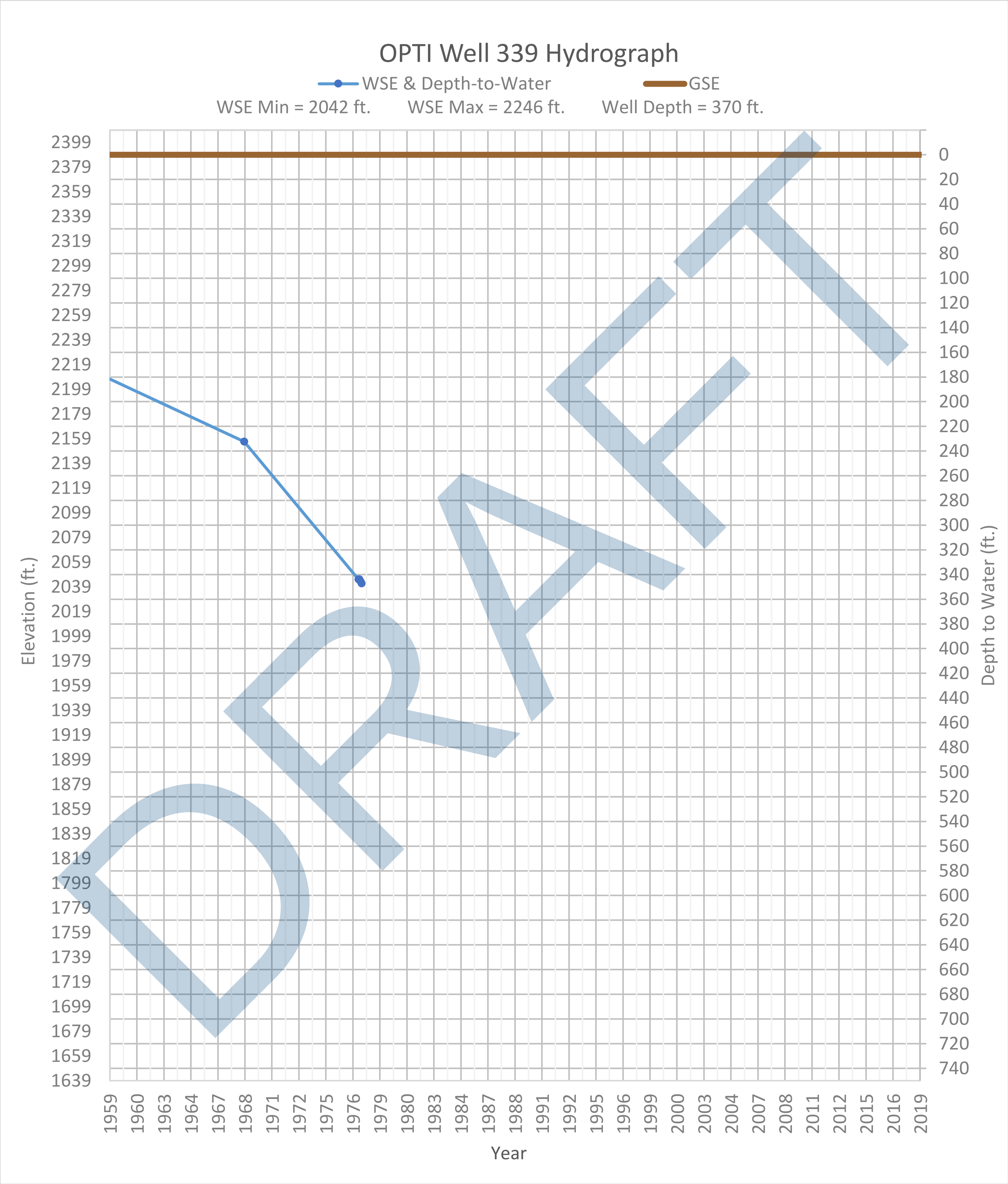
OPTI Well 335 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2133 ft.
WSE Max = 2133 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



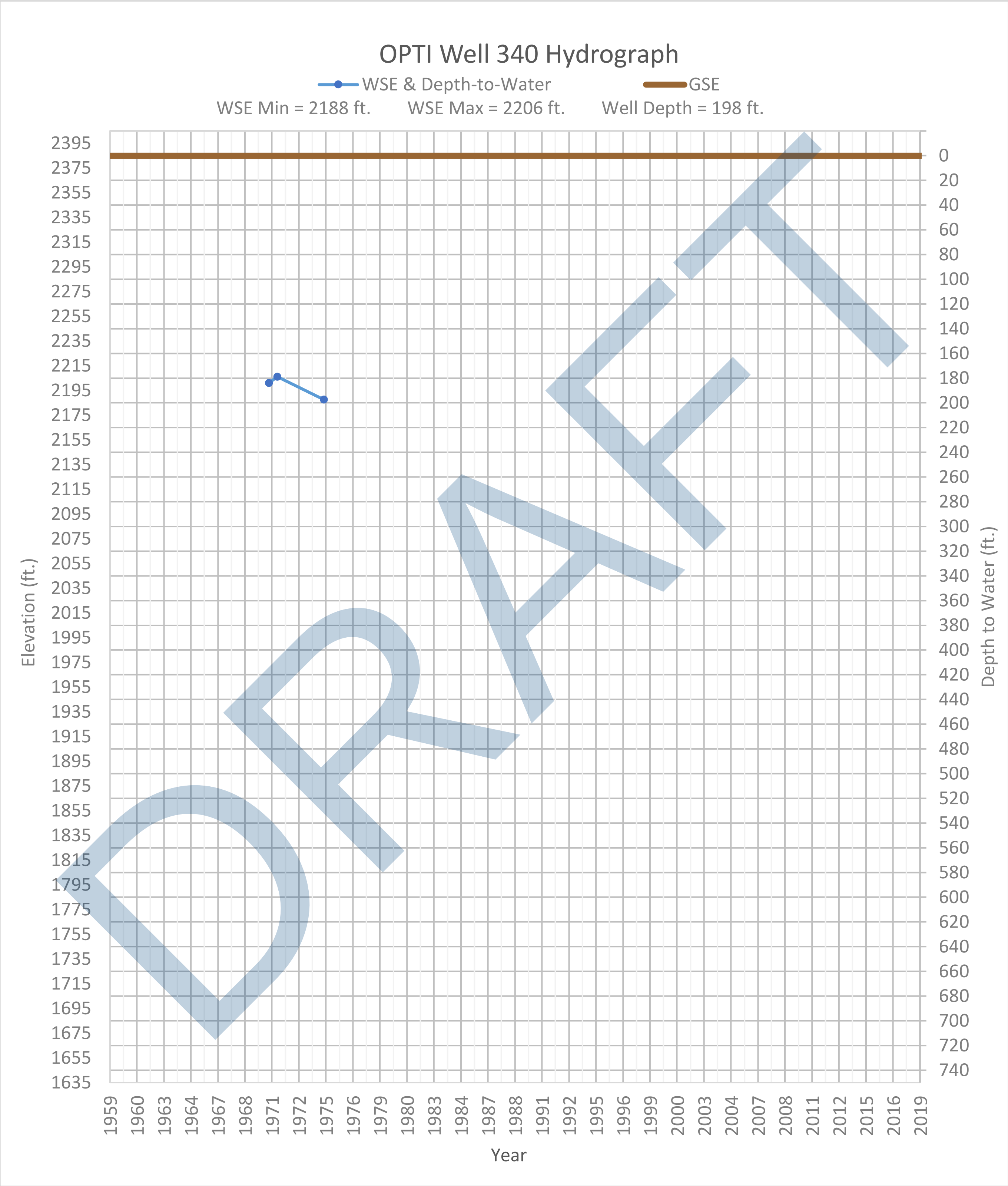
OPTI Well 336 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2251 ft.
WSE Max = 2257 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



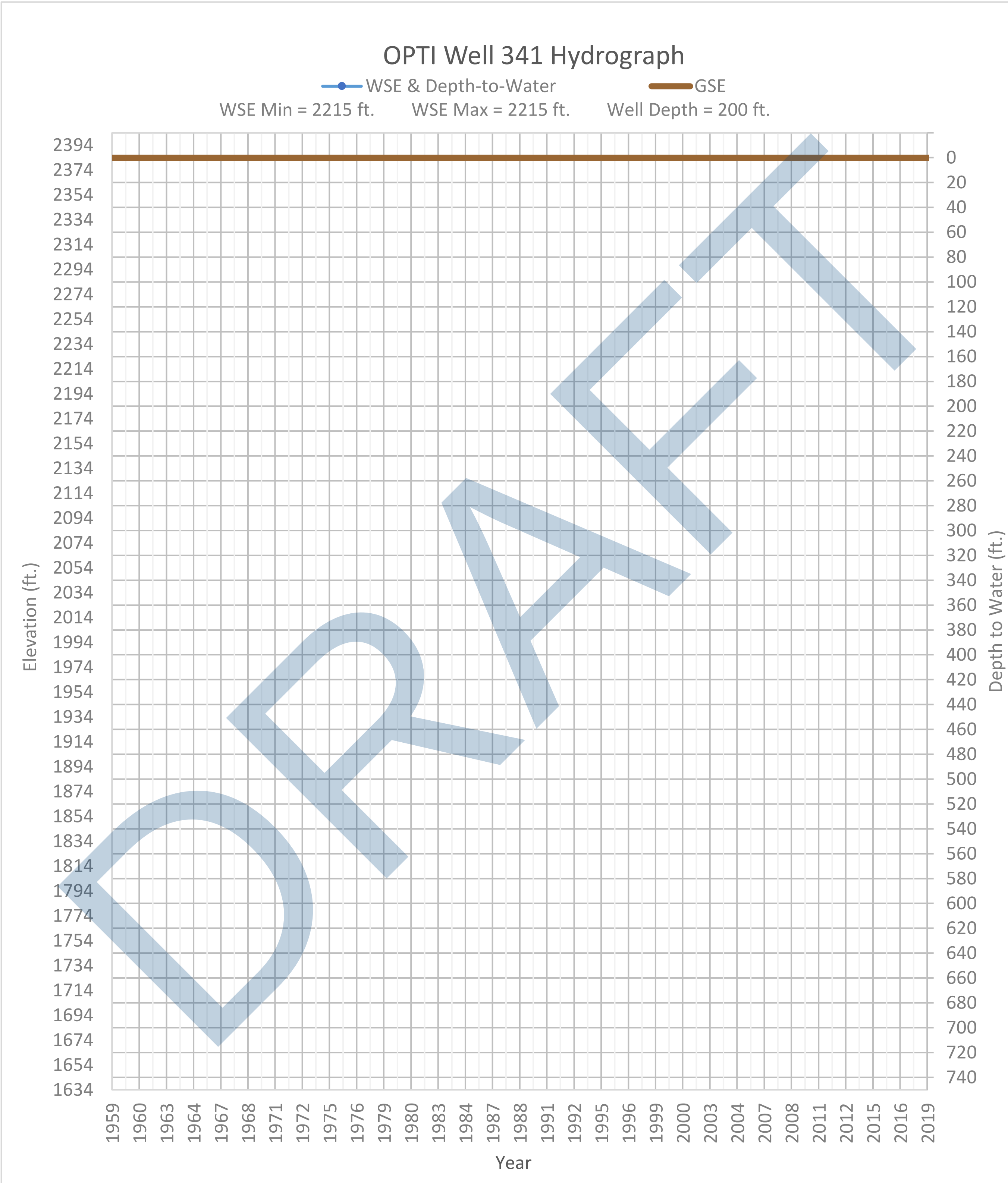
OPTI Well 337 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2253 ft.
WSE Max = 2253 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 339 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2042 ft.
WSE Max = 2246 ft.
Well Depth = 370 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 340 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2188 ft.
WSE Max = 2206 ft.
Well Depth = 198 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 341 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2215 ft.
WSE Max = 2215 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2394
2374
2354
2334
2314
2294
2274
2254
2234
2214
2194
2174
2154
2134
2114
2094
2074
2054
2034
2014
1994
1974
1954
1934
1914
1894
1874
1854
1834
1814
1794
1774
1754
1734
1714
1694
1674
1654
1634
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
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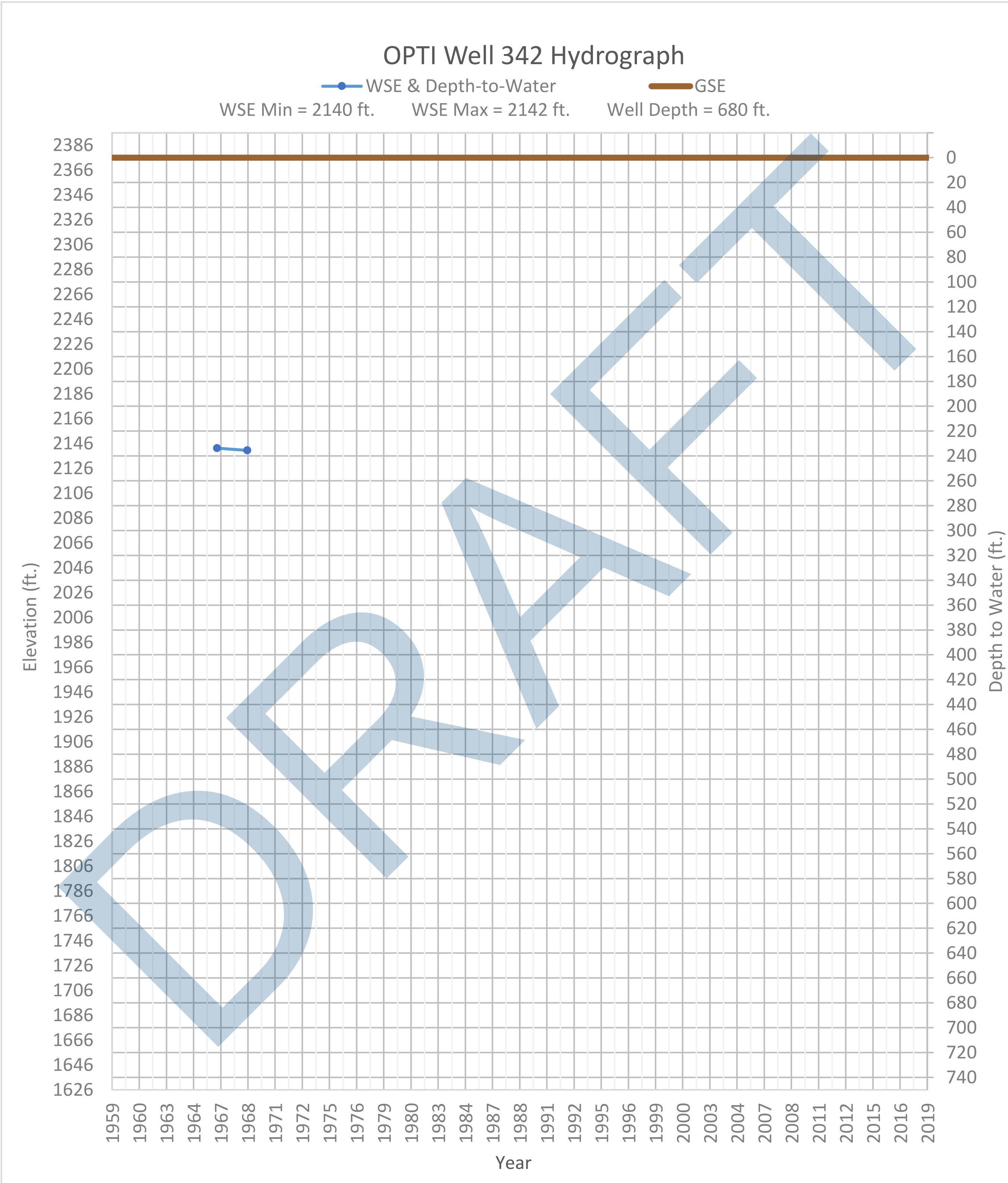
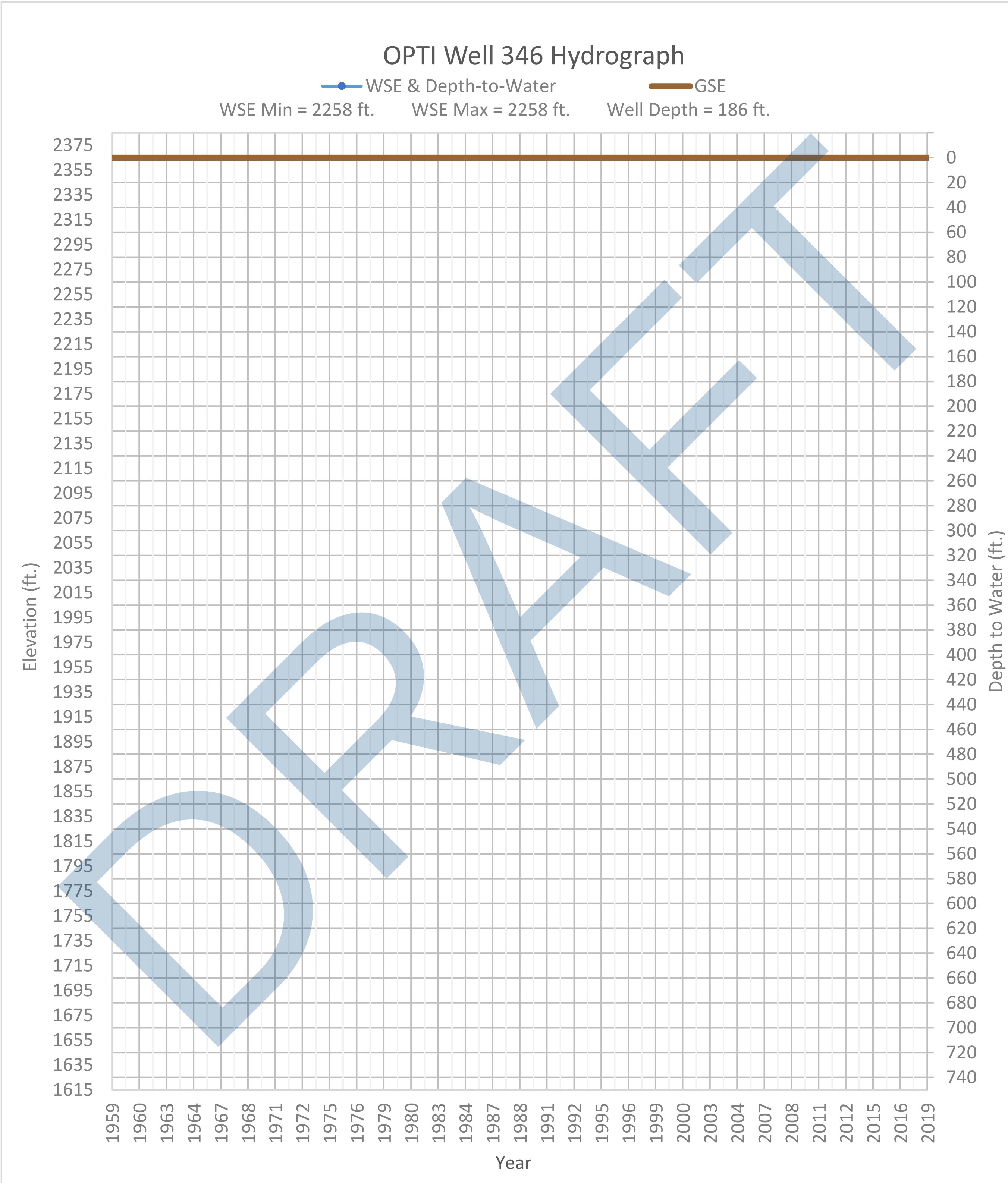
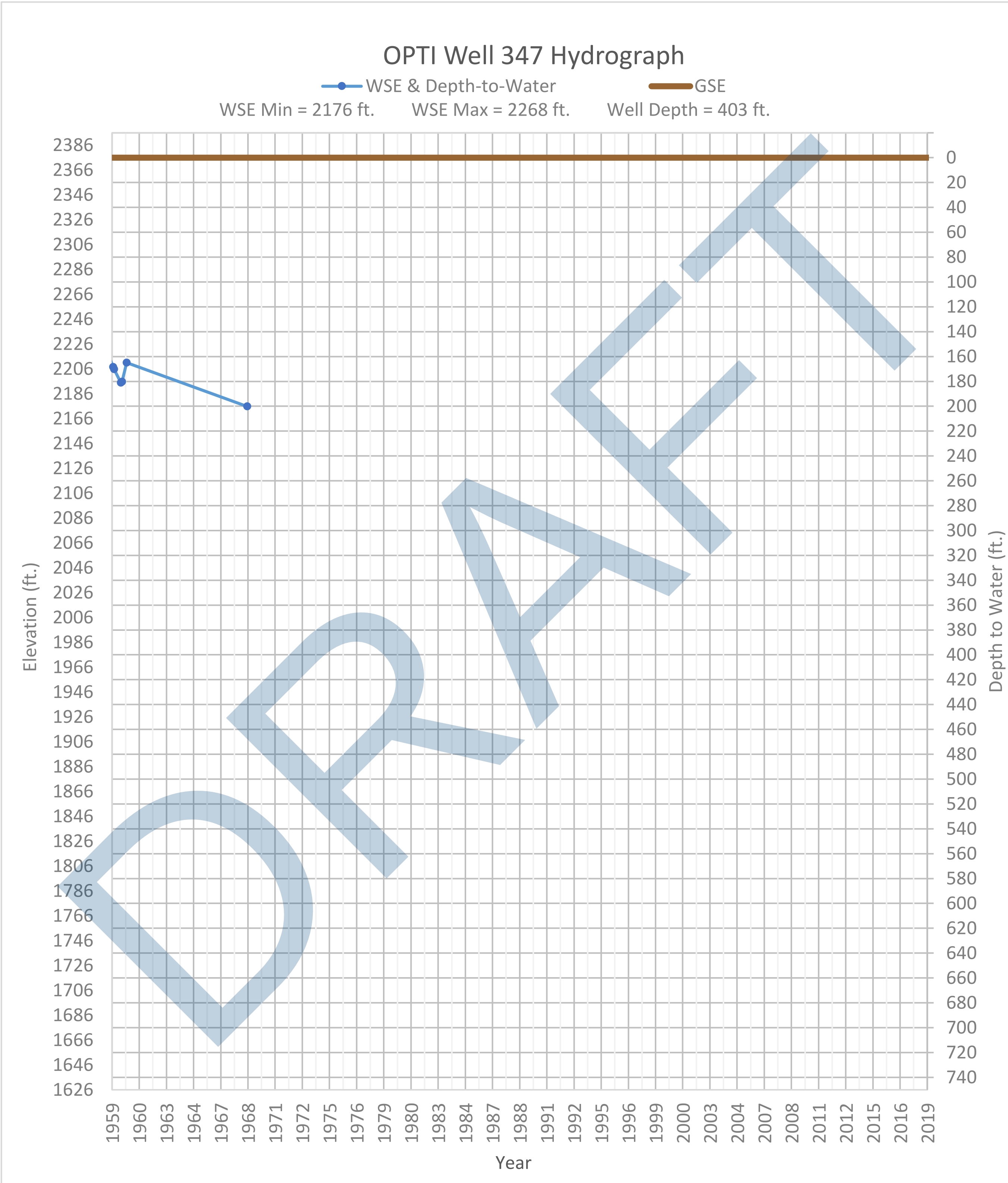
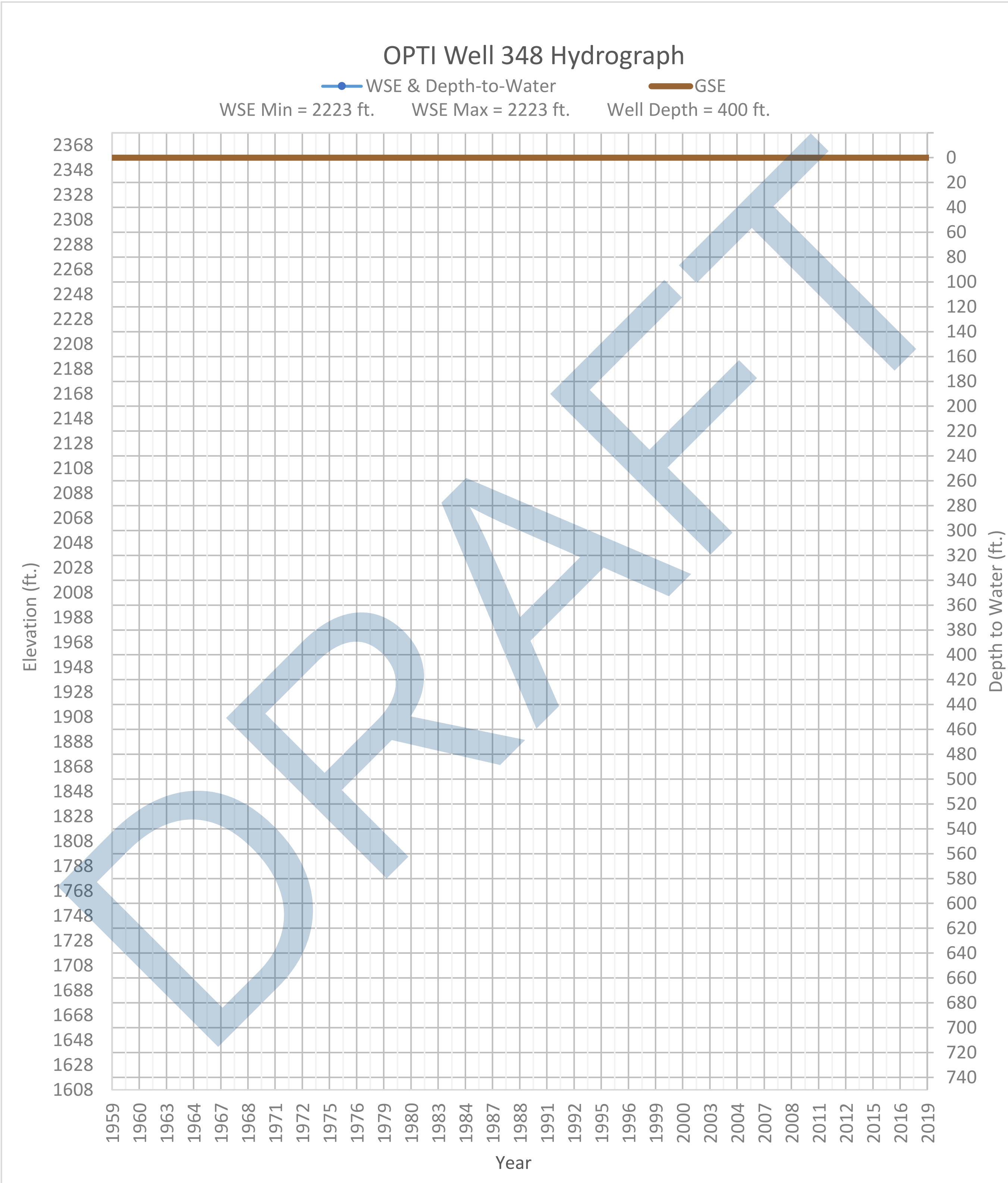
DRAFT


OPTI Well 342 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2140 ft.
WSE Max = 2142 ft.
Well Depth = 680 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

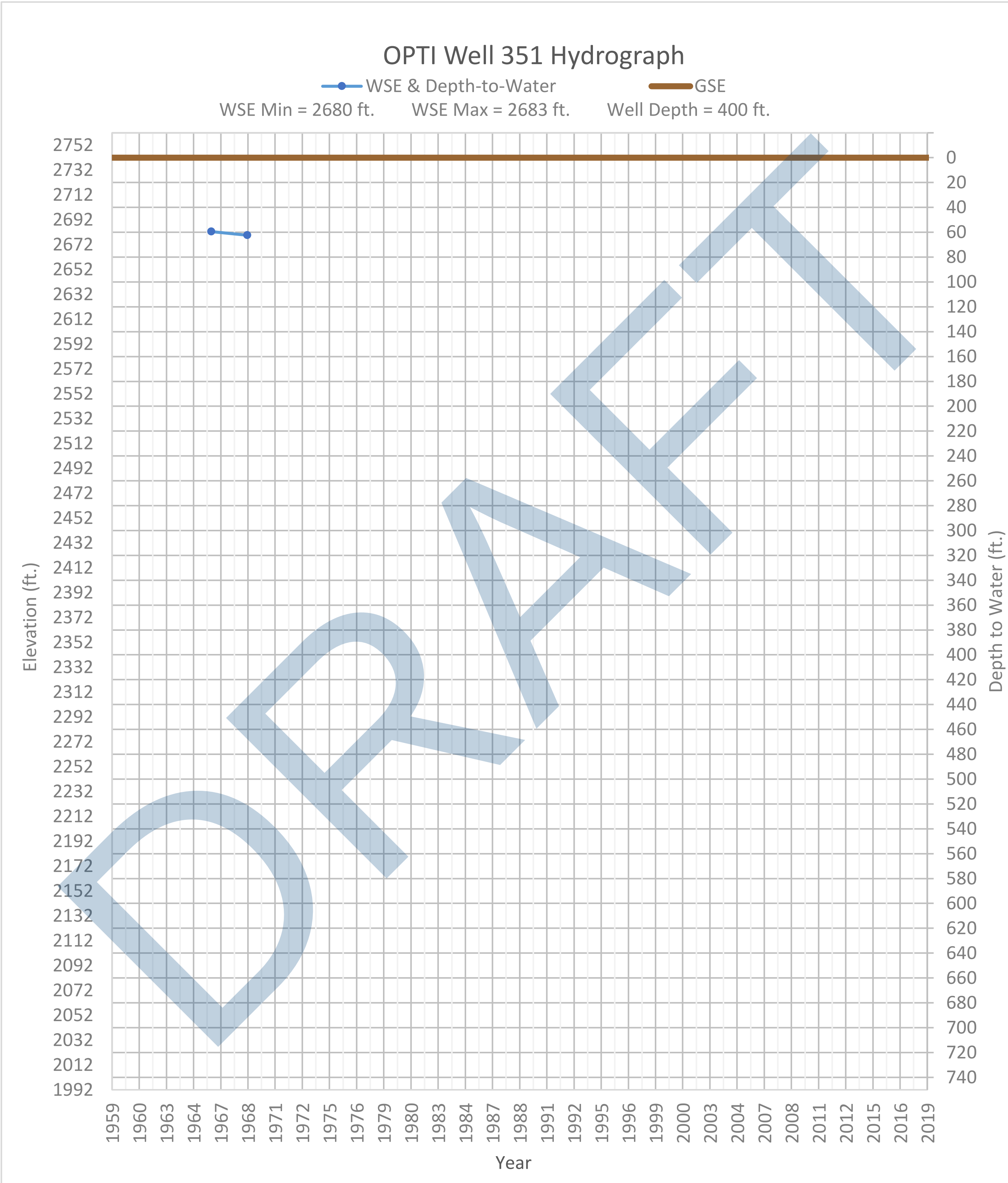


OPTI Well 346 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2258 ft.
WSE Max = 2258 ft.
Well Depth = 186 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

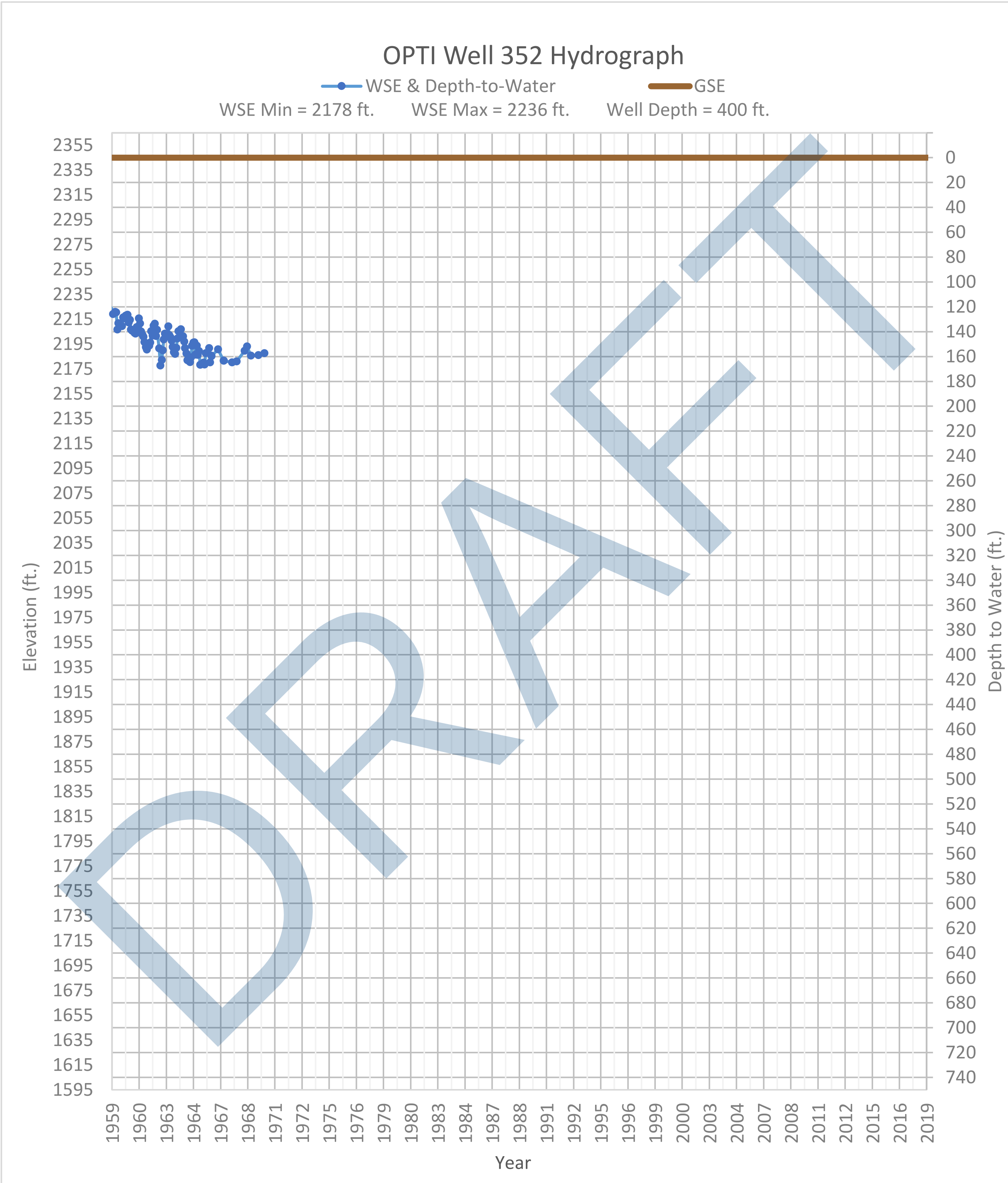

OPTI Well 347 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2176 ft.
WSE Max = 2268 ft.
Well Depth = 403 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



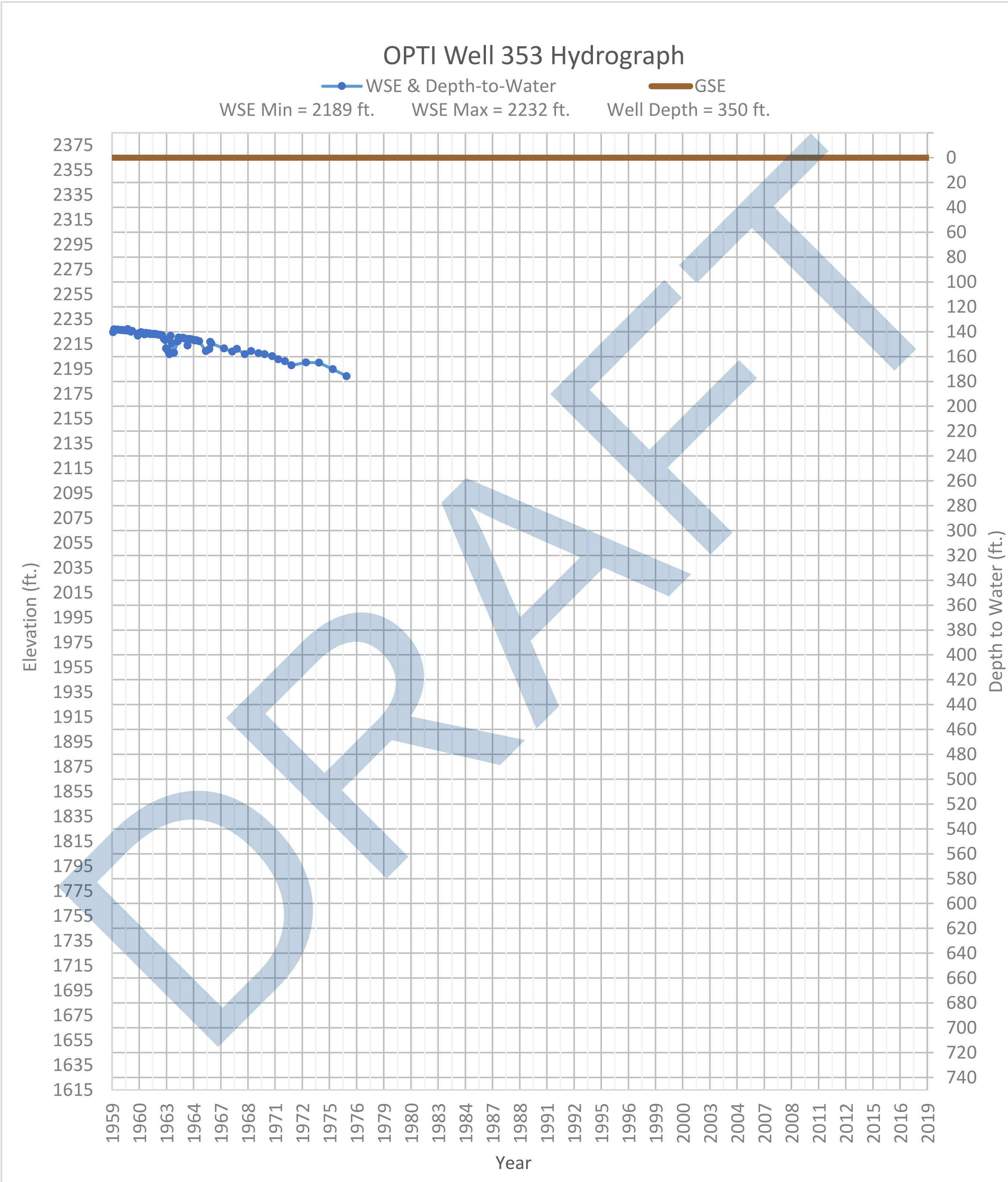
OPTI Well 348 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2223 ft.
WSE Max = 2223 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

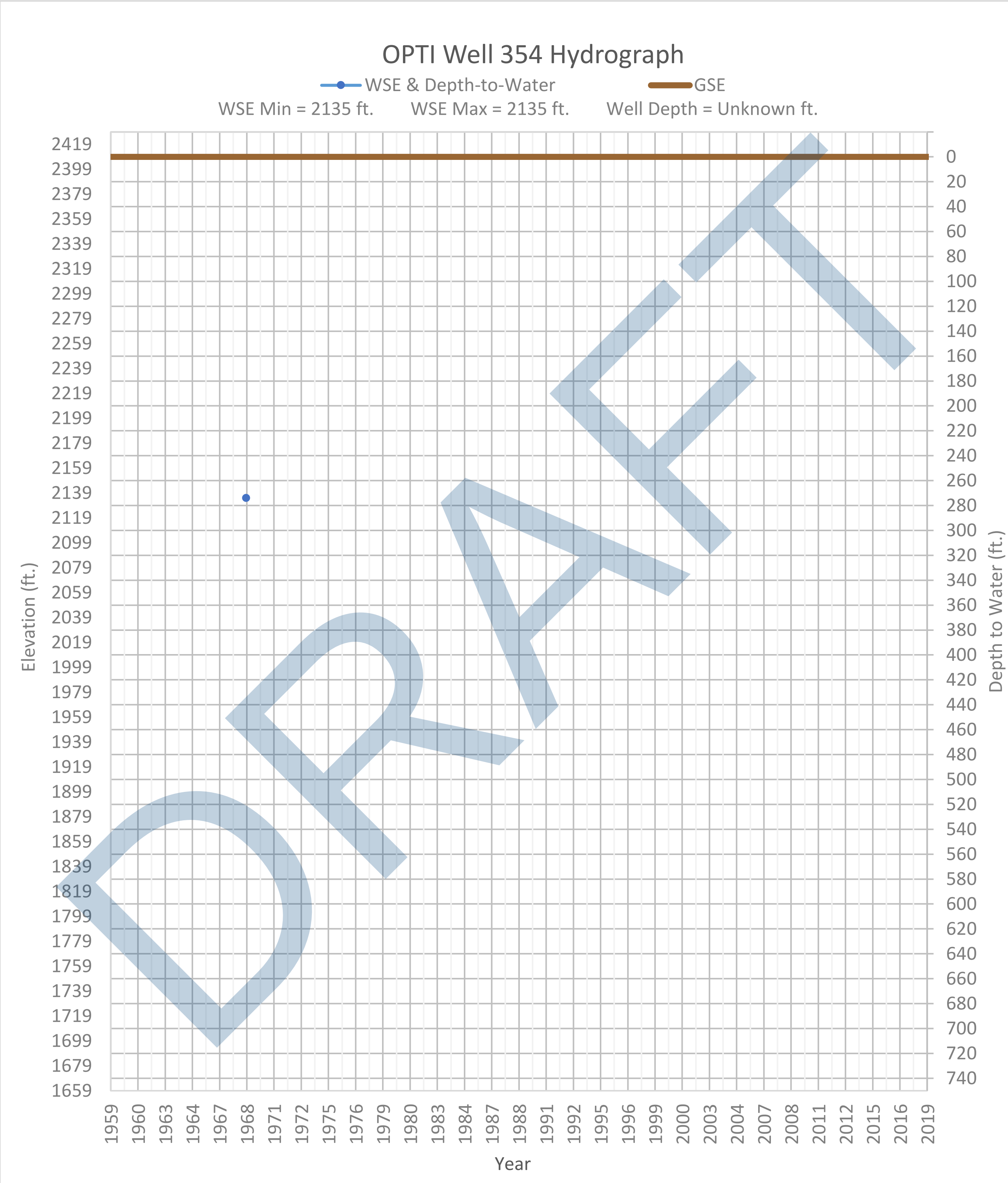


OPTI Well 351 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2680 ft.
WSE Max = 2683 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

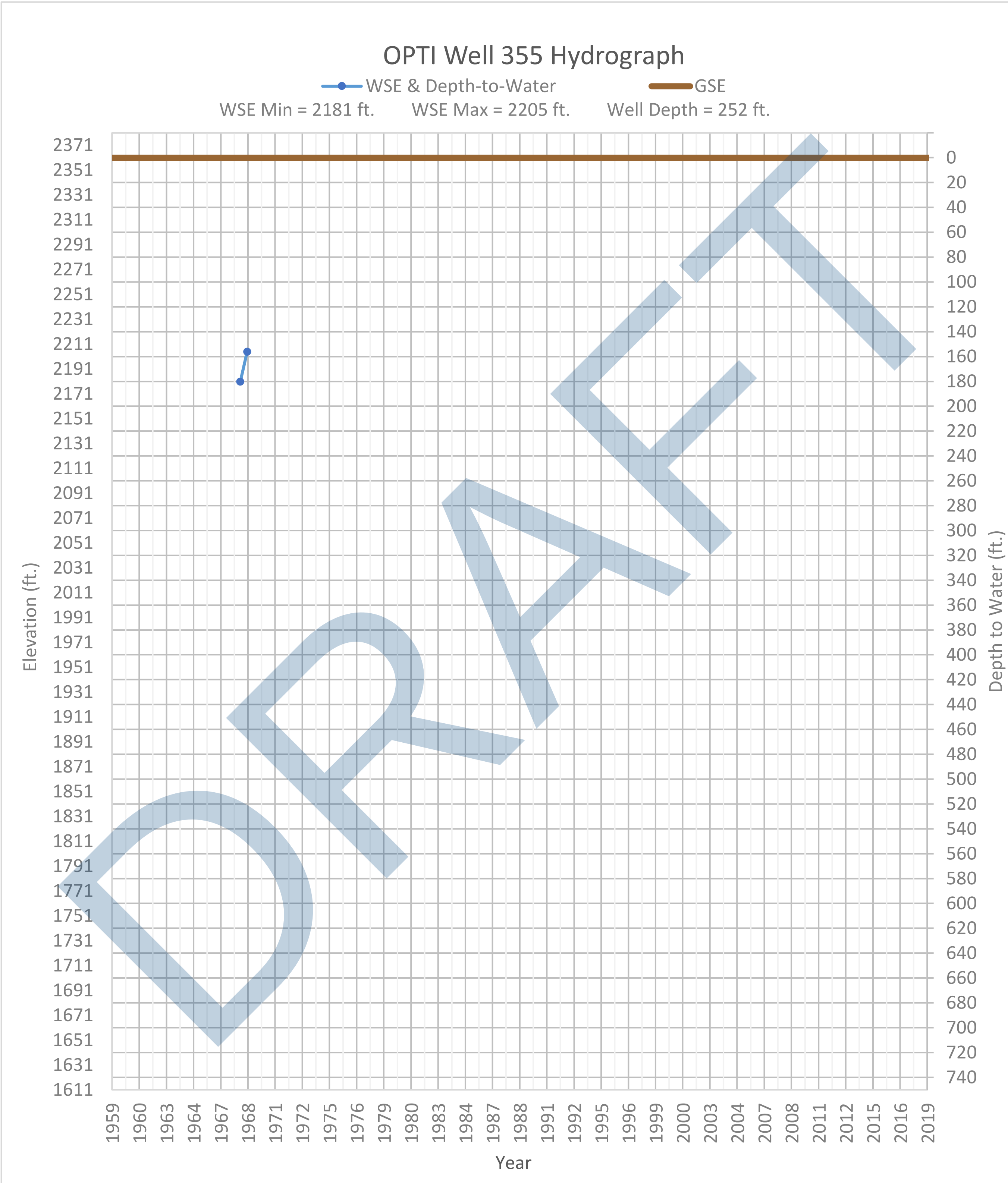


OPTI Well 352 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2178 ft.
WSE Max = 2236 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

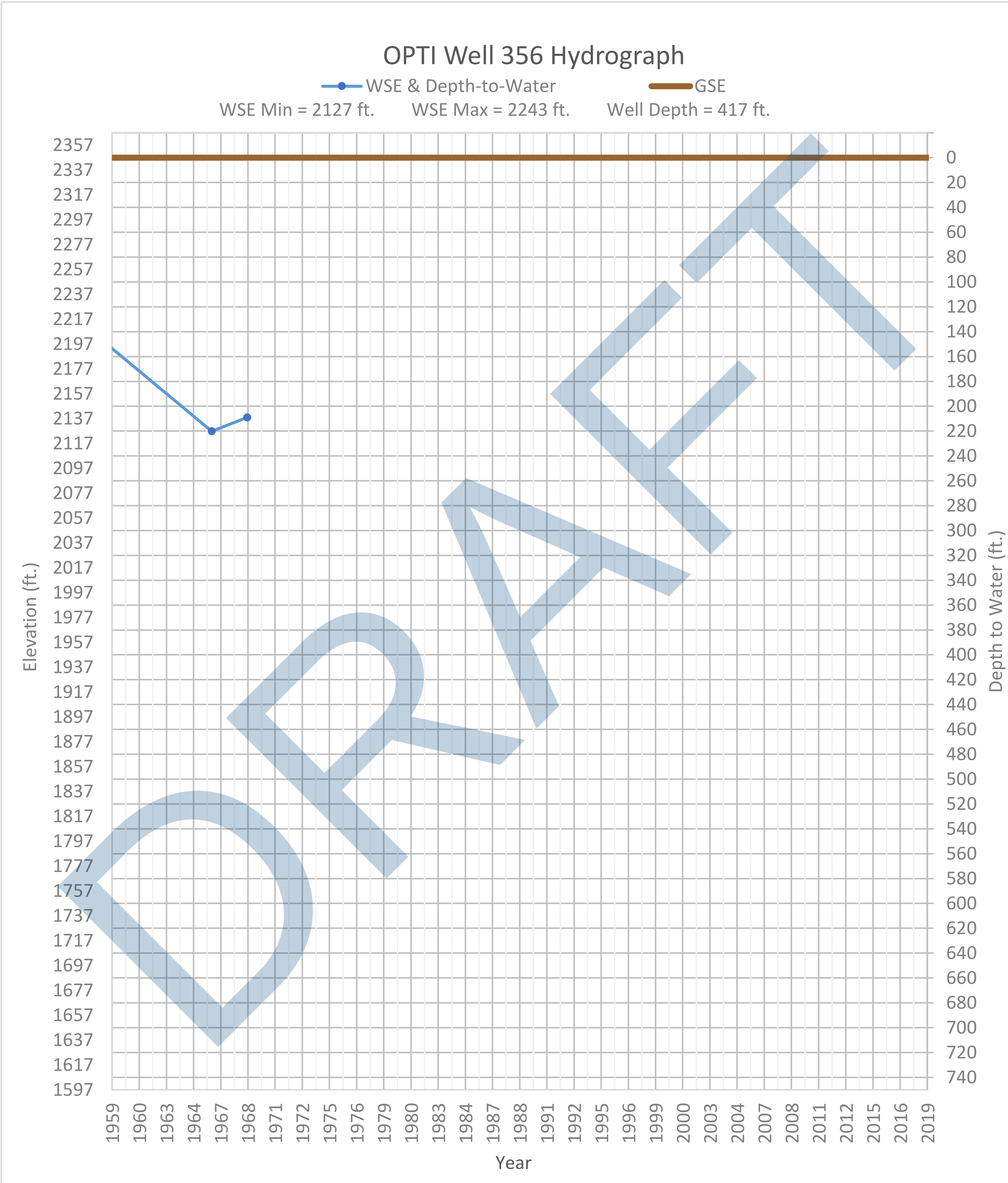

OPTI Well 353 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2189 ft.
WSE Max = 2232 ft.
Well Depth = 350 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

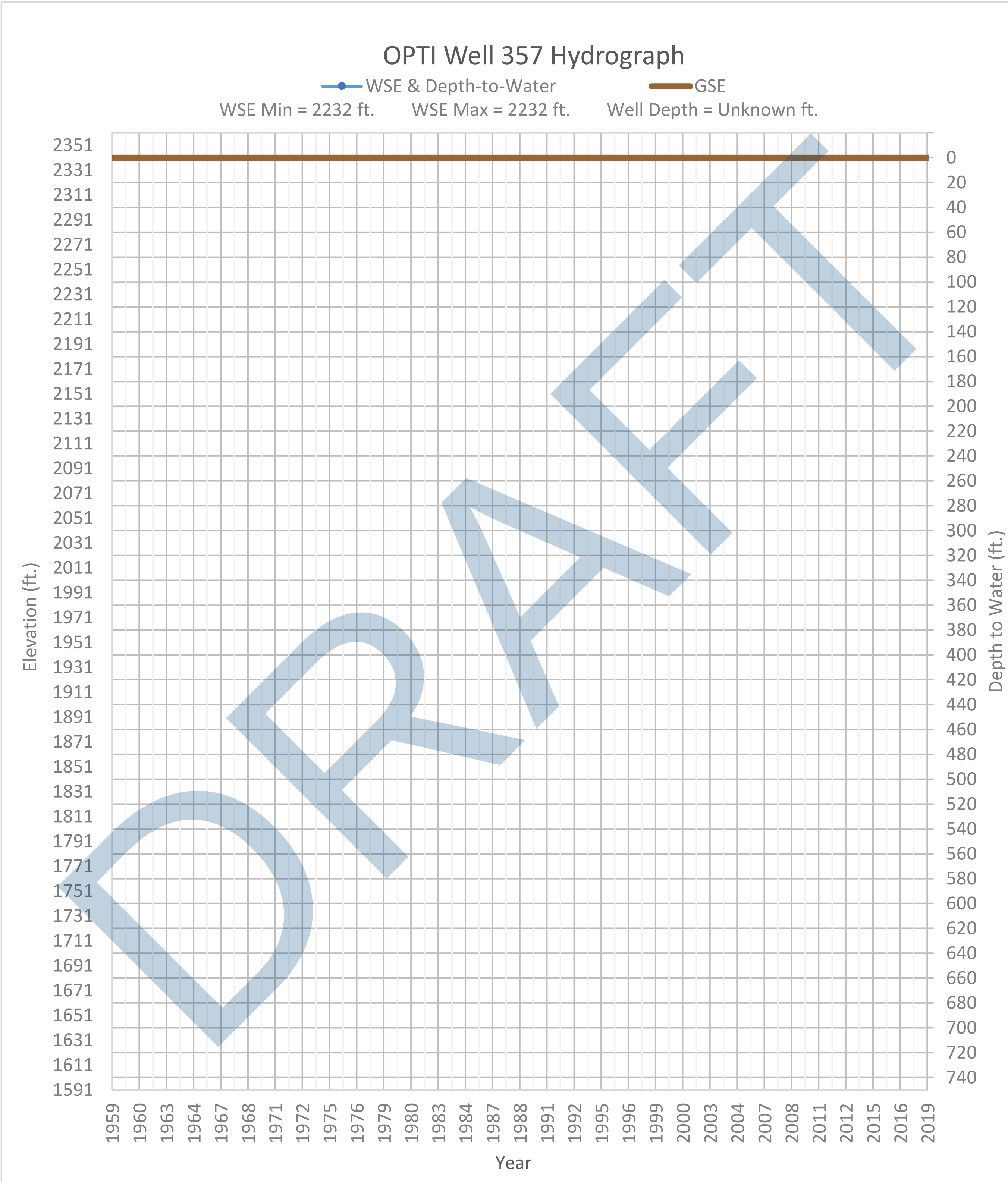


OPTI Well 354 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2135 ft.
WSE Max = 2135 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

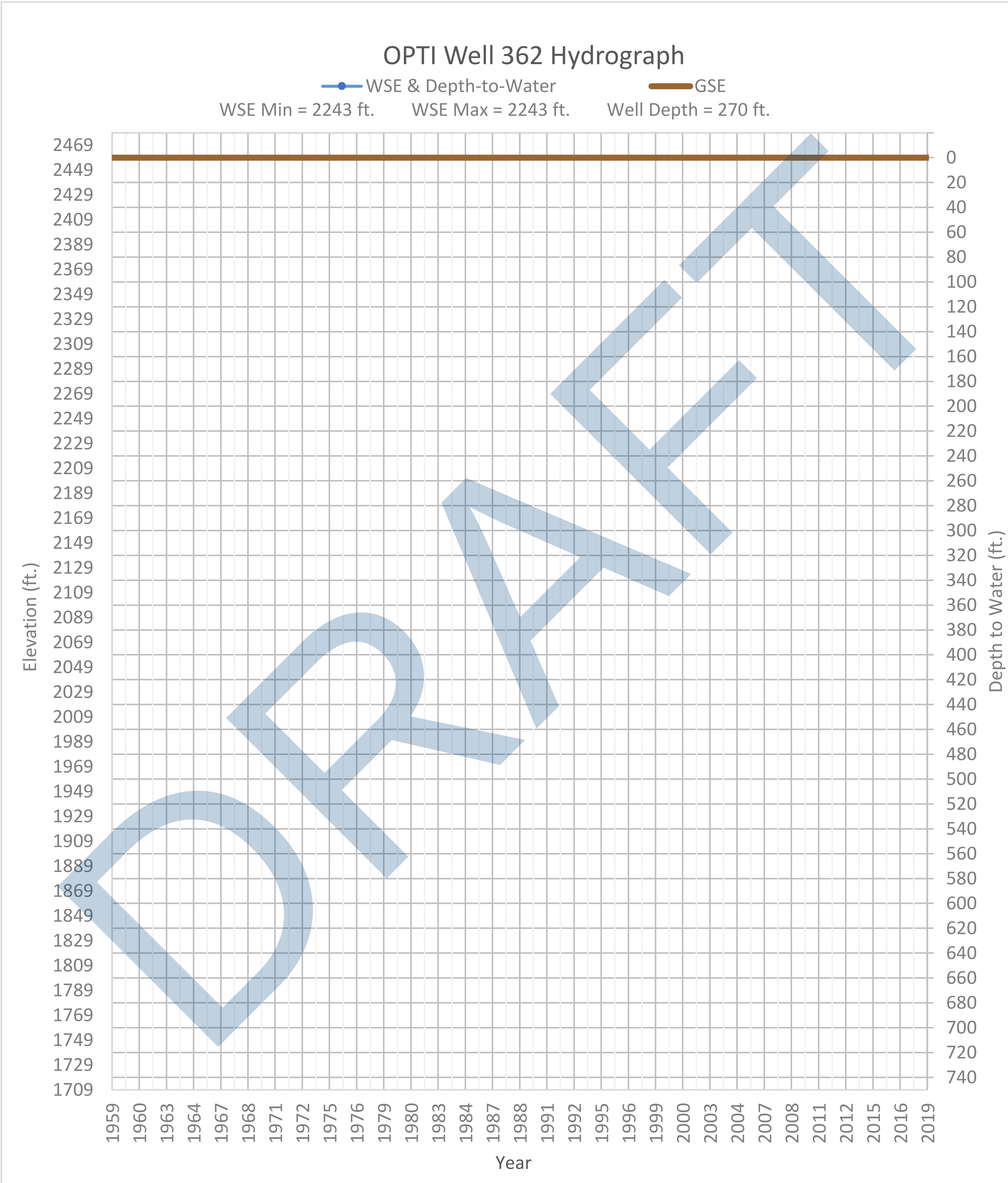


OPTI Well 355 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2181 ft.
WSE Max = 2205 ft.
Well Depth = 252 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

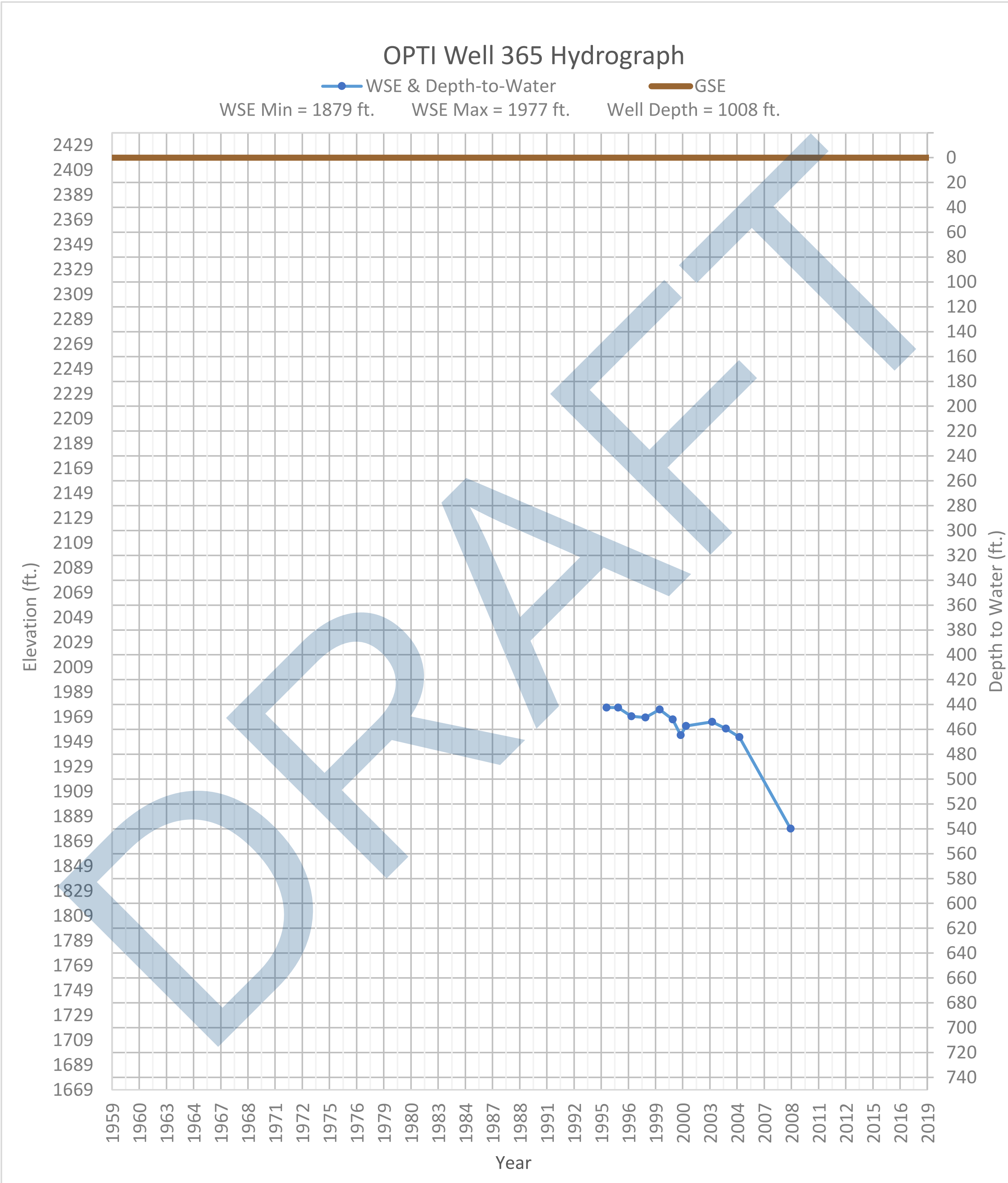

OPTI Well 356 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2127 ft.
WSE Max = 2243 ft.
Well Depth = 417 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



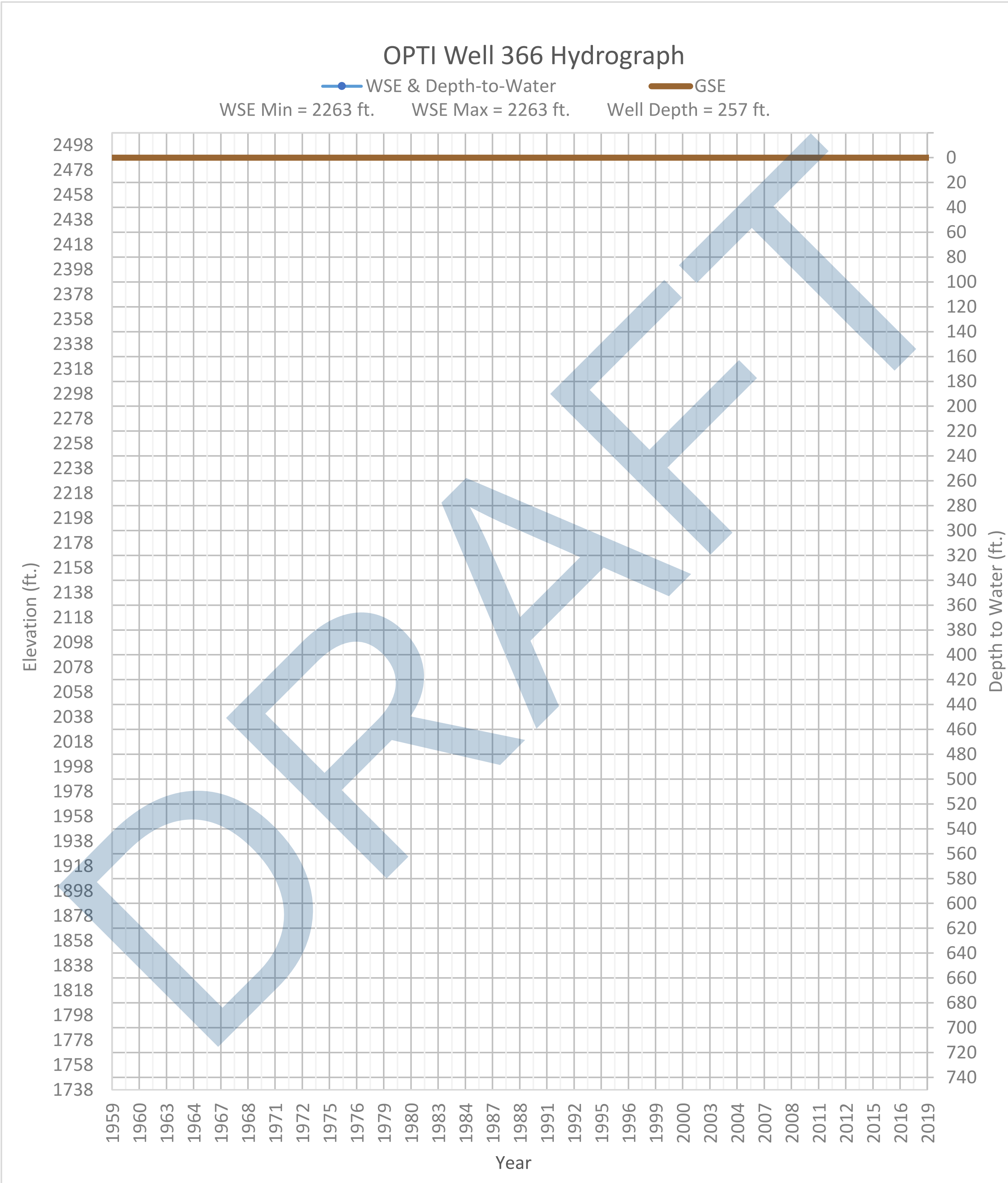
OPTI Well 357 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2232 ft.
WSE Max = 2232 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2351
2331
2311
2291
2271
2251
2231
2211
2191
2171
2151
2131
2111
2091
2071
2051
2031
2011
1991
1971
1951
1931
1911
1891
1871
1851
1831
1811
1791
1771
1751
1731
1711
1691
1671
1651
1631
1611
1591
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
1984
1987
1988
1991
1992
1995
1996
1999
2000
2003
2004
2007
2008
2011
2012
2015
2016
2019
DRAFT



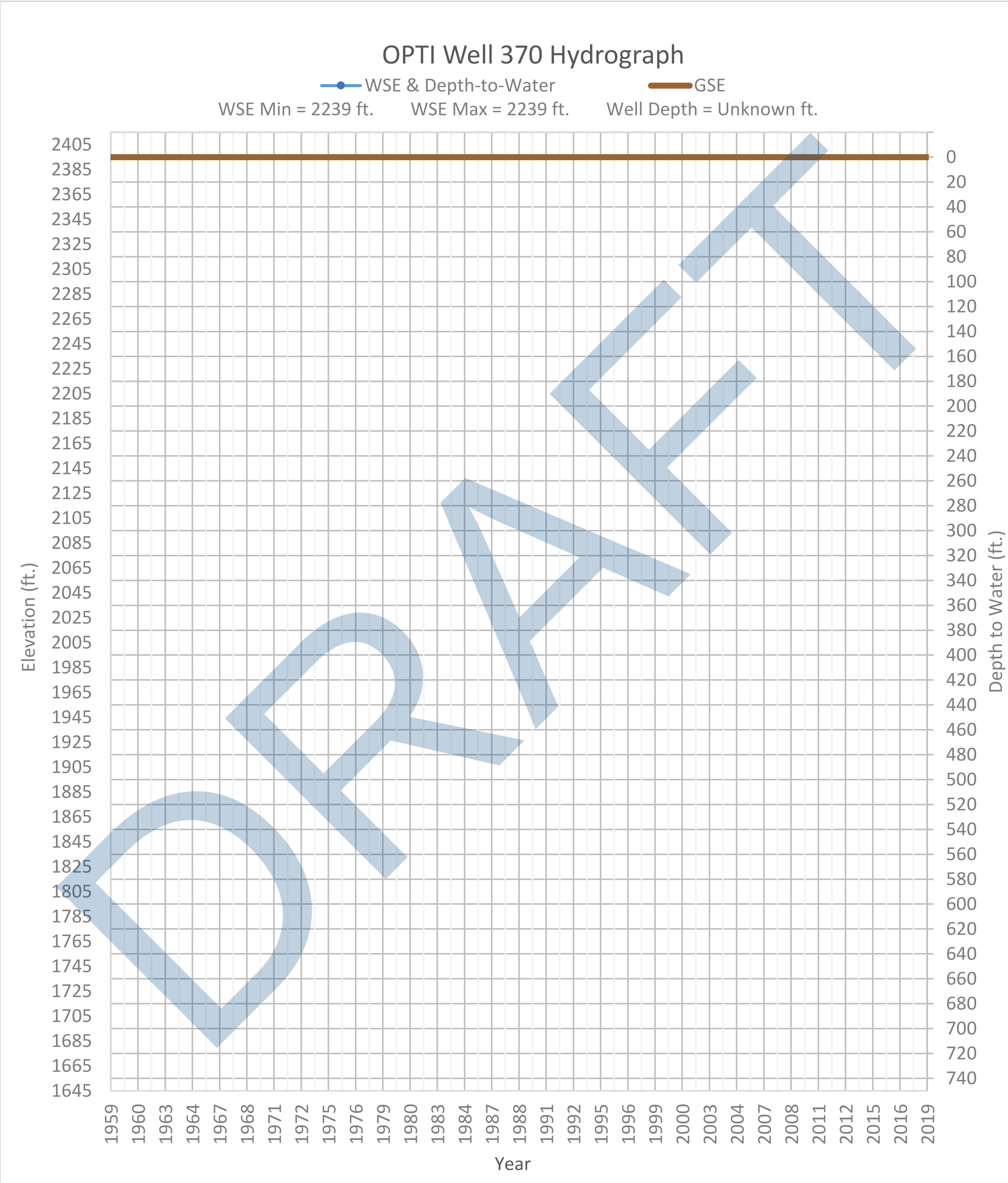
OPTI Well 362 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2243 ft.
WSE Max = 2243 ft.
Well Depth = 270 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 365 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1879 ft.
WSE Max = 1977 ft.
Well Depth = 1008 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 366 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2263 ft.
WSE Max = 2263 ft.
Well Depth = 257 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 370 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2239 ft.
WSE Max = 2239 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2405
2385
2365
2345
2325
2305
2285
2265
2245
2225
2205
2185
2165
2145
2125
2105
2085
2065
2045
2025
2005
1985
1965
1945
1925
1905
1885
1865
1845
1825
1805
1785
1765
1745
1725
1705
1685
1665
1645
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
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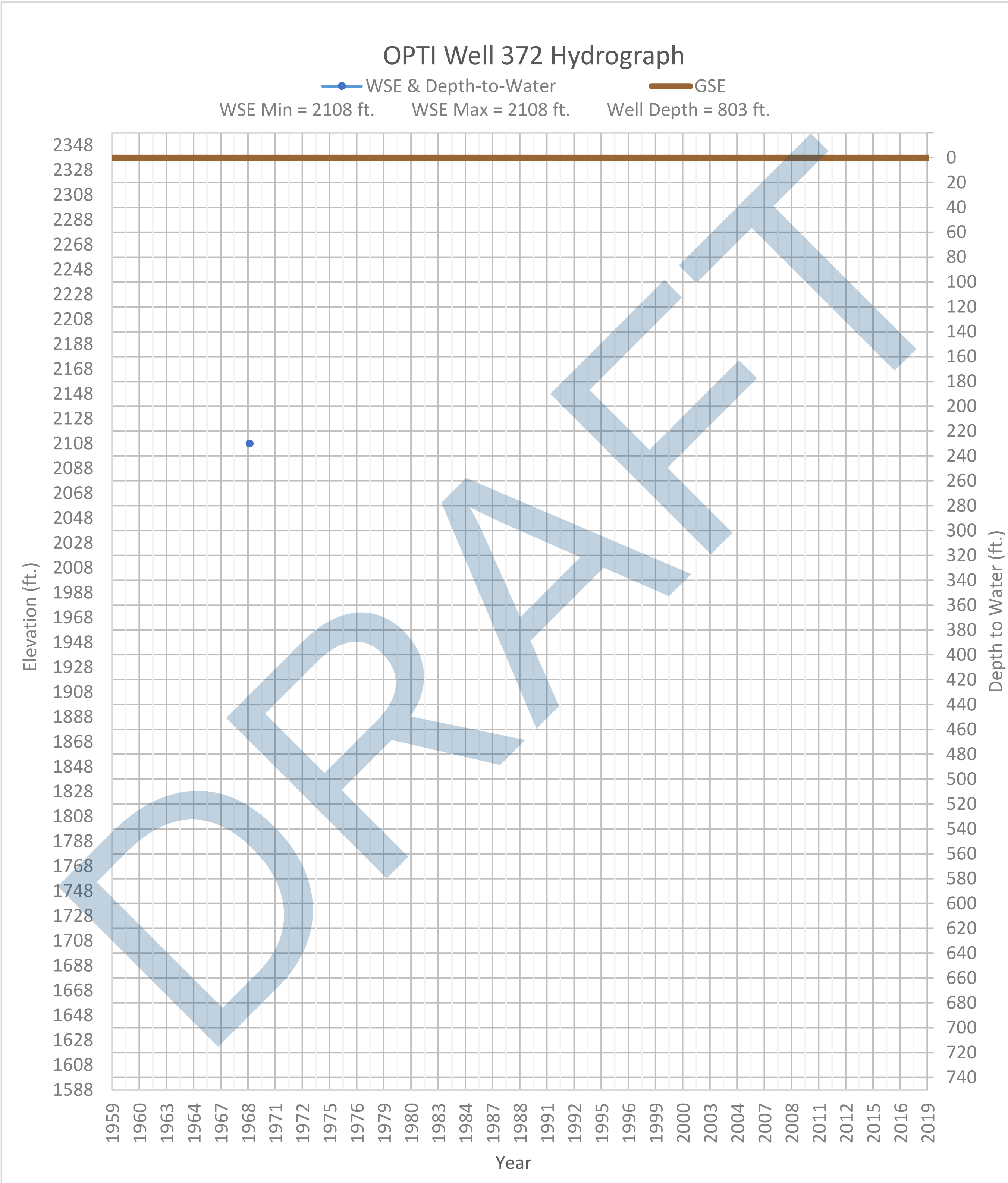
2012
2015
2016
2019
DRAFT



OPTI Well 372 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2108 ft.
WSE Max = 2108 ft.
Well Depth = 803 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2348
2328
2308
2288
2268
2248
2228
2208
2188
2168
2148
2128
2108
2088
2068
2048
2028
2008
1988
1968
1948
1928
1908
1888
1868
1848
1828
1808
1788
1768
1748
1728
1708
1688
1668
1648
1628
1608
1588
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
1984
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1991
1992
1995
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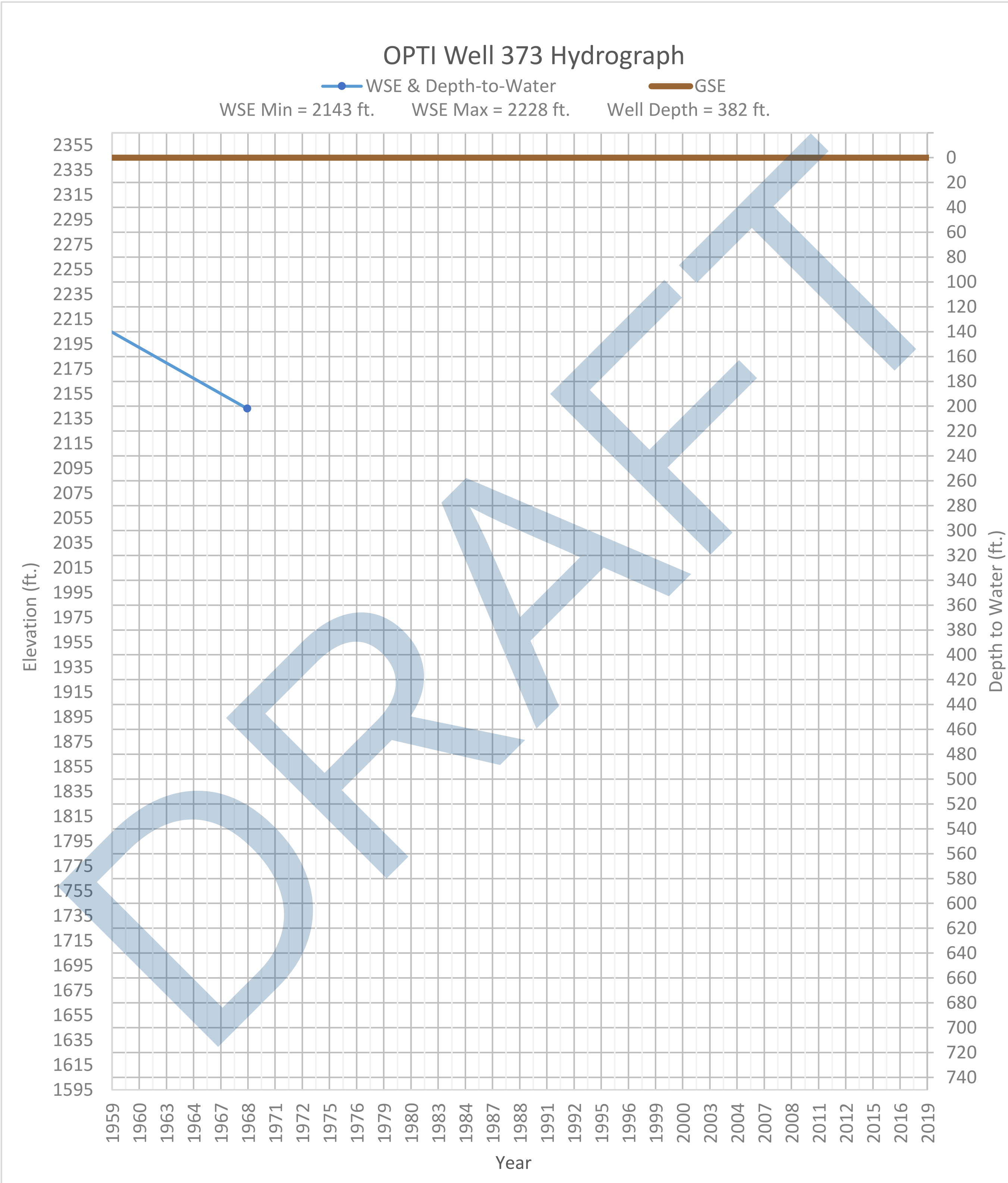
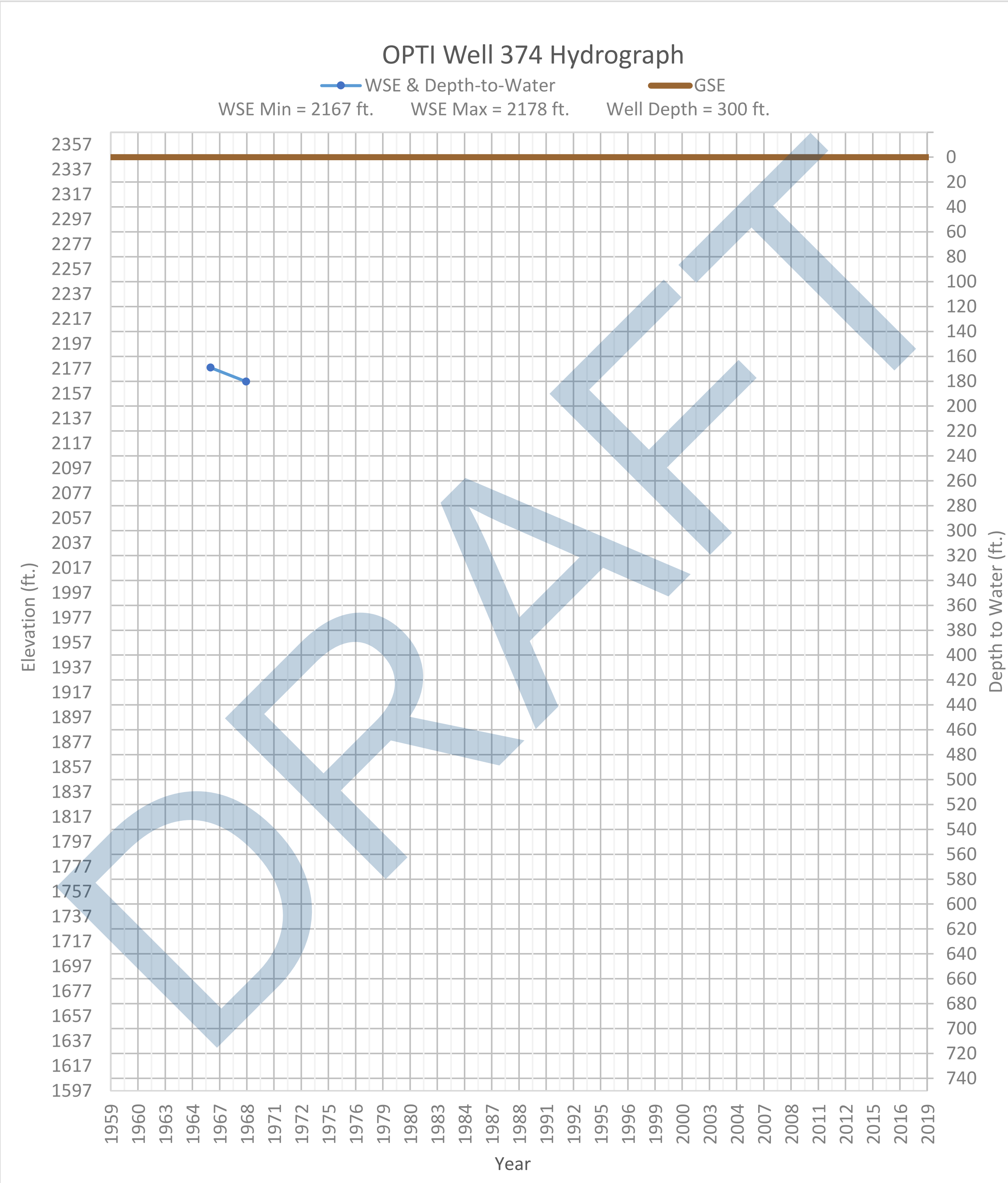
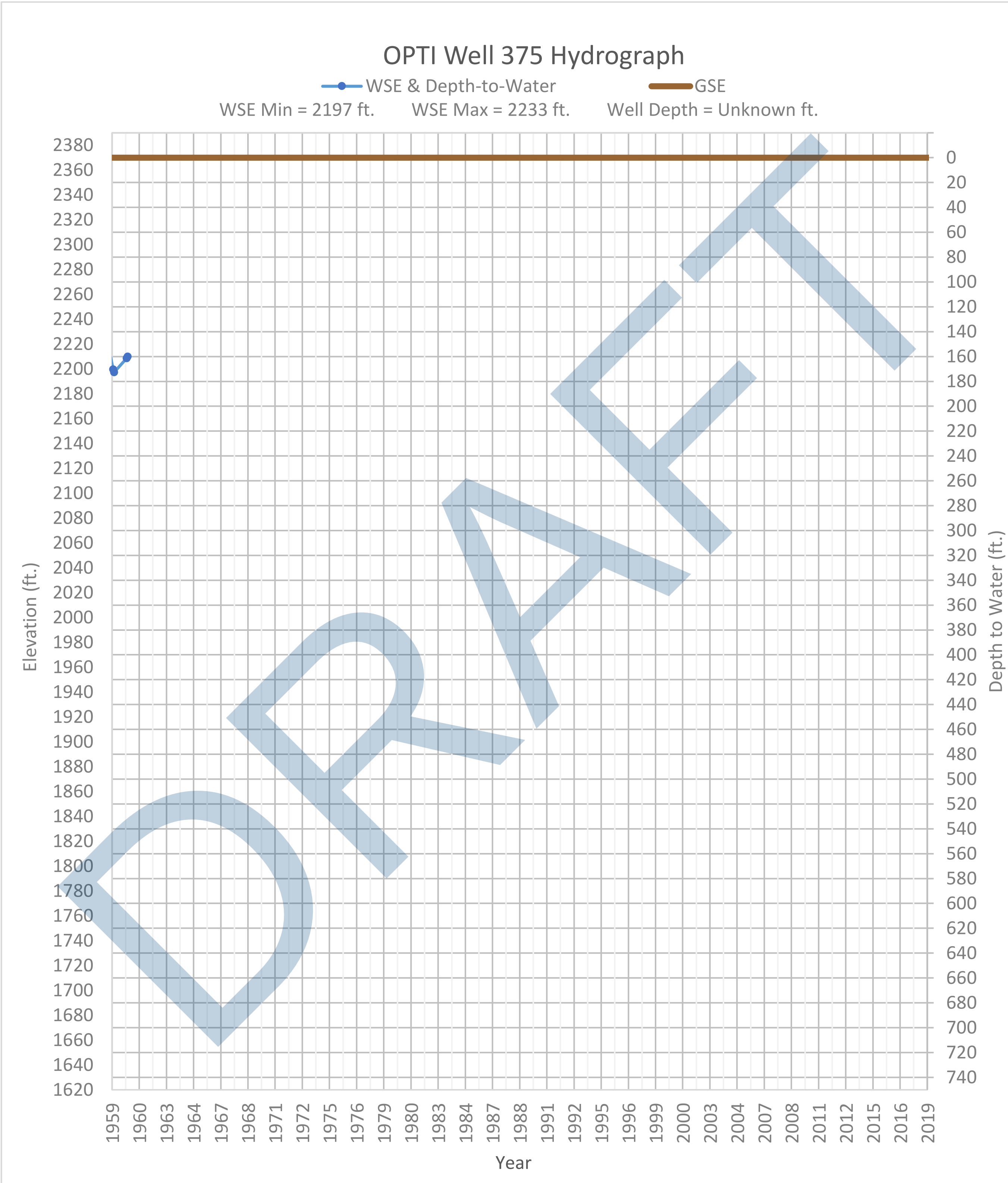
2003
2004
2007
2008
2011
2012
2015
2016
2019
DRAFT



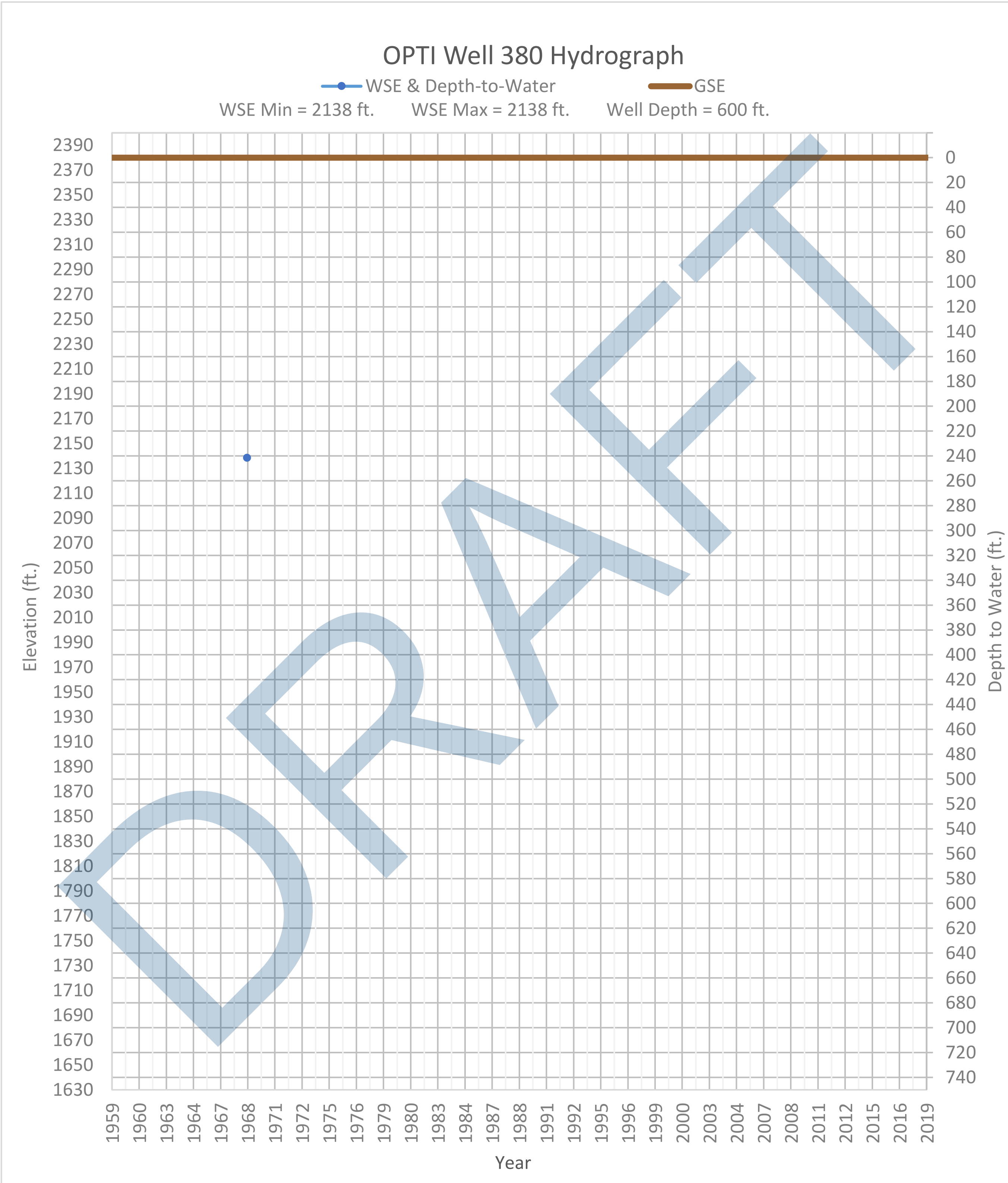
OPTI Well 373 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2143 ft.
WSE Max = 2228 ft.
Well Depth = 382 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

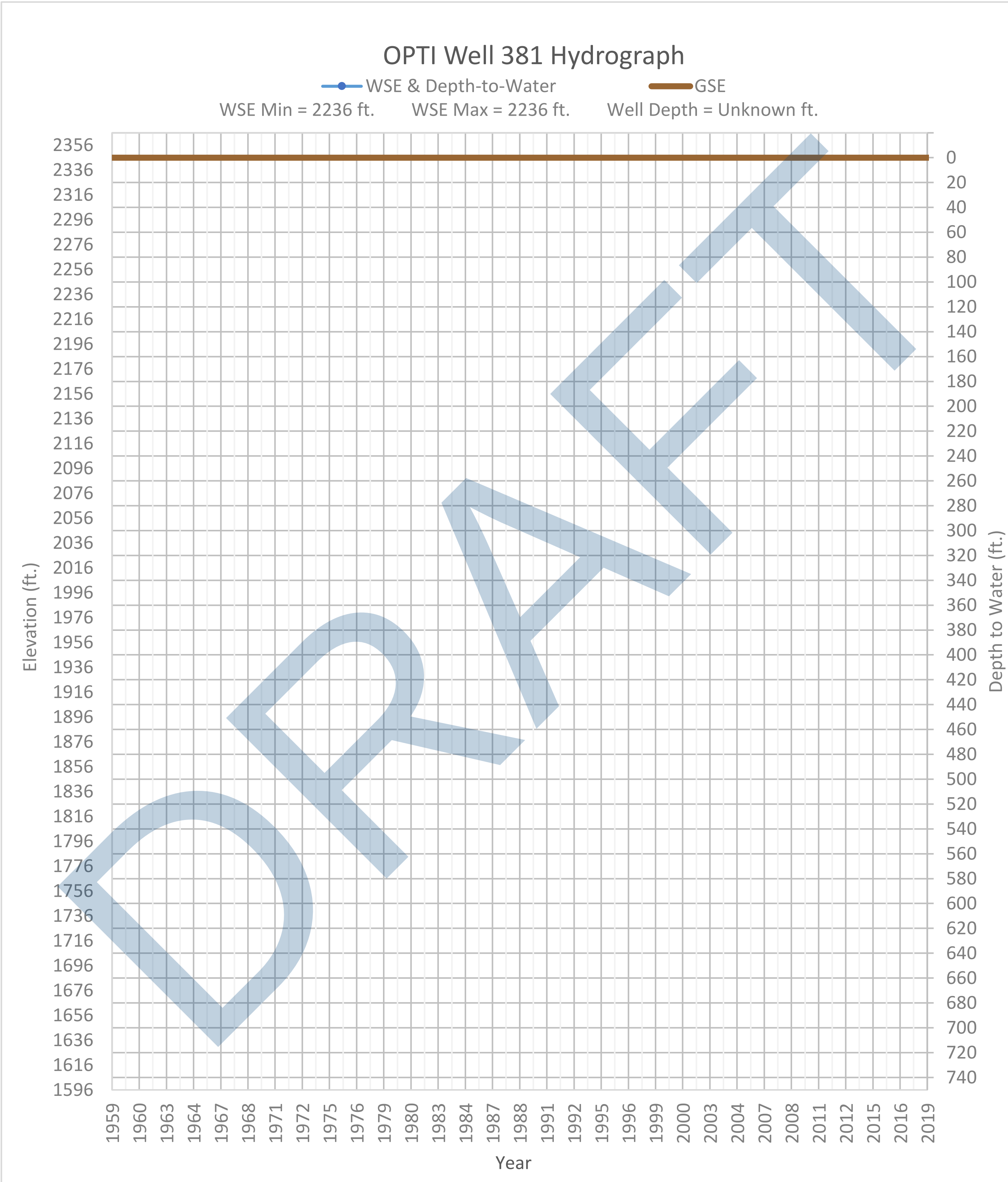


OPTI Well 374 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2167 ft.
WSE Max = 2178 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

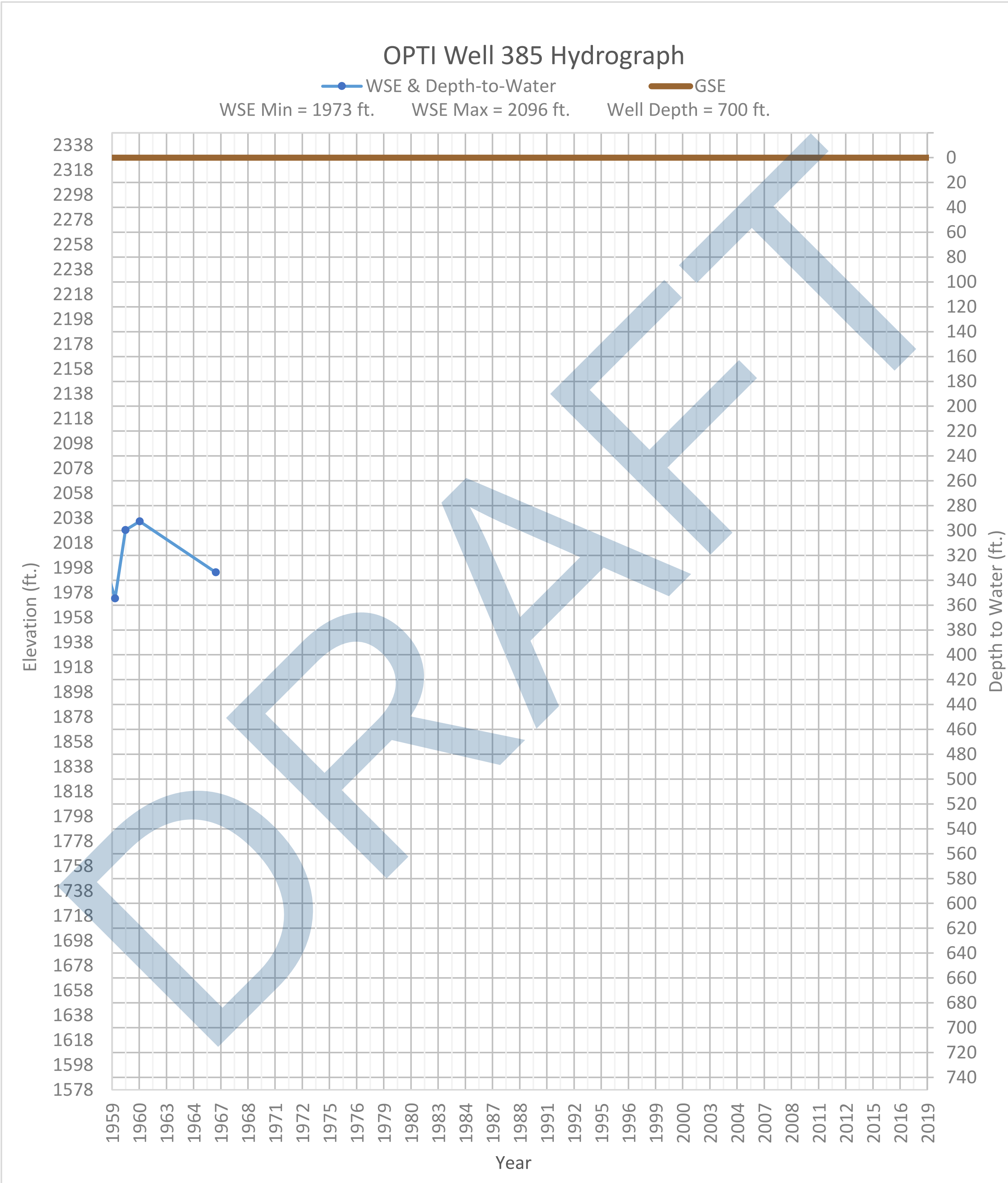


OPTI Well 375 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2197 ft.
WSE Max = 2233 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

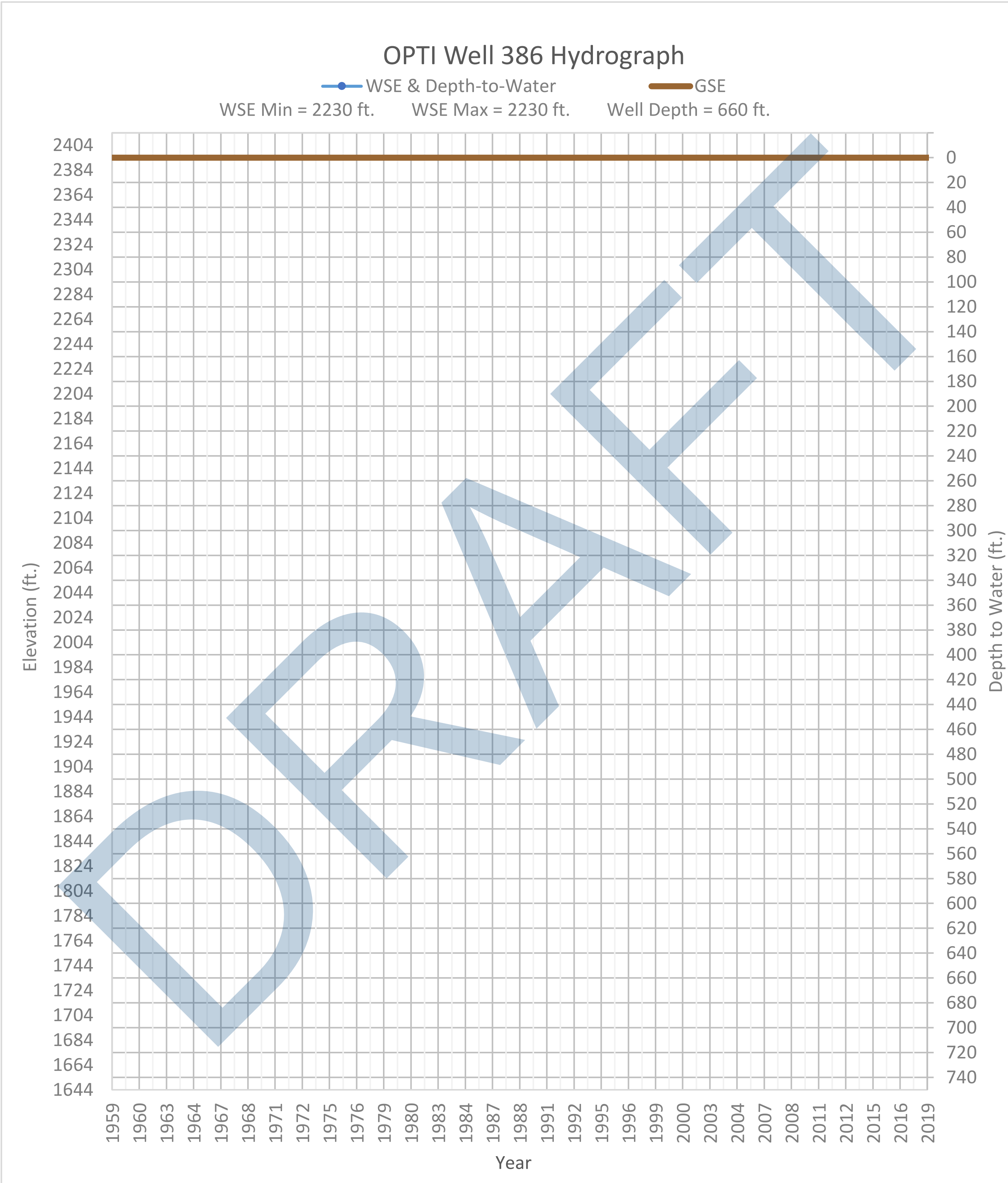

OPTI Well 380 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2138 ft.
WSE Max = 2138 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

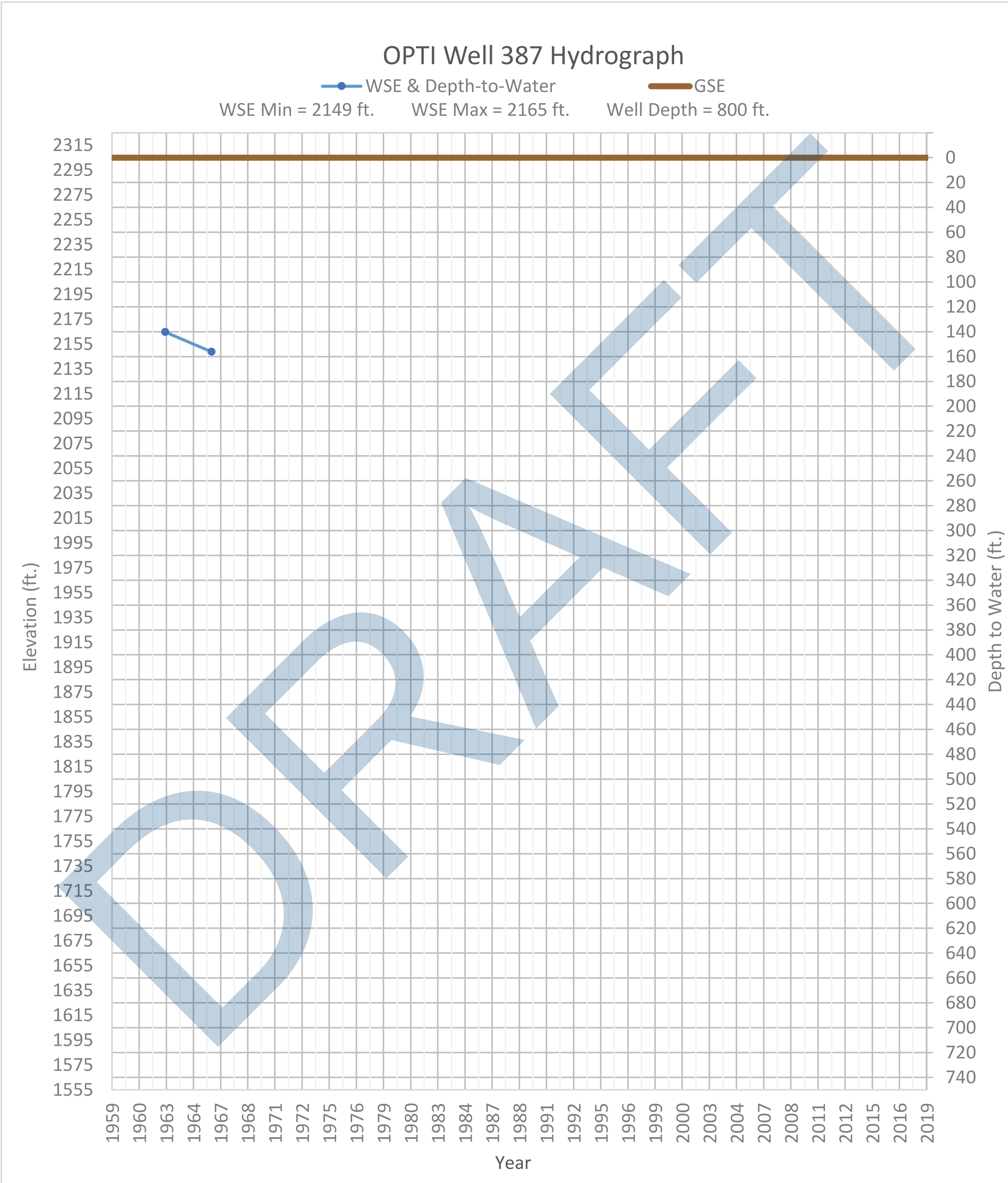


OPTI Well 381 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2236 ft.
WSE Max = 2236 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

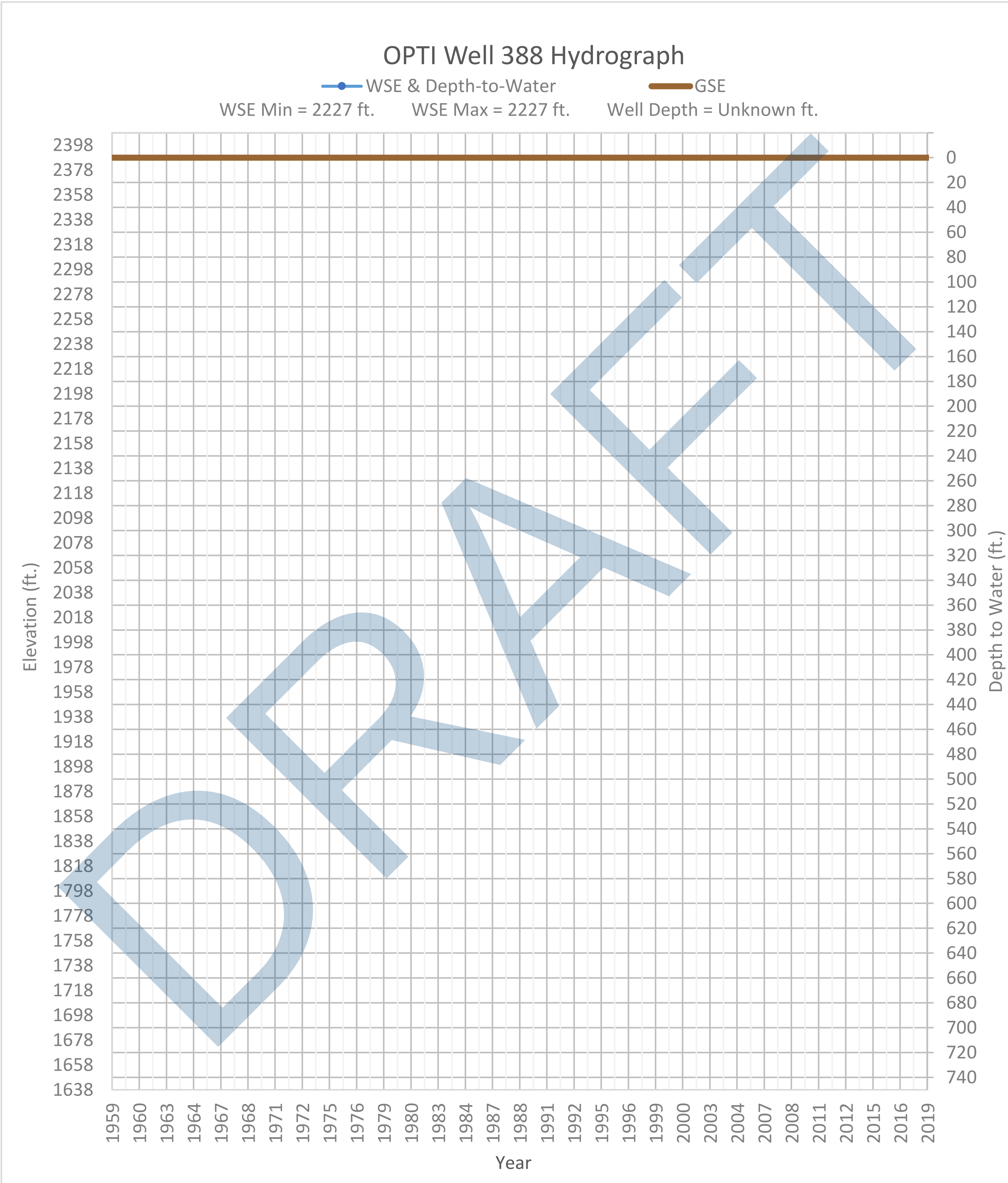


OPTI Well 385 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1973 ft.
WSE Max = 2096 ft.
Well Depth = 700 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

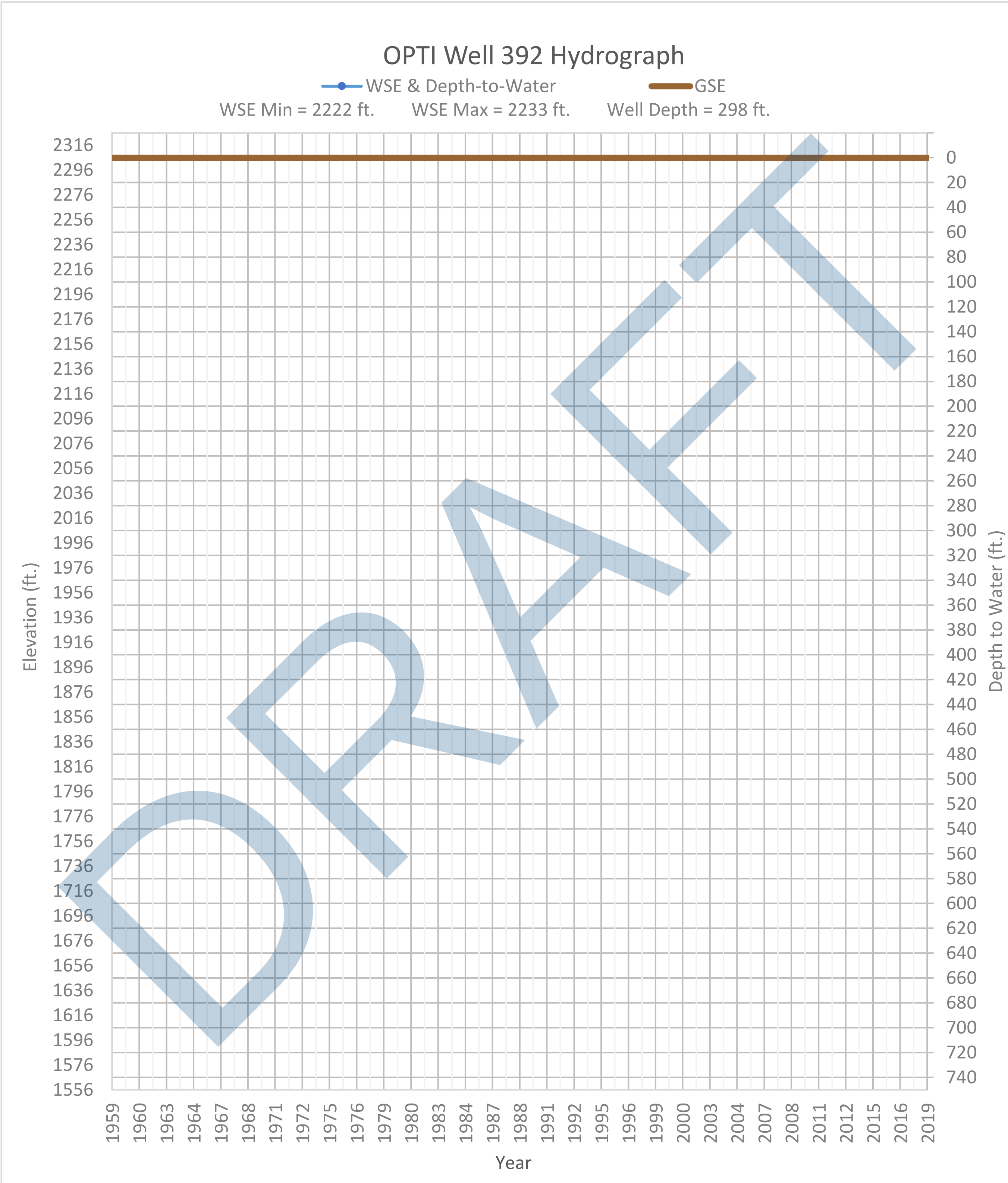

OPTI Well 386 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2230 ft.
WSE Max = 2230 ft.
Well Depth = 660 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



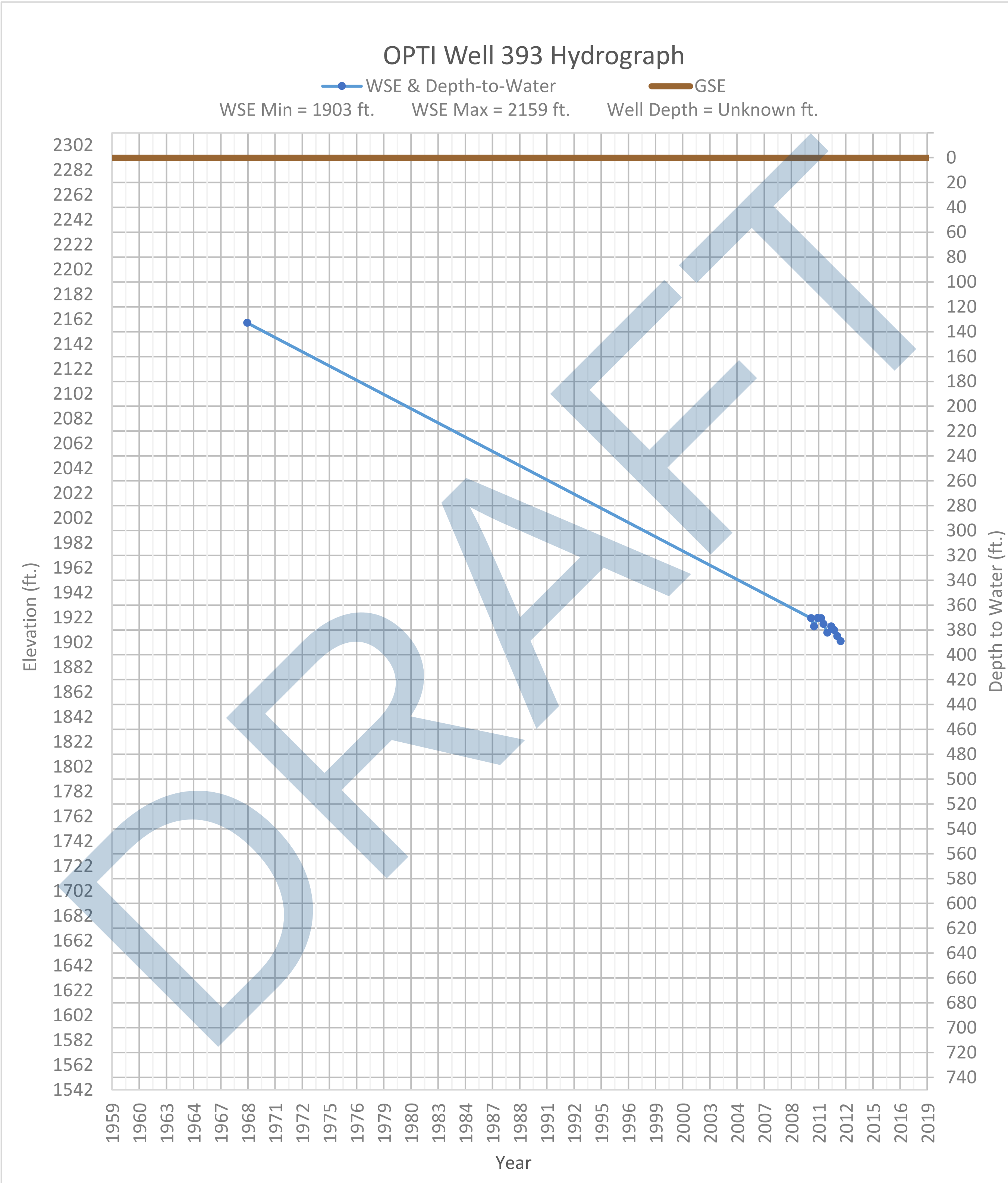
OPTI Well 387 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2149 ft.
WSE Max = 2165 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



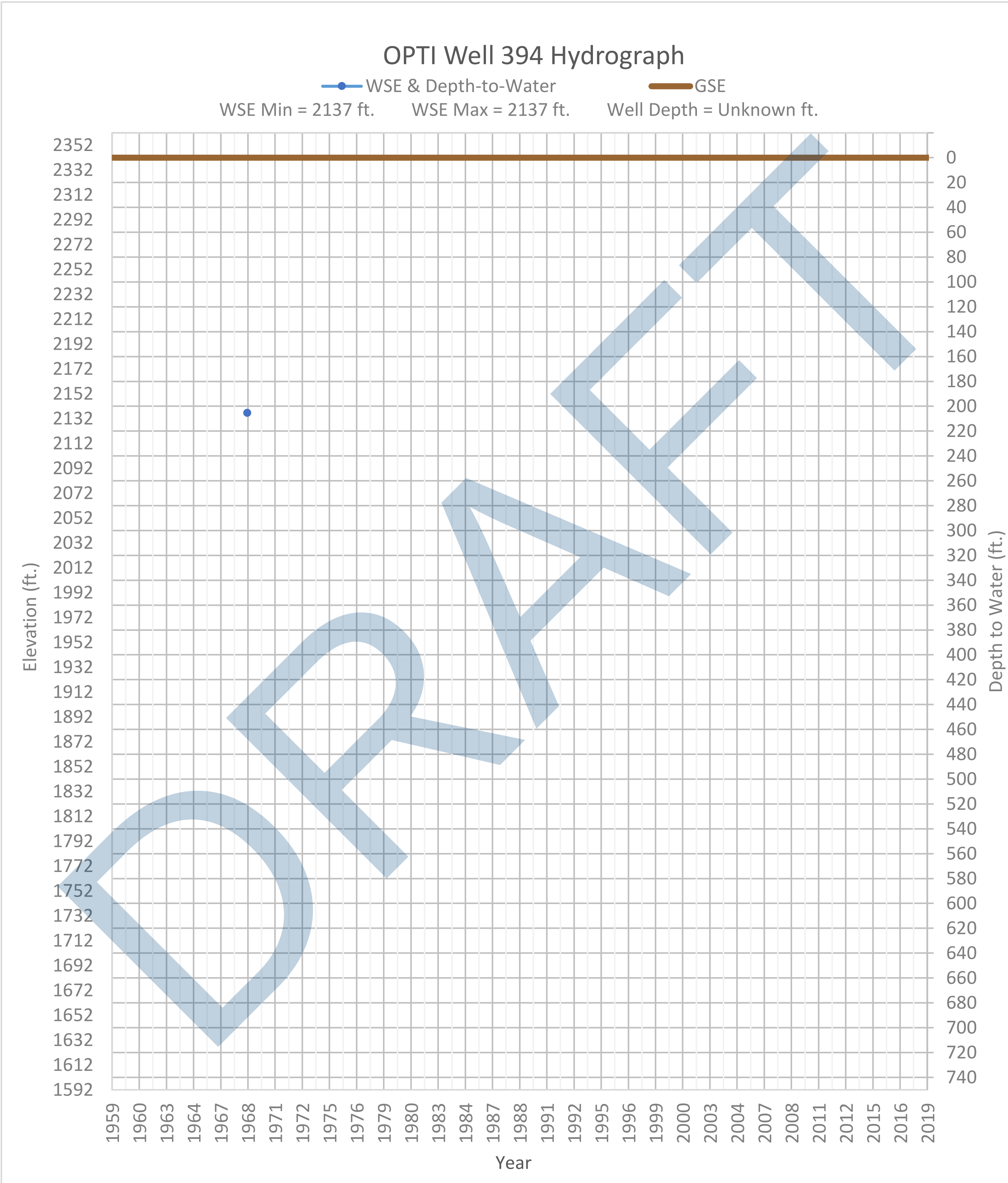
OPTI Well 388 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2227 ft.
WSE Max = 2227 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



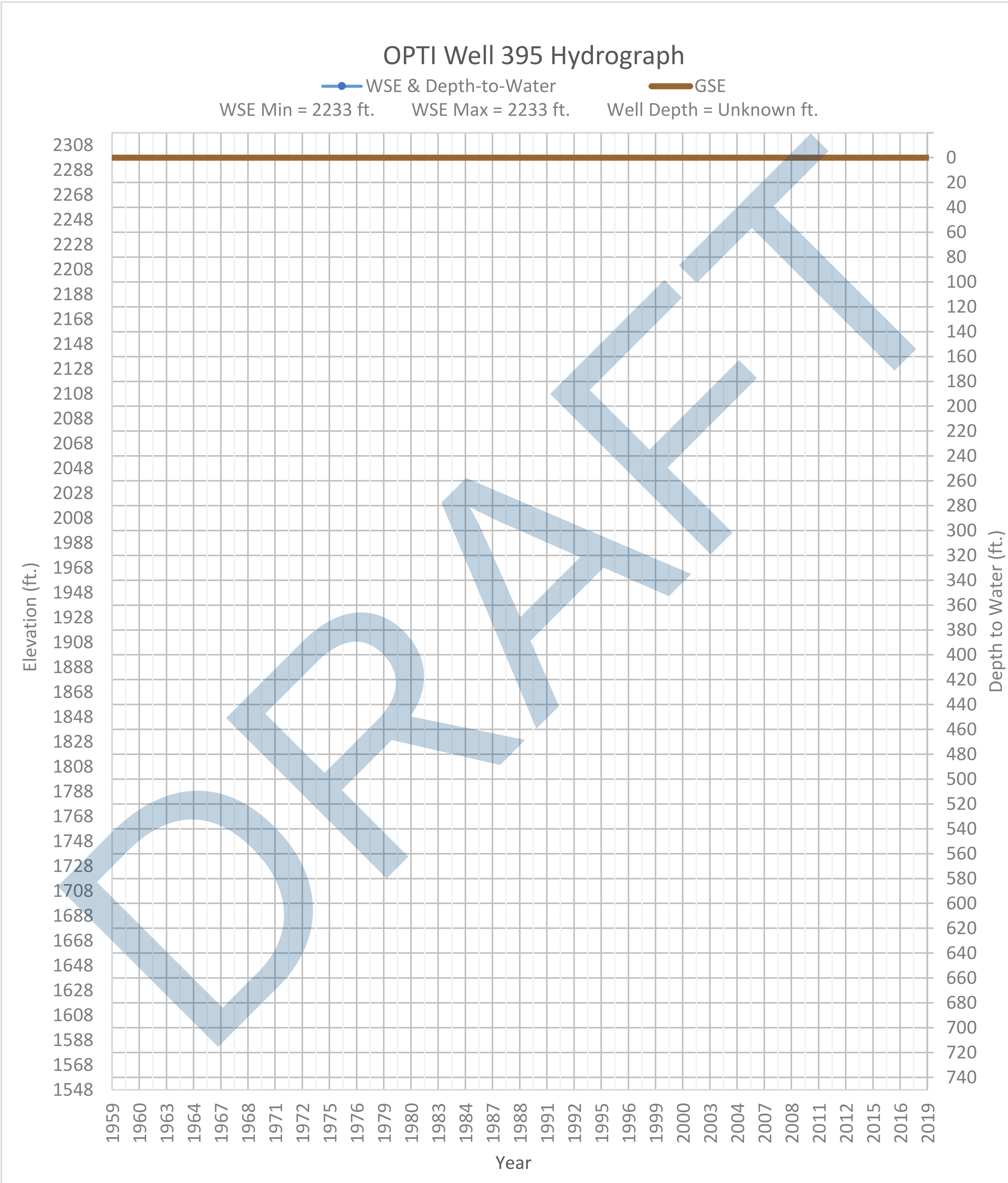
OPTI Well 392 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2222 ft.
WSE Max = 2233 ft.
Well Depth = 298 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



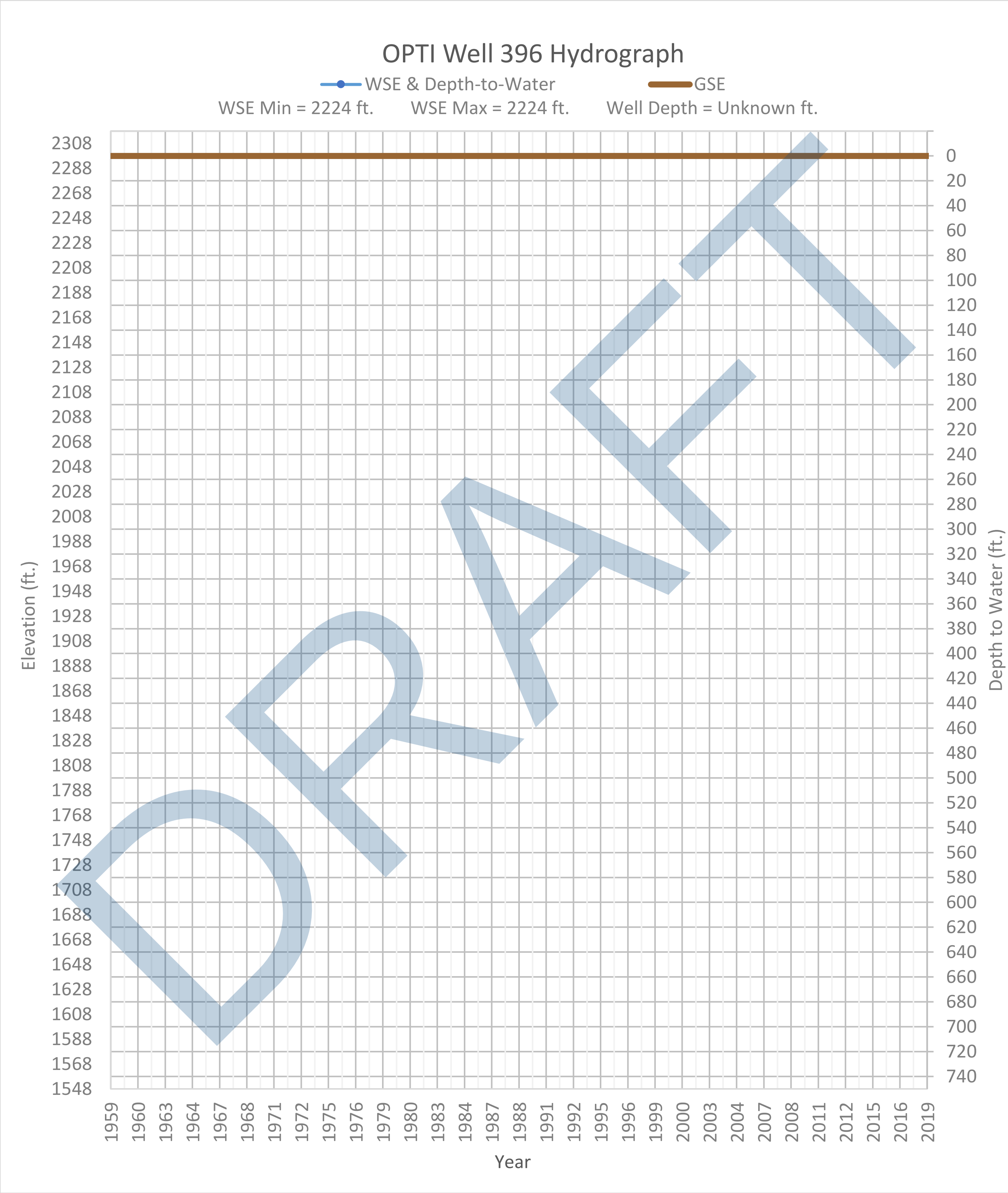
OPTI Well 393 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1903 ft.
WSE Max = 2159 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

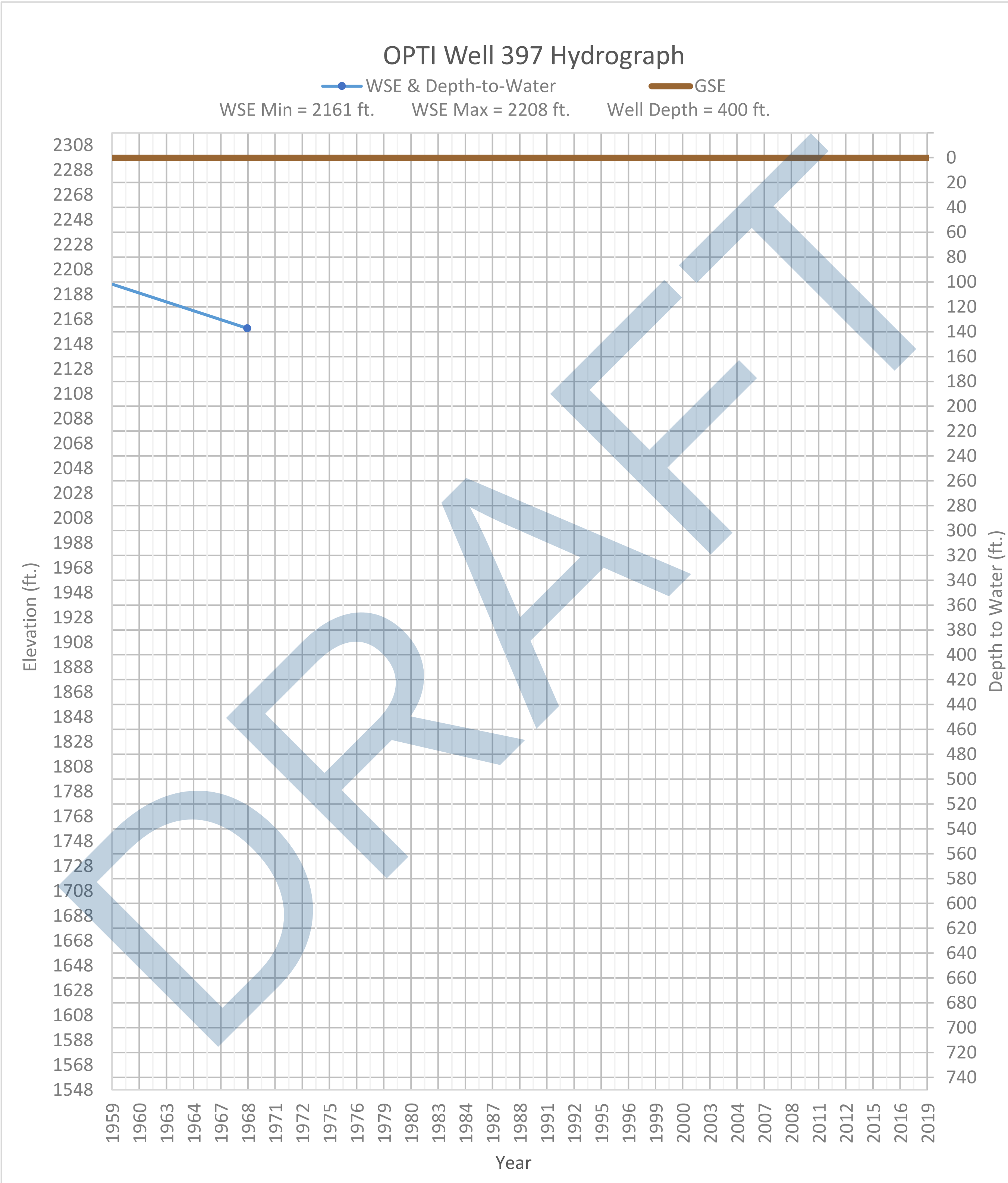


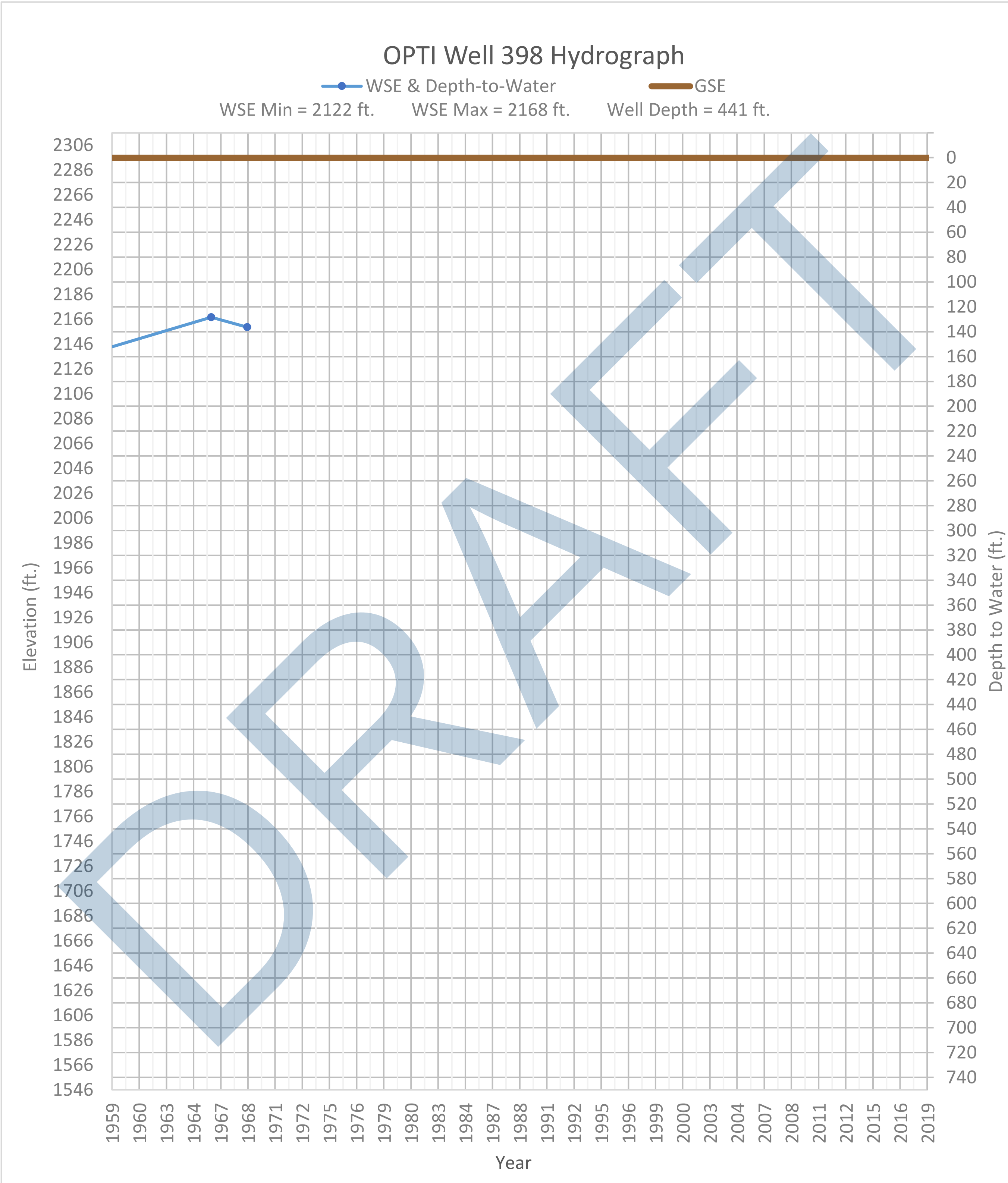
OPTI Well 394 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2137 ft.
WSE Max = 2137 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



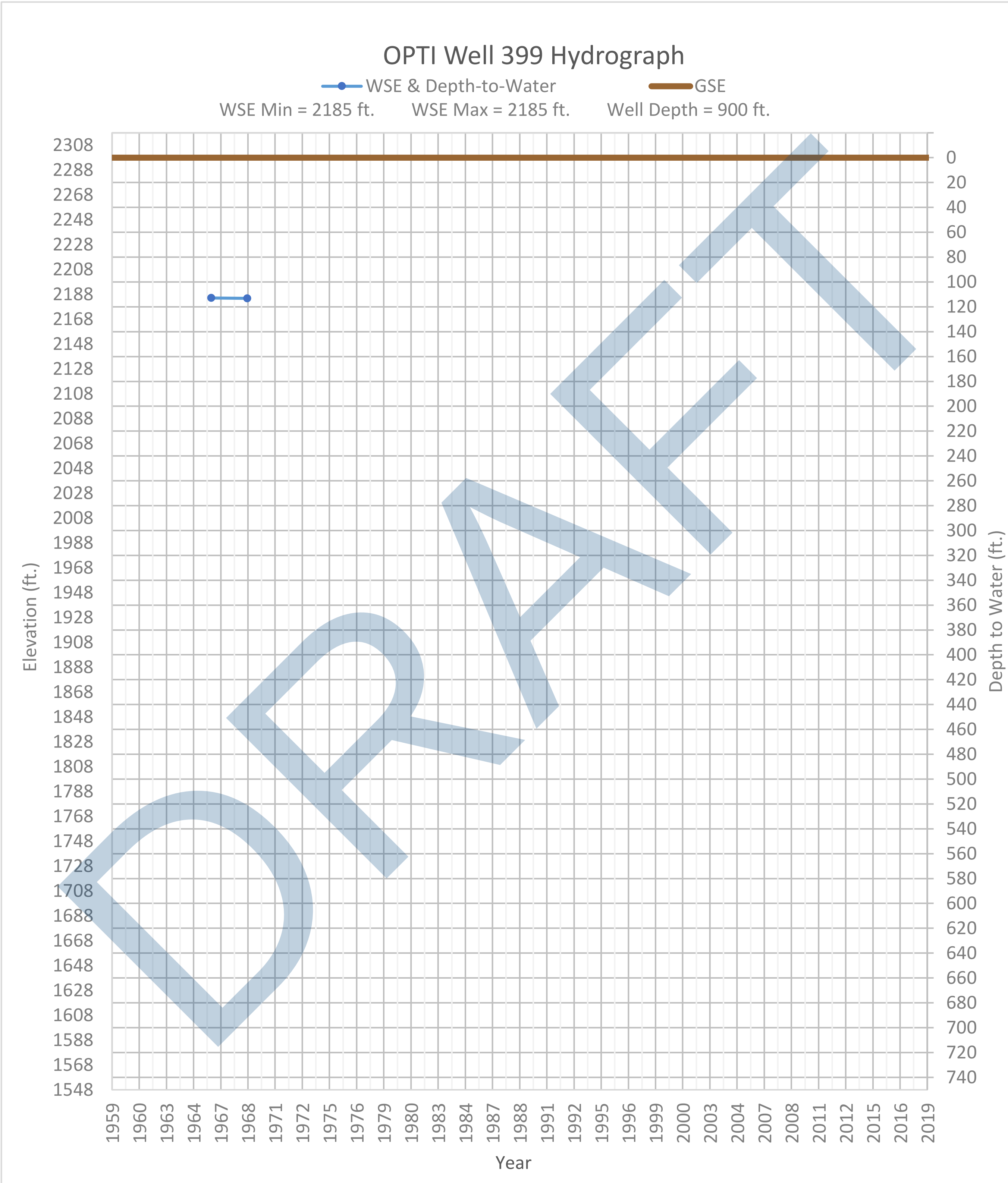
OPTI Well 395 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2233 ft.
WSE Max = 2233 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 396 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2224 ft.
WSE Max = 2224 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

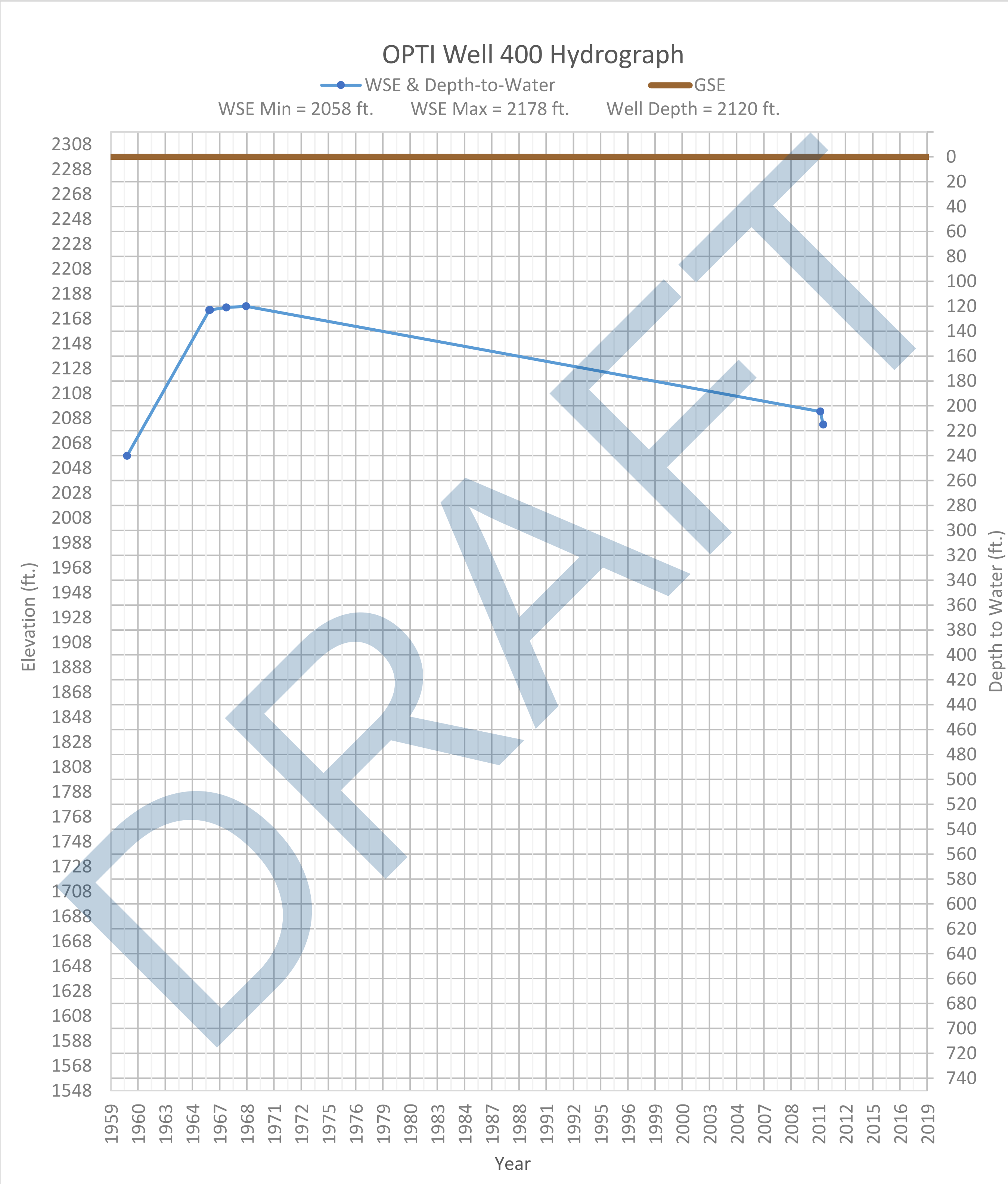

OPTI Well 397 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2161 ft.
WSE Max = 2208 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



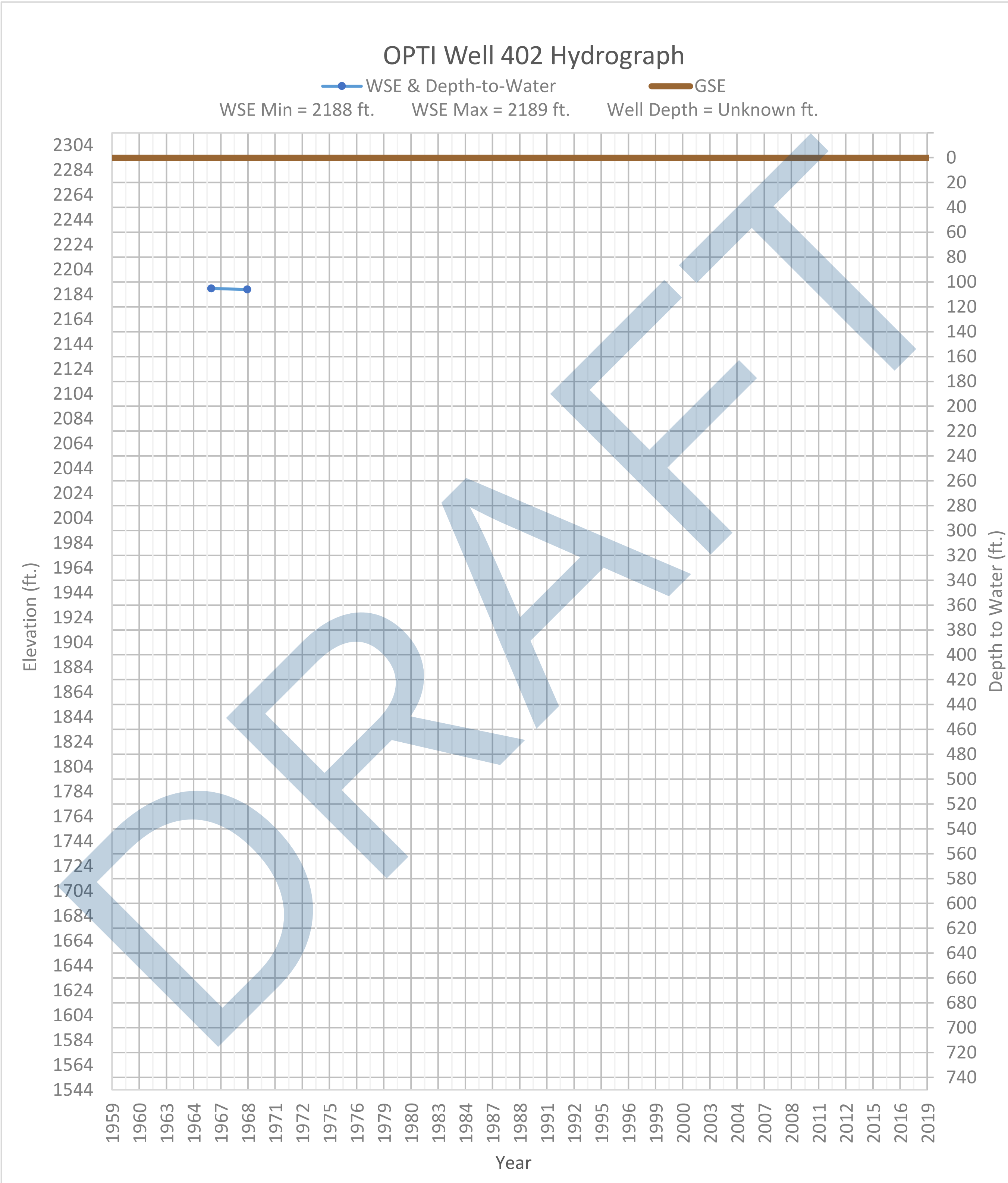
OPTI Well 398 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2122 ft.
WSE Max = 2168 ft.
Well Depth = 441 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

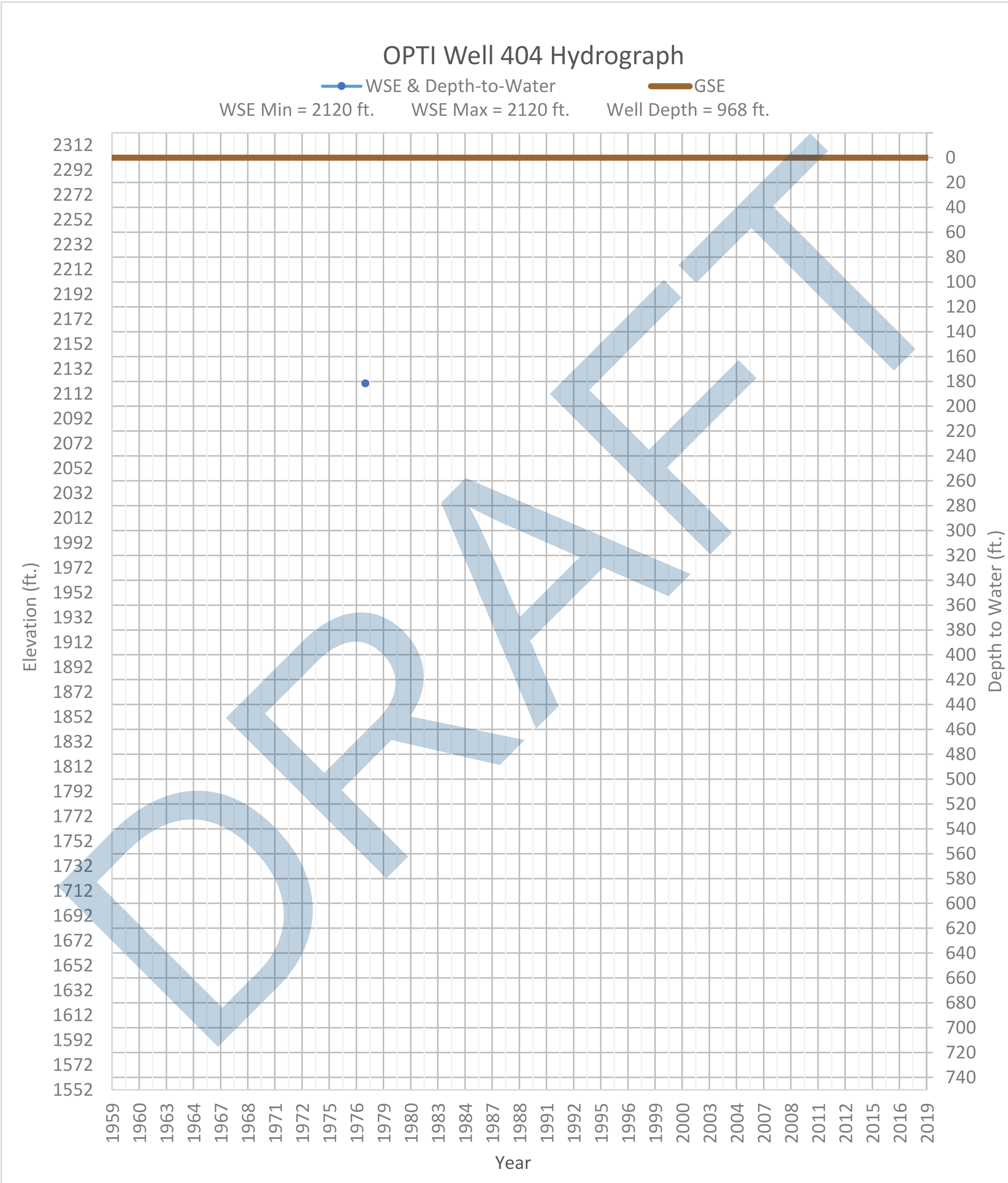


OPTI Well 399 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2185 ft.
WSE Max = 2185 ft.
Well Depth = 900 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

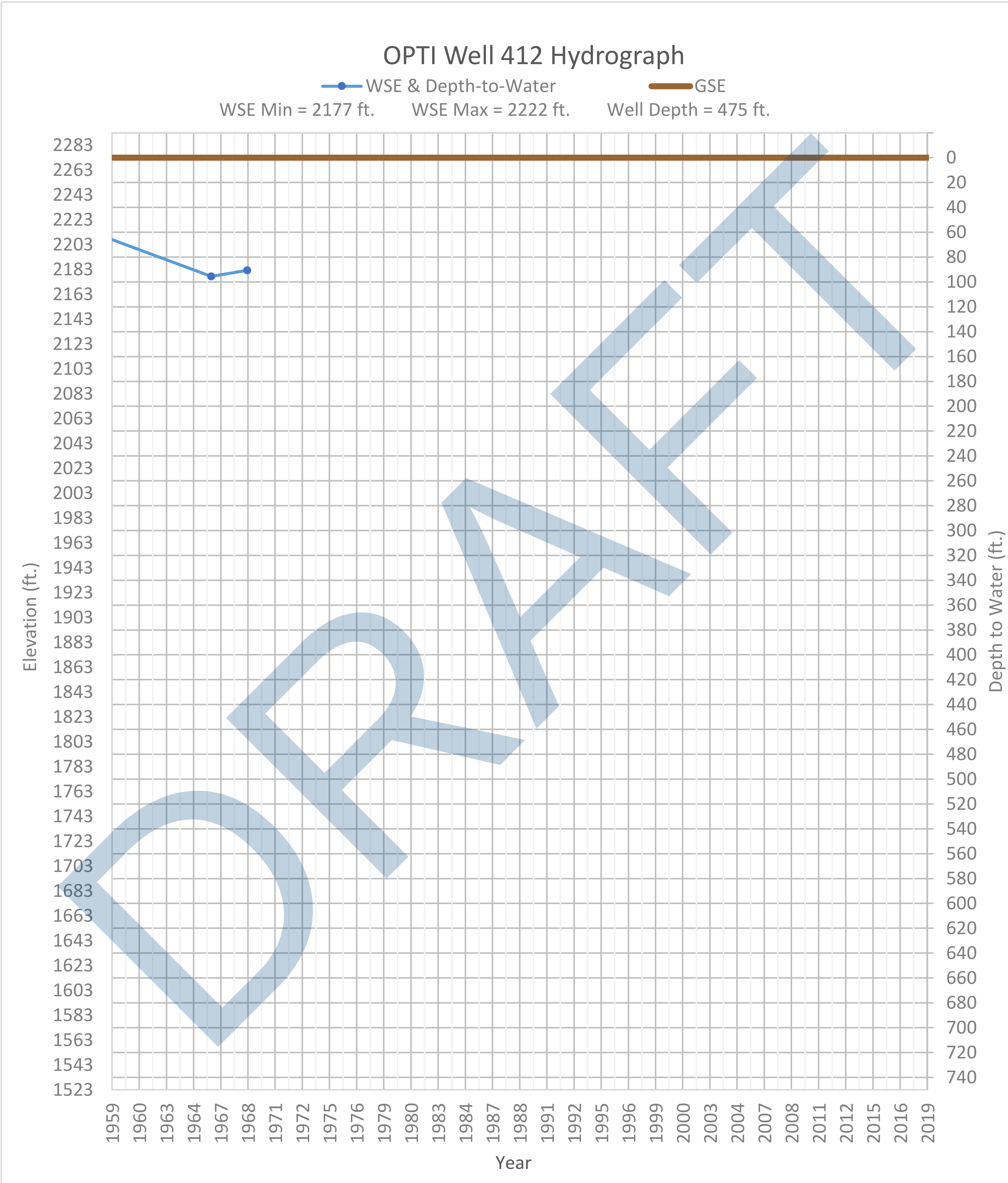


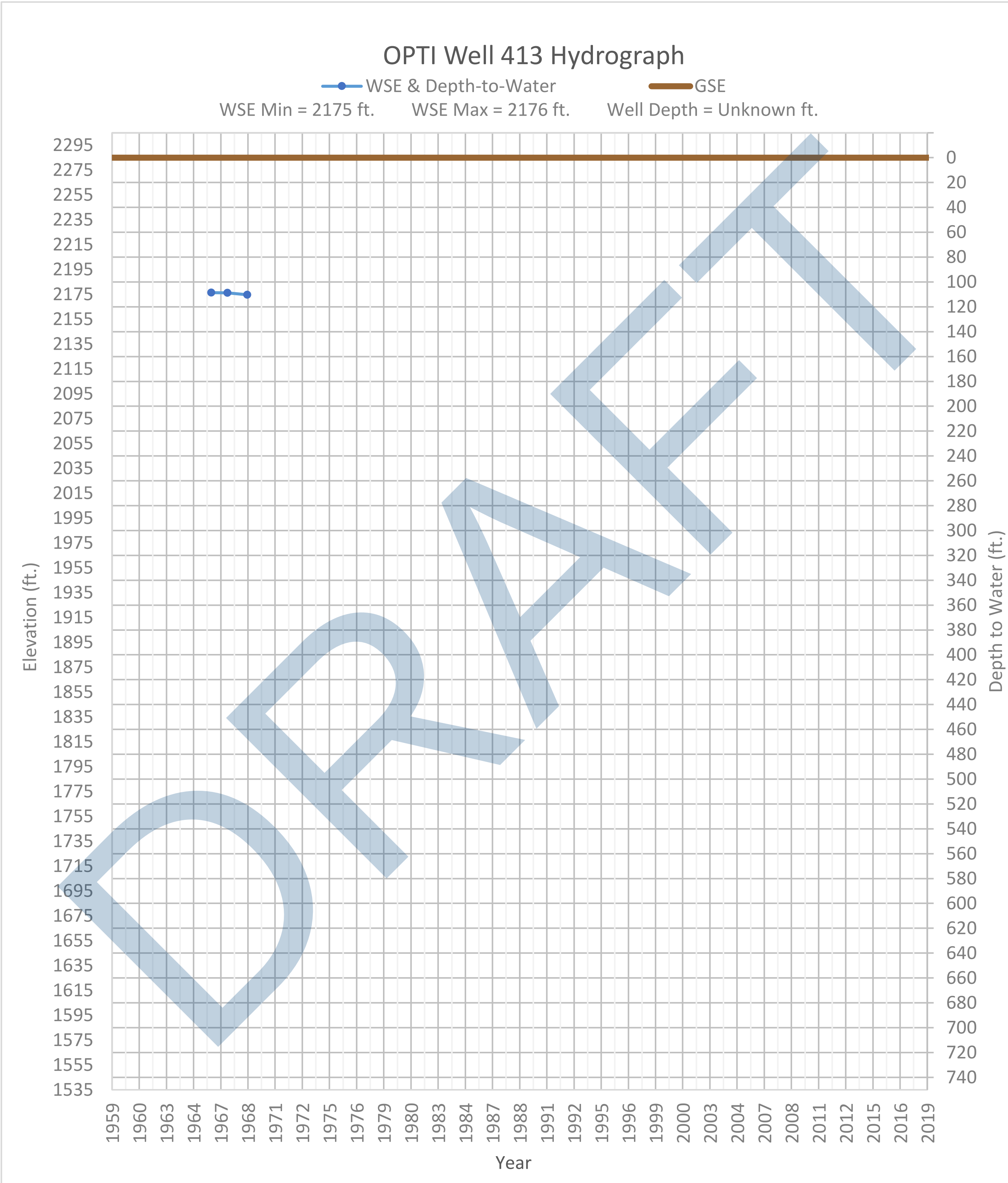
OPTI Well 400 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2058 ft.
WSE Max = 2178 ft.
Well Depth = 2120 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 402 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2188 ft.
WSE Max = 2189 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

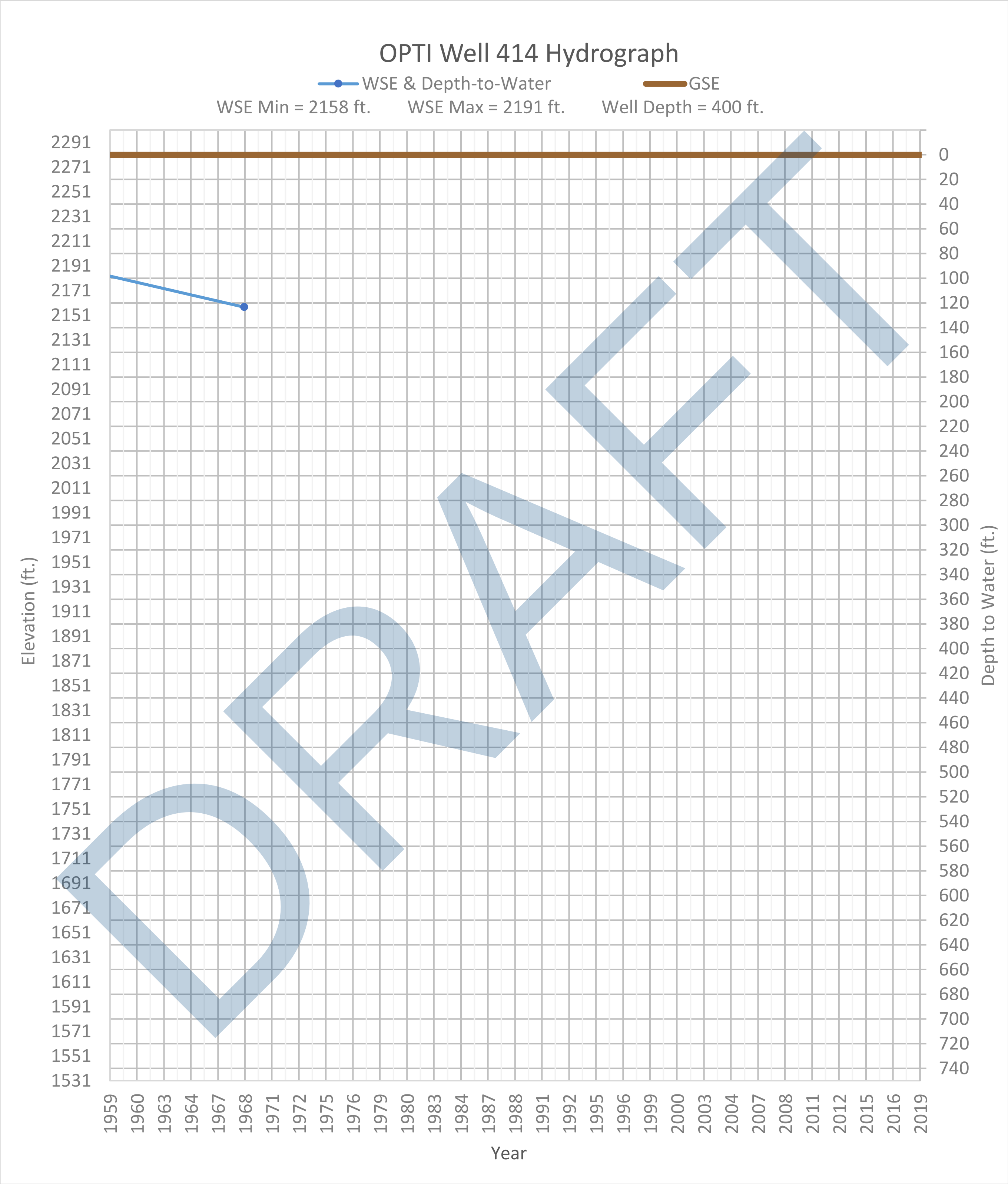


OPTI Well 404 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2120 ft.
WSE Max = 2120 ft.
Well Depth = 968 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

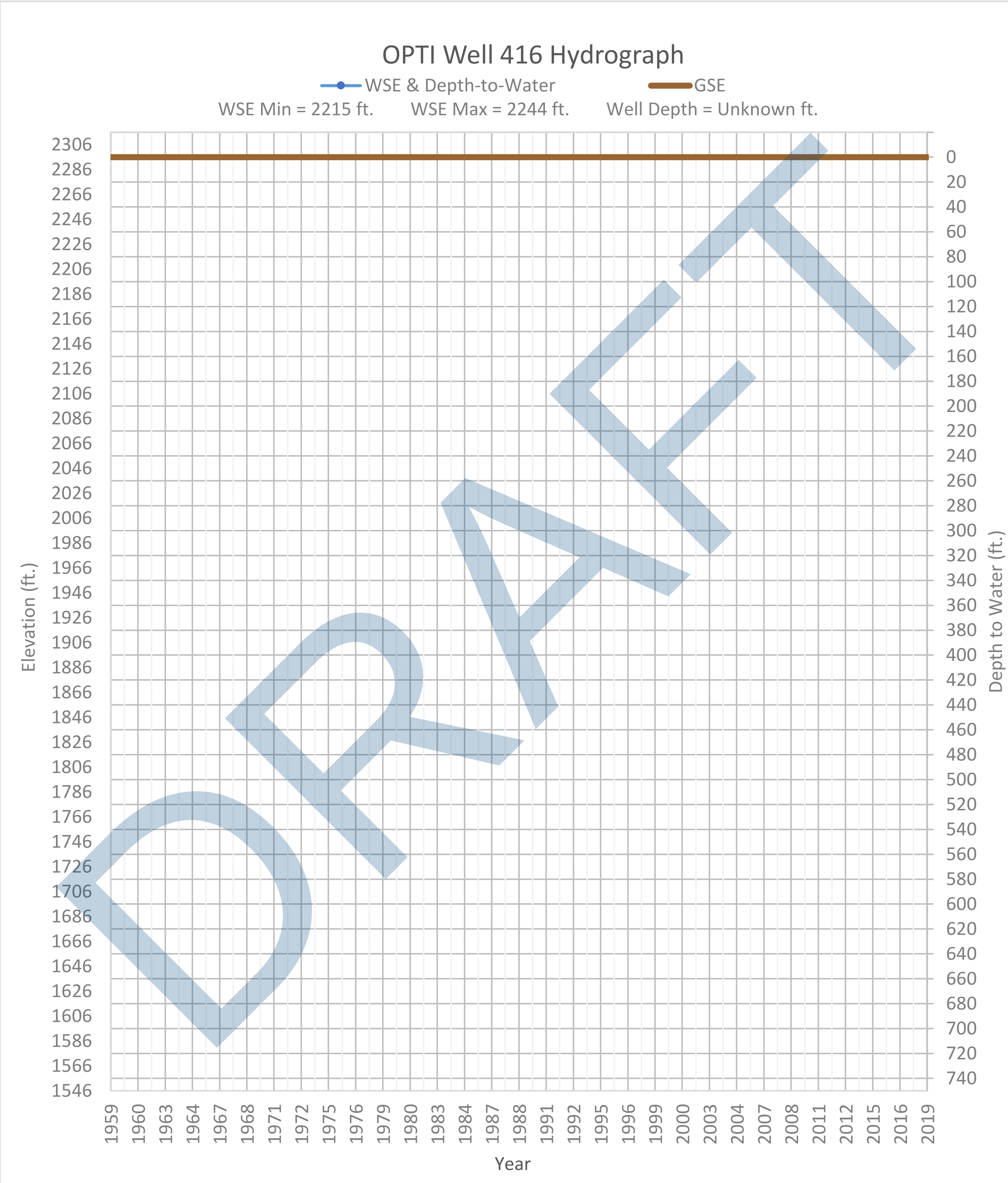

OPTI Well 412 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2177 ft.
WSE Max = 2222 ft.
Well Depth = 475 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



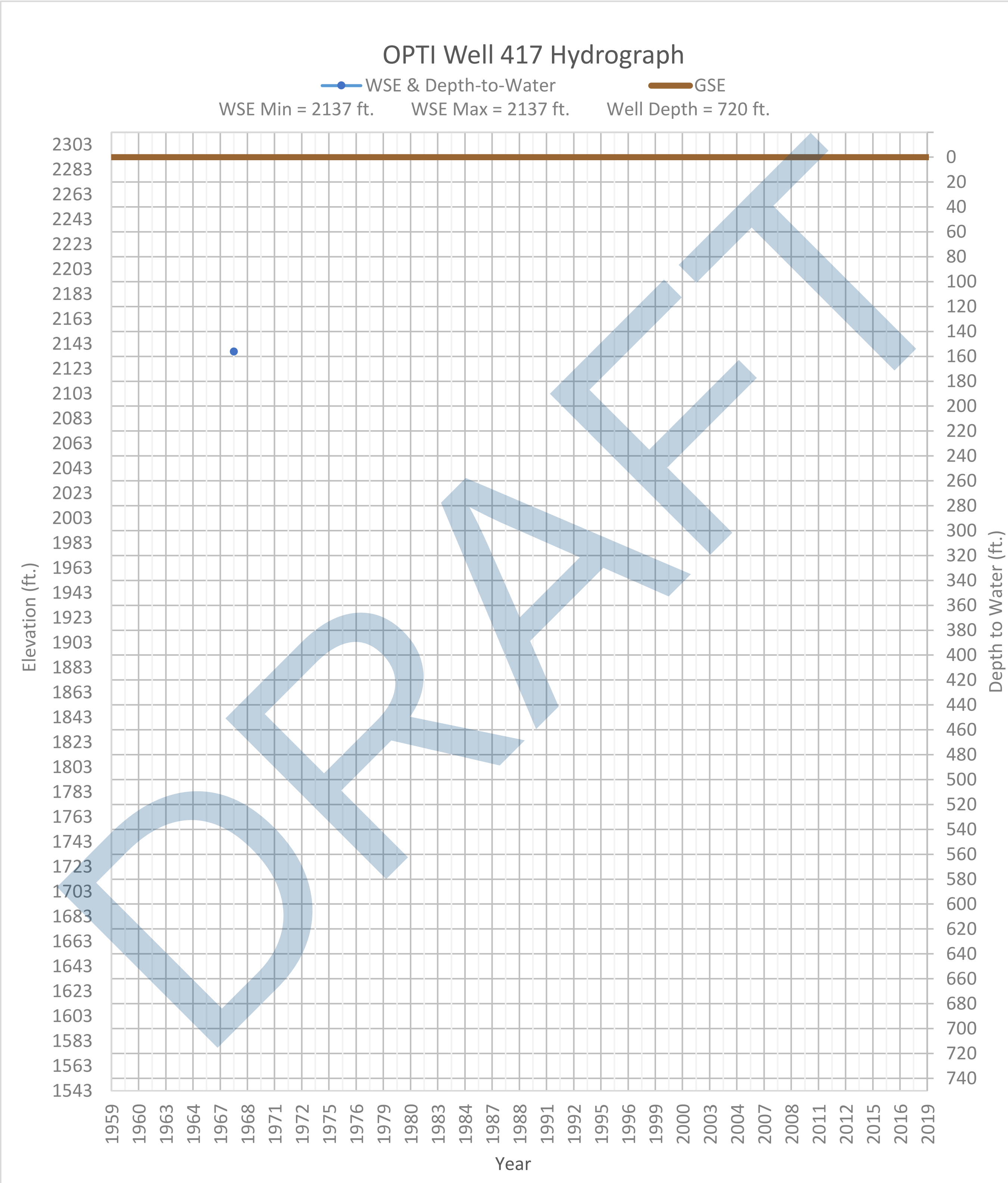
OPTI Well 413 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2175 ft.
WSE Max = 2176 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



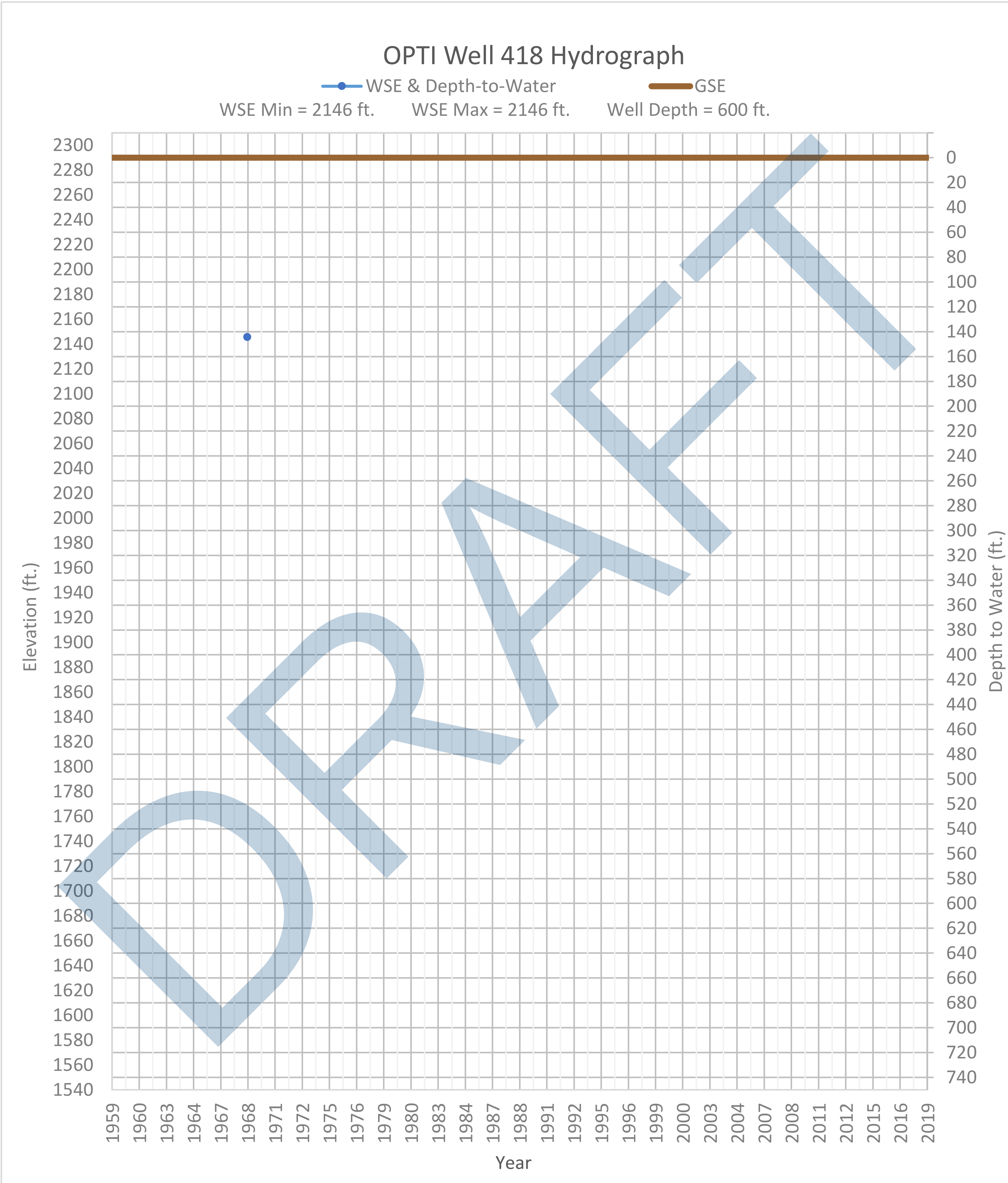
OPTI Well 414 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2158 ft.
WSE Max = 2191 ft.
Well Depth = 400 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



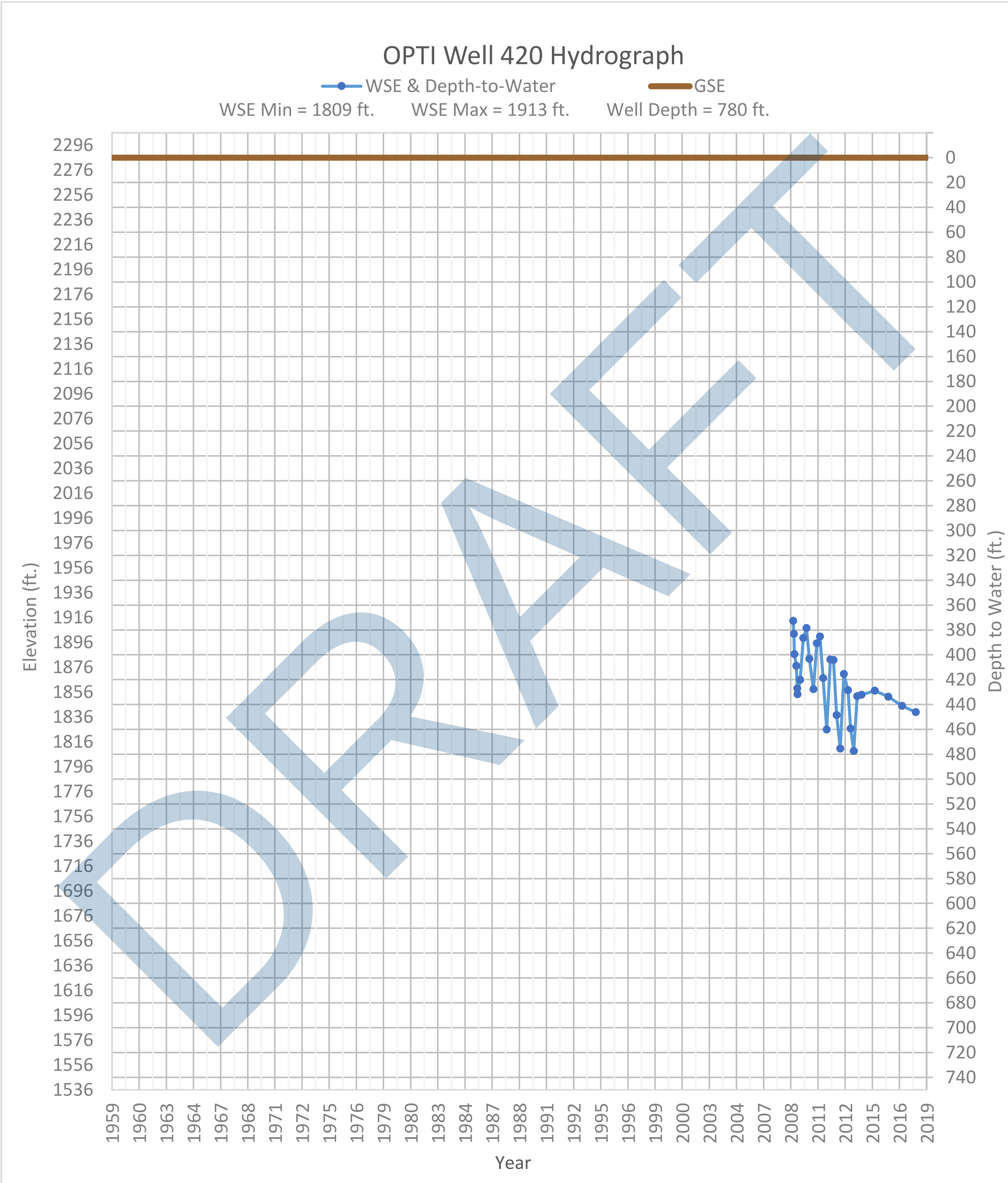
OPTI Well 416 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2215 ft.
WSE Max = 2244 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



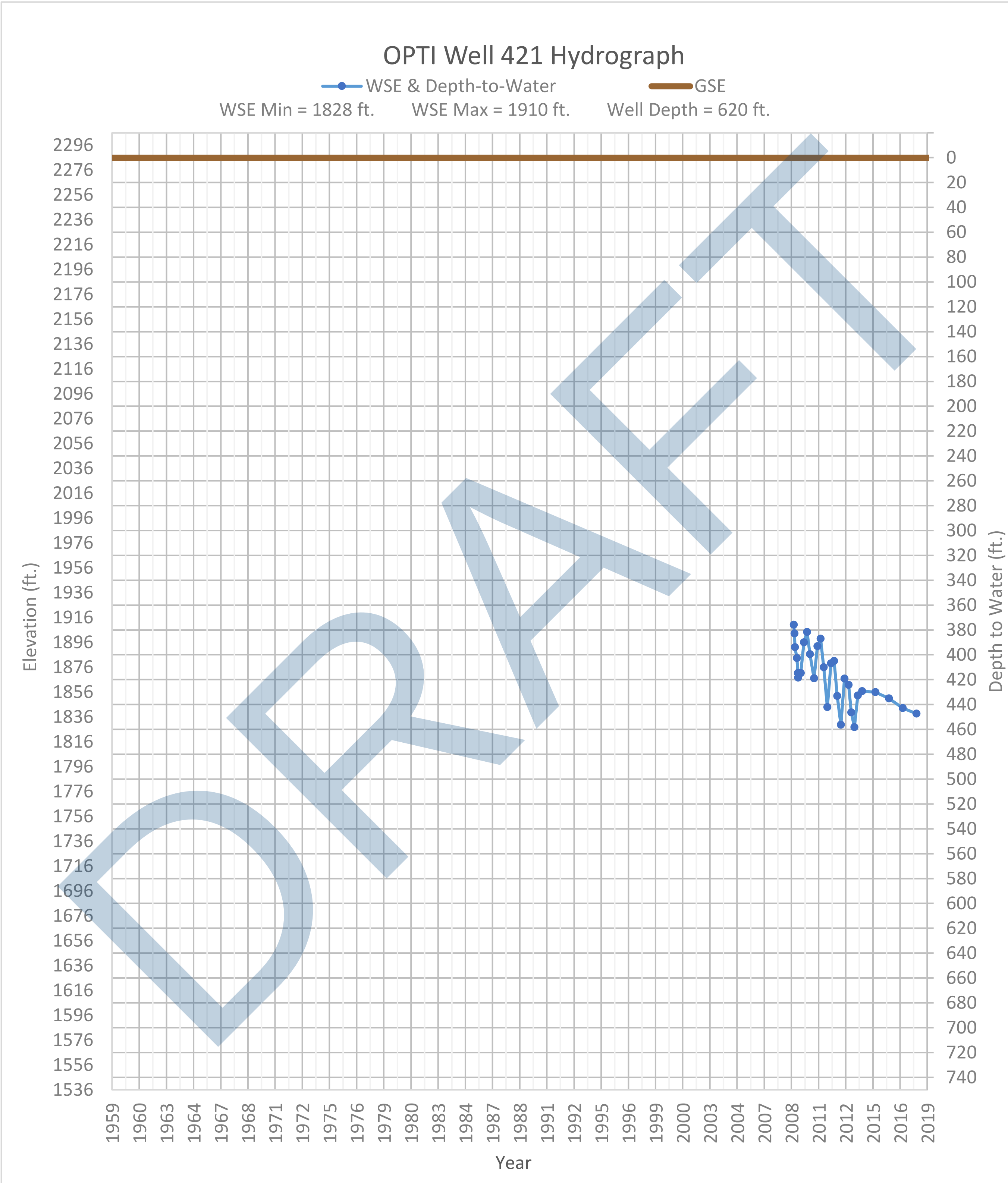
OPTI Well 417 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2137 ft.
WSE Max = 2137 ft.
Well Depth = 720 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

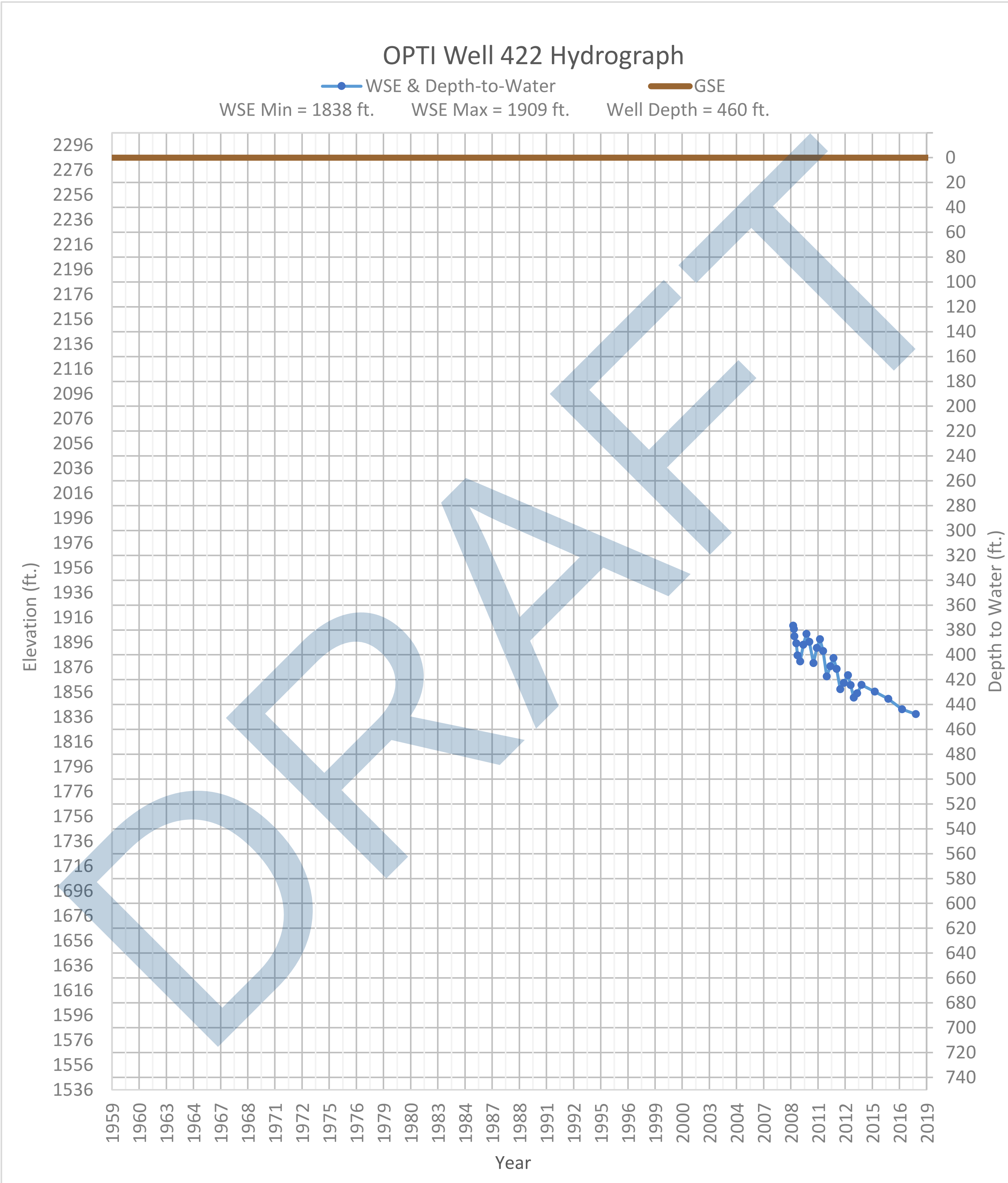


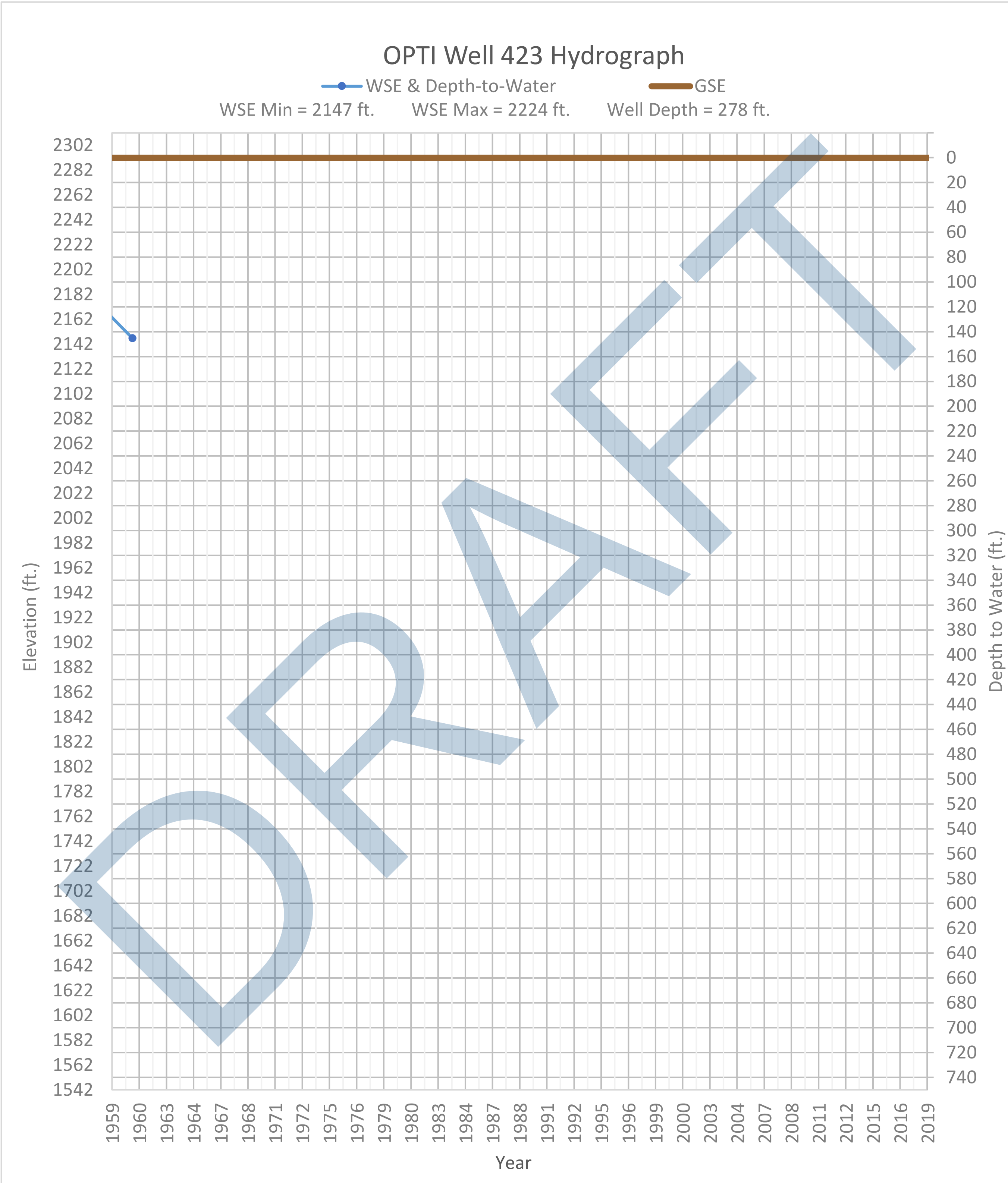
OPTI Well 418 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2146 ft.
WSE Max = 2146 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



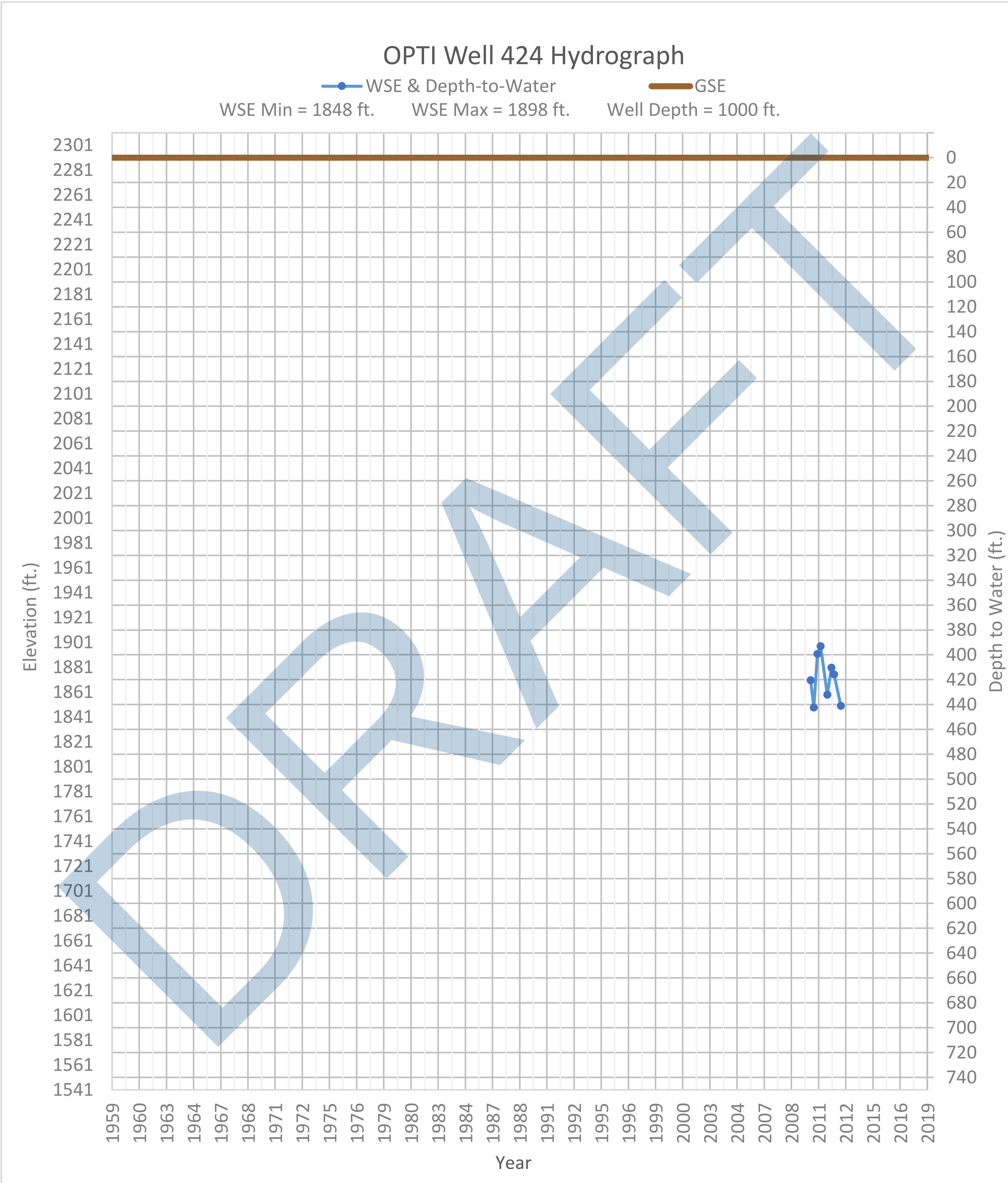
OPTI Well 420 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1809 ft.
WSE Max = 1913 ft.
Well Depth = 780 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 421 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1828 ft.
WSE Max = 1910 ft.
Well Depth = 620 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

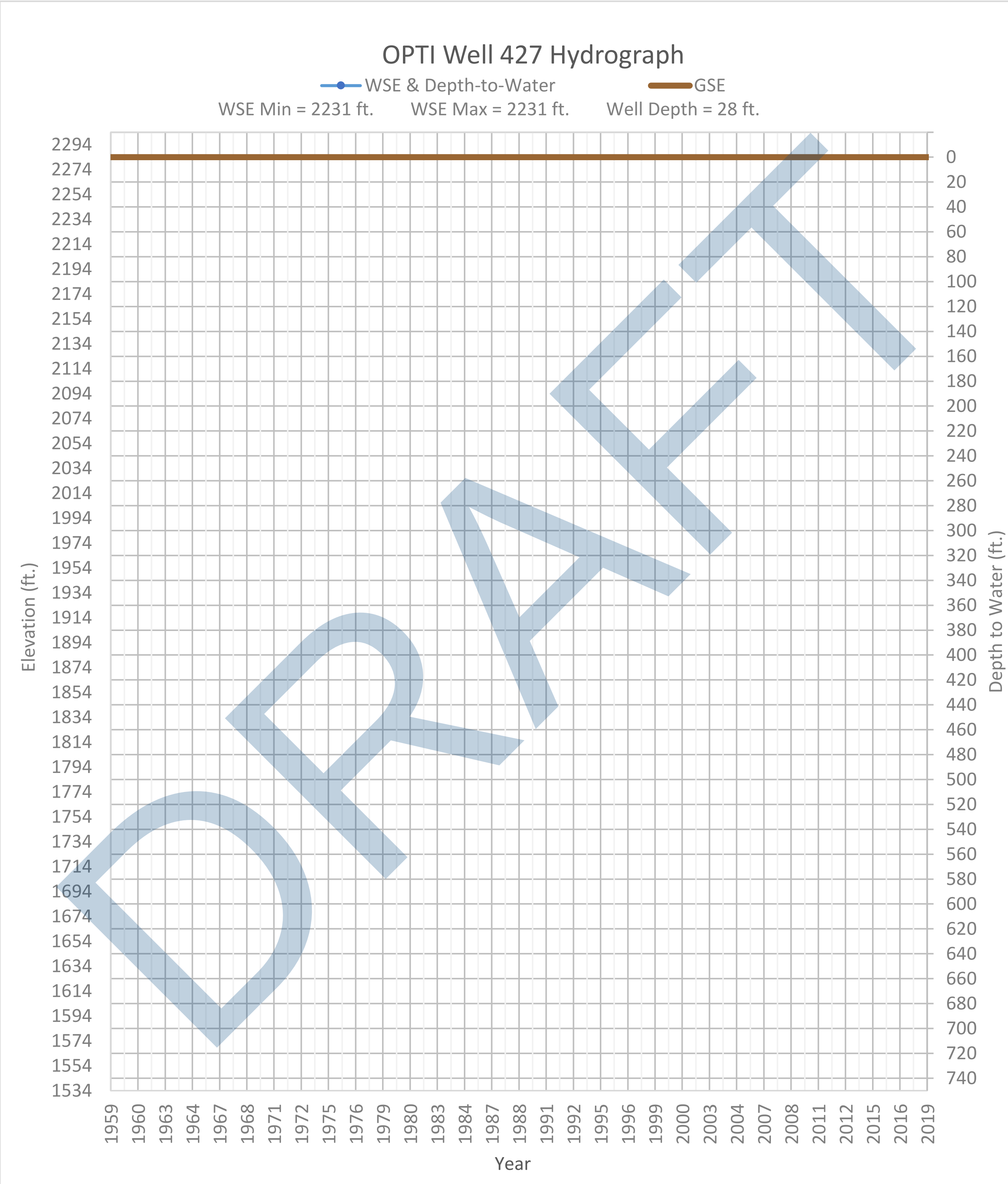

OPTI Well 422 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1838 ft.
WSE Max = 1909 ft.
Well Depth = 460 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



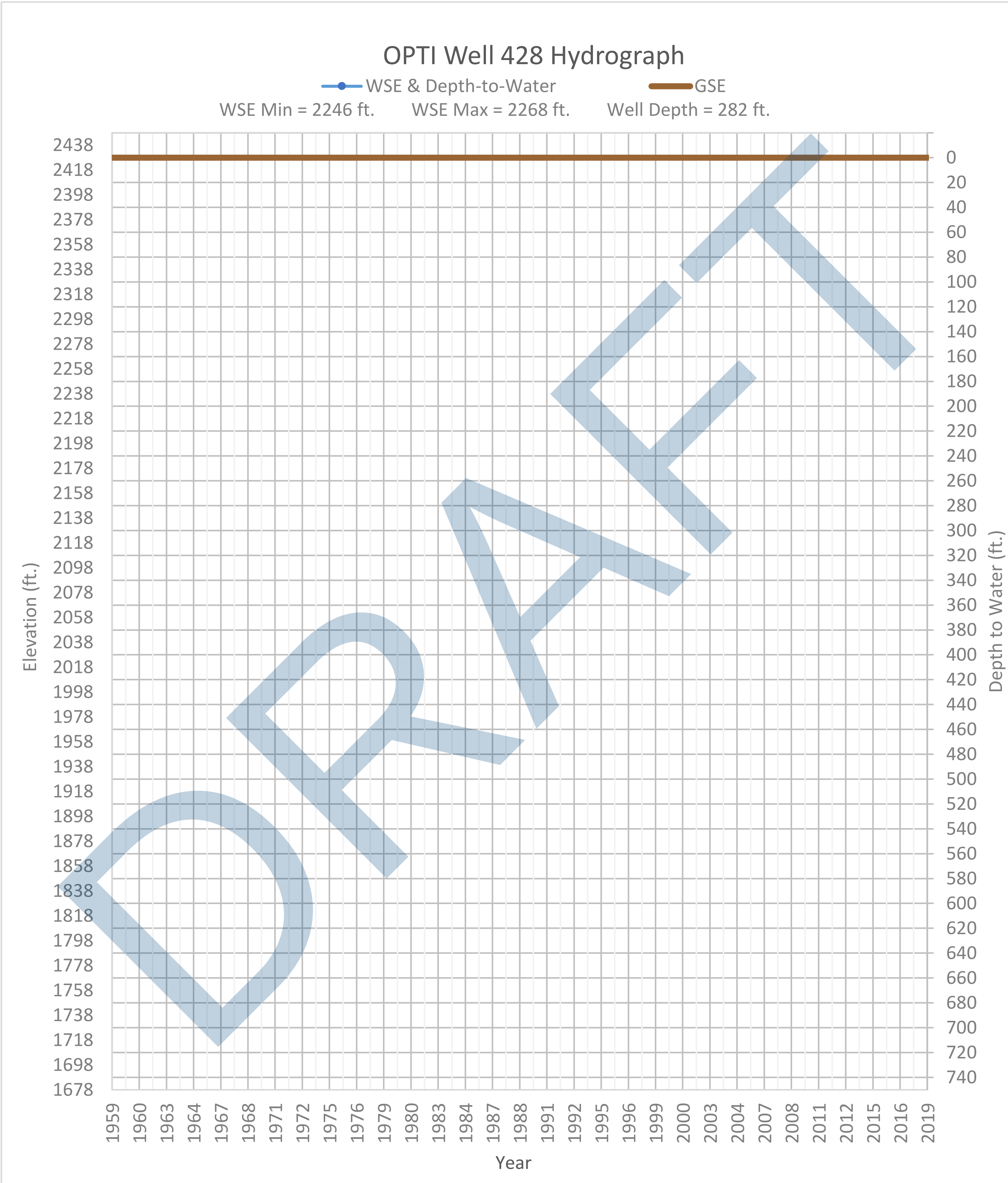
OPTI Well 423 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2147 ft.
WSE Max = 2224 ft.
Well Depth = 278 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



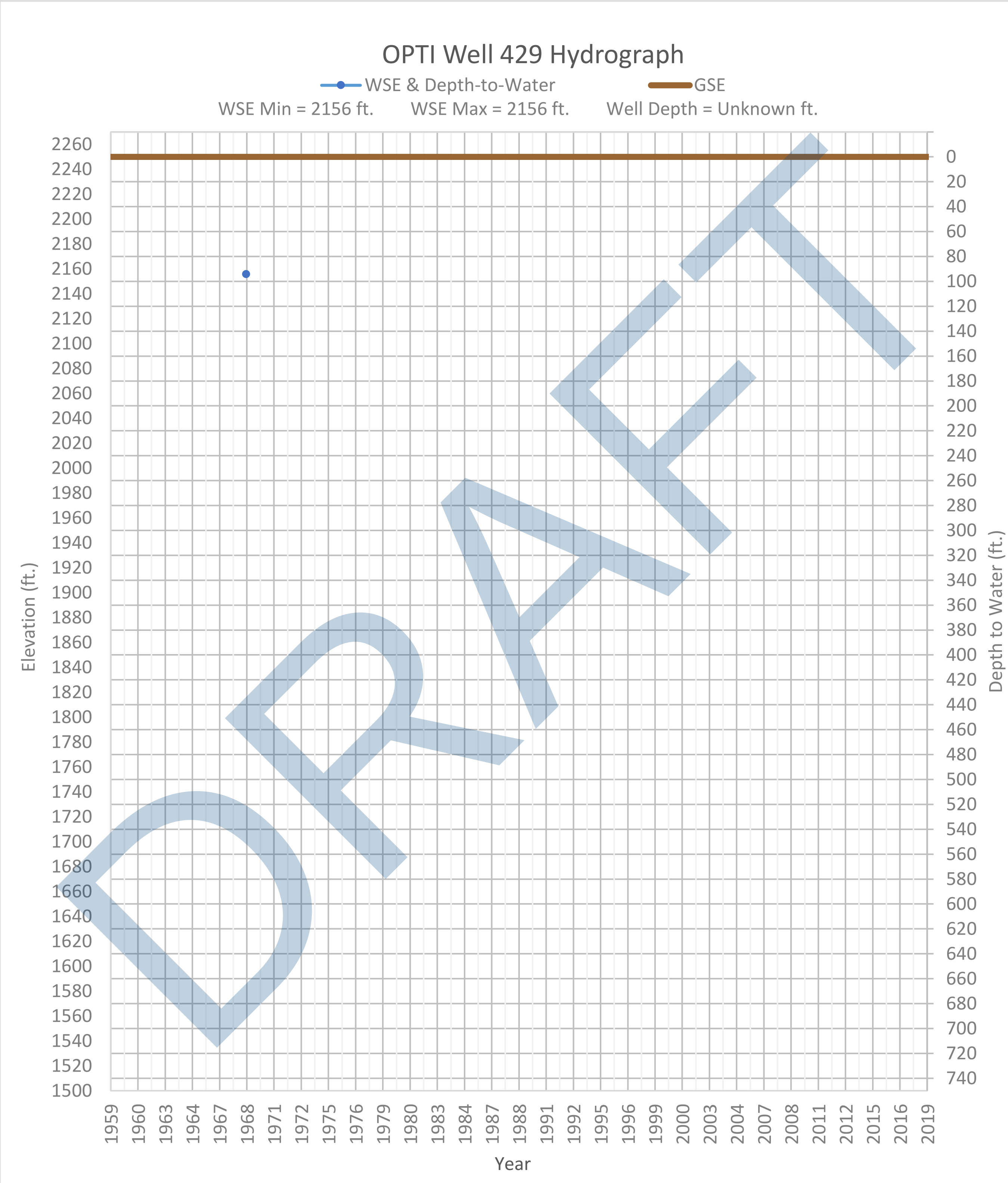
OPTI Well 424 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1848 ft.
WSE Max = 1898 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



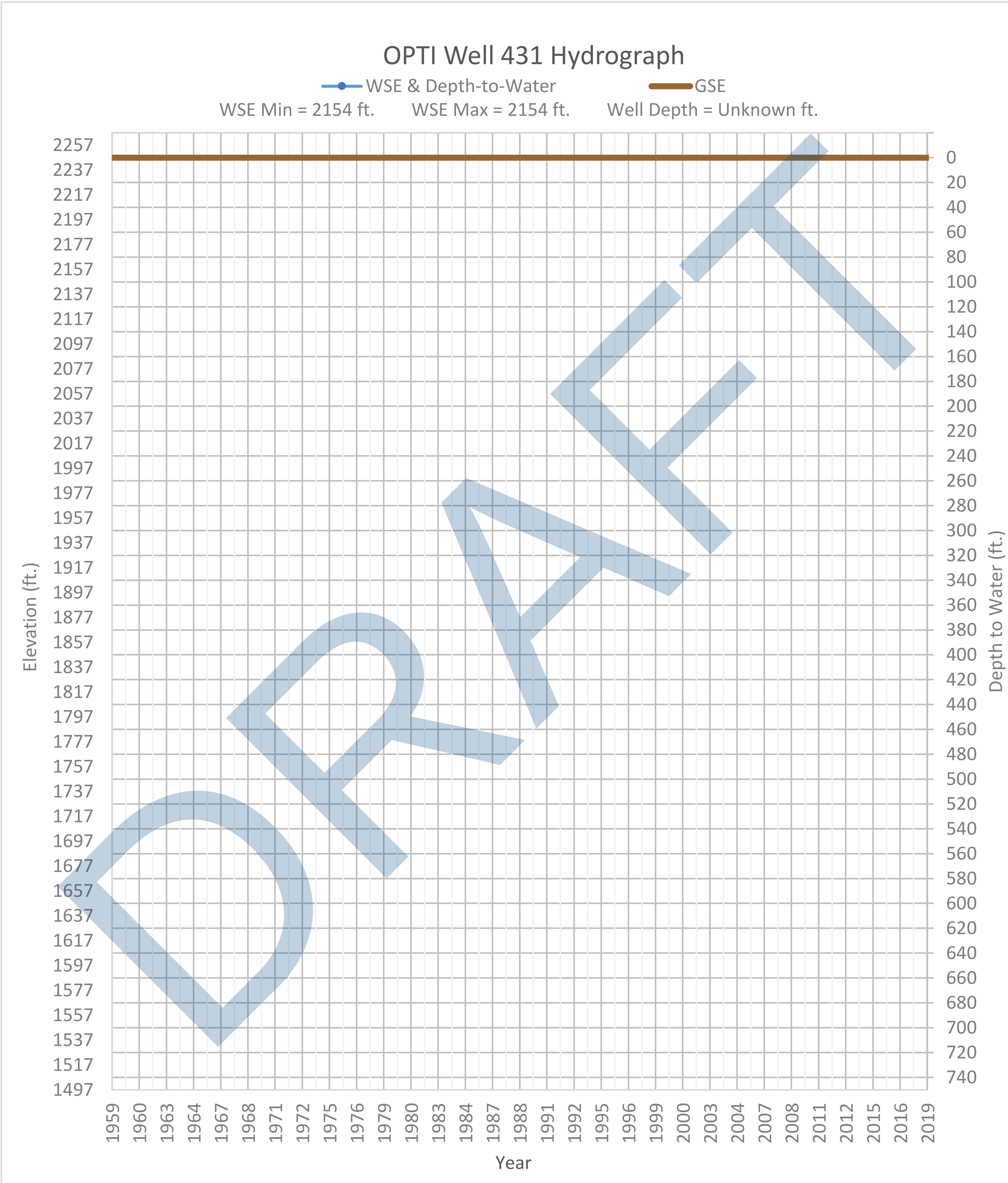
OPTI Well 427 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2231 ft.
WSE Max = 2231 ft.
Well Depth = 28 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



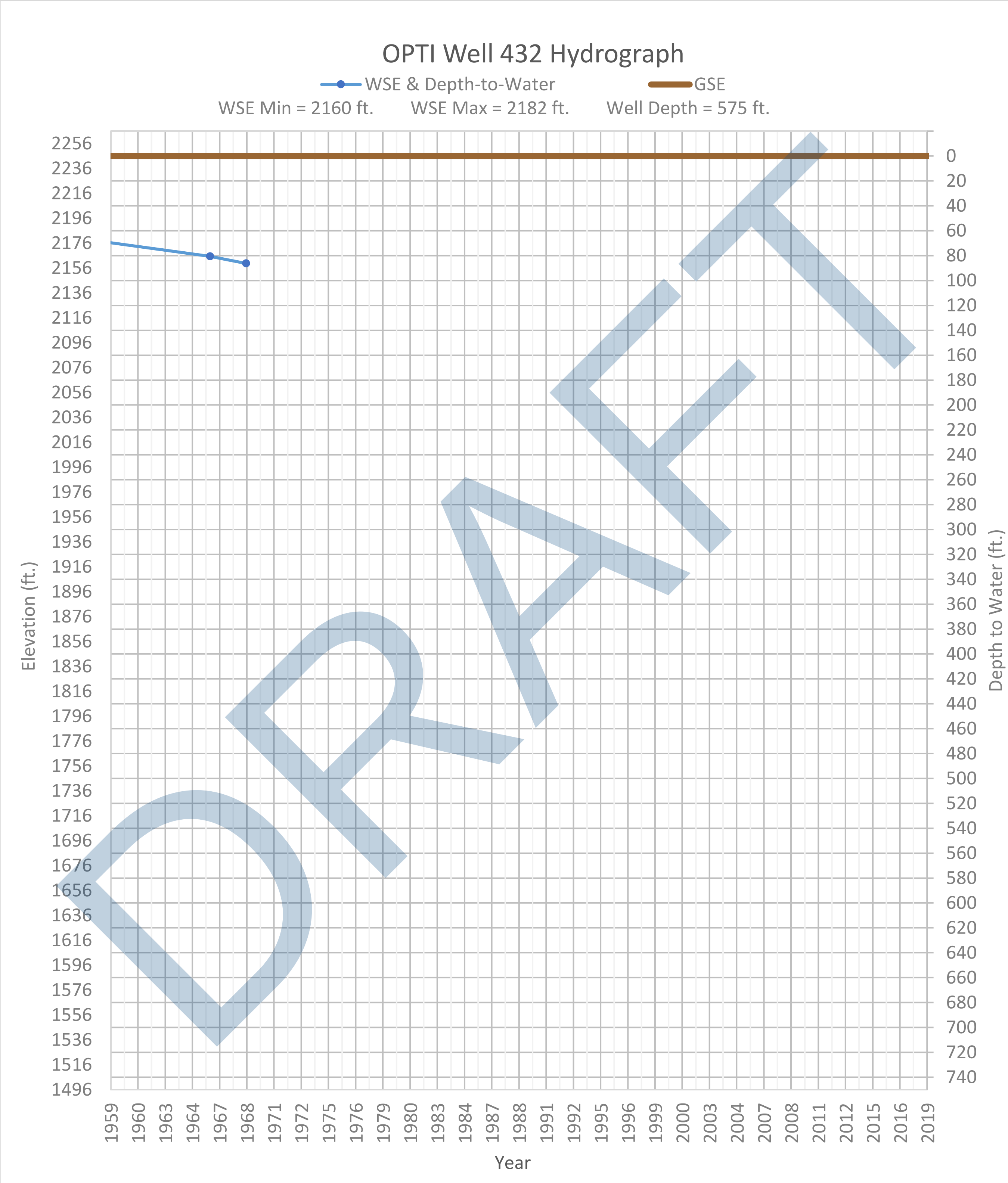
OPTI Well 428 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2246 ft.
WSE Max = 2268 ft.
Well Depth = 282 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



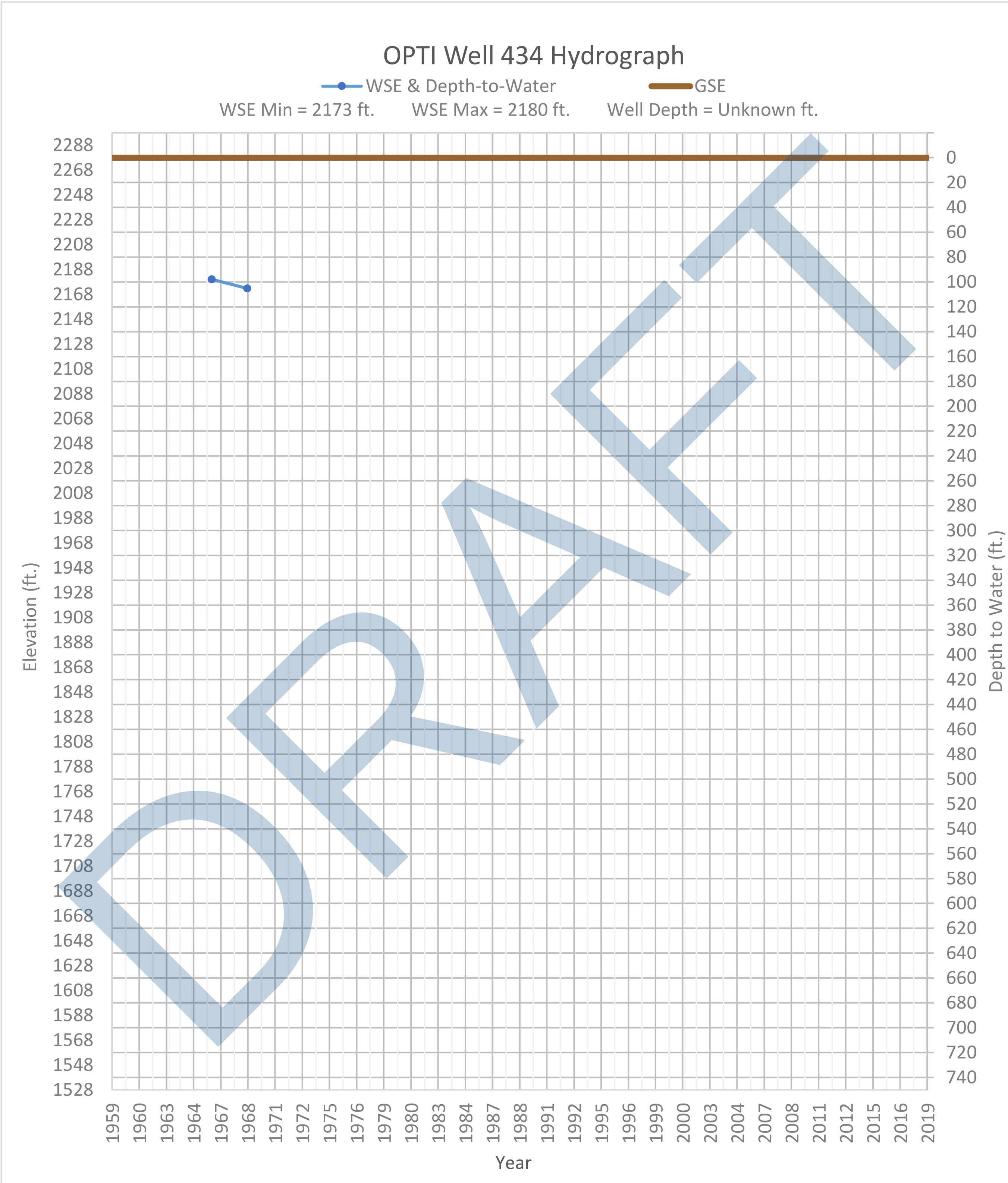
OPTI Well 429 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2156 ft.
WSE Max = 2156 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

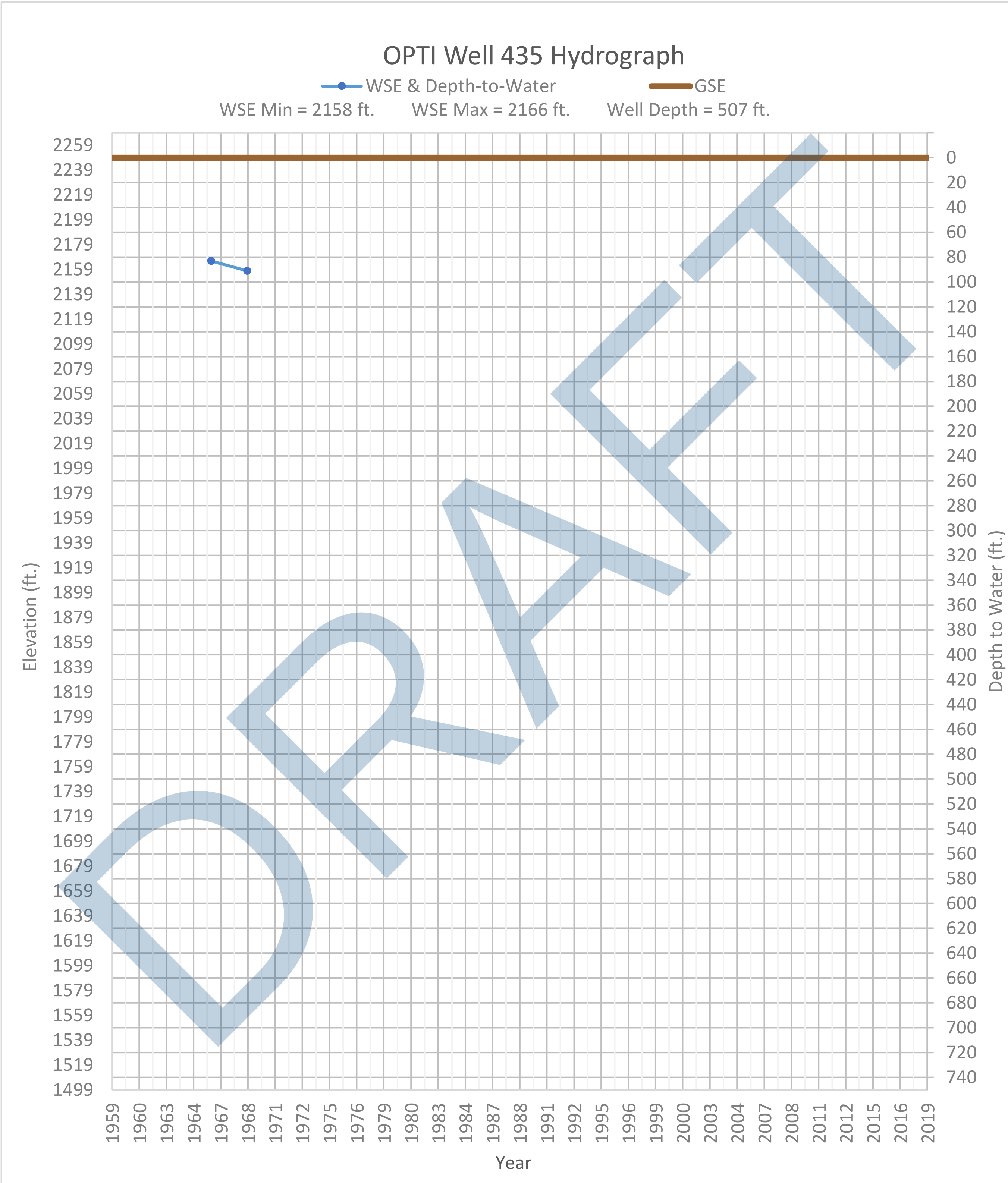


OPTI Well 431 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2154 ft.
WSE Max = 2154 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

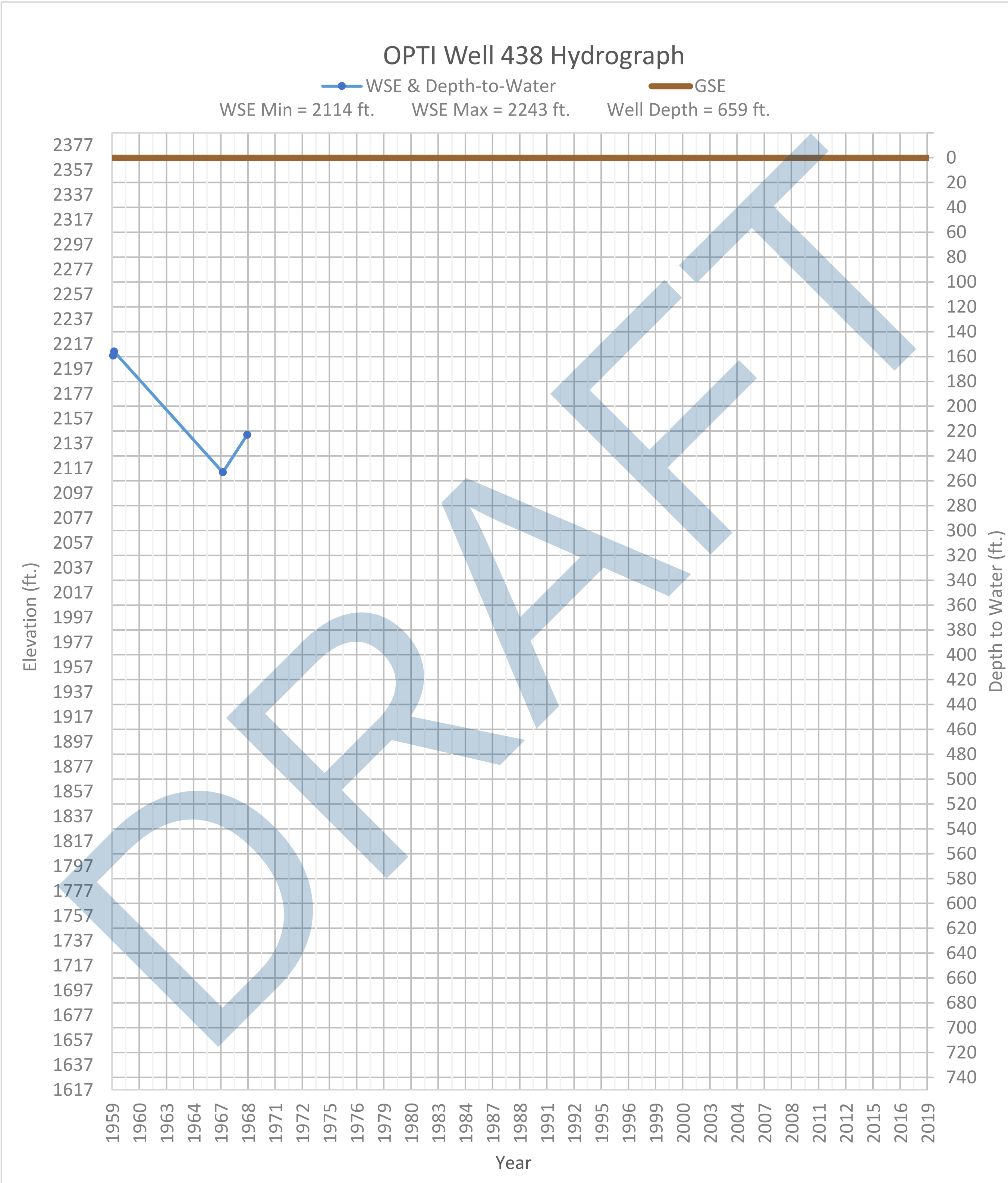


OPTI Well 432 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2160 ft.
WSE Max = 2182 ft.
Well Depth = 575 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

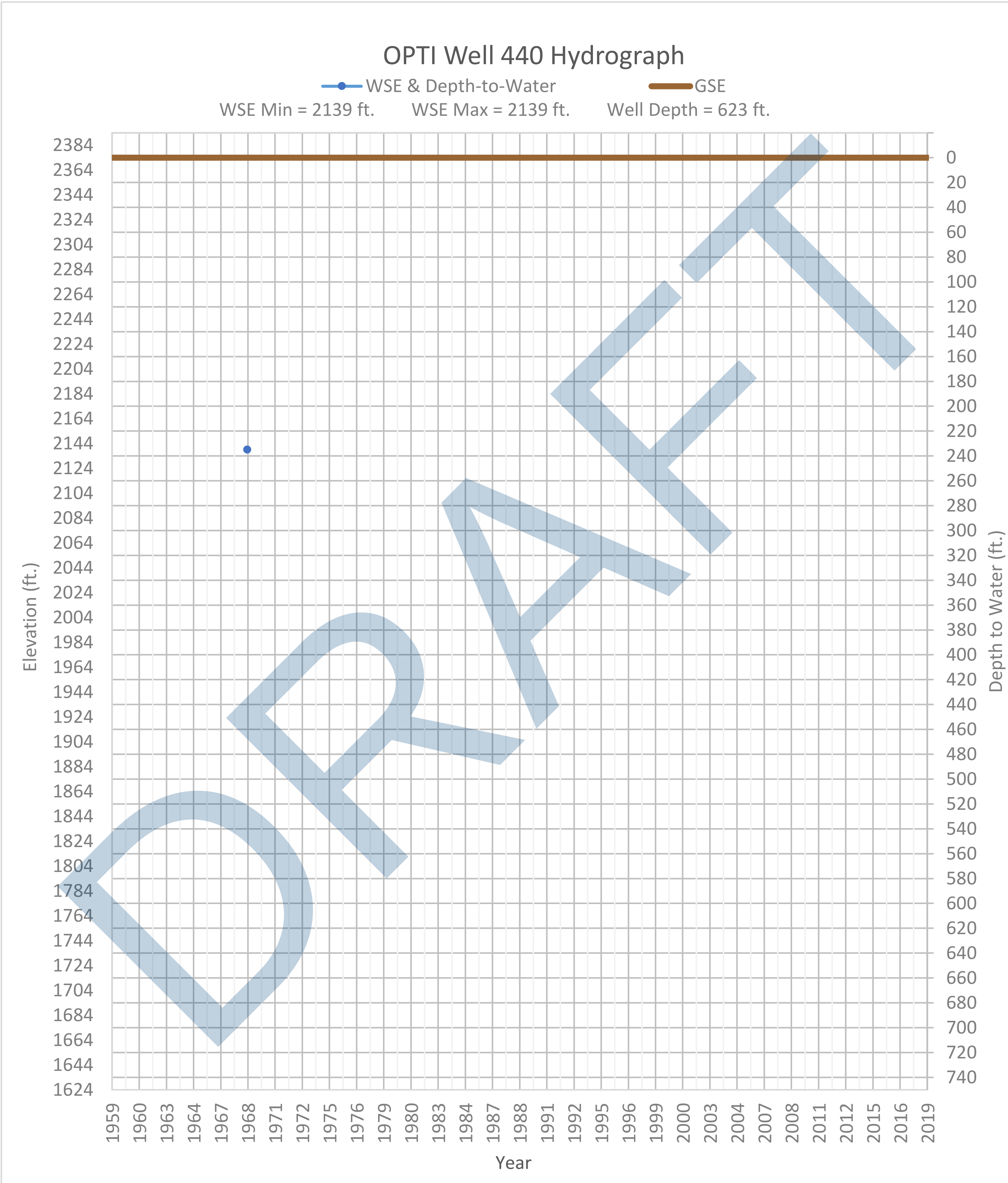

OPTI Well 434 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2173 ft.
WSE Max = 2180 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

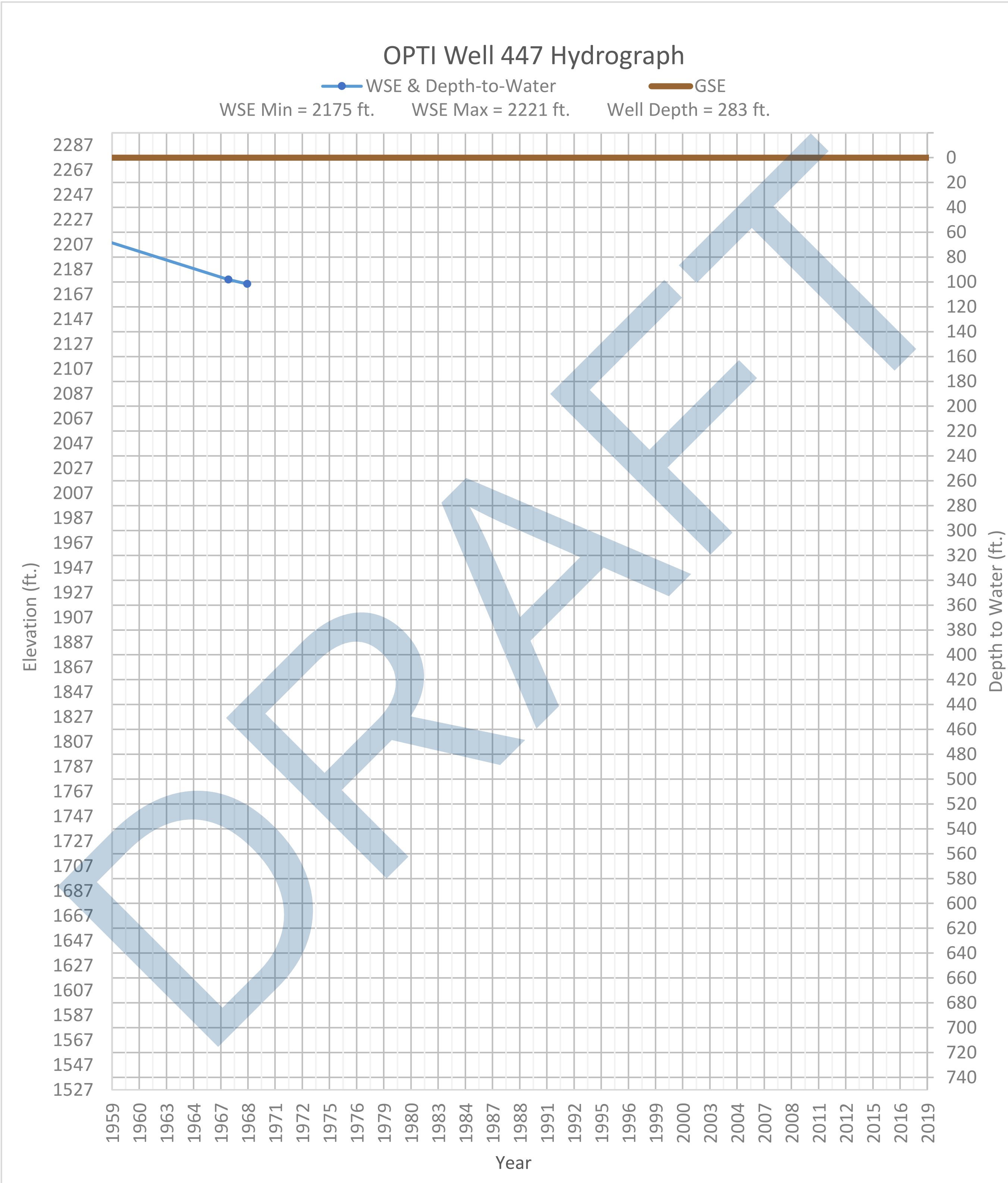


OPTI Well 435 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2158 ft.
WSE Max = 2166 ft.
Well Depth = 507 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

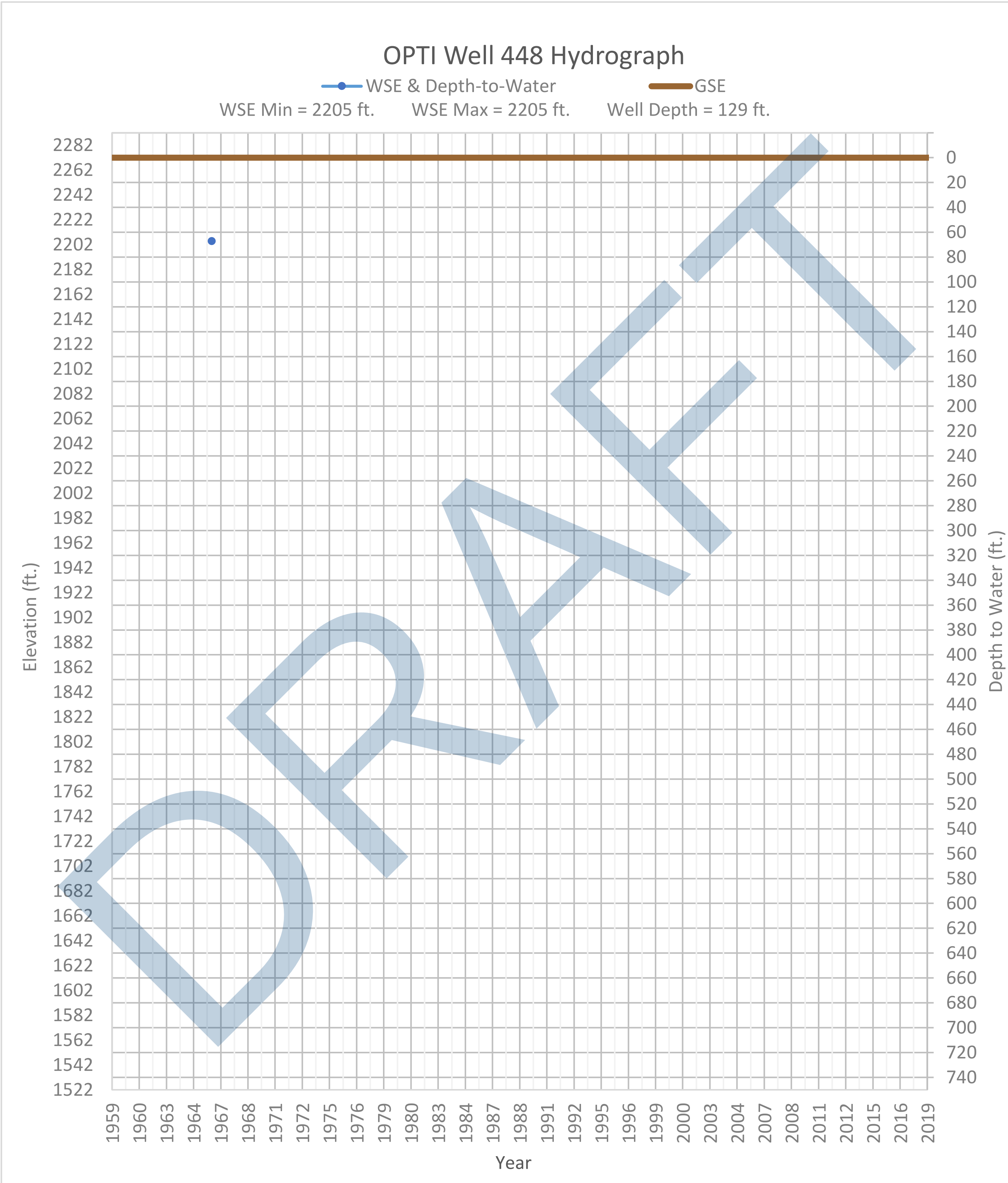


OPTI Well 438 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2114 ft.
WSE Max = 2243 ft.
Well Depth = 659 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

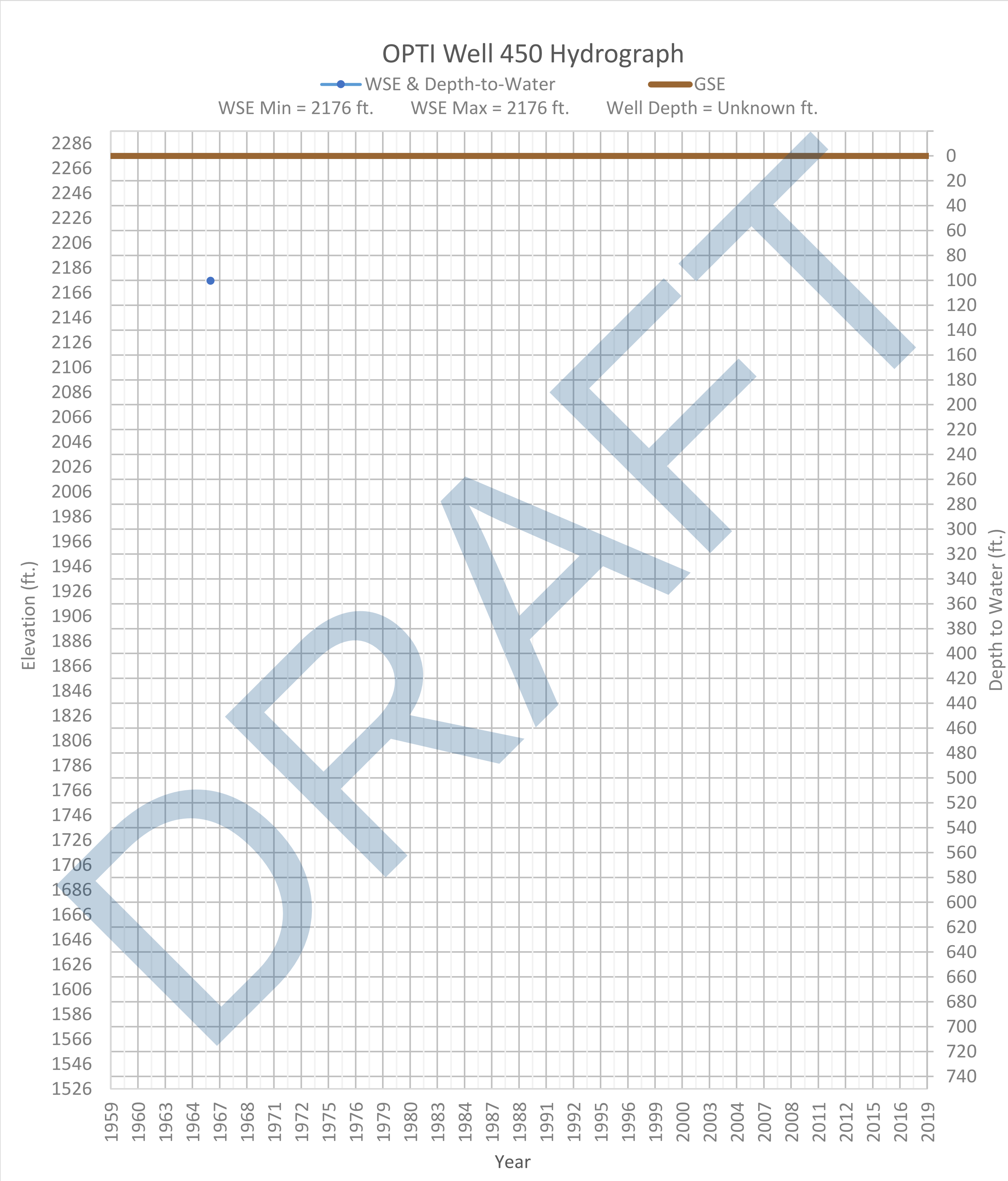

OPTI Well 440 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2139 ft.
WSE Max = 2139 ft.
Well Depth = 623 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



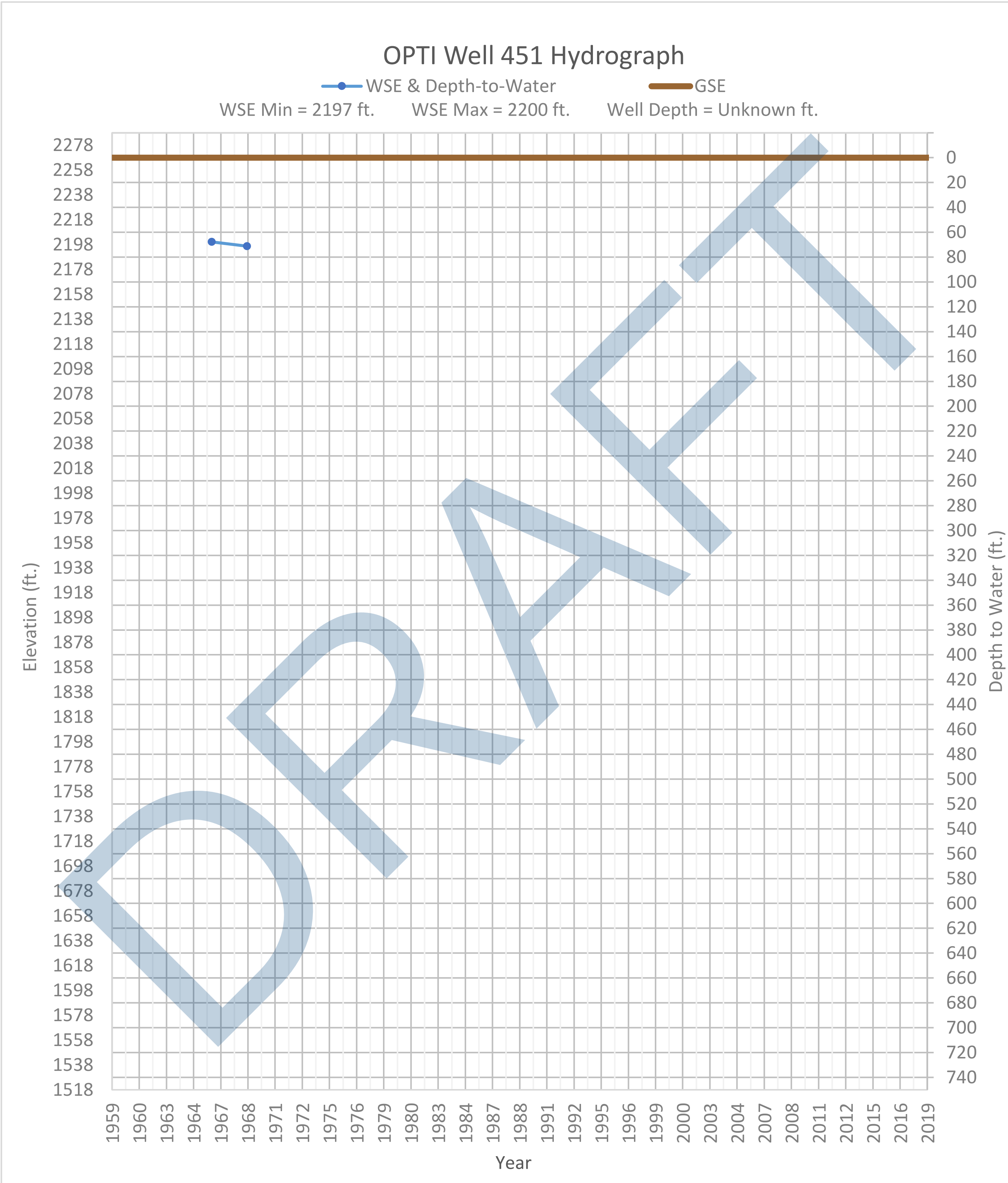
OPTI Well 447 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2175 ft.
WSE Max = 2221 ft.
Well Depth = 283 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

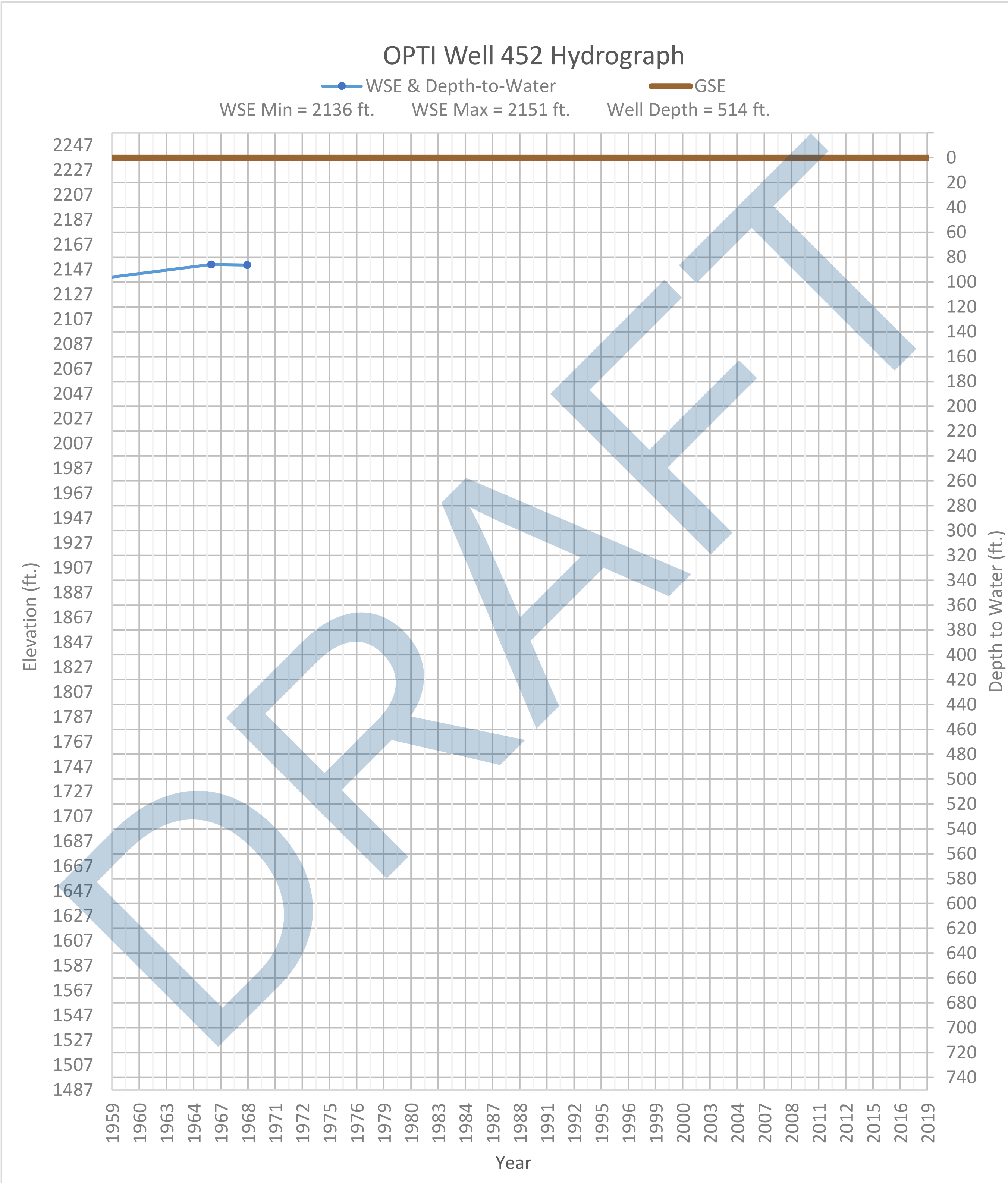


OPTI Well 448 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2205 ft.
WSE Max = 2205 ft.
Well Depth = 129 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

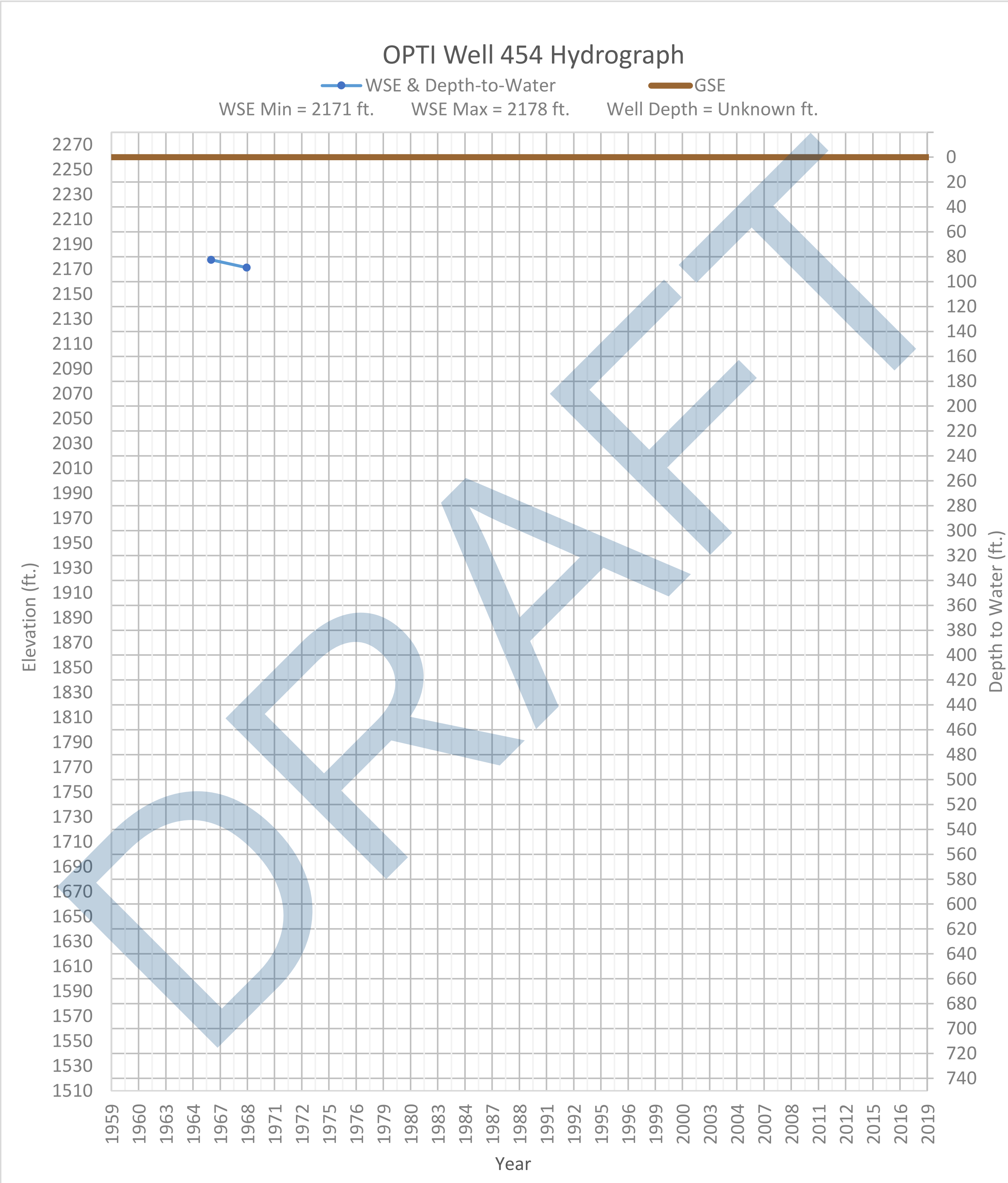


OPTI Well 450 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2176 ft.
WSE Max = 2176 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 451 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2197 ft.
WSE Max = 2200 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2278 2258 2238 2218 2198 2178 2158 2138 2118 2098 2078 2058 2038 2018 1998 1978 1958 1938 1918 1898 1878 1858 1838 1818 1798 1778 1758 1738 1718 1698 1678 1658 1638 1618 1598 1578 1558 1538 1518
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT



OPTI Well 452 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2136 ft.
WSE Max = 2151 ft.
Well Depth = 514 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 454 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2171 ft.
WSE Max = 2178 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2270
2250
2230
2210
2190
2170
2150
2130
2110
2090
2070
2050
2030
2010
1990
1970
1950
1930
1910
1890
1870
1850
1830
1810
1790
1770
1750
1730
1710
1690
1670
1650
1630
1610
1590
1570
1550
1530
1510
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
1984
1987
1988
1991
1992
1995
1996
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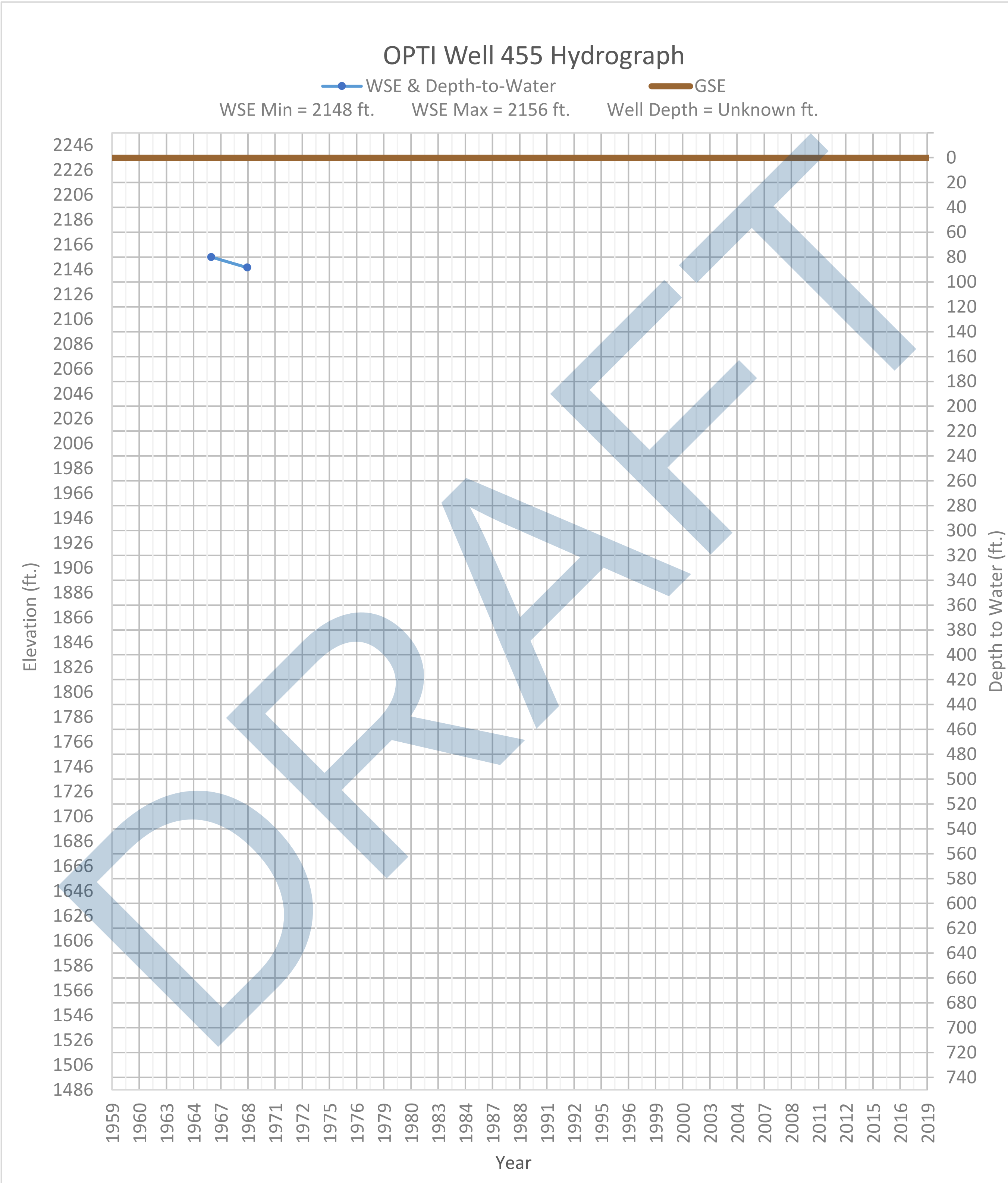
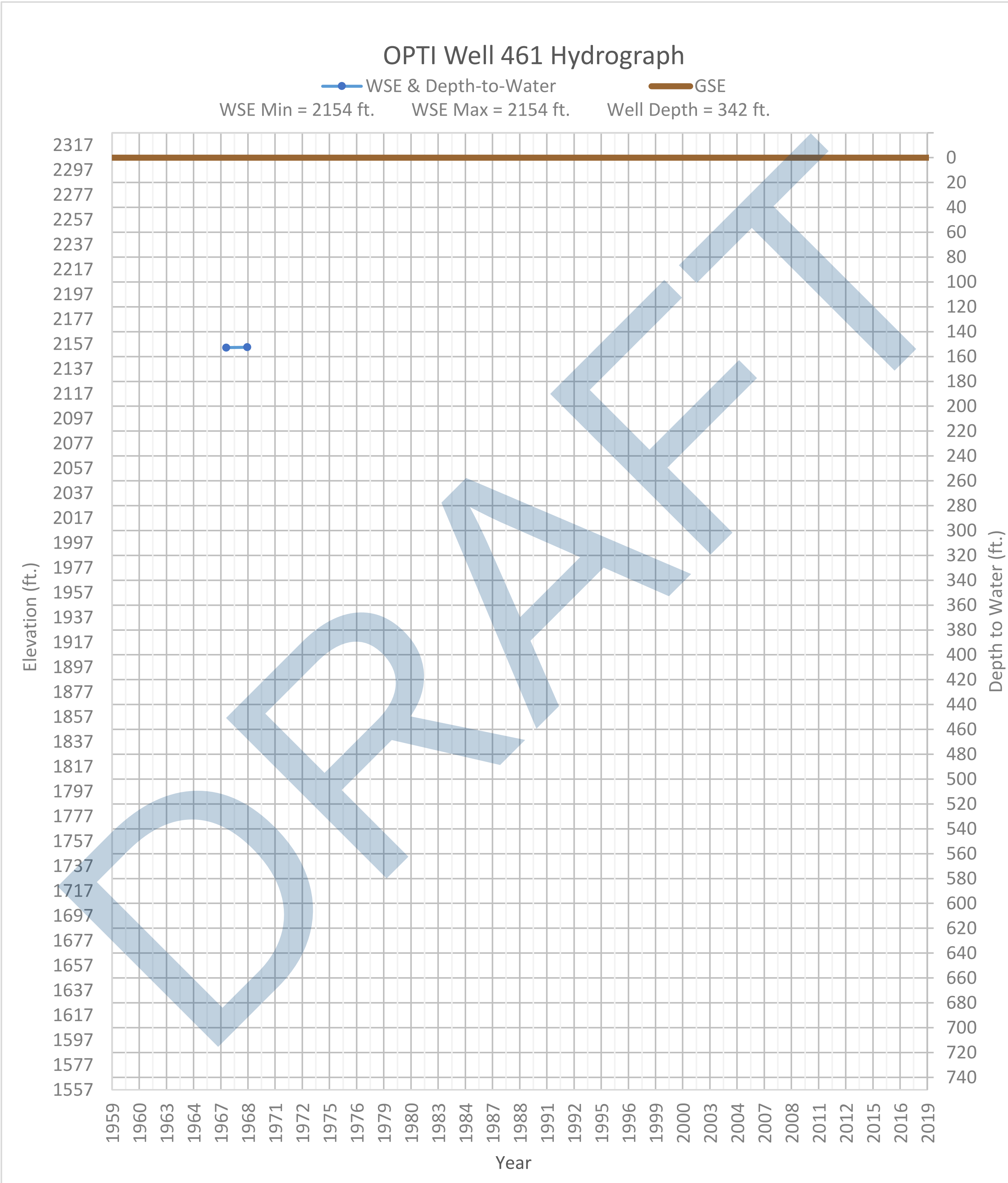
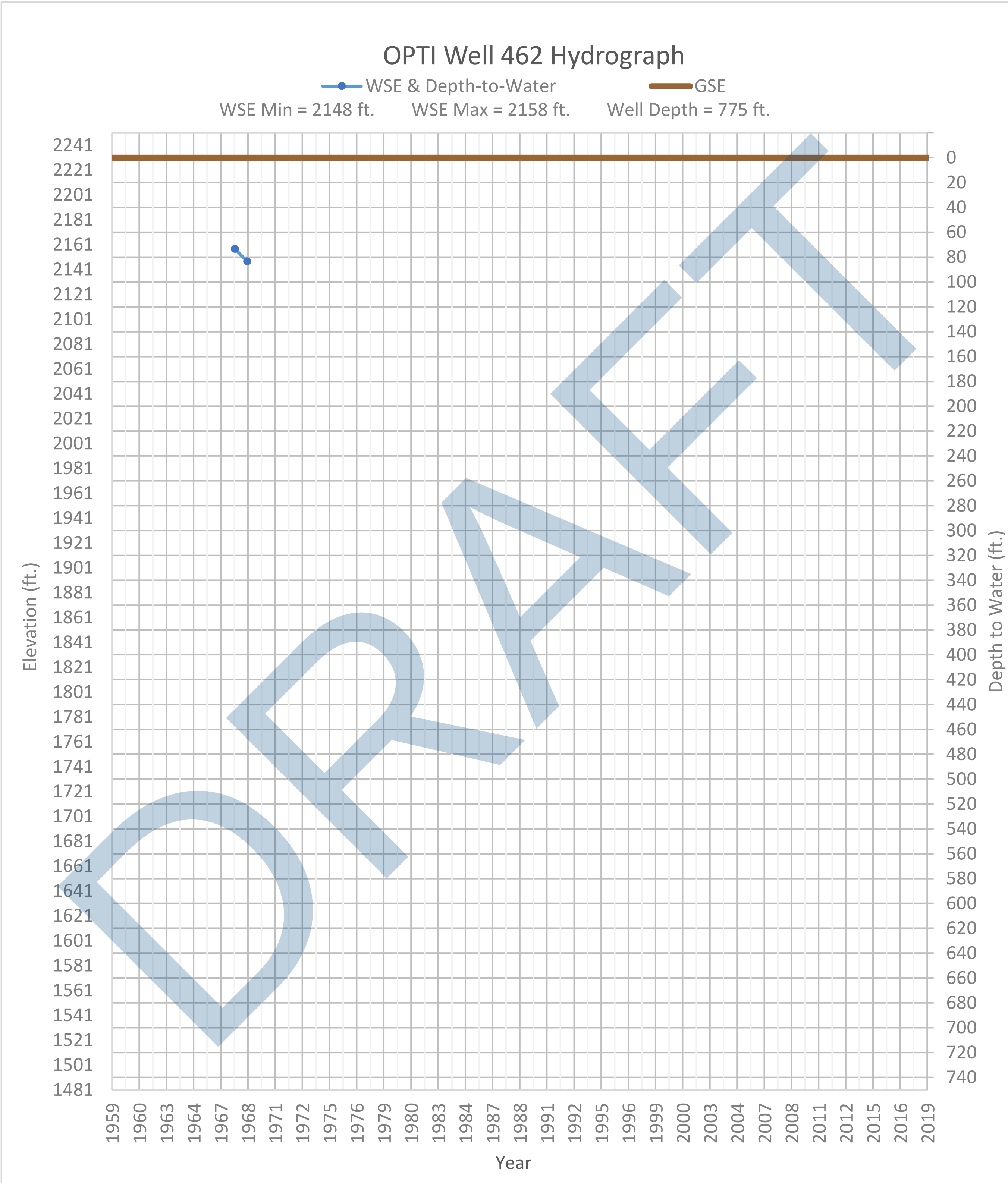
2000
2003
2004
2007
2008
2011
2012
2015
2016
2019
DRAFT

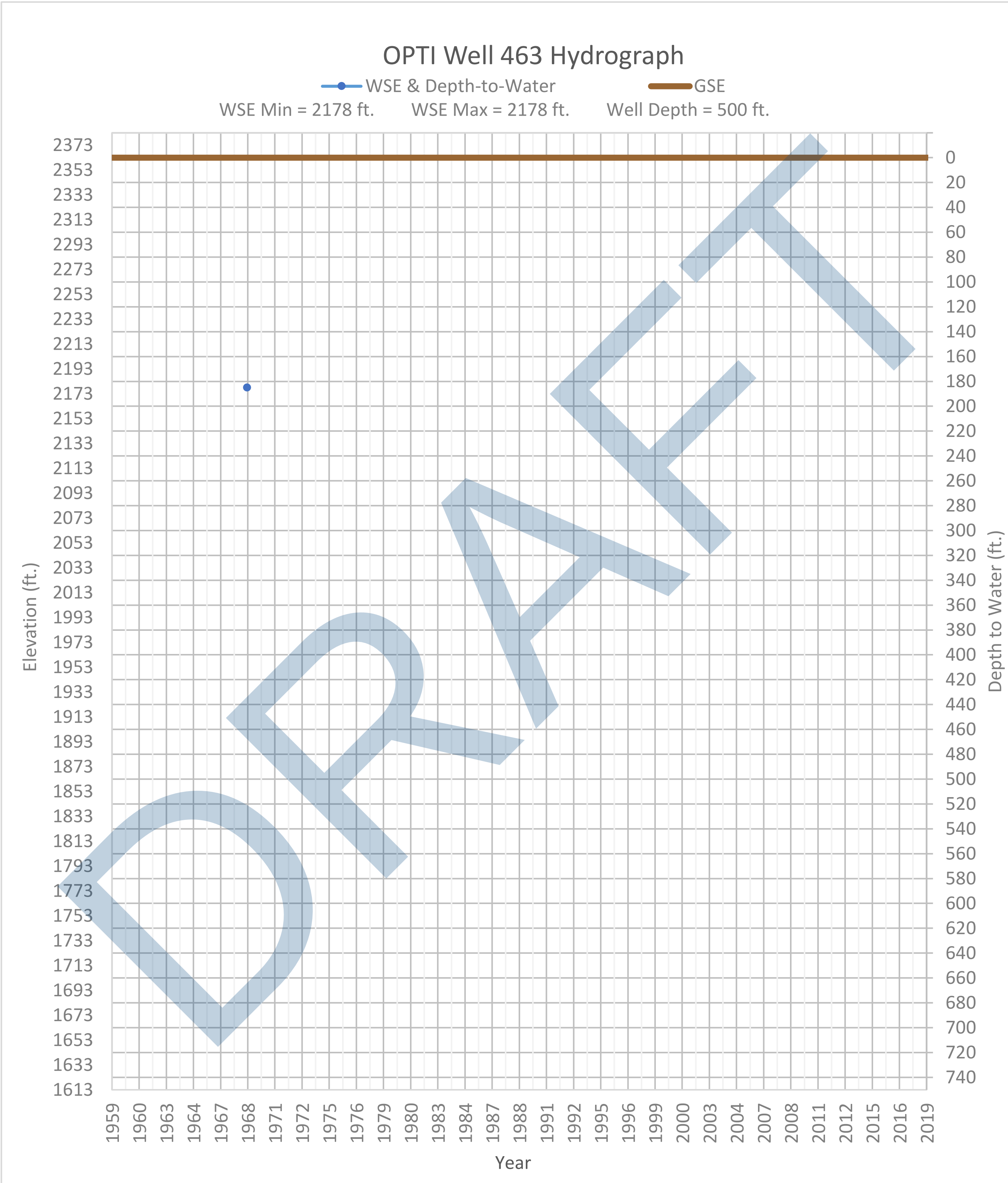


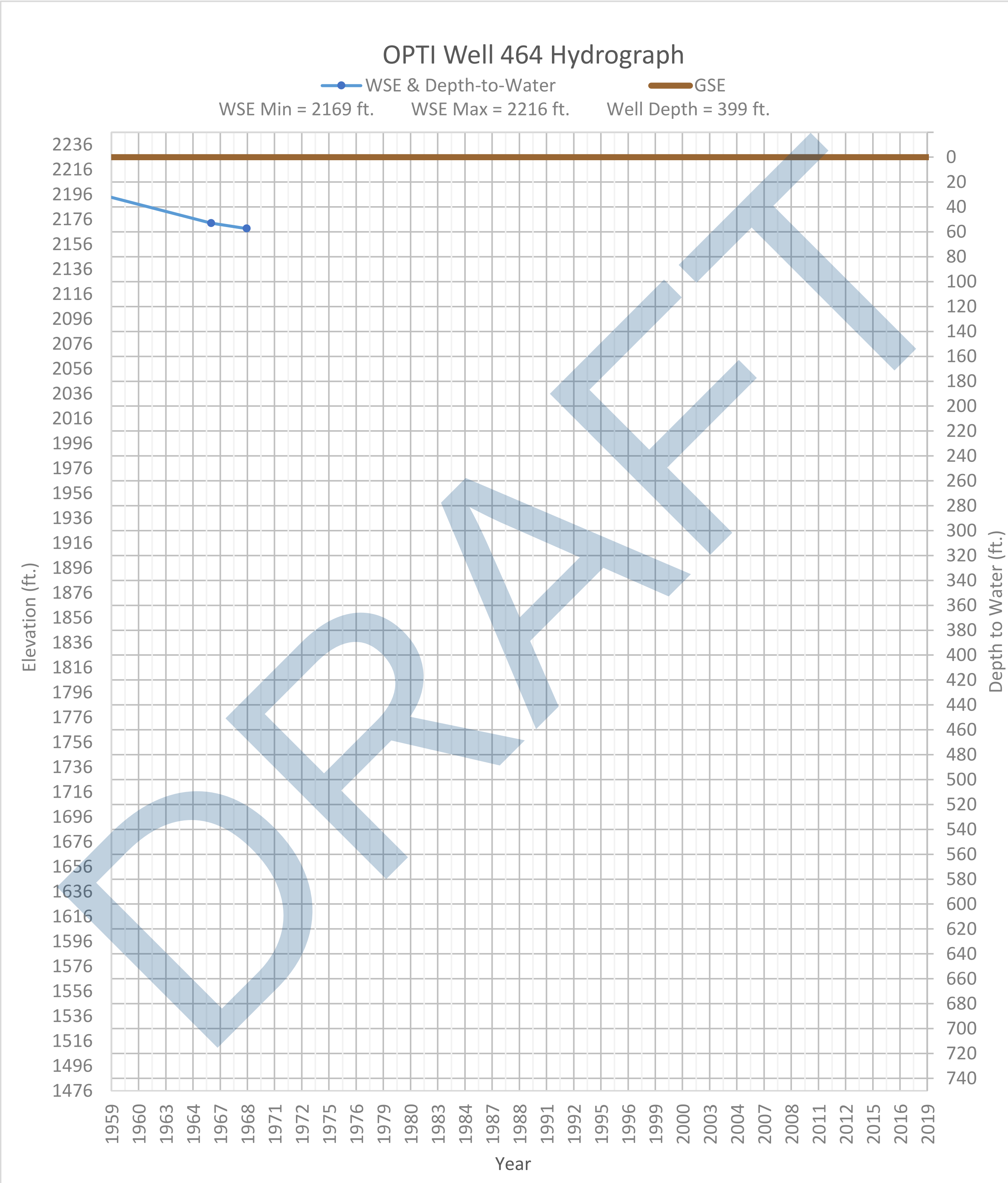
OPTI Well 455 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2148 ft.
WSE Max = 2156 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



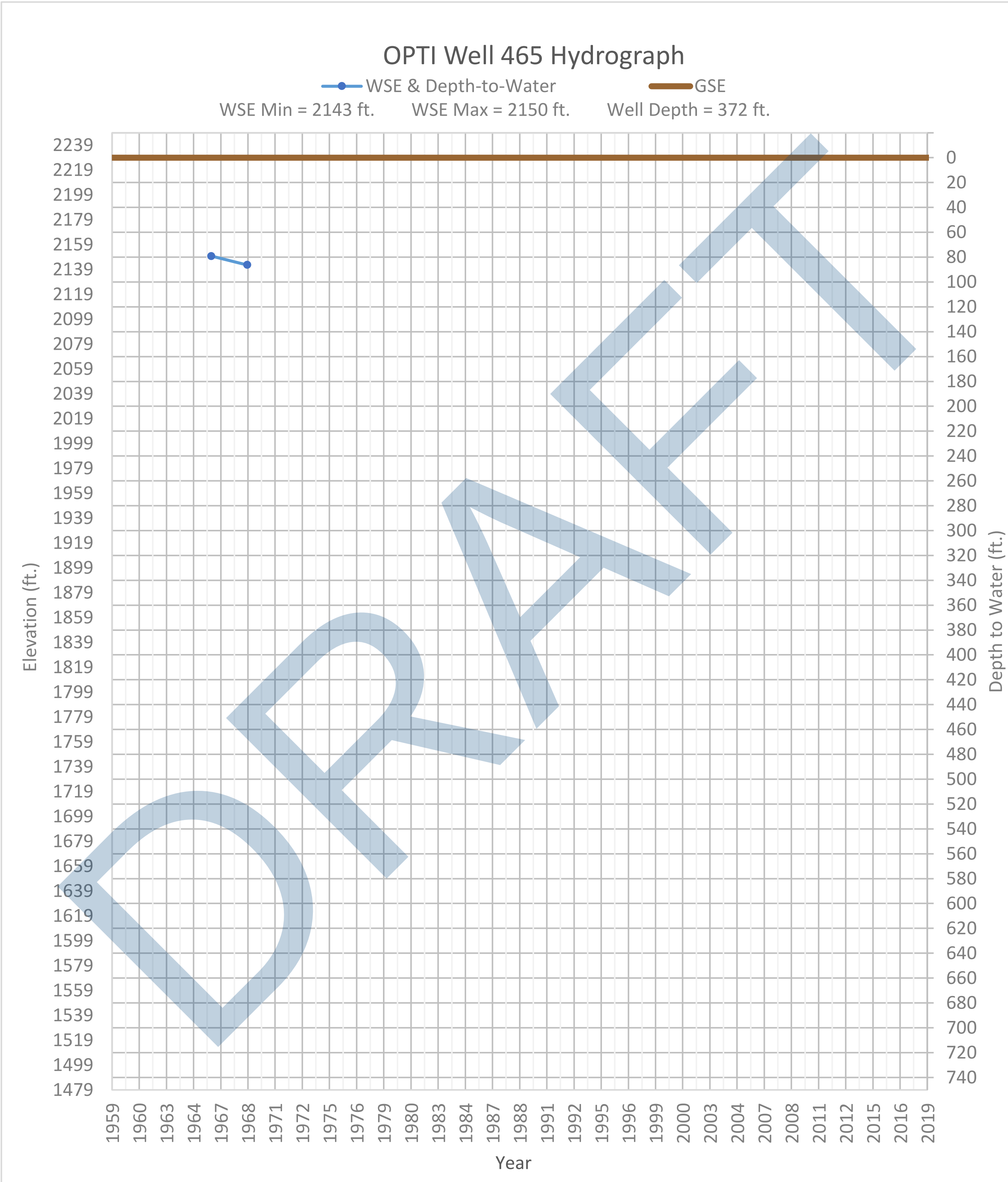
OPTI Well 461 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2154 ft.
WSE Max = 2154 ft.
Well Depth = 342 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 462 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2148 ft.
WSE Max = 2158 ft.
Well Depth = 775 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

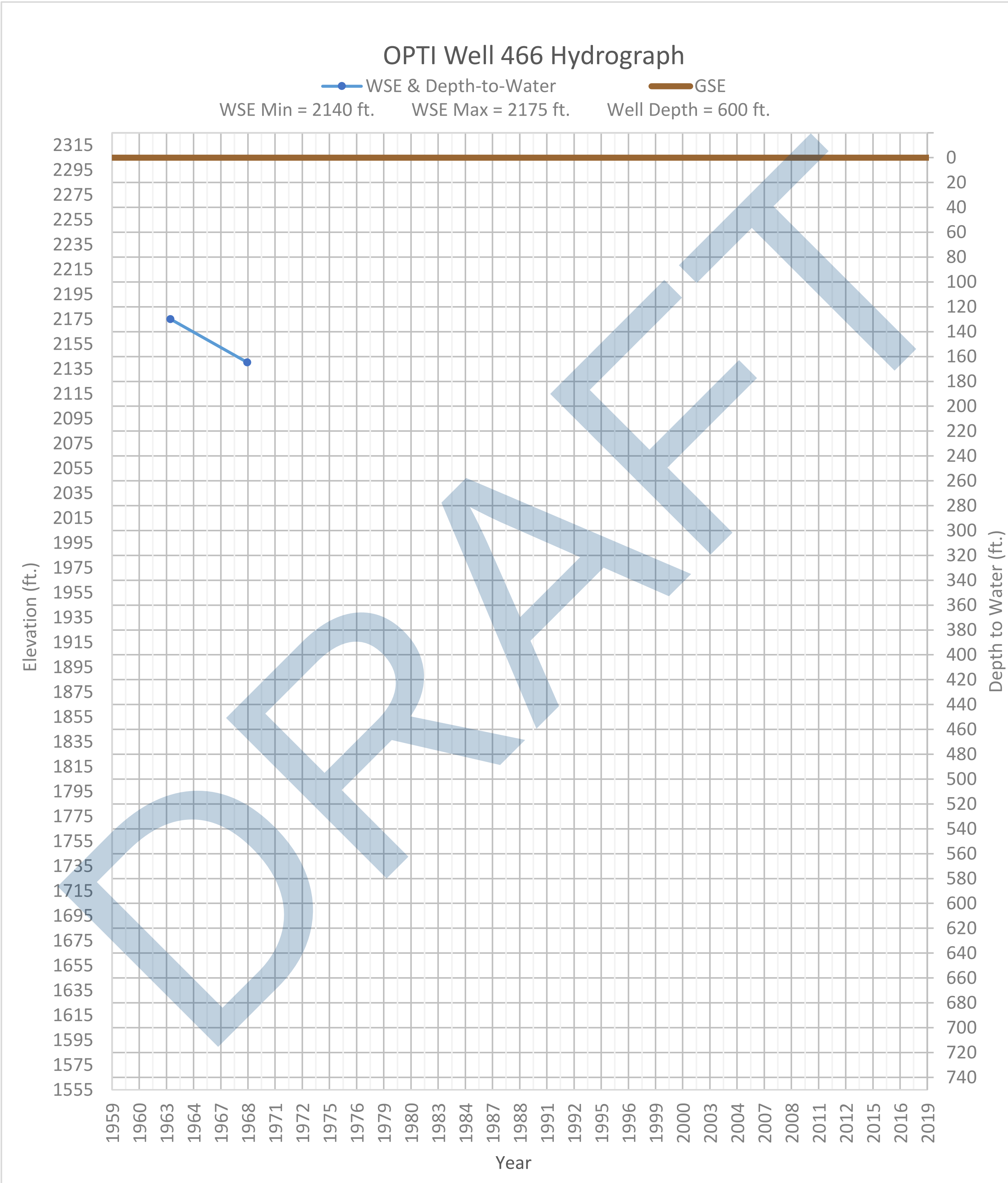

OPTI Well 463 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2178 ft.
WSE Max = 2178 ft.
Well Depth = 500 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



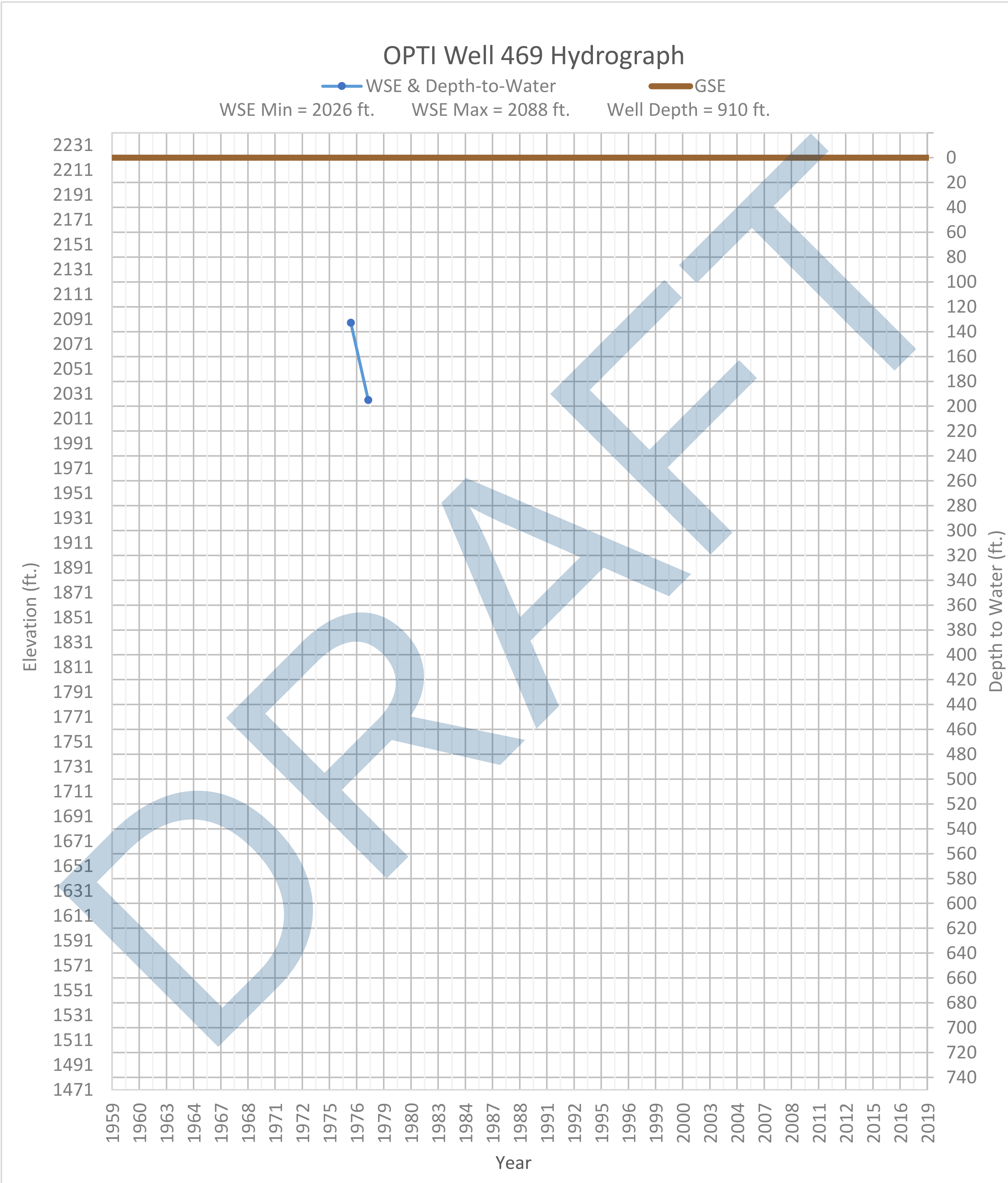
OPTI Well 464 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2169 ft.
WSE Max = 2216 ft.
Well Depth = 399 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



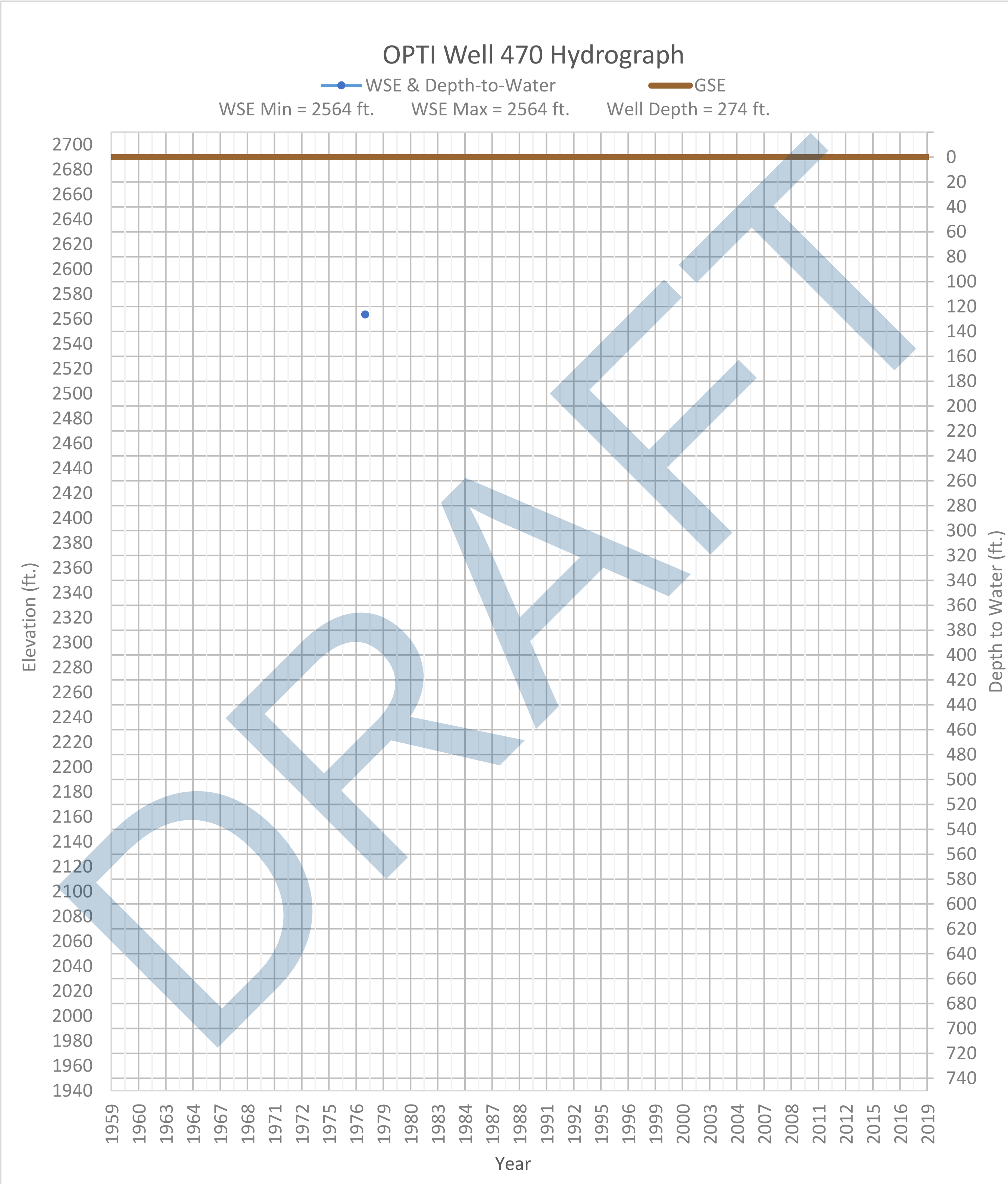
OPTI Well 465 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2143 ft.
WSE Max = 2150 ft.
Well Depth = 372 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

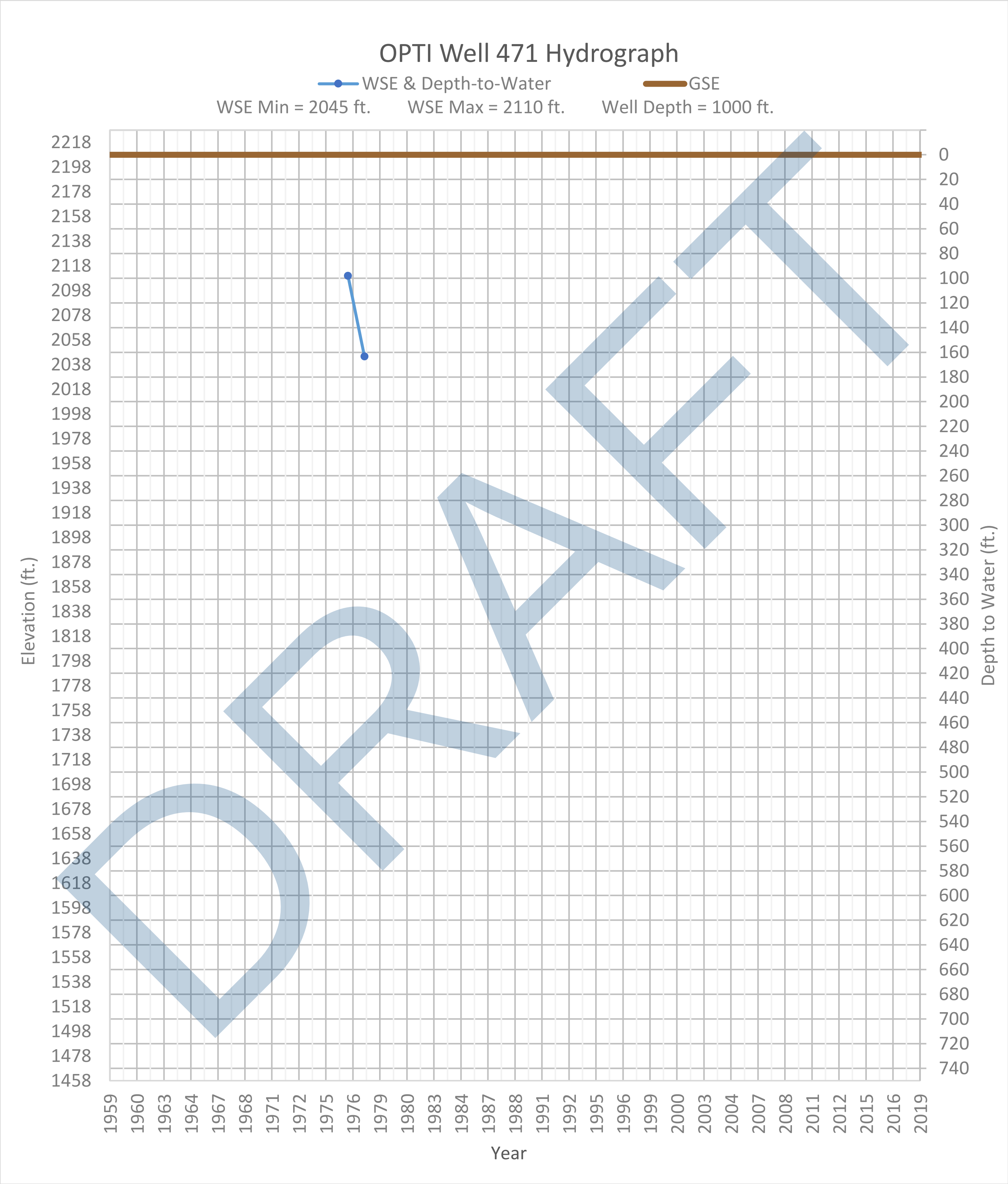


OPTI Well 466 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2140 ft.
WSE Max = 2175 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

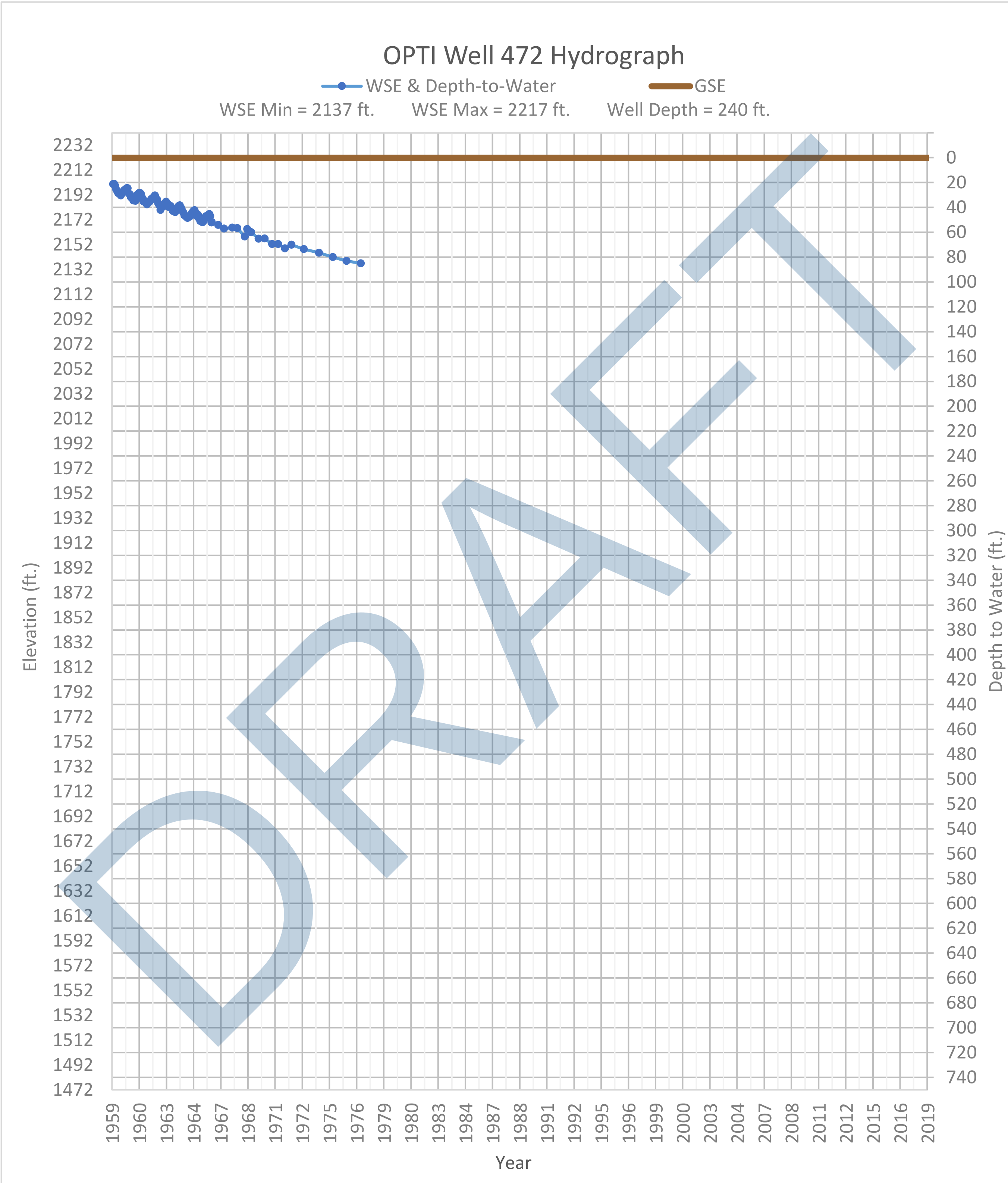


OPTI Well 469 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2026 ft.
WSE Max = 2088 ft.
Well Depth = 910 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

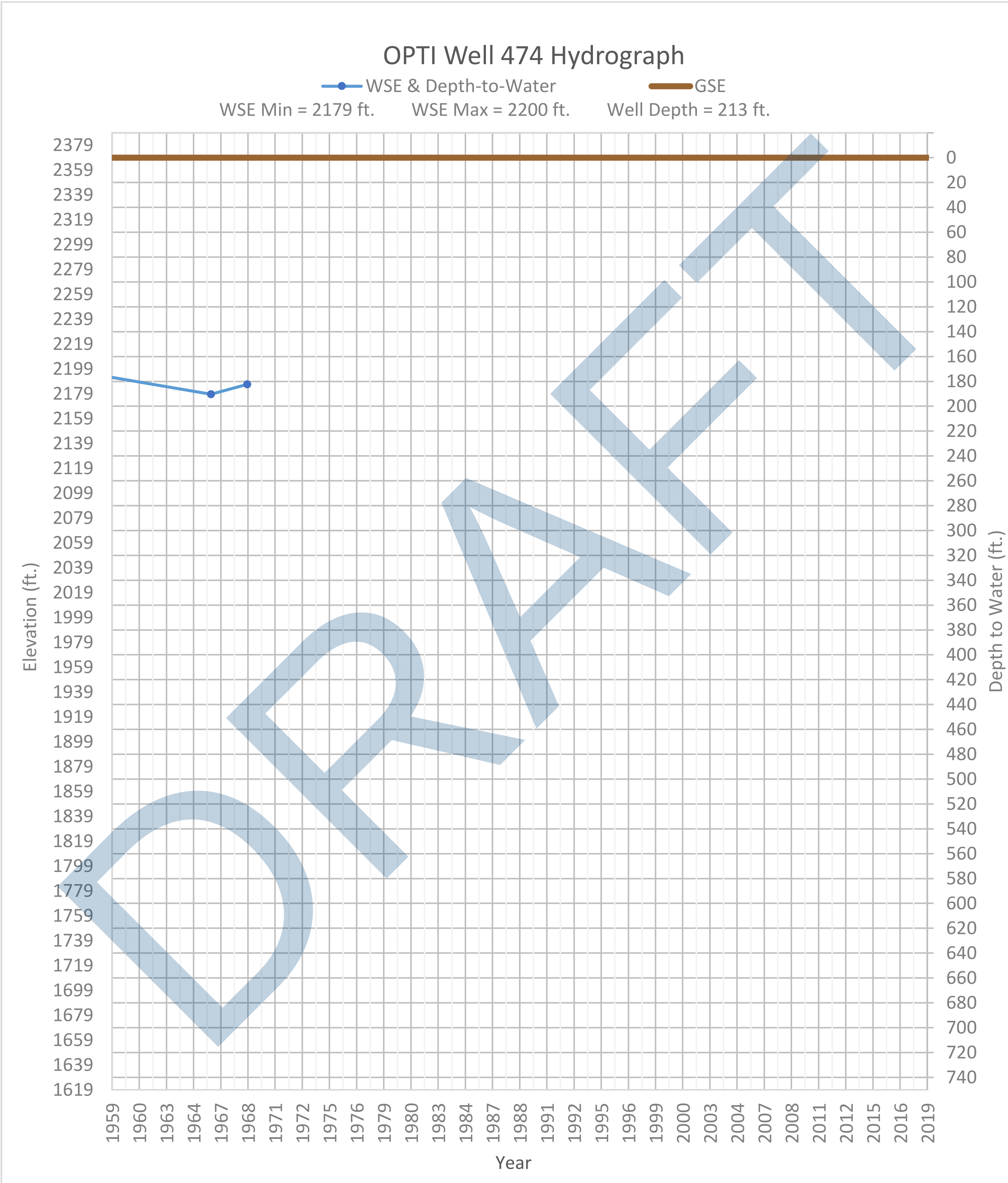

OPTI Well 470 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2564 ft.
WSE Max = 2564 ft.
Well Depth = 274 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



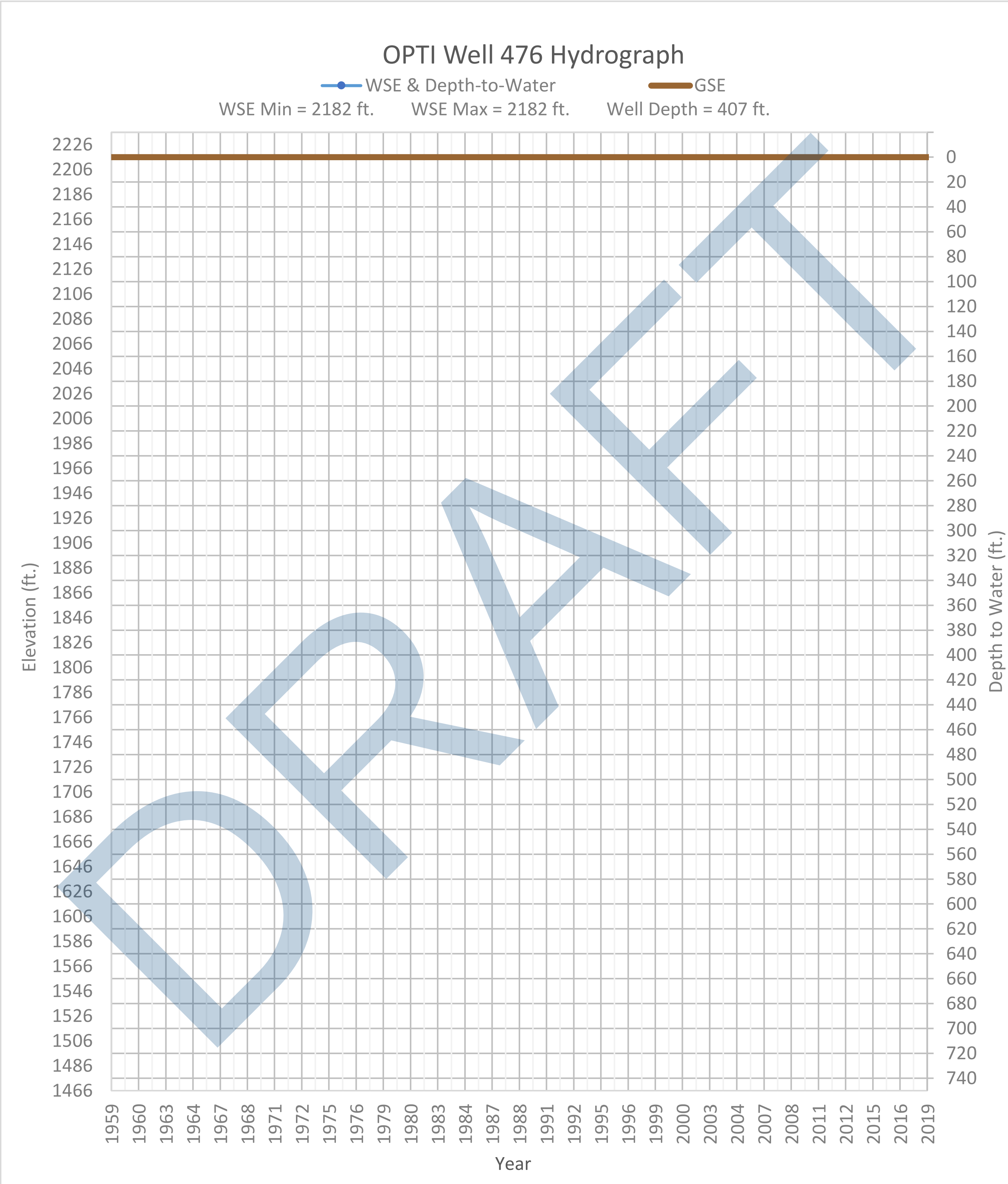
OPTI Well 471 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2045 ft.
WSE Max = 2110 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



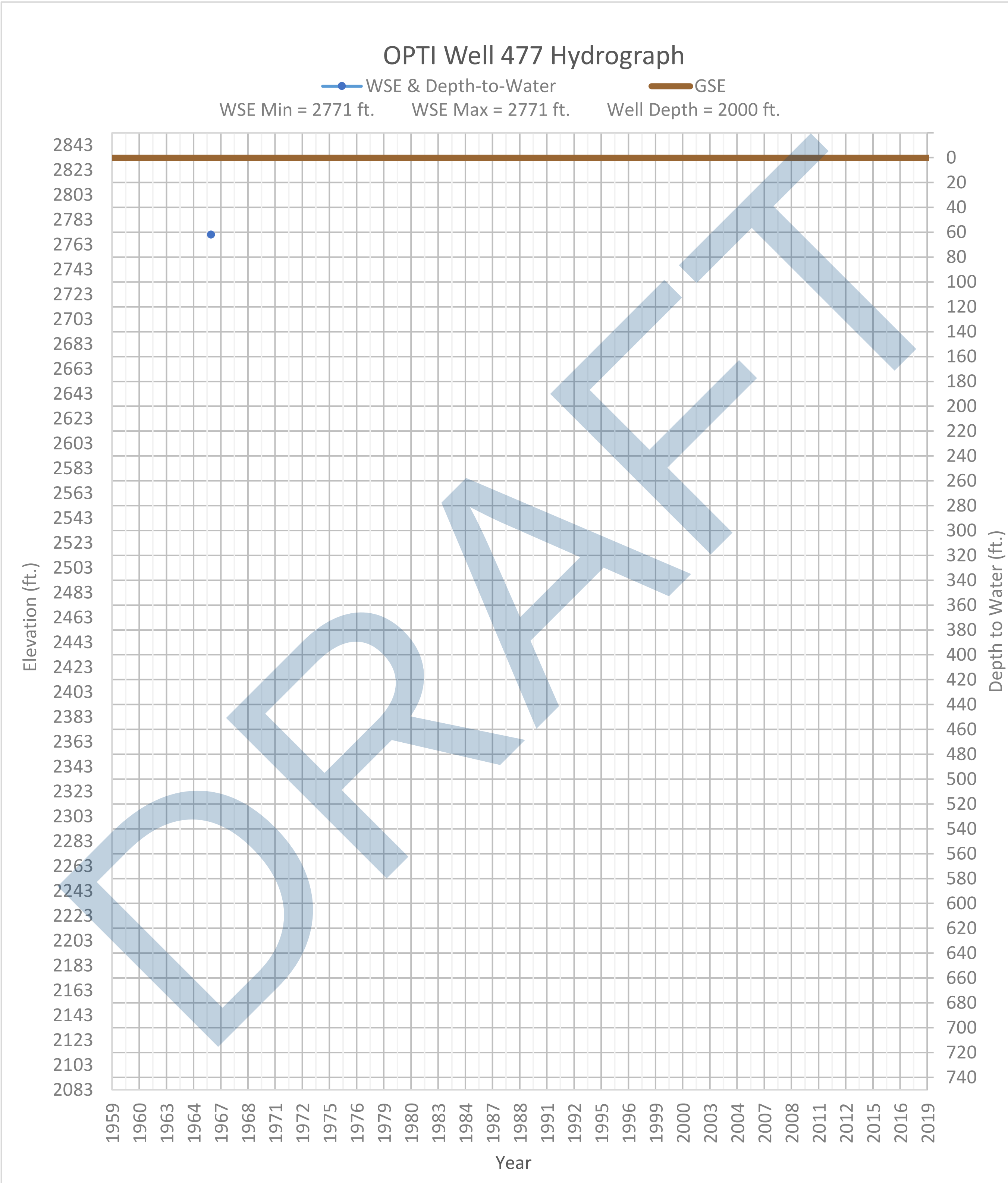
OPTI Well 472 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2137 ft.
WSE Max = 2217 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



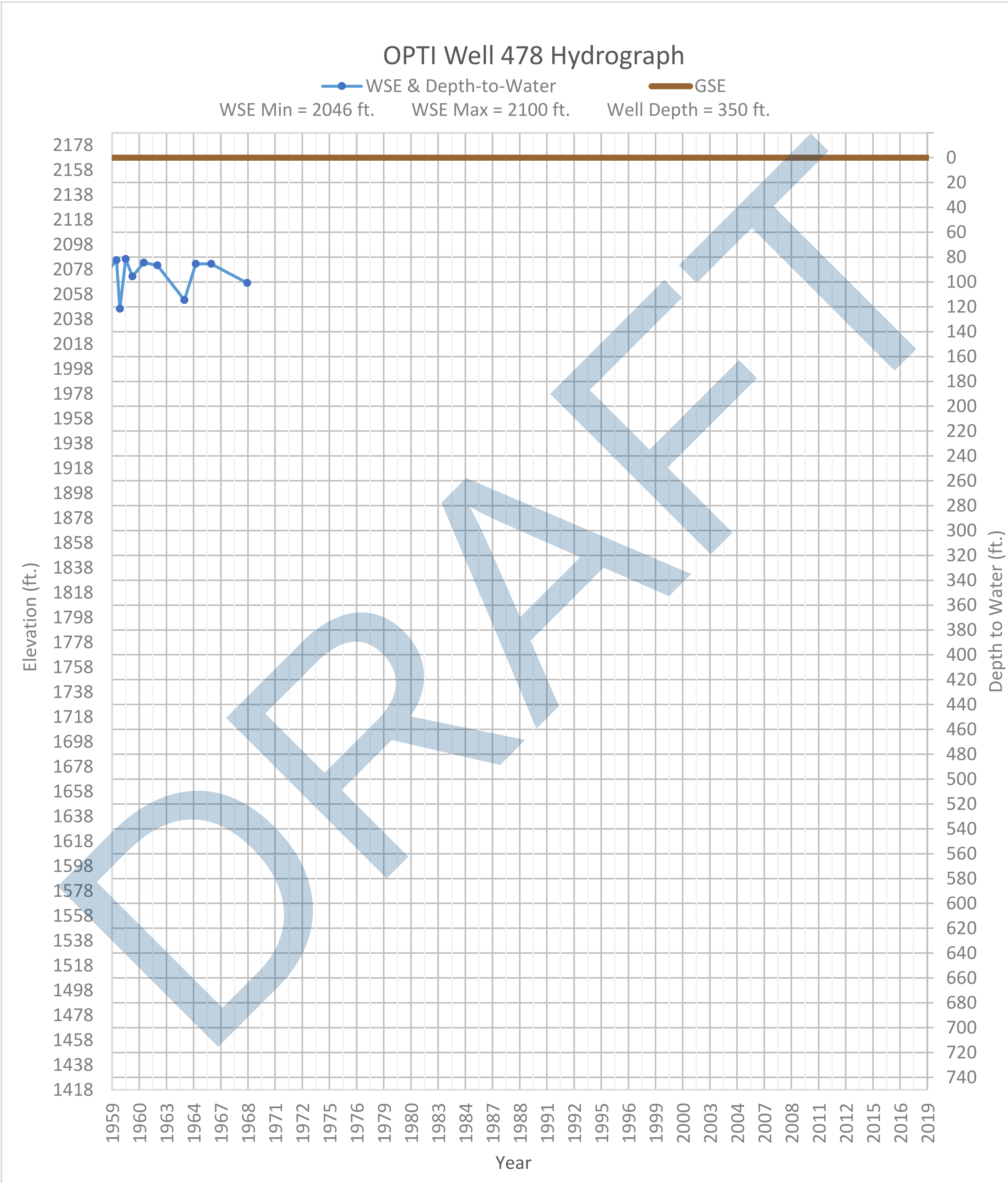
OPTI Well 474 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2179 ft.
WSE Max = 2200 ft.
Well Depth = 213 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



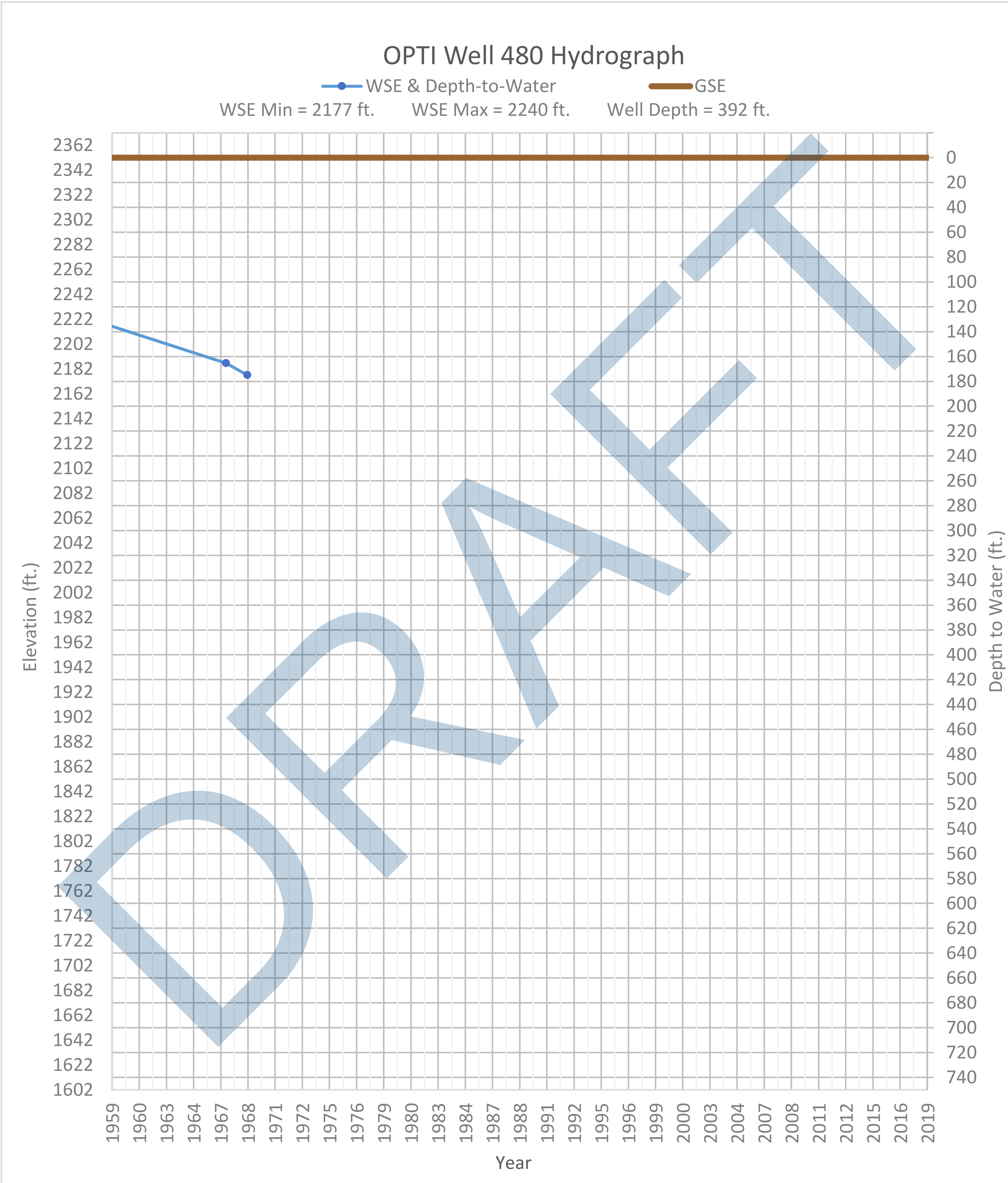
OPTI Well 476 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2182 ft.
WSE Max = 2182 ft.
Well Depth = 407 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 477 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2771 ft.
WSE Max = 2771 ft.
Well Depth = 2000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

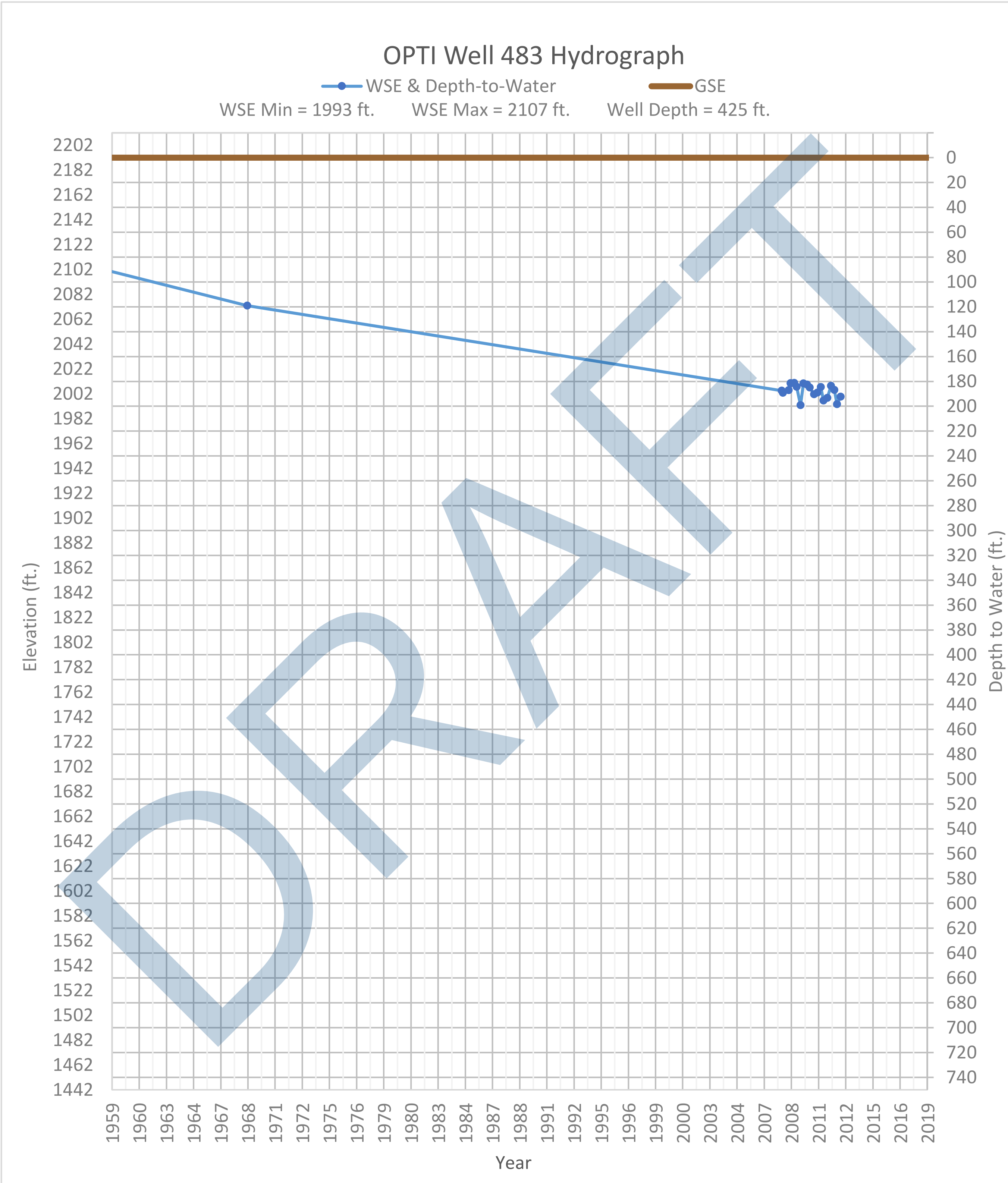


OPTI Well 478 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2046 ft.
WSE Max = 2100 ft.
Well Depth = 350 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

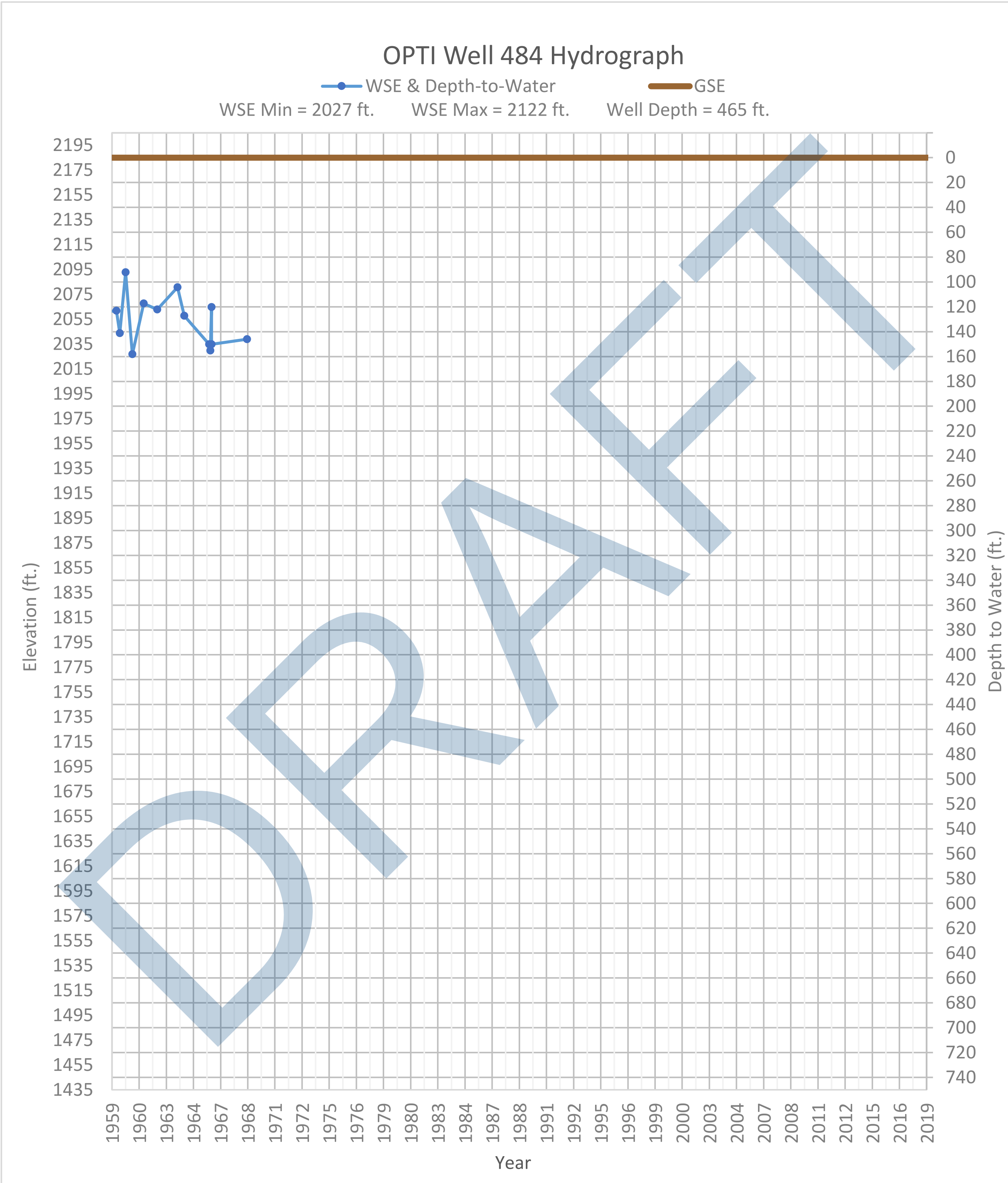


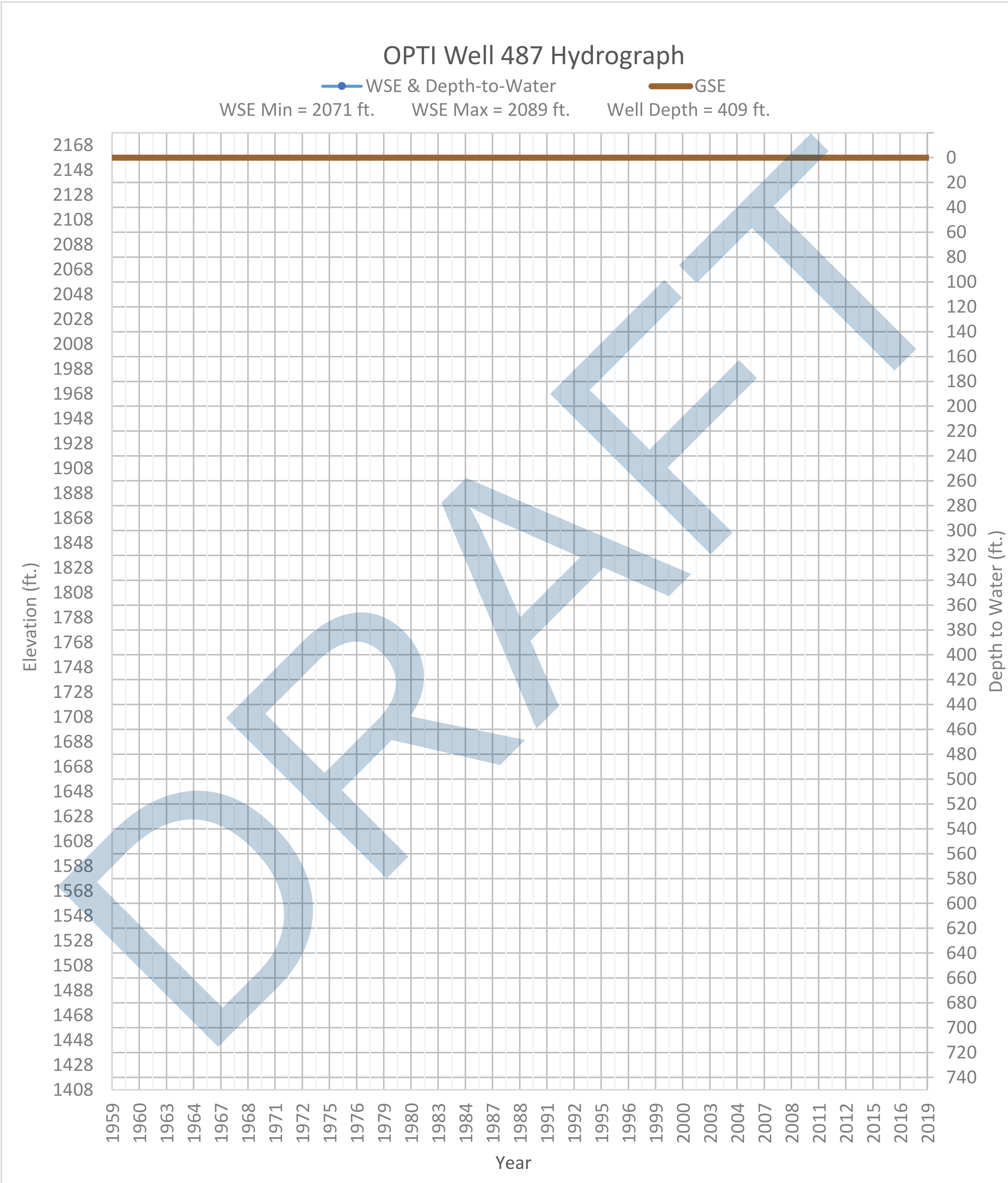
OPTI Well 480 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2177 ft.
WSE Max = 2240 ft.
Well Depth = 392 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

OPTI Well 482 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2037 ft.
WSE Max = 2123 ft.
Well Depth = 508 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

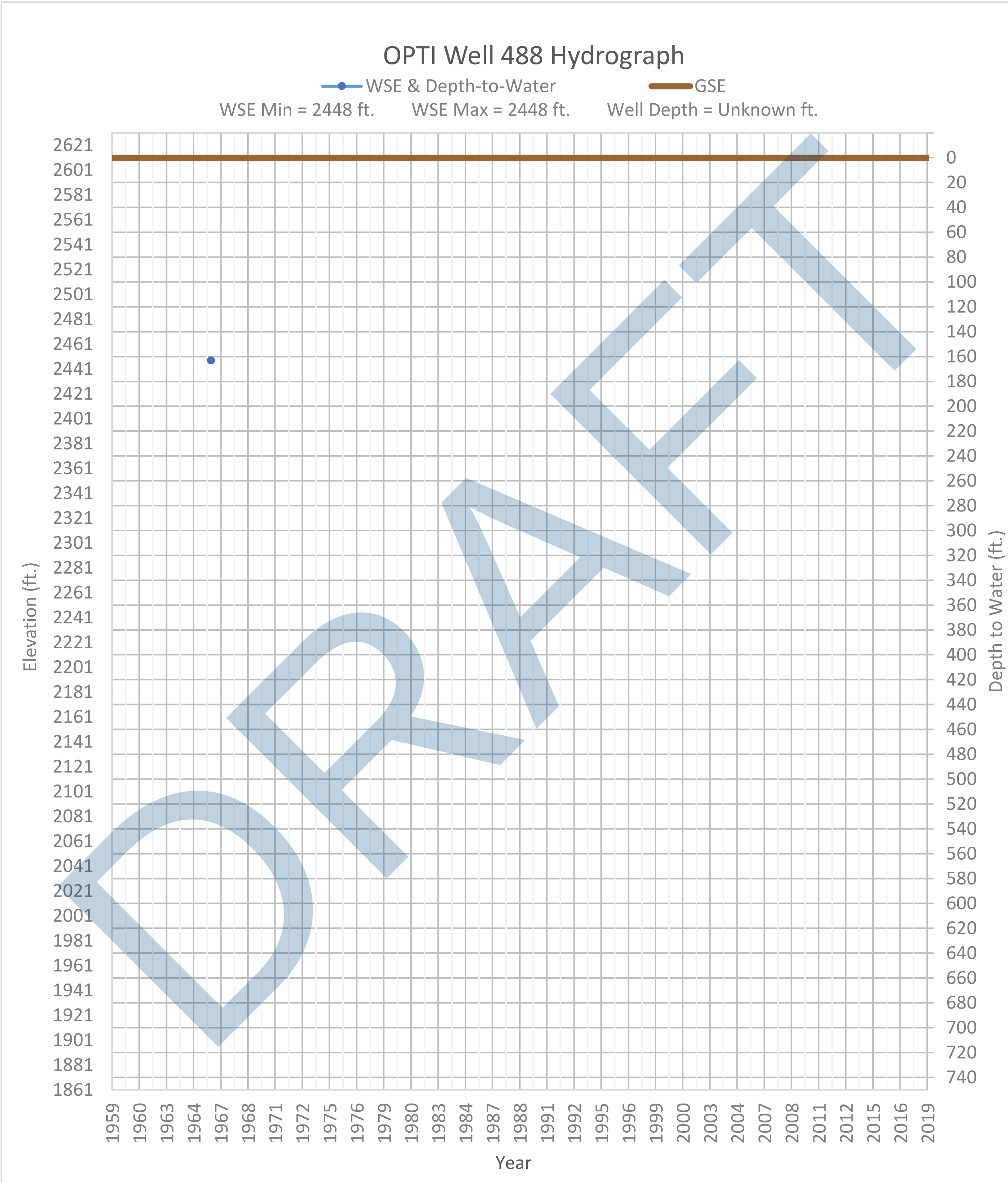


OPTI Well 483 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1993 ft.
WSE Max = 2107 ft.
Well Depth = 425 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

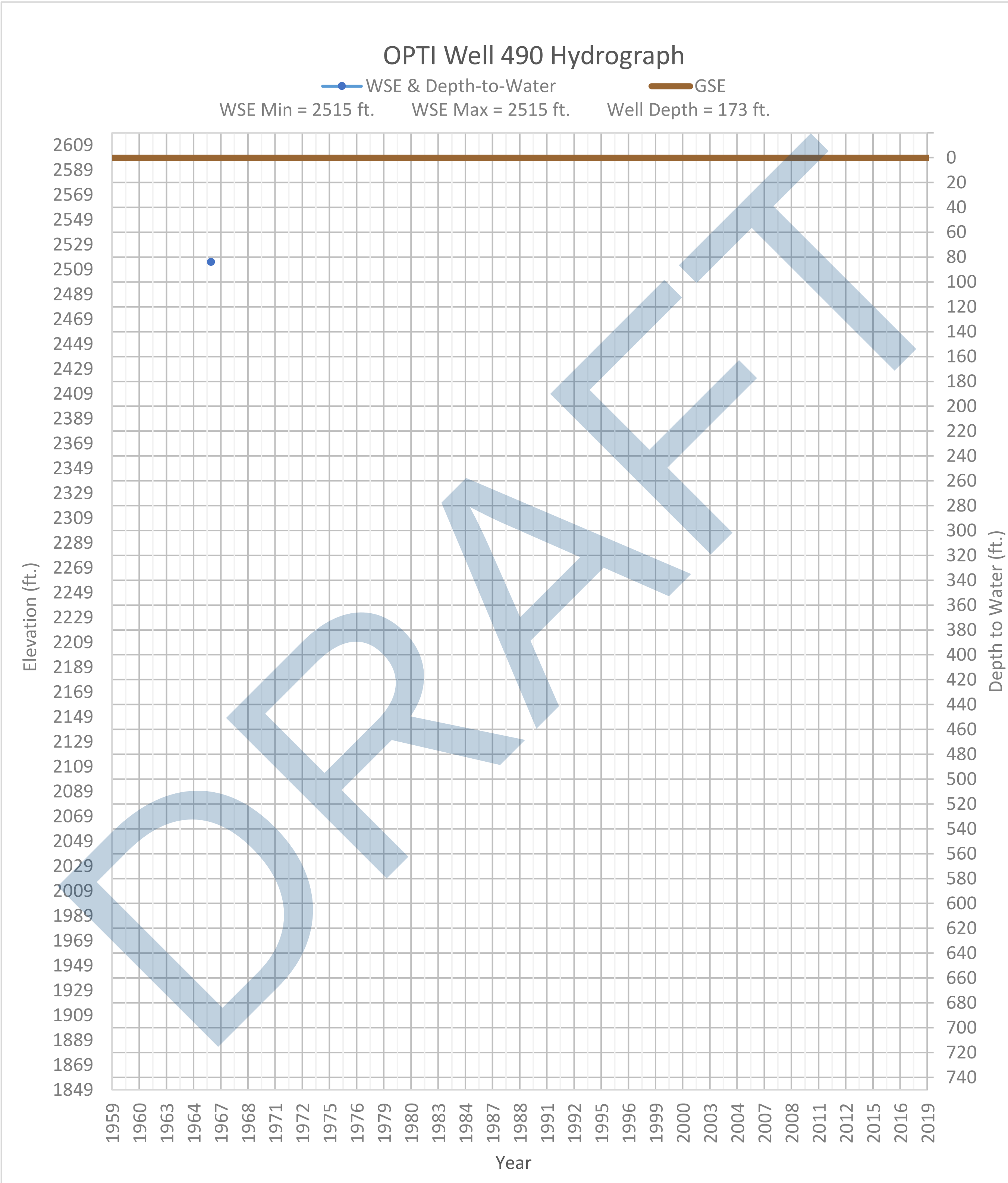

OPTI Well 484 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2027 ft.
WSE Max = 2122 ft.
Well Depth = 465 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



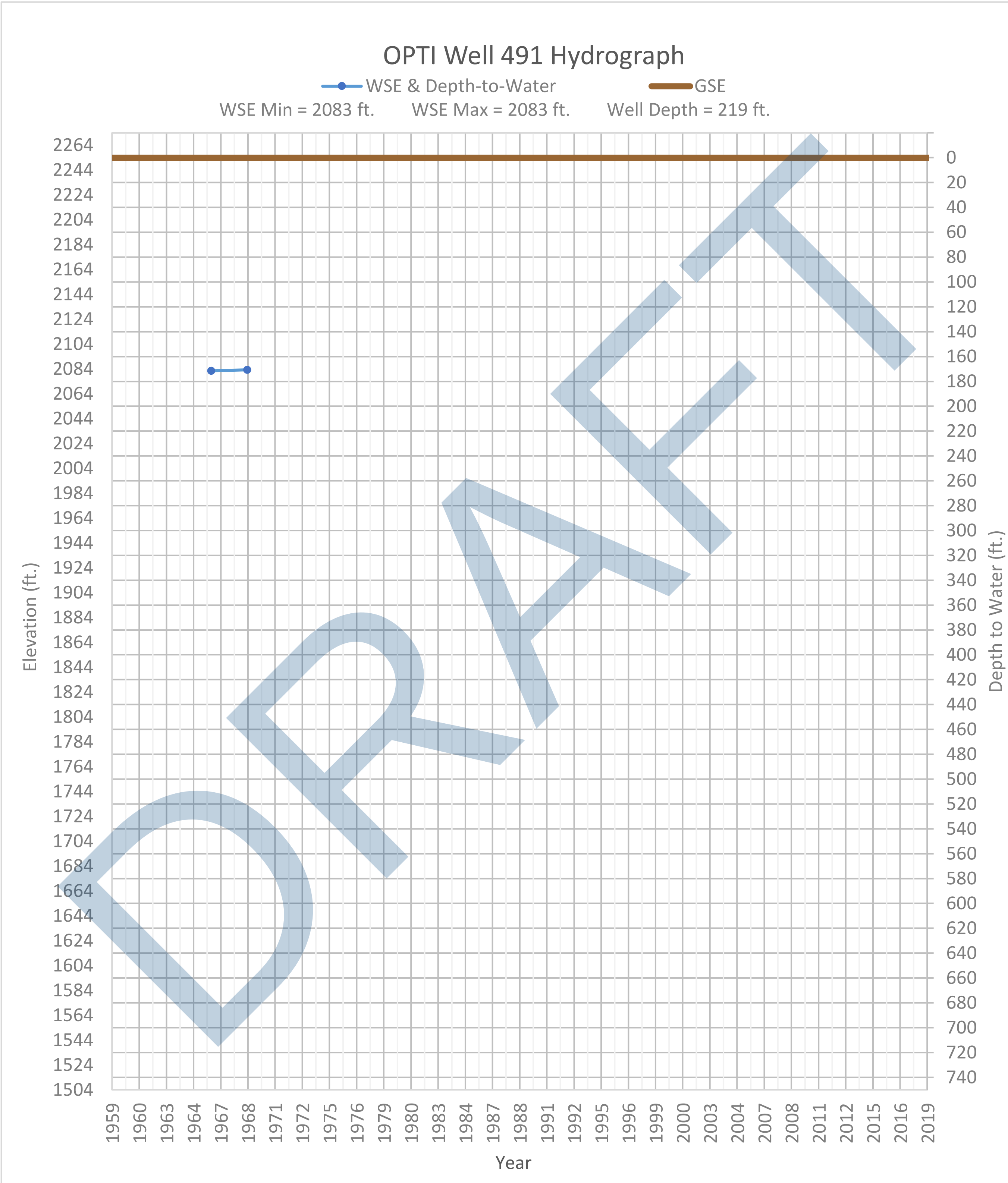
OPTI Well 487 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2071 ft.
WSE Max = 2089 ft.
Well Depth = 409 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



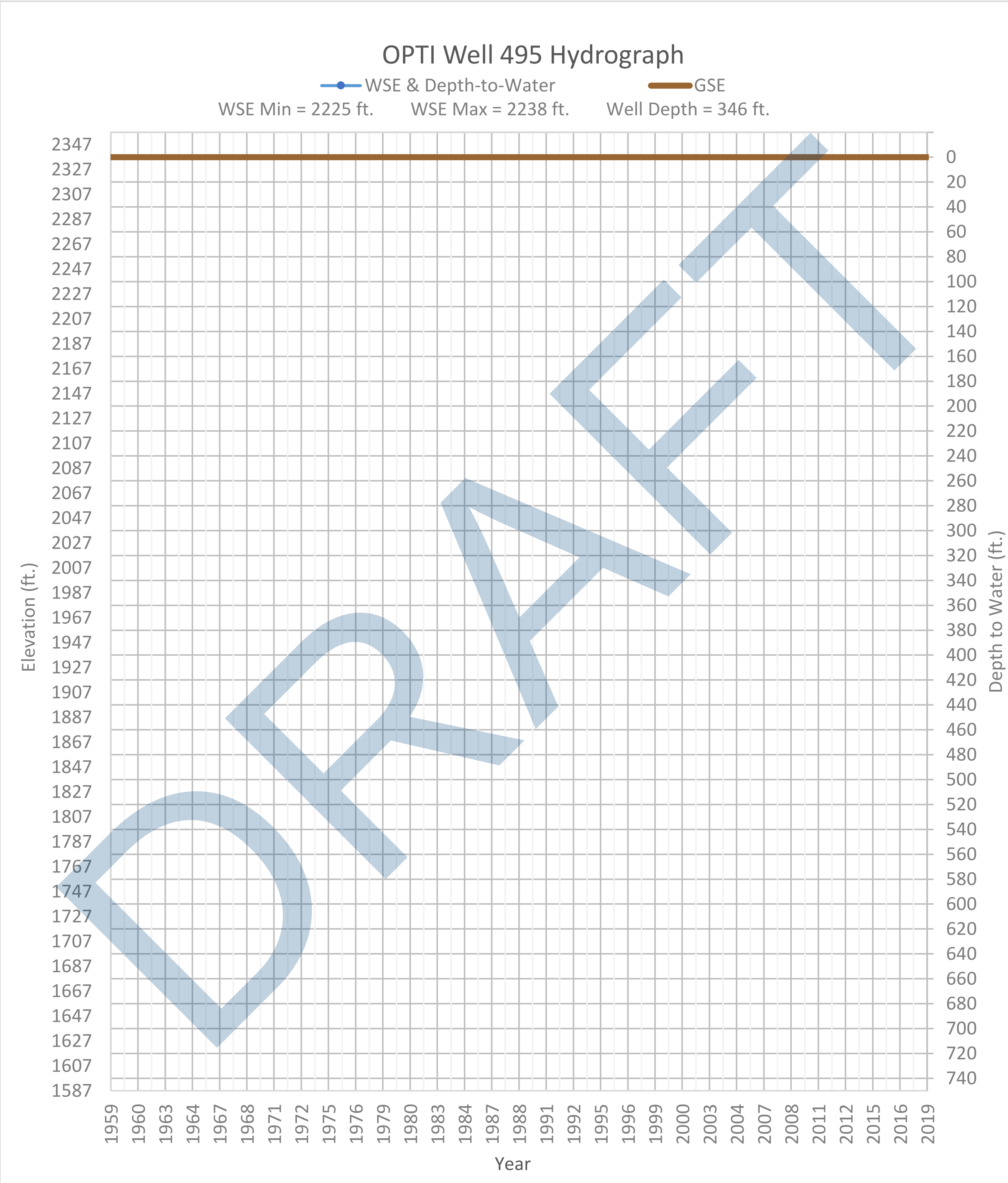
OPTI Well 488 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2448 ft.
WSE Max = 2448 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



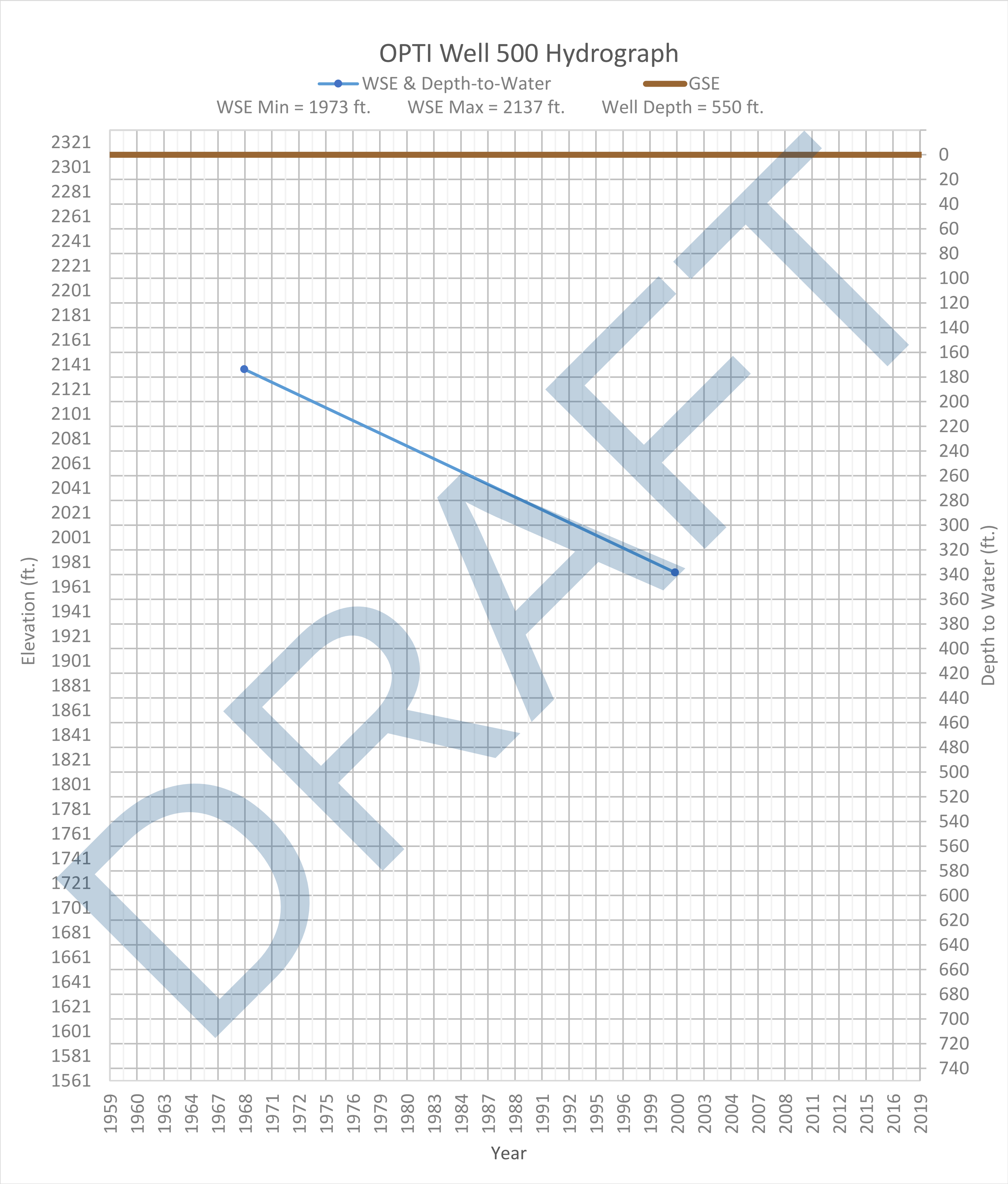
OPTI Well 490 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2515 ft.
WSE Max = 2515 ft.
Well Depth = 173 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

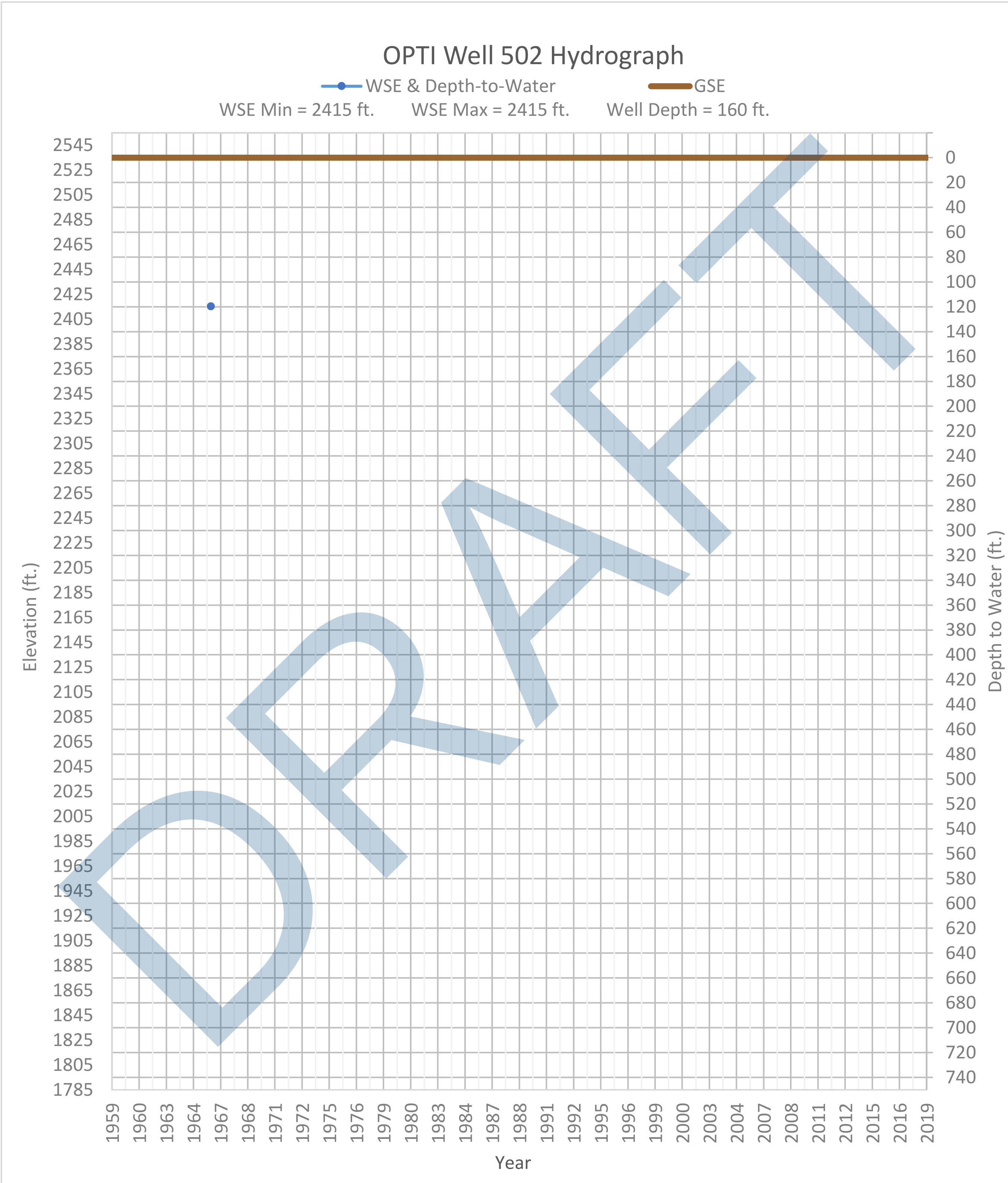


OPTI Well 491 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2083 ft.
WSE Max = 2083 ft.
Well Depth = 219 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

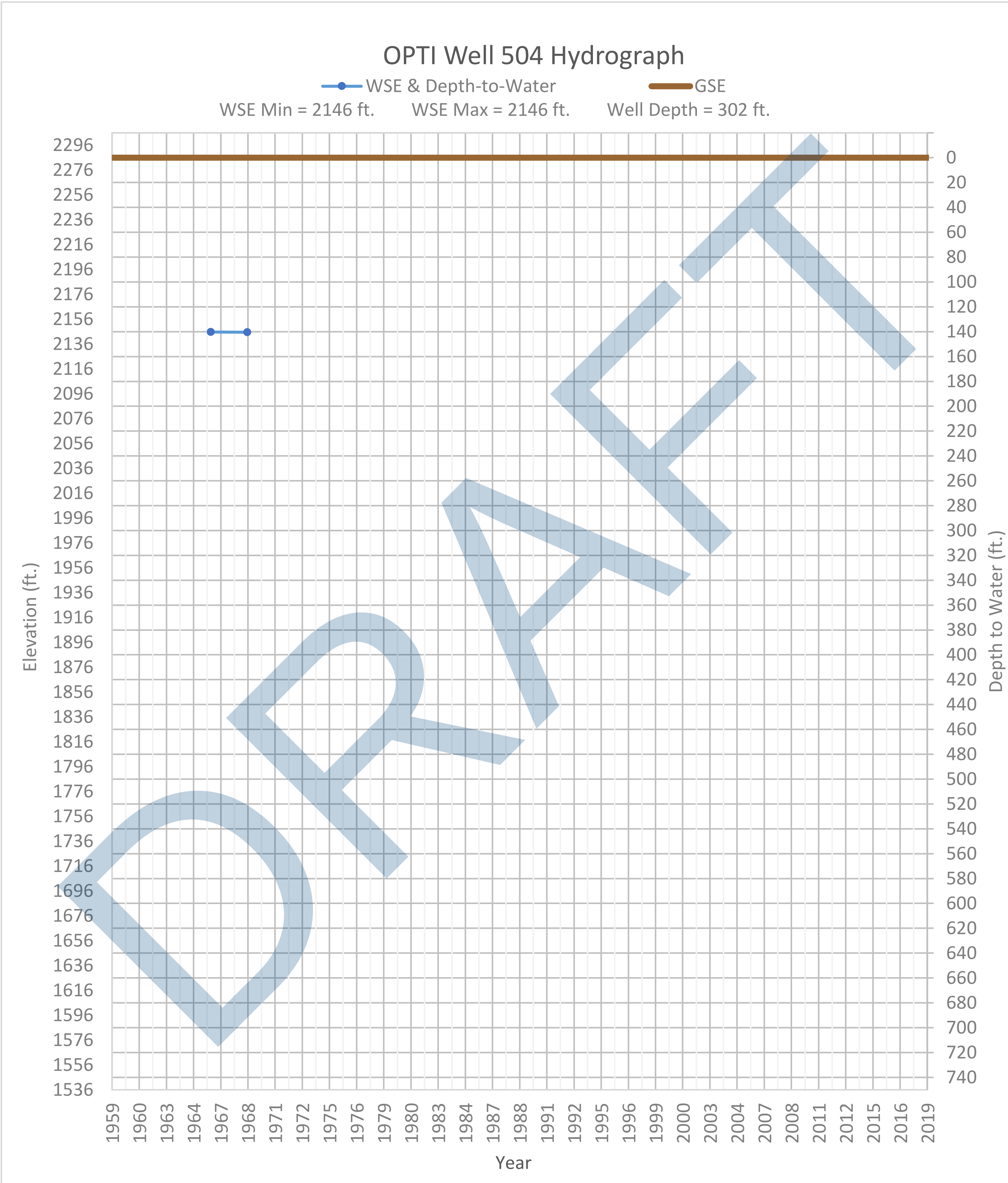


OPTI Well 495 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2225 ft.
WSE Max = 2238 ft.
Well Depth = 346 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

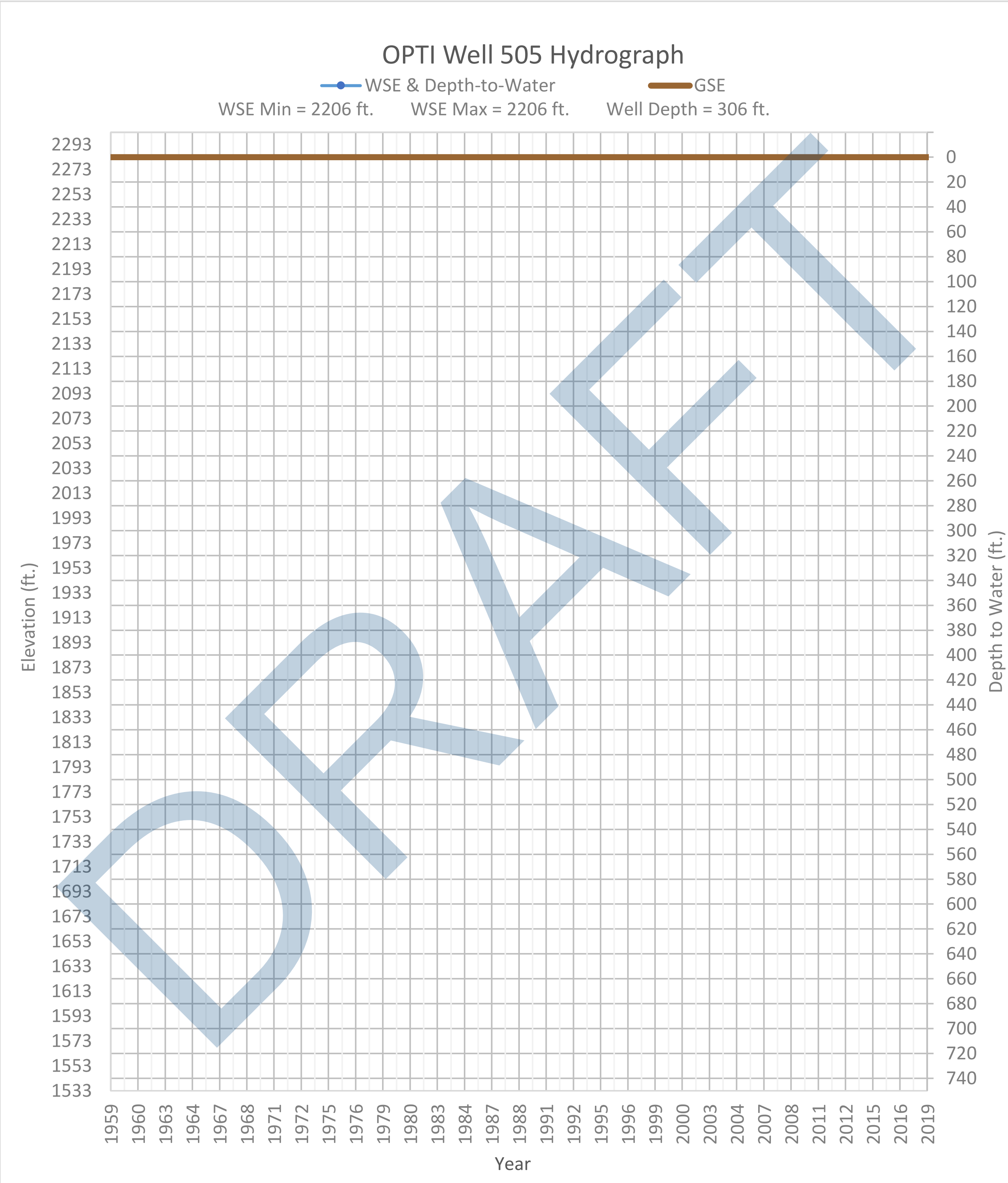

OPTI Well 500 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1973 ft.
WSE Max = 2137 ft.
Well Depth = 550 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



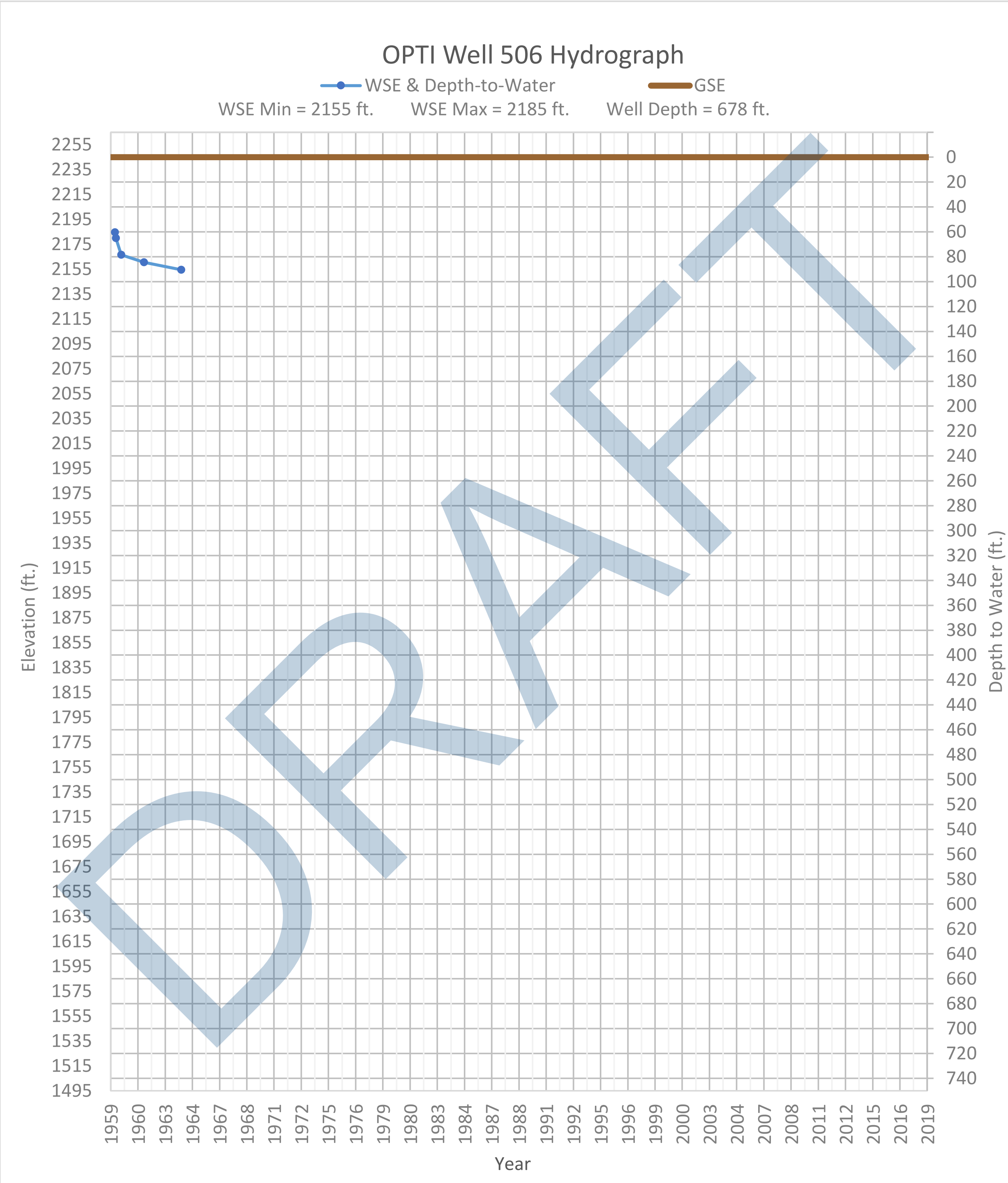
OPTI Well 502 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2415 ft.
WSE Max = 2415 ft.
Well Depth = 160 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



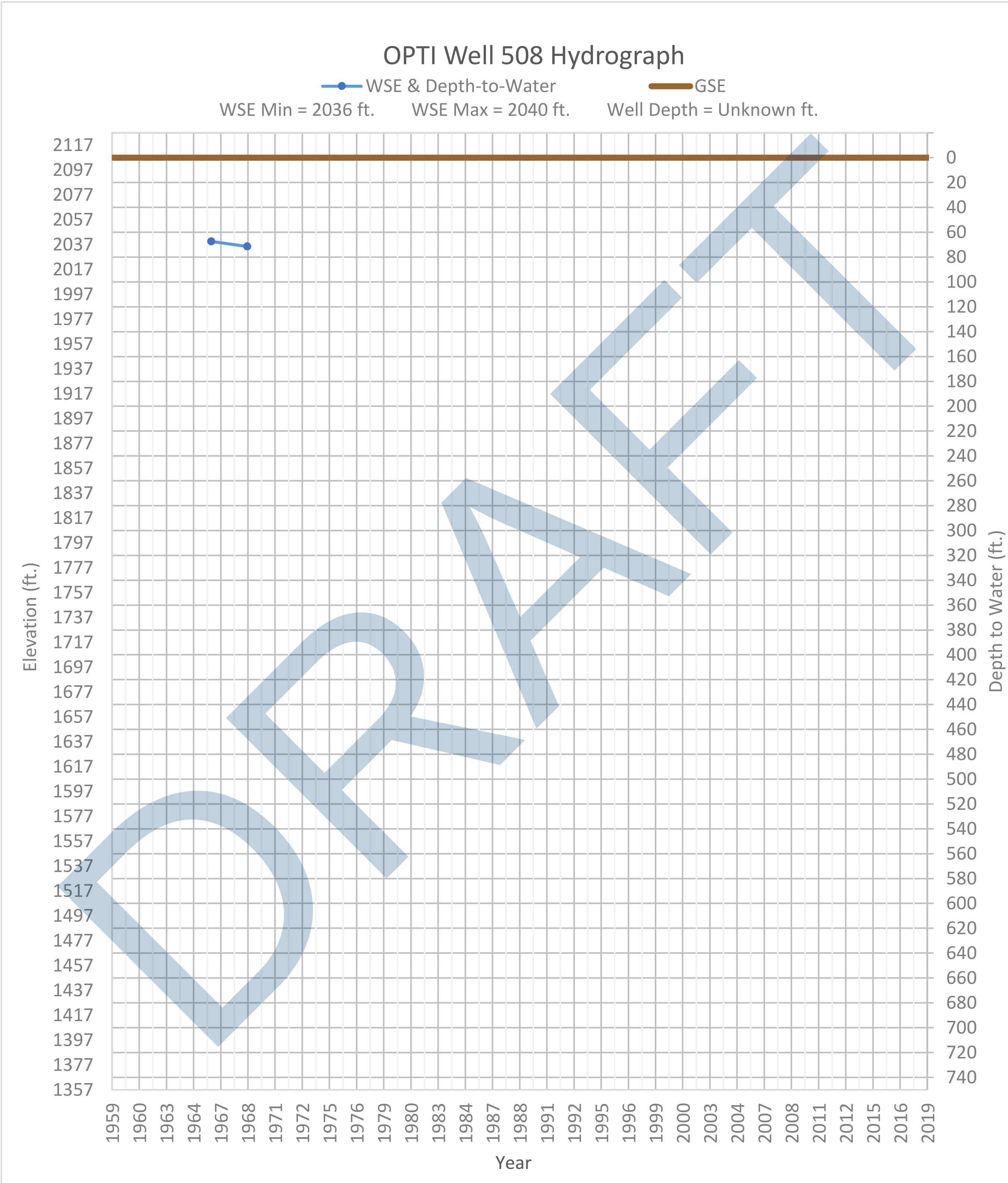
OPTI Well 504 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2146 ft.
WSE Max = 2146 ft.
Well Depth = 302 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



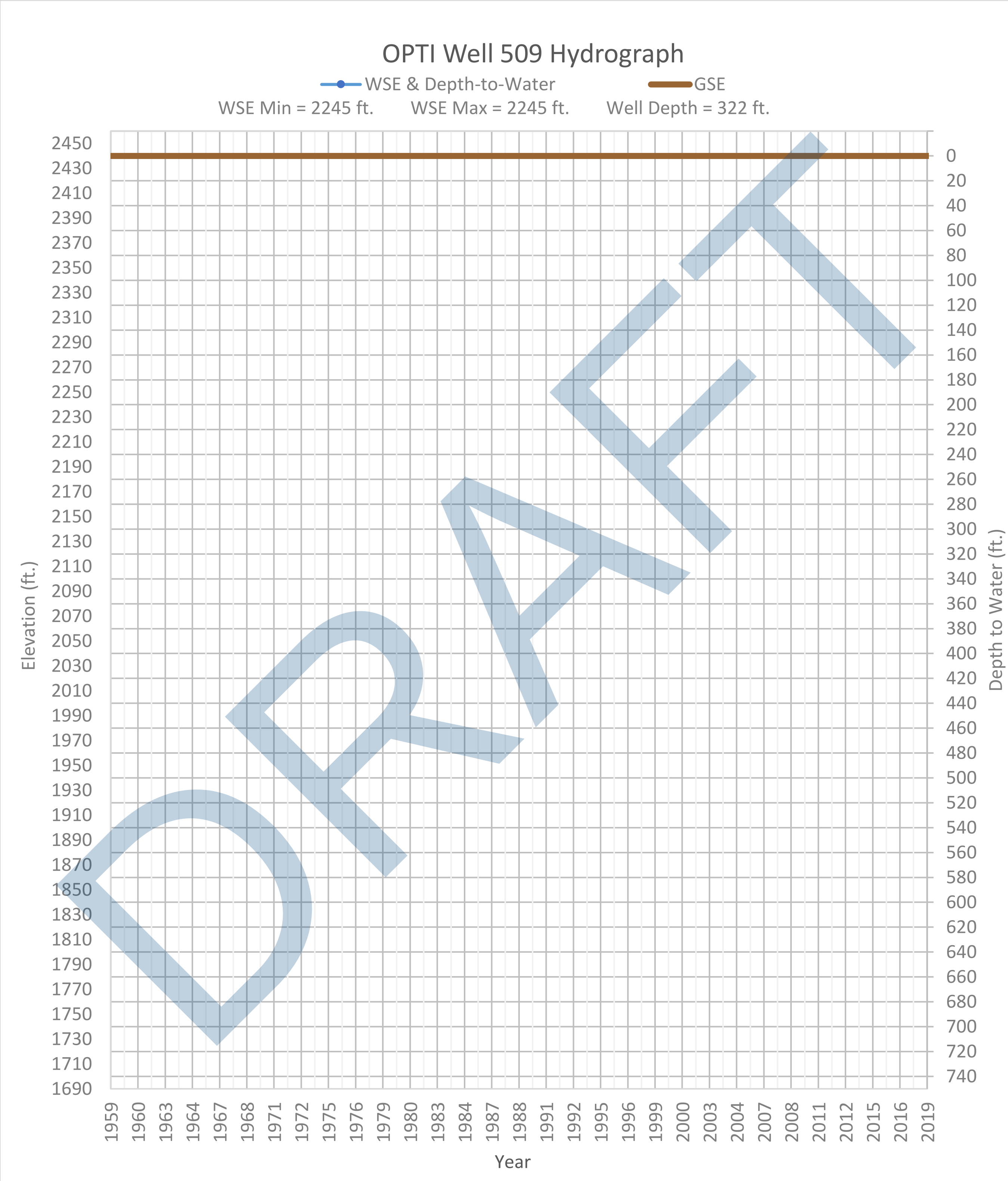
OPTI Well 505 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2206 ft.
WSE Max = 2206 ft.
Well Depth = 306 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



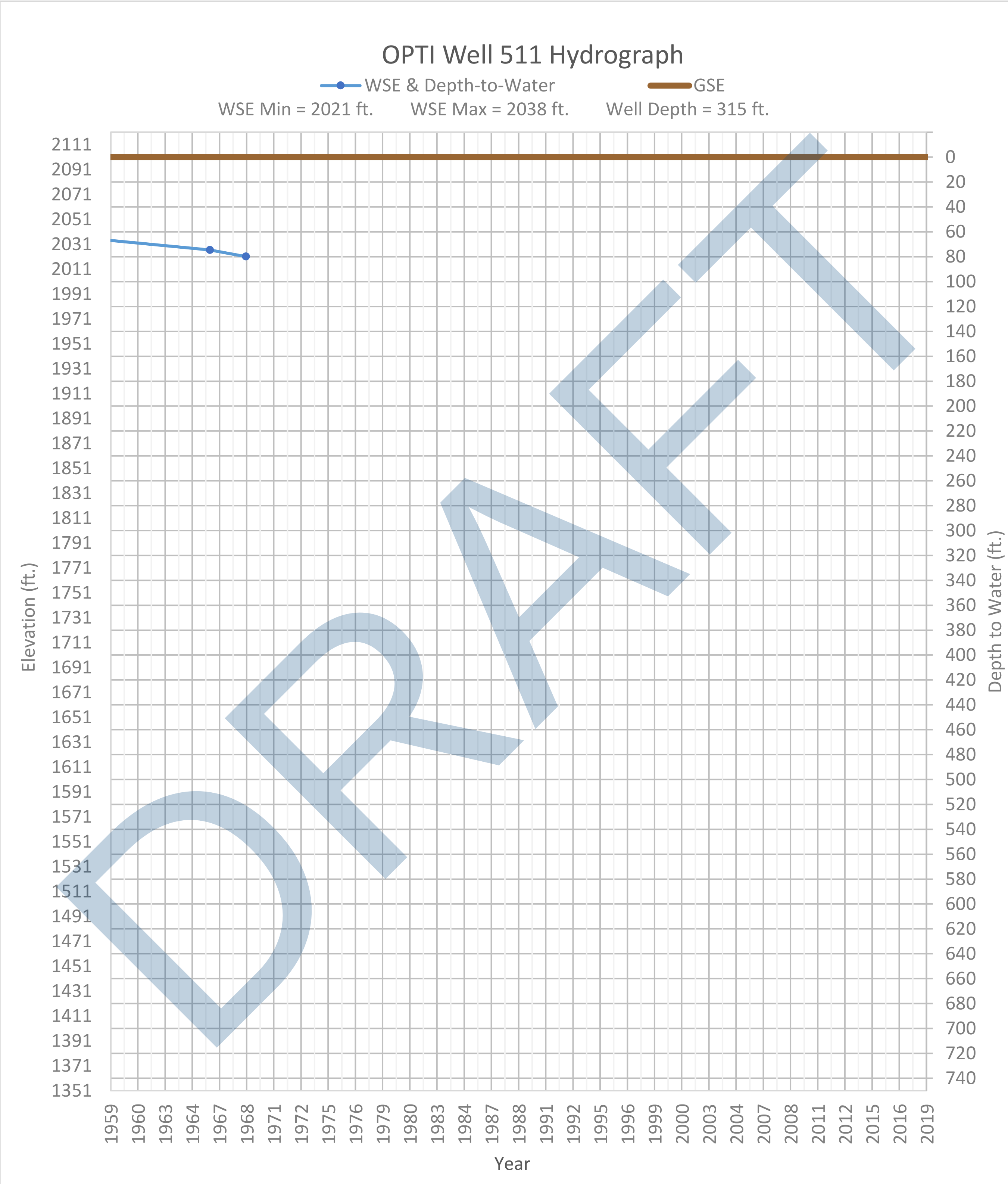
OPTI Well 506 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2155 ft.
WSE Max = 2185 ft.
Well Depth = 678 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



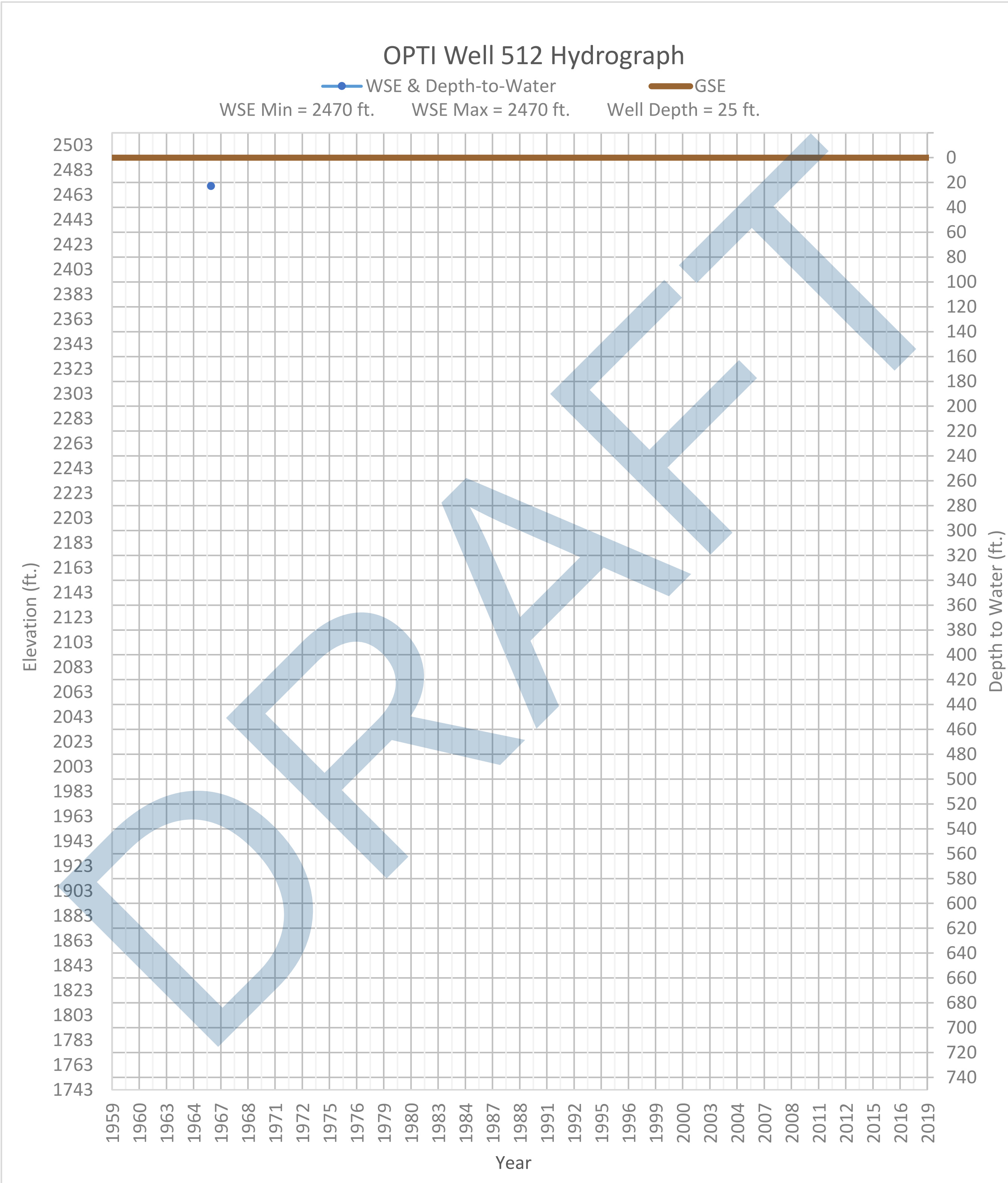
OPTI Well 508 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2036 ft.
WSE Max = 2040 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



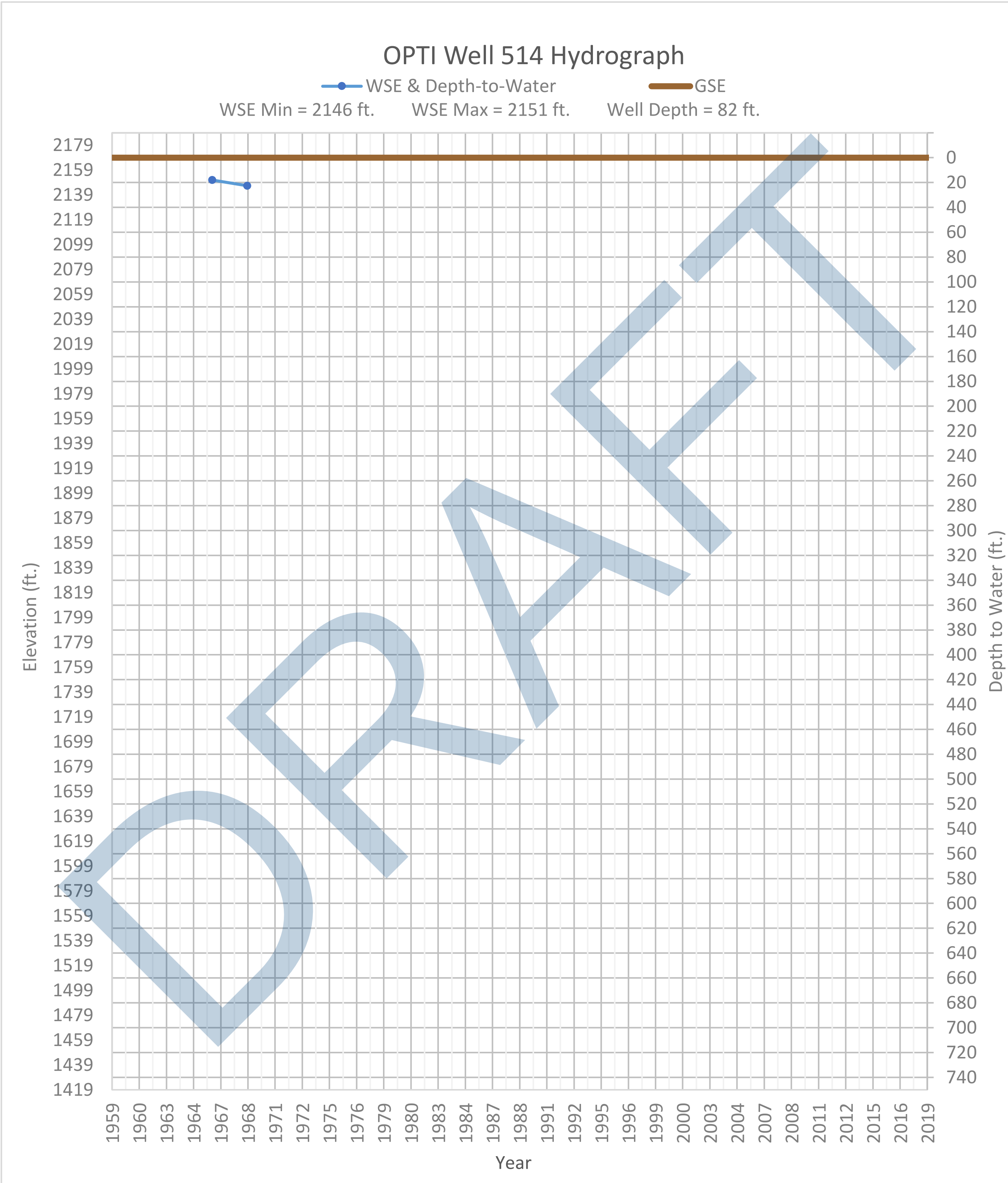
OPTI Well 509 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2245 ft.
WSE Max = 2245 ft.
Well Depth = 322 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



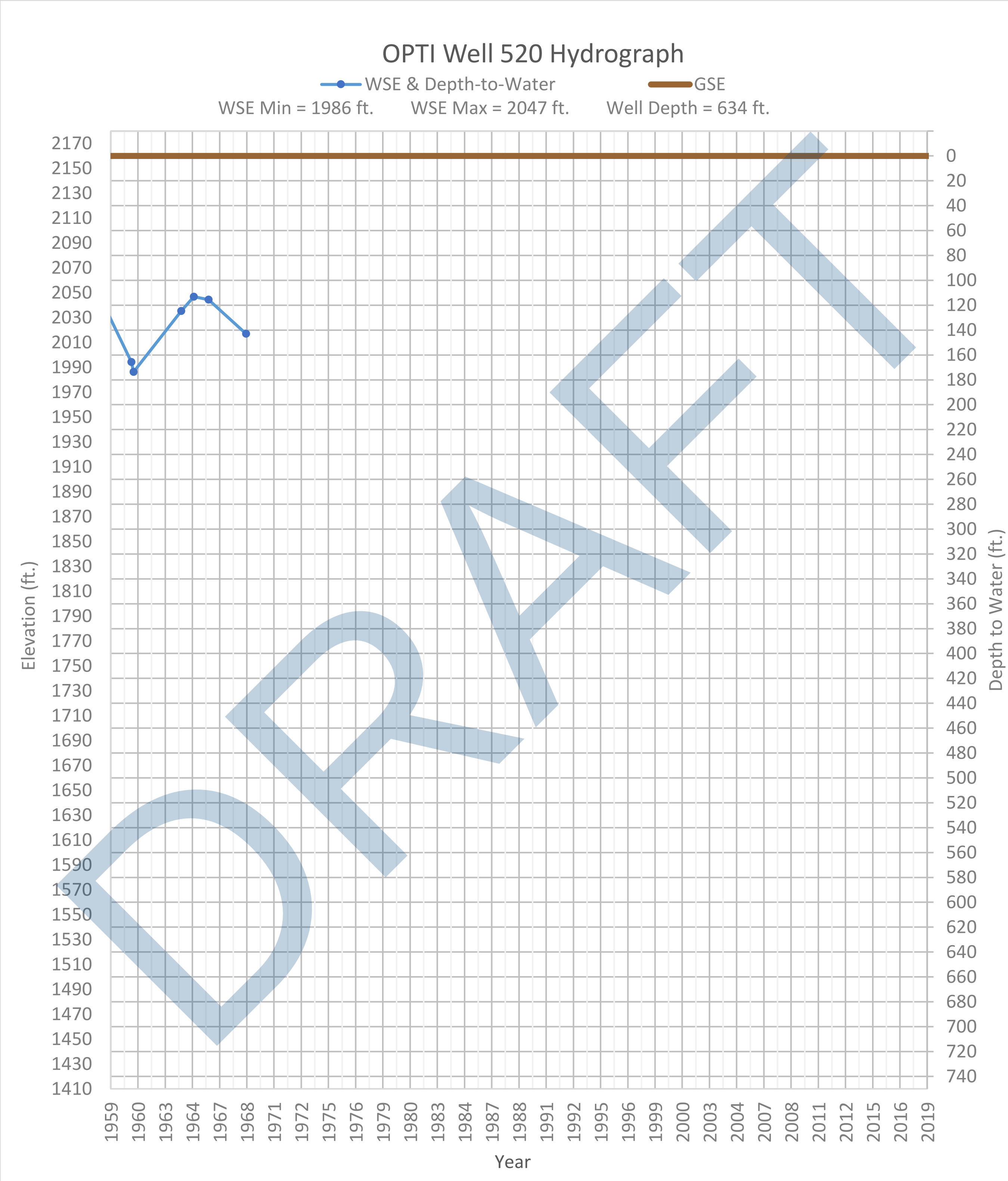
OPTI Well 511 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2021 ft.
WSE Max = 2038 ft.
Well Depth = 315 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



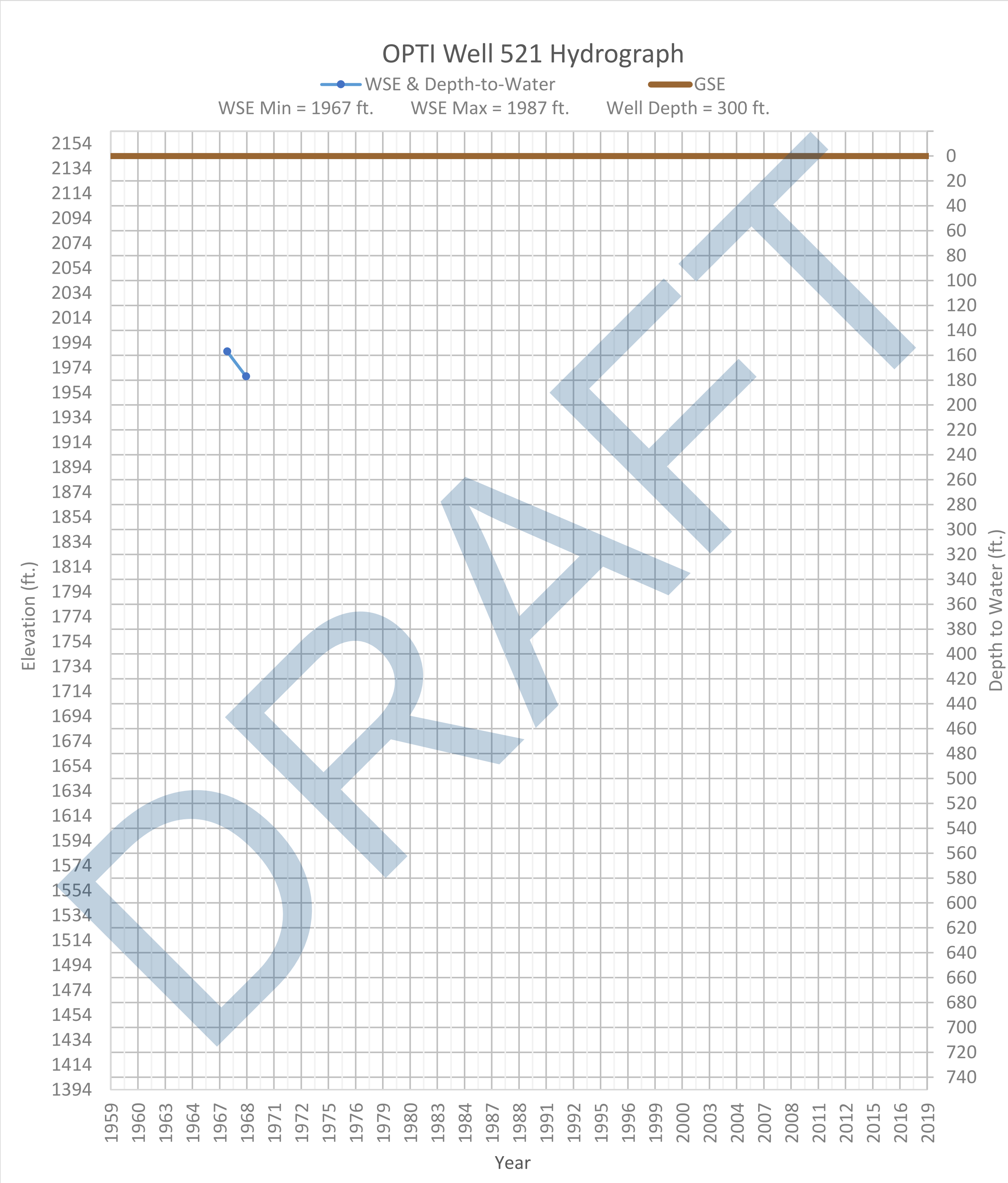
OPTI Well 512 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2470 ft.
WSE Max = 2470 ft.
Well Depth = 25 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



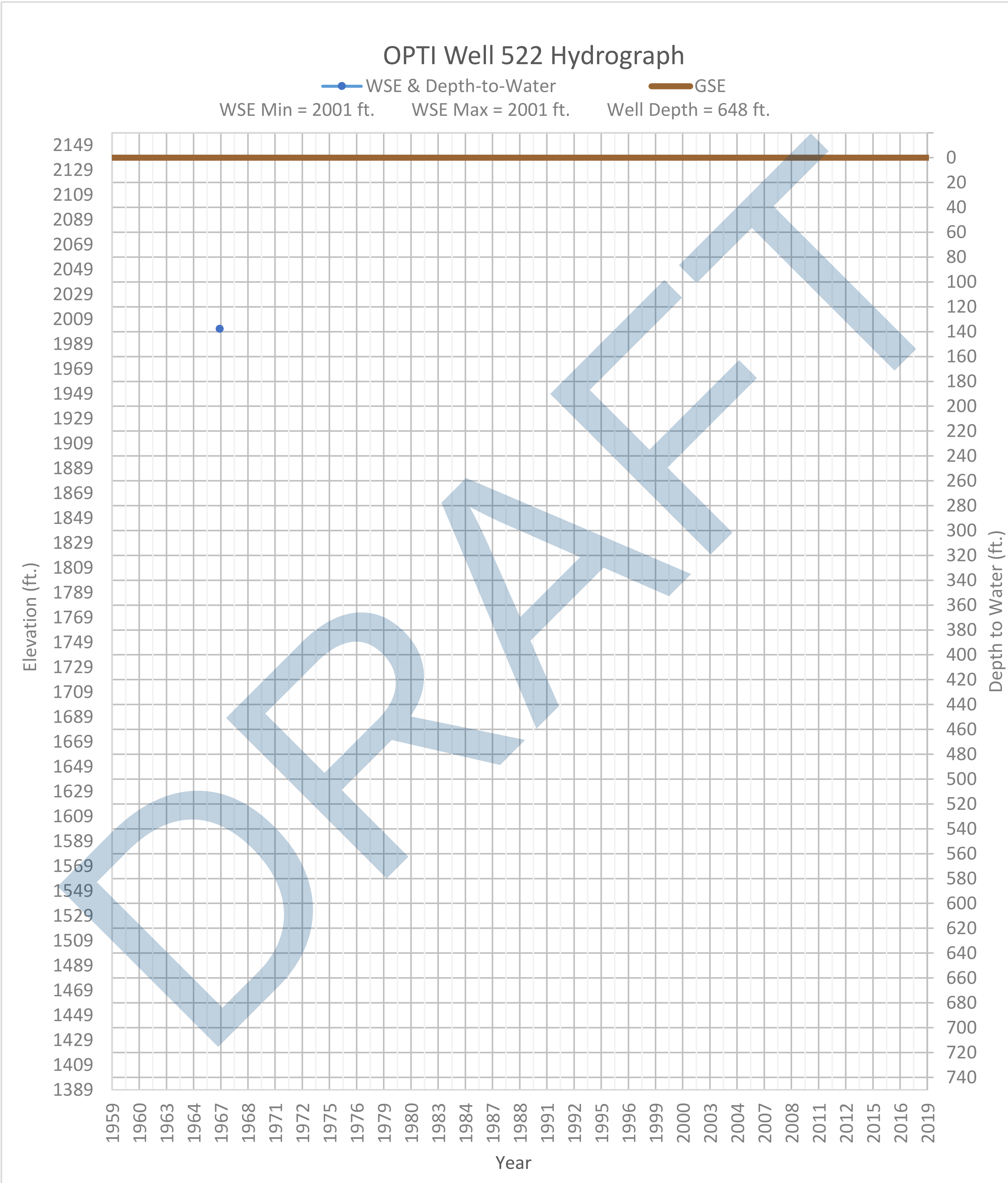
OPTI Well 514 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2146 ft.
WSE Max = 2151 ft.
Well Depth = 82 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2179
2159
2139
2119
2099
2079
2059
2039
2019
1999
1979
1959
1939
1919
1899
1879
1859
1839
1819
1799
1779
1759
1739
1719
1699
1679
1659
1639
1619
1599
1579
1559
1539
1519
1499
1479
1459
1439
1419
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
1975
1976
1979
1980
1983
1984
1987
1988
1991
1992
1995
1996
1999
2000
2003
2004
2007
2008
2011
2012
2015
2016
2019
DRAFT



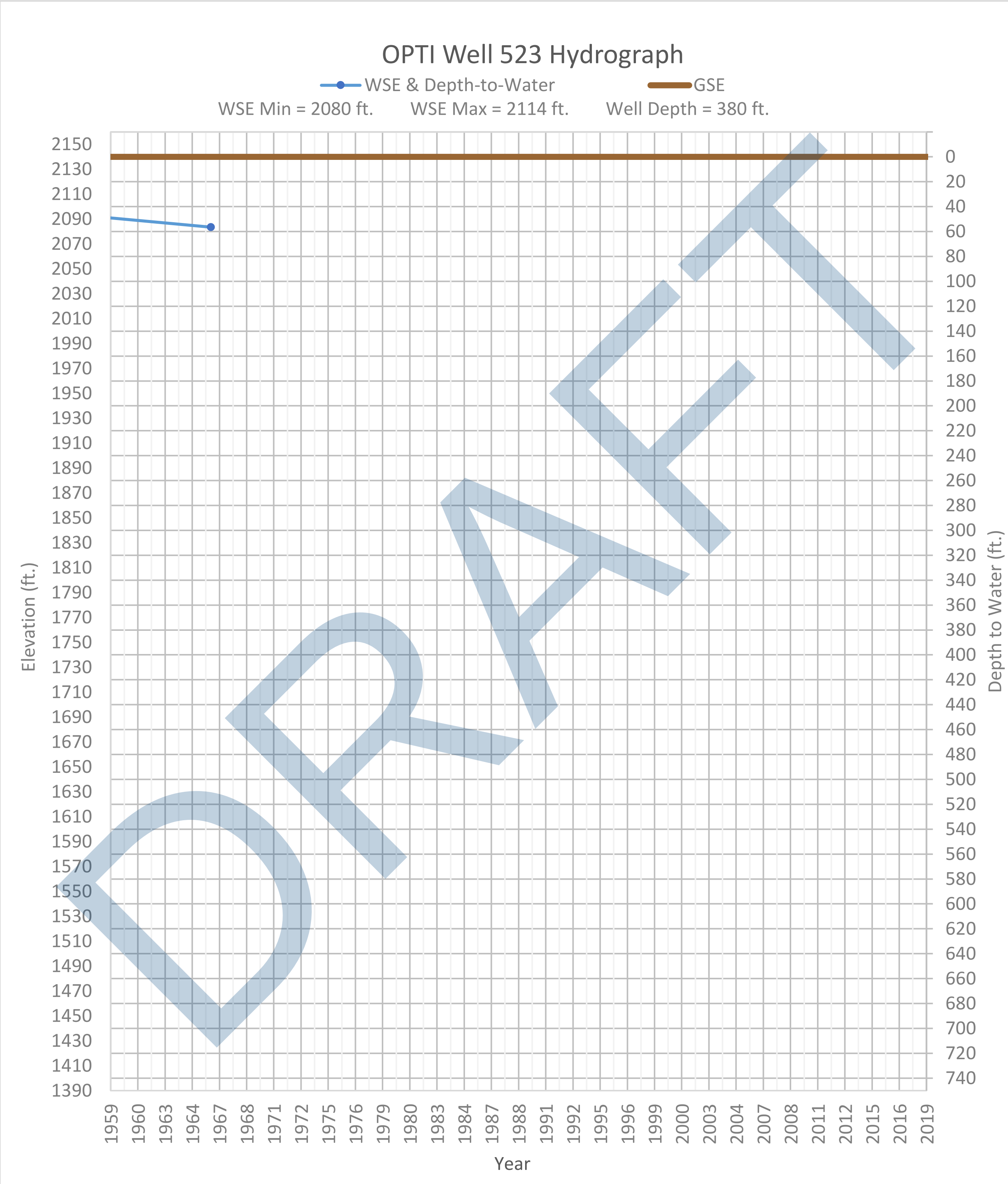
OPTI Well 520 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1986 ft.
WSE Max = 2047 ft.
Well Depth = 634 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

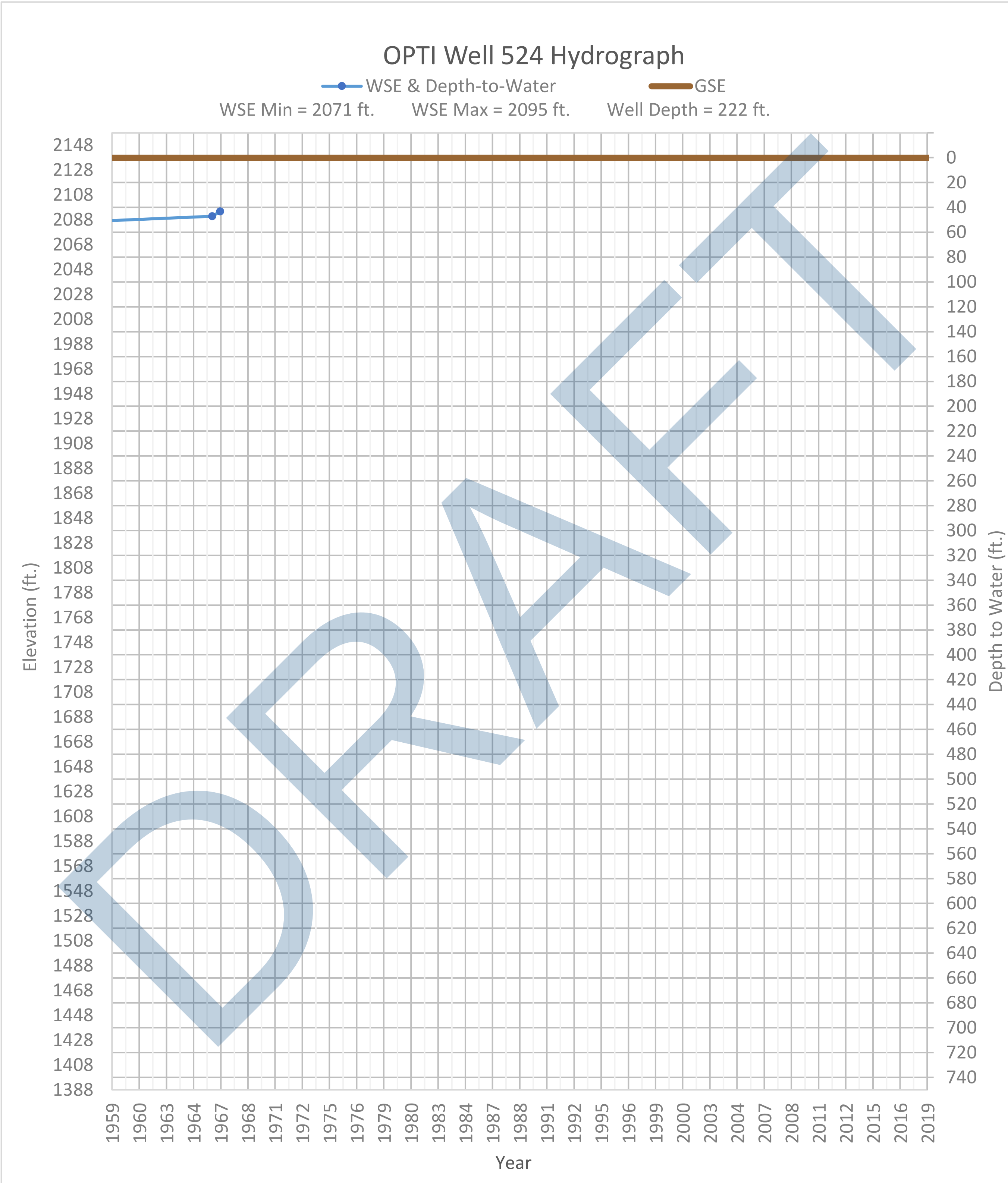


OPTI Well 521 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1967 ft.
WSE Max = 1987 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

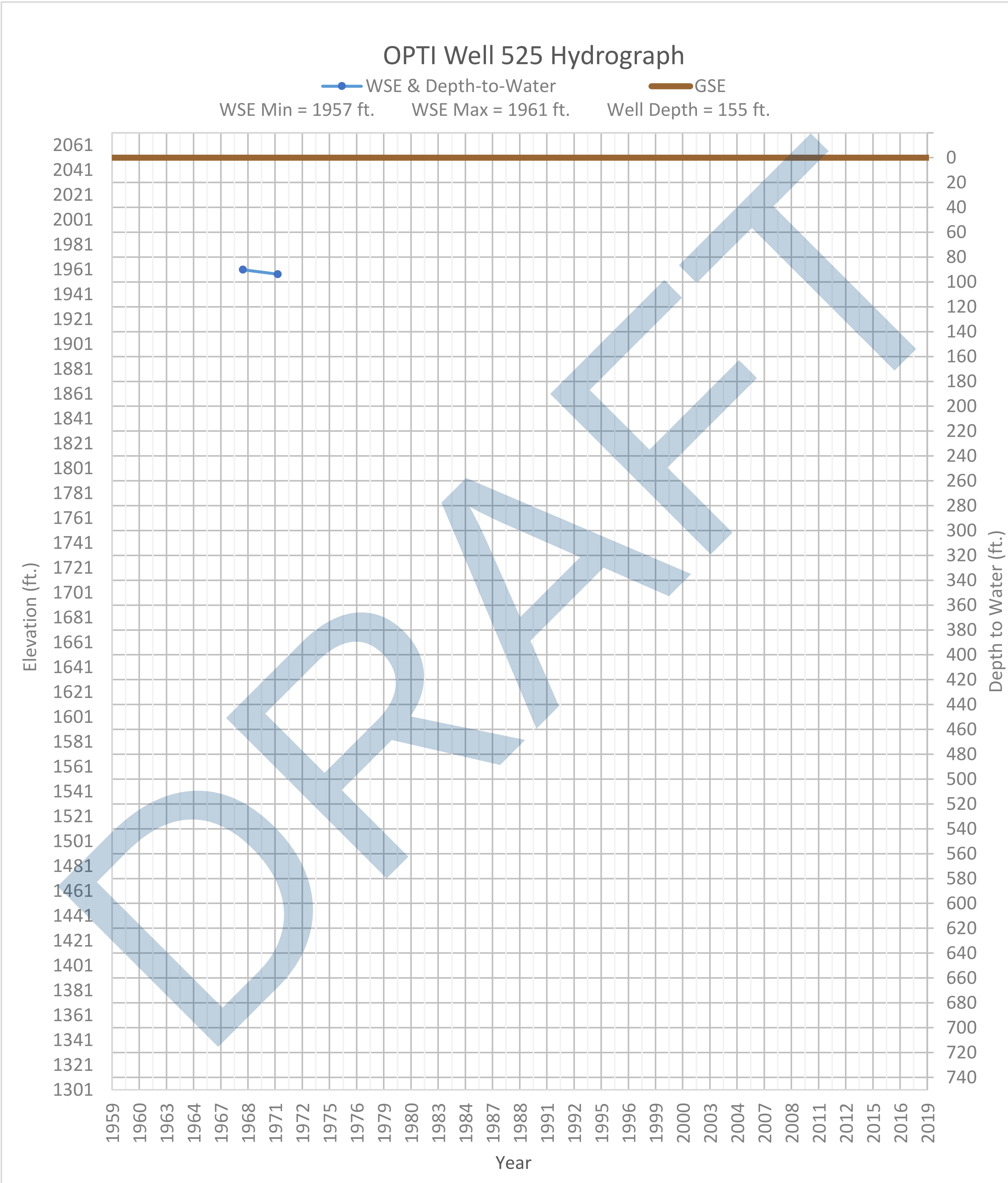


OPTI Well 522 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2001 ft.
WSE Max = 2001 ft.
Well Depth = 648 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

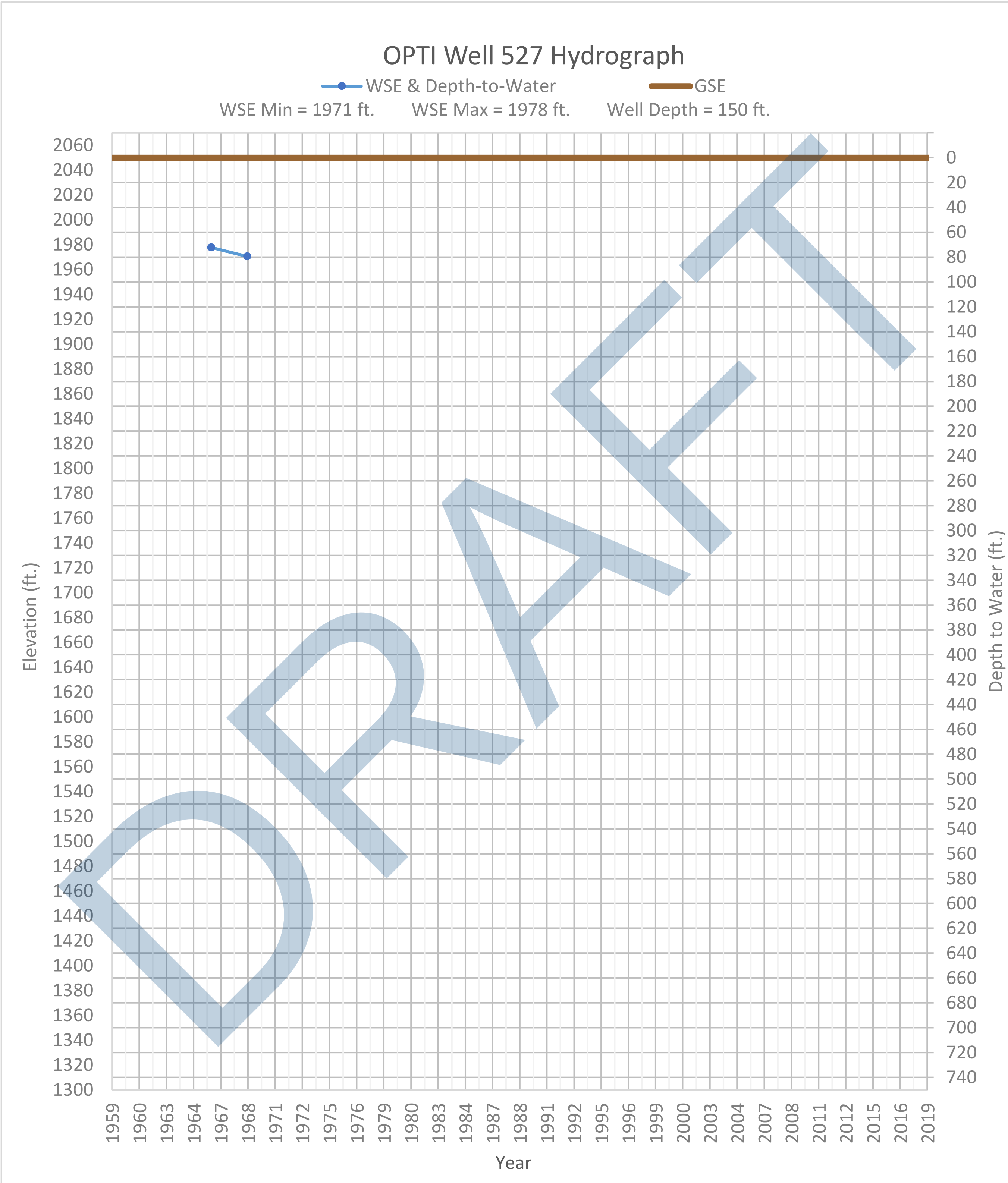

OPTI Well 523 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2080 ft.
WSE Max = 2114 ft.
Well Depth = 380 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



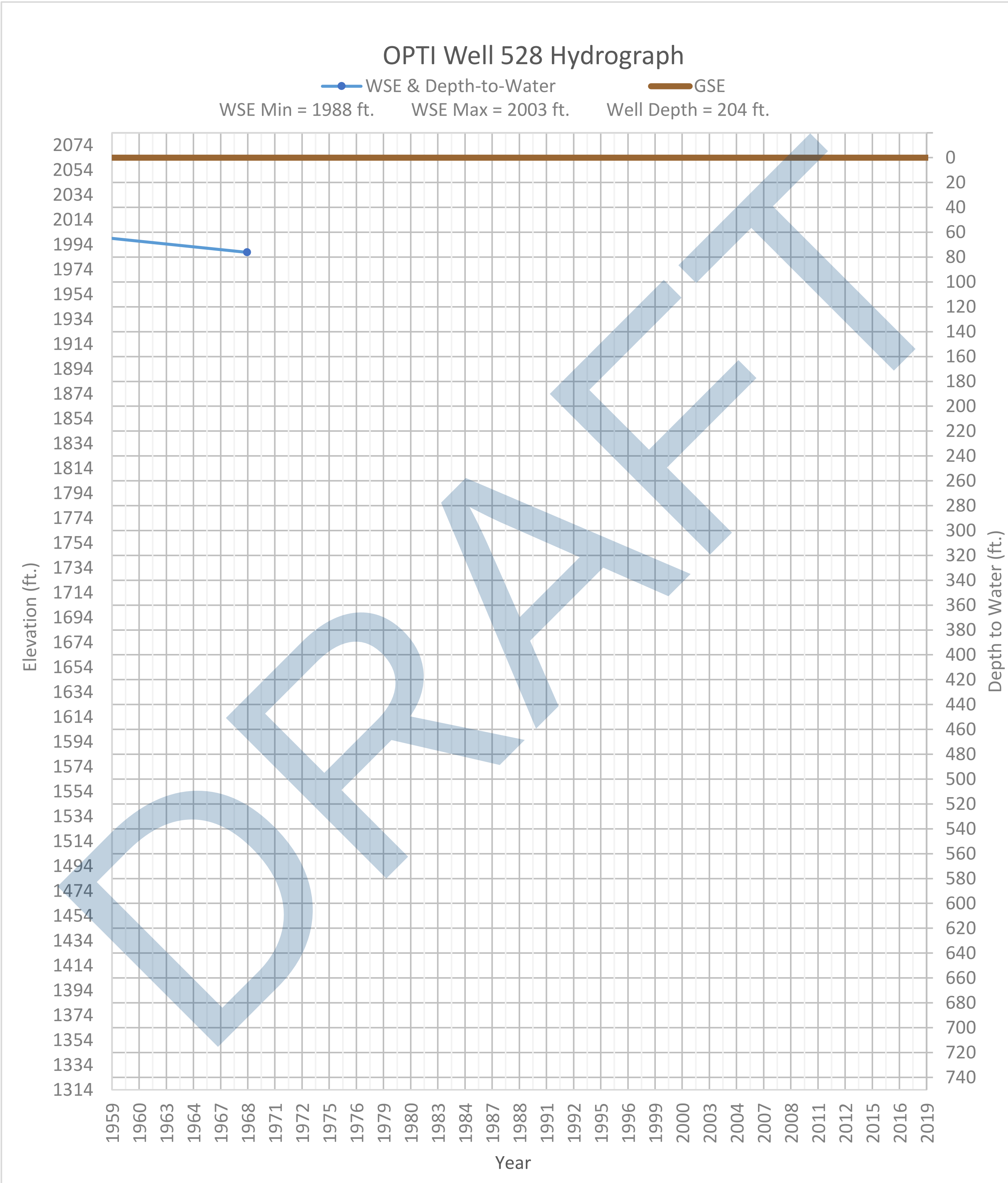
OPTI Well 524 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2071 ft.
WSE Max = 2095 ft.
Well Depth = 222 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



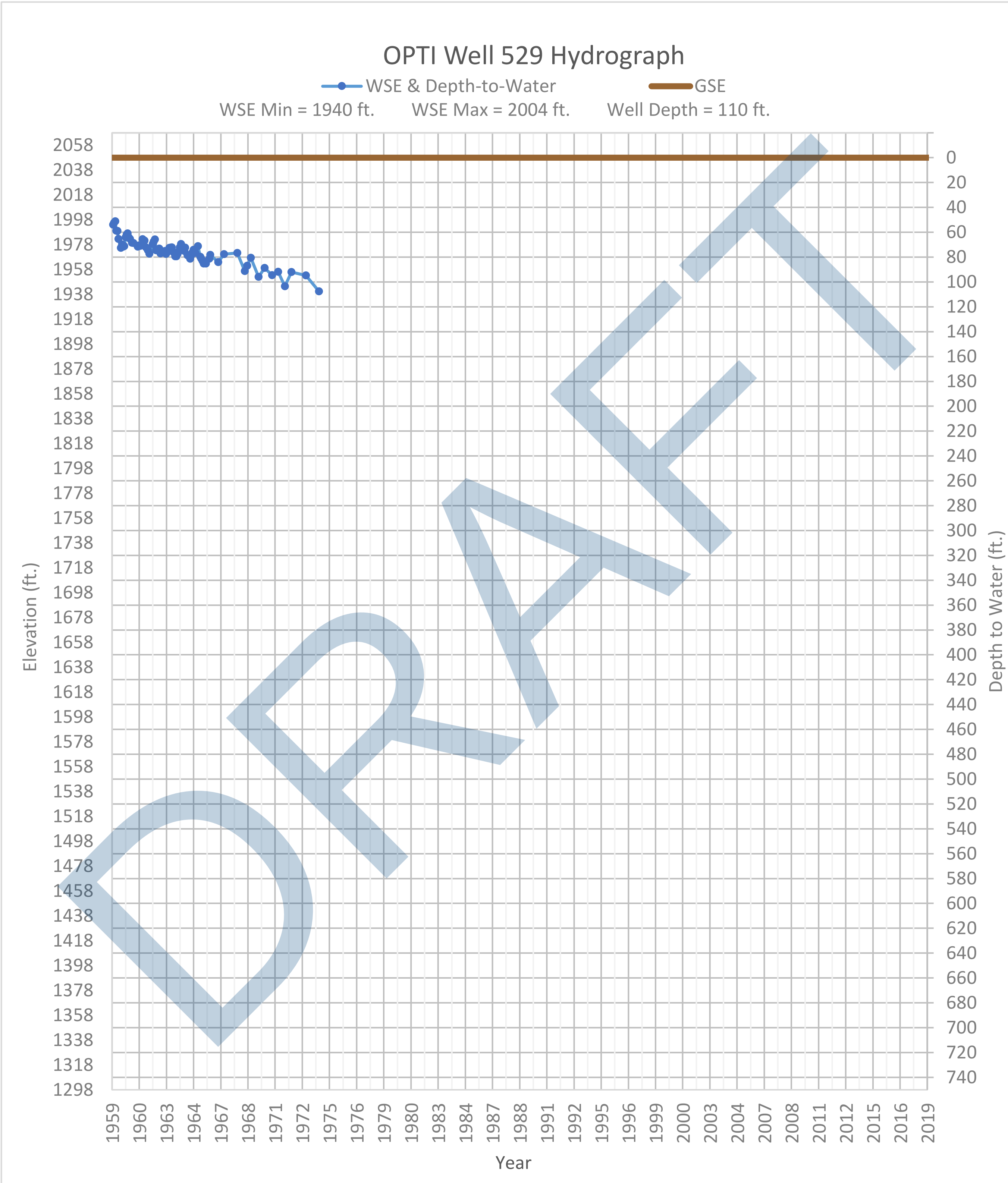
OPTI Well 525 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1957 ft.
WSE Max = 1961 ft.
Well Depth = 155 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



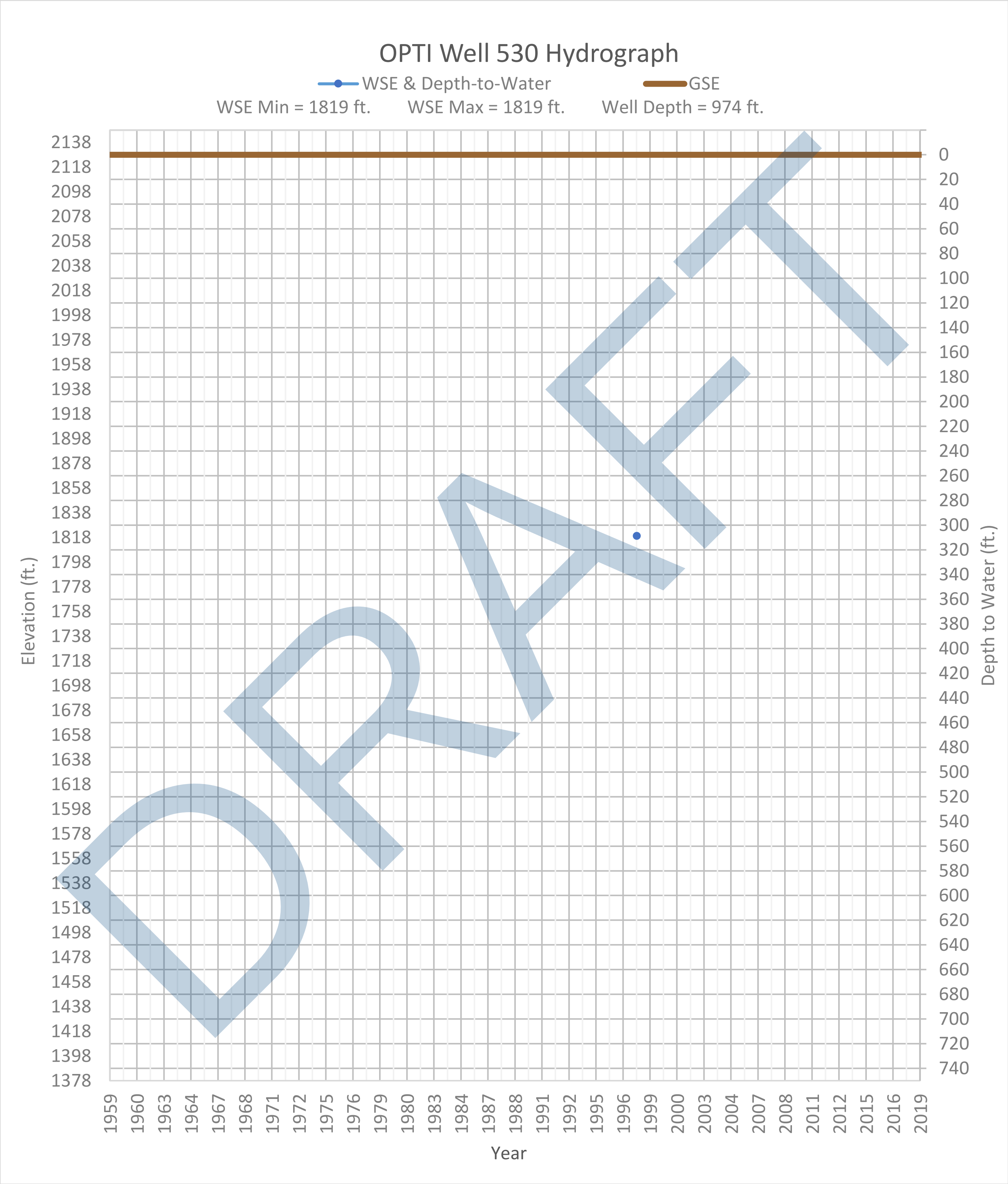
OPTI Well 527 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1971 ft.
WSE Max = 1978 ft.
Well Depth = 150 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

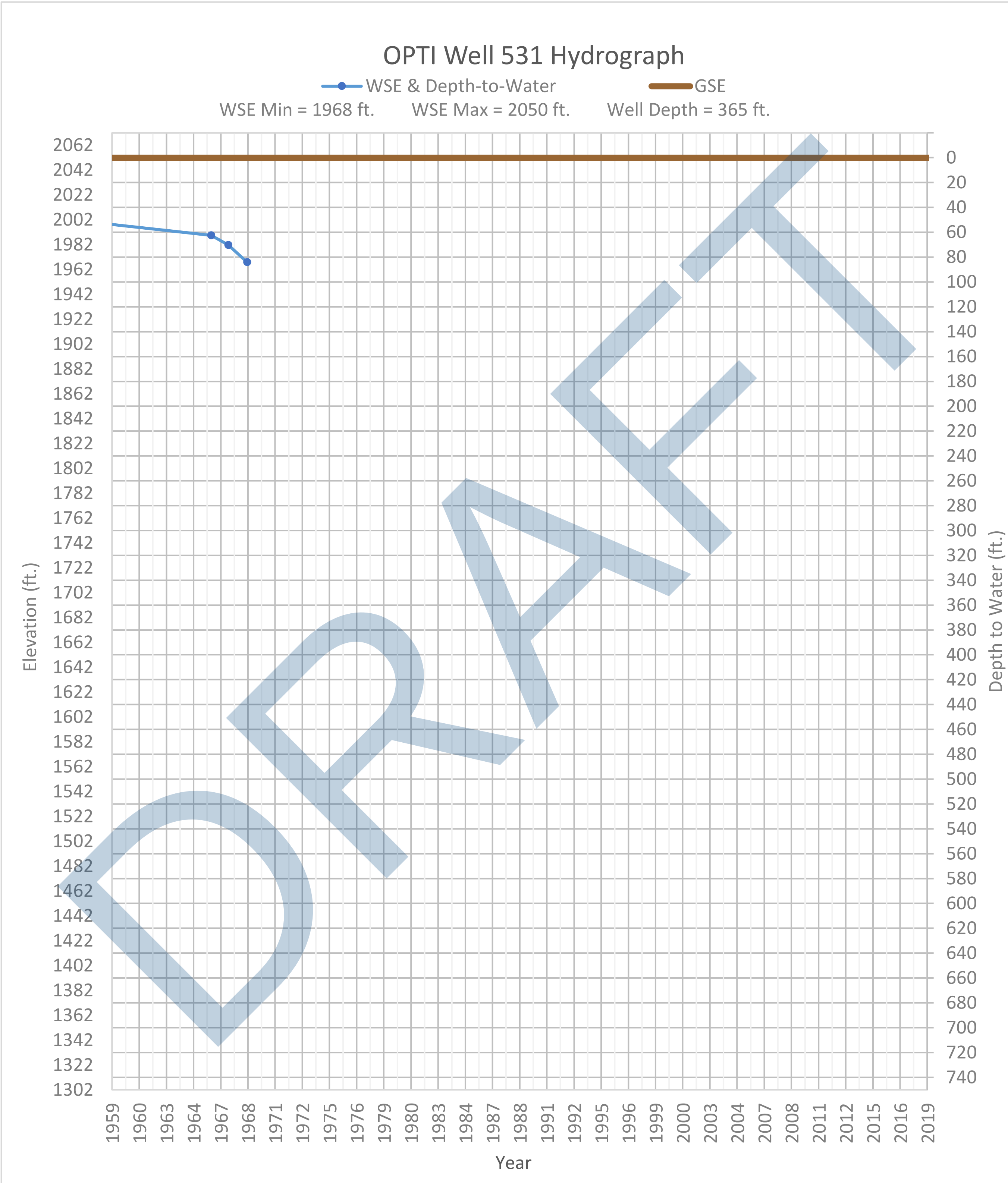


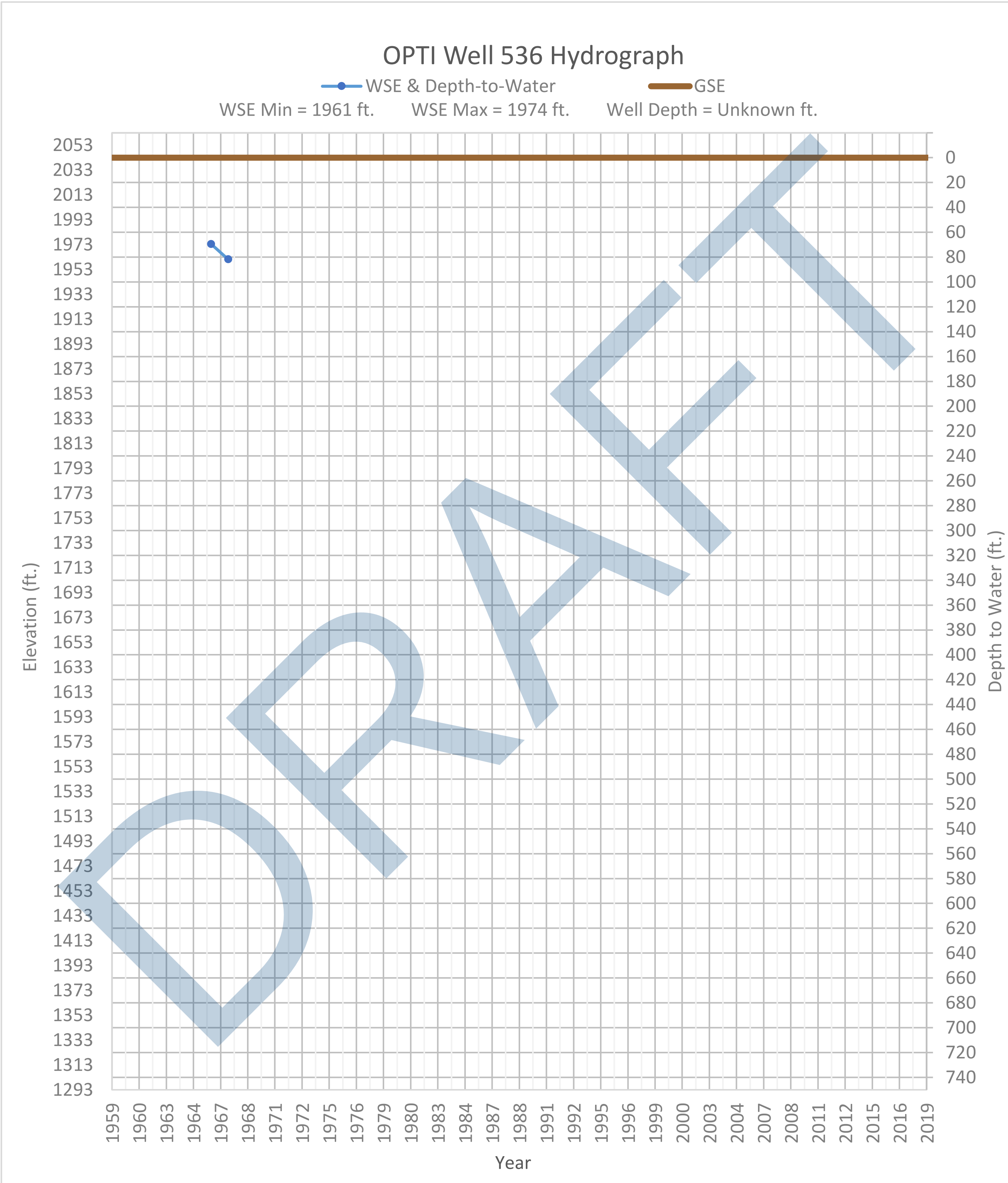
OPTI Well 528 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1988 ft.
WSE Max = 2003 ft.
Well Depth = 204 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

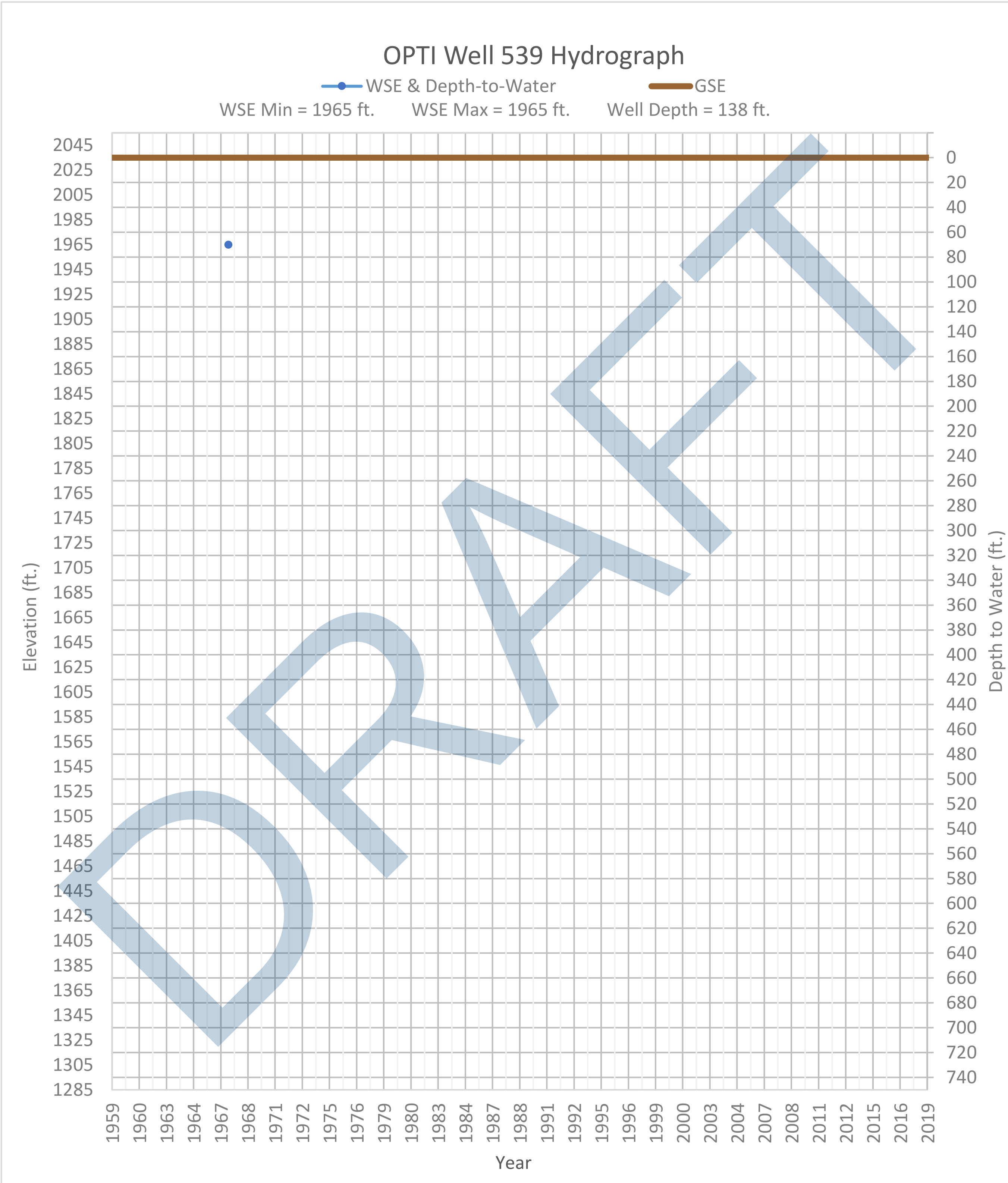


OPTI Well 529 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1940 ft.
WSE Max = 2004 ft.
Well Depth = 110 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

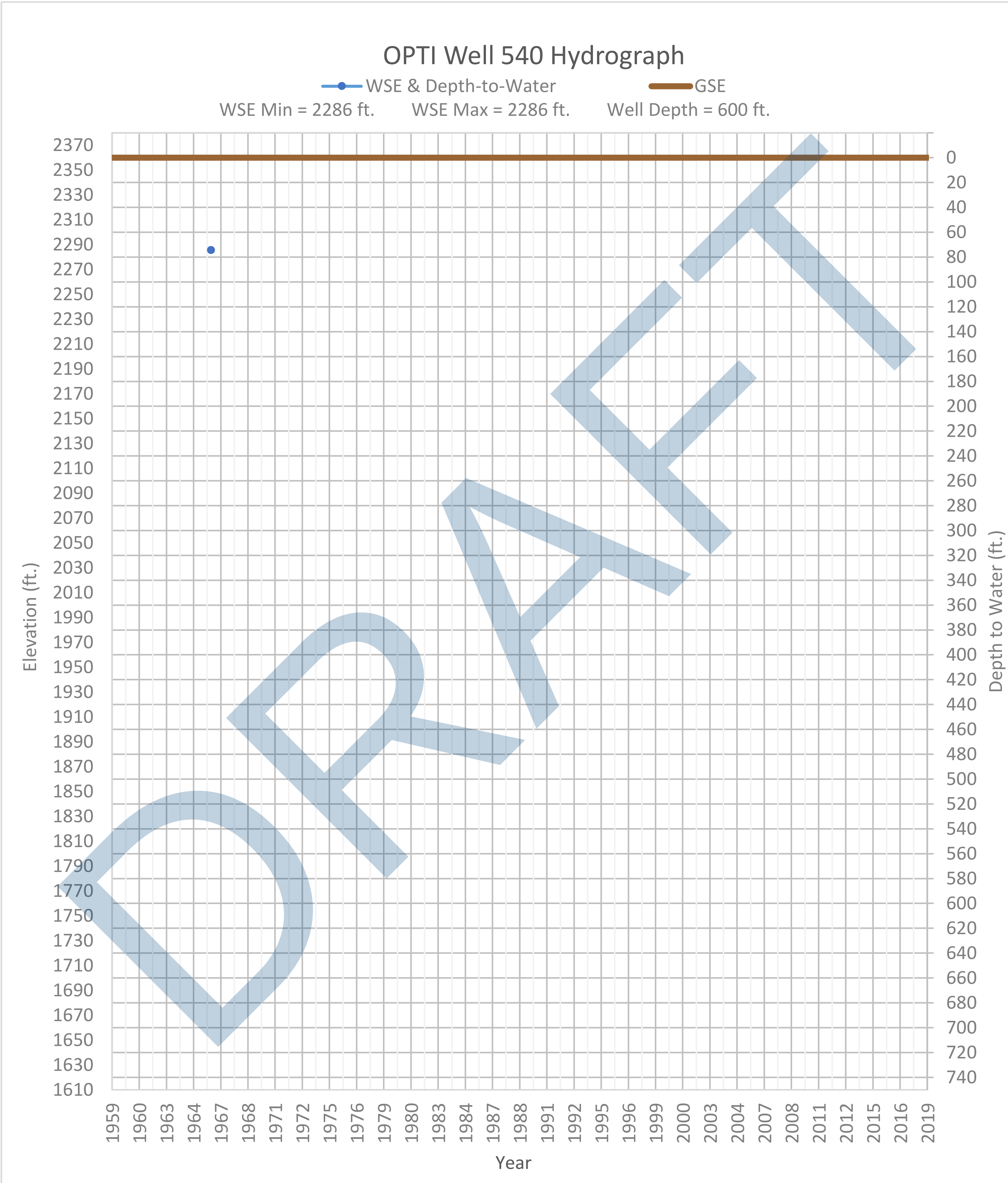

OPTI Well 530 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1819 ft.
WSE Max = 1819 ft.
Well Depth = 974 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

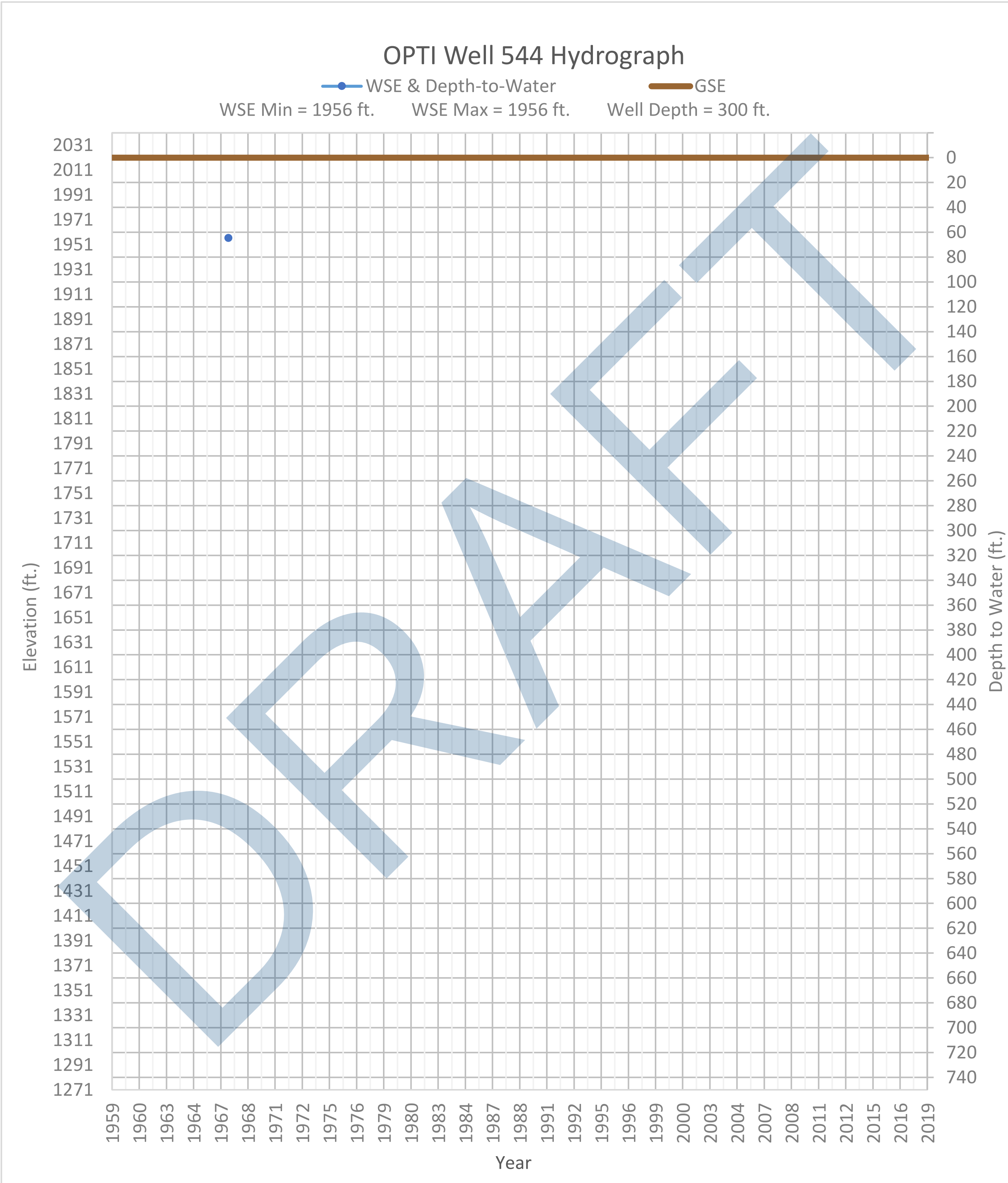

OPTI Well 531 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1968 ft.
WSE Max = 2050 ft.
Well Depth = 365 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 536 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1961 ft.
WSE Max = 1974 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2053 2033 2013 1993 1973 1953 1933 1913 1893 1873 1853 1833 1813 1793 1773 1753 1733 1713 1693 1673 1653 1633 1613 1593 1573 1553 1533 1513 1493 1473 1453 1433 1413 1393 1373 1353 1333 1313 1293
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT

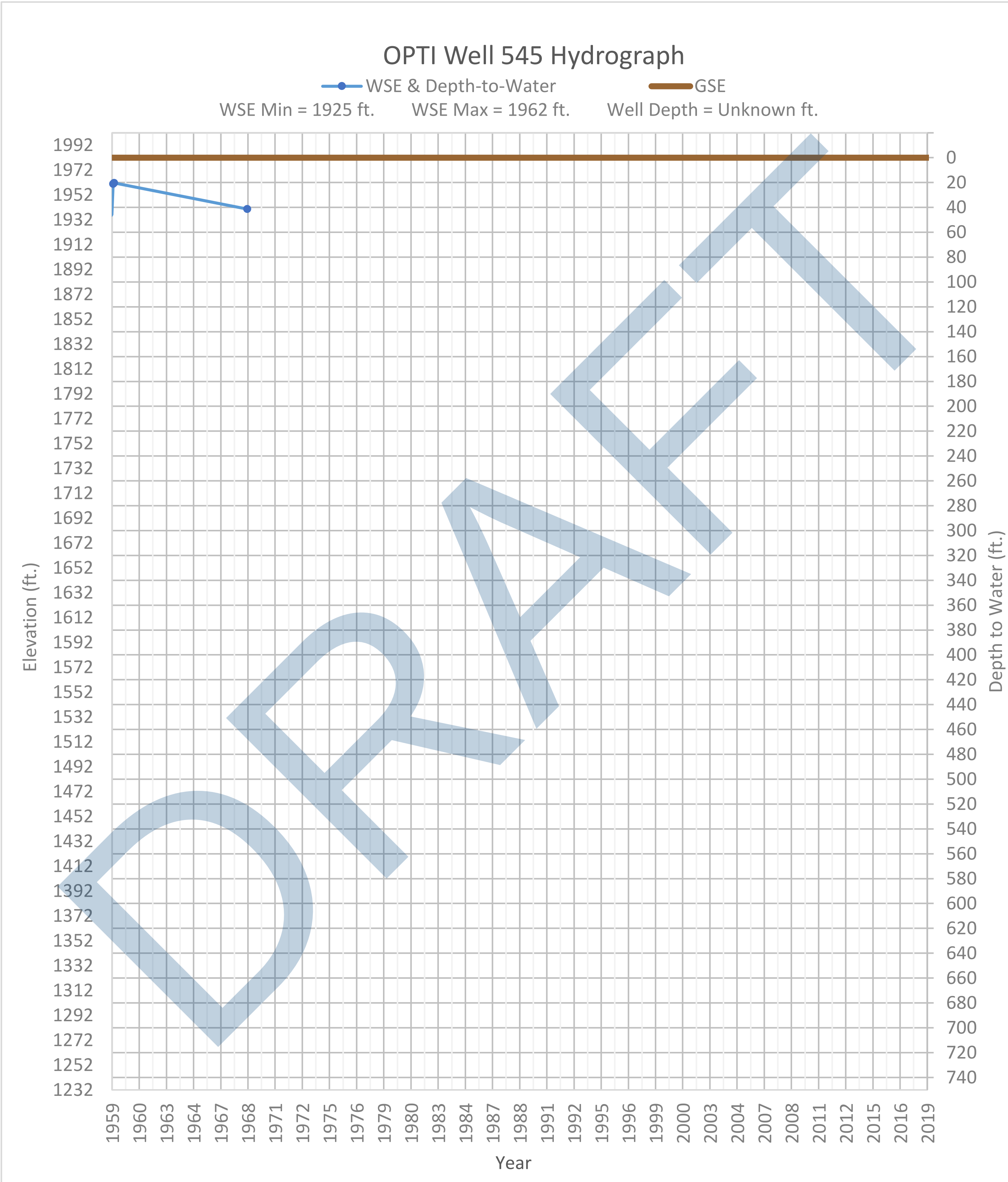


OPTI Well 539 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1965 ft.
WSE Max = 1965 ft.
Well Depth = 138 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

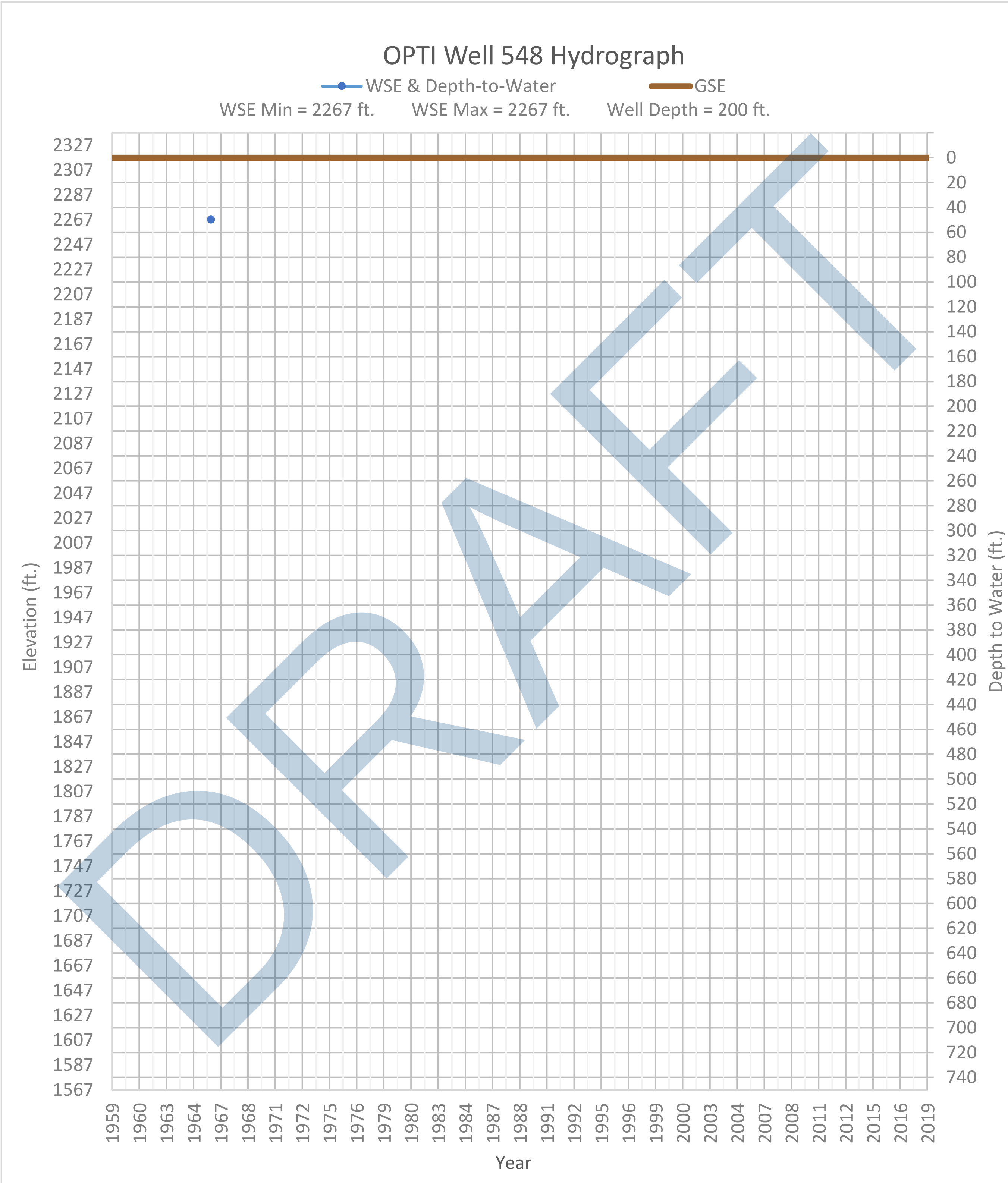

OPTI Well 540 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2286 ft.
WSE Max = 2286 ft.
Well Depth = 600 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2370 2350 2330 2310 2290 2270 2250 2230 2210 2190 2170 2150 2130 2110 2090 2070 2050 2030 2010 1990 1970 1950 1930 1910 1890 1870 1850 1830 1810 1790 1770 1750 1730 1710 1690 1670 1650 1630 1610
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT



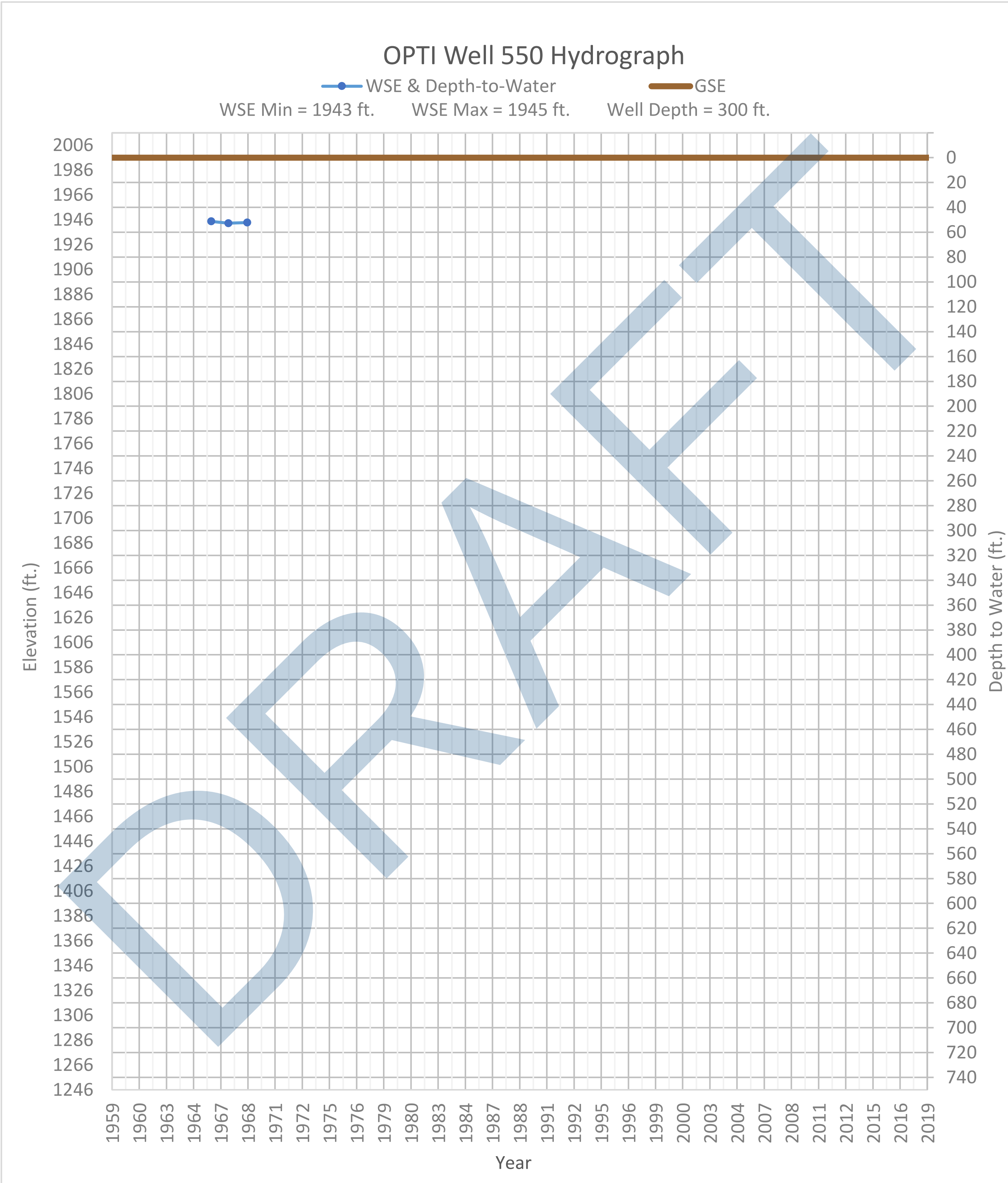
OPTI Well 544 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1956 ft.
WSE Max = 1956 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



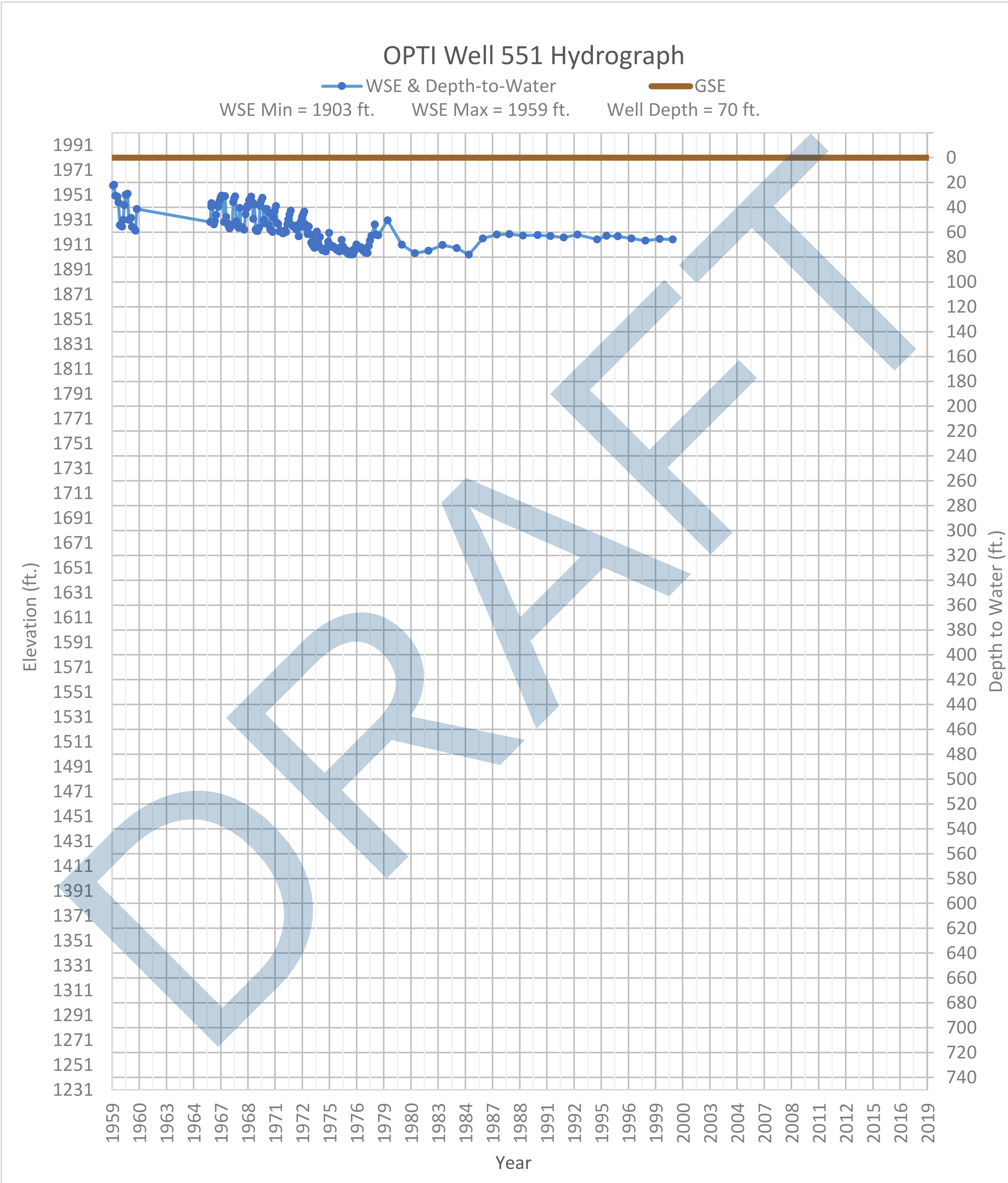
OPTI Well 545 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1925 ft.
WSE Max = 1962 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



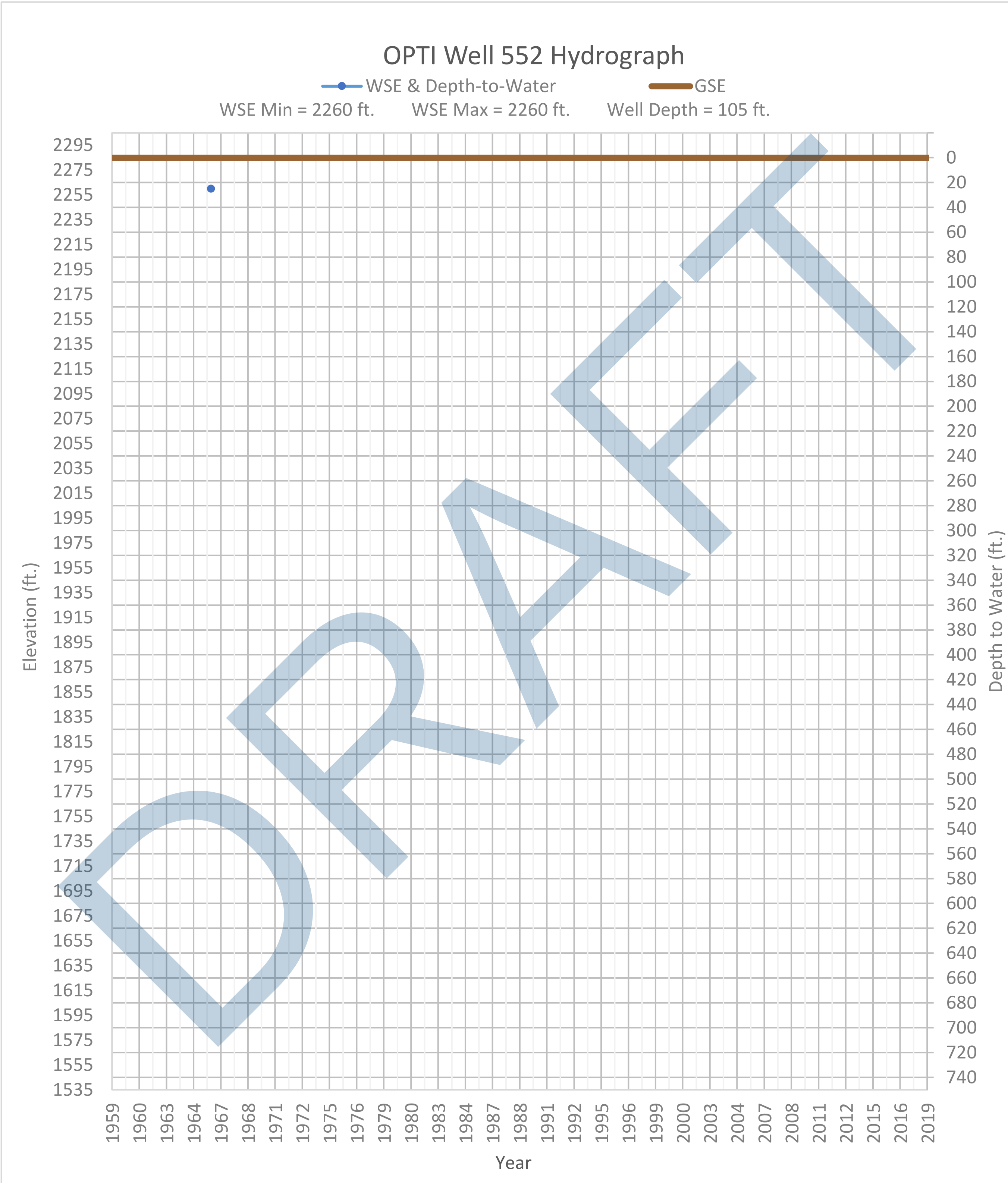
OPTI Well 548 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2267 ft.
WSE Max = 2267 ft.
Well Depth = 200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



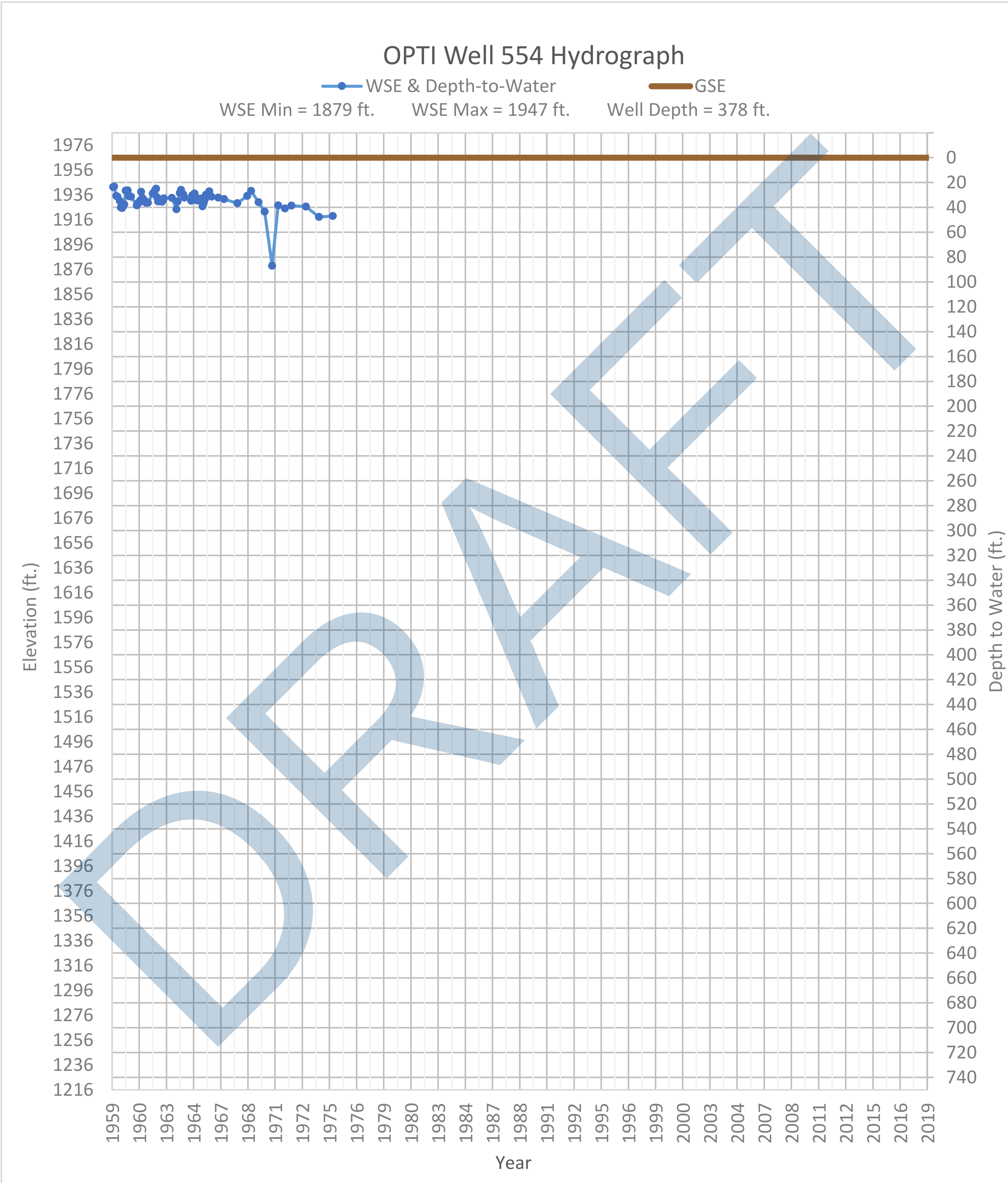
OPTI Well 550 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1943 ft.
WSE Max = 1945 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



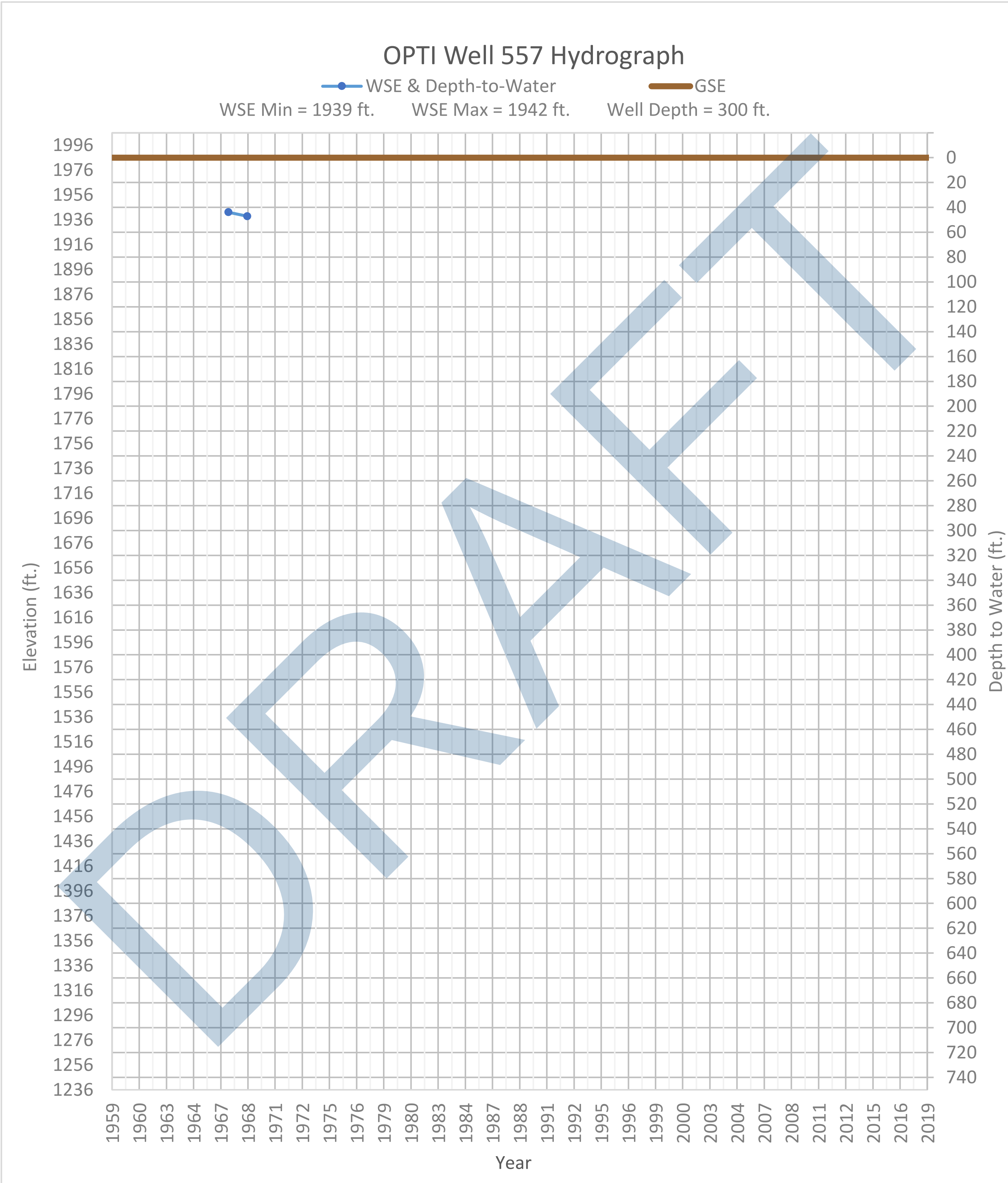
OPTI Well 551 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1903 ft.
WSE Max = 1959 ft.
Well Depth = 70 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



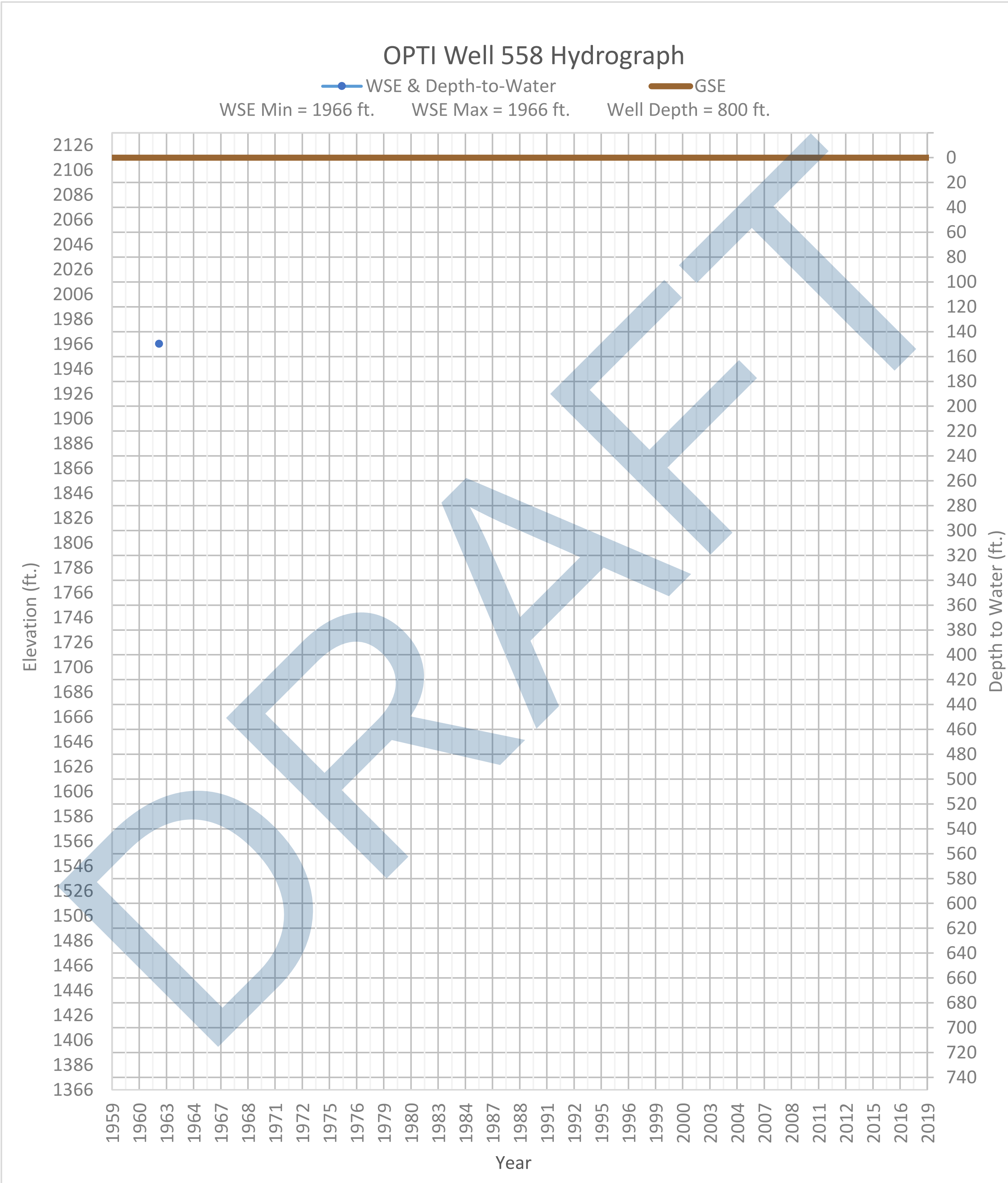
OPTI Well 552 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2260 ft.
WSE Max = 2260 ft.
Well Depth = 105 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



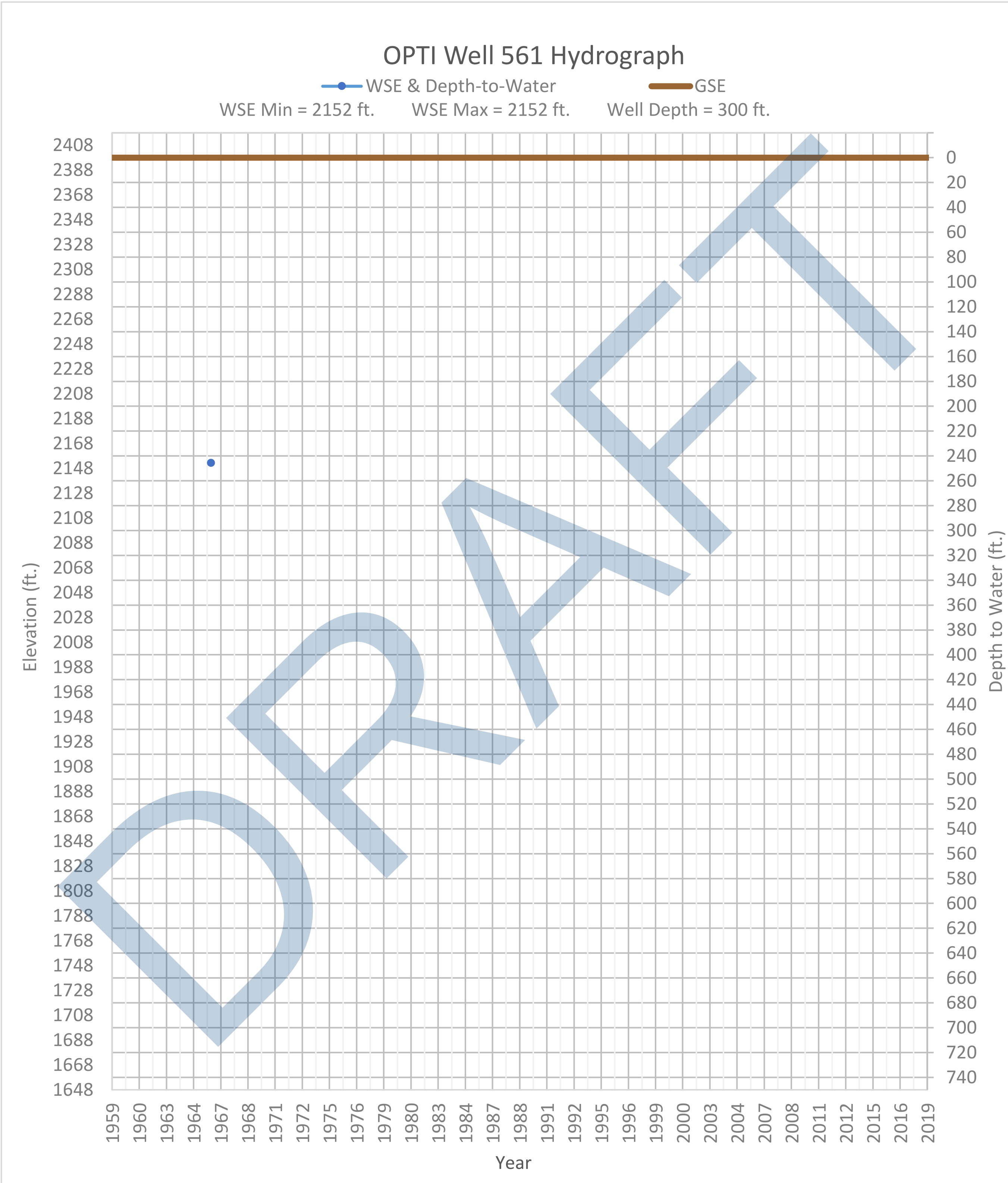
OPTI Well 554 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1879 ft.
WSE Max = 1947 ft.
Well Depth = 378 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

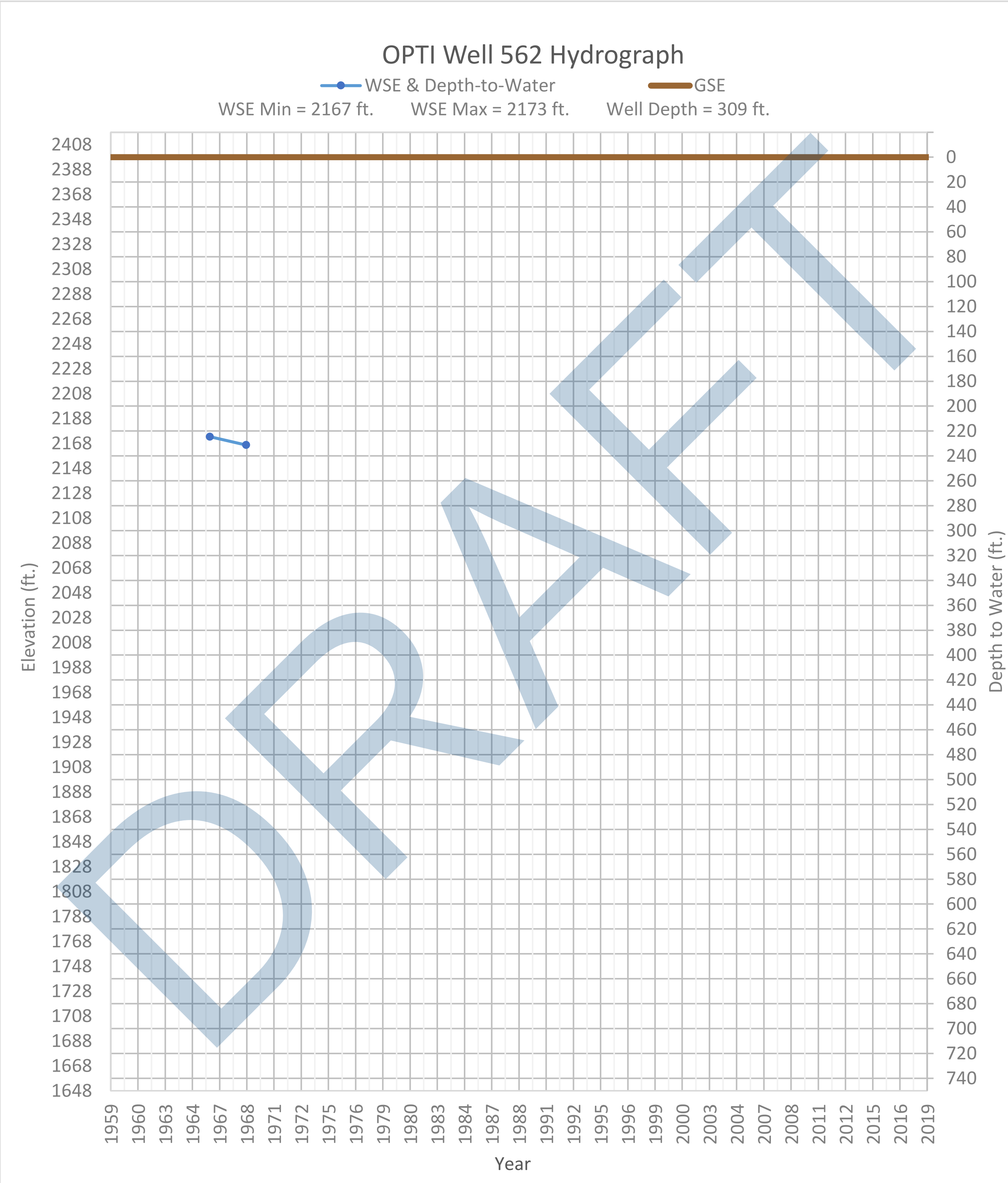


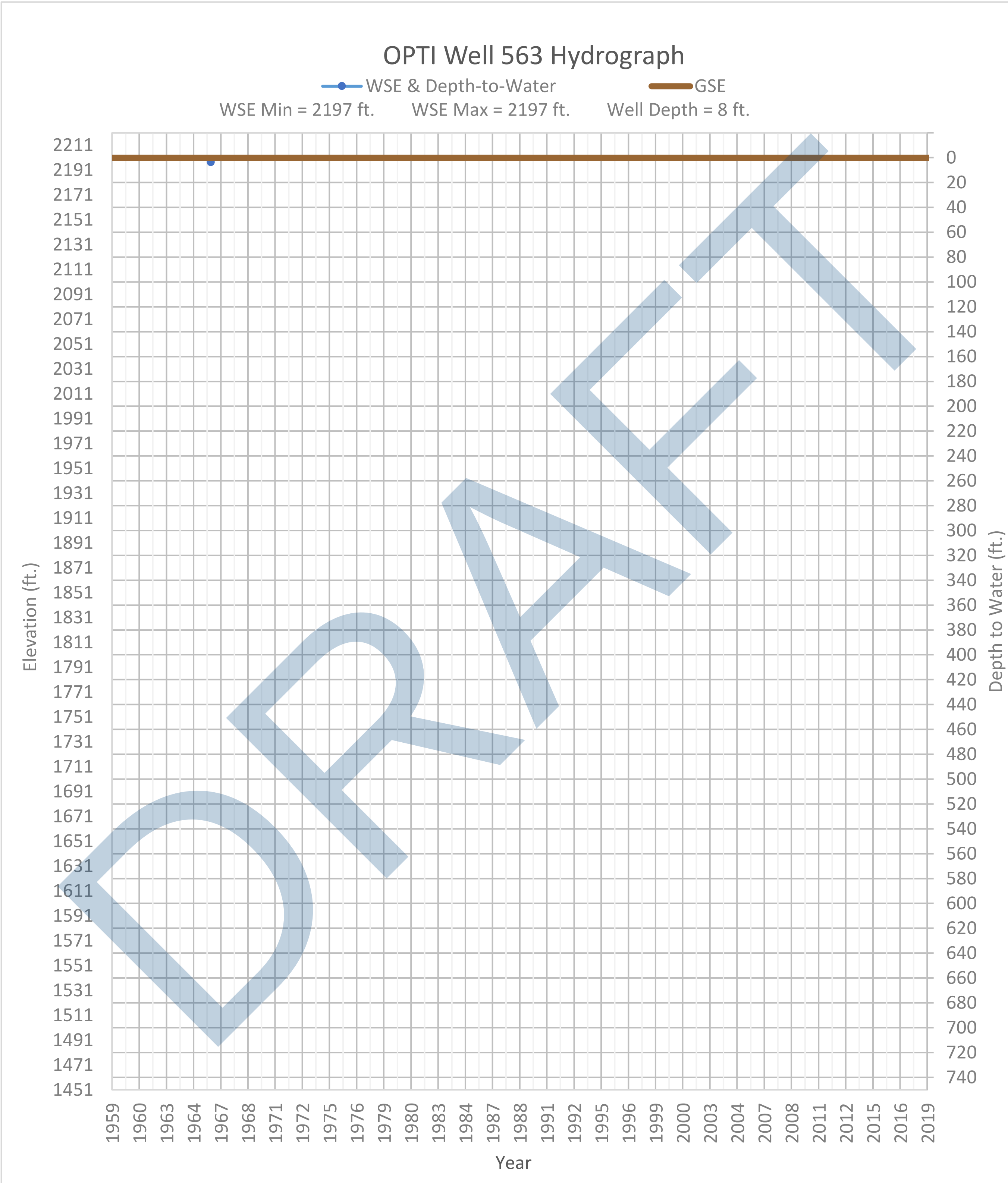
OPTI Well 557 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1939 ft.
WSE Max = 1942 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



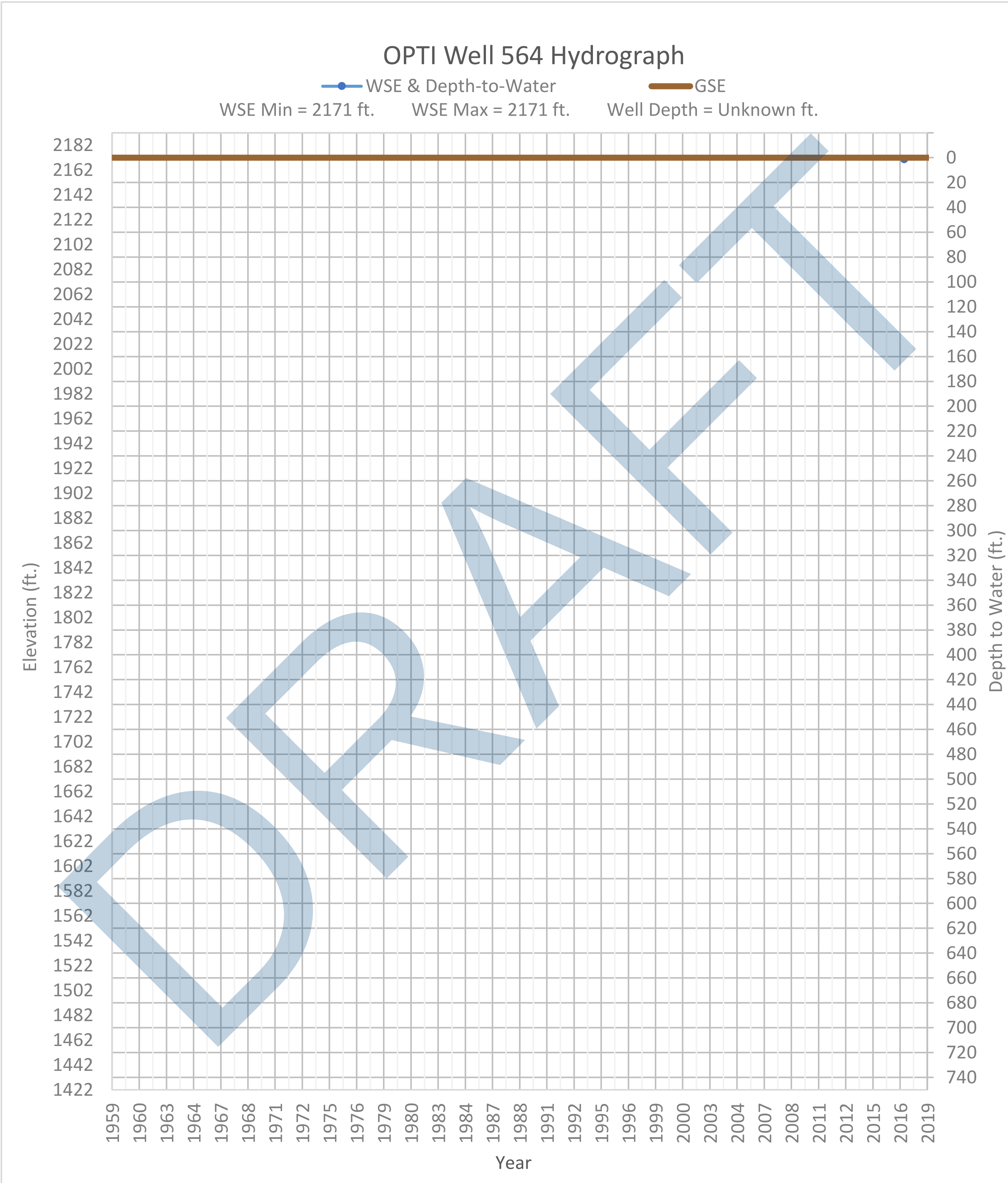
OPTI Well 558 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1966 ft.
WSE Max = 1966 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 561 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2152 ft.
WSE Max = 2152 ft.
Well Depth = 300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

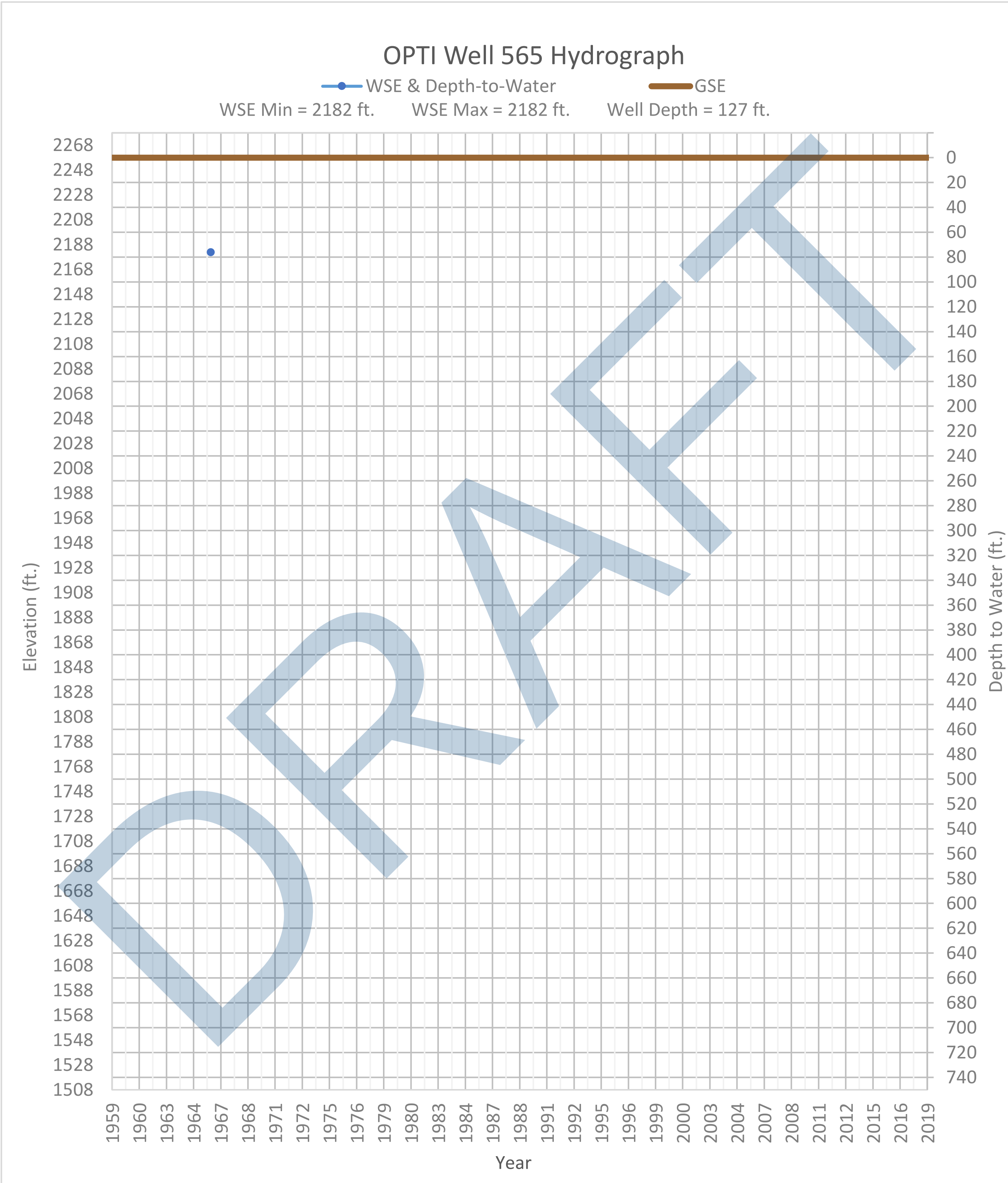

OPTI Well 562 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2167 ft.
WSE Max = 2173 ft.
Well Depth = 309 ft.
Elevation (ft.)
Depth to Water (ft.)
Year



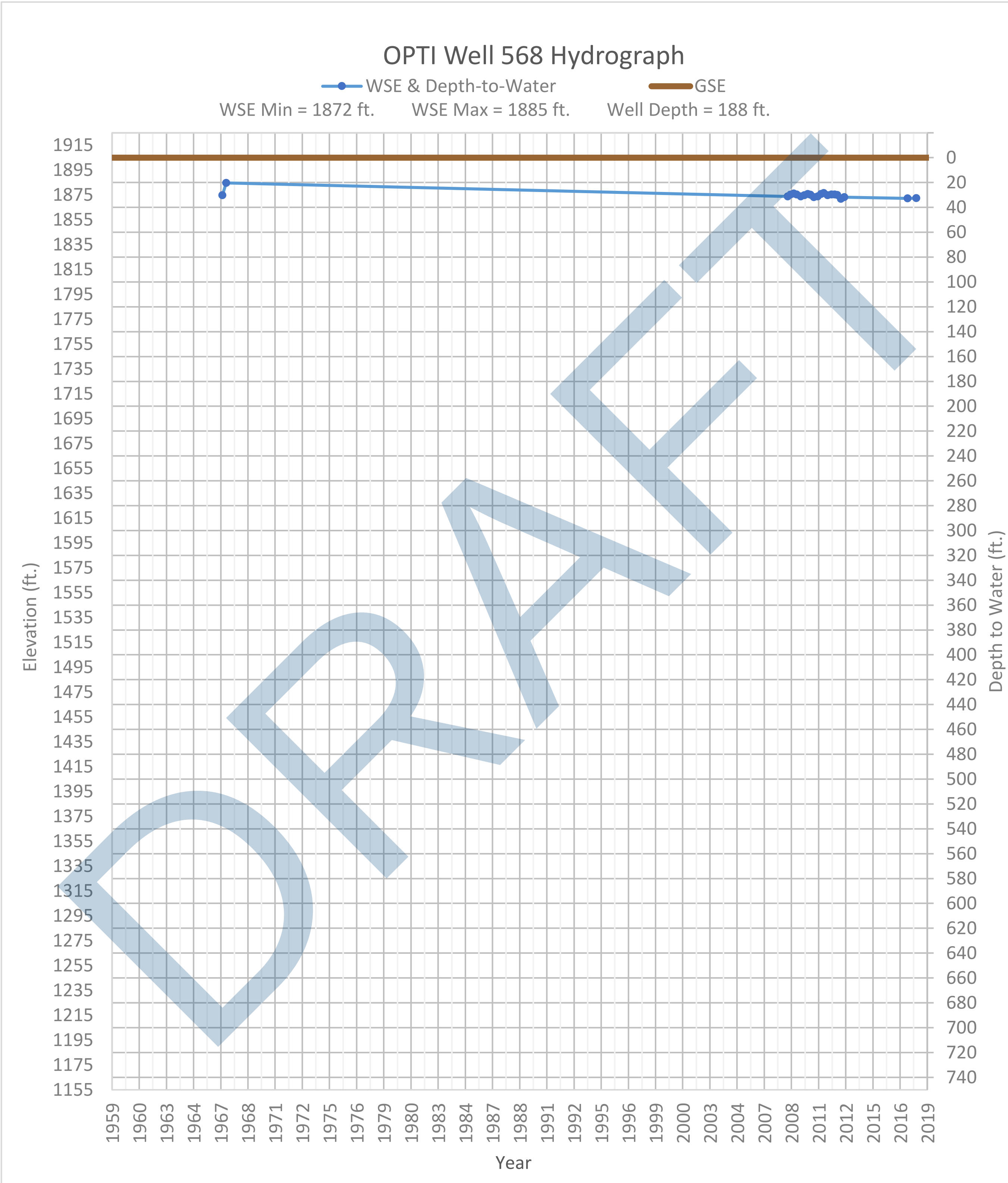
OPTI Well 563 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2197 ft.
WSE Max = 2197 ft.
Well Depth = 8 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



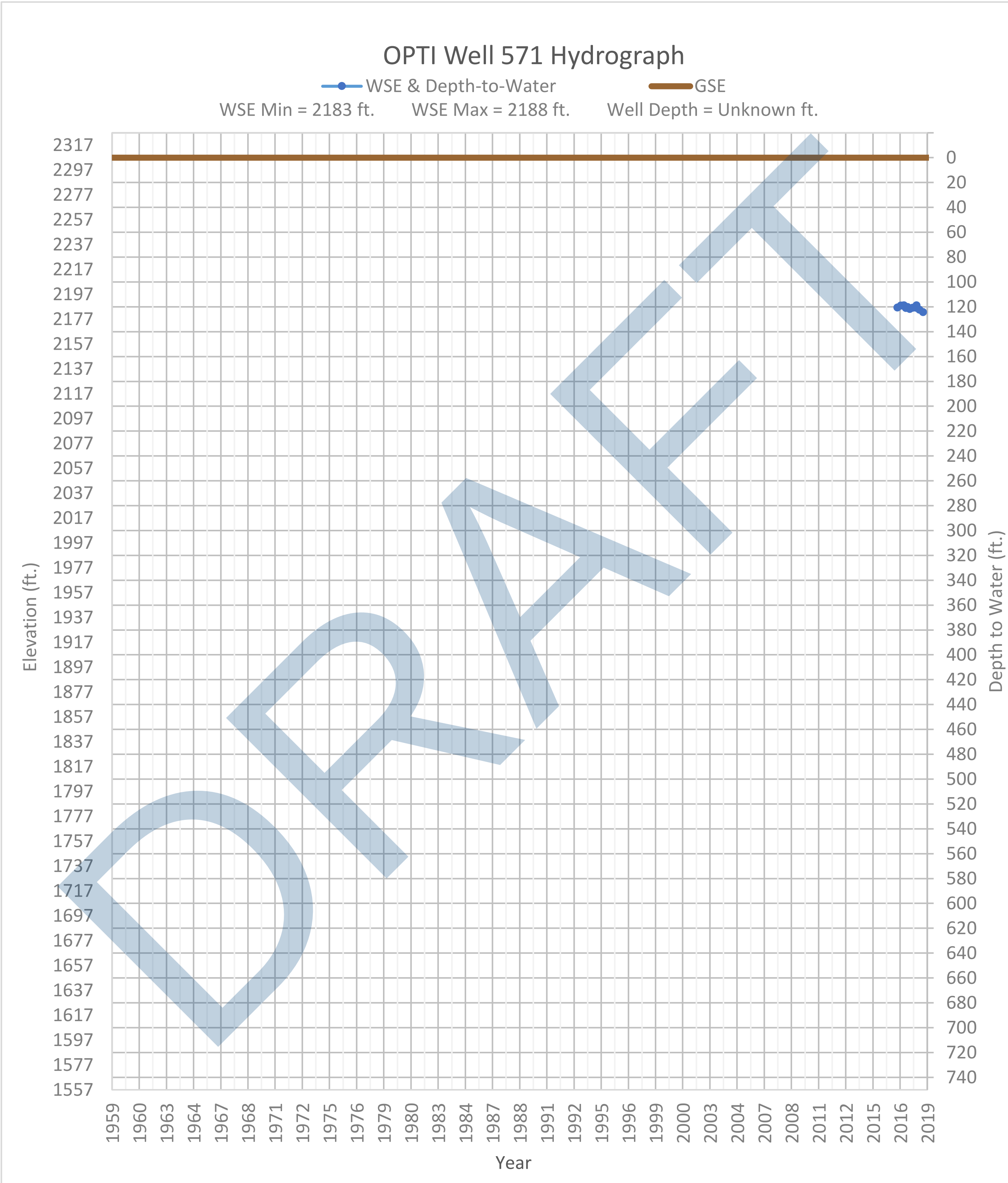
OPTI Well 564 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2171 ft.
WSE Max = 2171 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

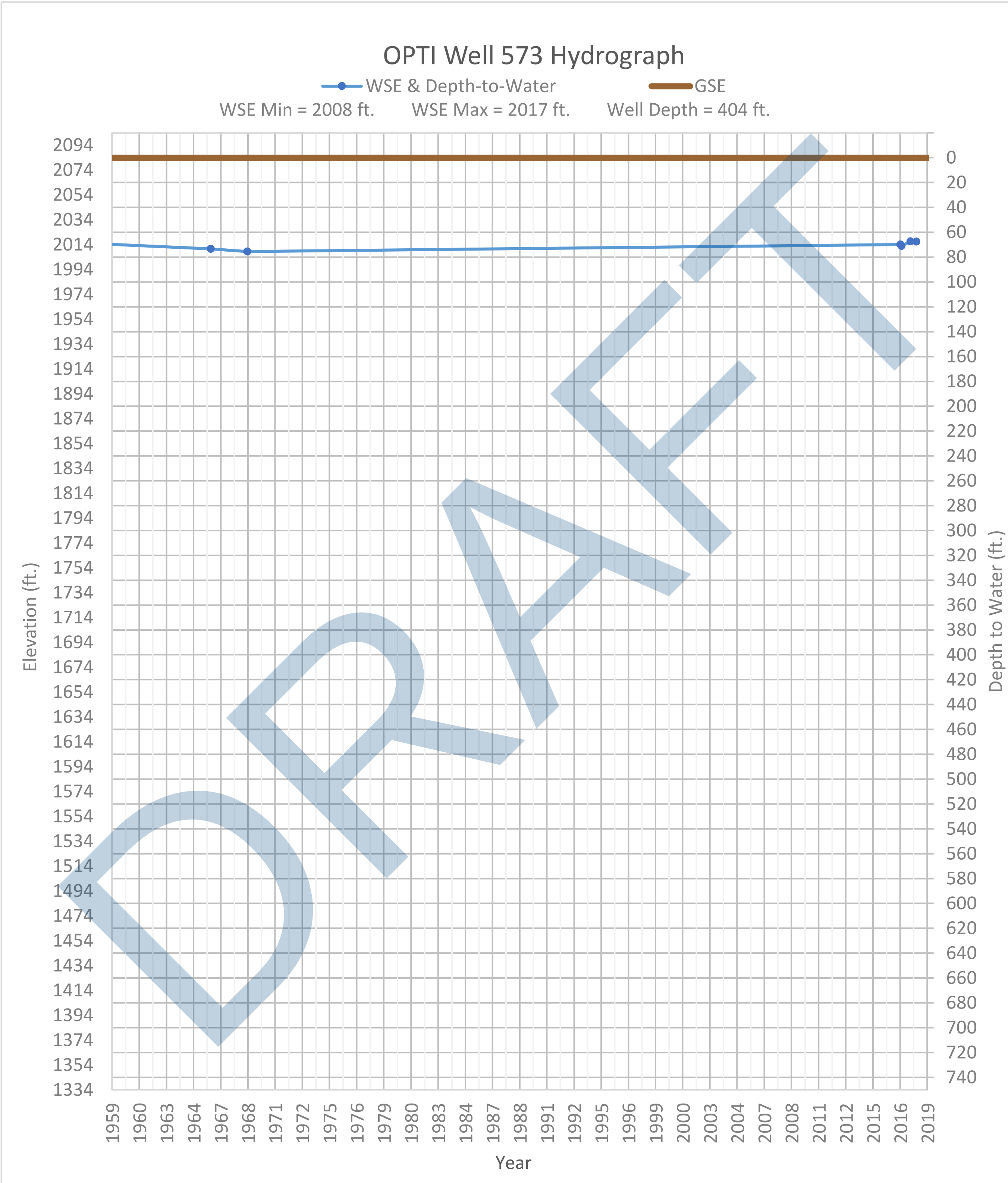


OPTI Well 565 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2182 ft.
WSE Max = 2182 ft.
Well Depth = 127 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

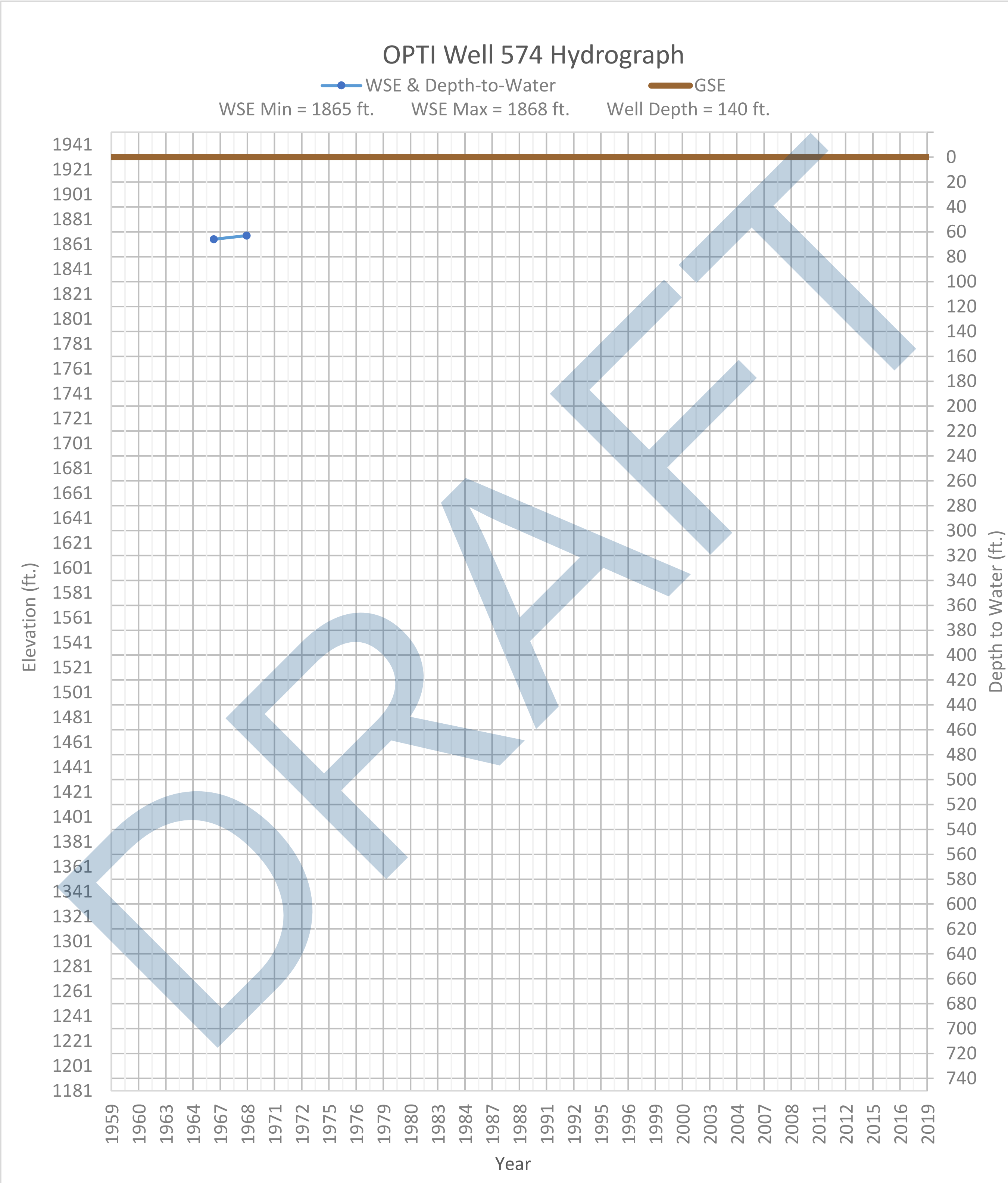


OPTI Well 568 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1872 ft.
WSE Max = 1885 ft.
Well Depth = 188 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

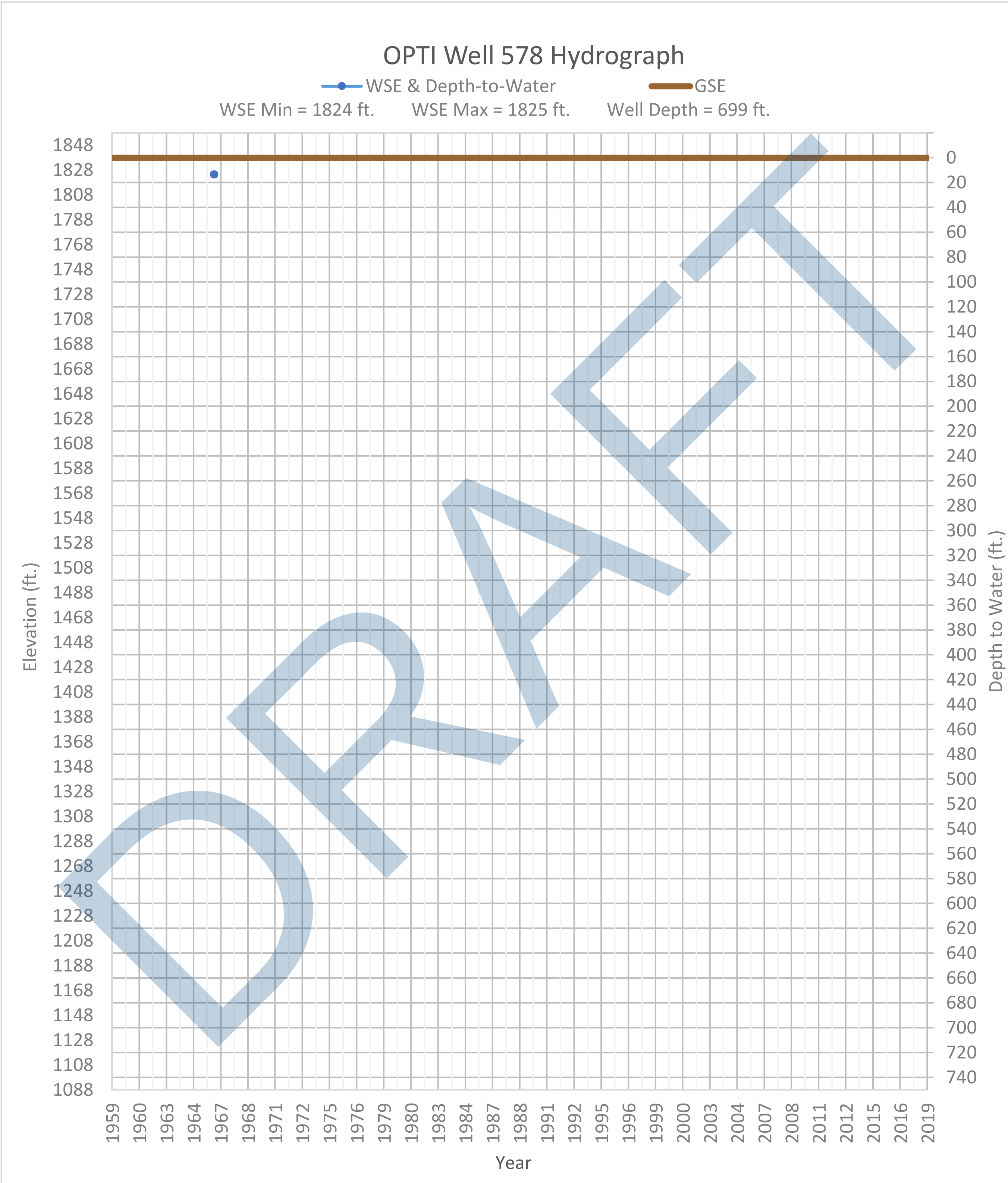

OPTI Well 571 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2183 ft.
WSE Max = 2188 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



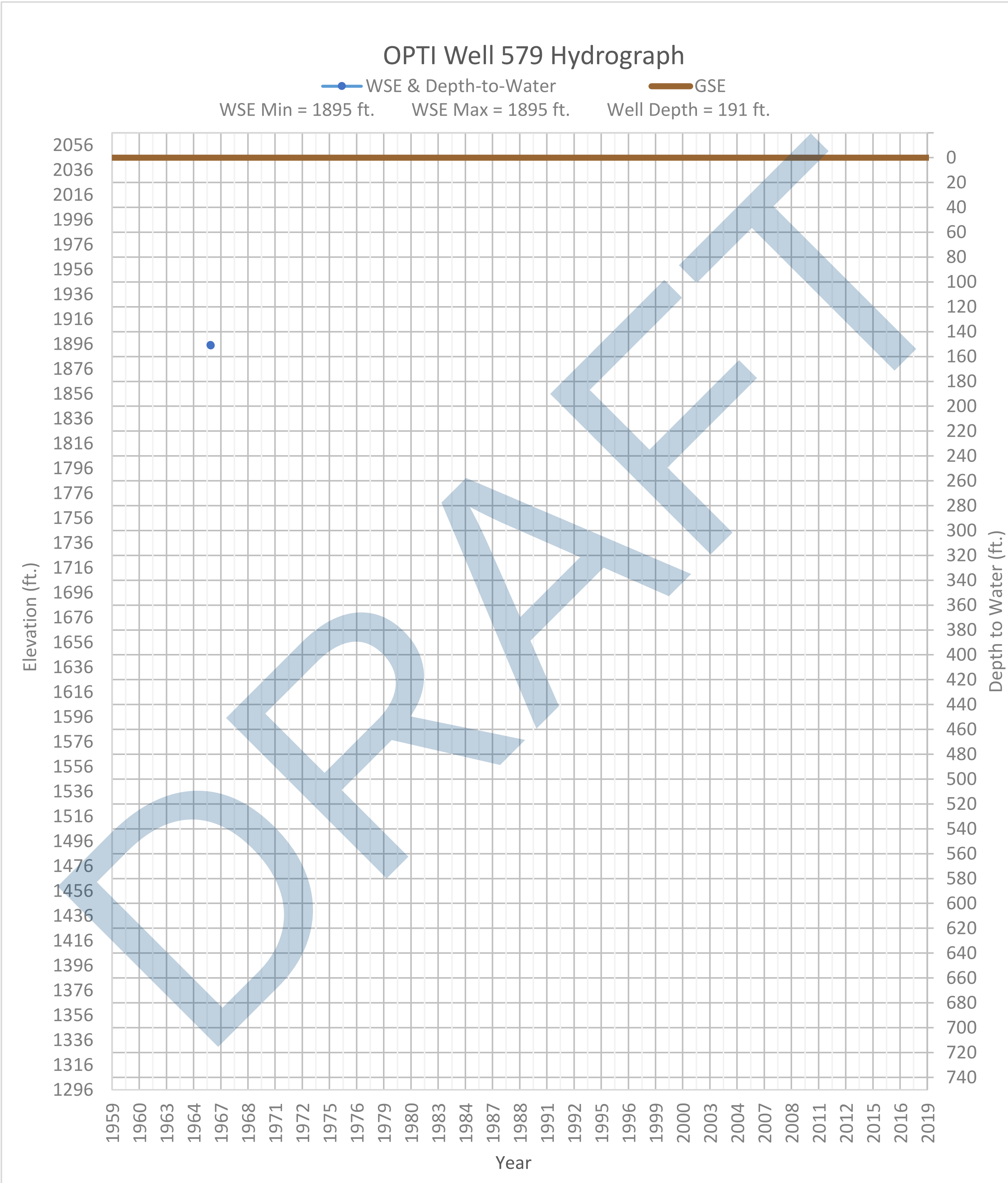
OPTI Well 573 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2008 ft.
WSE Max = 2017 ft.
Well Depth = 404 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



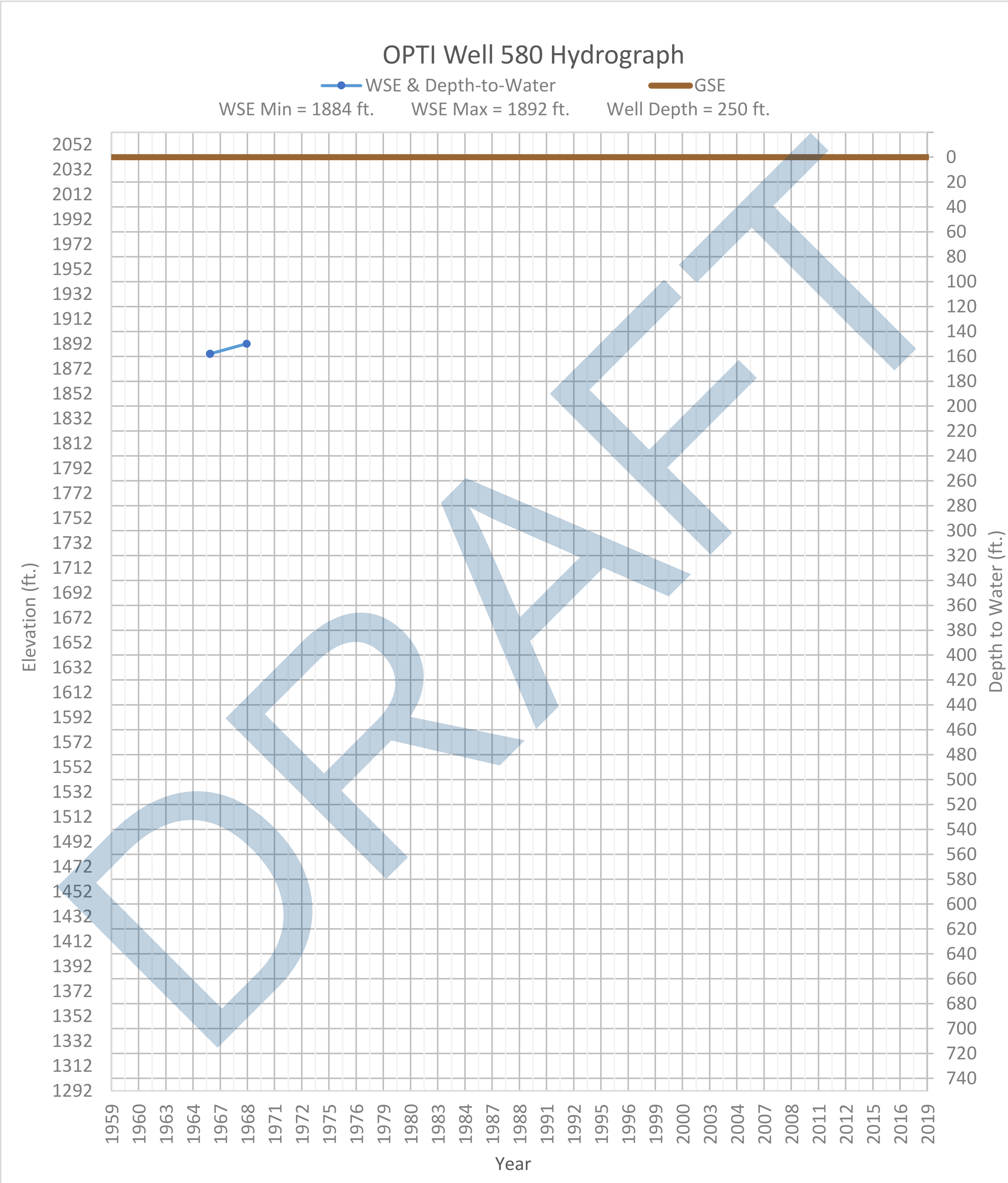
OPTI Well 574 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1865 ft.
WSE Max = 1868 ft.
Well Depth = 140 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

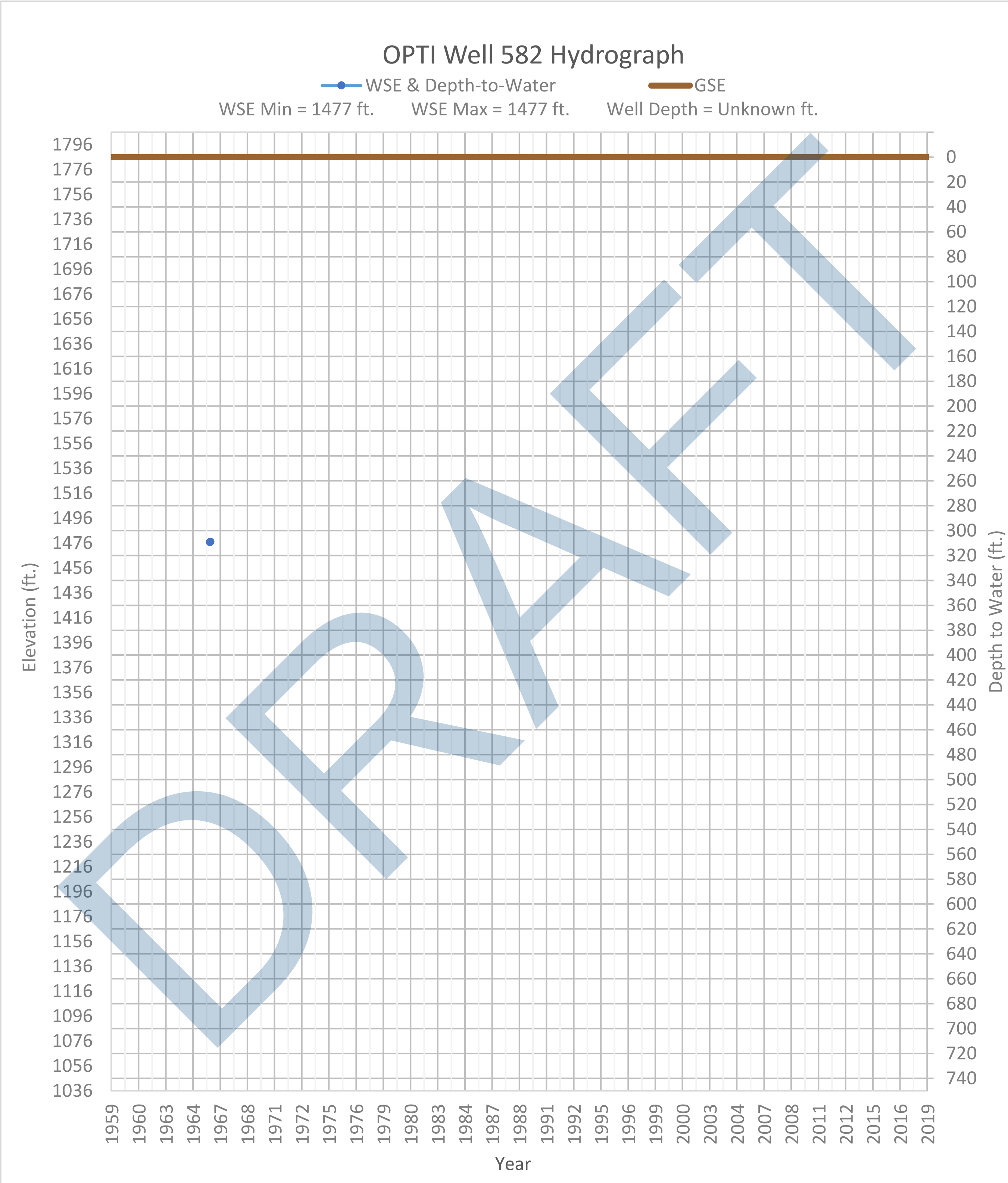


OPTI Well 578 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1824 ft.
WSE Max = 1825 ft.
Well Depth = 699 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

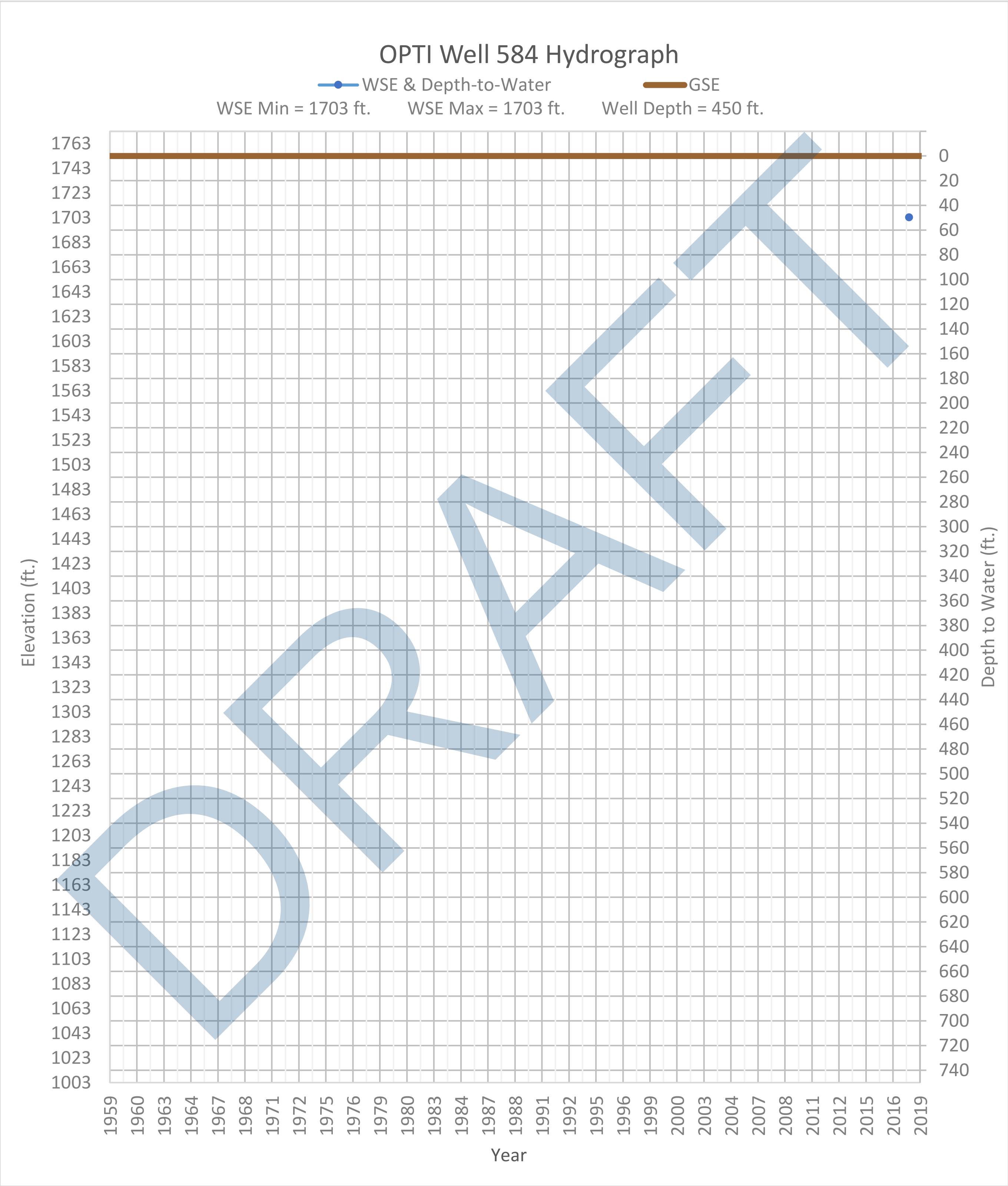


OPTI Well 579 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1895 ft.
WSE Max = 1895 ft.
Well Depth = 191 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

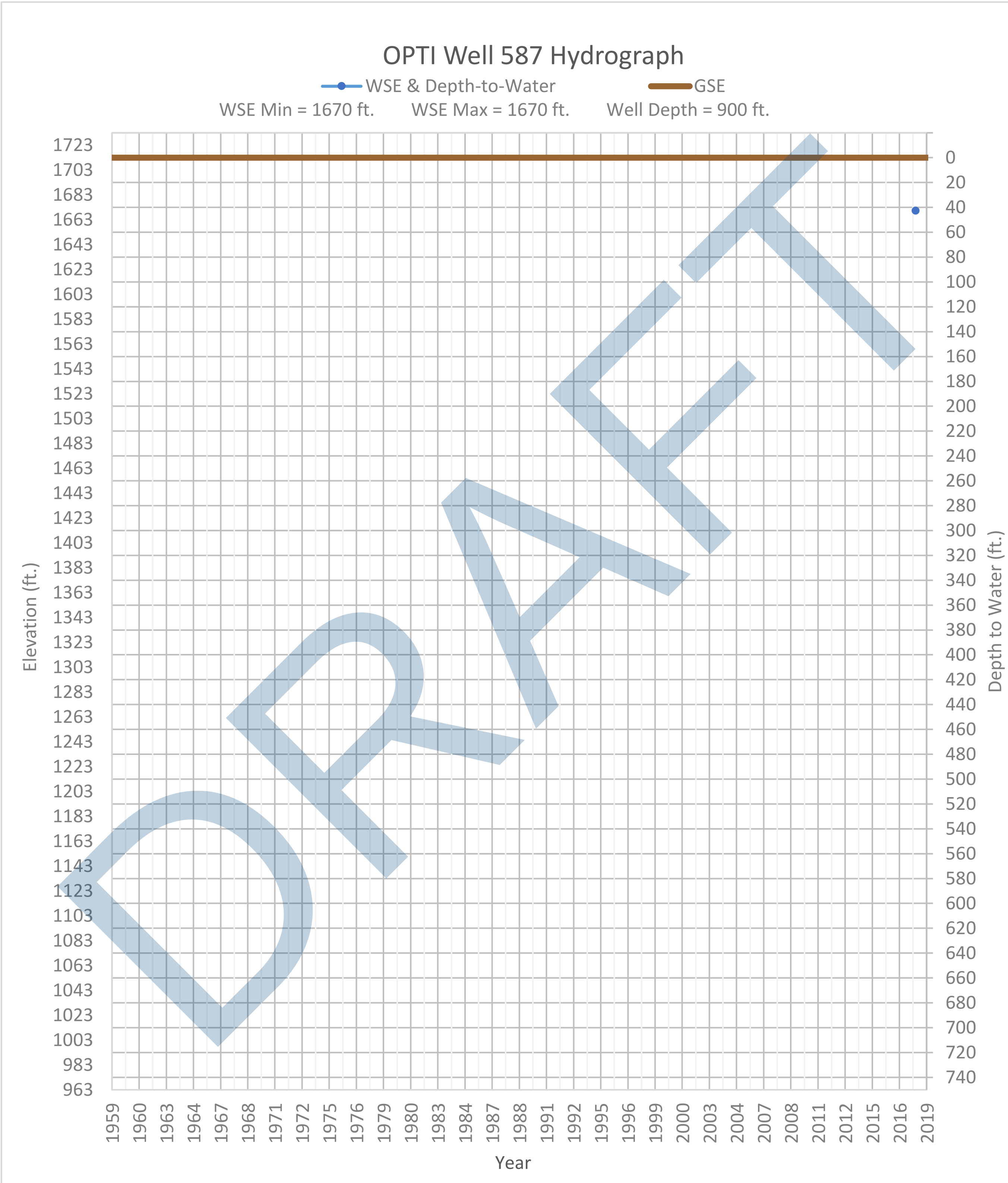

OPTI Well 580 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1884 ft.
WSE Max = 1892 ft.
Well Depth = 250 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



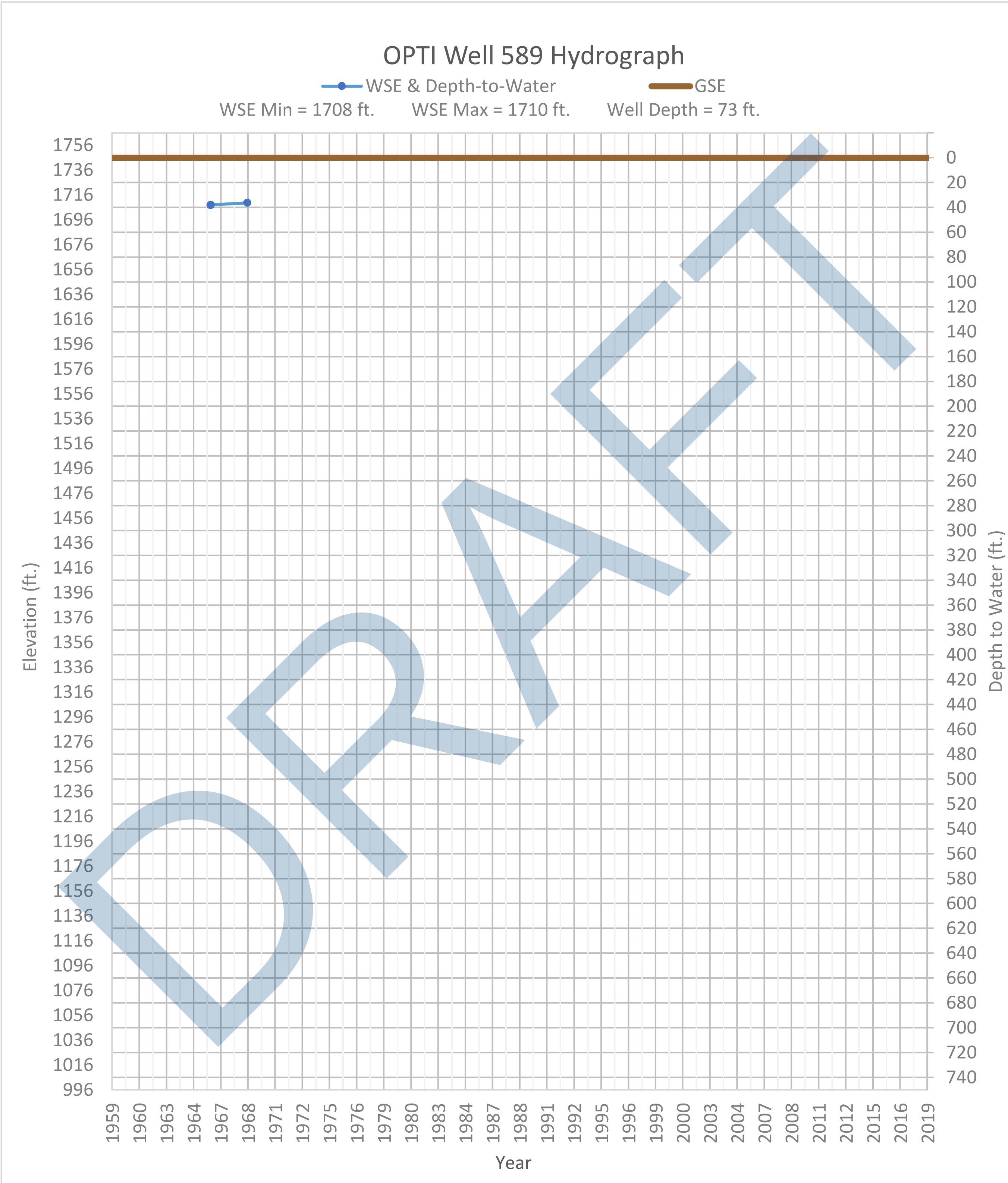
OPTI Well 582 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1477 ft.
WSE Max = 1477 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



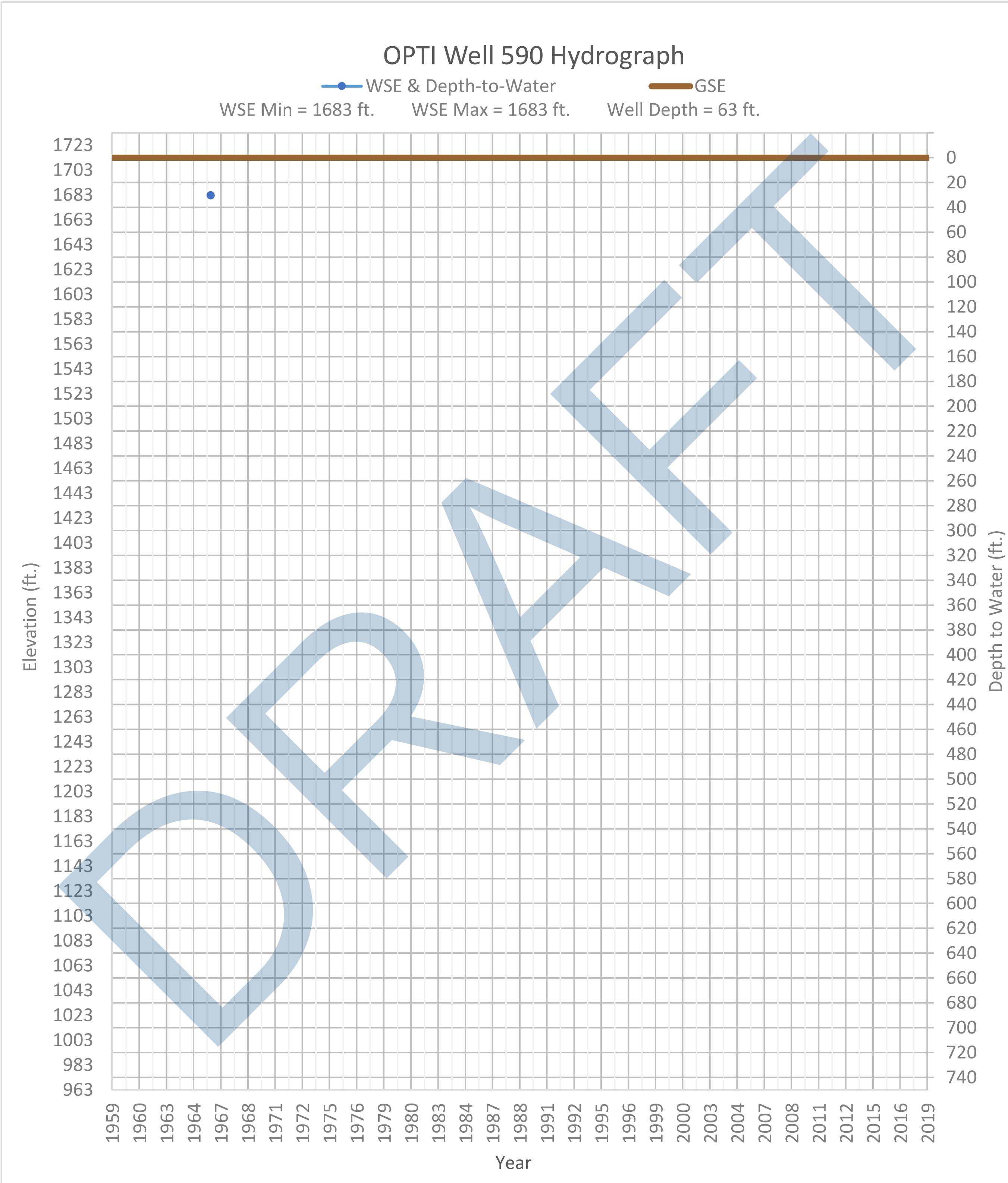
OPTI Well 584 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1703 ft.
WSE Max = 1703 ft.
Well Depth = 450 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 587 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1670 ft.
WSE Max = 1670 ft.
Well Depth = 900 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 589 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1708 ft.
WSE Max = 1710 ft.
Well Depth = 73 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 590 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1683 ft.
WSE Max = 1683 ft.
Well Depth = 63 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
1723
1703
1683
1663
1643
1623
1603
1583
1563
1543
1523
1503
1483
1463
1443
1423
1403
1383
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1343
1323
1303
1283
1263
1243
1223
1203
1183
1163
1143
1123
1103
1083
1063
1043
1023
1003
983
963
0
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80
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120
140
160
180
200
220
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260
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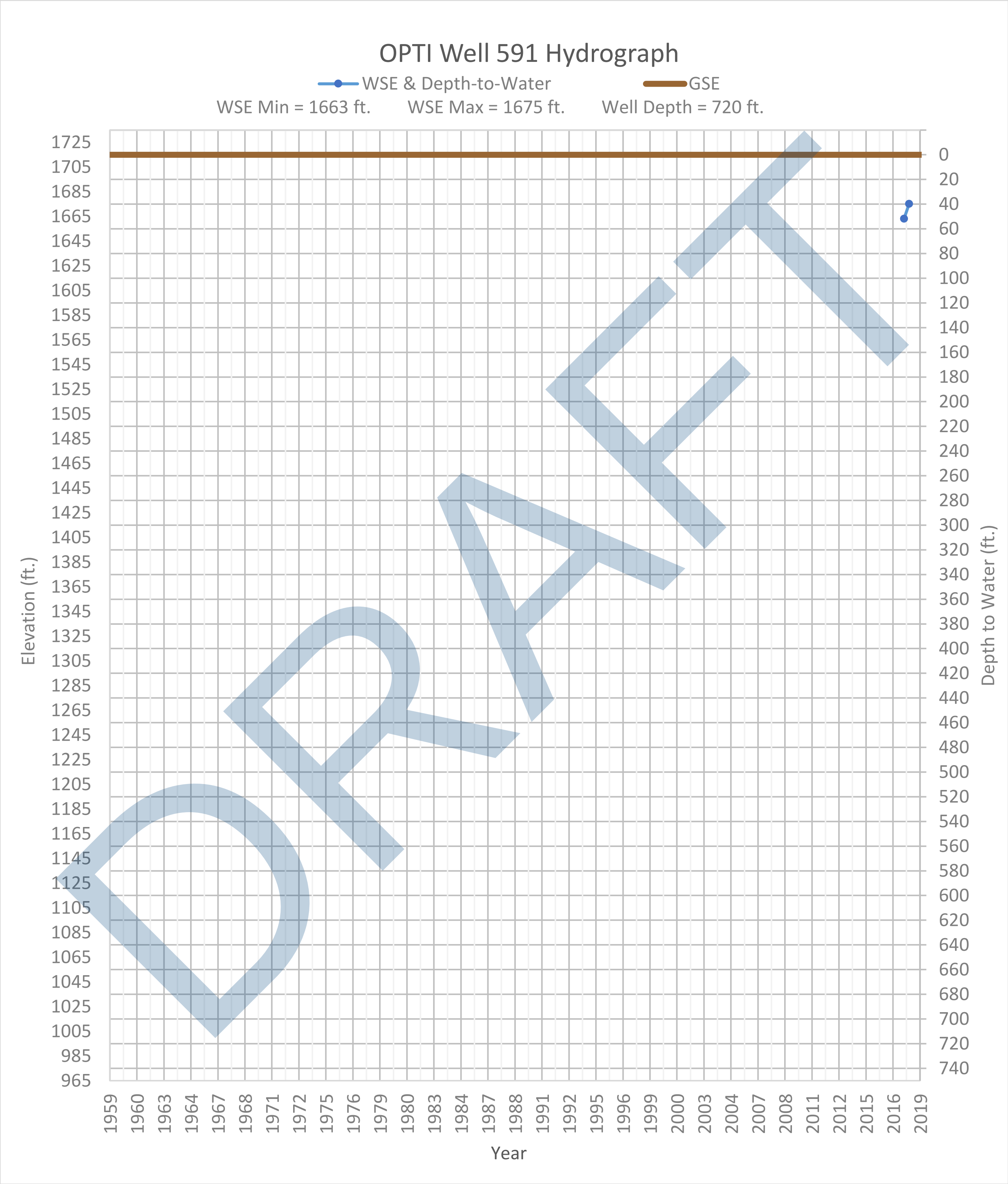
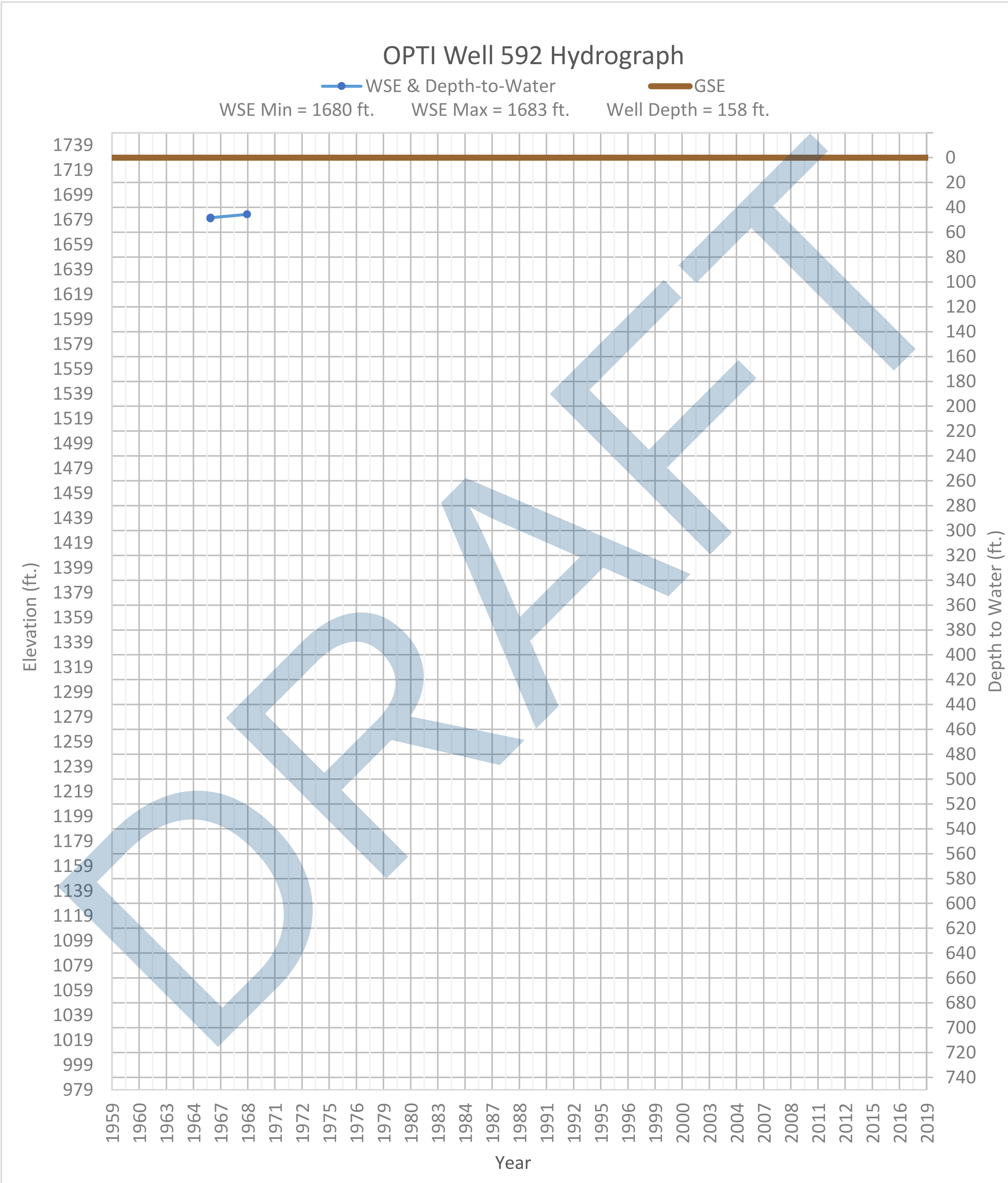
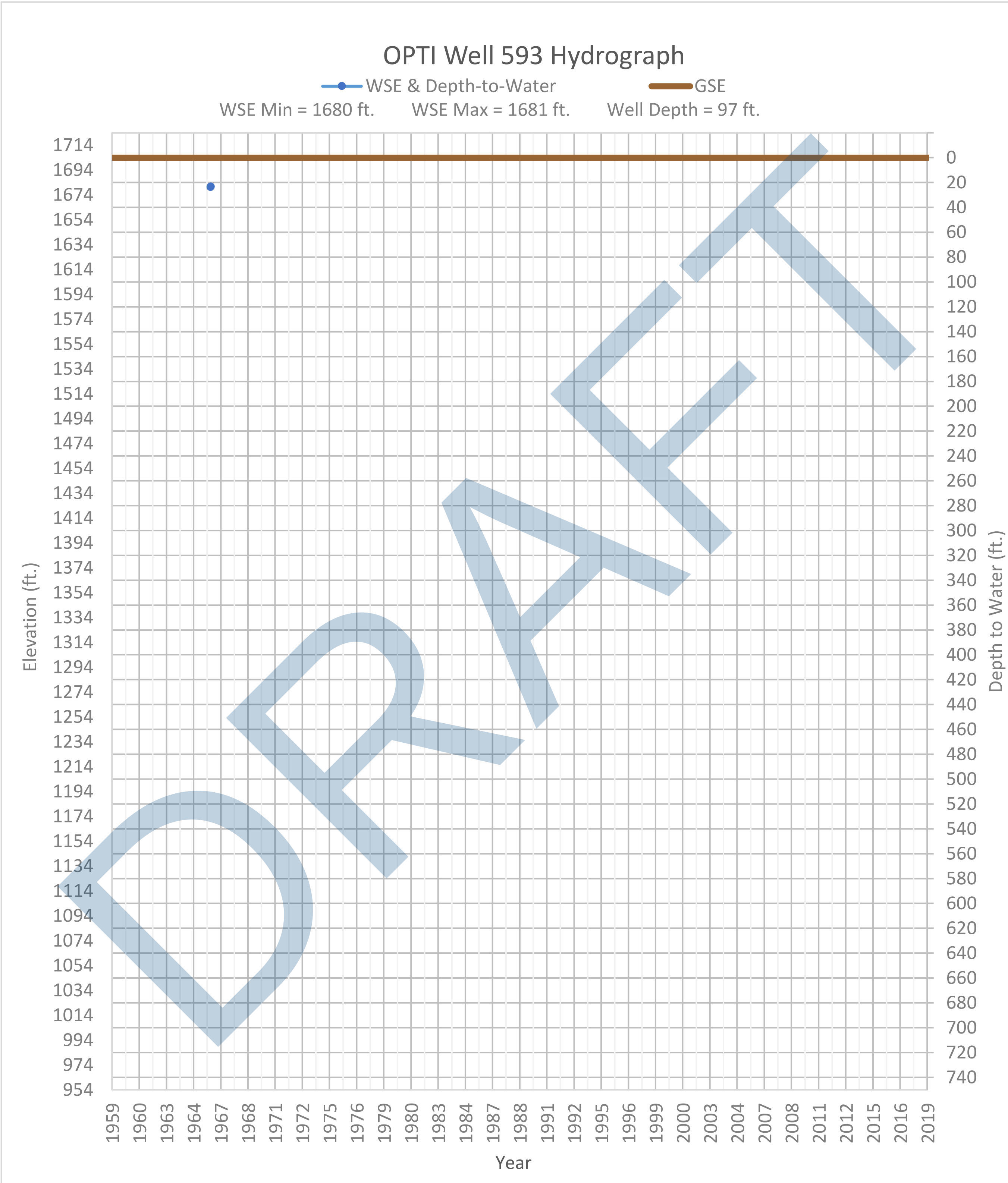
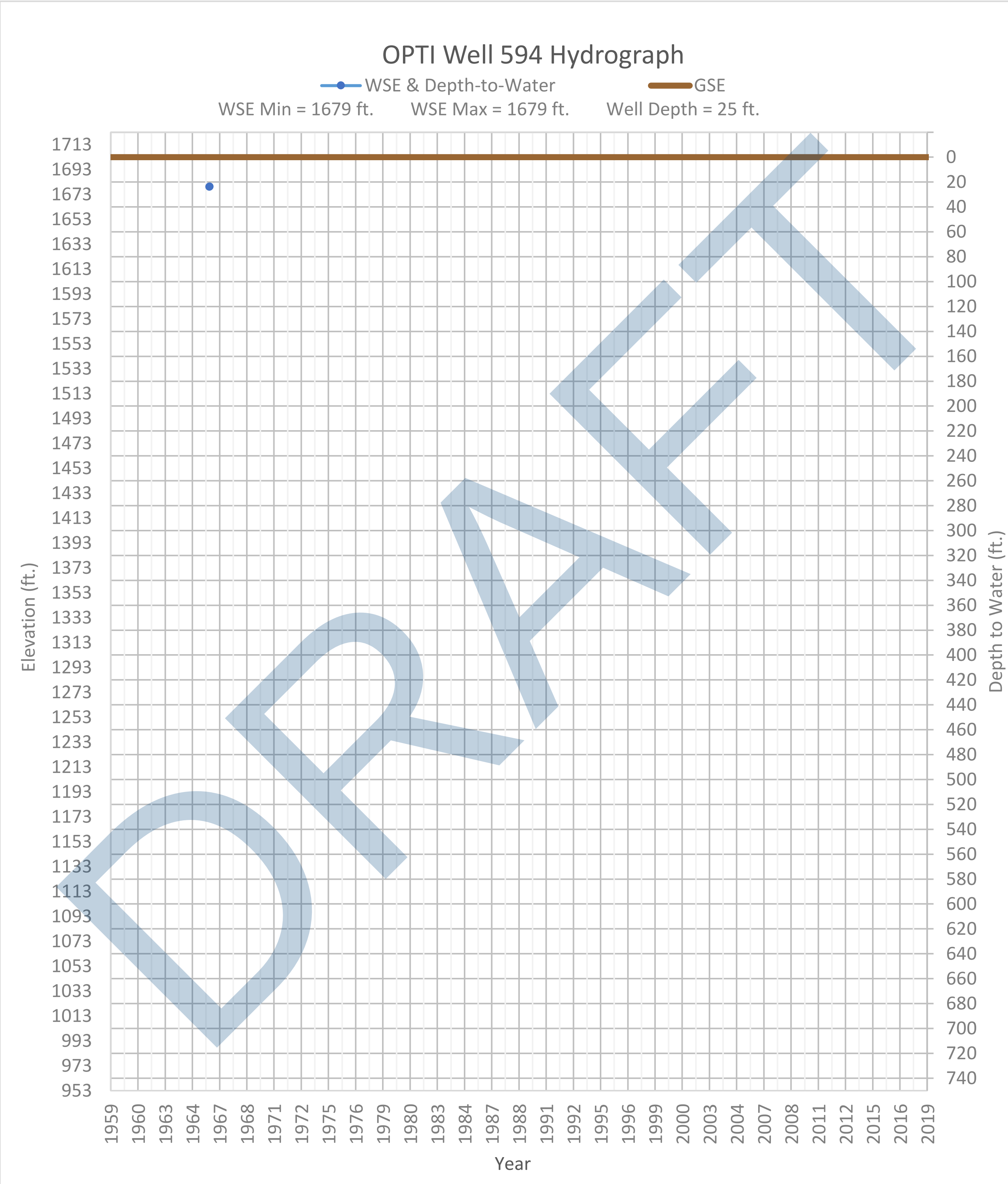
2019
DRAFT



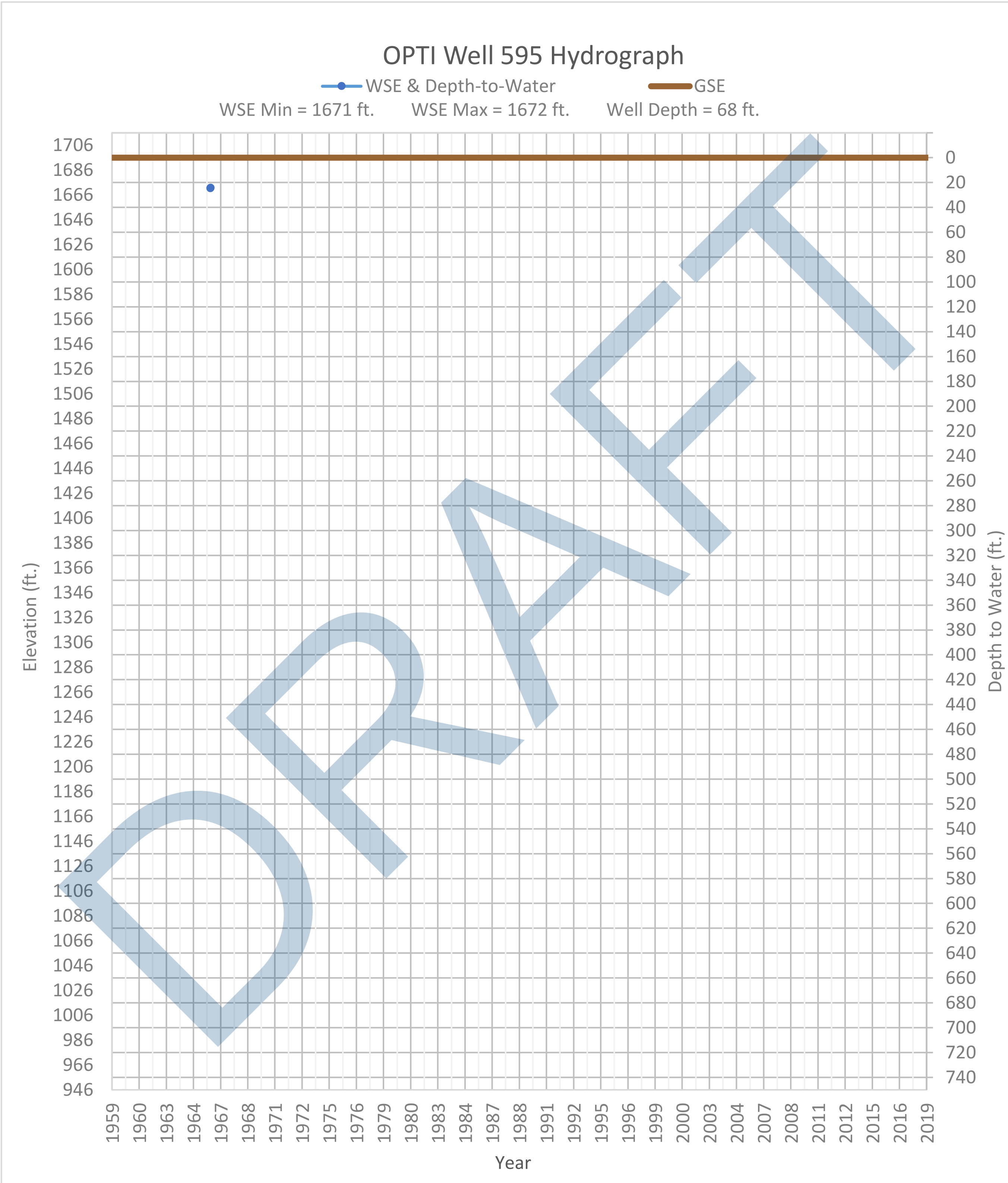
OPTI Well 591 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1663 ft.
WSE Max = 1675 ft.
Well Depth = 720 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 592 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1680 ft.
WSE Max = 1683 ft.
Well Depth = 158 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

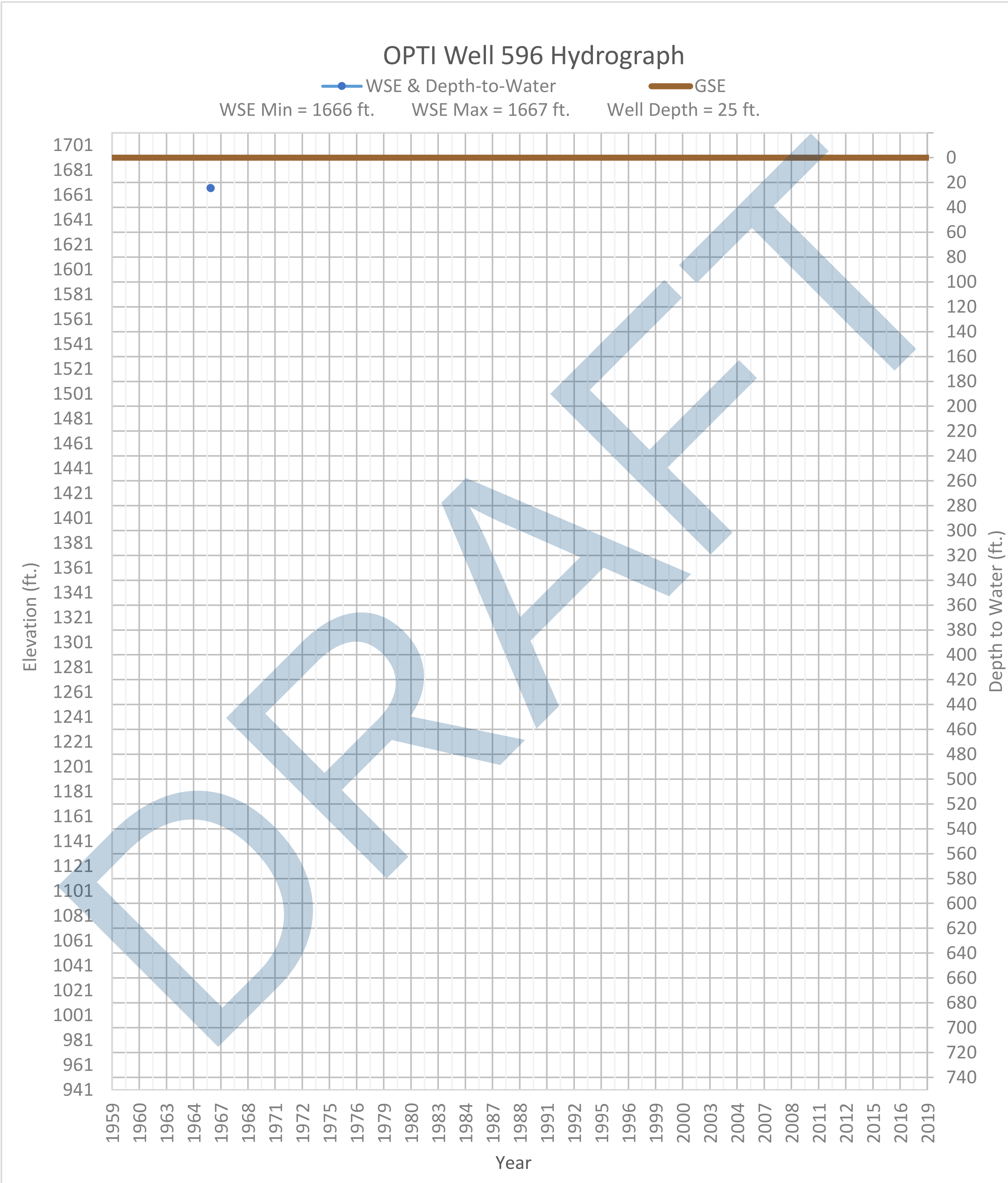

OPTI Well 593 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1680 ft.
WSE Max = 1681 ft.
Well Depth = 97 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



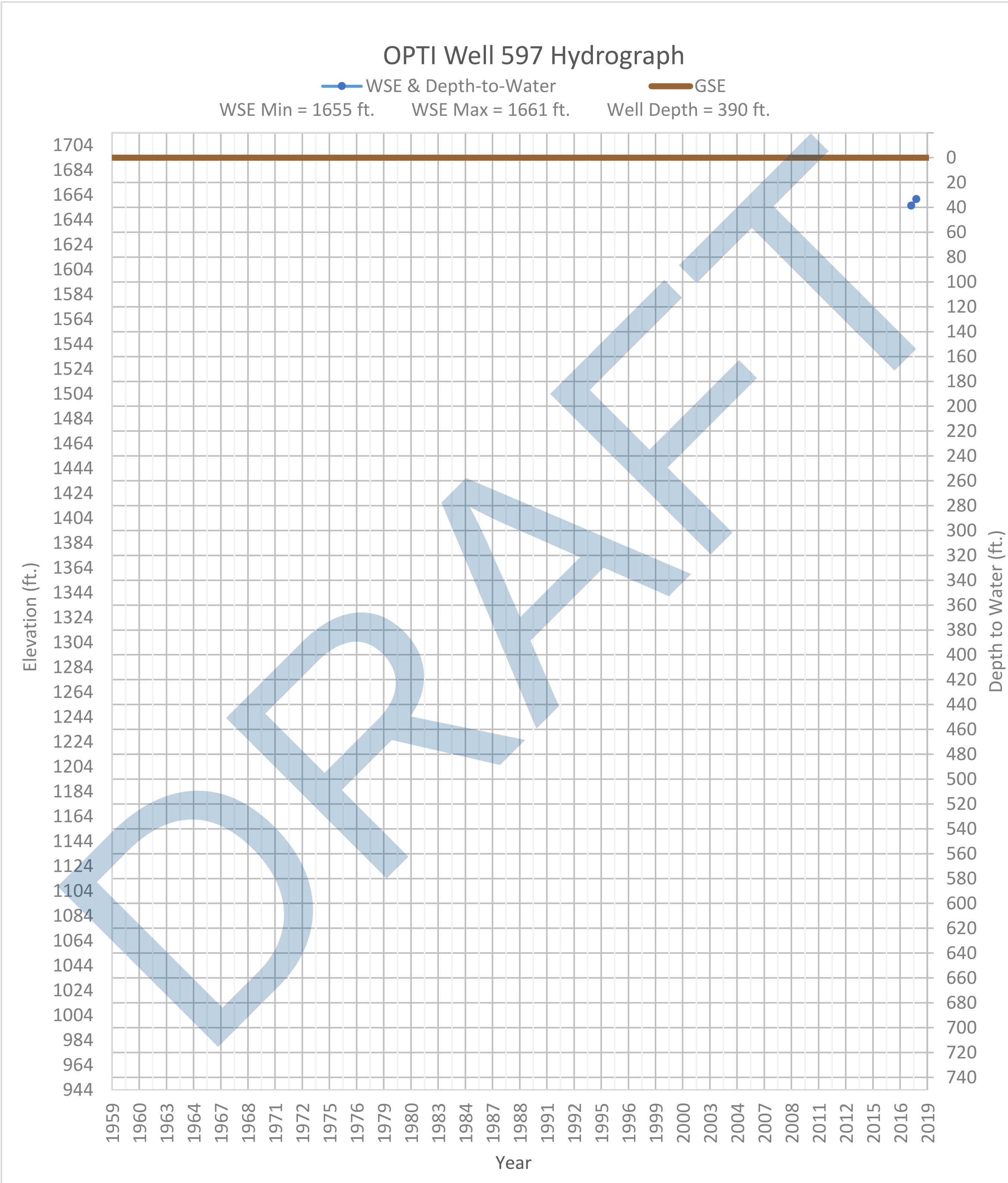
OPTI Well 594 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1679 ft.
WSE Max = 1679 ft.
Well Depth = 25 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



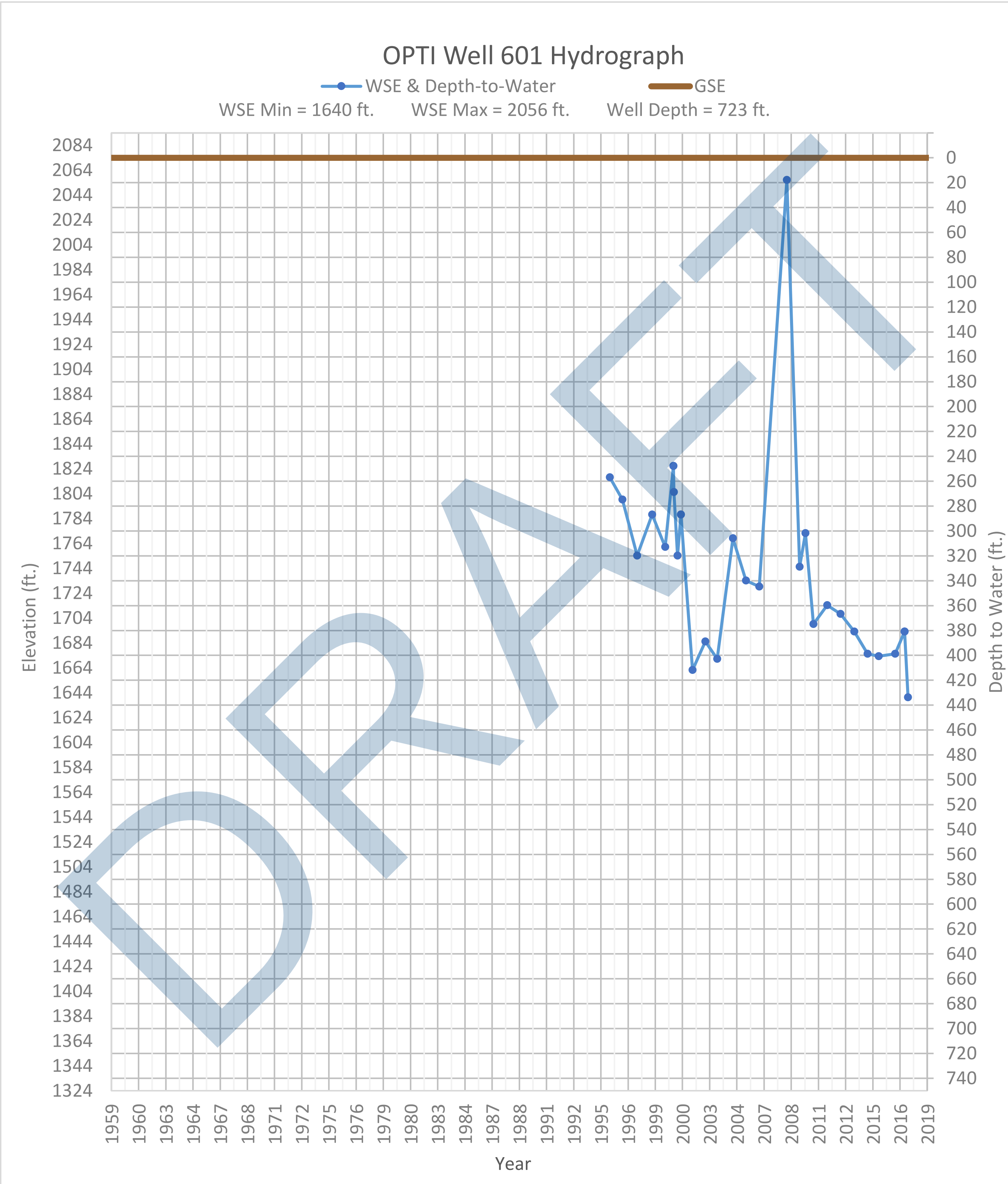
OPTI Well 595 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1671 ft.
WSE Max = 1672 ft.
Well Depth = 68 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



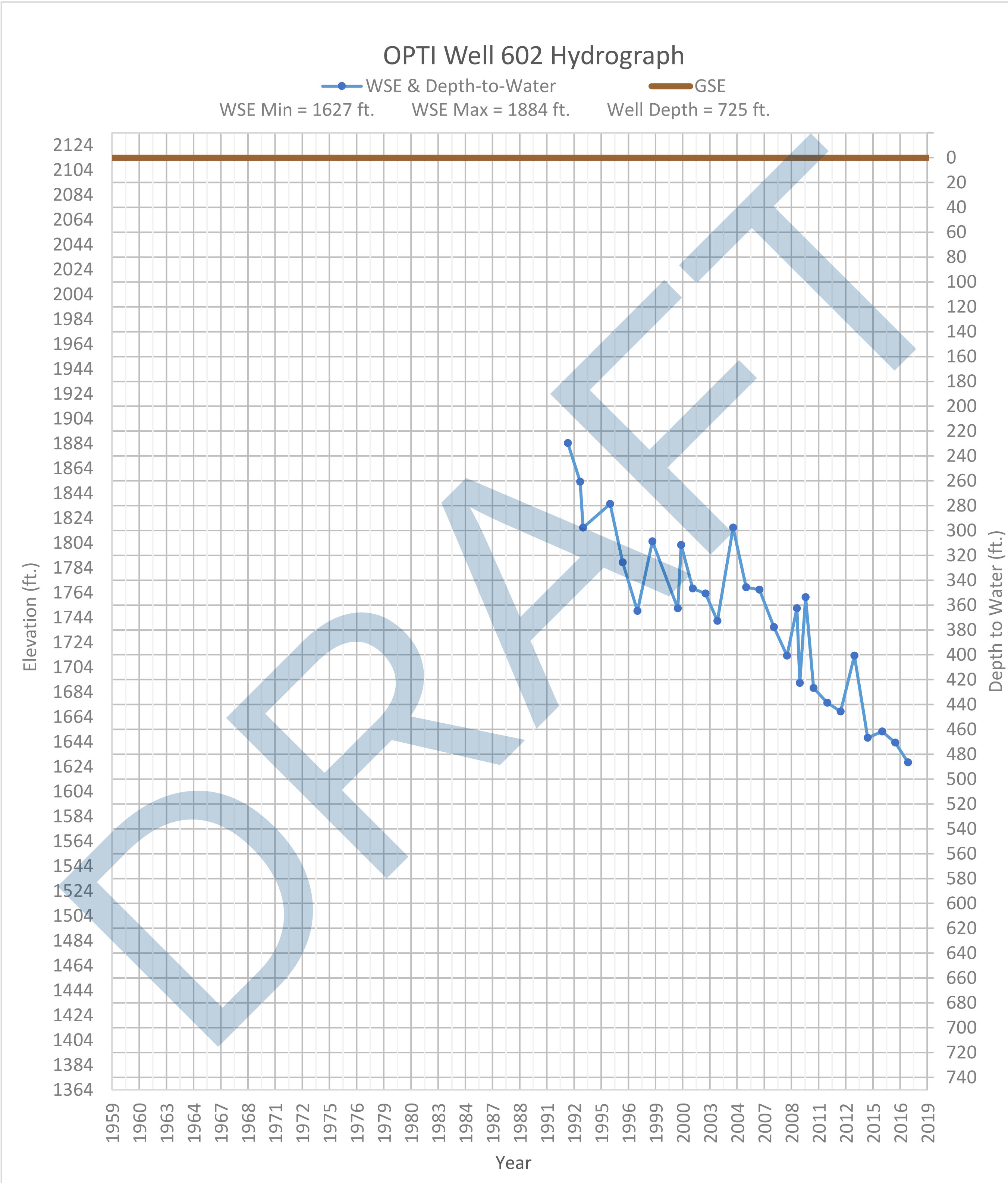
OPTI Well 596 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1666 ft.
WSE Max = 1667 ft.
Well Depth = 25 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

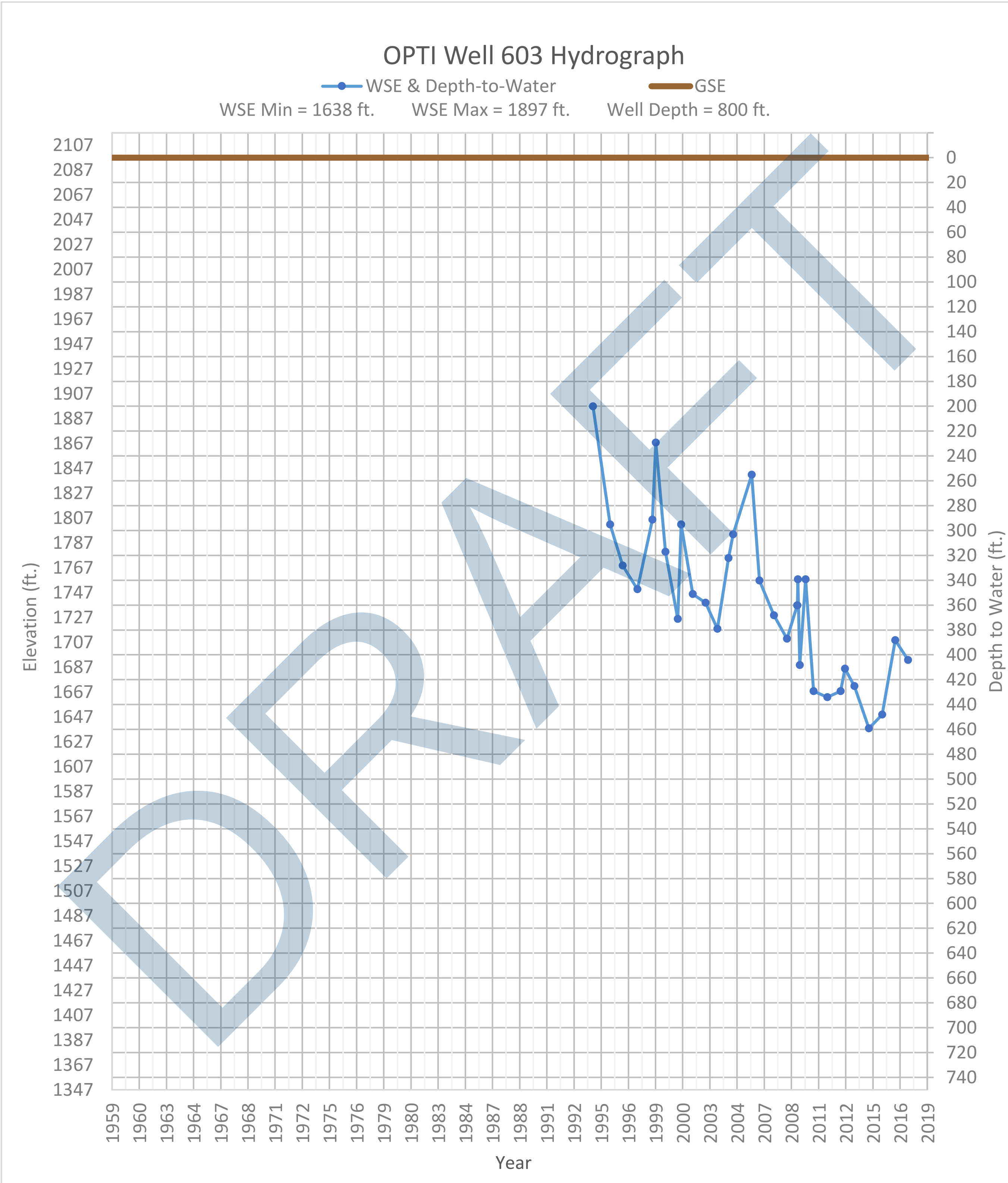


OPTI Well 597 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1655 ft.
WSE Max = 1661 ft.
Well Depth = 390 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

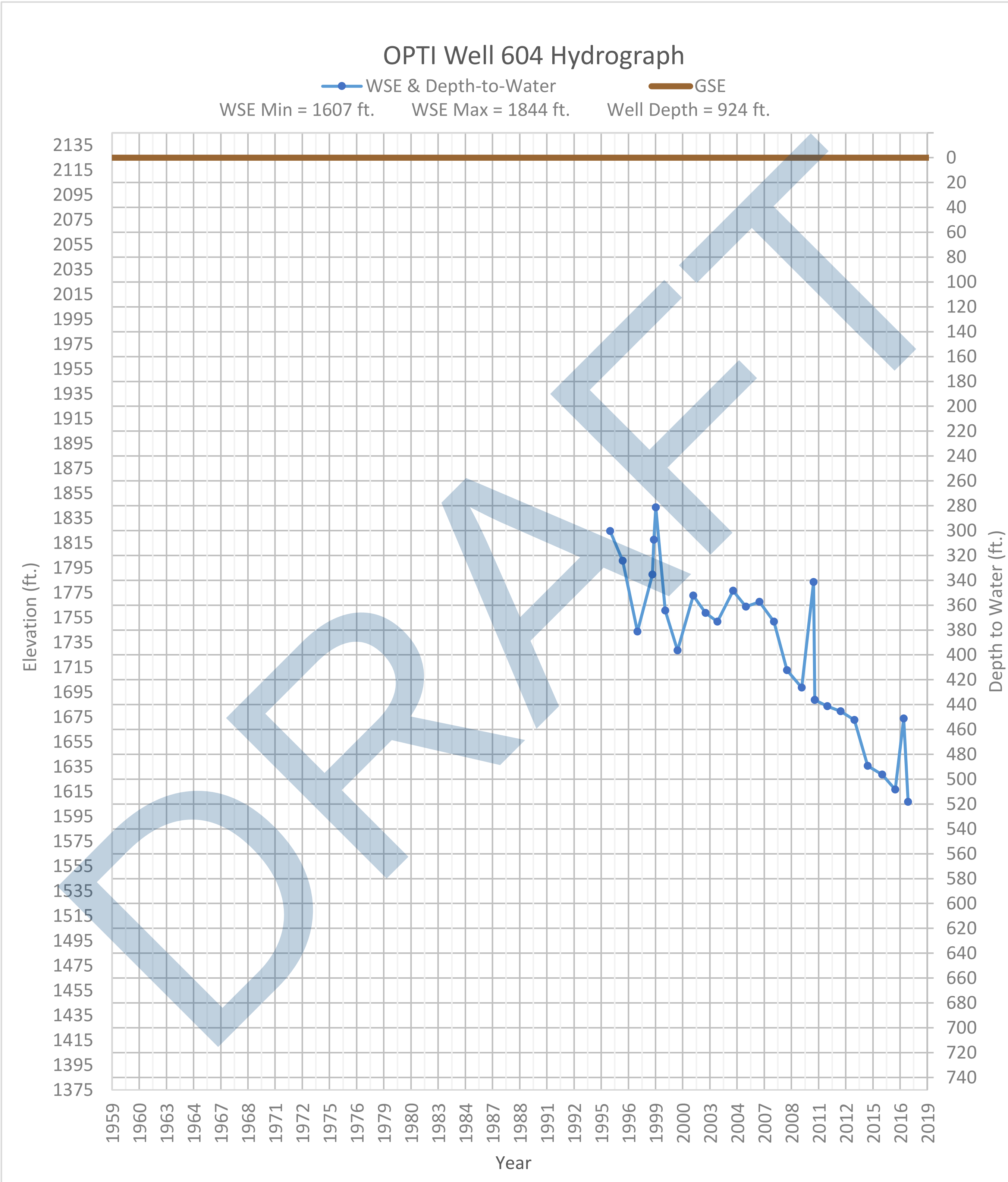


OPTI Well 601 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1640 ft.
WSE Max = 2056 ft.
Well Depth = 723 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

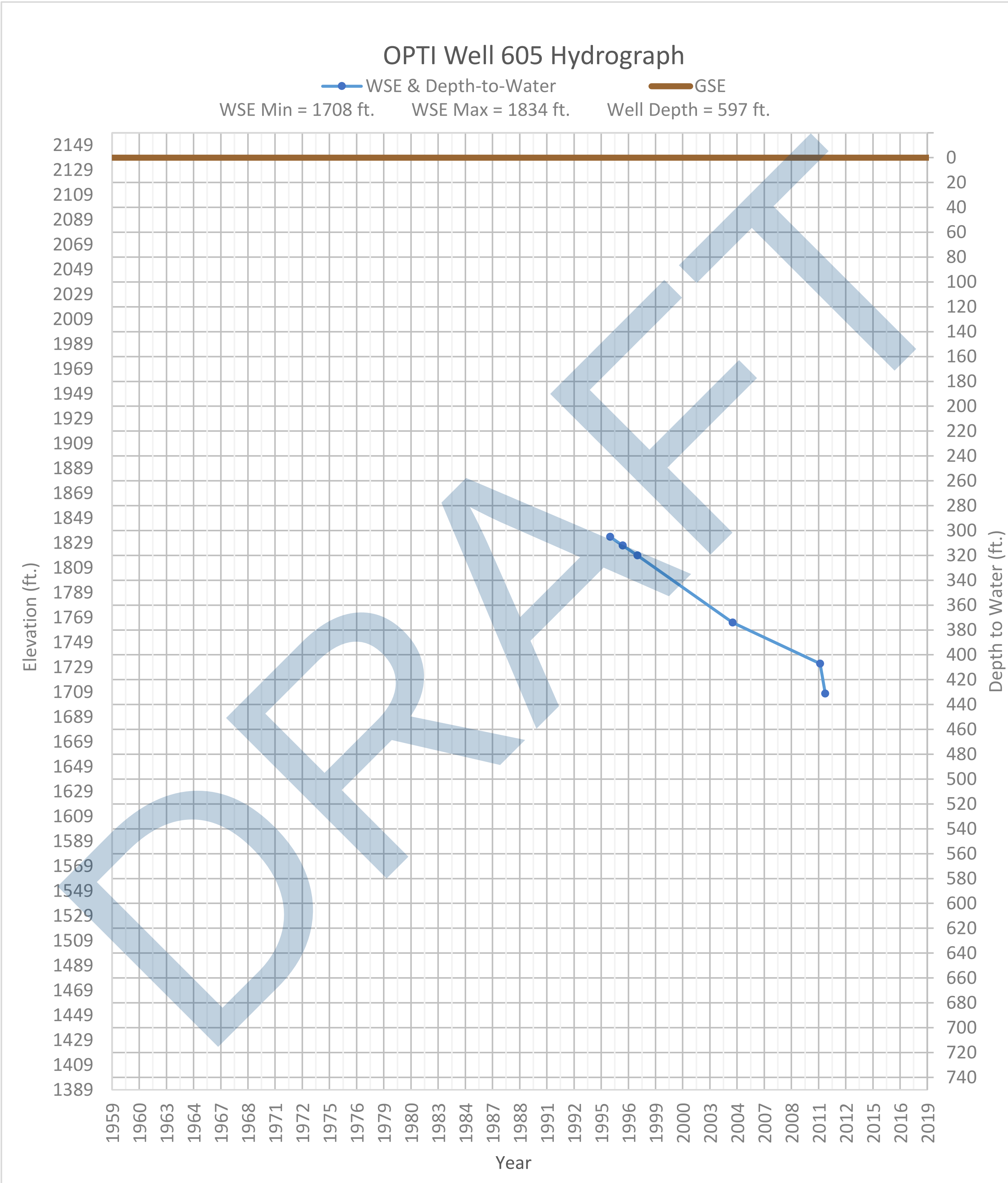

OPTI Well 602 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1627 ft.
WSE Max = 1884 ft.
Well Depth = 725 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



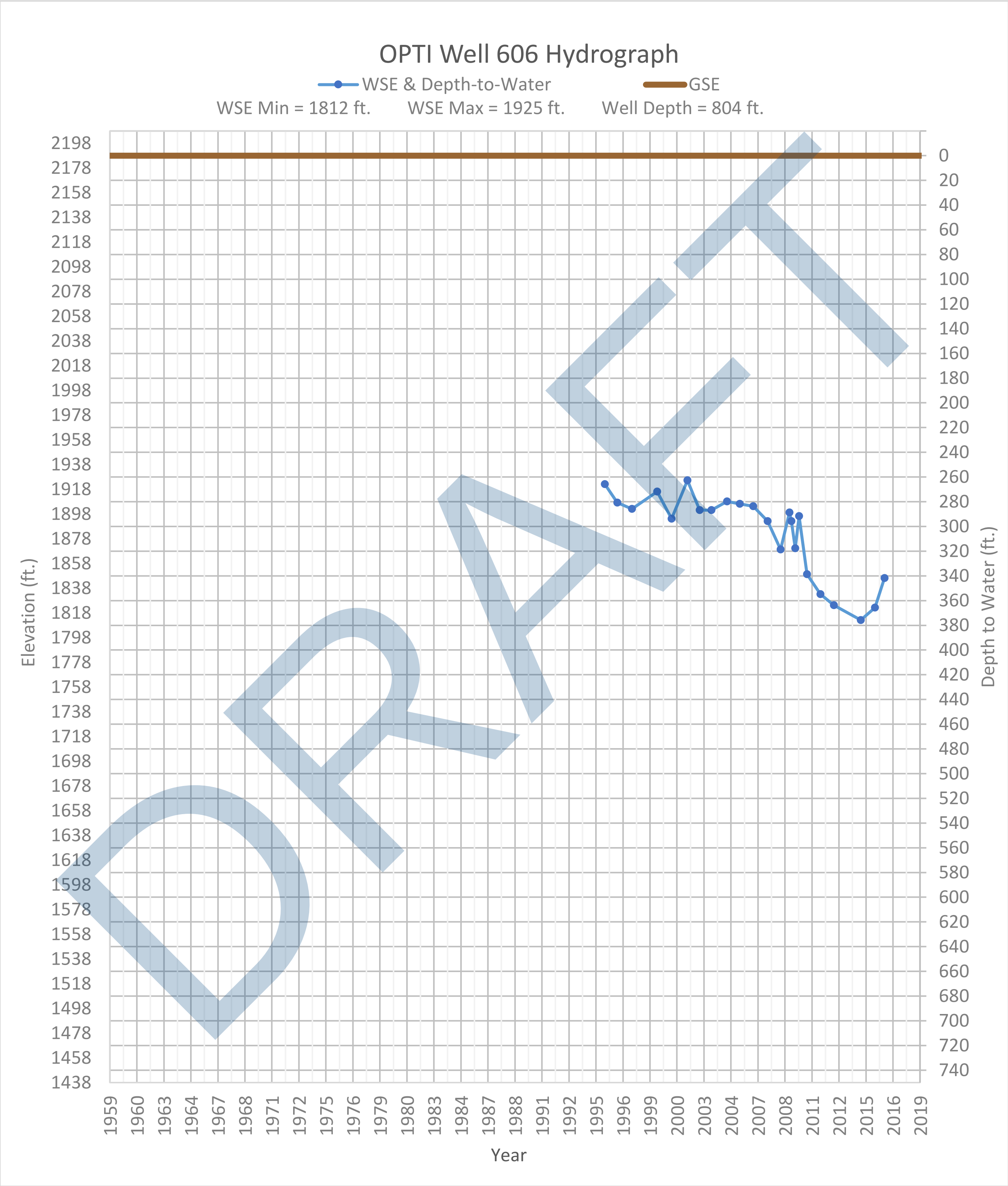
OPTI Well 603 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1638 ft.
WSE Max = 1897 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



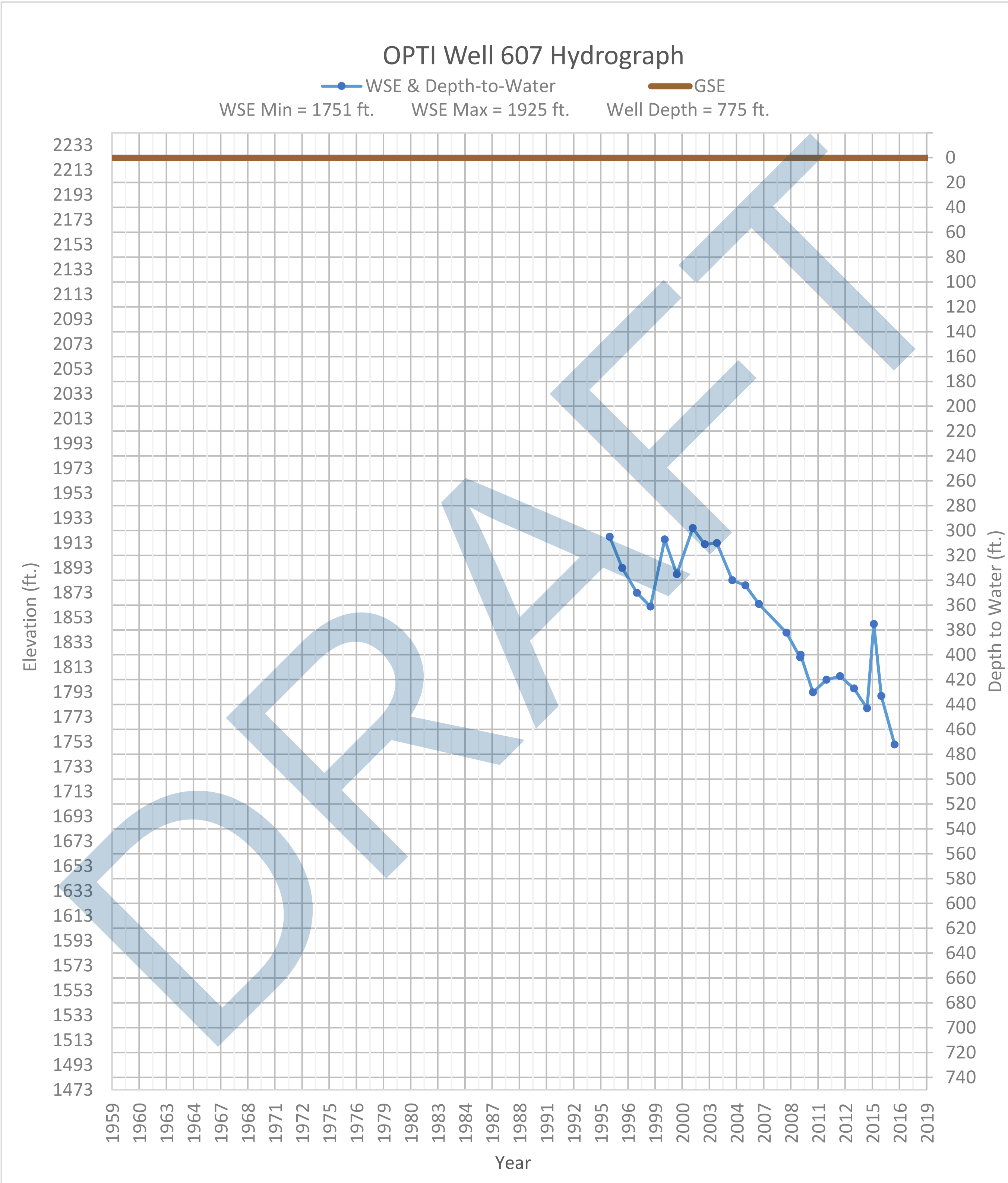
OPTI Well 604 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1607 ft.
WSE Max = 1844 ft.
Well Depth = 924 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



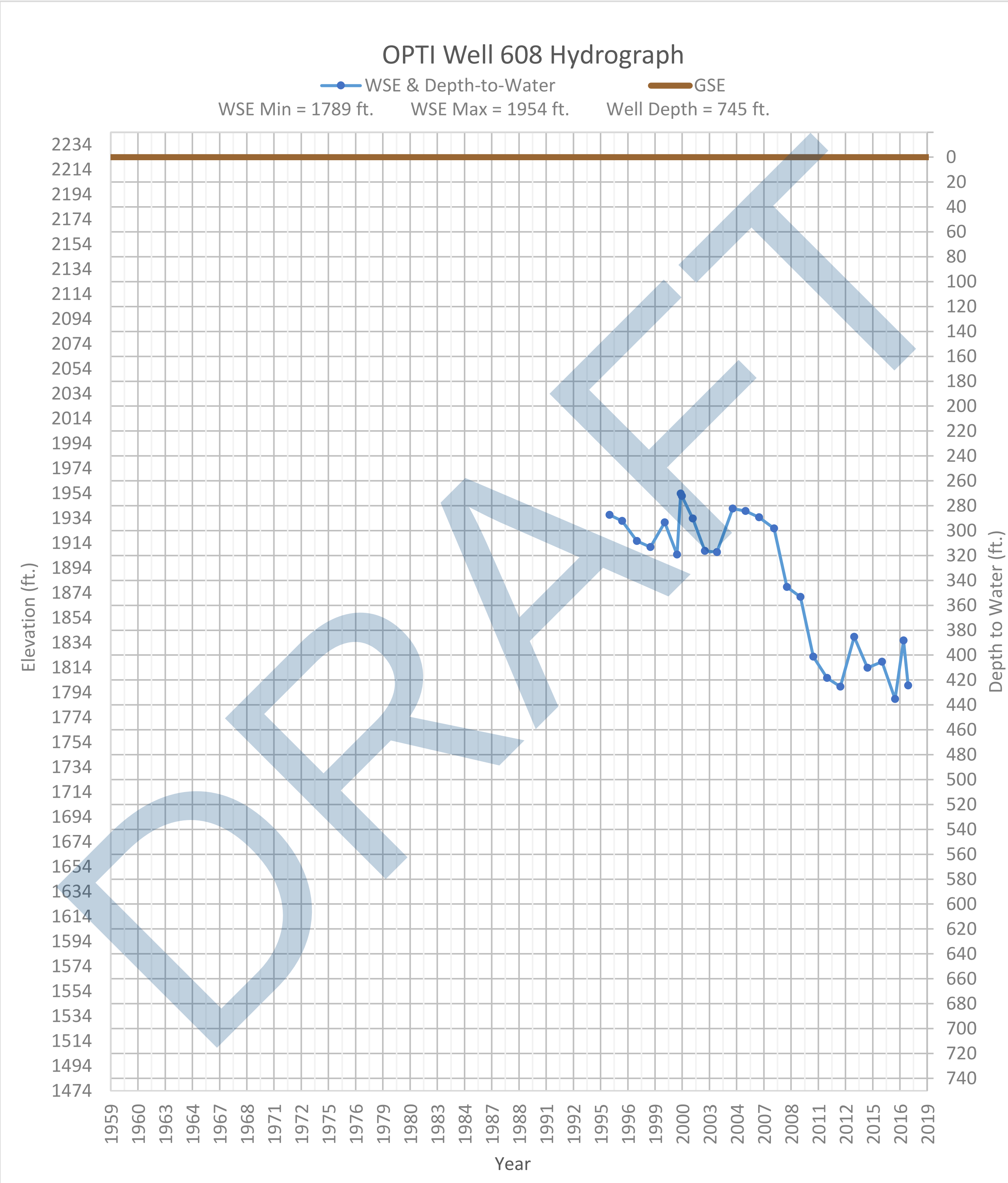
OPTI Well 605 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1708 ft.
WSE Max = 1834 ft.
Well Depth = 597 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



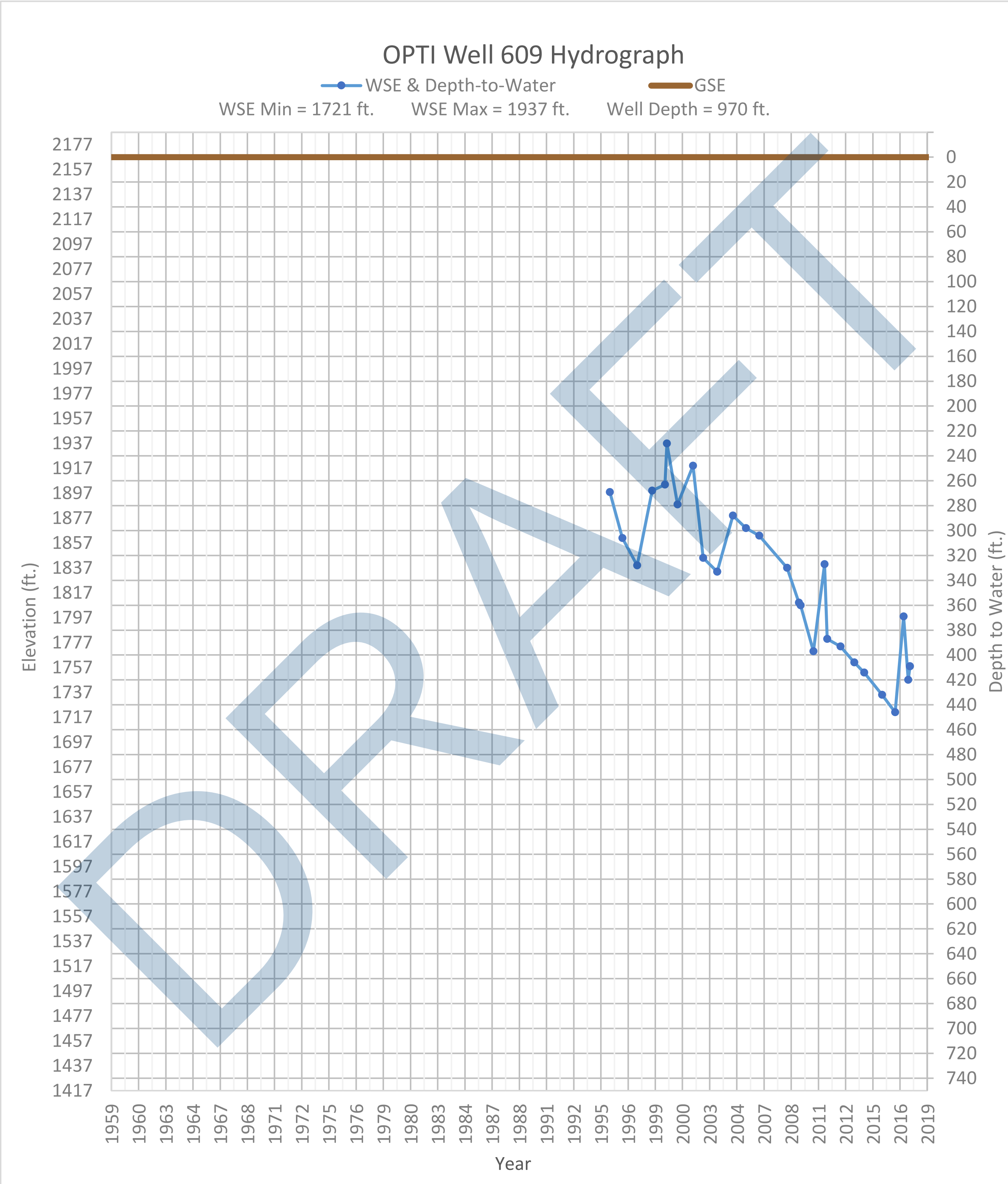
OPTI Well 606 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1812 ft.
WSE Max = 1925 ft.
Well Depth = 804 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

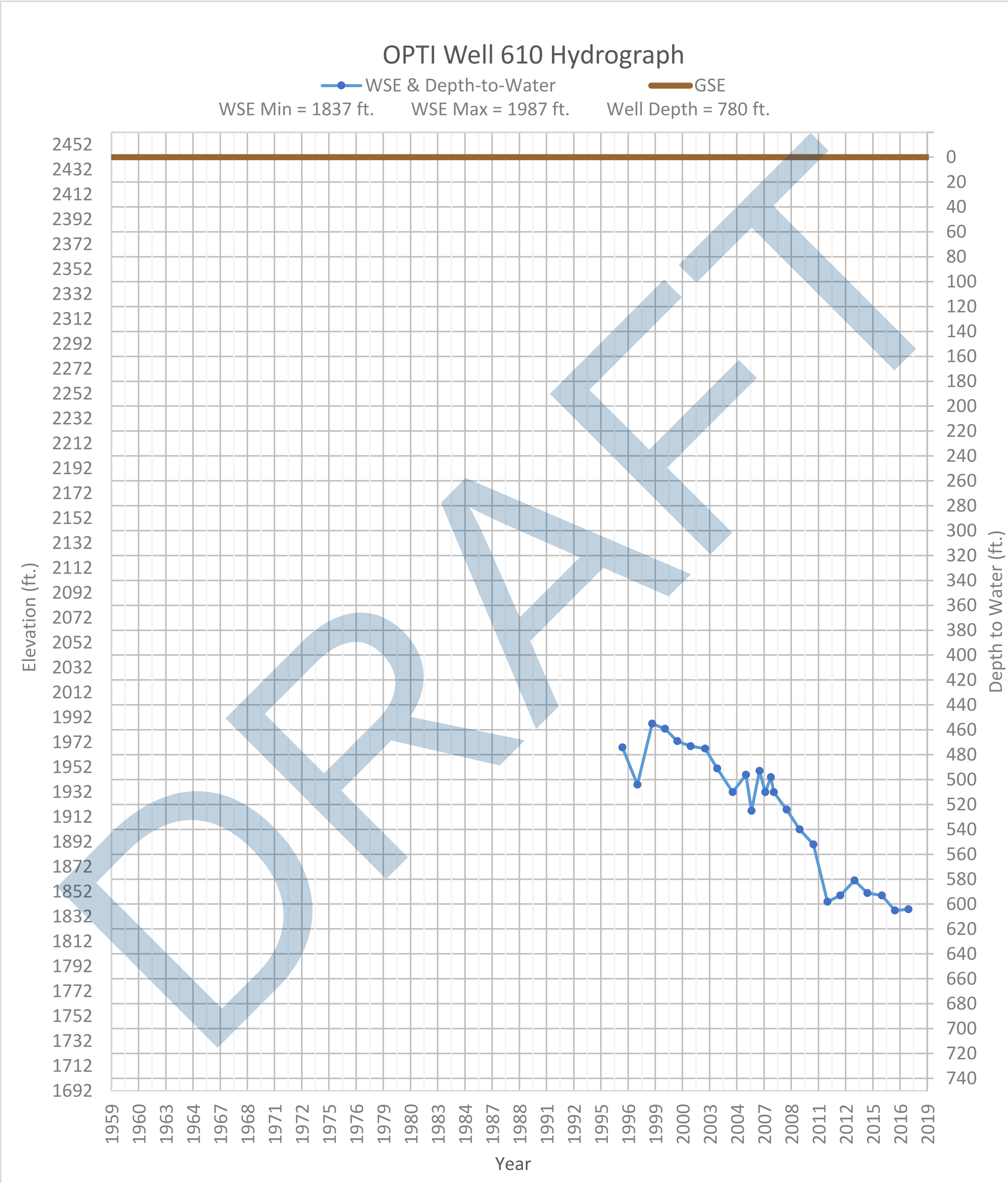


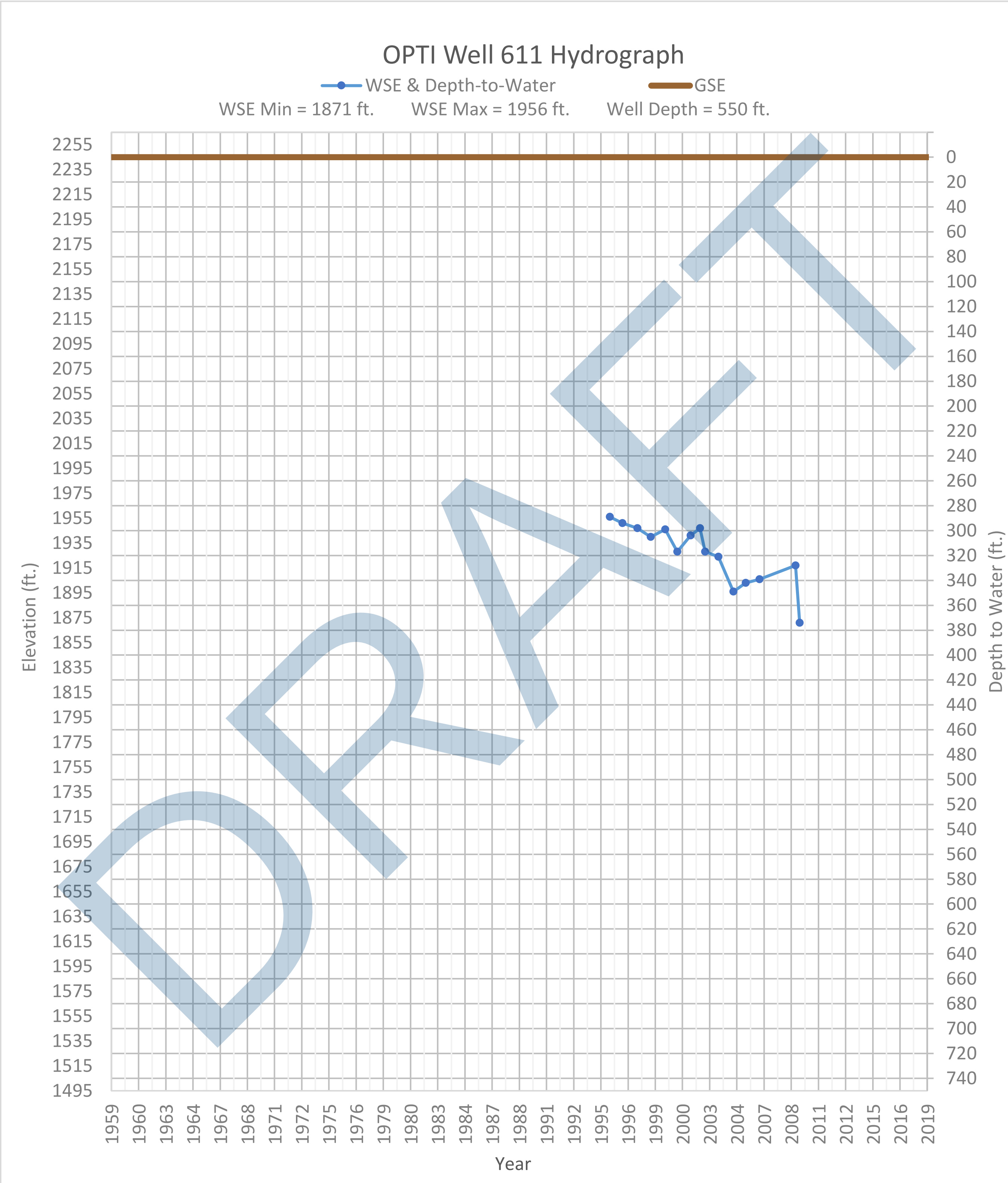
OPTI Well 607 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1751 ft.
WSE Max = 1925 ft.
Well Depth = 775 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



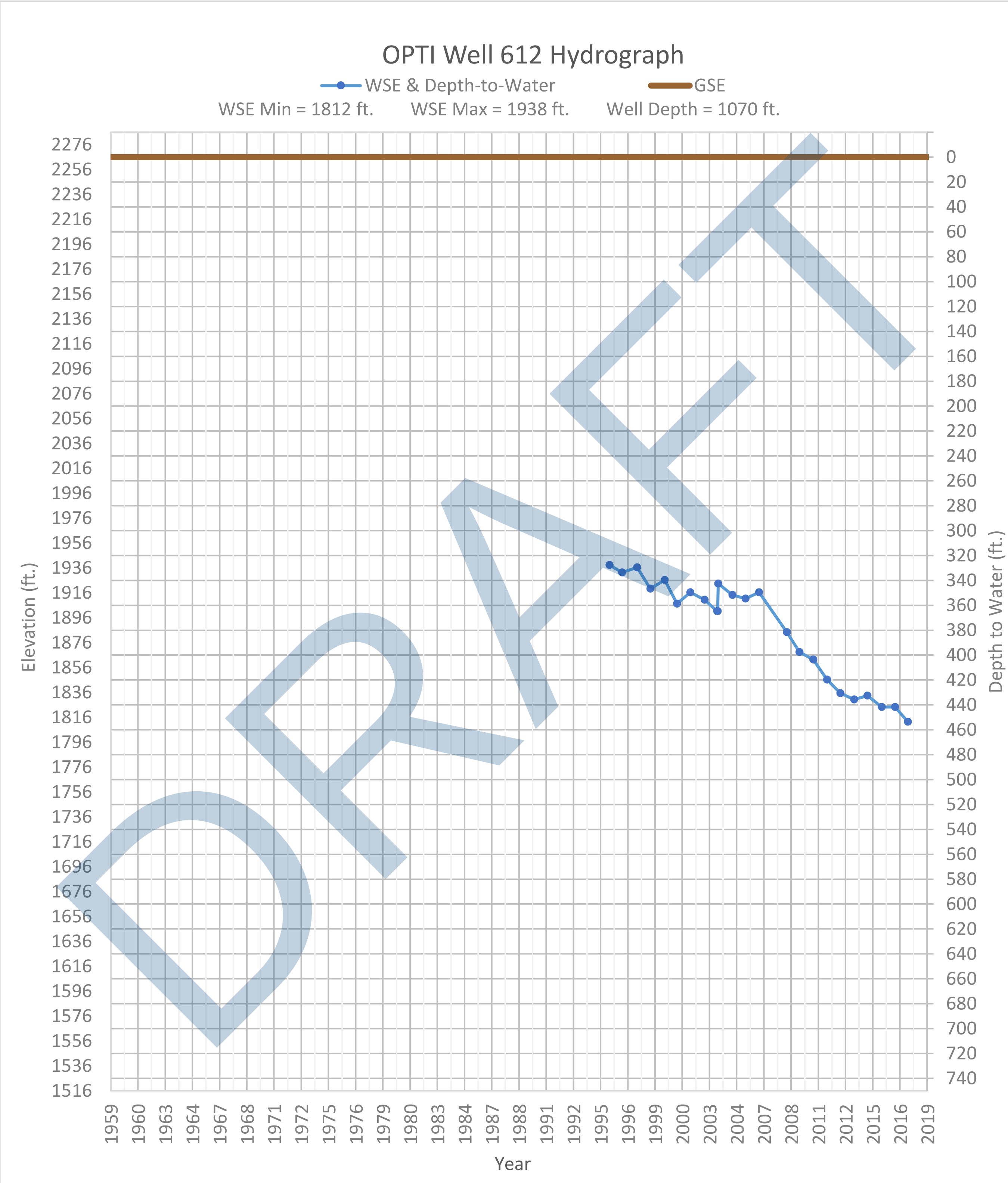
OPTI Well 608 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1789 ft.
WSE Max = 1954 ft.
Well Depth = 745 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 609 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1721 ft.
WSE Max = 1937 ft.
Well Depth = 970 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

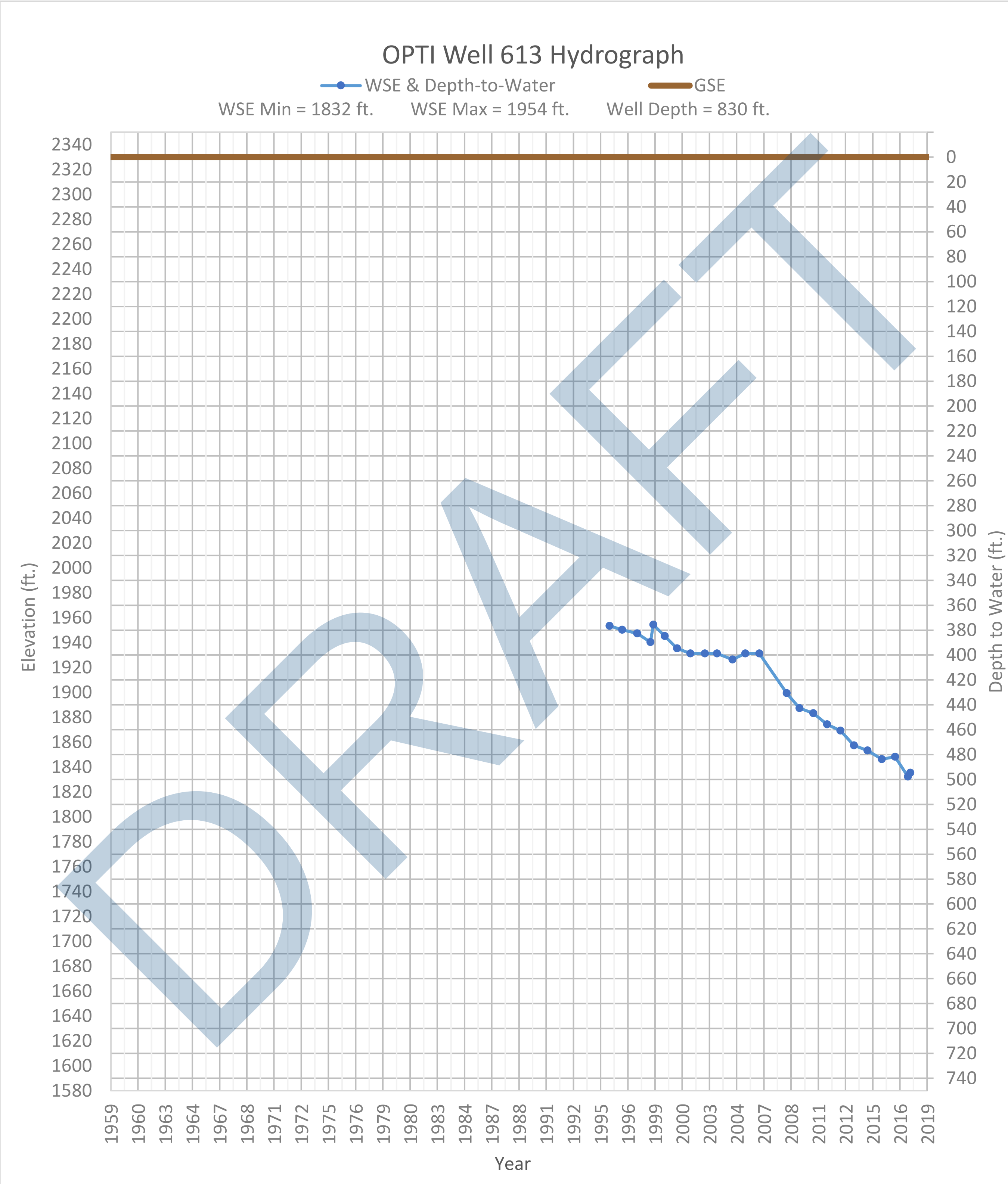

OPTI Well 610 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1837 ft.
WSE Max = 1987 ft.
Well Depth = 780 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



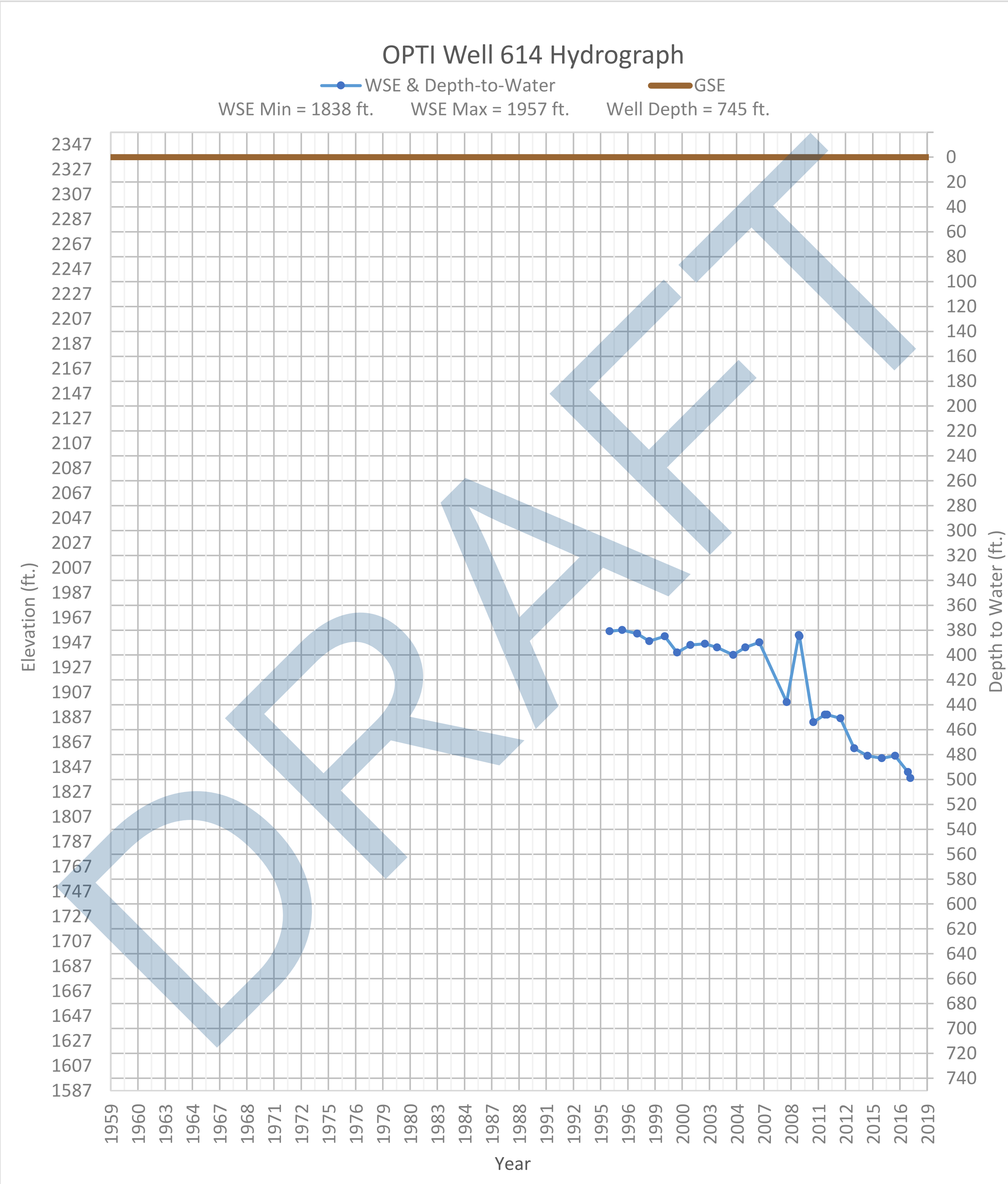
OPTI Well 611 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1871 ft.
WSE Max = 1956 ft.
Well Depth = 550 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



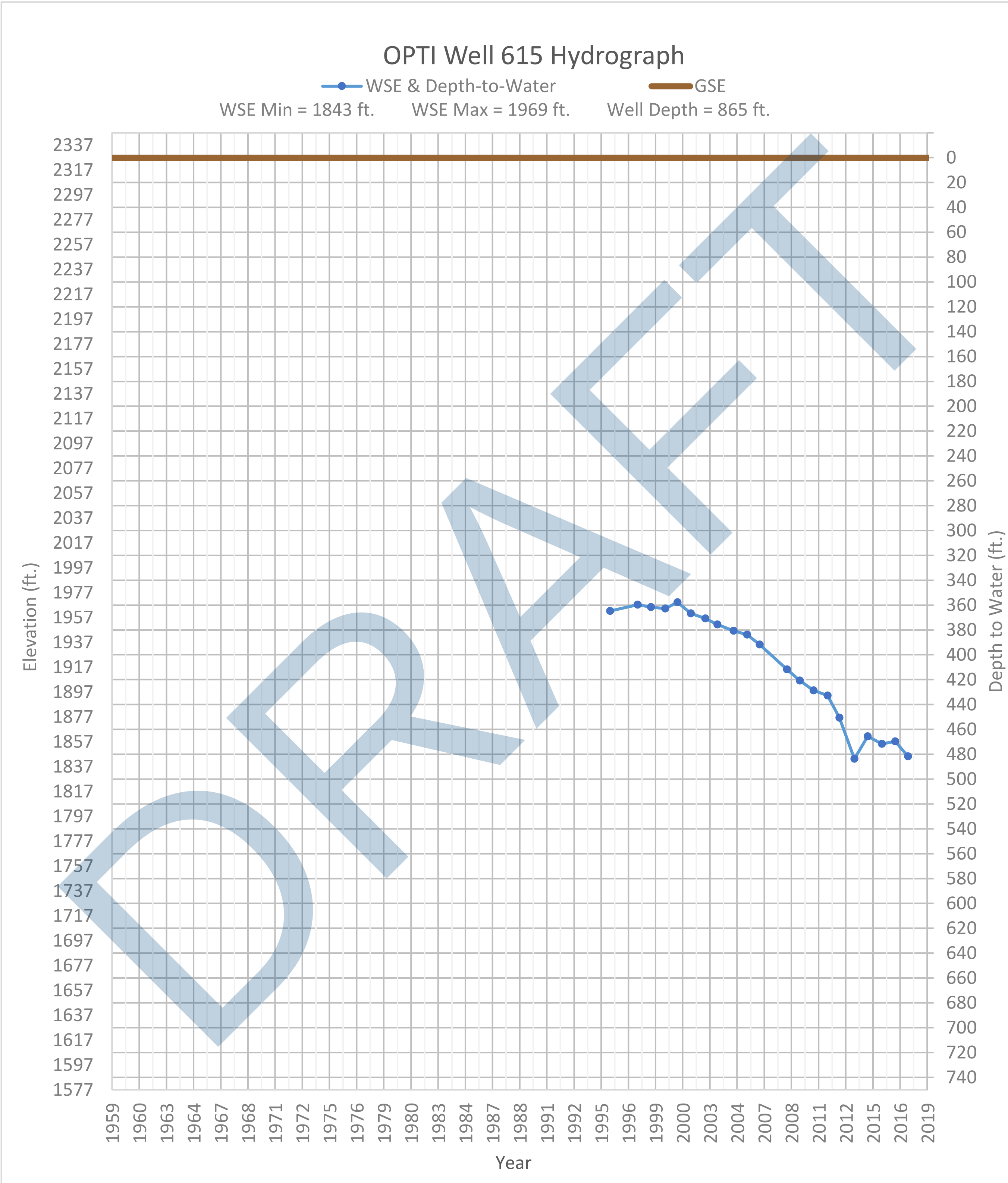
OPTI Well 612 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1812 ft.
WSE Max = 1938 ft.
Well Depth = 1070 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



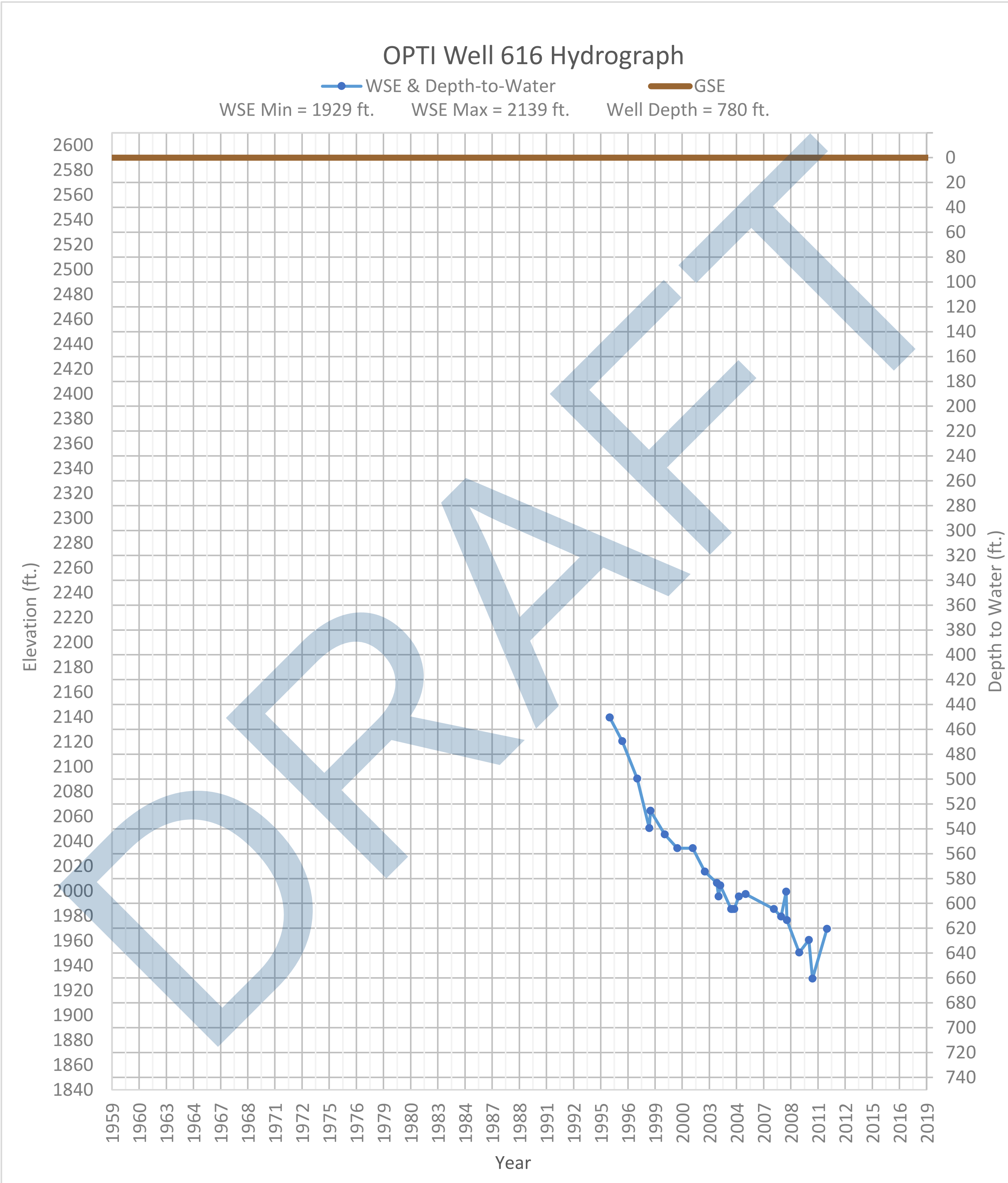
OPTI Well 613 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1832 ft.
WSE Max = 1954 ft.
Well Depth = 830 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

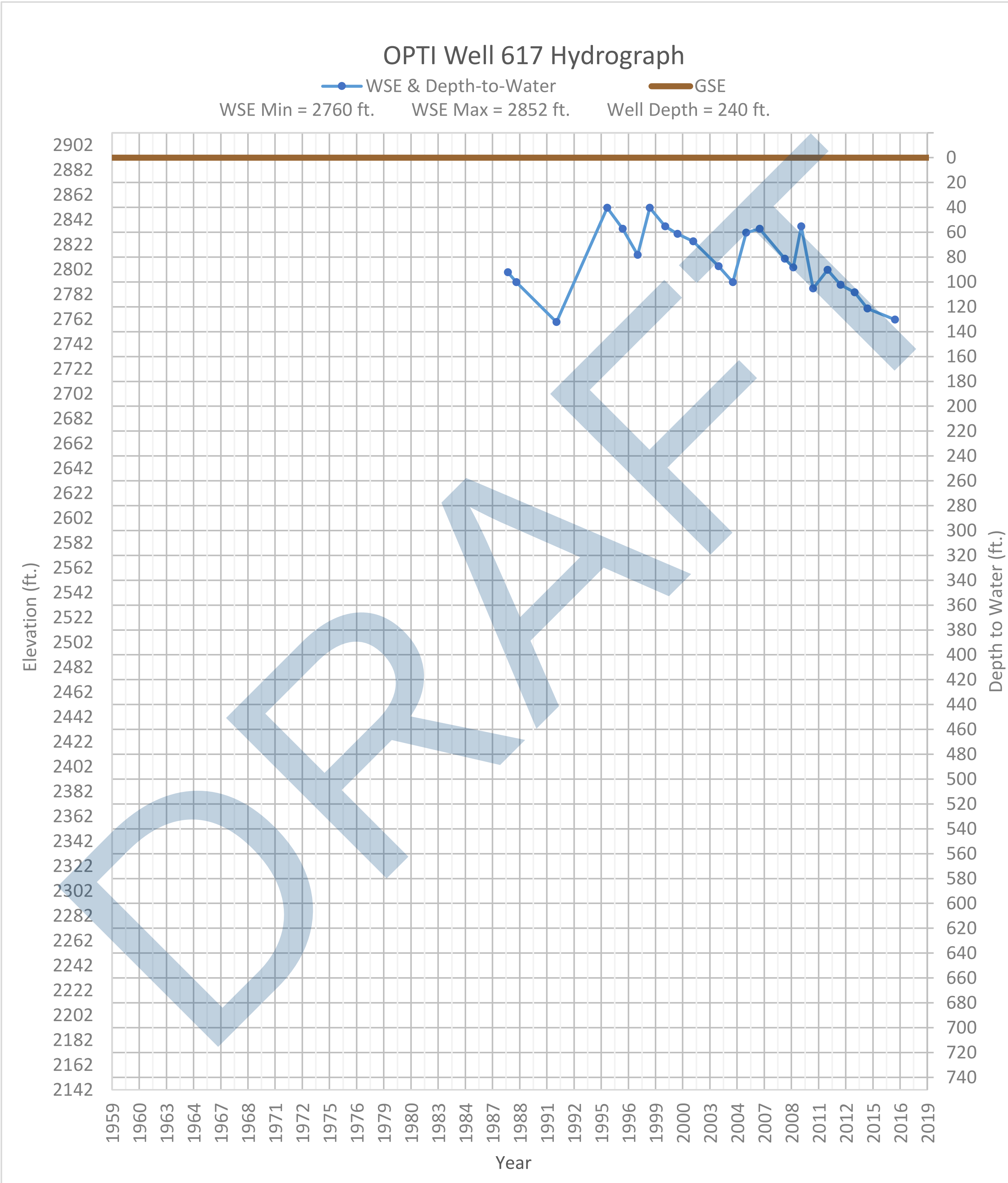


OPTI Well 614 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1838 ft.
WSE Max = 1957 ft.
Well Depth = 745 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

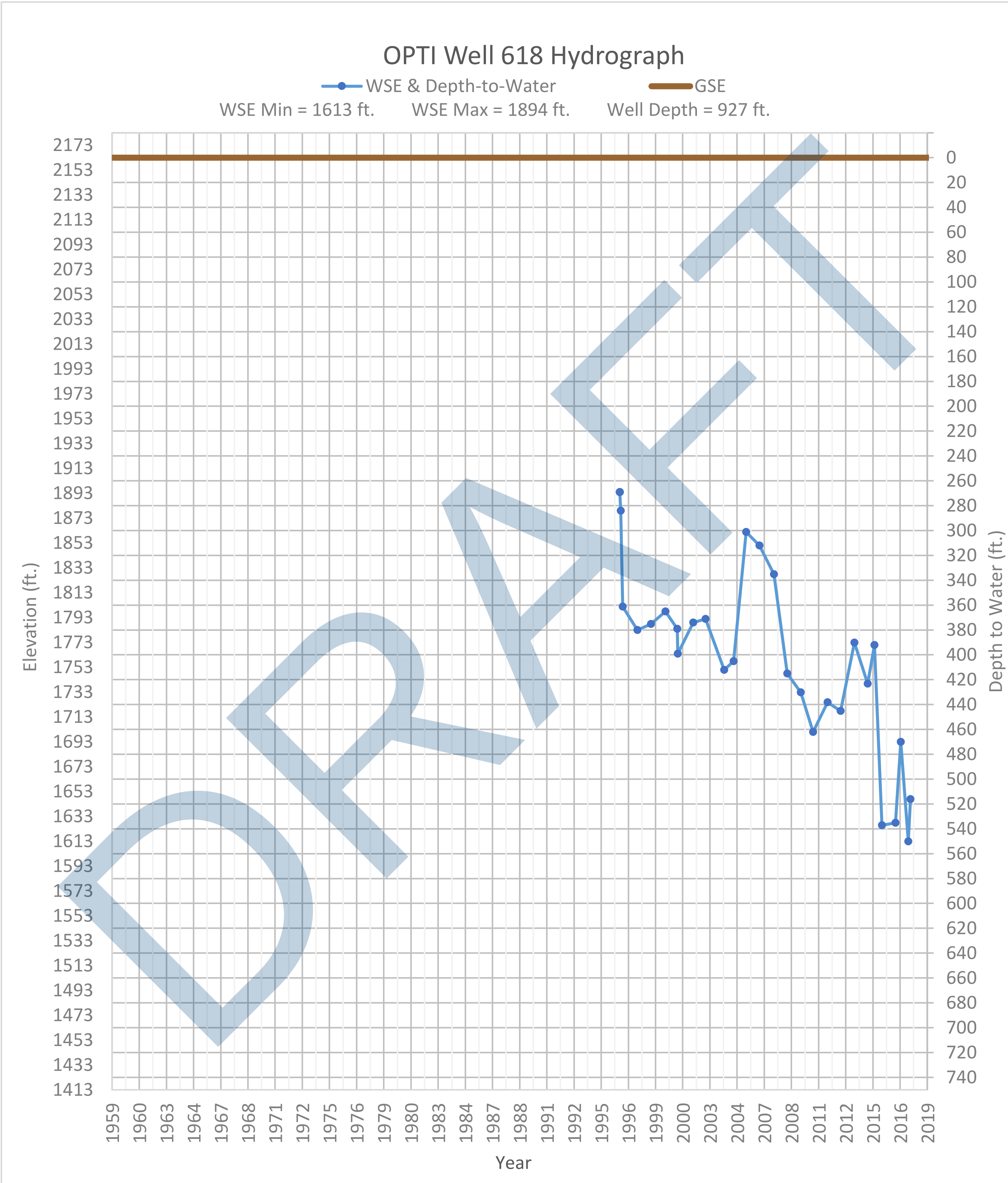


OPTI Well 615 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1843 ft.
WSE Max = 1969 ft.
Well Depth = 865 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

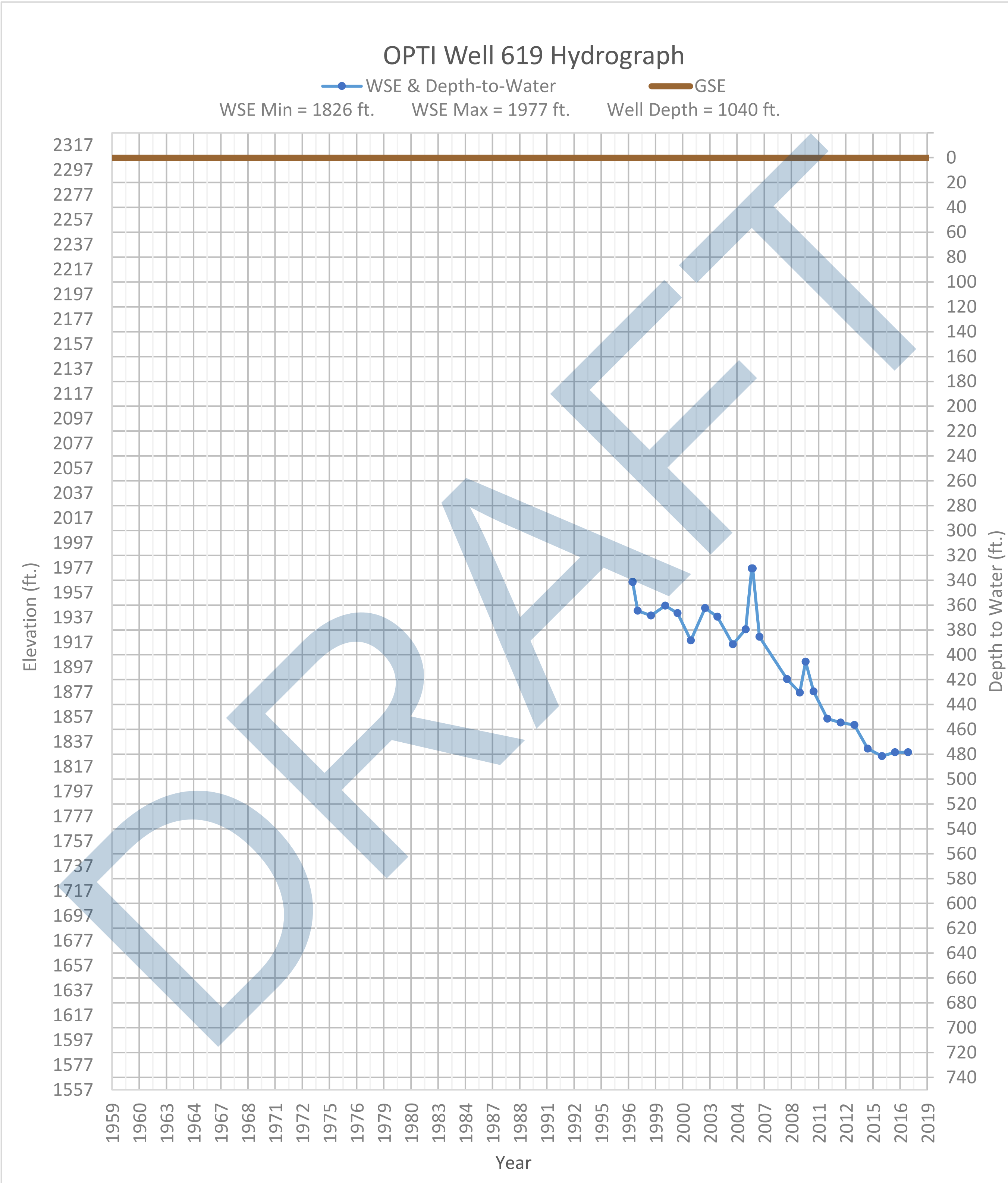

OPTI Well 616 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1929 ft.
WSE Max = 2139 ft.
Well Depth = 780 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



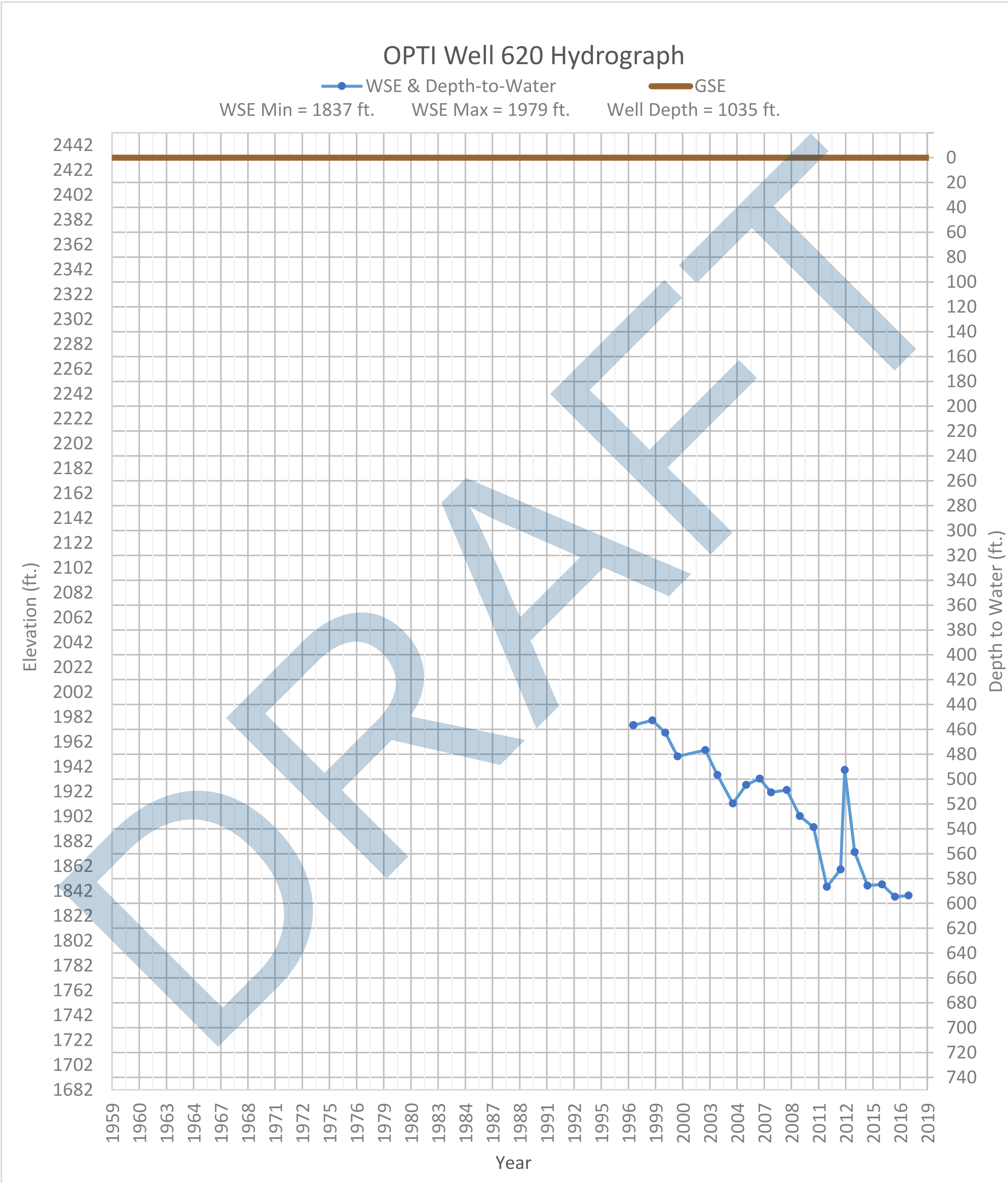
OPTI Well 617 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2760 ft.
WSE Max = 2852 ft.
Well Depth = 240 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



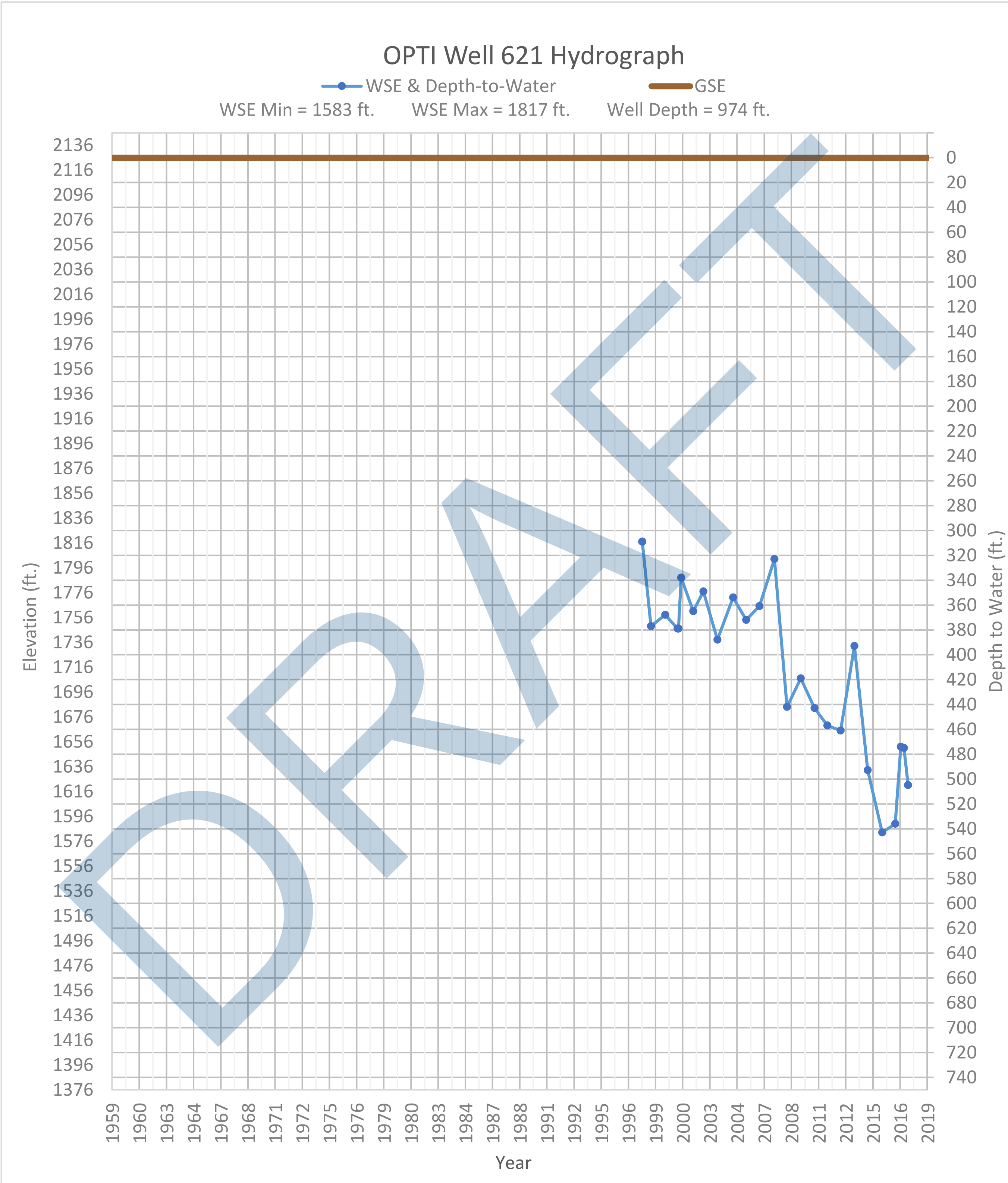
OPTI Well 618 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1613 ft.
WSE Max = 1894 ft.
Well Depth = 927 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



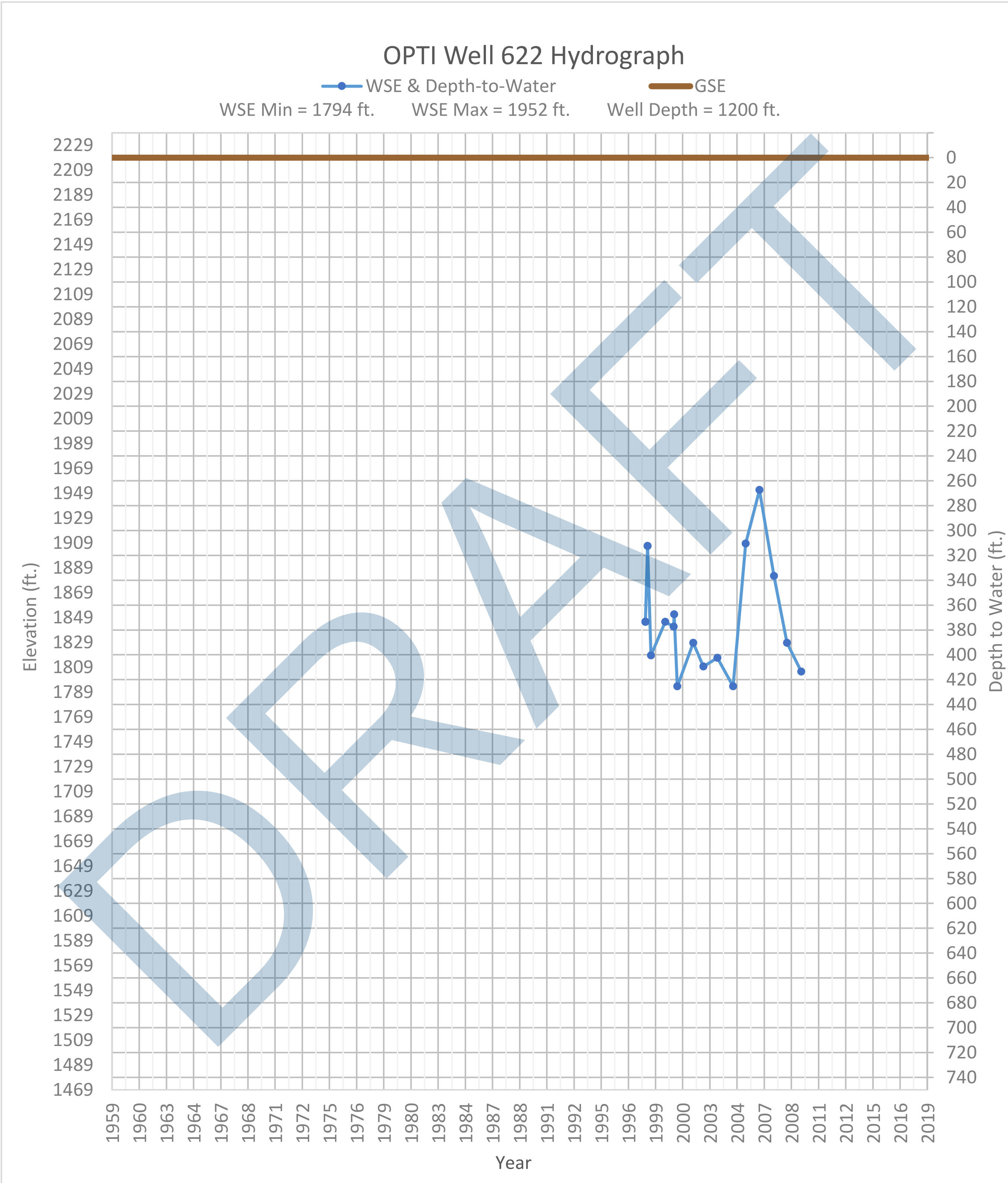
OPTI Well 619 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1826 ft.
WSE Max = 1977 ft.
Well Depth = 1040 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



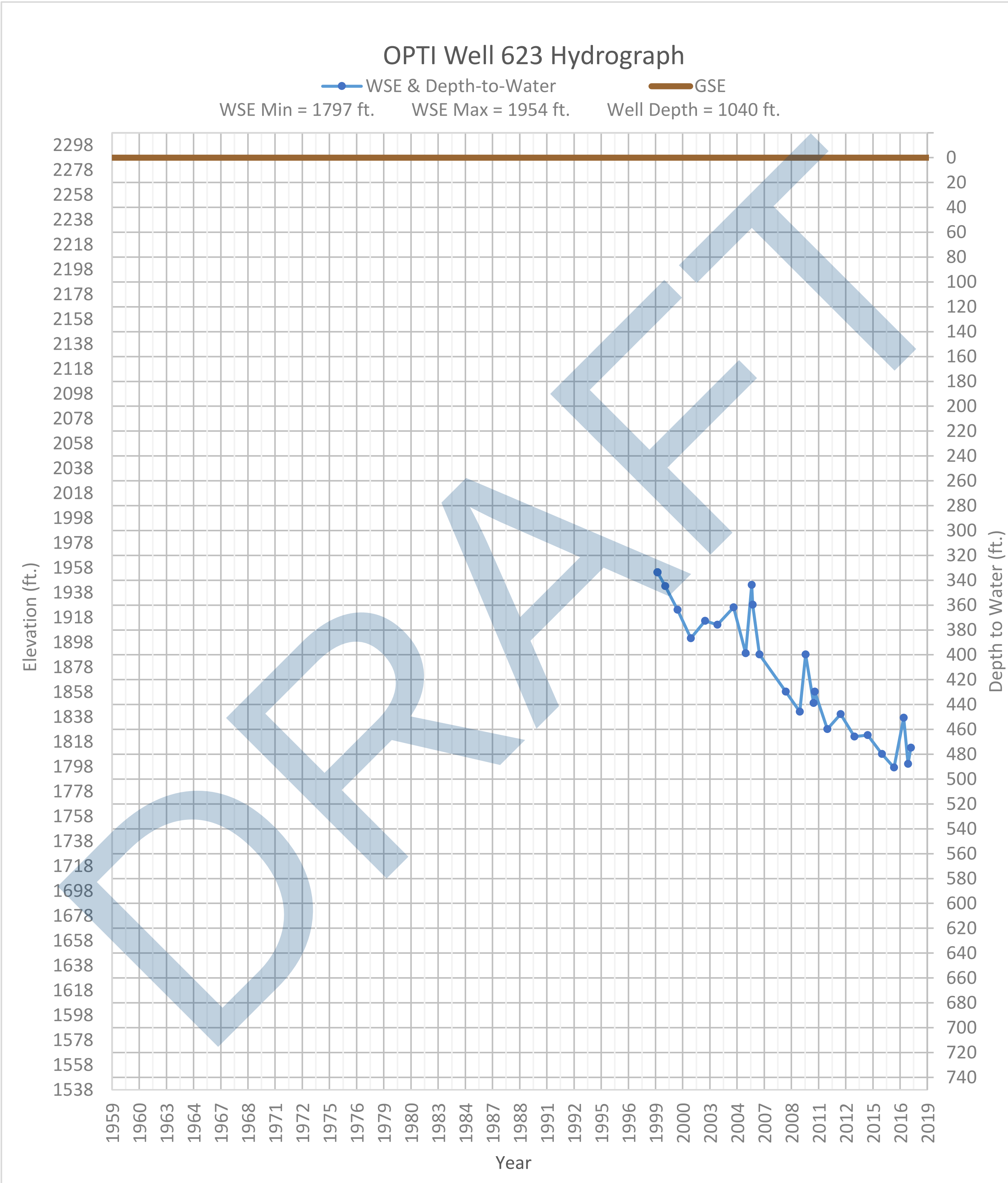
OPTI Well 620 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1837 ft.
WSE Max = 1979 ft.
Well Depth = 1035 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



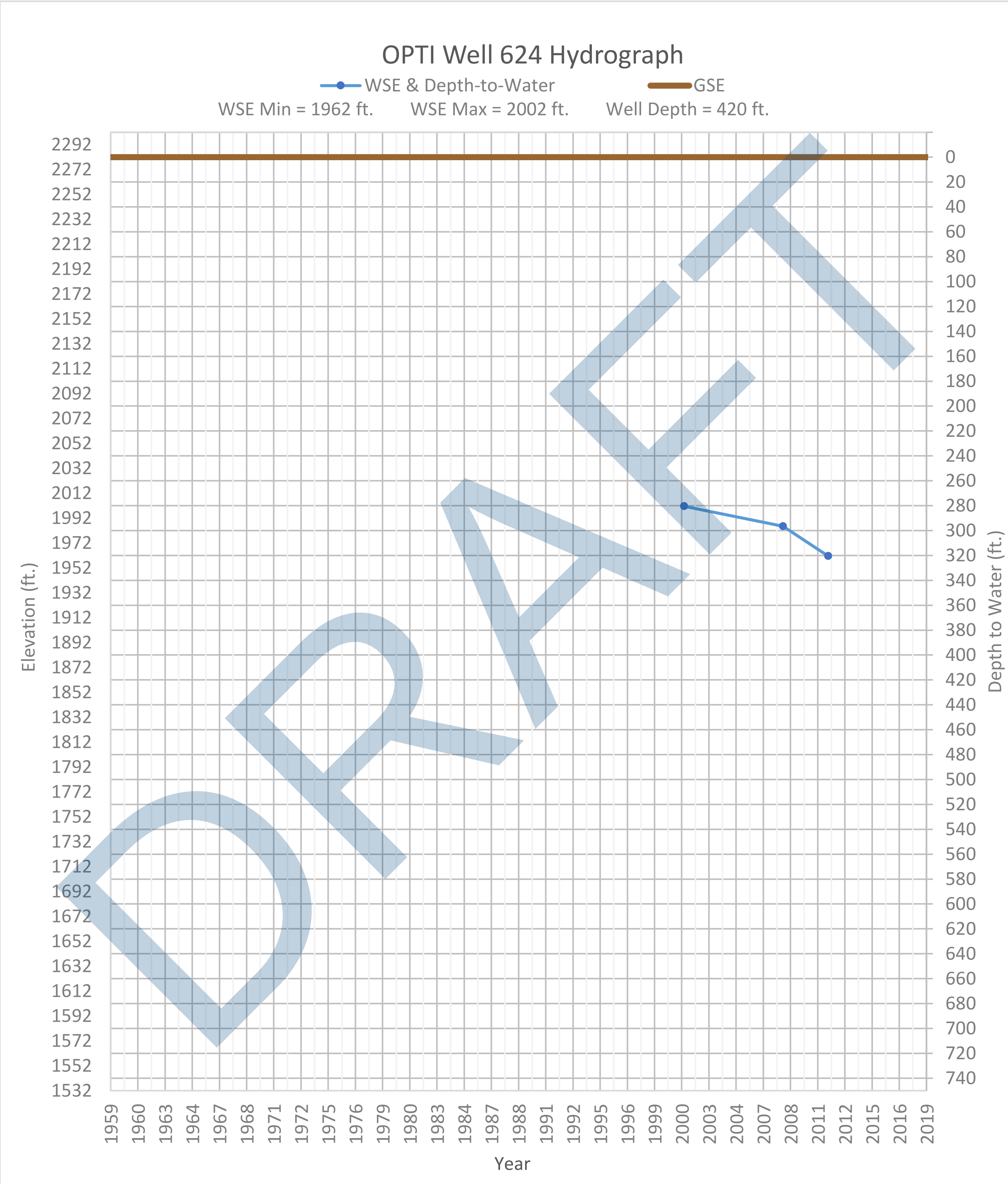
OPTI Well 621 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1583 ft.
WSE Max = 1817 ft.
Well Depth = 974 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2136 2116 2096 2076 2056 2036 2016 1996 1976 1956 1936 1916 1896 1876 1856 1836 1816 1796 1776 1756 1736 1716 1696 1676 1656 1636 1616 1596 1576 1556 1536 1516 1496 1476 1456 1436 1416 1396 1376
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT



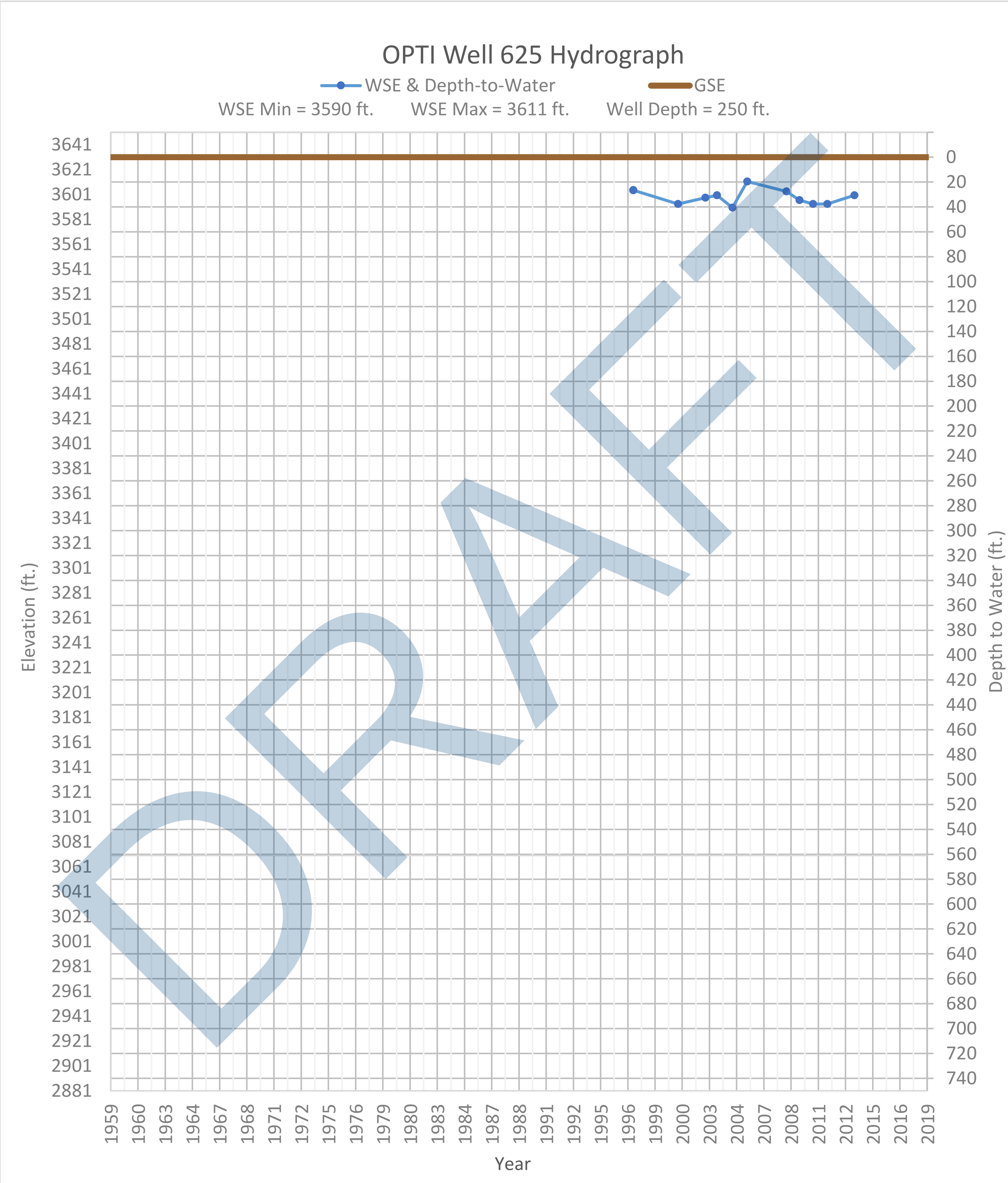
OPTI Well 622 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1794 ft.
WSE Max = 1952 ft.
Well Depth = 1200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



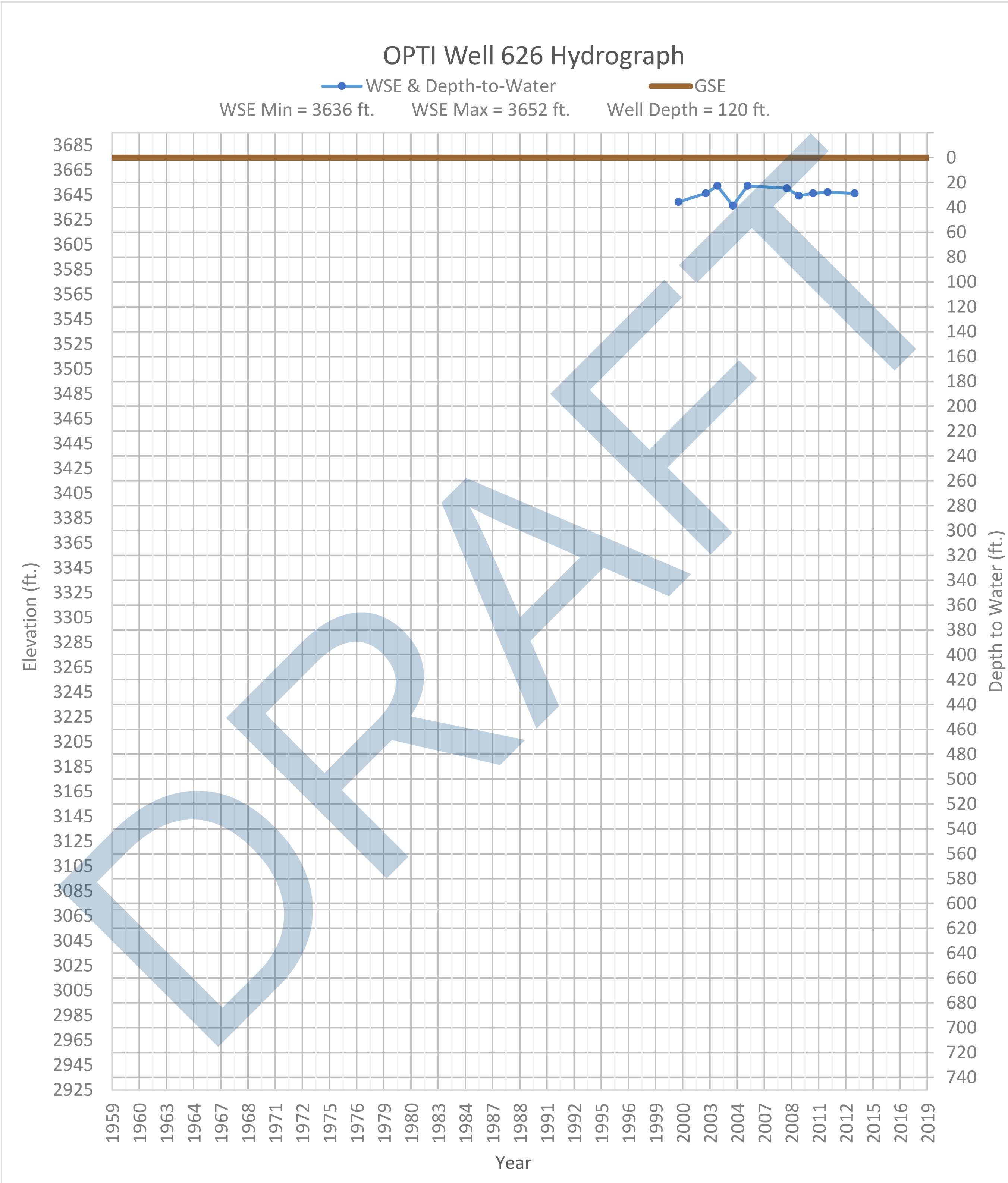
OPTI Well 623 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1797 ft.
WSE Max = 1954 ft.
Well Depth = 1040 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



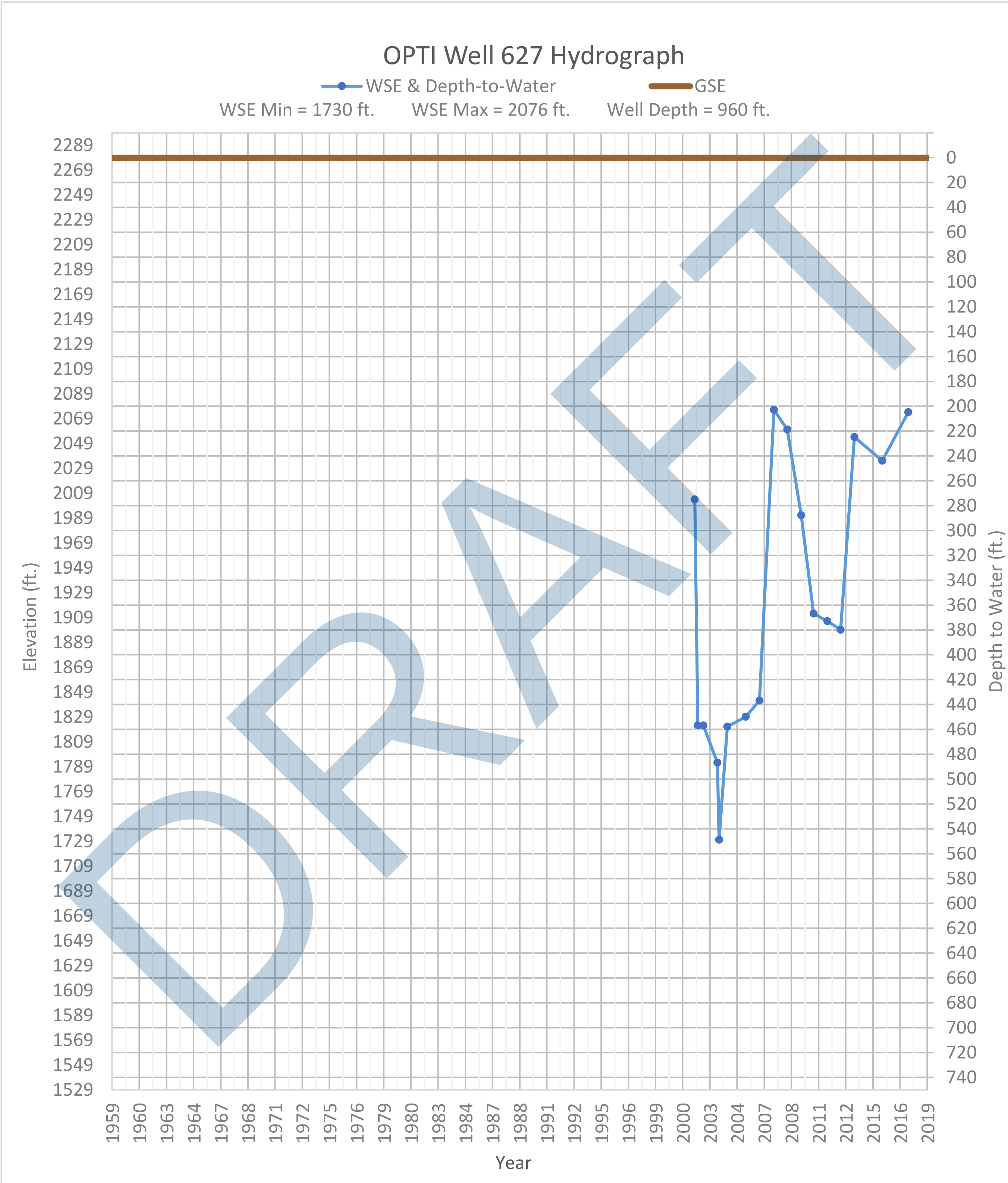
OPTI Well 624 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1962 ft.
WSE Max = 2002 ft.
Well Depth = 420 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 625 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3590 ft.
WSE Max = 3611 ft.
Well Depth = 250 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

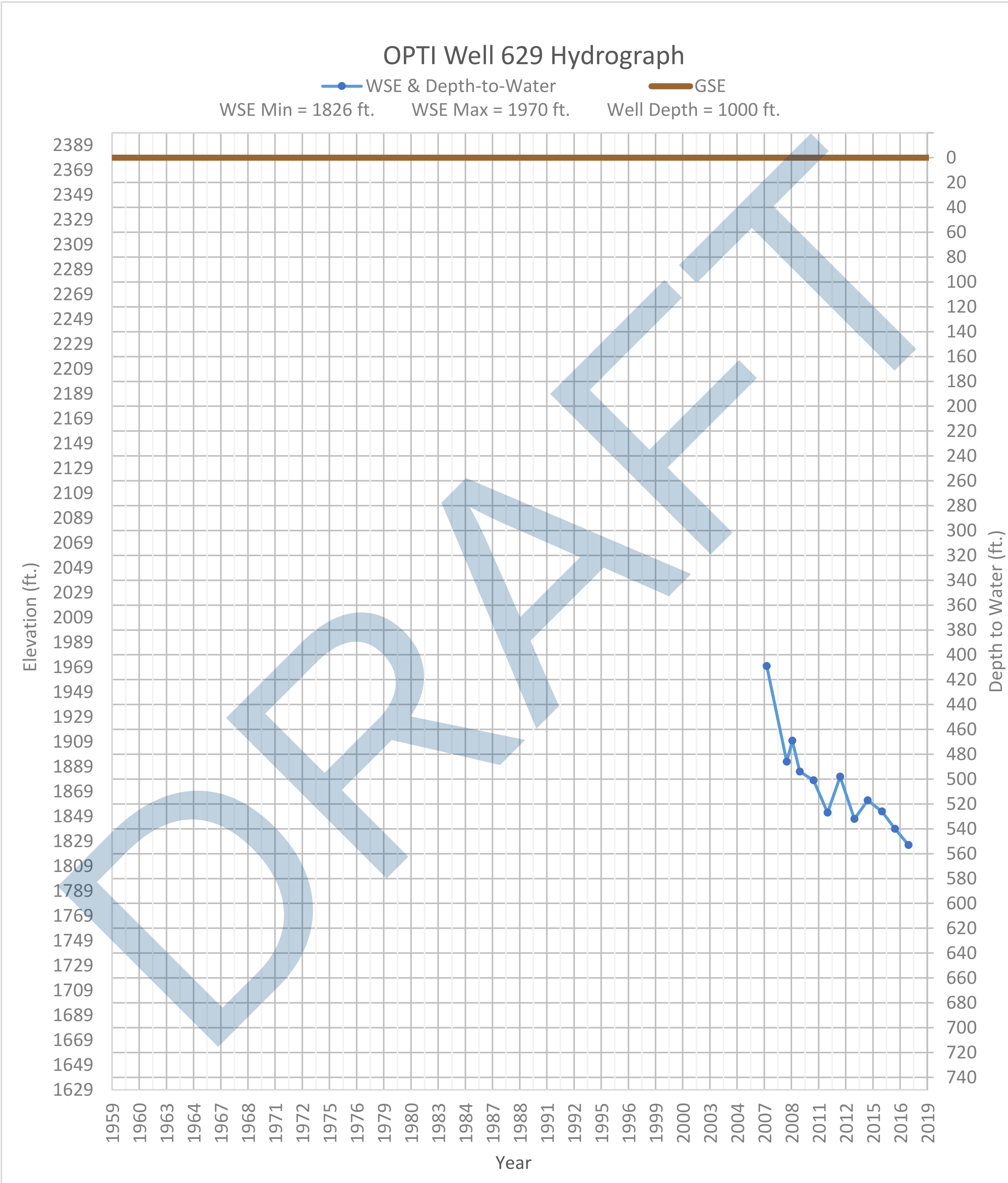


OPTI Well 626 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 3636 ft.
WSE Max = 3652 ft.
Well Depth = 120 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

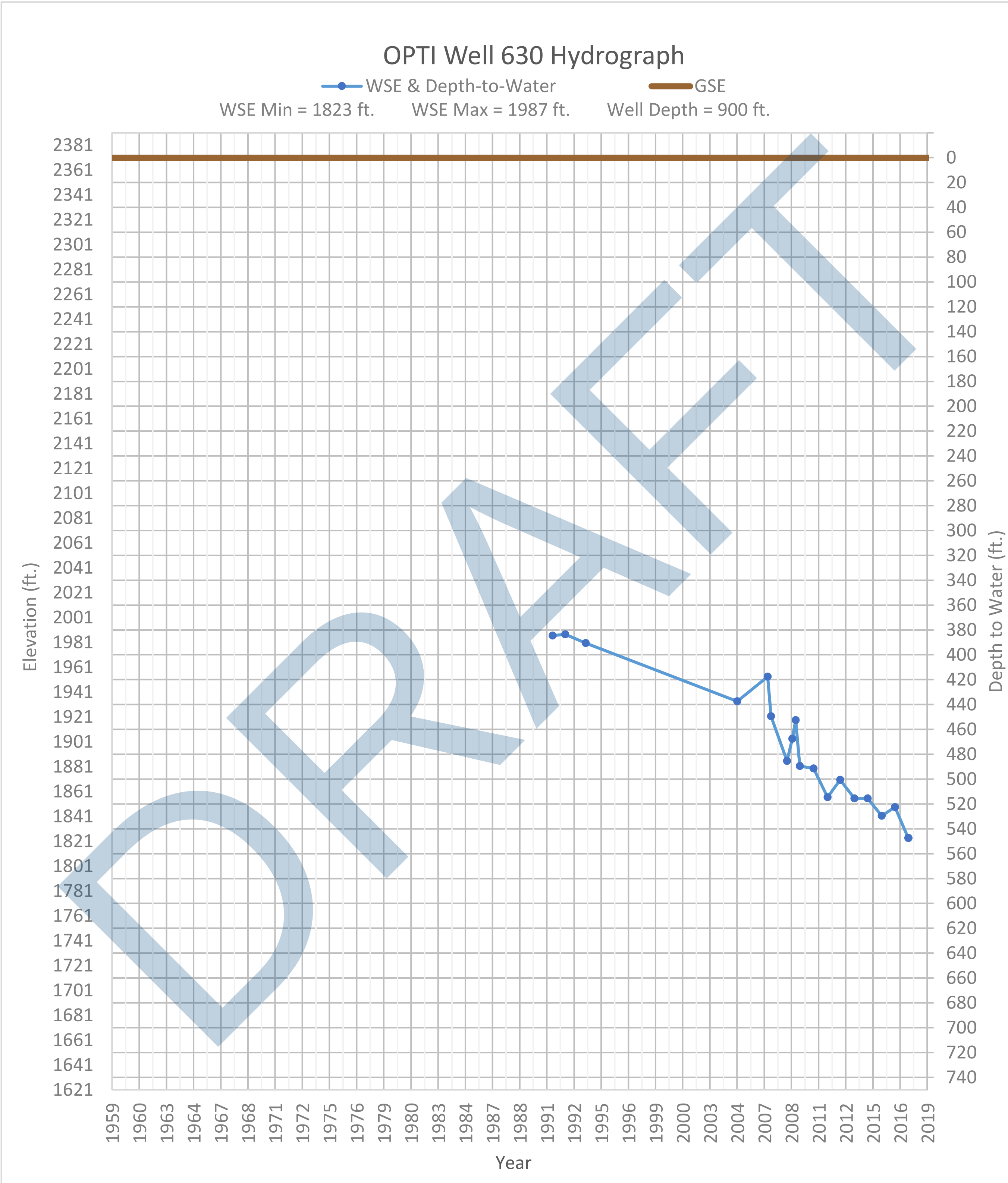


OPTI Well 627 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1730 ft.
WSE Max = 2076 ft.
Well Depth = 960 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

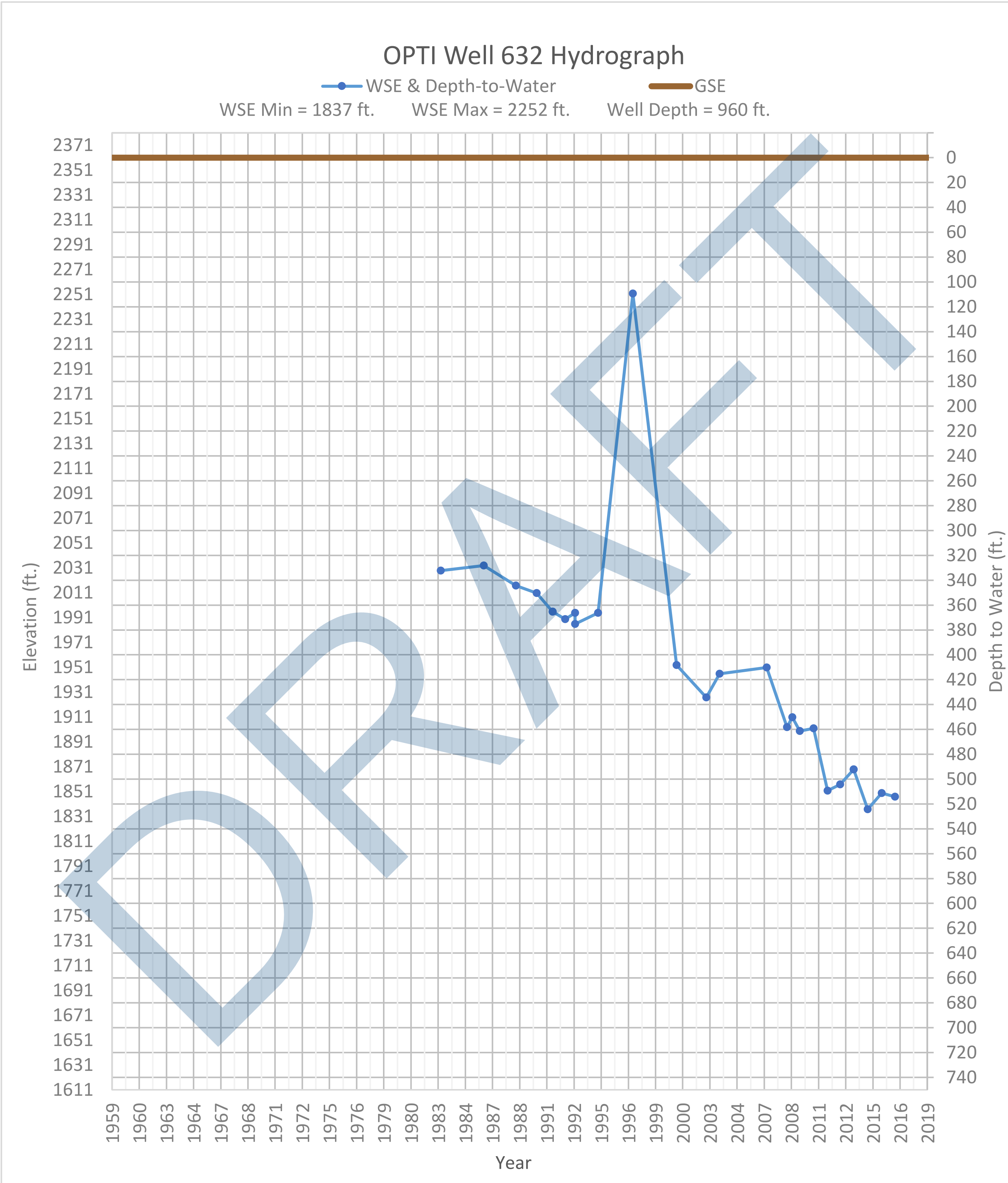
OPTI Well 628 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1792 ft.
WSE Max = 2078 ft.
Well Depth = 941 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 629 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1826 ft.
WSE Max = 1970 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 630 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1823 ft.
WSE Max = 1987 ft.
Well Depth = 900 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

OPTI Well 631 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1830 ft.
WSE Max = 2033 ft.
Well Depth = 960 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 632 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1837 ft.
WSE Max = 2252 ft.
Well Depth = 960 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT
2371
2351
2331
2311
2291
2271
2251
2231
2211
2191
2171
2151
2131
2111
2091
2071
2051
2031
2011
1991
1971
1951
1931
1911
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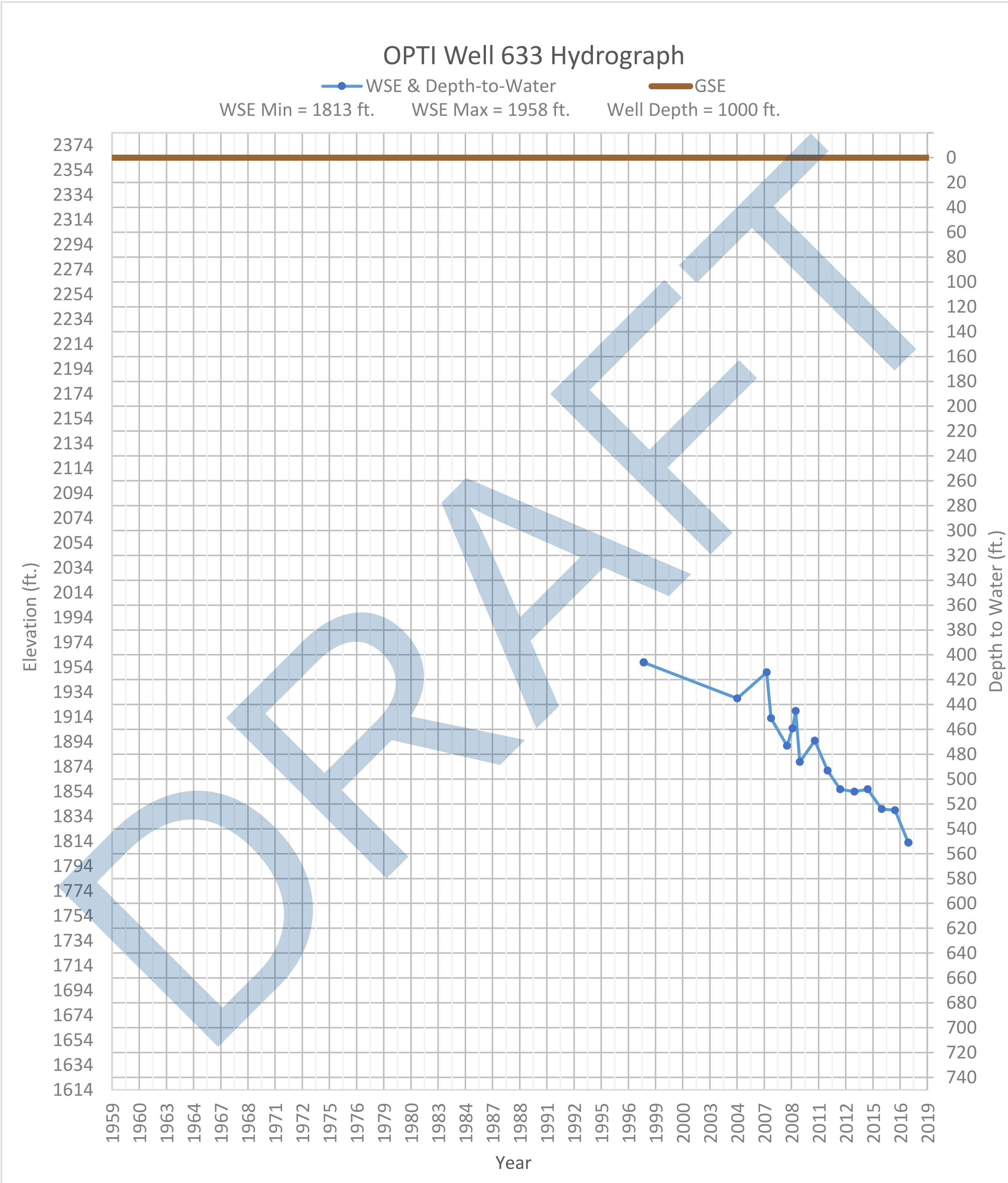
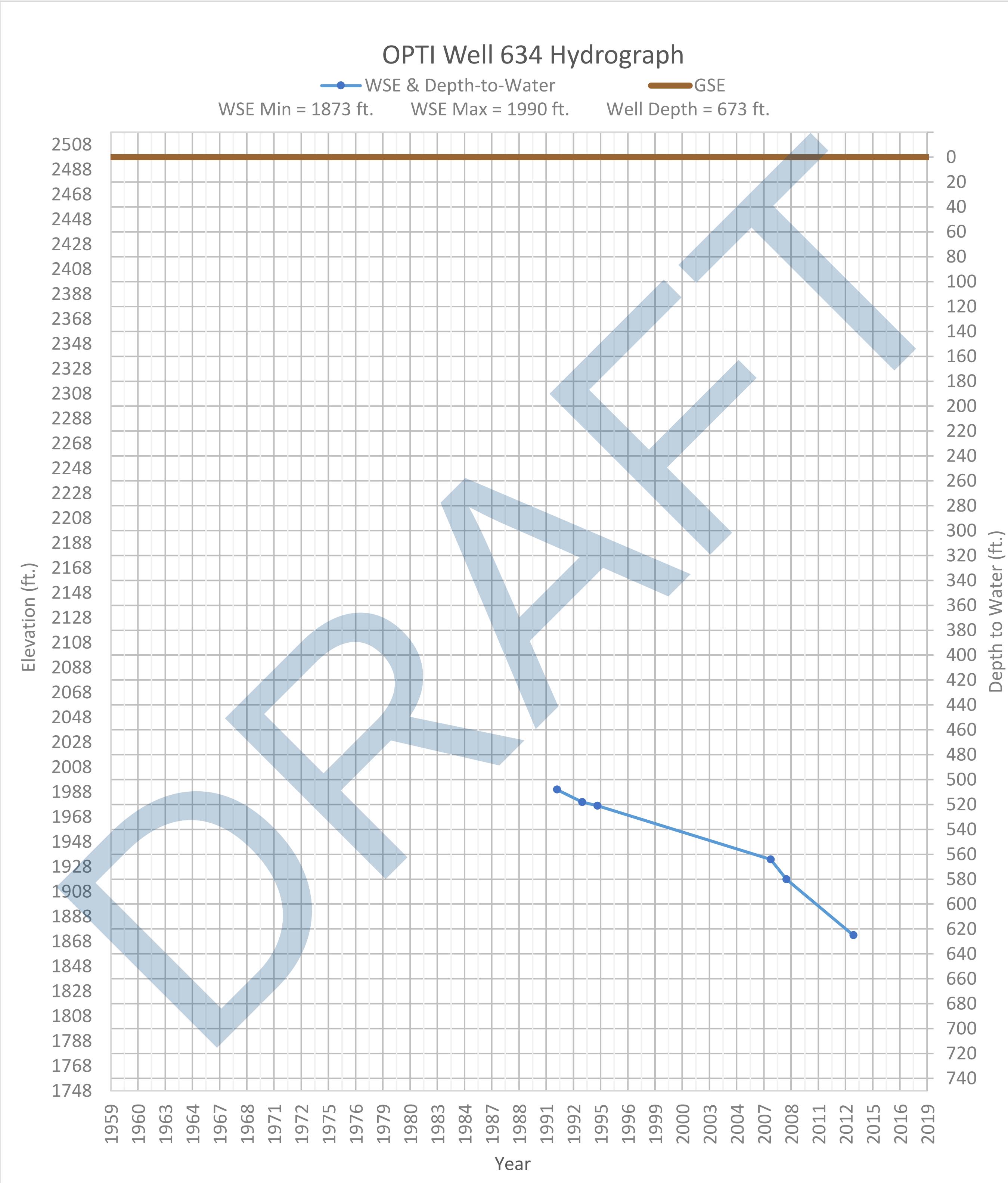
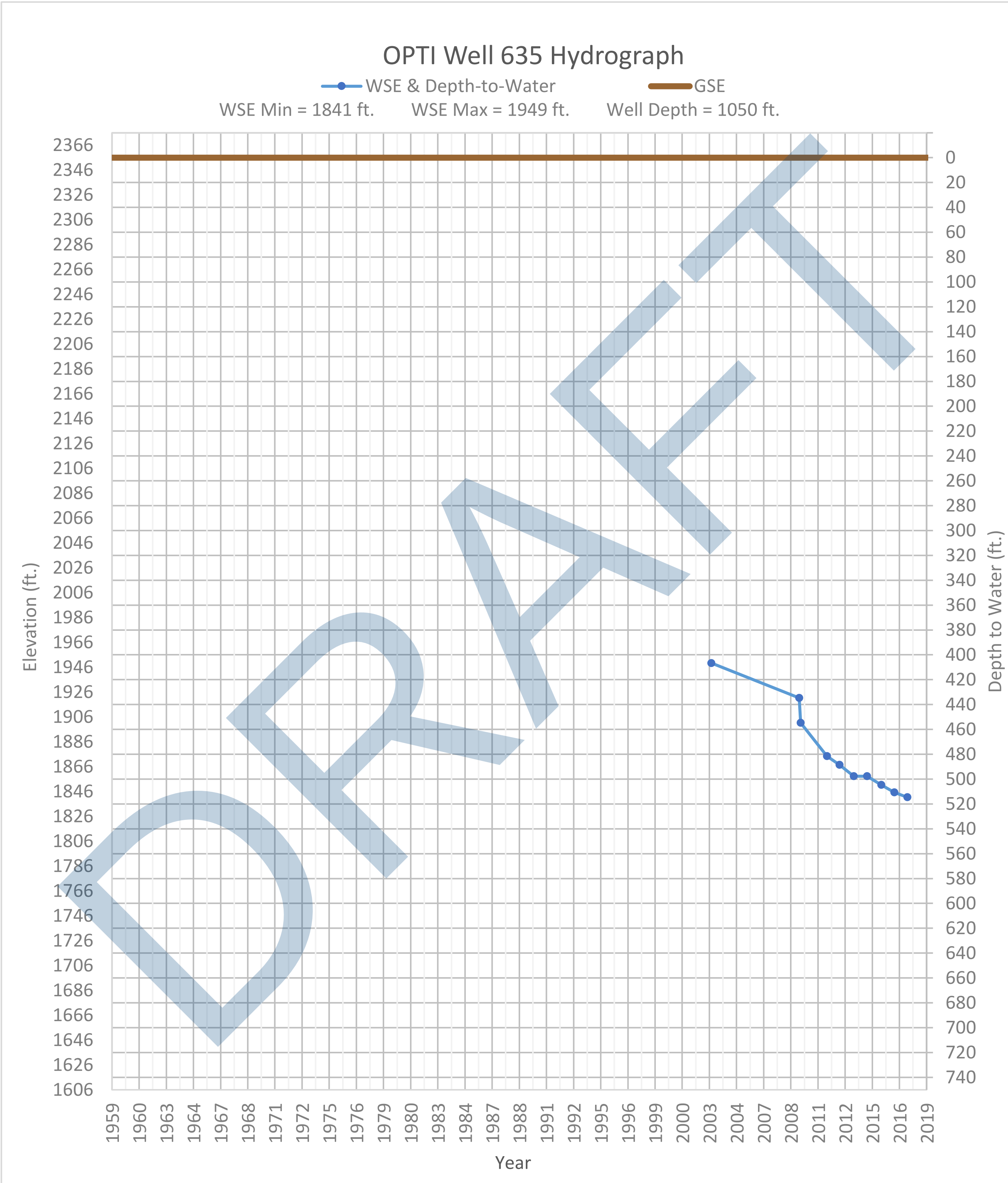
2016
2019



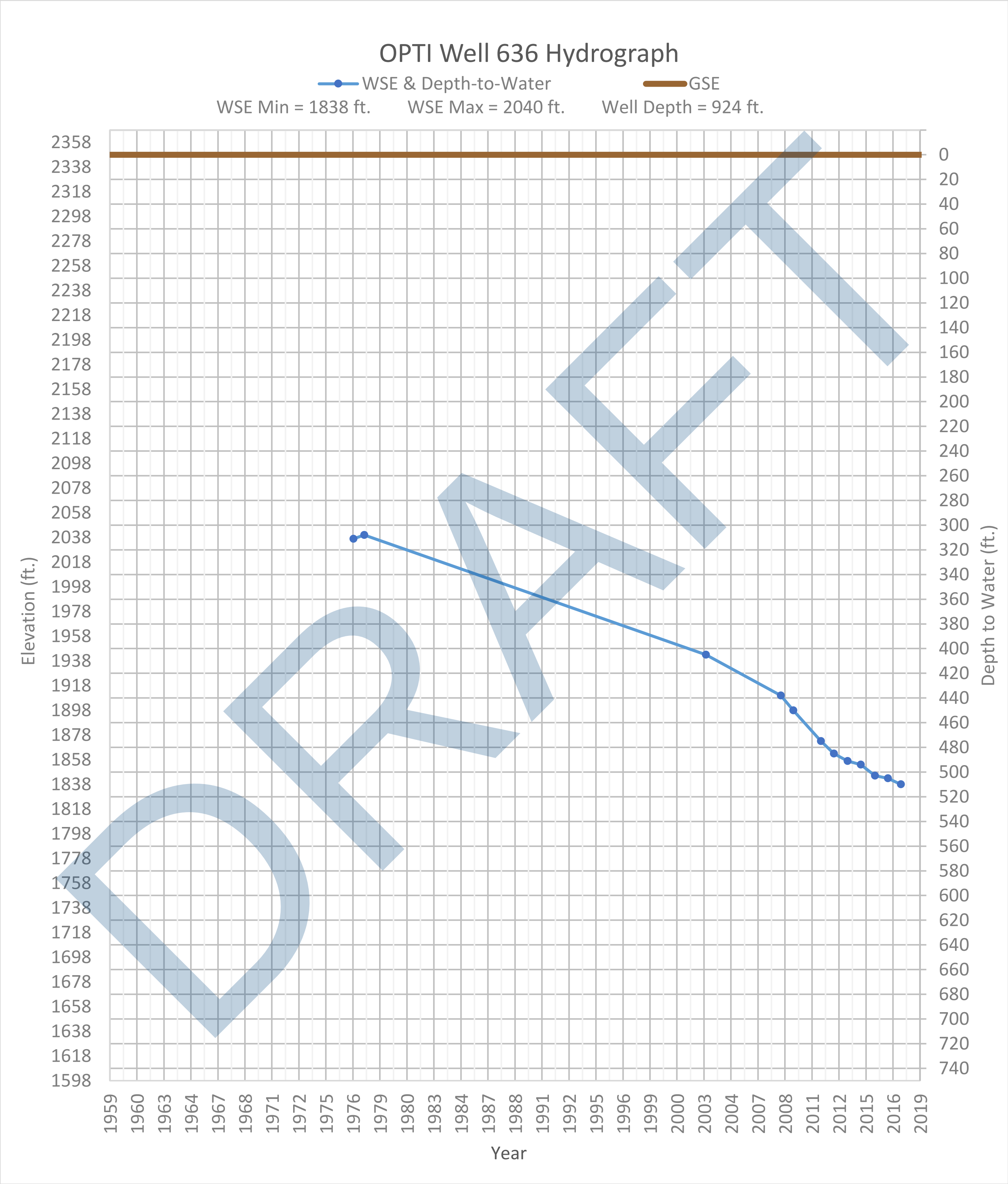
OPTI Well 633 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1813 ft.
WSE Max = 1958 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

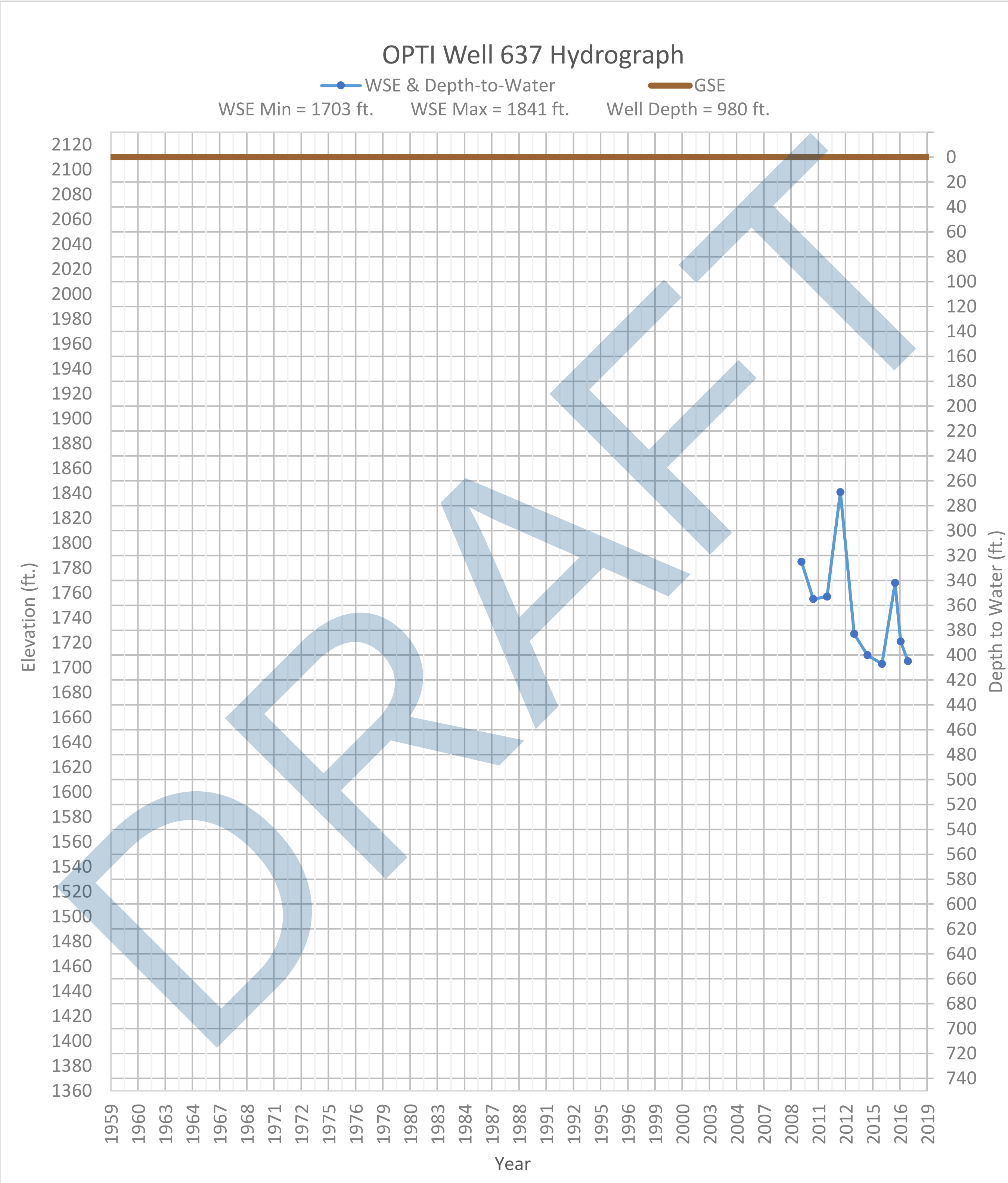


OPTI Well 634 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1873 ft.
WSE Max = 1990 ft.
Well Depth = 673 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

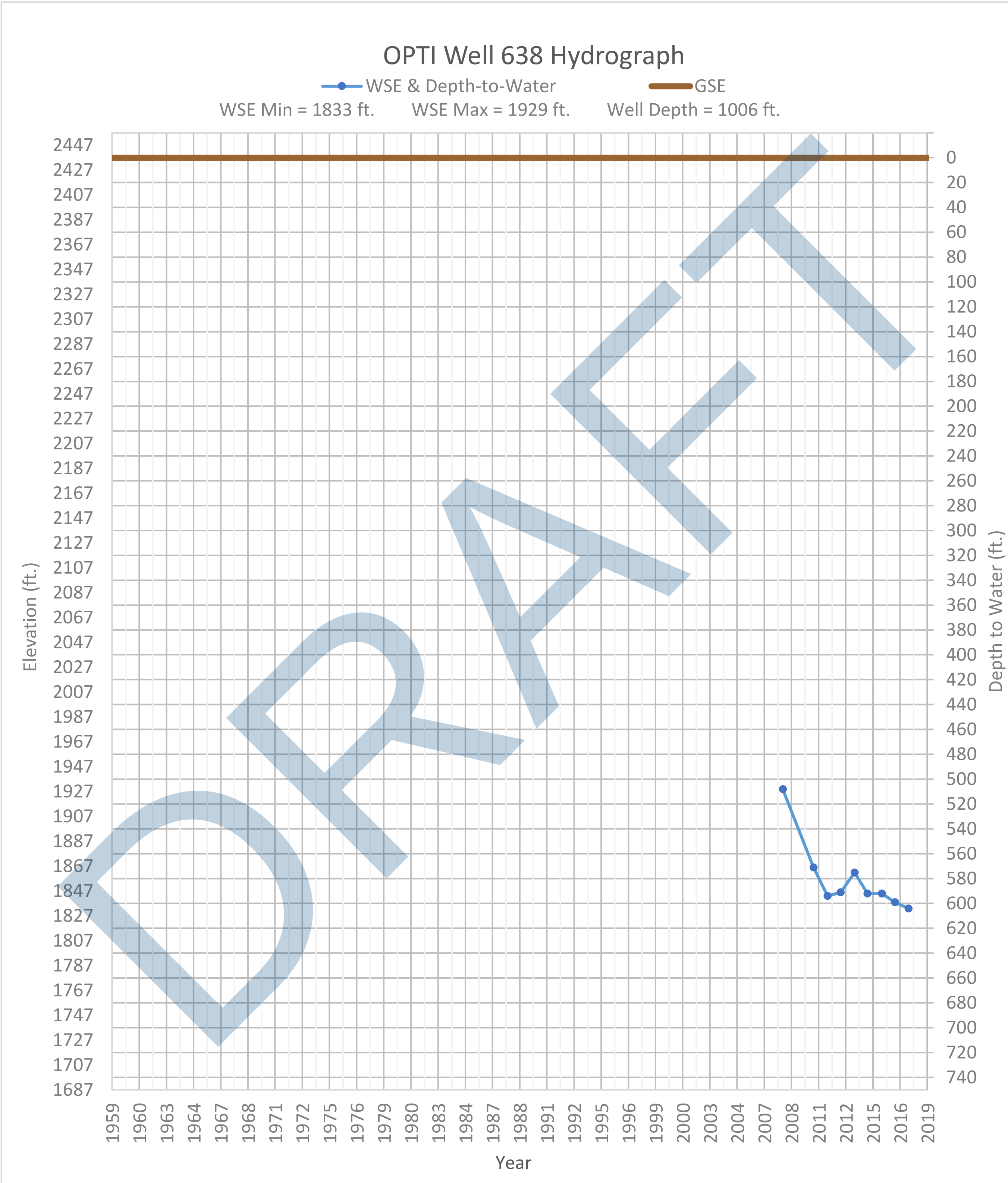


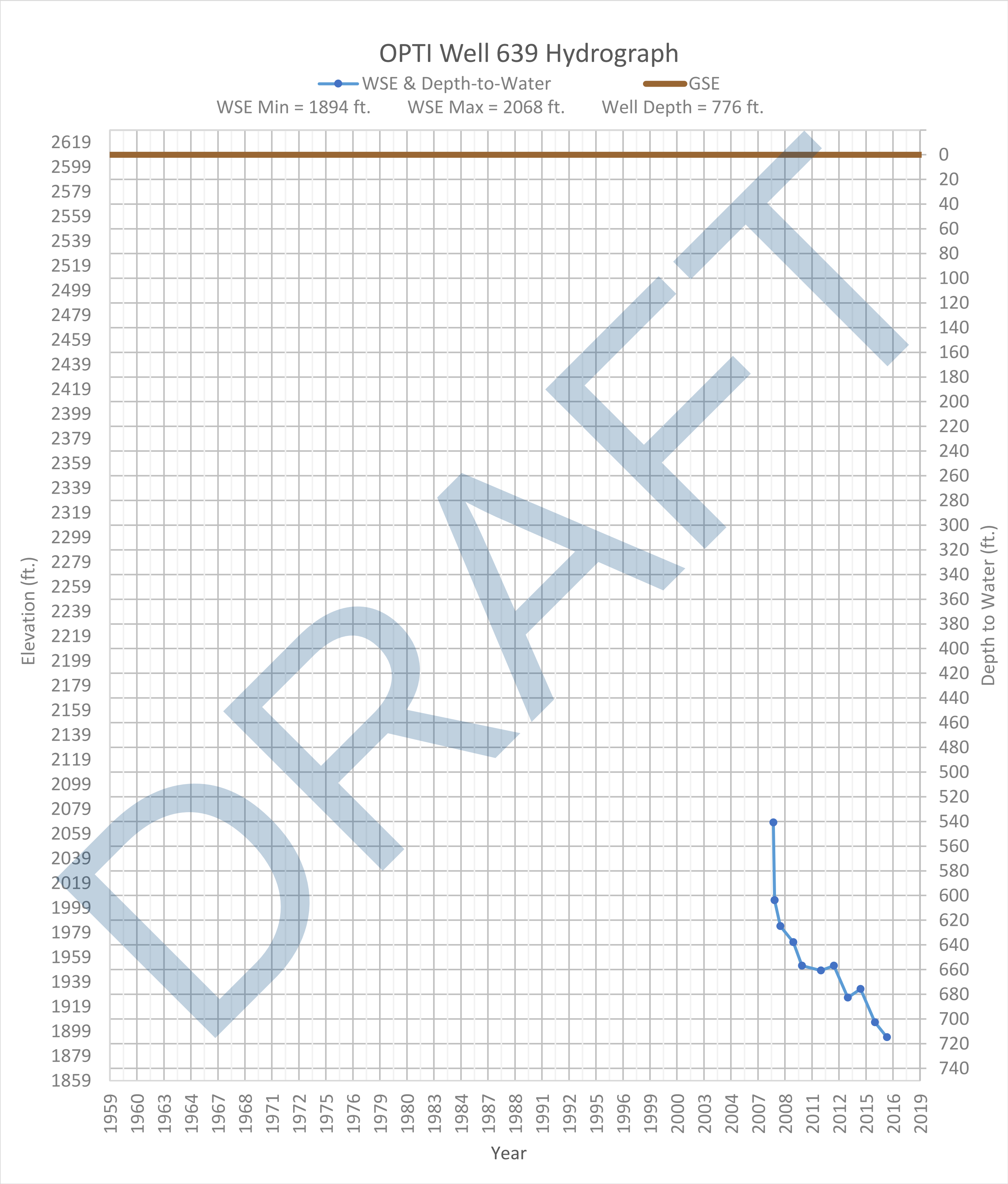
OPTI Well 635 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1841 ft.
WSE Max = 1949 ft.
Well Depth = 1050 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 636 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1838 ft.
WSE Max = 2040 ft.
Well Depth = 924 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

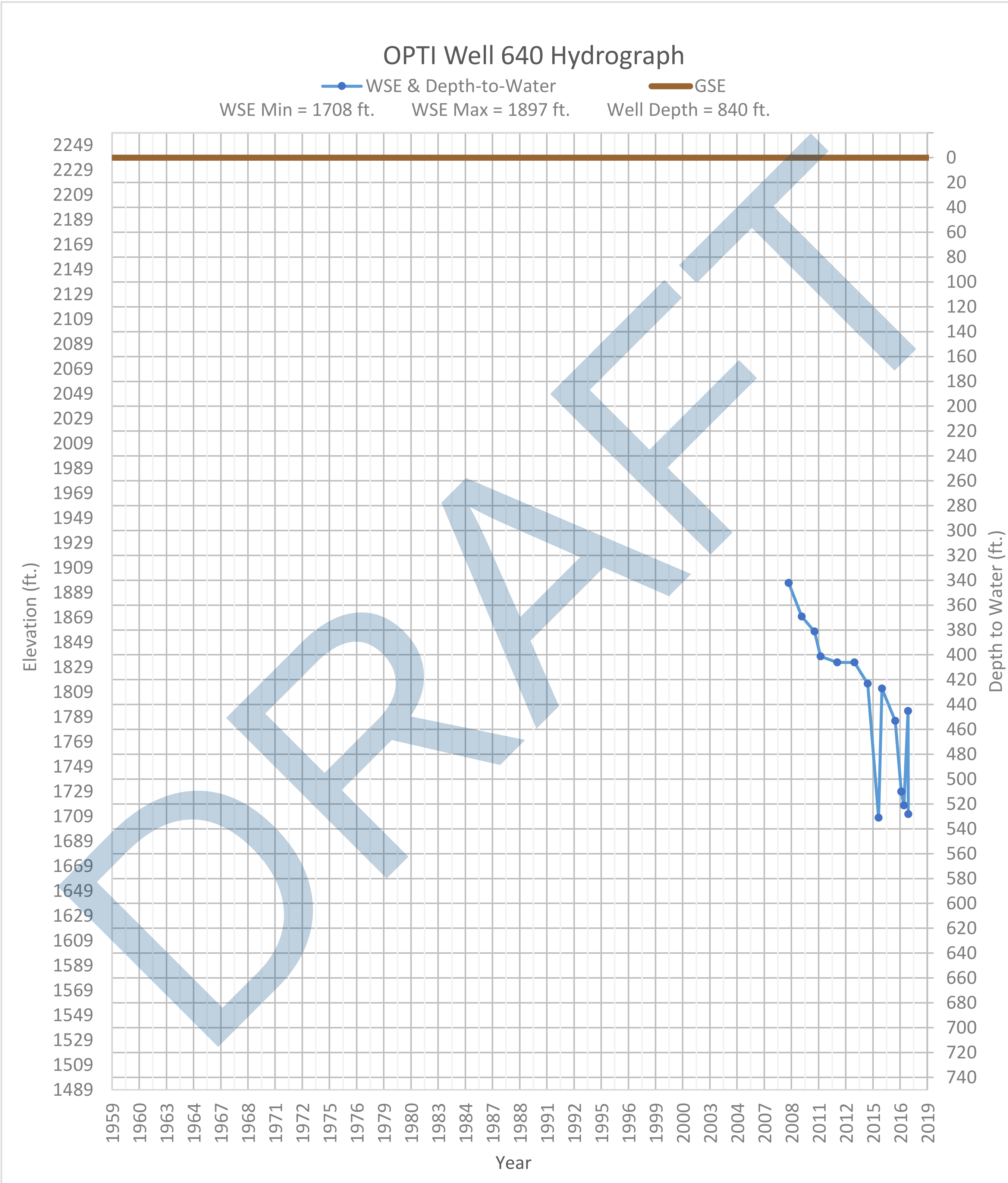


OPTI Well 637 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1703 ft.
WSE Max = 1841 ft.
Well Depth = 980 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

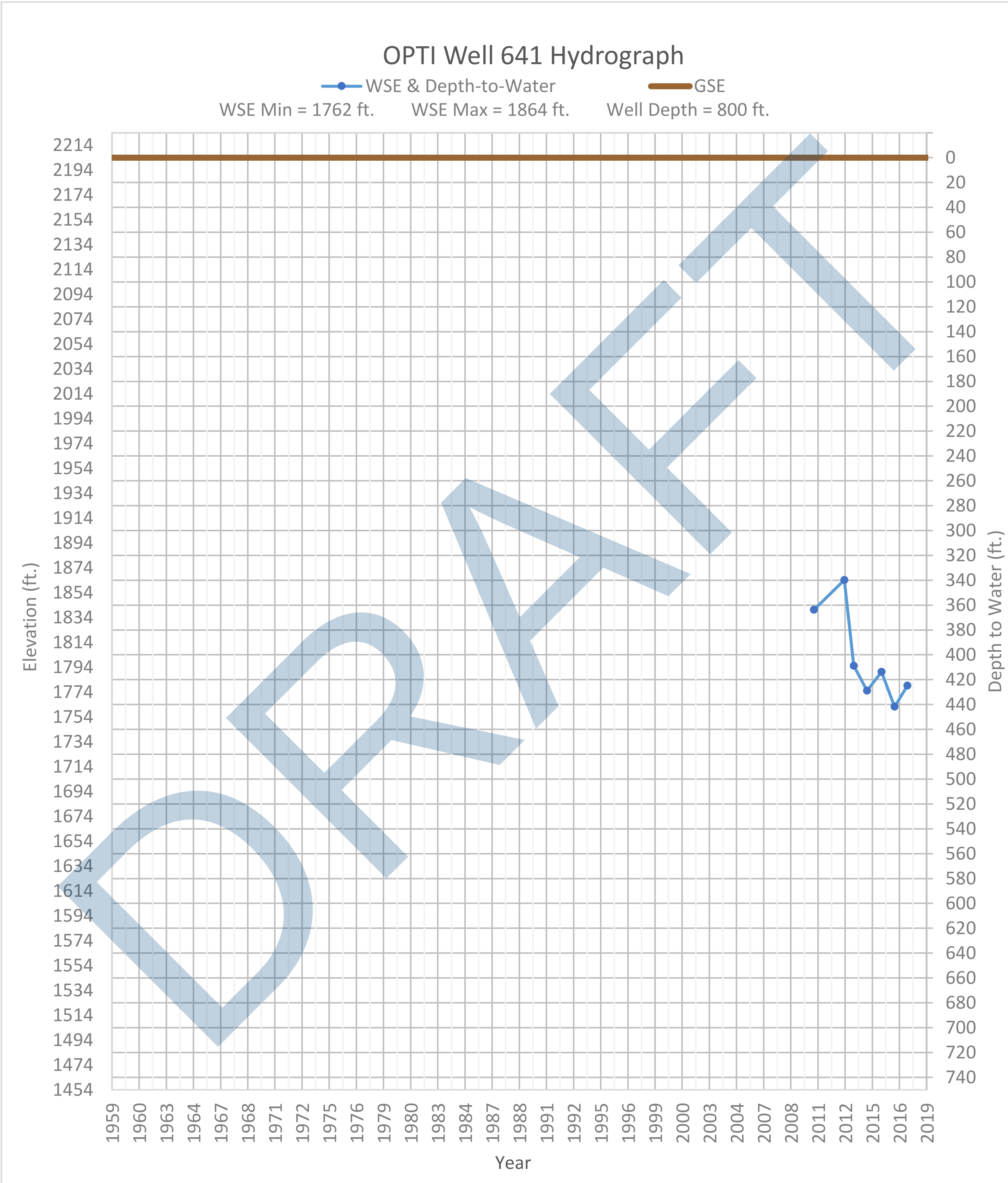

OPTI Well 638 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1833 ft.
WSE Max = 1929 ft.
Well Depth = 1006 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



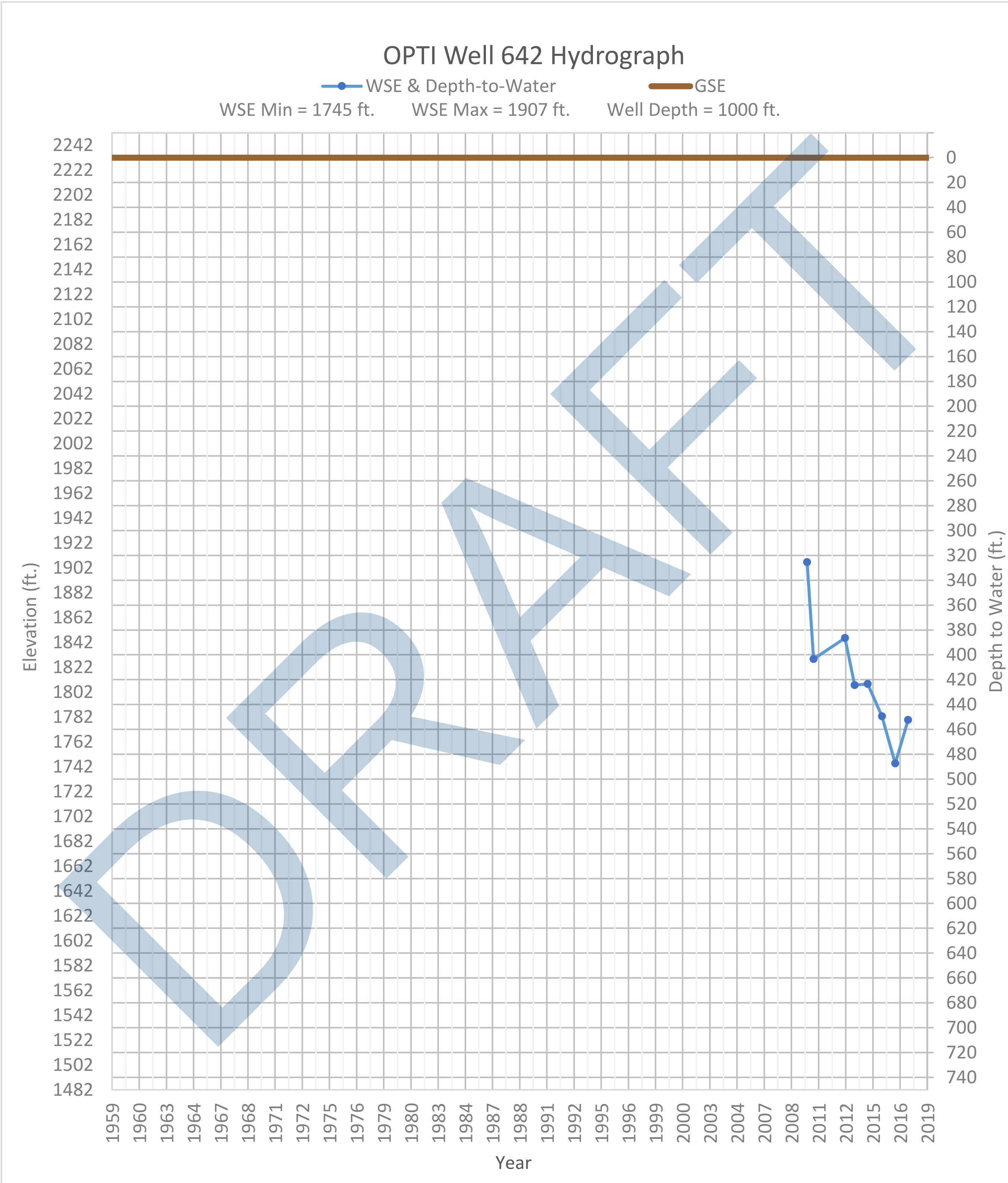
OPTI Well 639 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1894 ft.
WSE Max = 2068 ft.
Well Depth = 776 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



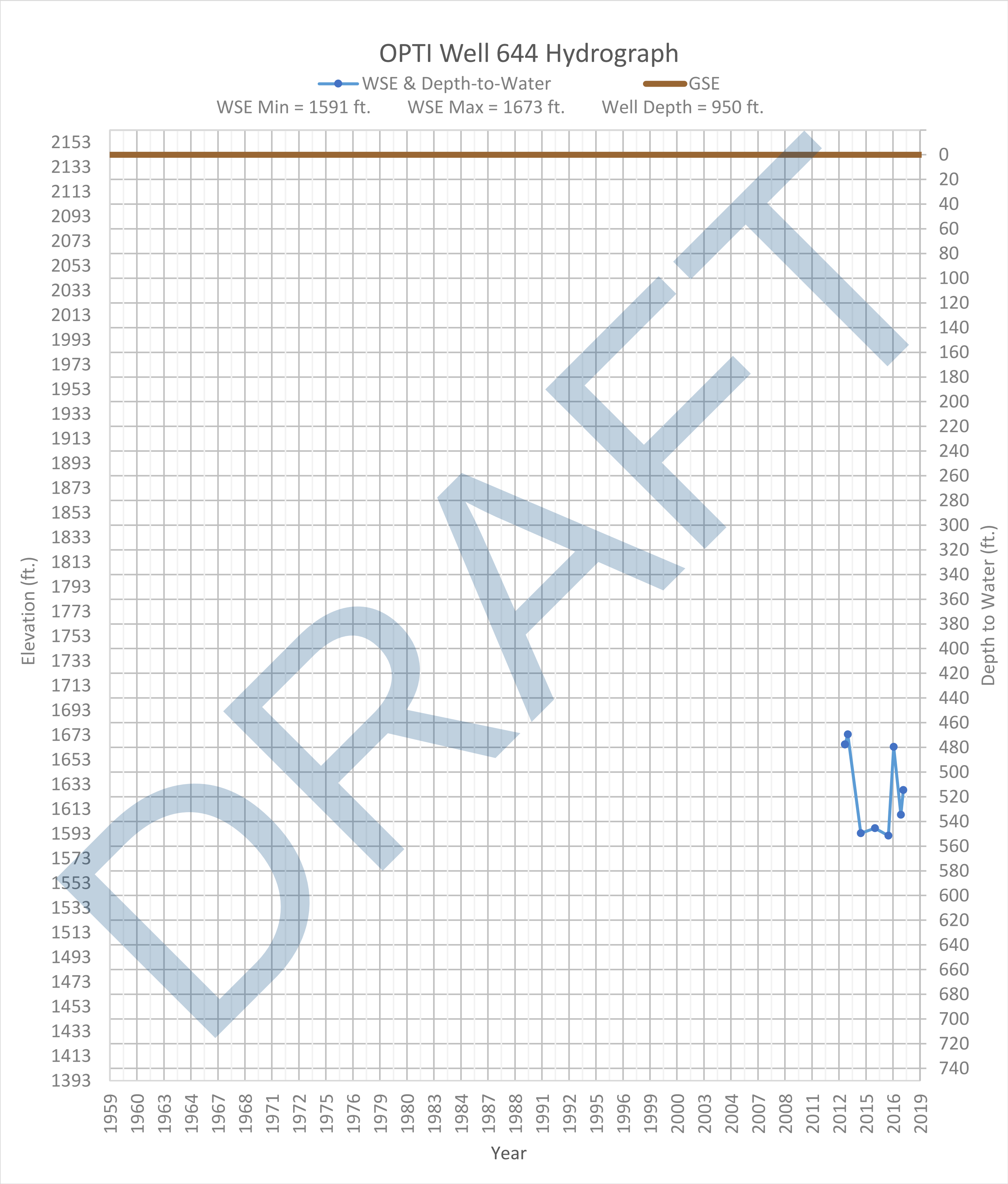
OPTI Well 640 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1708 ft.
WSE Max = 1897 ft.
Well Depth = 840 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



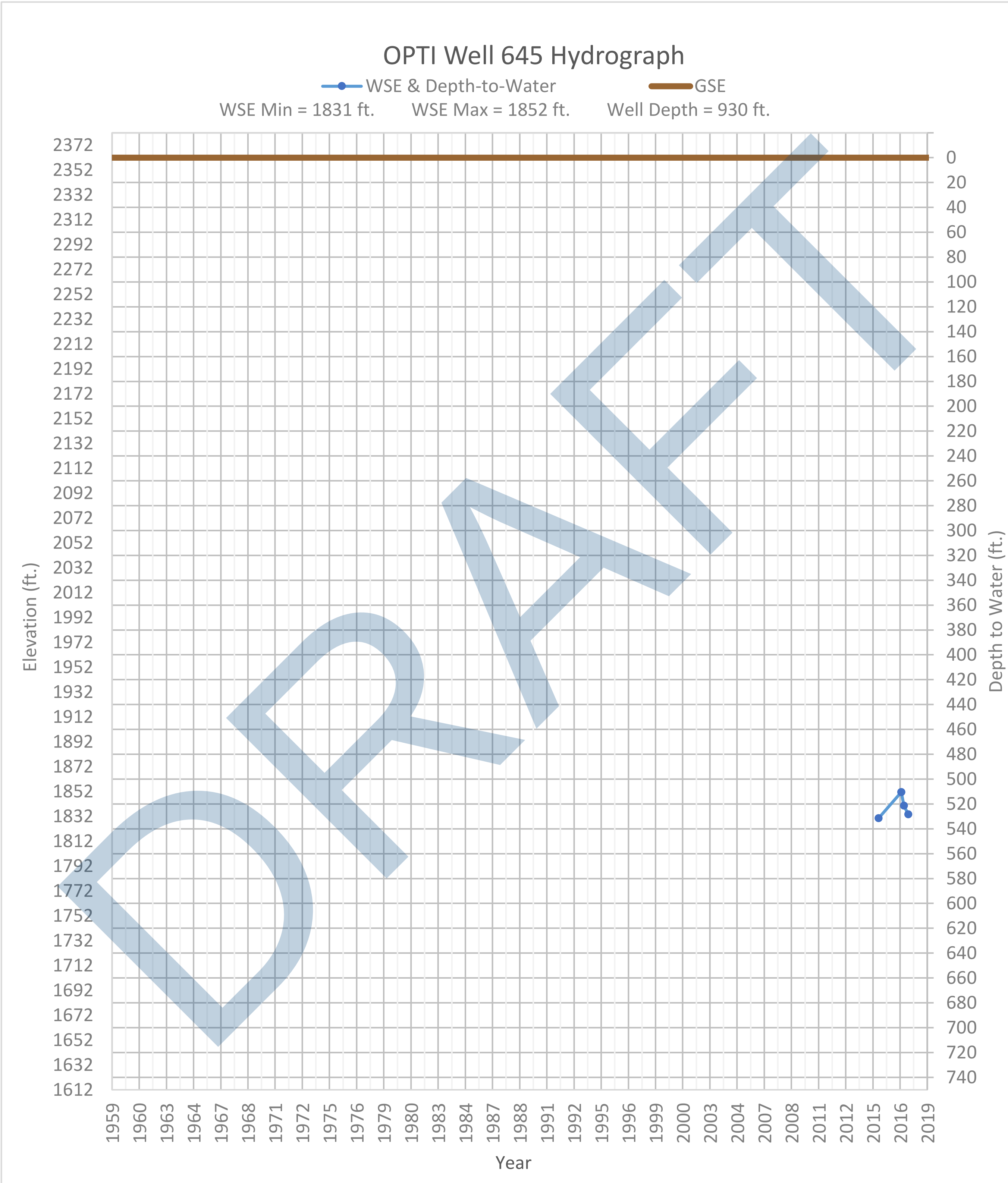
OPTI Well 641 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1762 ft.
WSE Max = 1864 ft.
Well Depth = 800 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

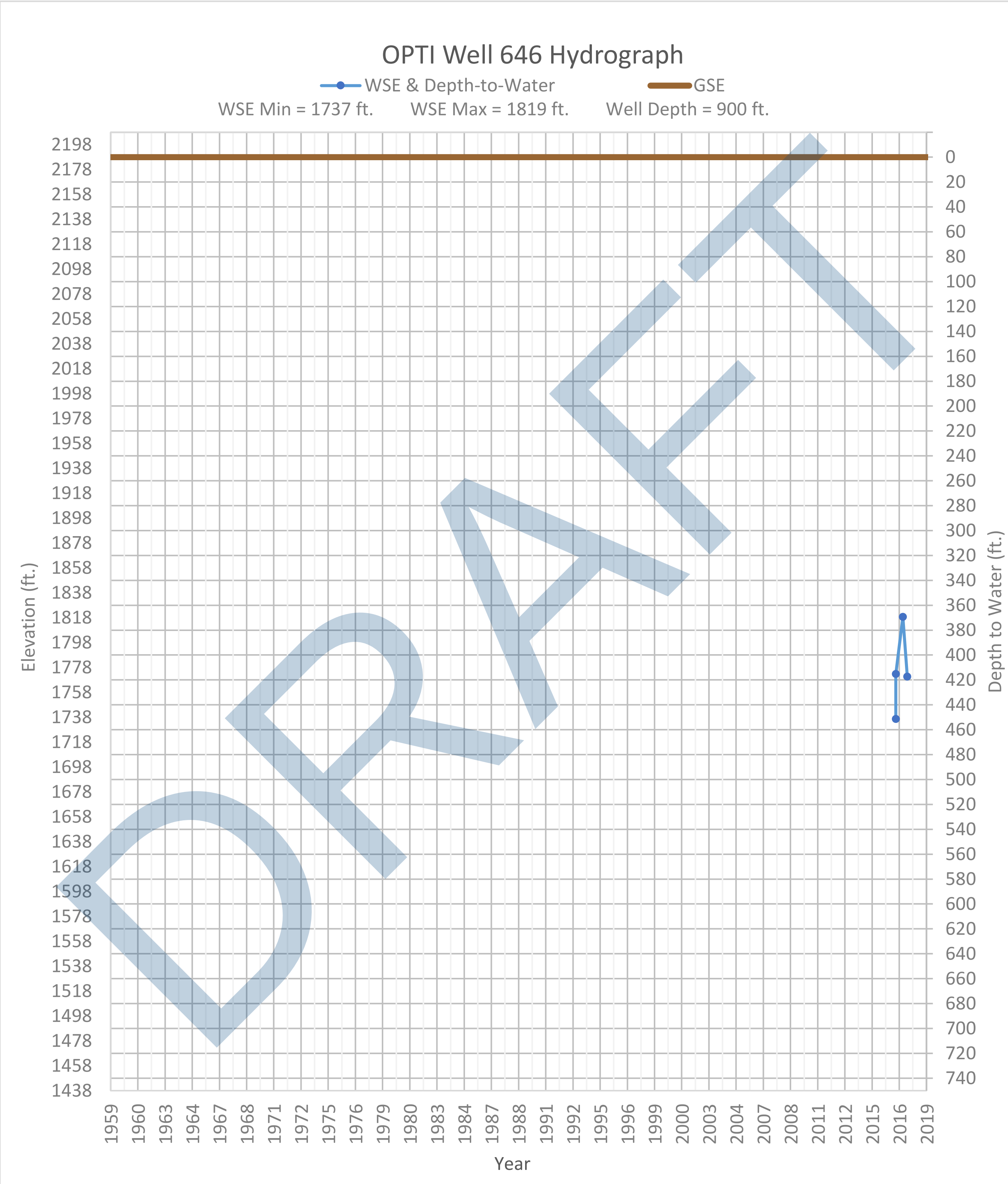


OPTI Well 642 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1745 ft.
WSE Max = 1907 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

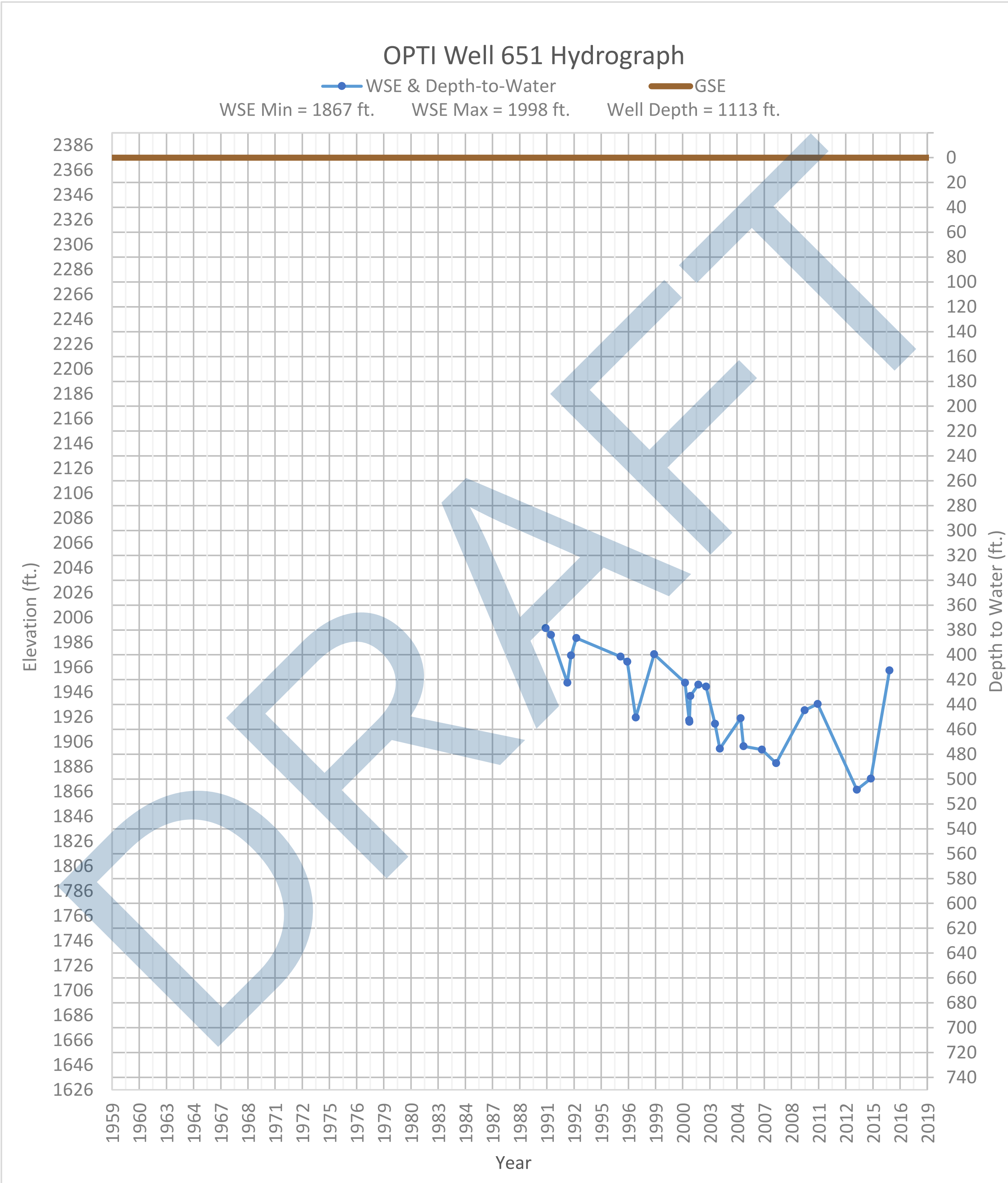


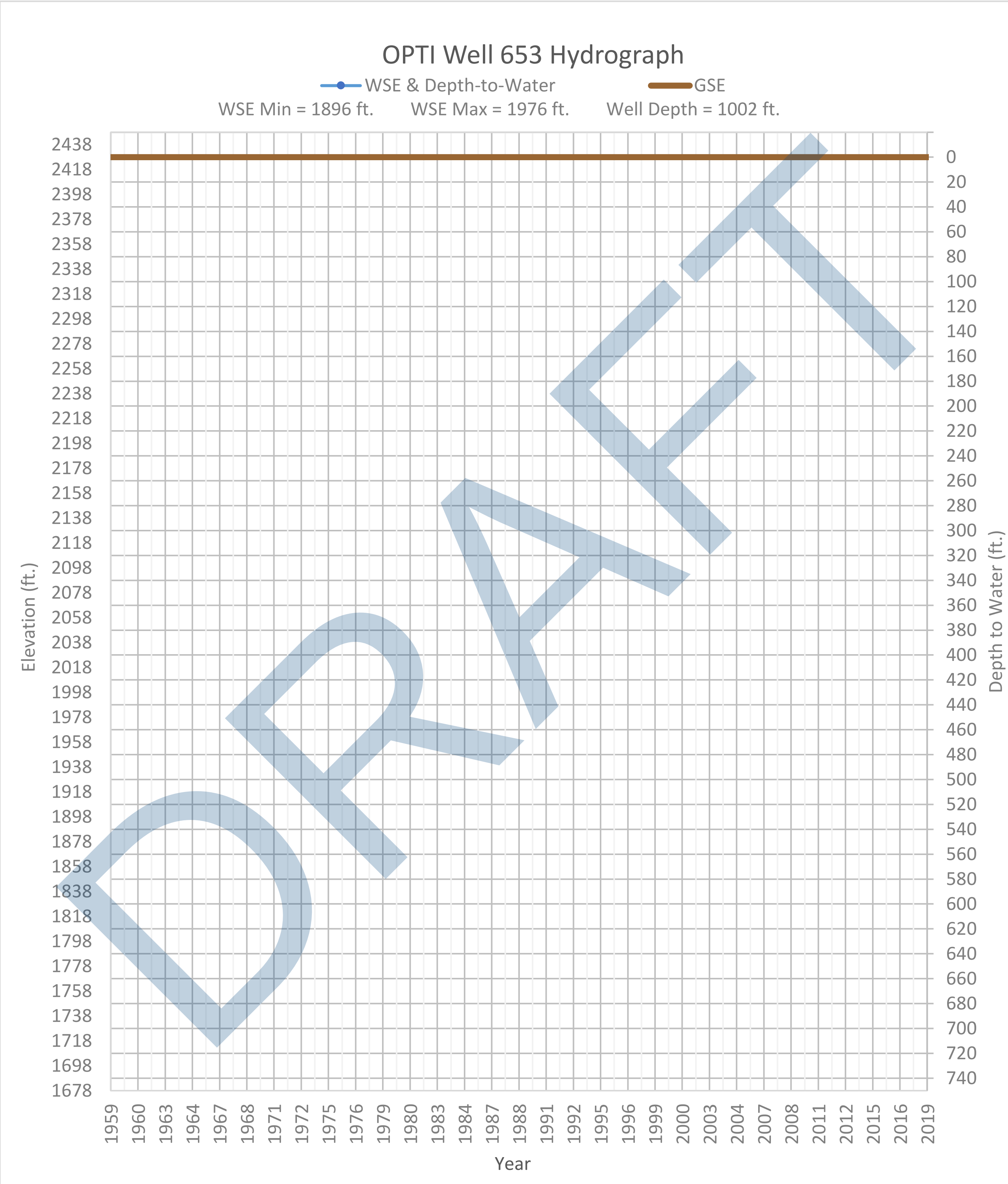
OPTI Well 644 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1591 ft.
WSE Max = 1673 ft.
Well Depth = 950 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 645 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1831 ft.
WSE Max = 1852 ft.
Well Depth = 930 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

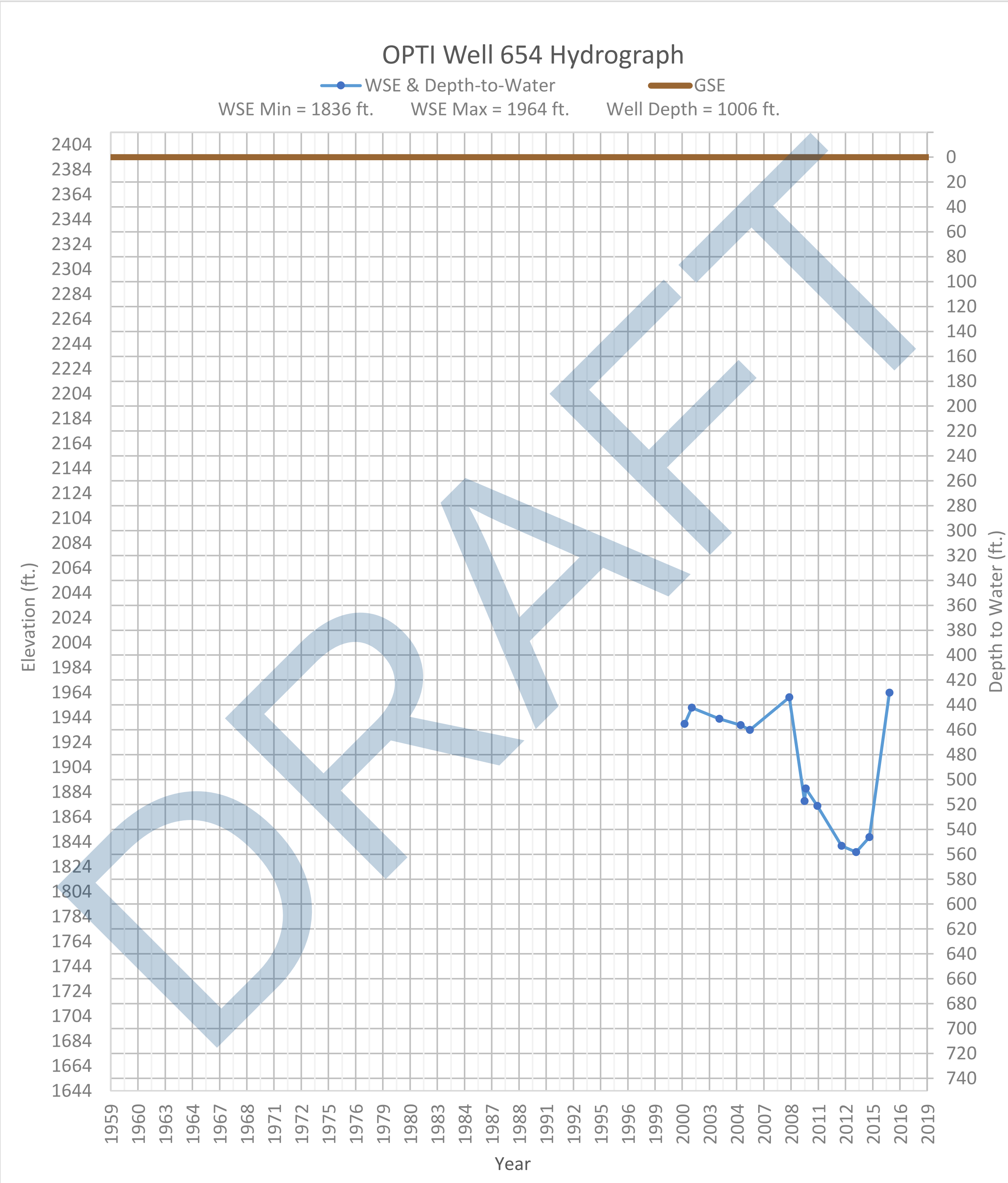


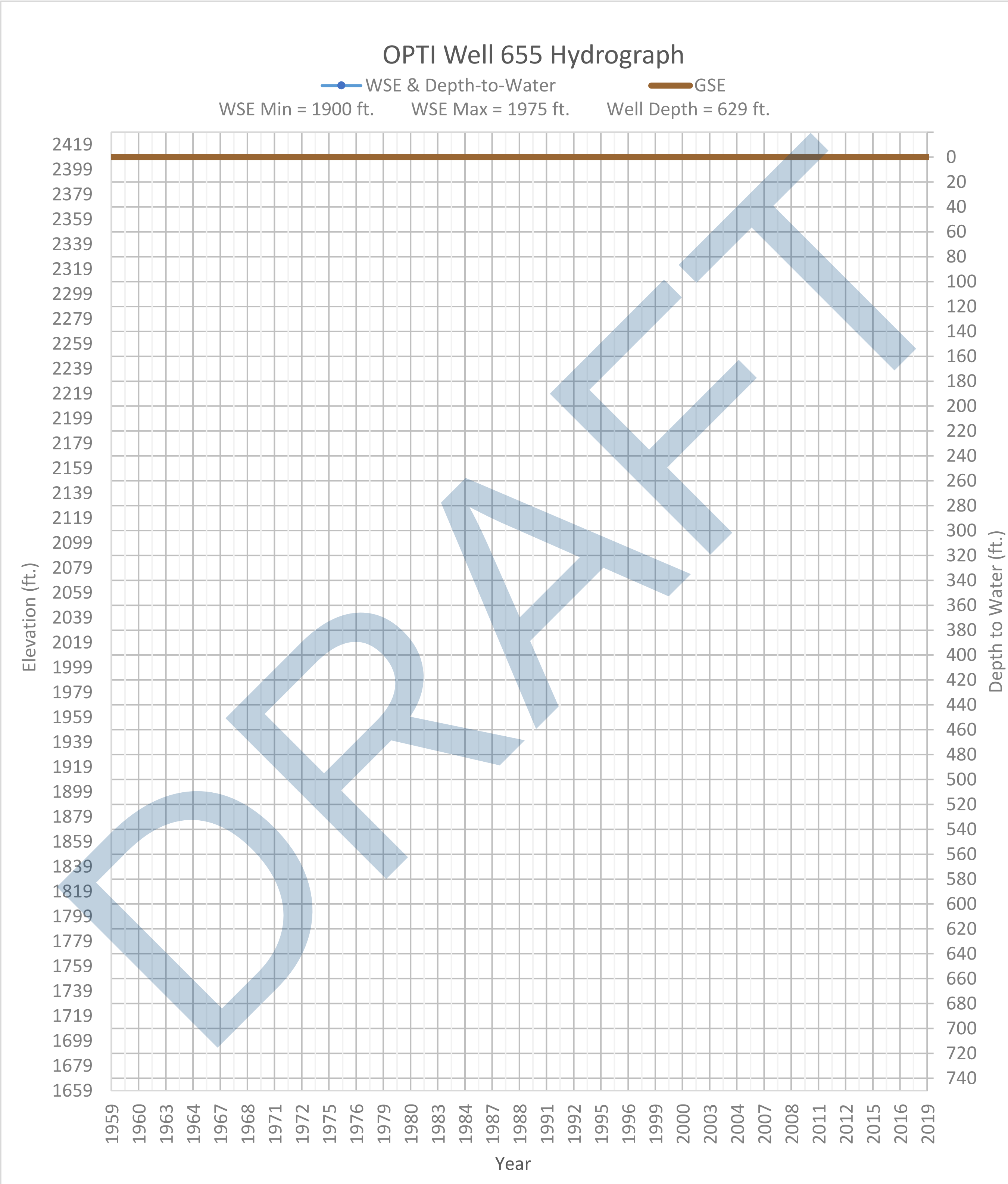
OPTI Well 646 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1737 ft.
WSE Max = 1819 ft.
Well Depth = 900 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 651 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1867 ft.
WSE Max = 1998 ft.
Well Depth = 1113 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

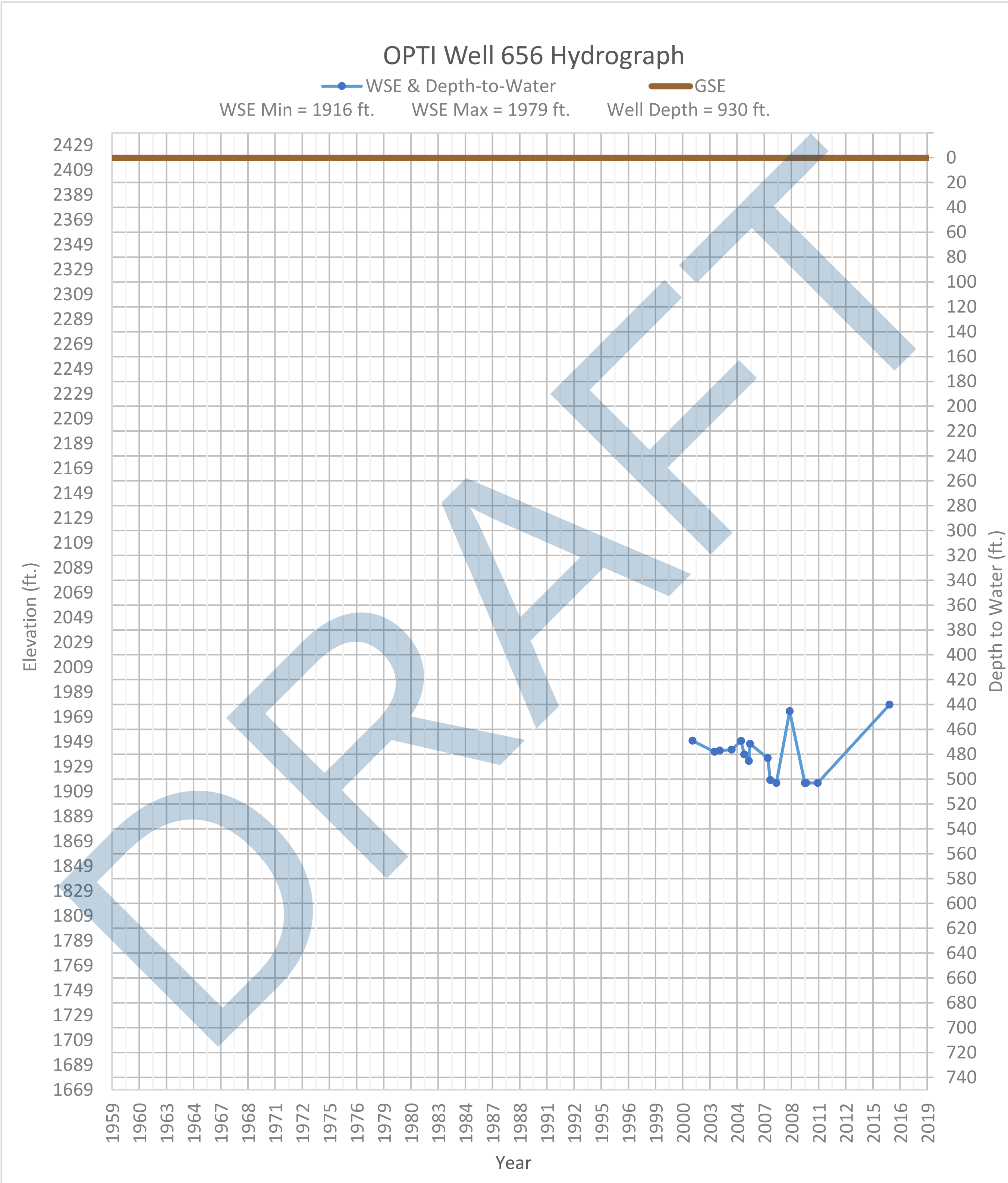


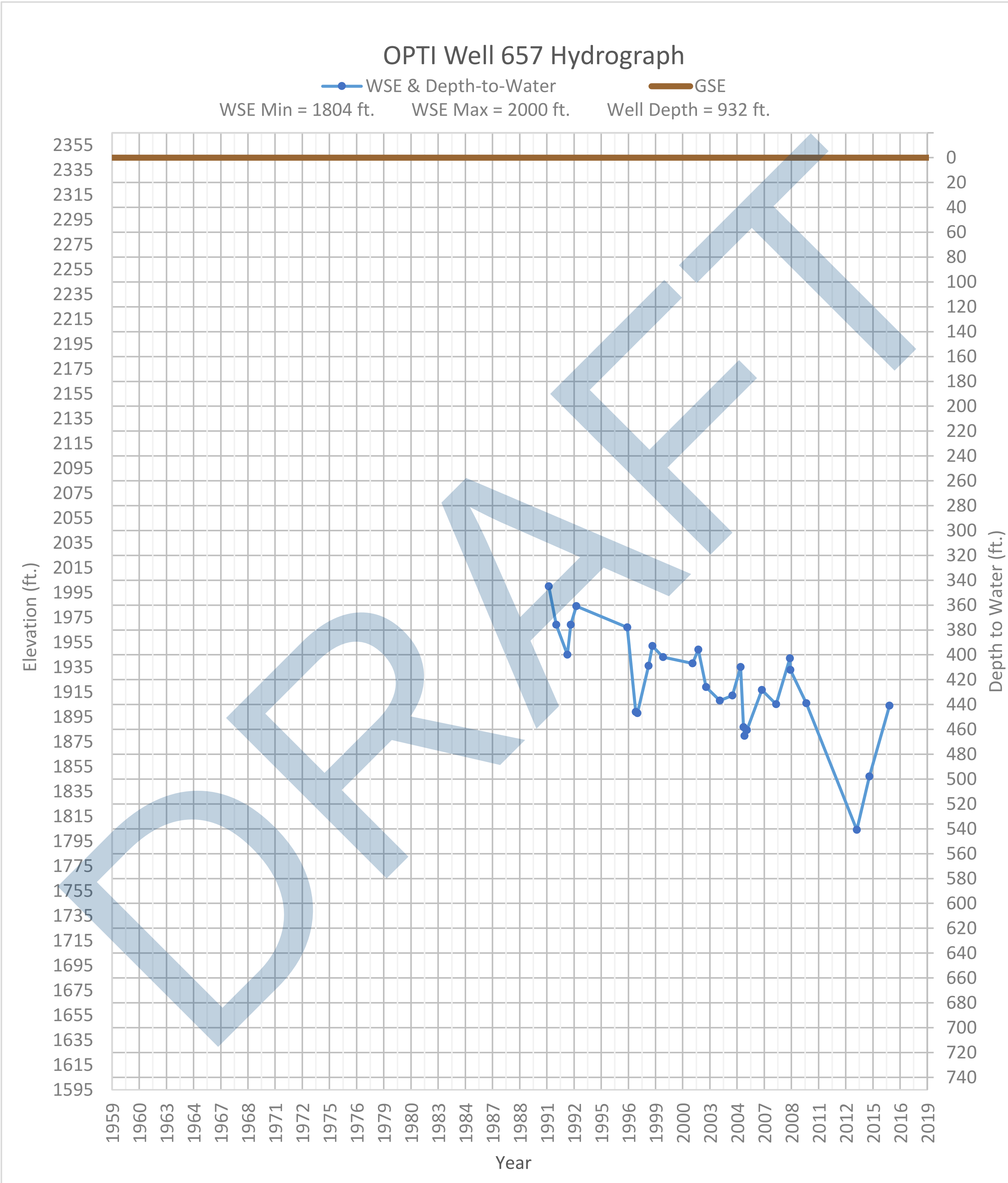
OPTI Well 653 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1896 ft.
WSE Max = 1976 ft.
Well Depth = 1002 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 654 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1836 ft.
WSE Max = 1964 ft.
Well Depth = 1006 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

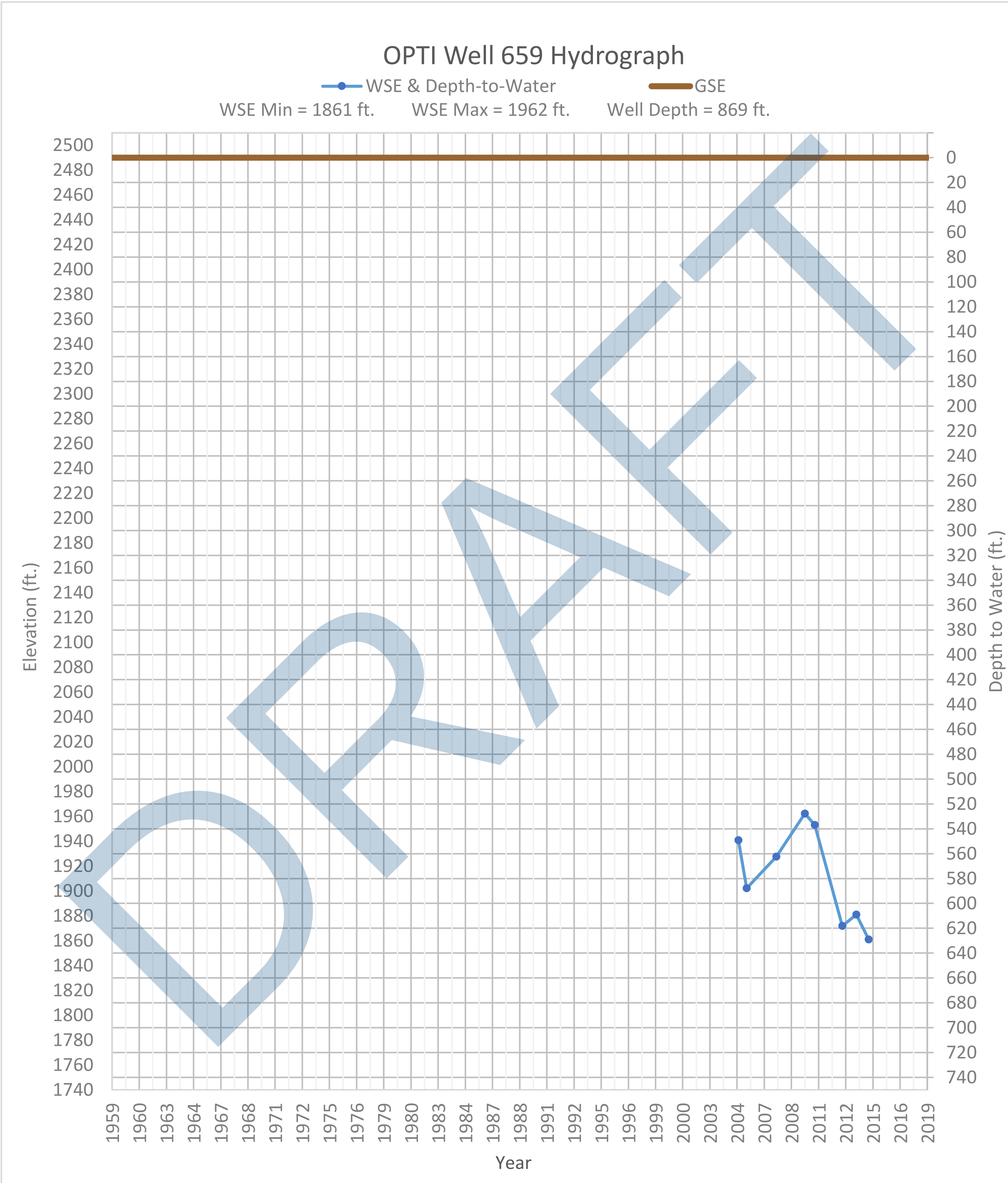


OPTI Well 655 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1900 ft.
WSE Max = 1975 ft.
Well Depth = 629 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

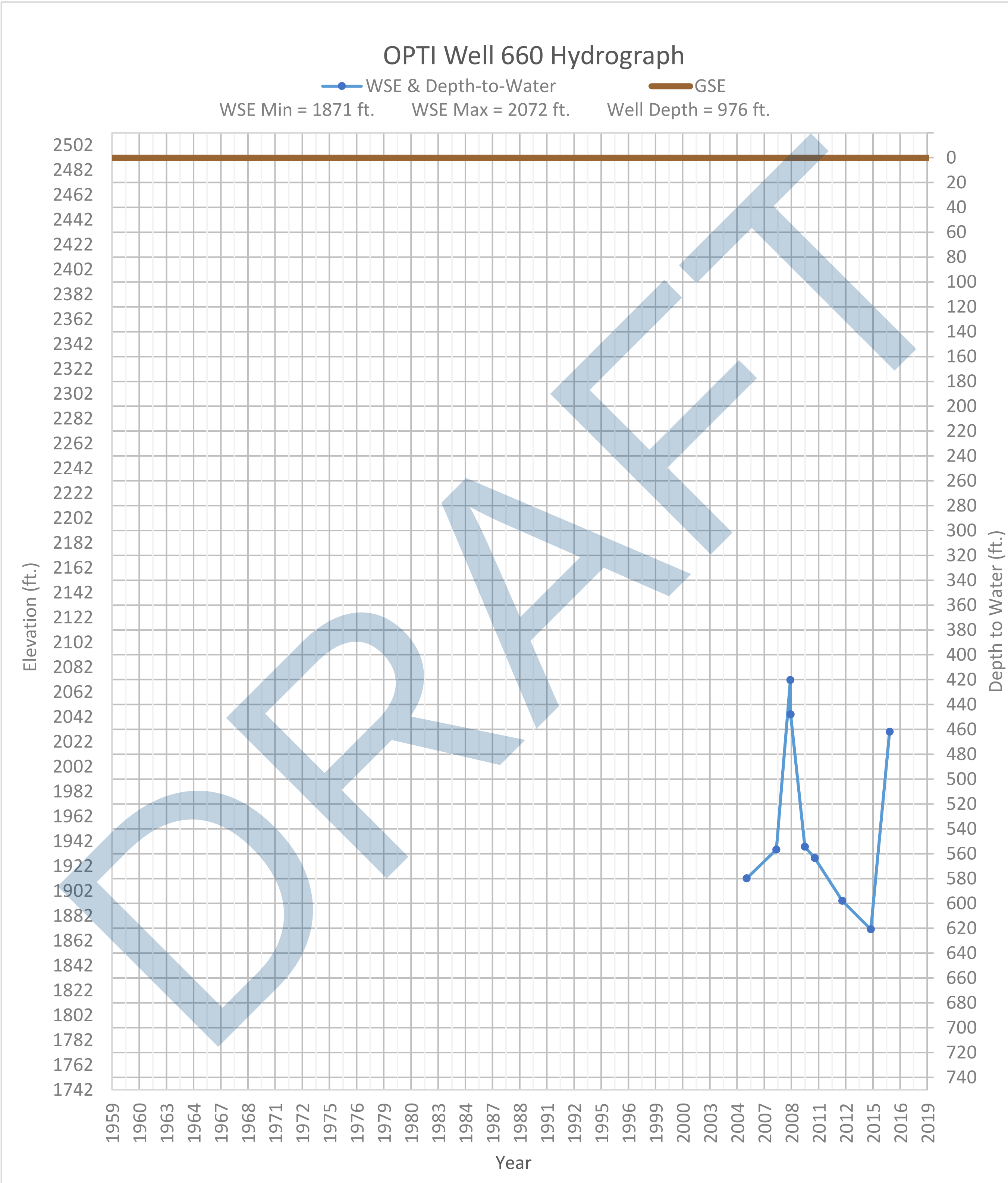

OPTI Well 656 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1916 ft.
WSE Max = 1979 ft.
Well Depth = 930 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



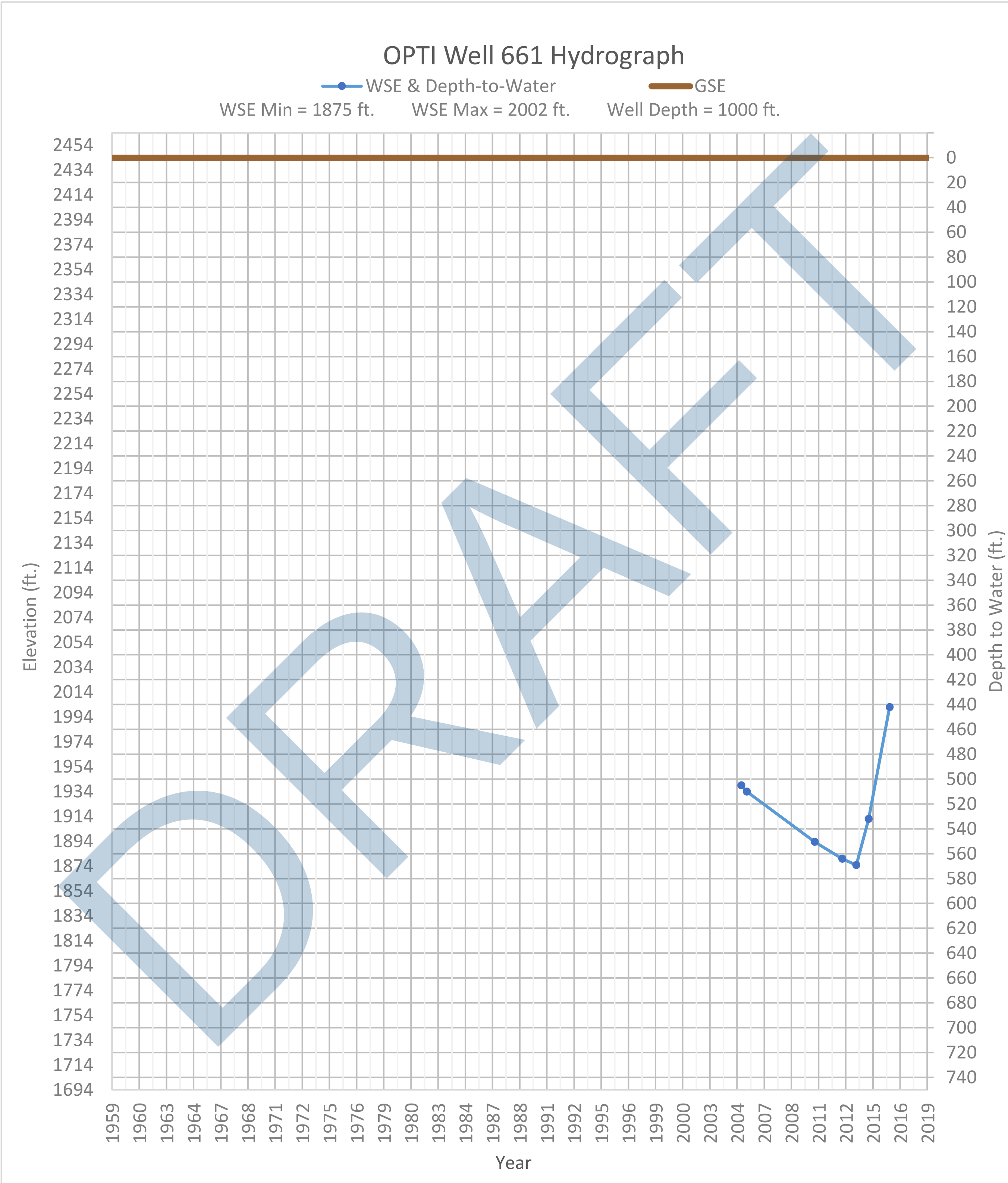
OPTI Well 657 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1804 ft.
WSE Max = 2000 ft.
Well Depth = 932 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



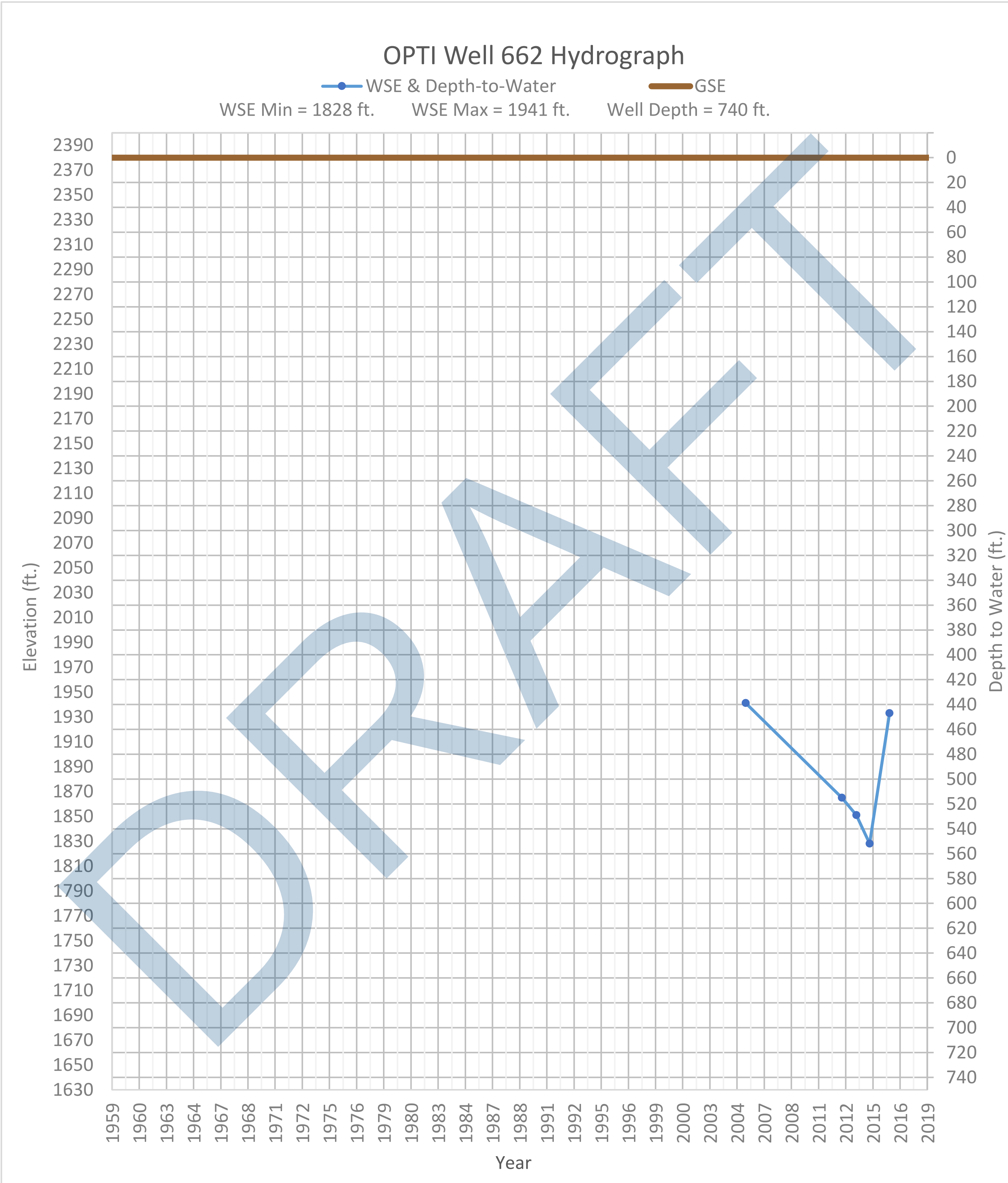
OPTI Well 659 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1861 ft.
WSE Max = 1962 ft.
Well Depth = 869 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



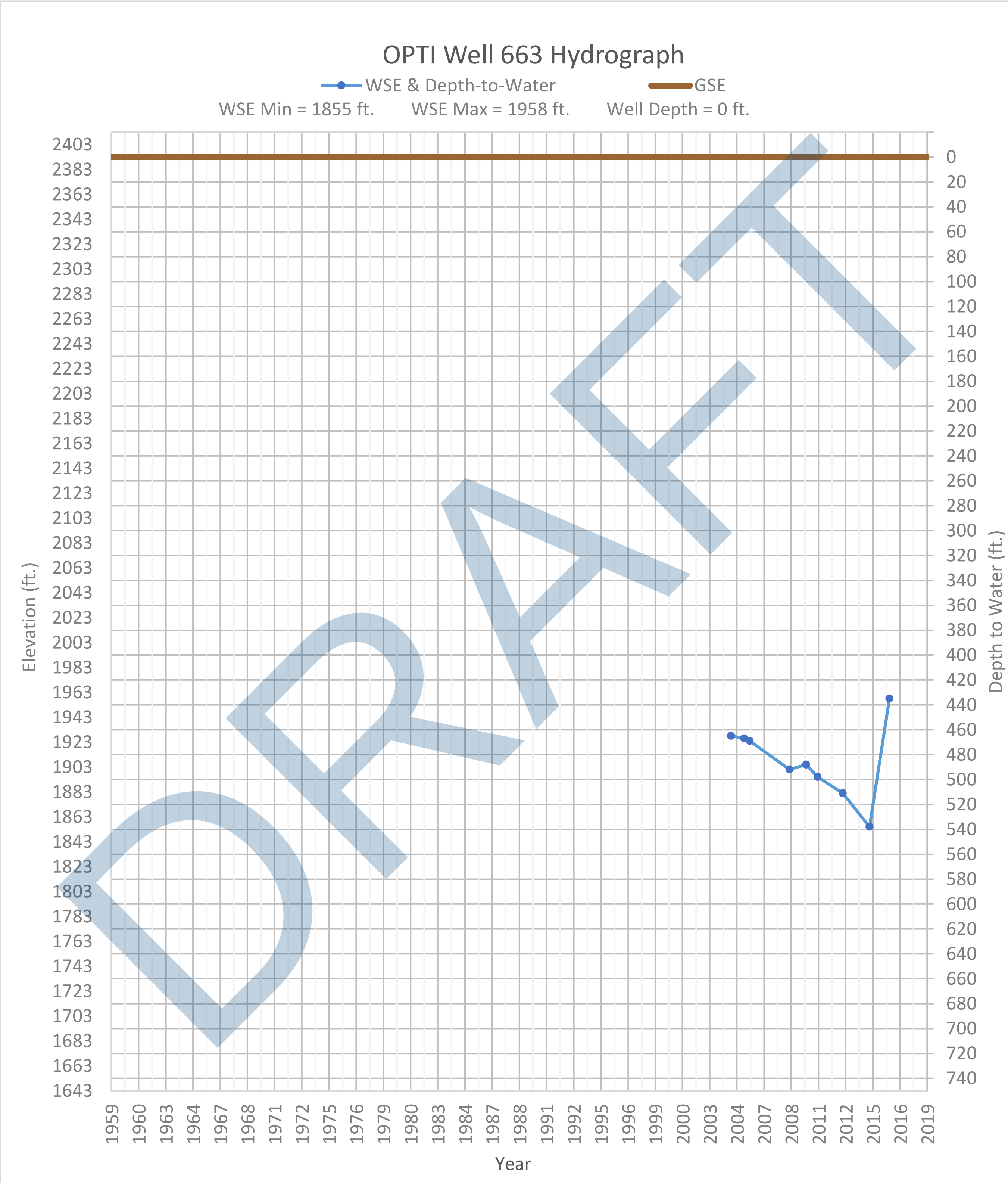
OPTI Well 660 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1871 ft.
WSE Max = 2072 ft.
Well Depth = 976 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

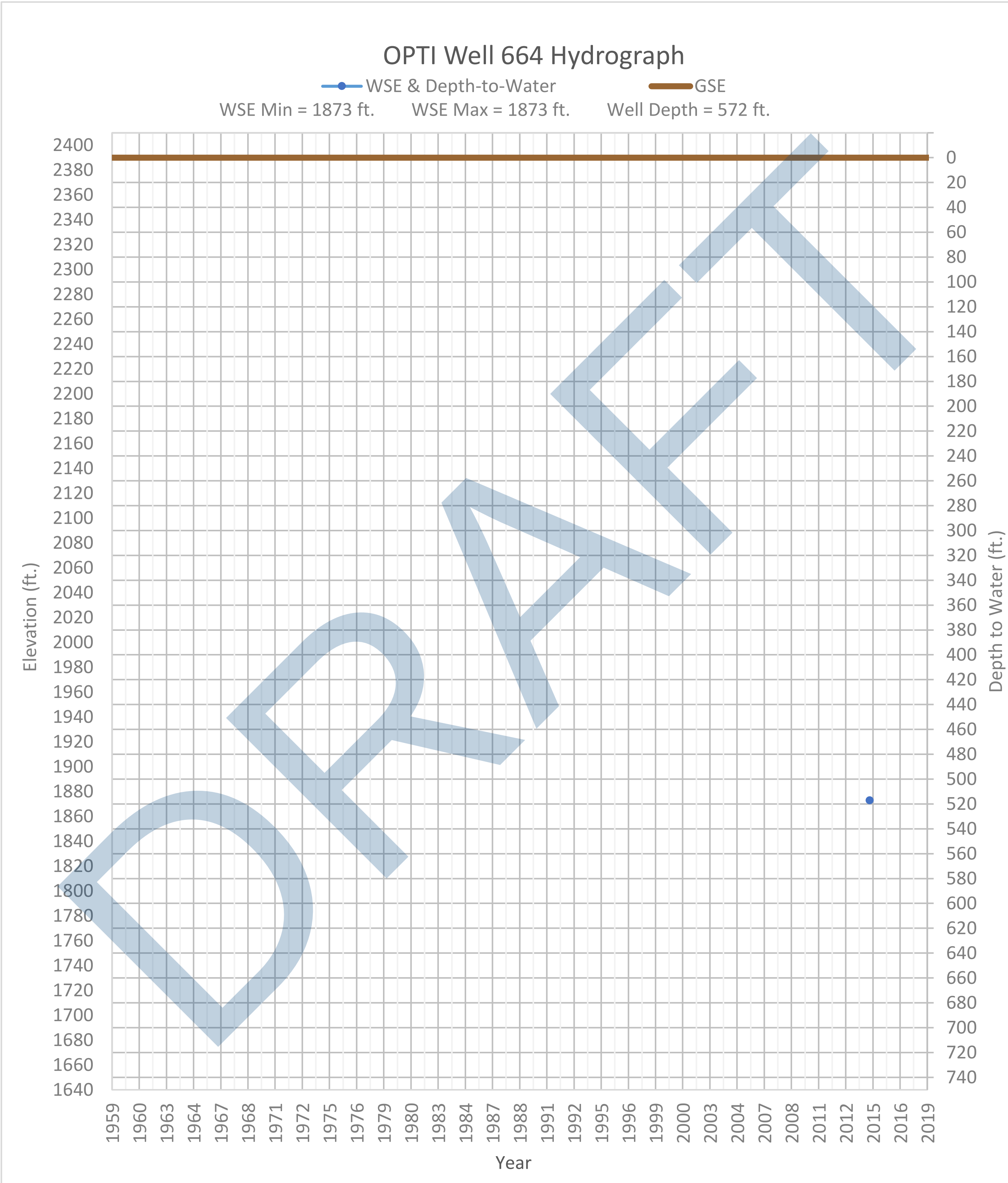


OPTI Well 661 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1875 ft.
WSE Max = 2002 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

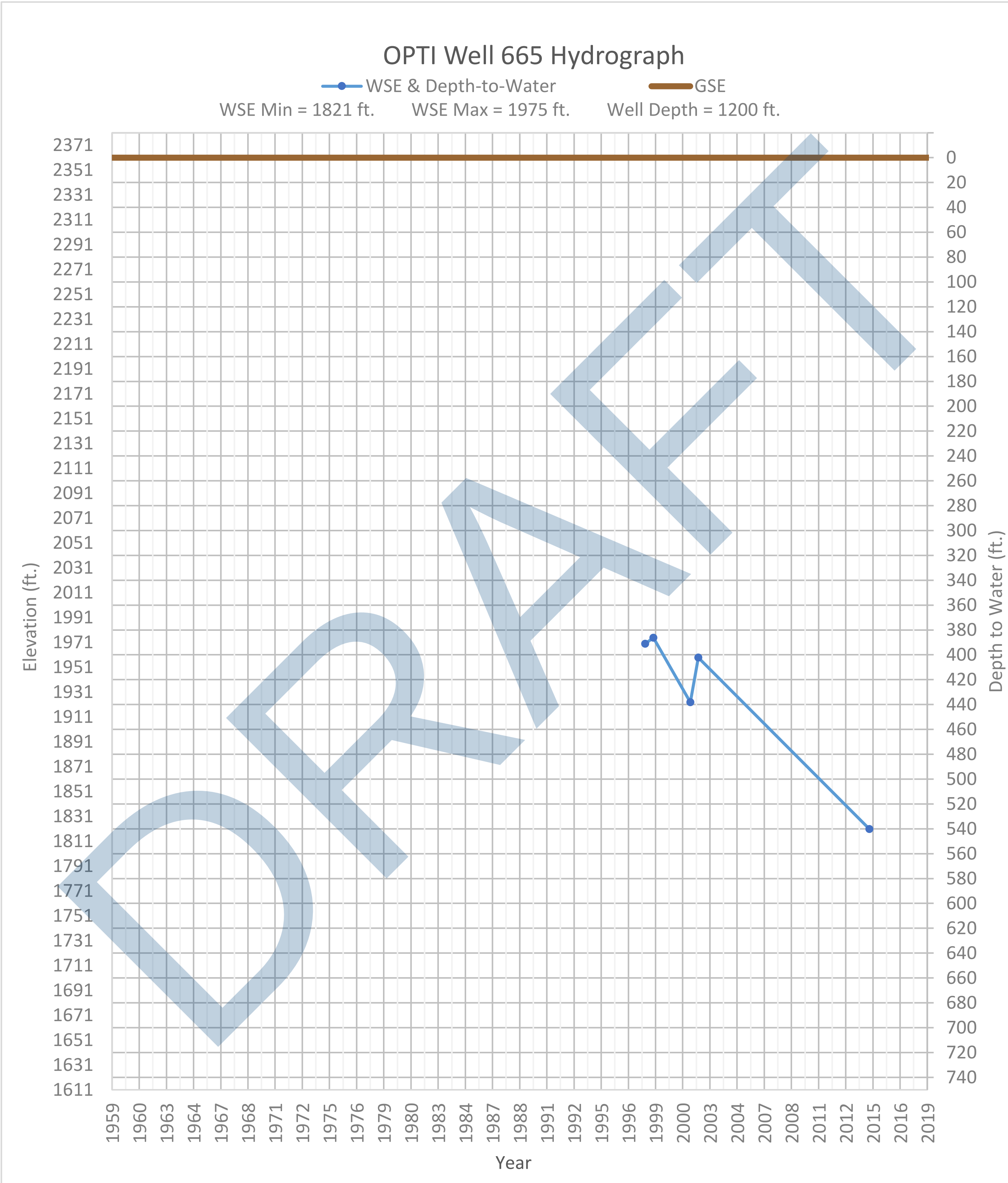


OPTI Well 662 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1828 ft.
WSE Max = 1941 ft.
Well Depth = 740 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 663 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1855 ft.
WSE Max = 1958 ft.
Well Depth = 0 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 664 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1873 ft.
WSE Max = 1873 ft.
Well Depth = 572 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 665 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1821 ft.
WSE Max = 1975 ft.
Well Depth = 1200 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2371
2351
2331
2311
2291
2271
2251
2231
2211
2191
2171
2151
2131
2111
2091
2071
2051
2031
2011
1991
1971
1951
1931
1911
1891
1871
1851
1831
1811
1791
1771
1751
1731
1711
1691
1671
1651
1631
1611
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500
520
540
560
580
600
620
640
660
680
700
720
740
1959
1960
1963
1964
1967
1968
1971
1972
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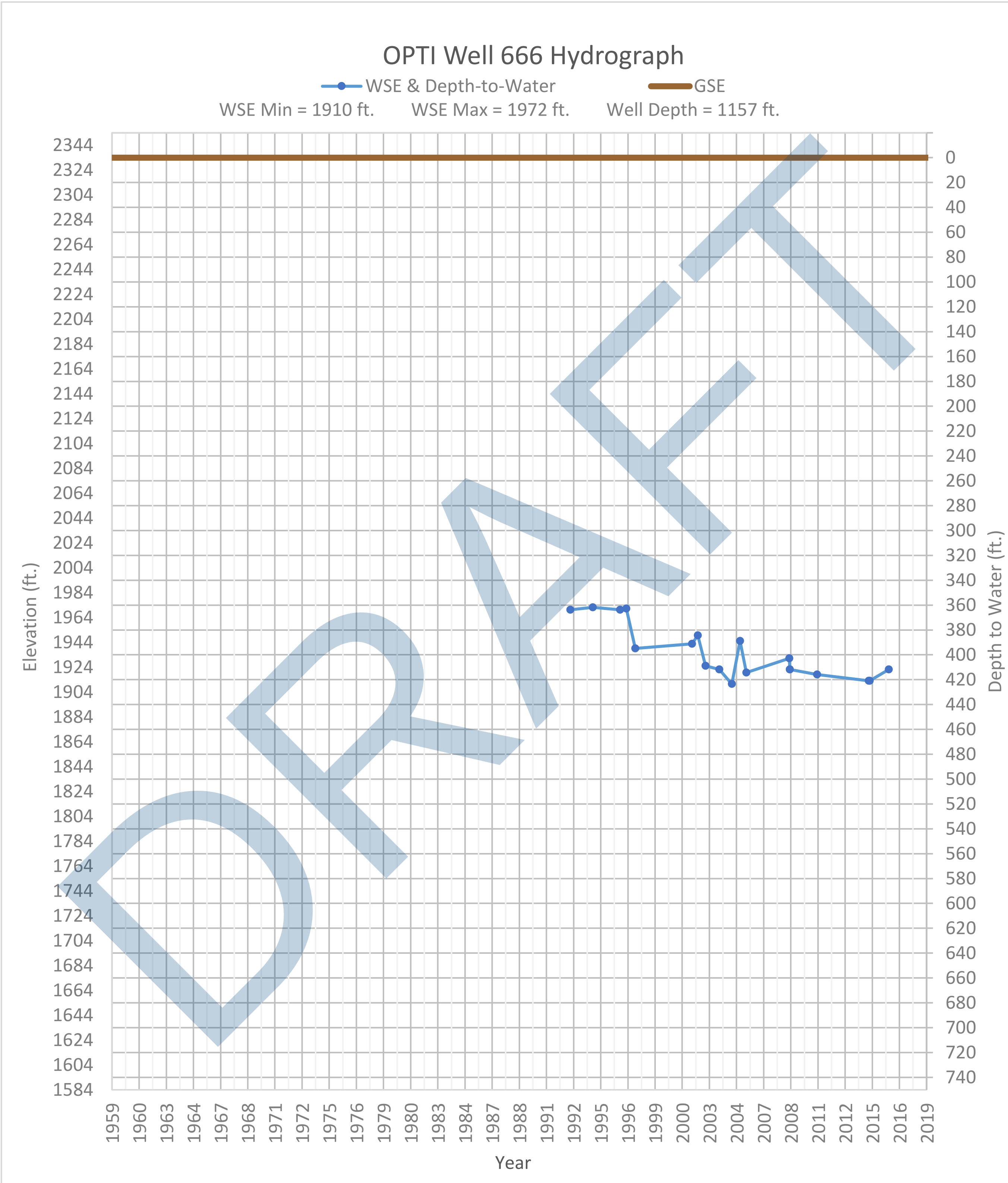
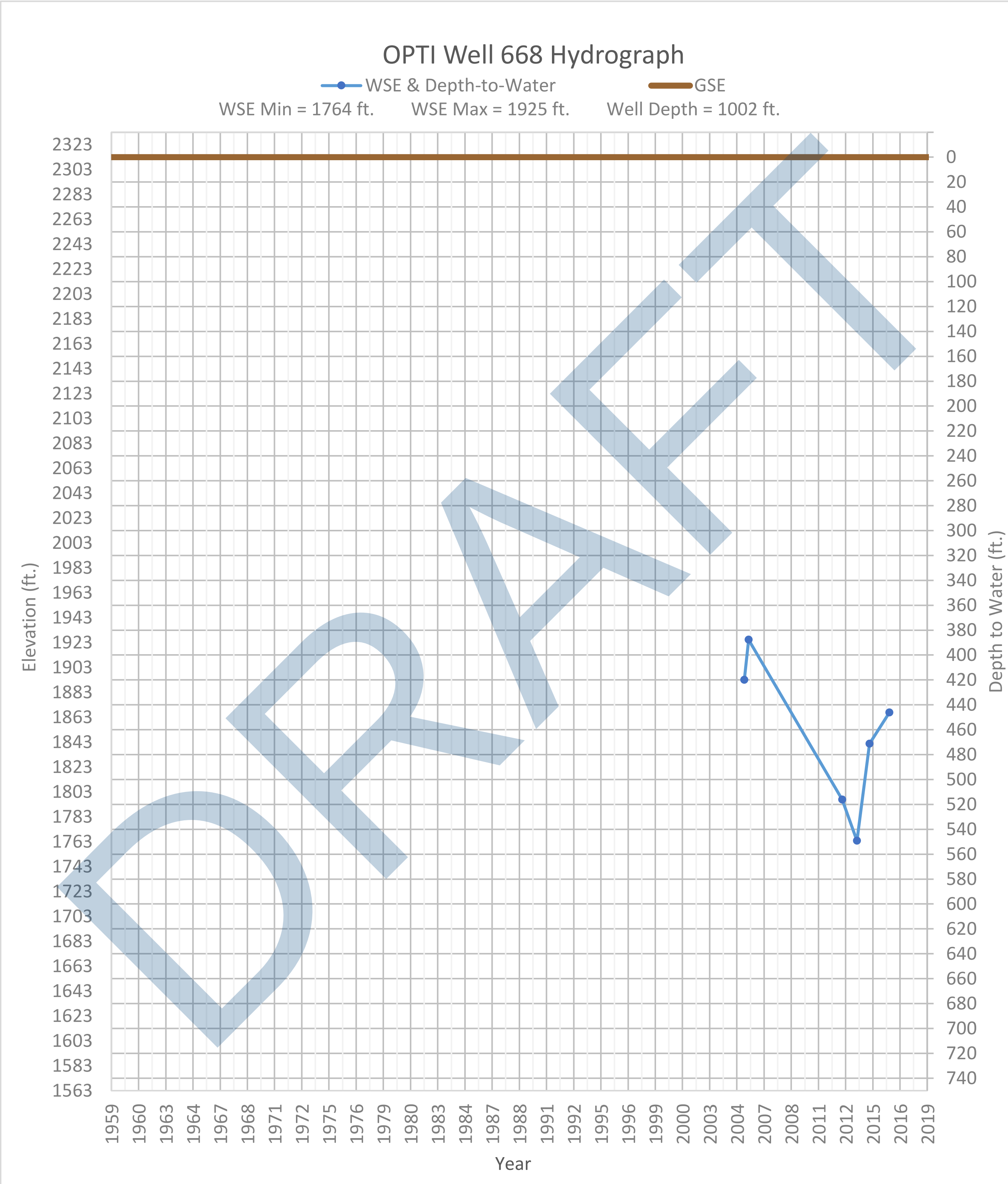
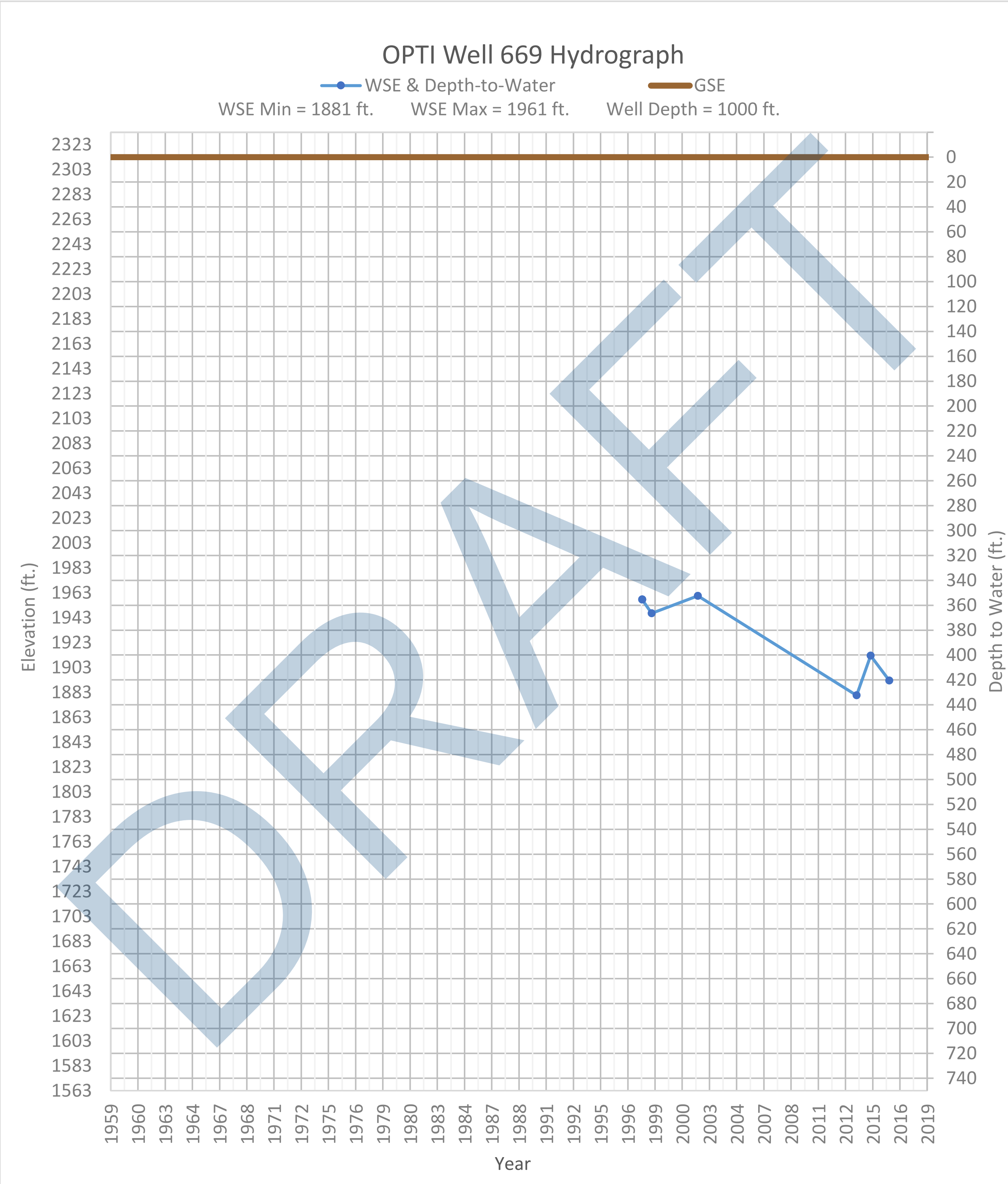
2016
2019
DRAFT


OPTI Well 666 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1910 ft.
WSE Max = 1972 ft.
Well Depth = 1157 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

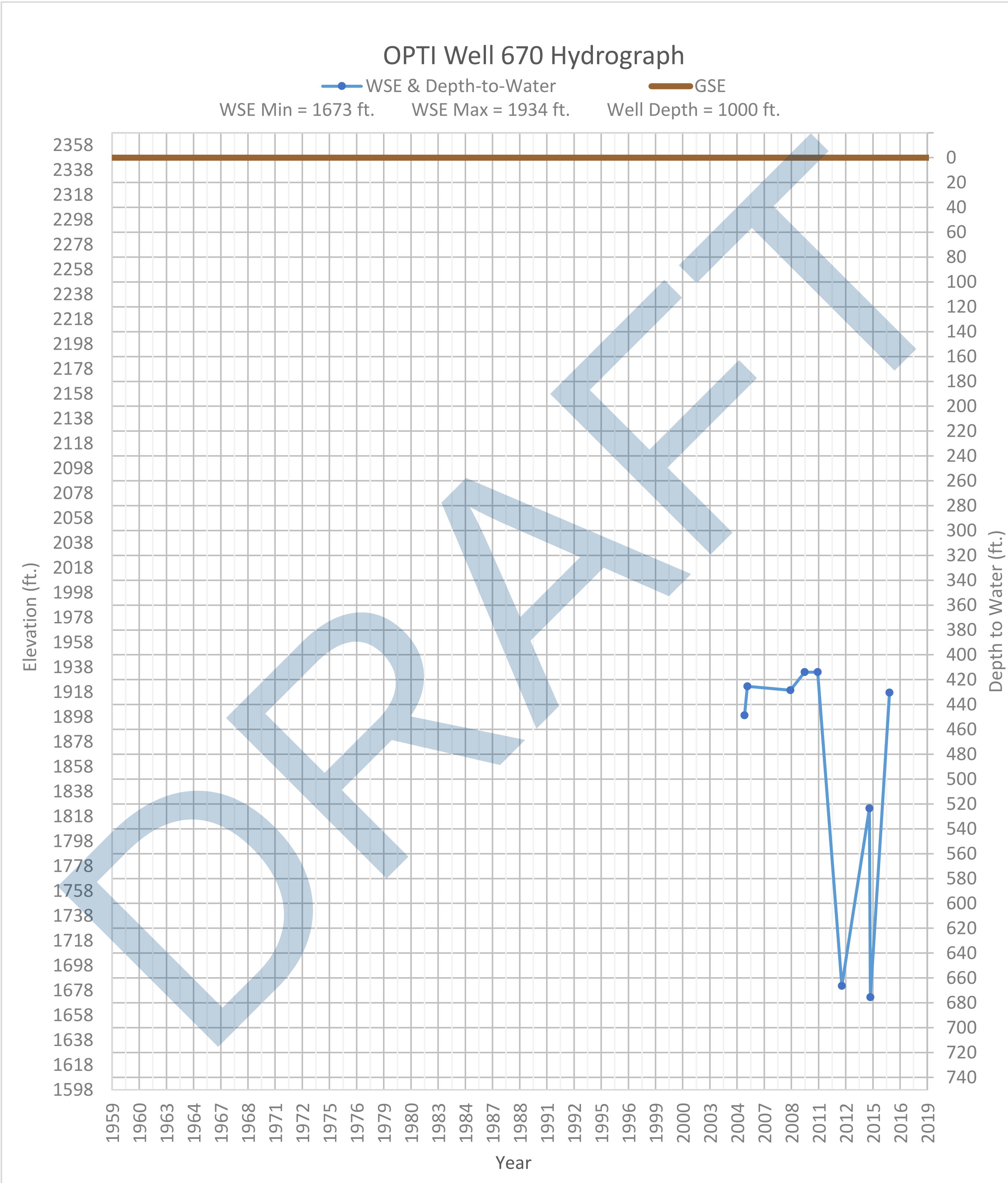

OPTI Well 667 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1829 ft.
WSE Max = 2219 ft.
Well Depth = 1083 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

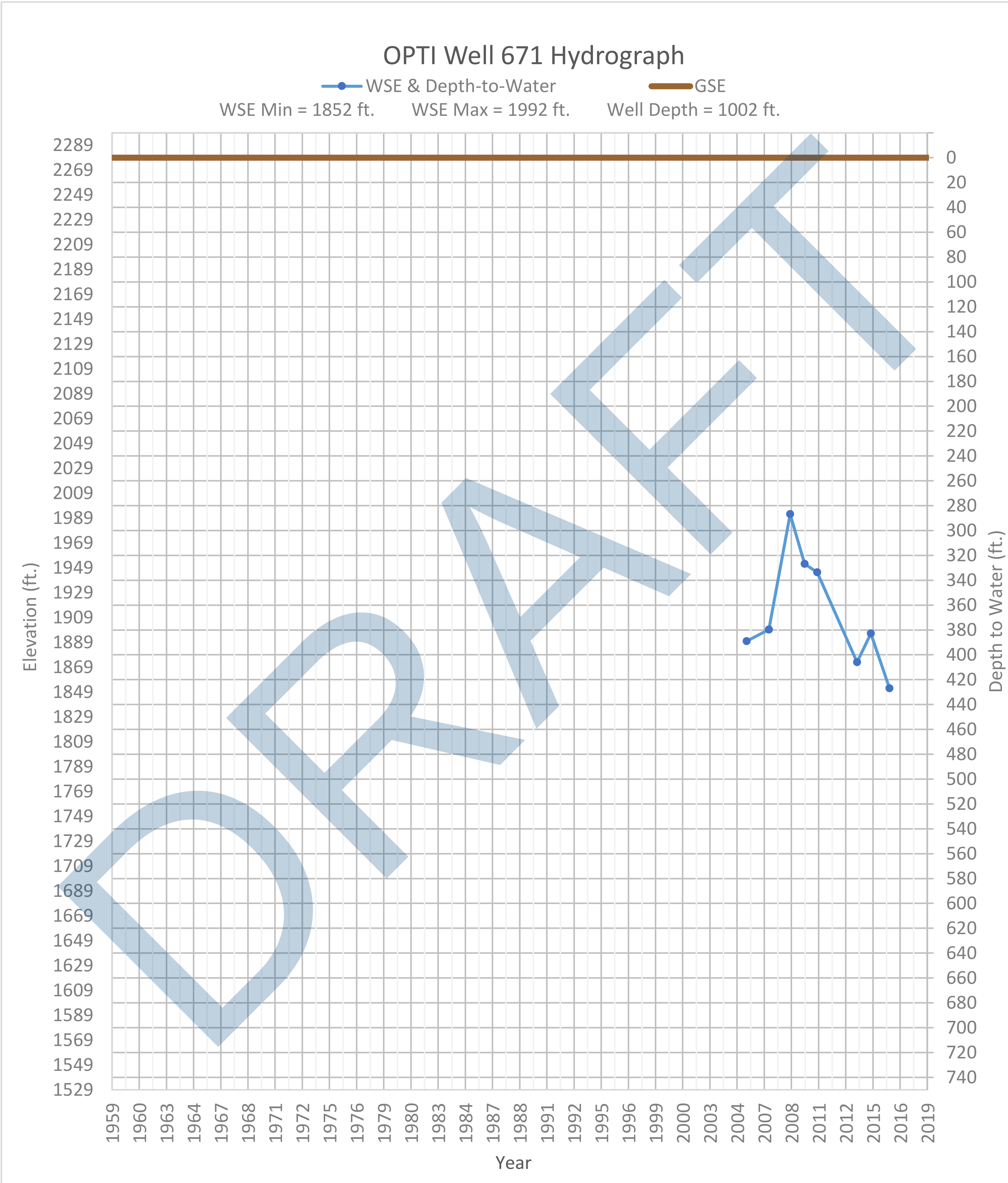


OPTI Well 668 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1764 ft.
WSE Max = 1925 ft.
Well Depth = 1002 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

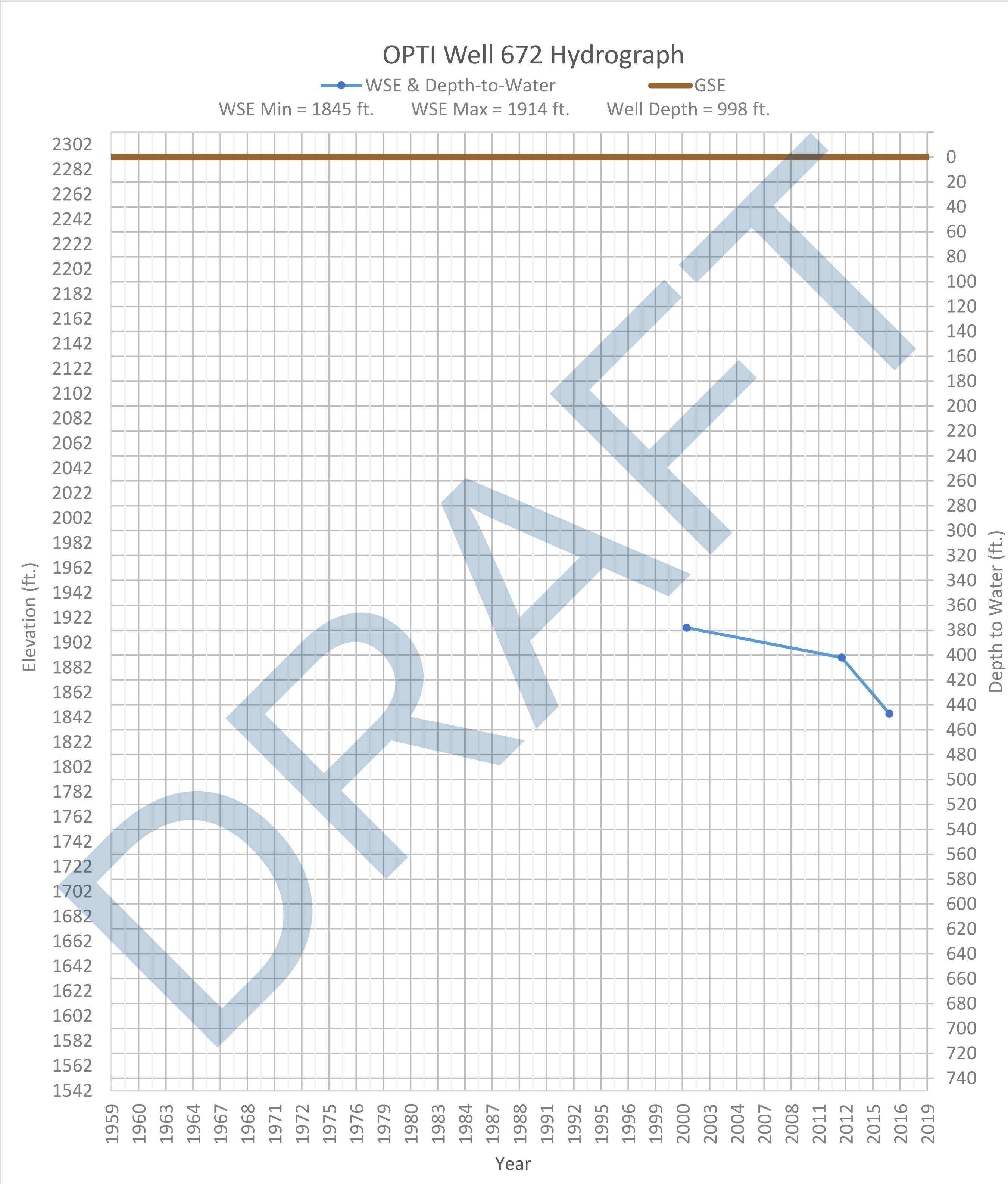


OPTI Well 669 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1881 ft.
WSE Max = 1961 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 670 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1673 ft.
WSE Max = 1934 ft.
Well Depth = 1000 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
2358 2338 2318 2298 2278 2258 2238 2218 2198 2178 2158 2138 2118 2098 2078 2058 2038 2018 1998 1978 1958 1938 1918 1898 1878 1858 1838 1818 1798 1778 1758 1738 1718 1698 1678 1658 1638 1618 1598
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580 600 620 640 660 680 700 720 740
1959 1960 1963 1964 1967 1968 1971 1972 1975 1976 1979 1980 1983 1984 1987 1988 1991 1992 1995 1996 1999 2000 2003 2004 2007 2008 2011 2012 2015 2016 2019
DRAFT



OPTI Well 671 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1852 ft.
WSE Max = 1992 ft.
Well Depth = 1002 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 672 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1845 ft.
WSE Max = 1914 ft.
Well Depth = 998 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT
2302
2282
2262
2242
2222
2202
2182
2162
2142
2122
2102
2082
2062
2042
2022
2002
1982
1962
1942
1922
1902
1882
1862
1842
1822
1802
1782
1762
1742
1722
1702
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1662
1642
1622
1602
1582
1562
1542
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180
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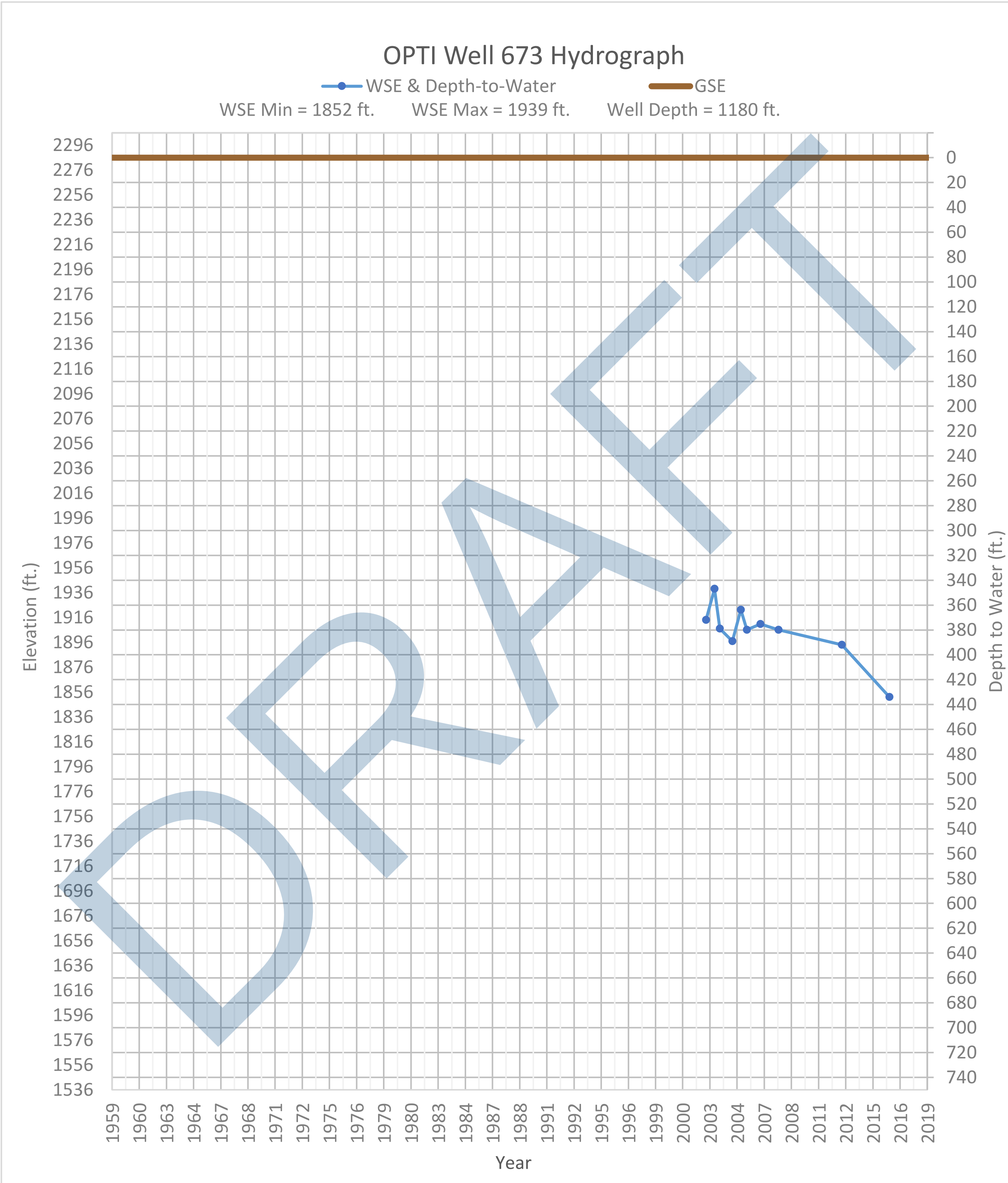
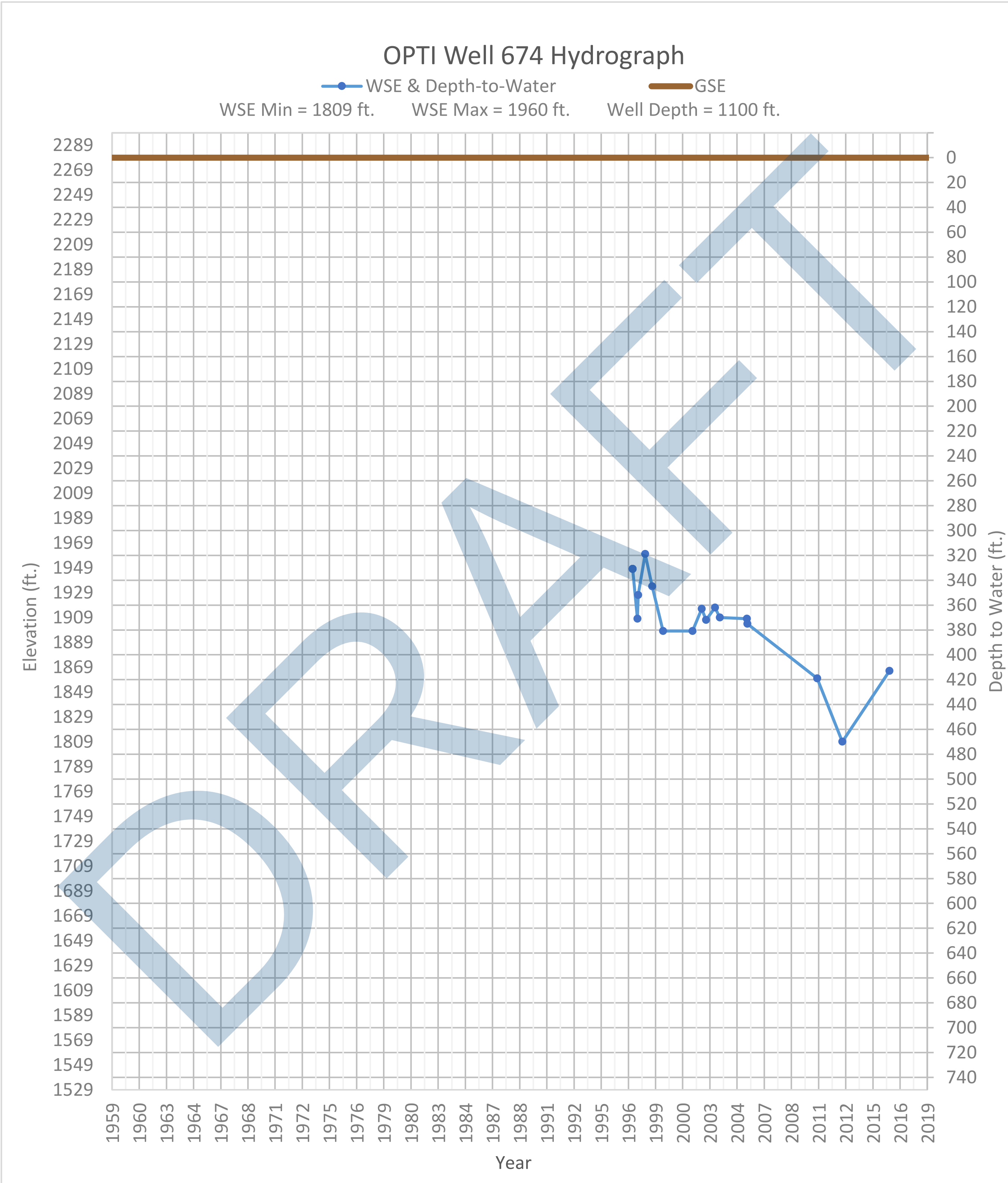
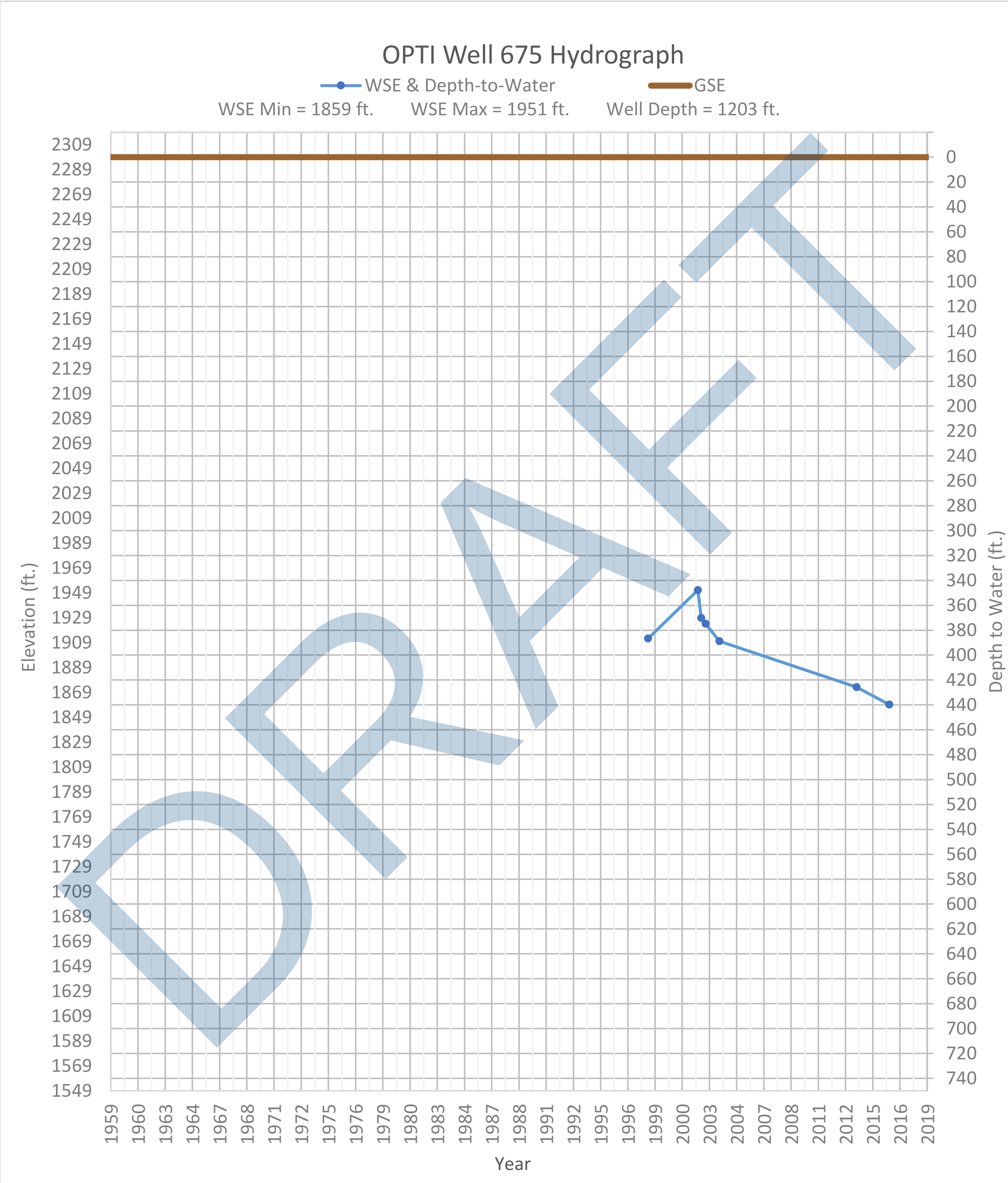


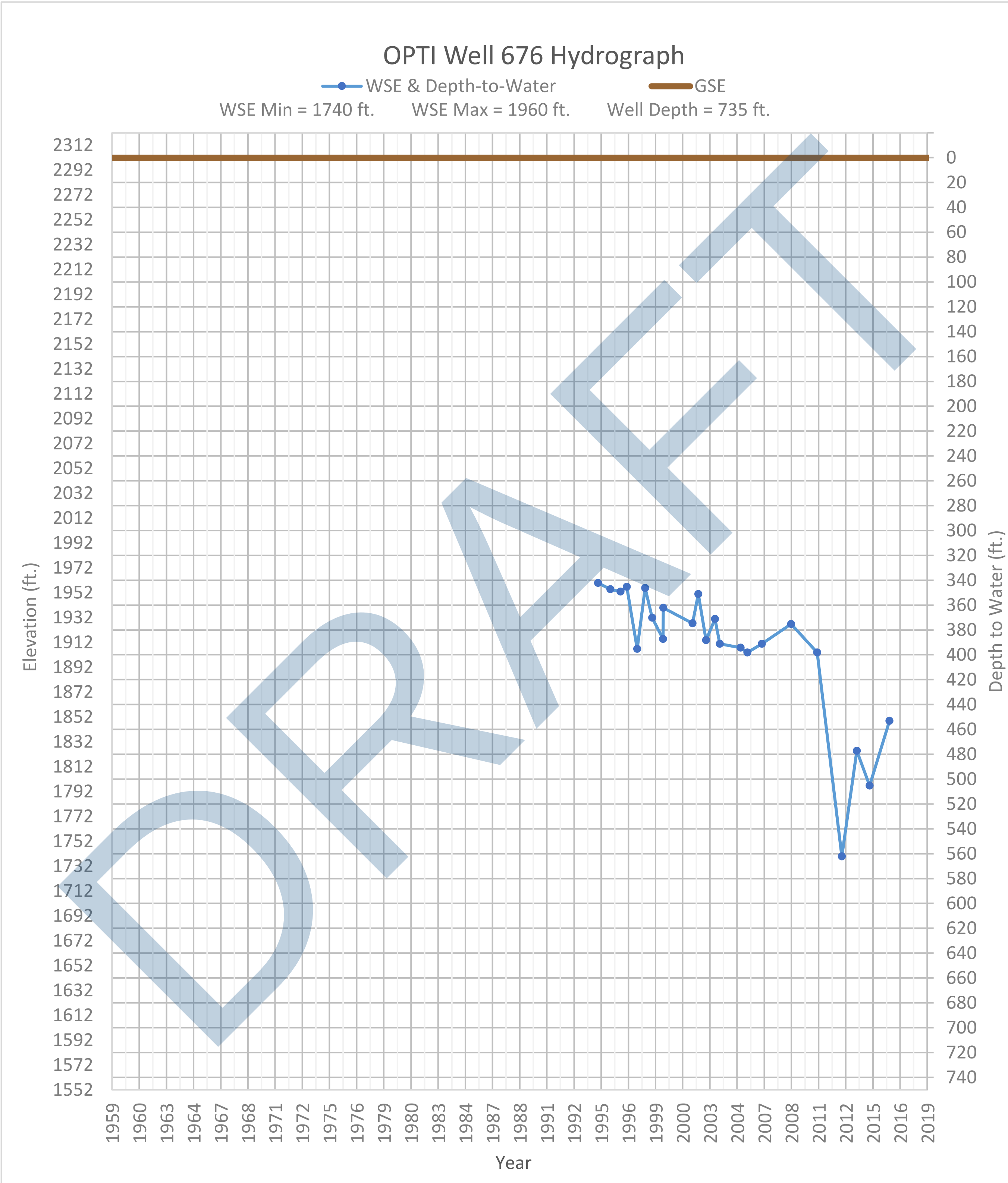
OPTI Well 673 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1852 ft.
WSE Max = 1939 ft.
Well Depth = 1180 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



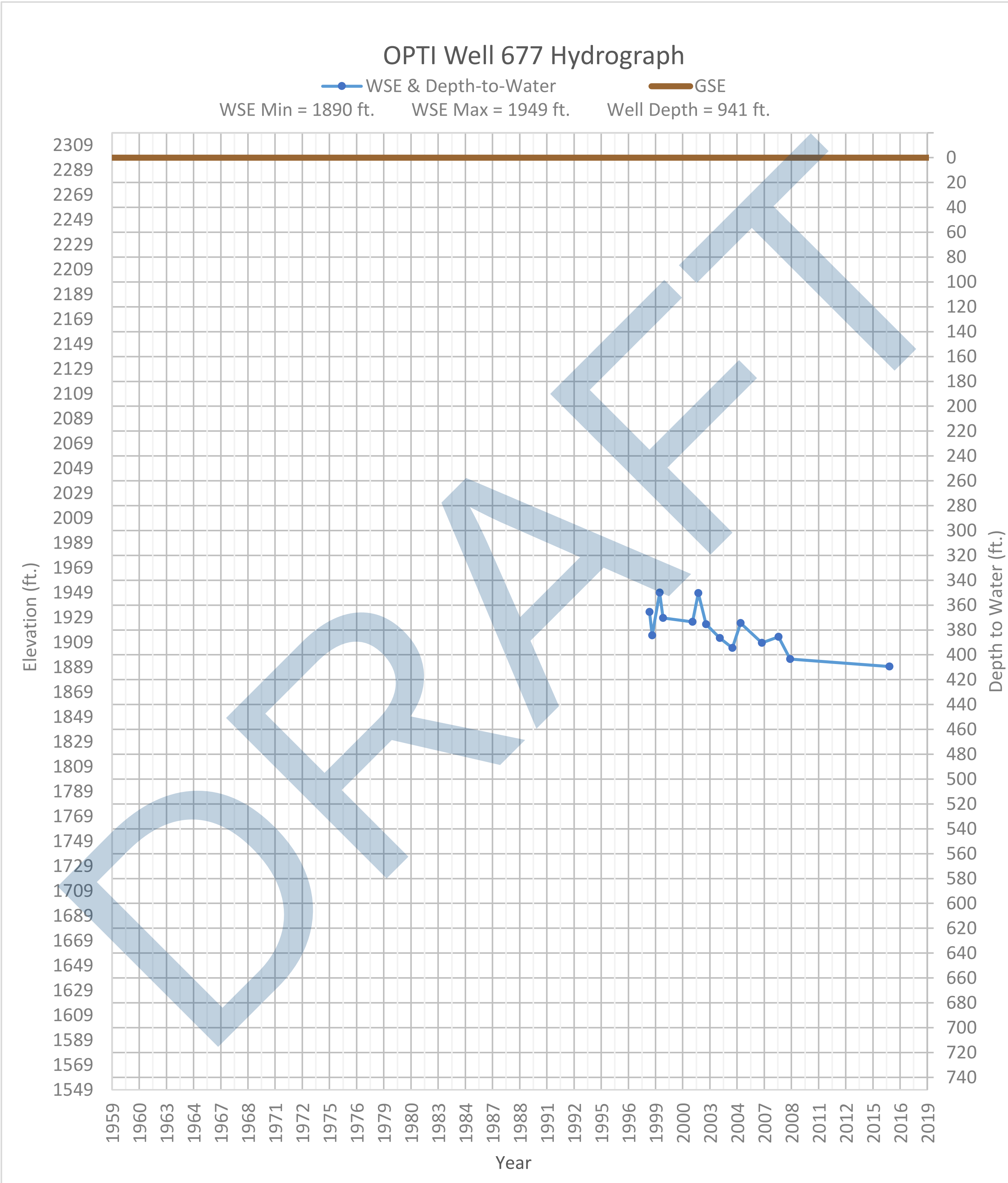
OPTI Well 674 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1809 ft.
WSE Max = 1960 ft.
Well Depth = 1100 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

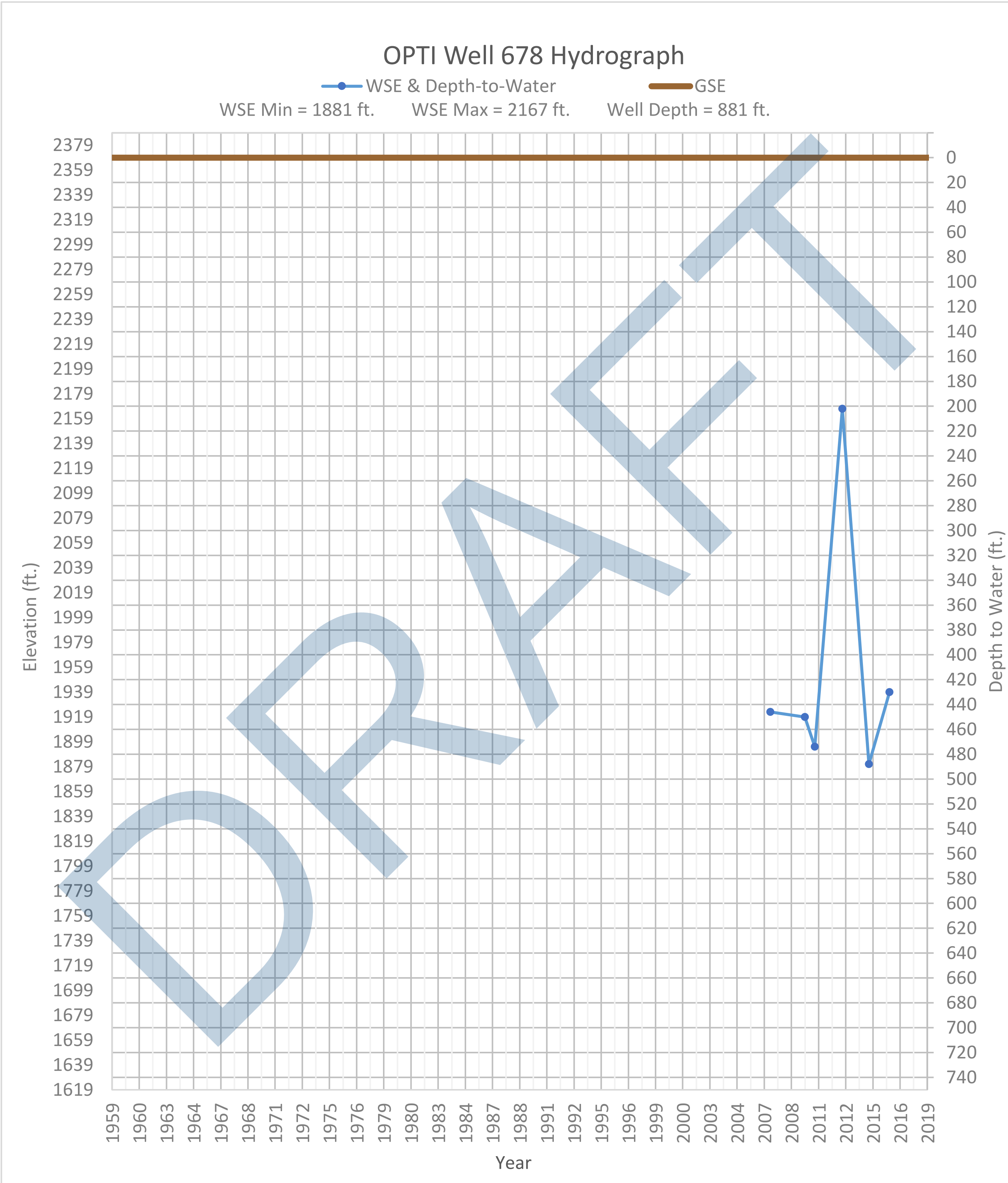


OPTI Well 675 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1859 ft.
WSE Max = 1951 ft.
Well Depth = 1203 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

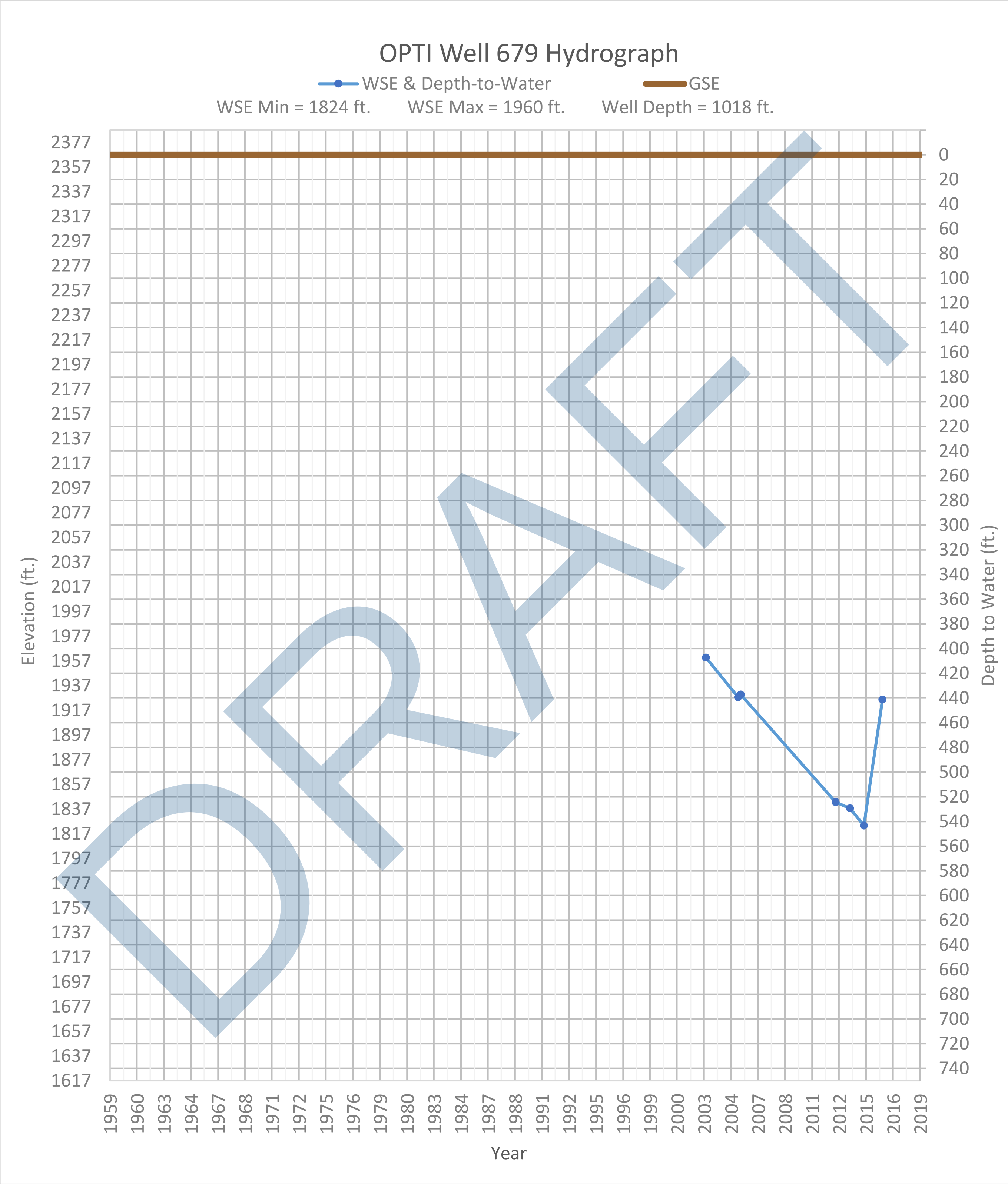


OPTI Well 676 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1740 ft.
WSE Max = 1960 ft.
Well Depth = 735 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

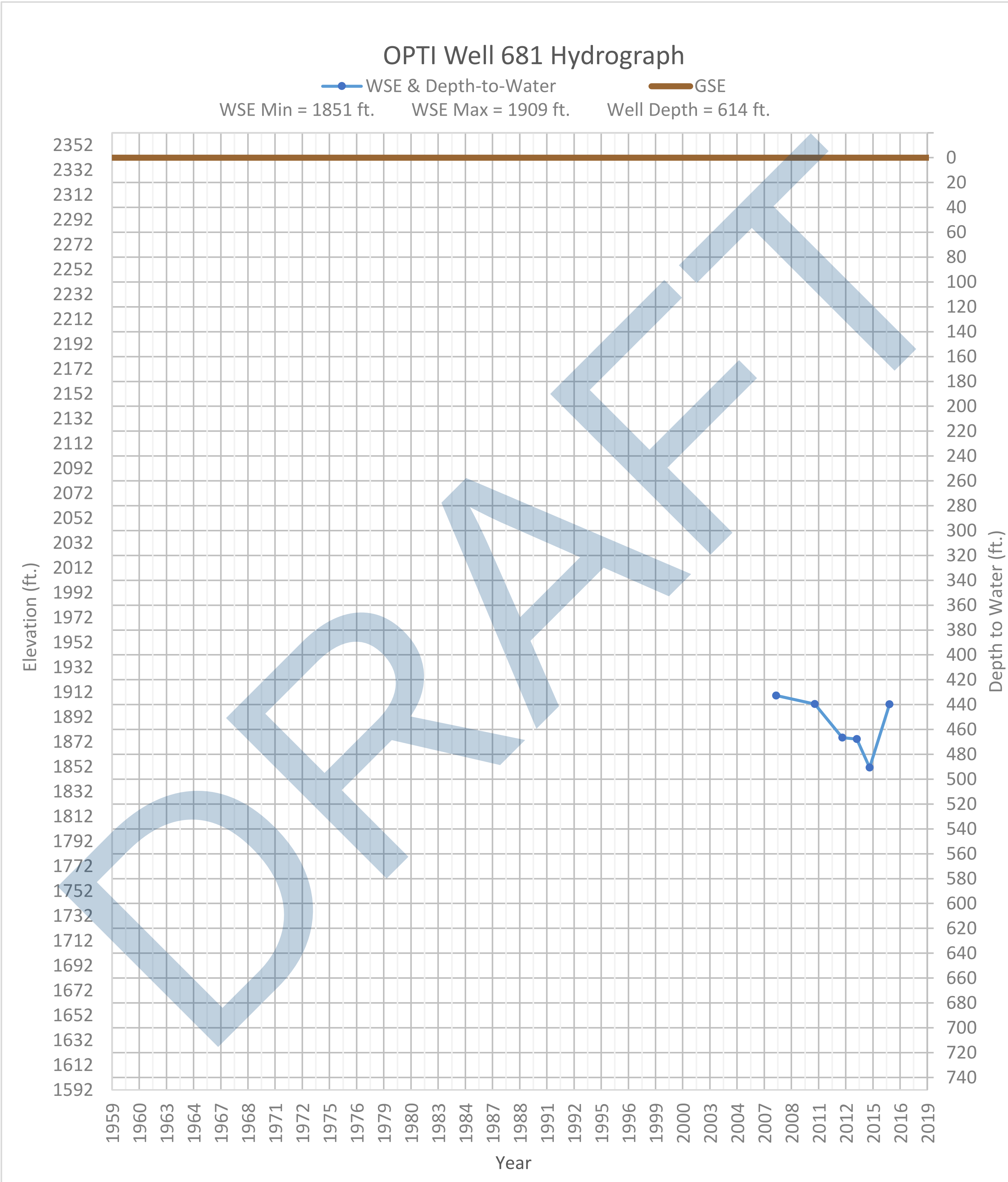

OPTI Well 677 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1890 ft.
WSE Max = 1949 ft.
Well Depth = 941 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



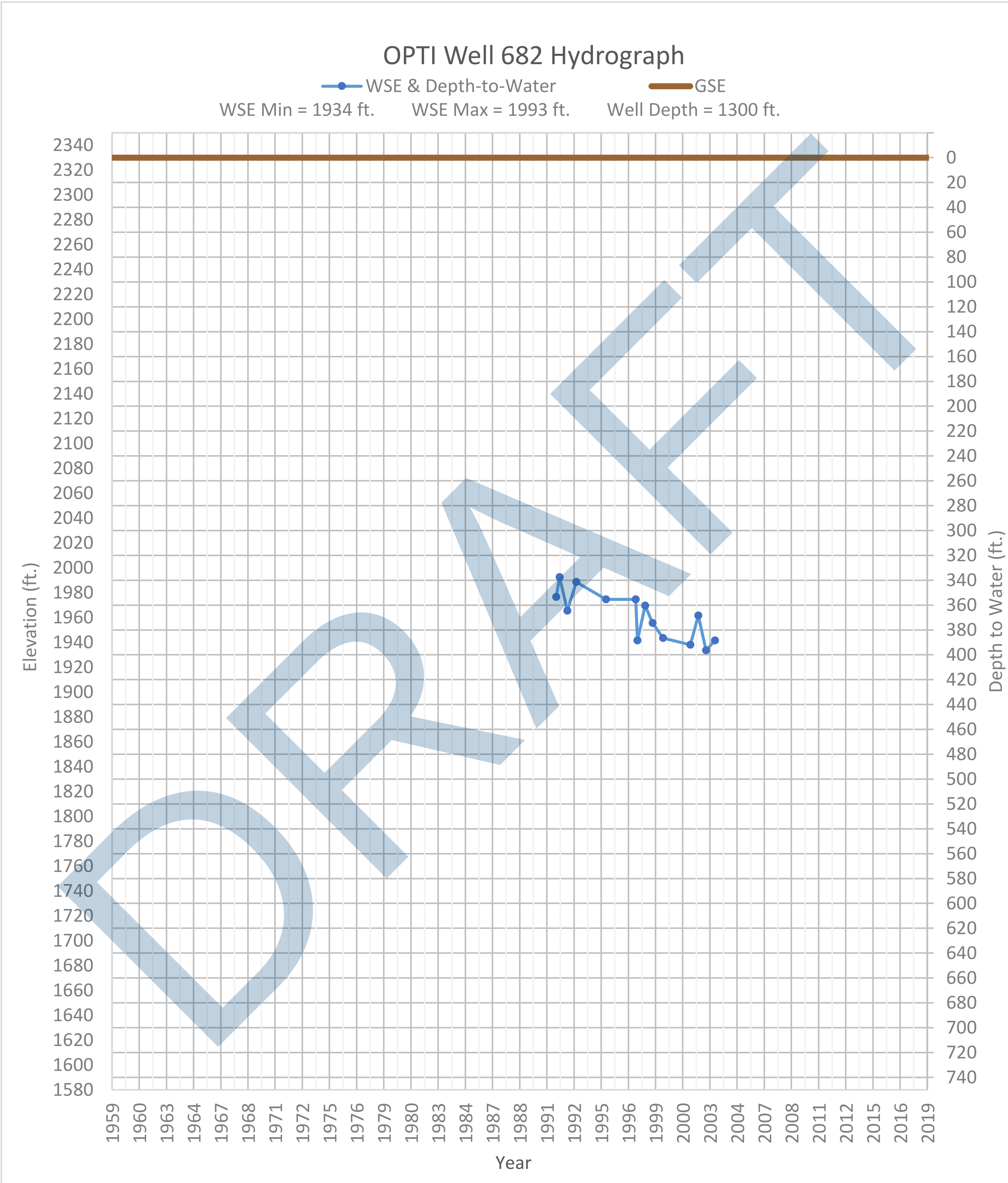
OPTI Well 678 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1881 ft.
WSE Max = 2167 ft.
Well Depth = 881 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



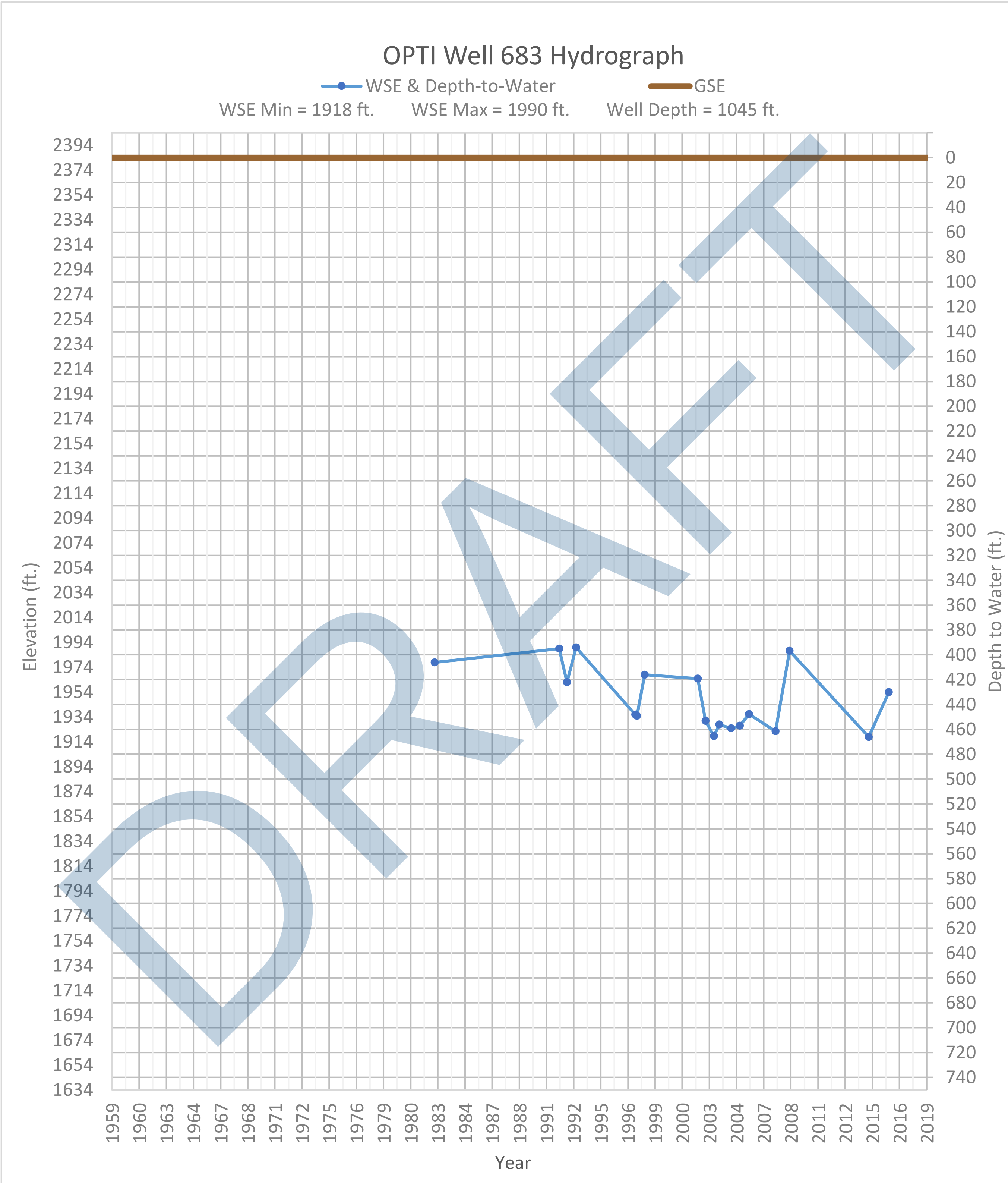
OPTI Well 679 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1824 ft.
WSE Max = 1960 ft.
Well Depth = 1018 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 681 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1851 ft.
WSE Max = 1909 ft.
Well Depth = 614 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 682 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1934 ft.
WSE Max = 1993 ft.
Well Depth = 1300 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 683 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1918 ft.
WSE Max = 1990 ft.
Well Depth = 1045 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
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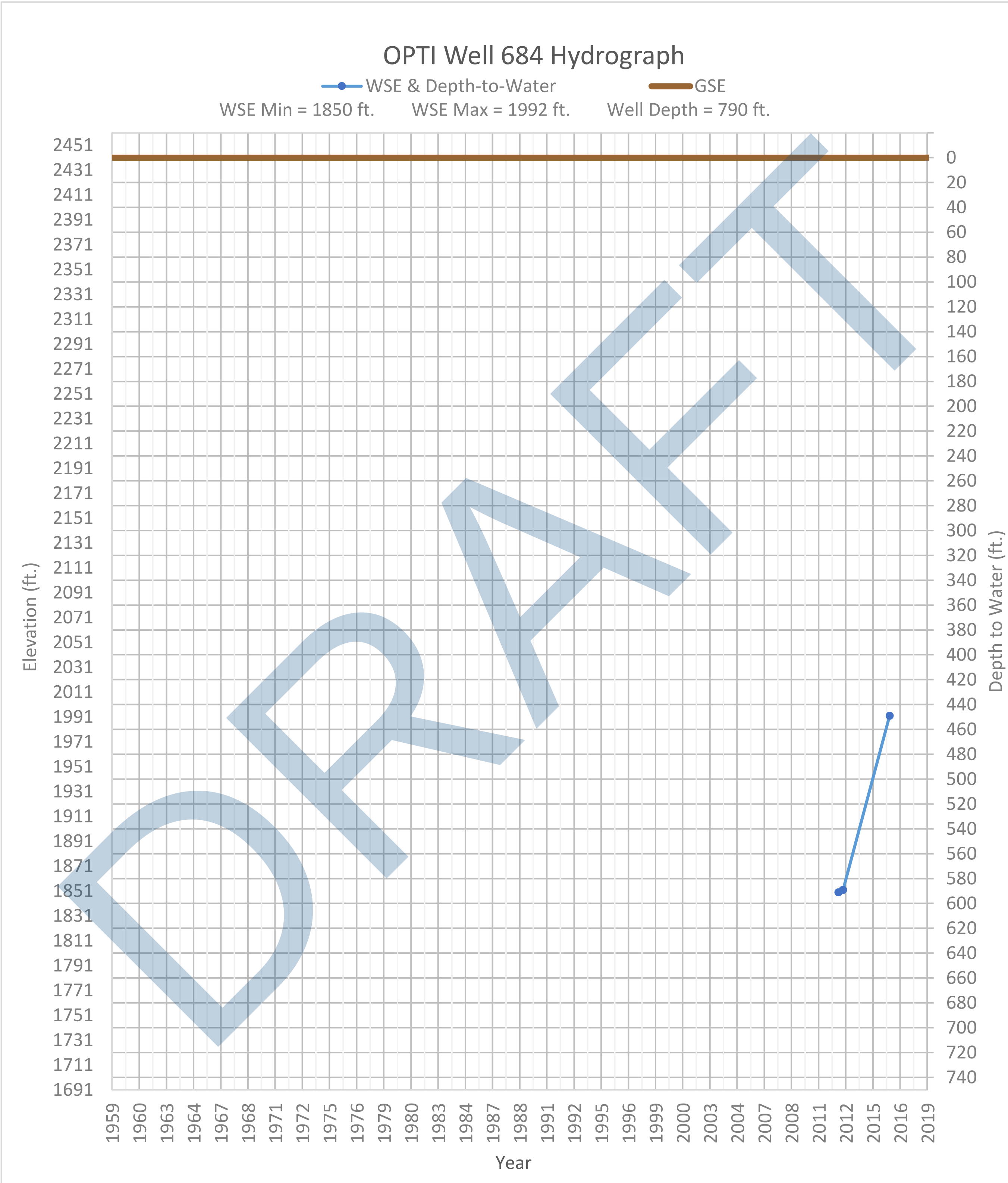

OPTI Well 684 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1850 ft.
WSE Max = 1992 ft.
Well Depth = 790 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
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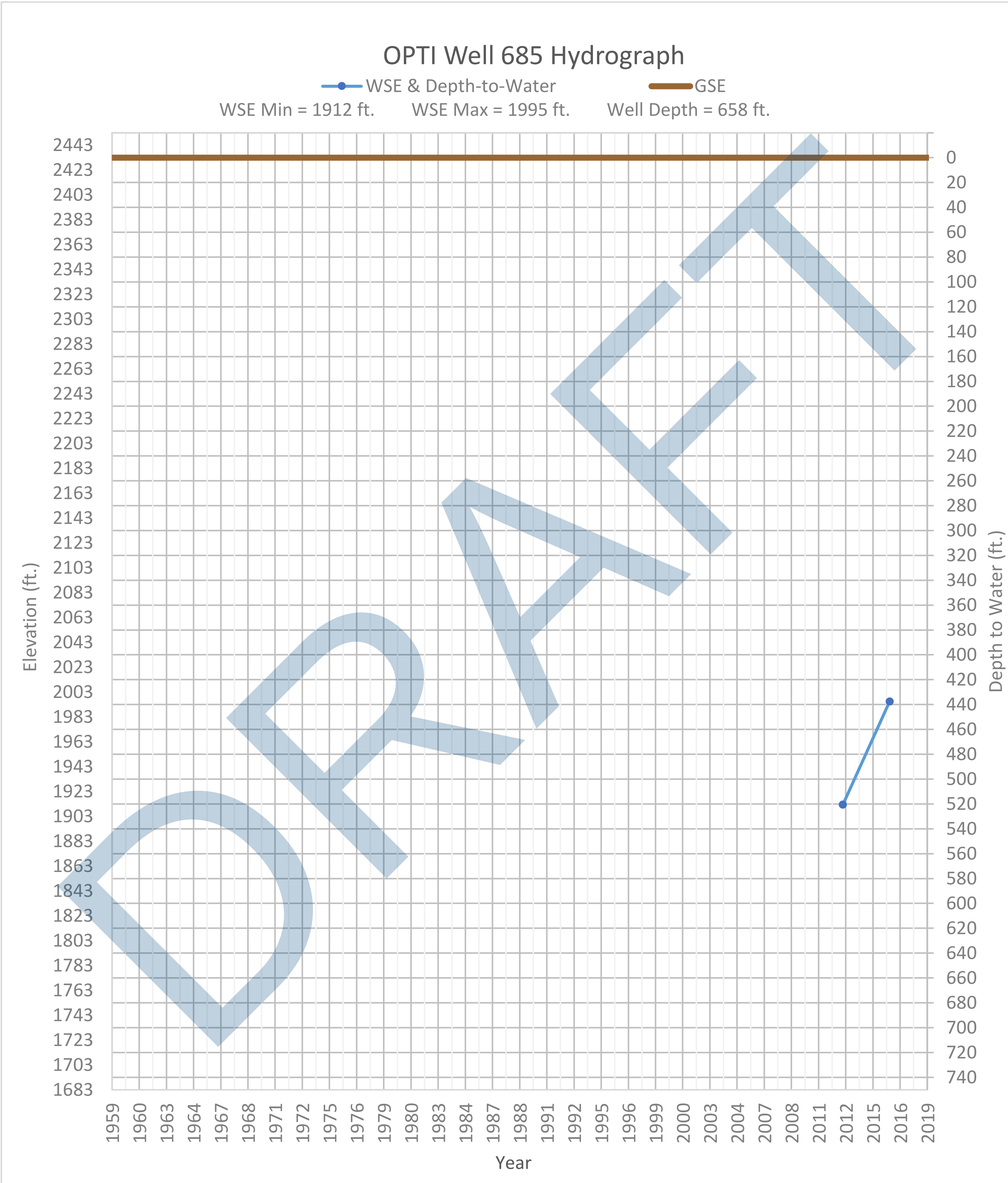
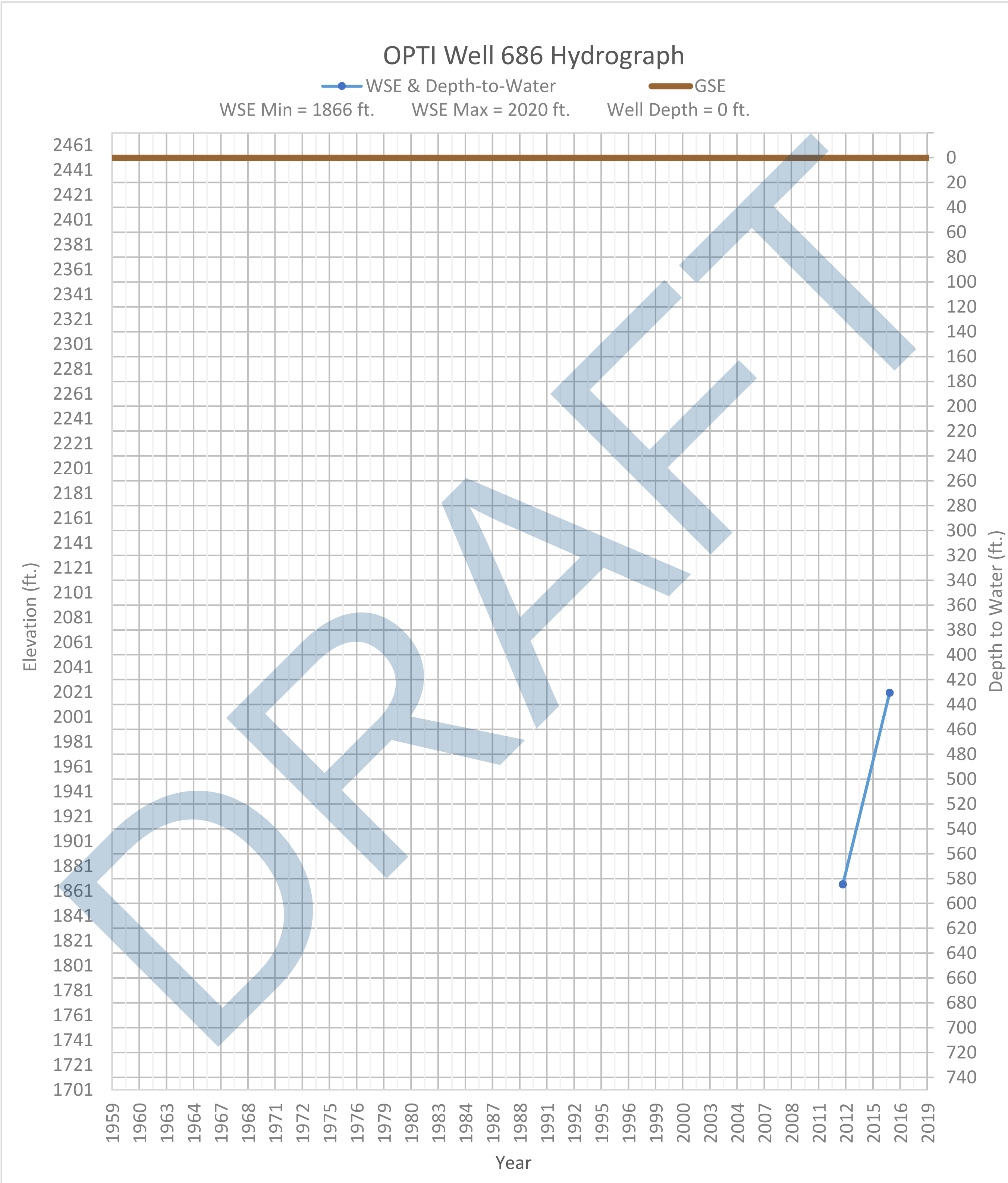
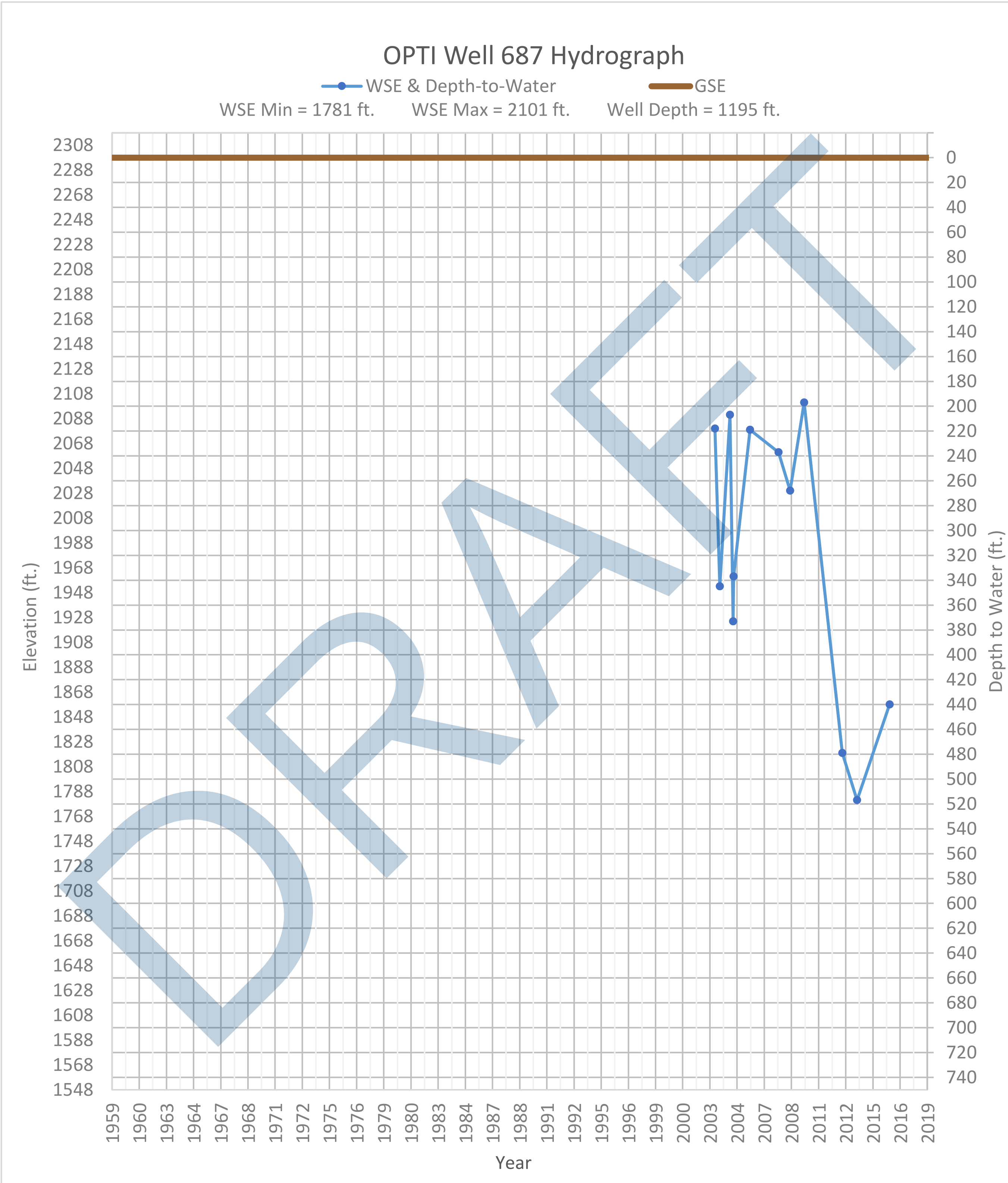


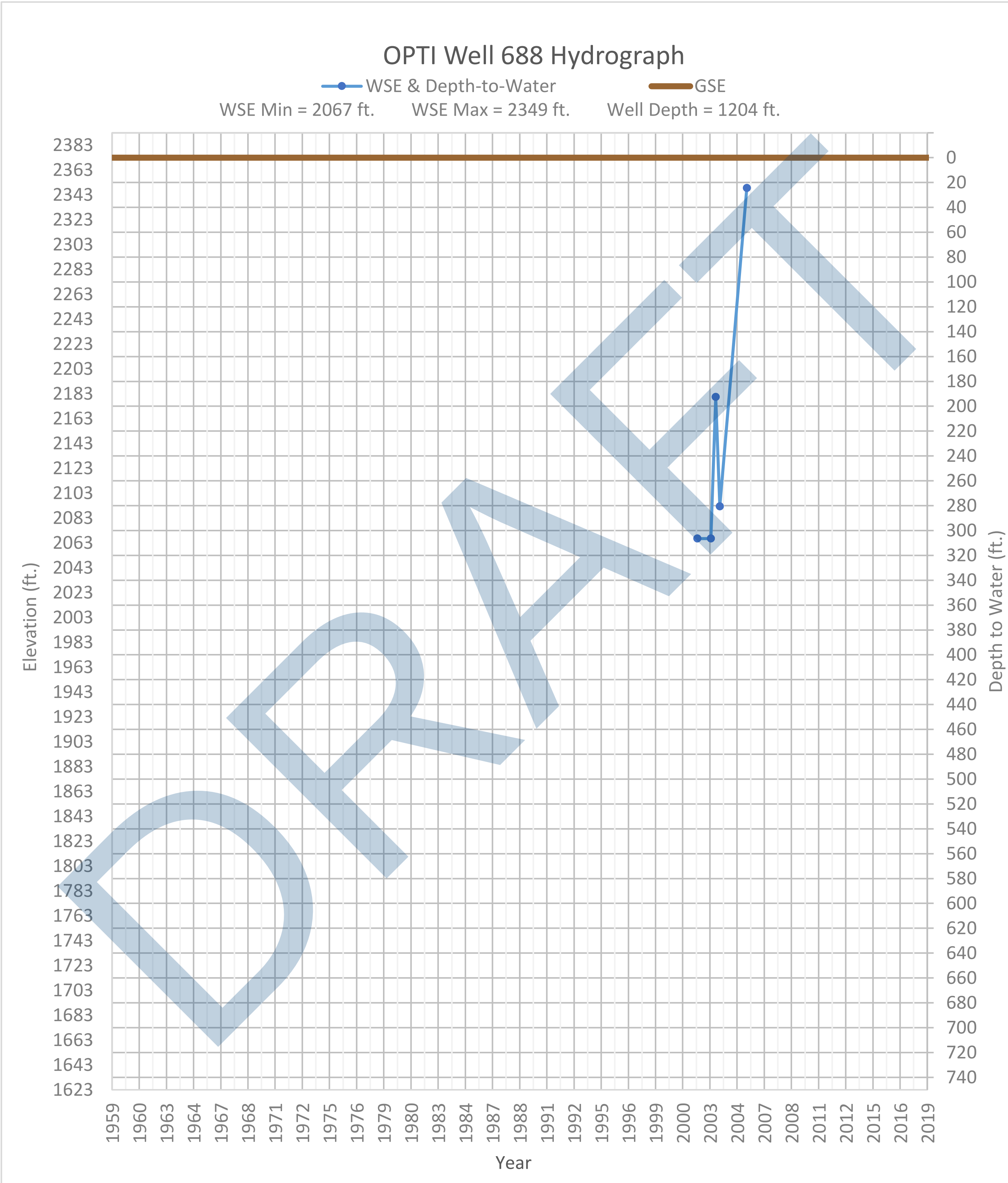
OPTI Well 685 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1912 ft.
WSE Max = 1995 ft.
Well Depth = 658 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

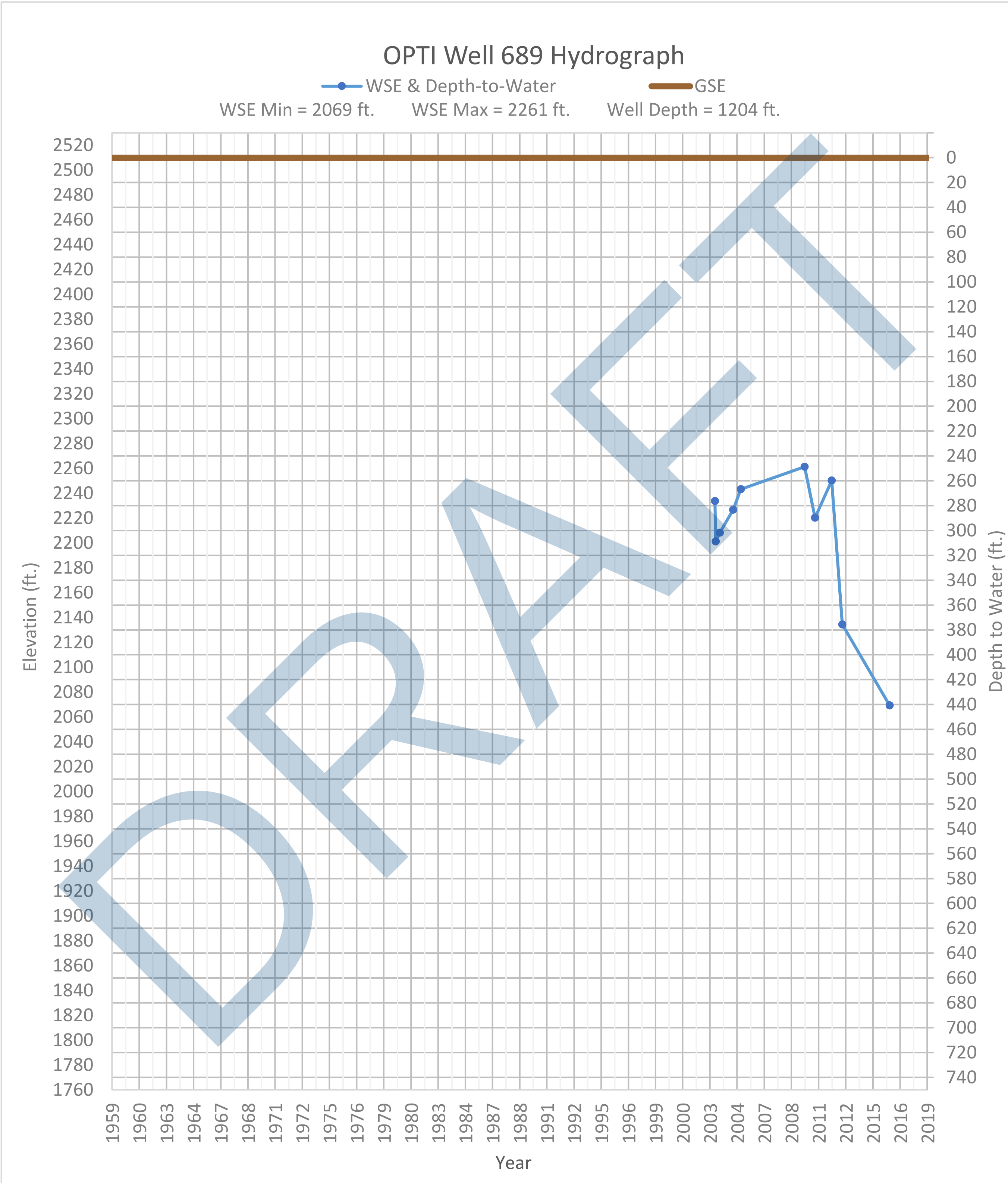


OPTI Well 686 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1866 ft.
WSE Max = 2020 ft.
Well Depth = 0 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

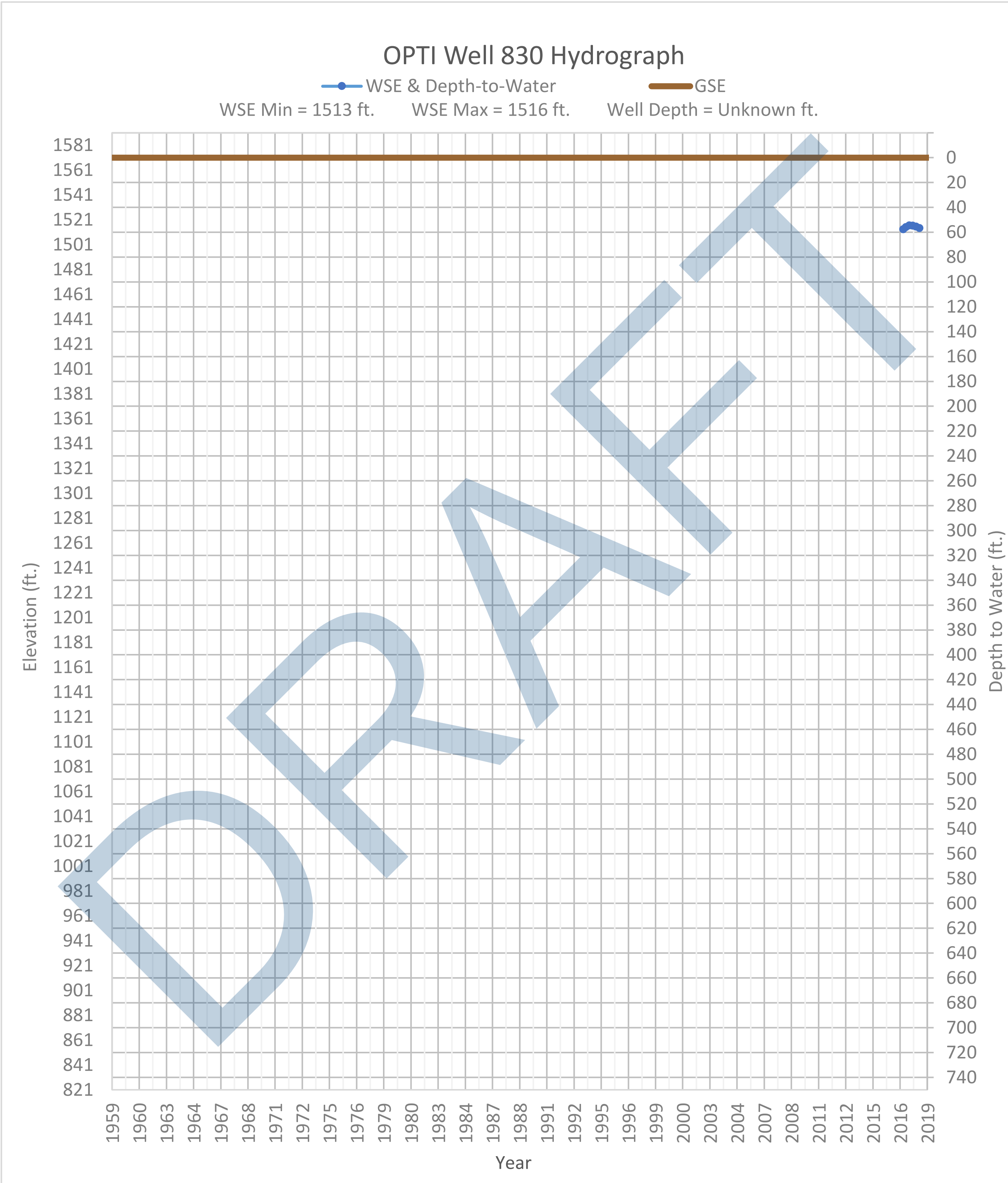


OPTI Well 687 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1781 ft.
WSE Max = 2101 ft.
Well Depth = 1195 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

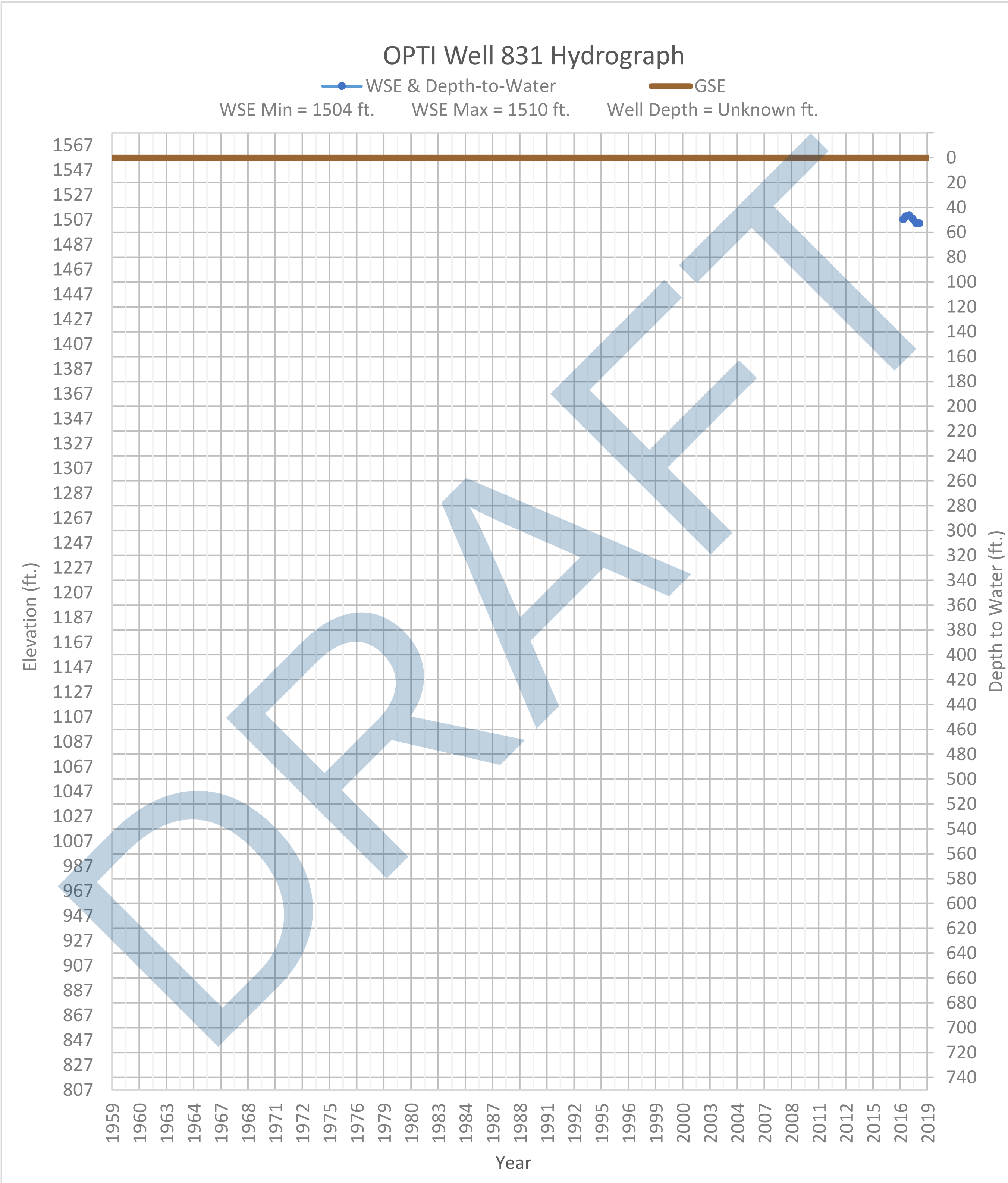

OPTI Well 688 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2067 ft.
WSE Max = 2349 ft.
Well Depth = 1204 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



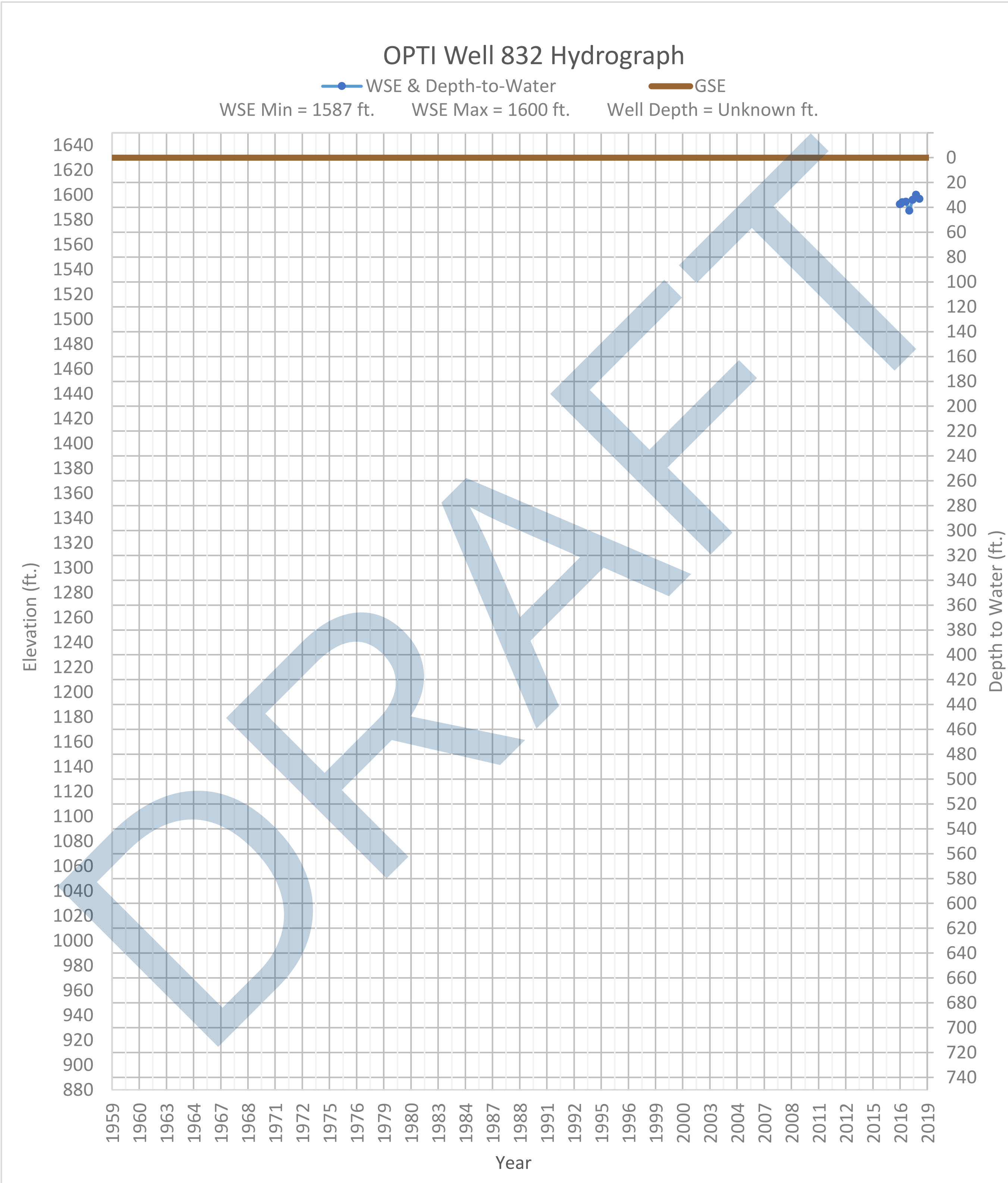
OPTI Well 689 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 2069 ft.
WSE Max = 2261 ft.
Well Depth = 1204 ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



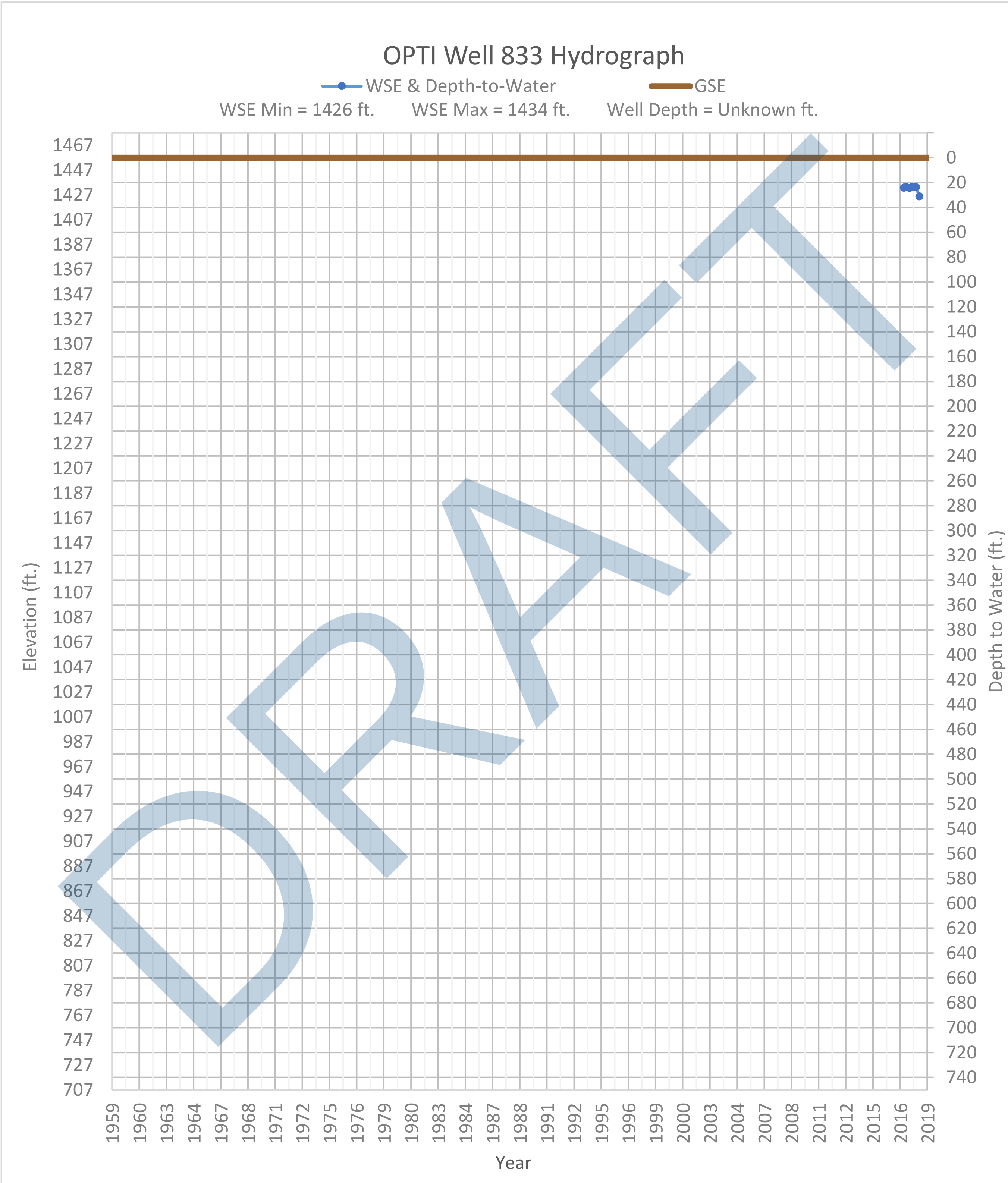
OPTI Well 830 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1513 ft.
WSE Max = 1516 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

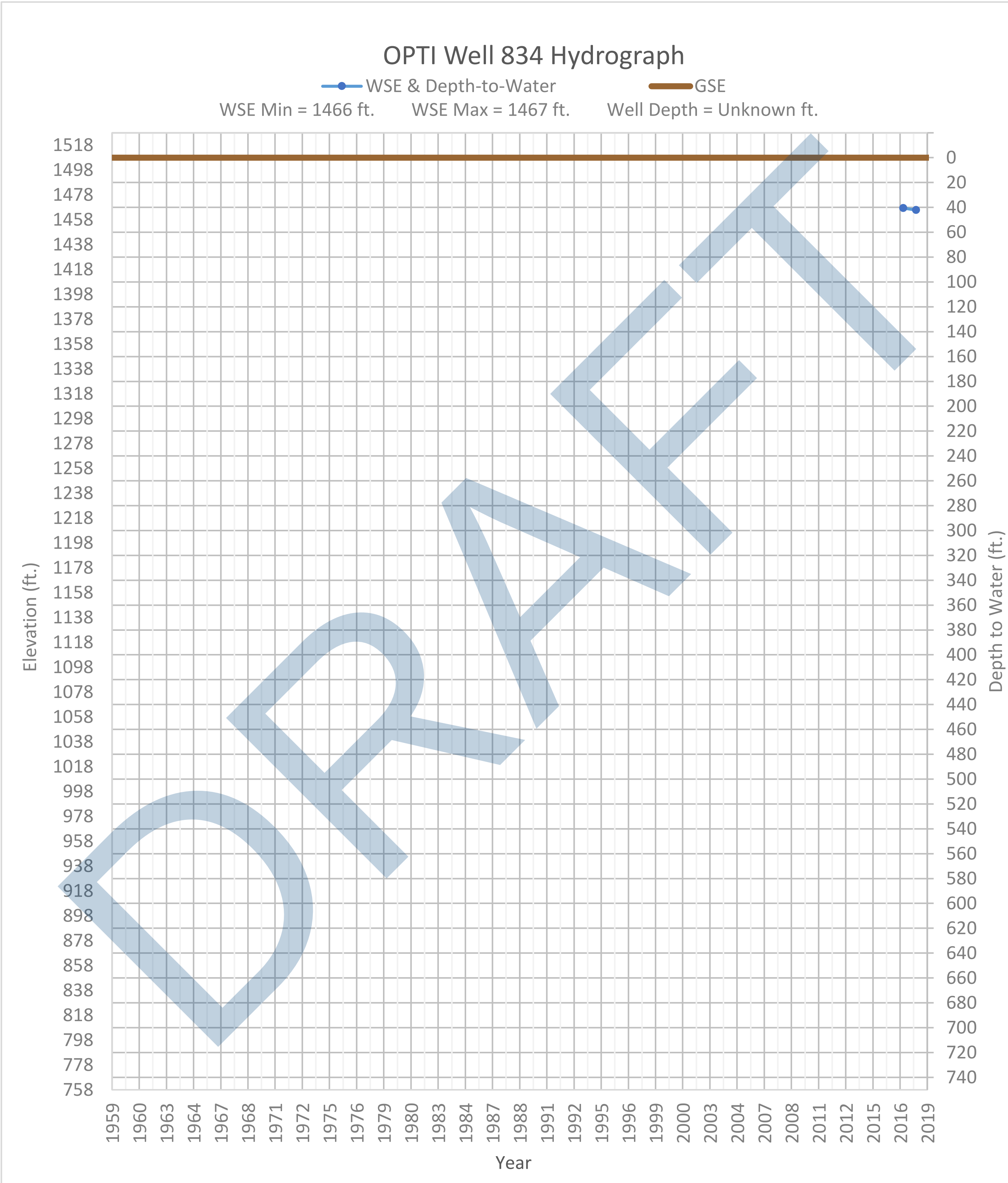


OPTI Well 831 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1504 ft.
WSE Max = 1510 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

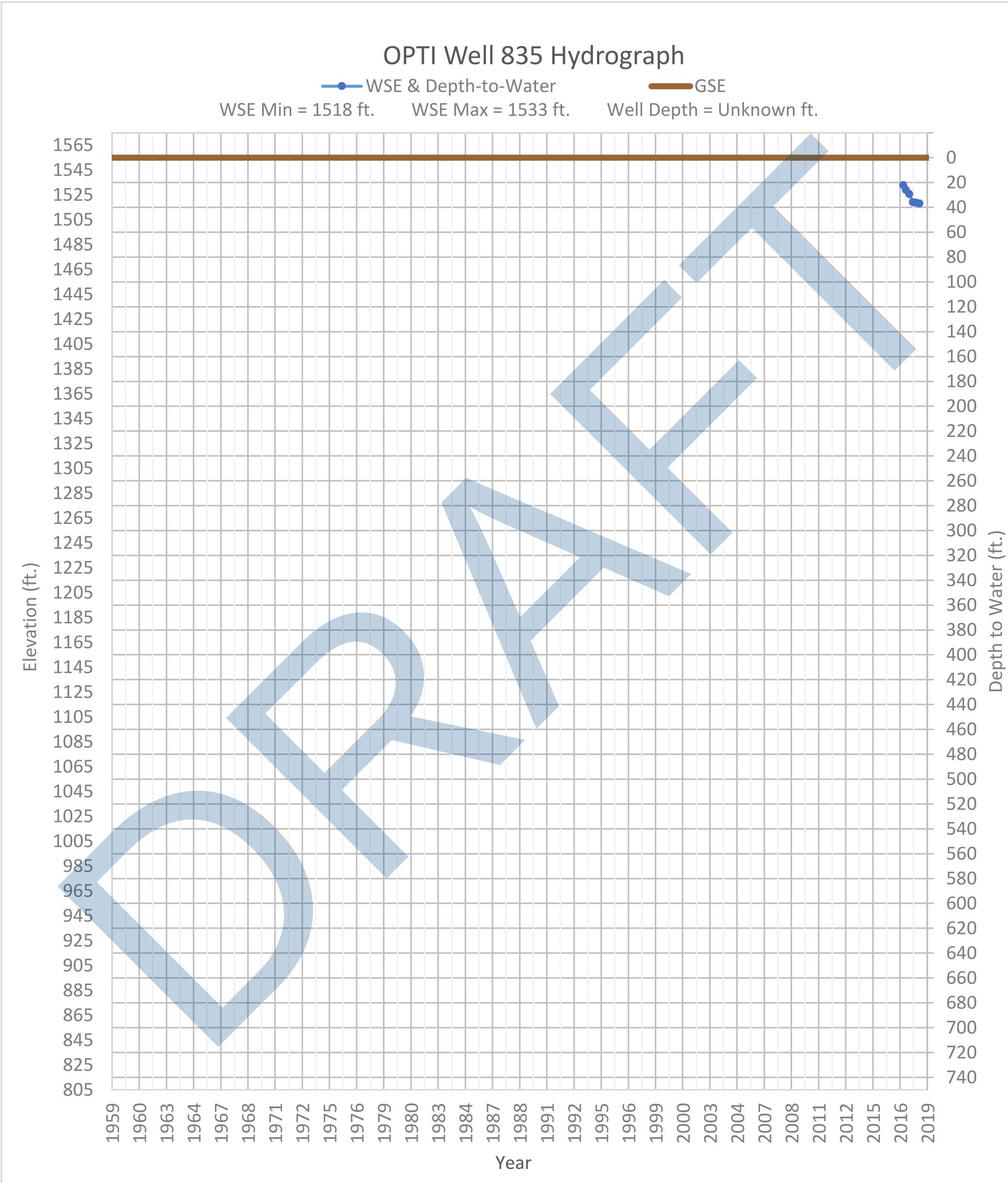


OPTI Well 832 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1587 ft.
WSE Max = 1600 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

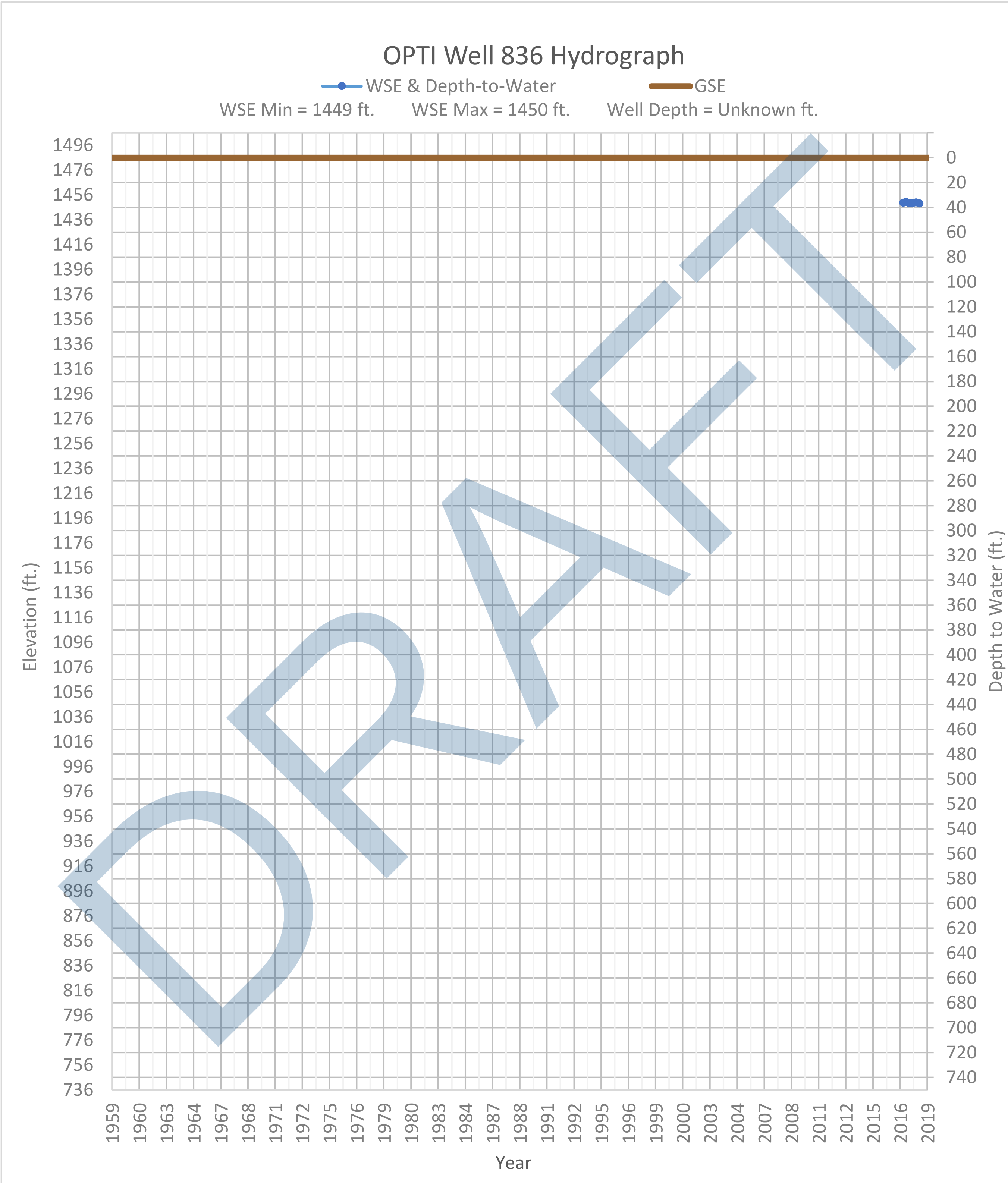

OPTI Well 833 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1426 ft.
WSE Max = 1434 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



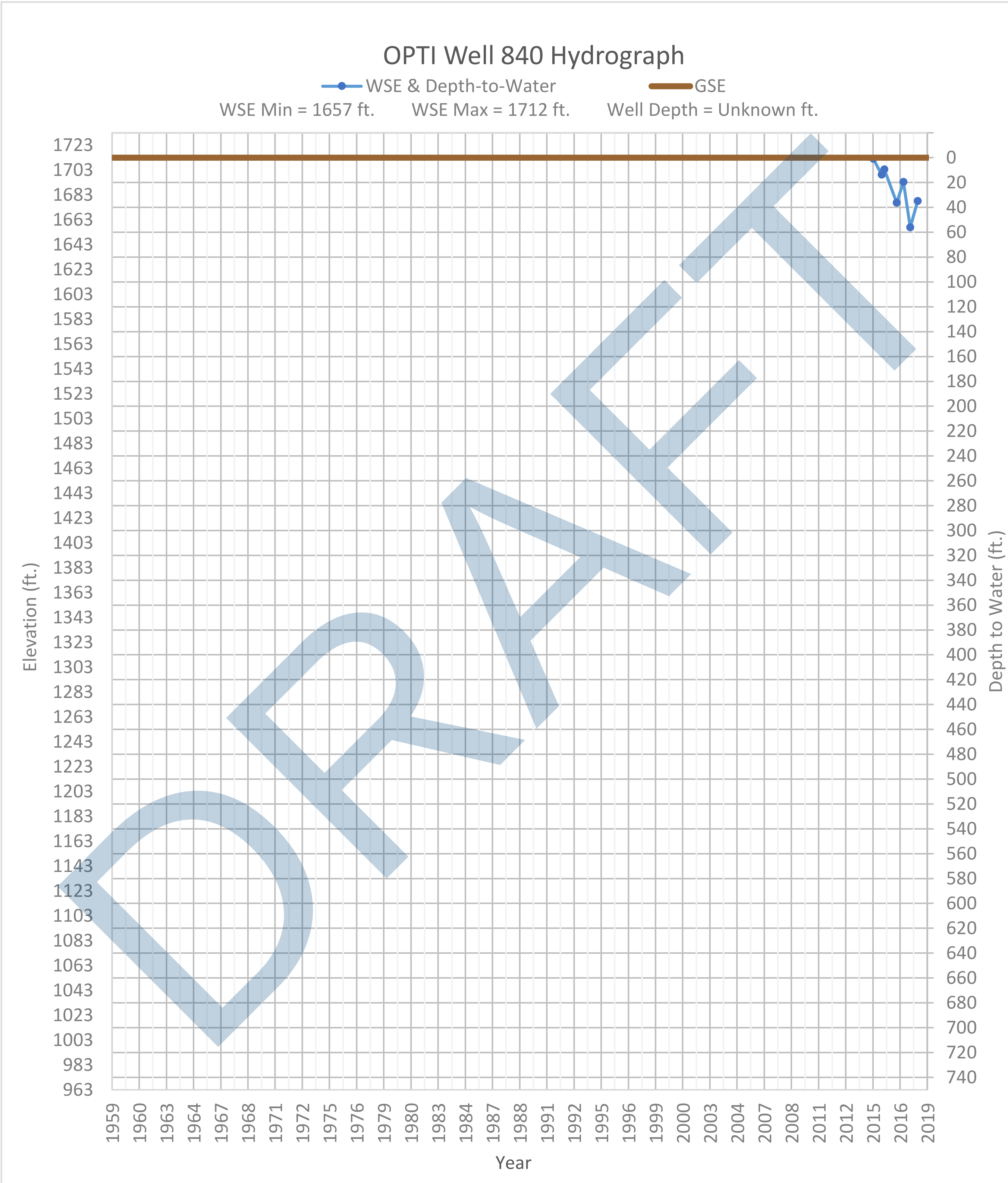
OPTI Well 834 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1466 ft.
WSE Max = 1467 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



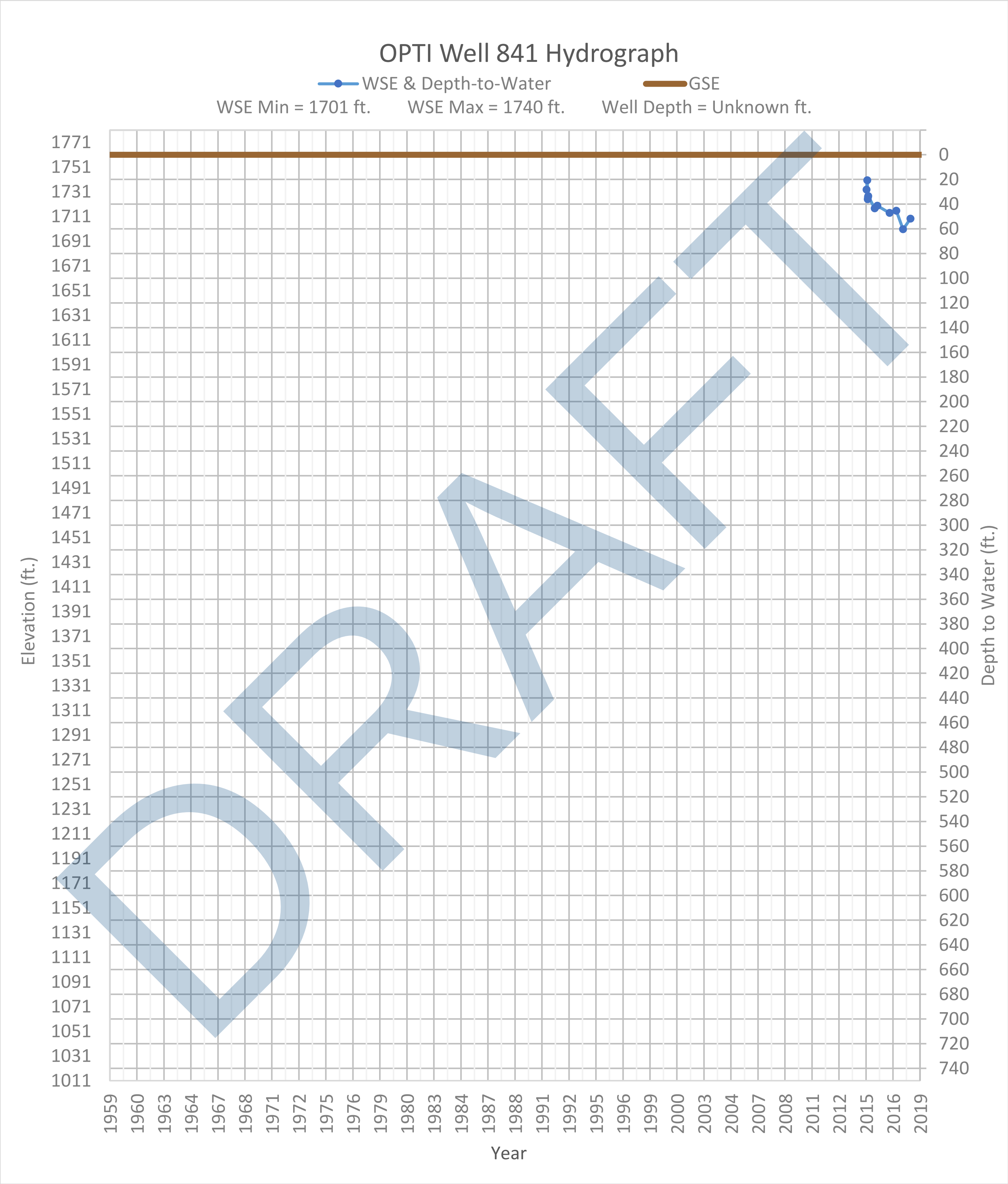
OPTI Well 835 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1518 ft.
WSE Max = 1533 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



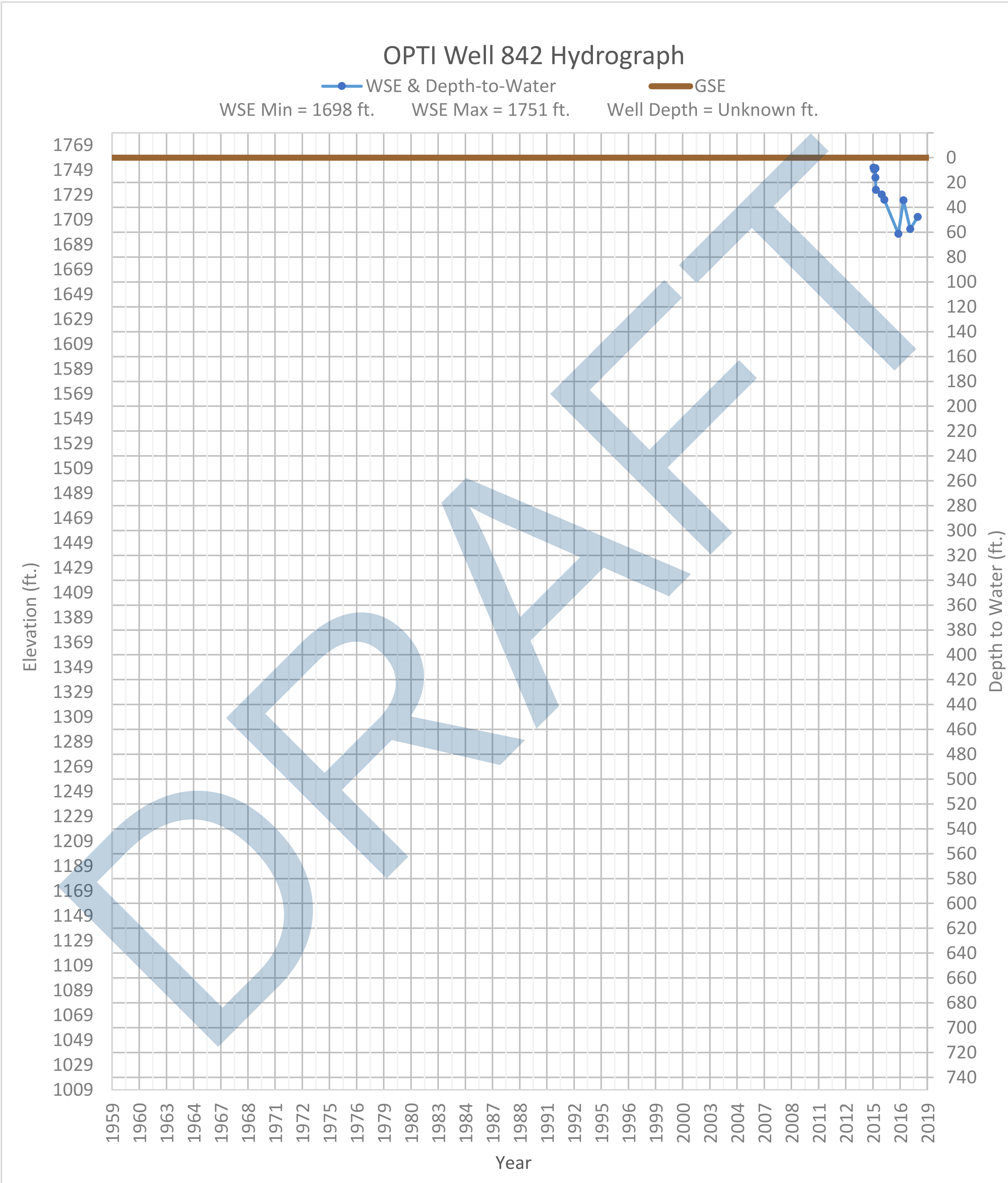
OPTI Well 836 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1449 ft.
WSE Max = 1450 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



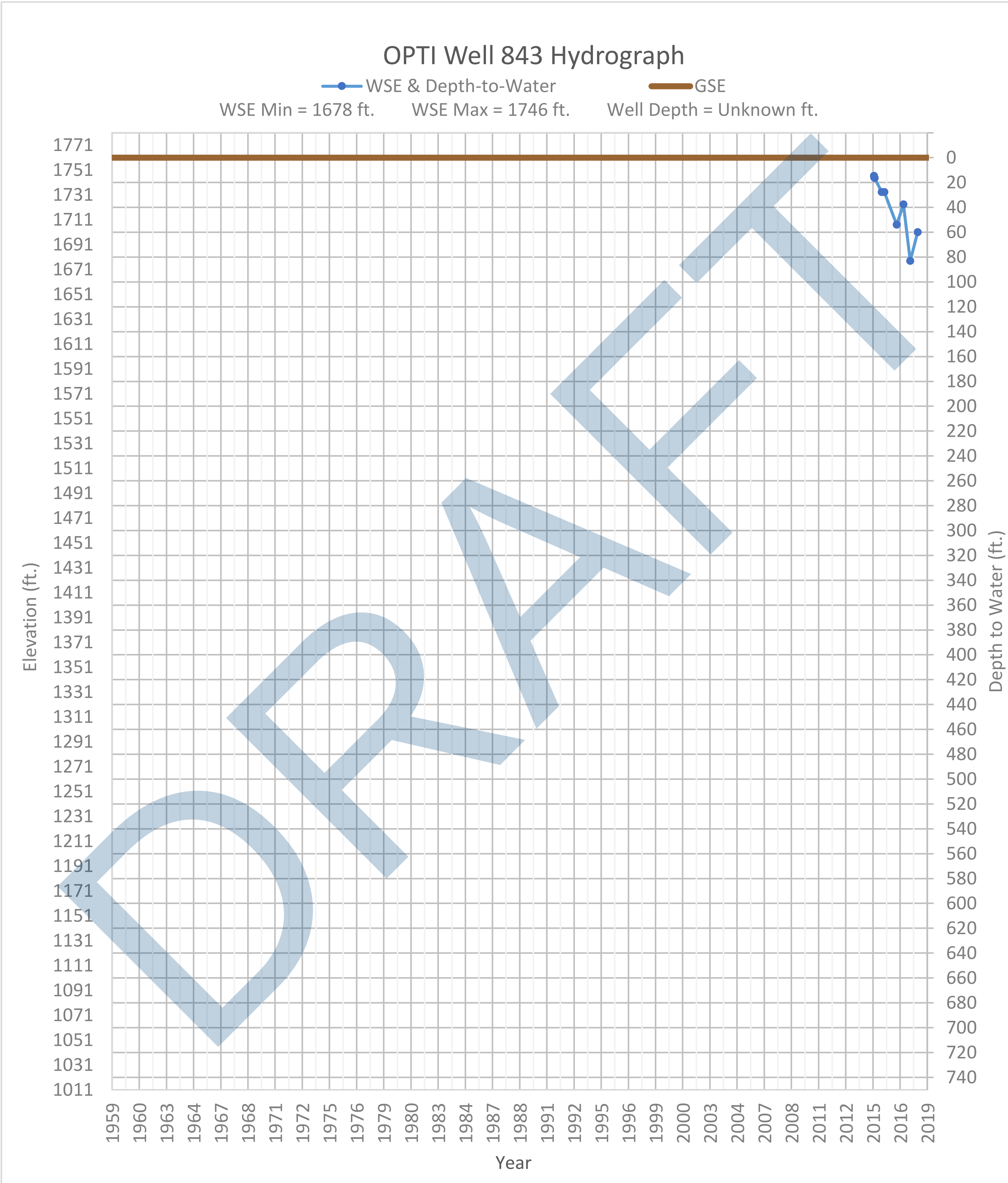
OPTI Well 840 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1657 ft.
WSE Max = 1712 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 841 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1701 ft.
WSE Max = 1740 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 842 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1698 ft.
WSE Max = 1751 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 843 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1678 ft.
WSE Max = 1746 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
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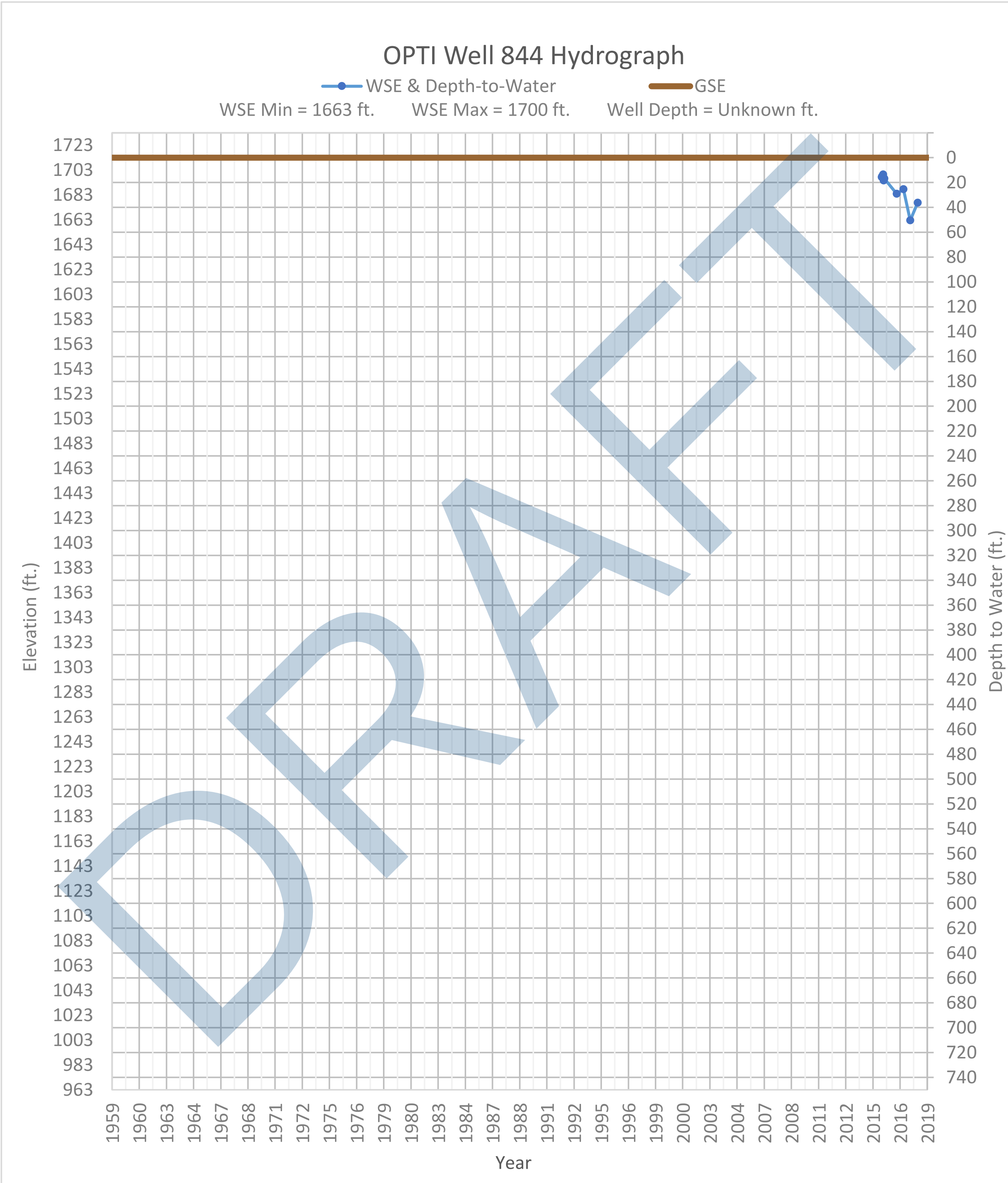
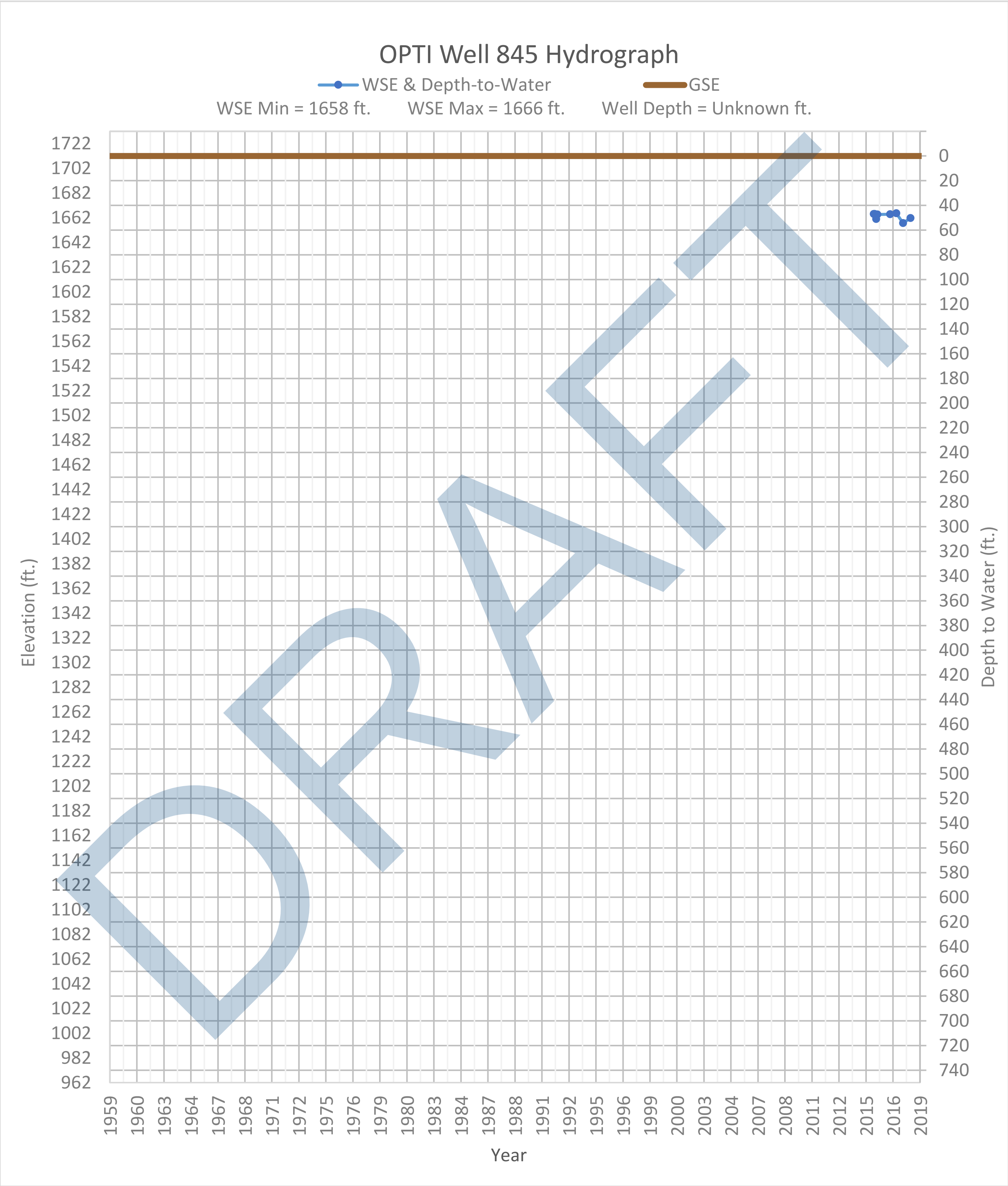
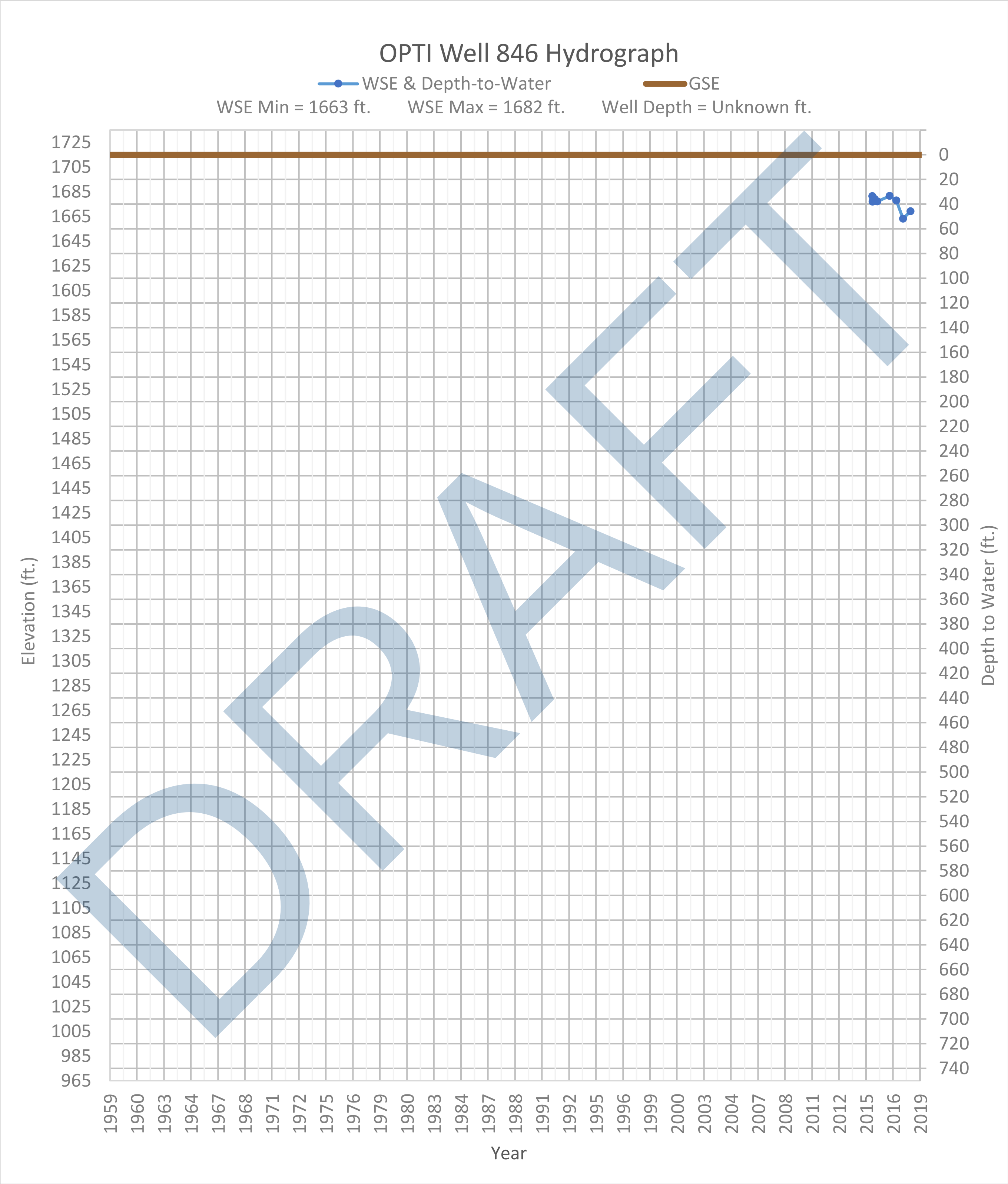
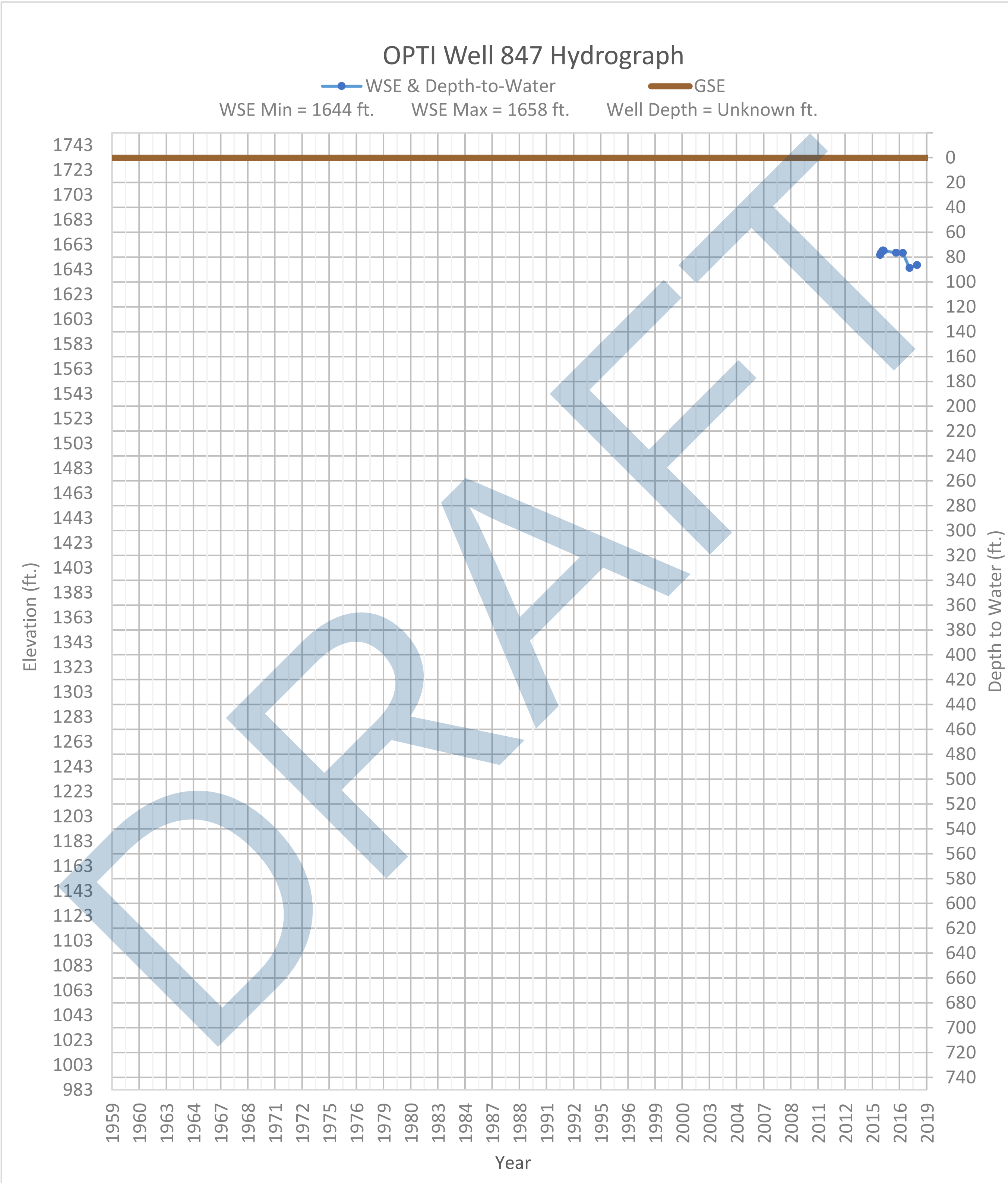
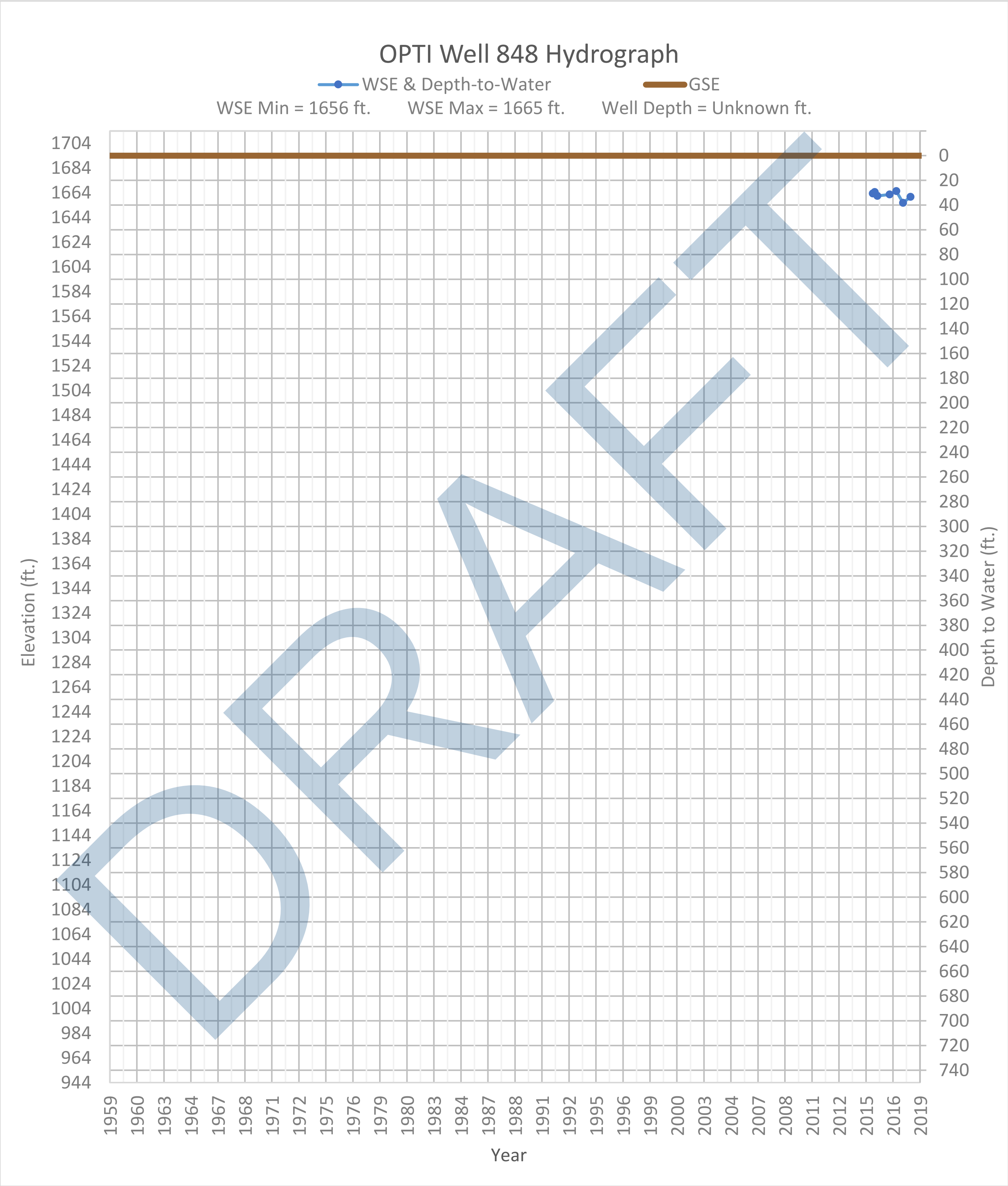

OPTI Well 844 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1663 ft.
WSE Max = 1700 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT


OPTI Well 845 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1658 ft.
WSE Max = 1666 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

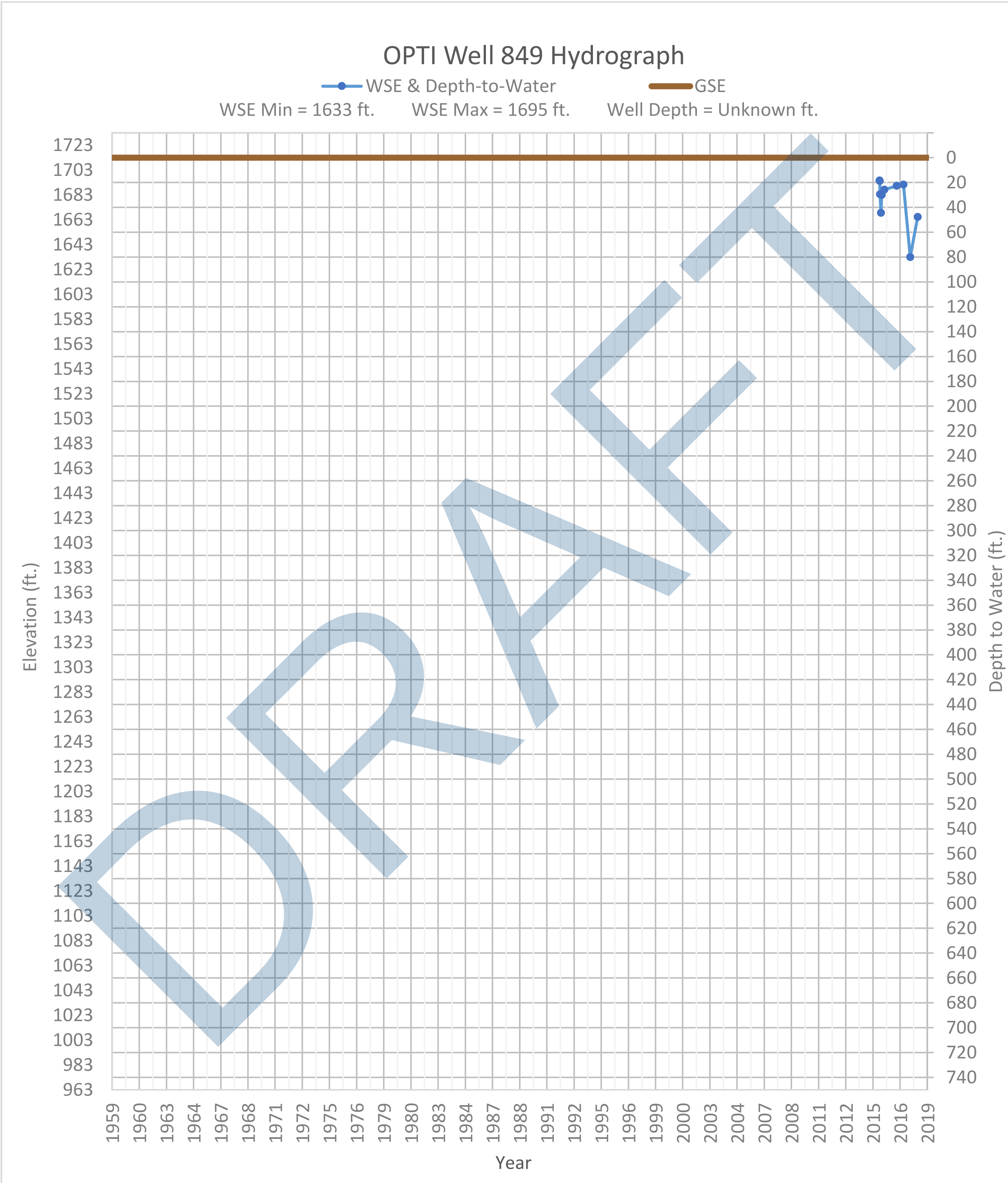

OPTI Well 846 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1663 ft.
WSE Max = 1682 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



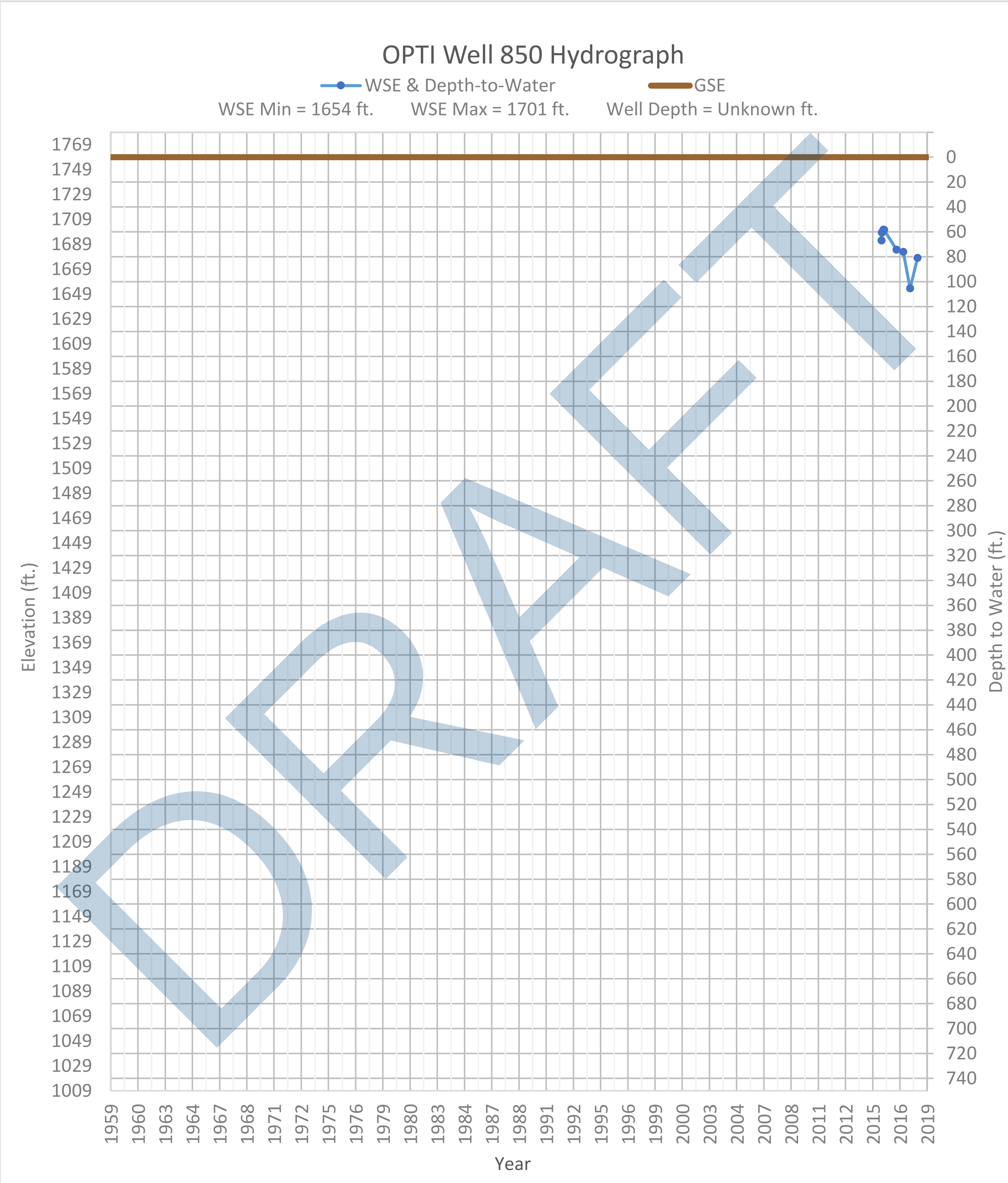
OPTI Well 847 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1644 ft.
WSE Max = 1658 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 848 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1656 ft.
WSE Max = 1665 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 849 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1633 ft.
WSE Max = 1695 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT



OPTI Well 850 Hydrograph
WSE & Depth-to-Water
GSE
WSE Min = 1654 ft.
WSE Max = 1701 ft.
Well Depth = Unknown ft.
Elevation (ft.)
Depth to Water (ft.)
Year
DRAFT

# Appendix B

## White Paper: Subsidence and Subsidence Monitoring Techniques

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# Subsidence White Paper

**Author: C. Micah Eggleton** - *Environmental Planner* at Woodard & Curran, September 19, 2017.
meggleton@woodardcurran.com

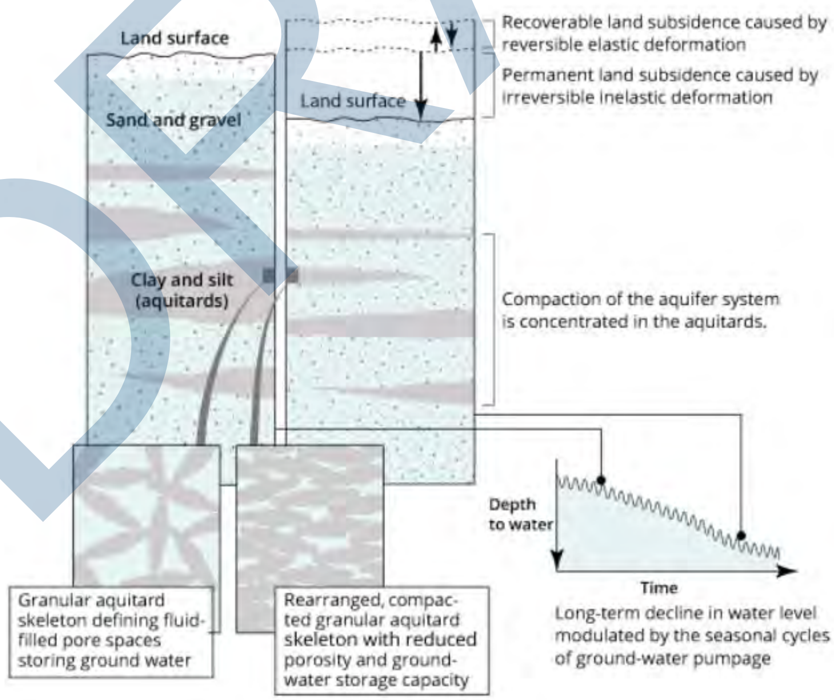
## What is Subsidence?

Land subsidence is the sinking or downward settling of the earth's surface, not restricted in rate, magnitude, or area involved. Subsidence is often a result of over-extraction of subsurface water. In these cases, subsidence generally occurs over a large to very large area (10's to 100's of km$^2$) and may happen over several years.

## How Subsidence Occurs

Groundwater saturates the sediments in the subsurface where groundwater is present. Sediments in water bearing units are commonly made up of sands, gravels, silts, and clays. Aquitards are composed of clay materials, and may have multiple thin layers or larger extensive, and/or thicker layers. Groundwater in these materials fills the pore spaces and supports the material's structure. As groundwater levels decline, the sands, gravels, silts, and clays in water bearing units are dewatered, and the water's support of the structure of the materials is removed. Clays in particular rearrange when dewatered and clay grains orient in a similar direction, which reduces the amount of pore space and thus, the clay compacts. As the clays compact, ground surface elevation begins to drop.

**Figure 1: Subsidence and Compaction Process**




Source: USGS, Ladn Subsidence: Cause and Effect. 9/17/2017. https://ca.water.usgs.gov/land_subsidence/california-subsidence-cause-effect.html#pumping

This is problematic all over the world but is of particular concern in California agricultural communities such as the Cuyama Basin. Cuyama Basin subsidence may have effects on agriculture in a few ways.

1. Water delivery systems that may deliver irrigation water can be affected by land subsidence. Surface canals or gravity lines may not have enough elevation gradient to transport water or may even have reverse flows due to changes in ground surface elevation.
2. Infrastructure such as buildings and roads may be de-leveled and need repair

Not all groundwater pumping results in permanent subsidence. Groundwater reservoirs have an *elastic* and *inelastic* range of stress. Within the elastic range of stress, water levels in a groundwater storage unit can fluctuate without damaging the storage unit's ability to recharge to its original capacity. If water levels in a storage system dip into the inelastic range, the clays compact and cause inelastic land subsidence.

Clays and silts, such as those present in the Younger Alluvium, Older Alluvium, and Upper Morales Formations, generally have lower elastic capabilities, meaning they are not able to recover to their original volume once water has been removed. Once clays and silts are heavily compacted, they often cannot return to their previous saturation capacity even if groundwater levels are increased; this permanently reduces the storage capacity of the aquifer. This loss of aquifer is limited to the water that was stored in the compressed clays, and storage capacity lost is limited to the water that was stored in clays that were compressed, which is reflected in the amount of subsidence measured. Water stored in clay materials is generally not available for use by wells.


**Figure 2: Subsidence Visualized**

Source: USGS, https://ca.water.usgs.gov/land_subsidence/



## Methods of Measuring Land Subsidence

Measurements of elevations, aquifer-system compaction, and water levels are used to improve our understanding of the processes responsible for land-surface elevation changes. Elevation or elevation-change measurements are fundamental to monitoring land subsidence and have been measured by using interferometric synthetic aperture radar (InSAR), continuous GPS (CGPS) measurements, extensometers, and spirit-leveling surveying.

Interferometric Synthetic Aperture Radar (InSAR)

InSAR is a method and product of remote sensing imagery that measure changes in land-surface altitude by sending radar signals (historically C-band but new equipment often uses L- or X-band) to the land surface and measuring the return time of that signal. Changes in land surface elevation are calculated by taking the difference between two SAR images of the same area taken at different times. The difference between the two shows the ground-surface displacement (range change) between the two time periods.

The spatial resolution of InSAR is dependent on the location and resolution of the remote imagery, and whether it is taken from a plane or by orbiting satellite. At its finest resolution, InSAR has a sampling pixel of approximately 25' by 25' from satellites. The resolution of vertical displacement is dependent upon meteorological, observational, and other conditions, but is typically within a few centimeters to millimeters.

Raw InSAR data requires specialized computer programs to process and view. Some agencies and organizations, such as the California Water Science Center, provide InSAR imagery online. Direct data downloads are possible, but require registration approved with UNAVCO as an affiliate with an institution engaged in SAR research to download data. Data is available for anyone to browse online, and there are several agencies/institutes that publish data for specific regions.

Currently, InSAR imagery is obtained via specialized radar equipment on an aircraft and managed by NASA's Jet Propulsion Laboratory (JPL). In December 2021, the satellite NISAR is scheduled to launch; NISAR will provide coverage every 12 days and all NASA data will be free.

Continuous Global Positing System (CGPS)

CGPS stations continuously measure the three-dimensional position of a sensor. There are more than 1,000 sensors in Western North America, with hundreds in California. Most sensors are managed by the Plate Boundary Observatory/UNAVCO and by Scripps Orbit and Permanent Arrary Center (SOPAC), but other groups such as Caltrans also operate sensors. These monitoring stations help measure tectonic movements as well as subsidence, which means data is taken in the X, Y, and Z axis.

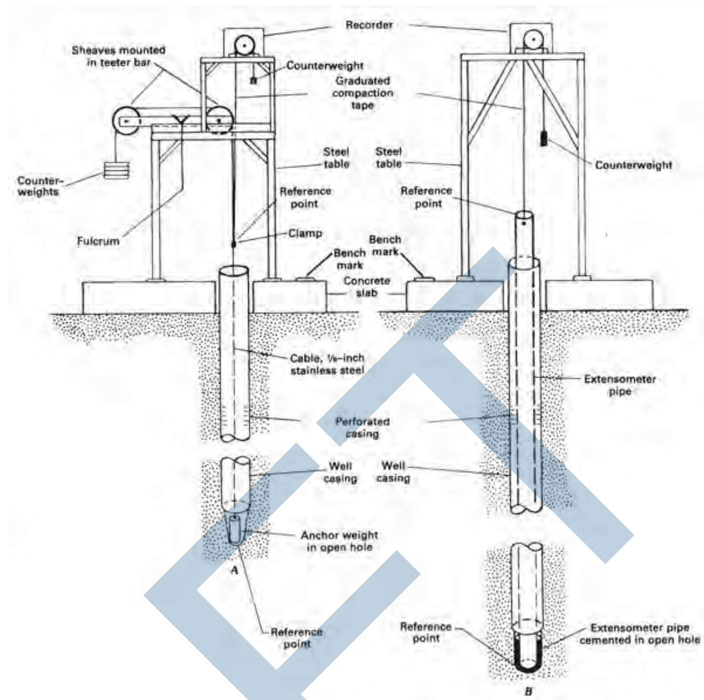
Measurements are typically taken every 15 seconds and are processed to produce a daily position. The CGPS system has data/information published online, however, some use is limited and registration is required for certain data access.

Currently, subsidence measurements in and immediately around the Cuyama Basin are taken through CGPS instrumentation.

Spirit Leveling

This is the oldest method of measuring subsidence and was used long before electronic aids such as GPS. The primary tool is a Spirit Level in combination with a telescope and graduated vertical rods. Measurements are based on one reference point. This technique is best used for smaller survey areas (5 miles or less) and areas where high spatial density is desired. This is a good option for localized surveying and where cost is a priority.

<u>Extensometers</u>




Extensometers are *one dimensional* indicators of change in a specified depth. In regards to land subsidence, they often measure the change in an aquifer system within a specific depth range – that is to say, if the extensometer extends 20 meters into the ground, it can only measure the change in compaction (or expansion) within those 20m. It is also important to understand that extensometers measure compaction/expansion, *not* elevation.

Between the 1950s and 1970s, more than two dozen extensometers were installed in California's Central Valley by the USGS, with additional units installed since then.

Most extensometers are constructed as cable or pipe borehole extensometers (see the figure to the right above). They function by having a cable or pipe extend to the bottom of a drilled hole to the measuring depth at a specific reference point. At the top of this cable or pipe is a reference point, and attached to the reference point is another cable that extends to the top of a platform near the ground surface, around a wheel, and to a counter weight which maintains tension on all cables. As the ground elevation and bottom reference point change in relation to one another, the wheel turns as the counter weight either drops or rises. This change in the position of the counter weight is equal to the amount of compaction between the two reference points.

Although simple in theory, extensometers can be costly to install due to the drilling that is required and robust equipment needed. In addition, multiple extensometers are often needed to measure compaction across a range of depths and to determine which portion of the subsurface is compacting.

<u>Piezometers</u>

Piezometers measure the hydraulic pressure in a groundwater system. Piezometers are paired with extensometers or CGPS data to analyze stress-strain characteristics of a groundwater system. These systems allow for the calculation of the *skeletal storage coefficient*, which is the standard measure of an aquifer's storage directly related to the compressibility of the soil/storage system. This is what largely controls how "recoverable" an aquifer system is when it is recharged with water.

If water levels continue to decline into the inelastic range of stress, it can become possible to compute the *inelastic storage coefficient* that governs the permanent compaction of the aquifer system. If water levels fluctuate into both of these ranges seasonally or annually, it may be possible to calculate both.

# Appendix C

Cuyama Basin Integrated Water Flow Model

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## Table of Contents



## Tables

## Figures



## Attachments

# Appendix C — Cuyama Basin Water Resources Model Documentation

## Introduction

### Goals of Model Development

The Cuyama Basin Water Resources Model (CBWRM) was developed to evaluate the recent historical, current, and projected surface water and groundwater conditions in the Cuyama Groundwater Basin (Basin), and simulate various scenarios as part of the Basin's *Groundwater Sustainability Plan* (GSP). The fine temporal and spatial scale of the CBRWM allows the Cuyama Basin Groundwater Sustainability Agency (CBGSA) and its stakeholders to evaluate the effect of changing groundwater conditions in different parts of the Basin.

The CBWRM was developed in consultation with members of the Technical Forum, which includes technical staff and consultants representing a range of public and private entities in the Basin. Technical Forum members are listed in Chapter 1, Section 1.3. The Technical Forum held 14 monthly conference calls over the course of CBWRM development, and model data and outputs were provided to Technical Forum members to facilitate review and feedback on model development. This allowed Technical Forum members to review and comment on all major aspects of CBWRM development.

### Basin Overview

The Basin encompasses an area of approximately 378 square miles, and includes the communities of New Cuyama and Cuyama, which are located along State Route (SR) 166 and Ventucopa, which is located along SR 33. Figure C-1 shows the Cuyama Basin and its key geographic features. The Basin encompasses an approximately 55-mile stretch of the Cuyama River, which runs through the Basin for much of its extent before leaving the Basin to the northwest and flowing toward the Pacific Ocean. The Basin also encompasses reaches of Wells Creek in its north-central area, Santa Barbara Creek in the south-central area, and the Quatal Canyon drainage and Cuyama Creek in the southern area of the Basin. Primary land use and development in the Basin is agricultural use, which mostly occurs in the central portion east of New Cuyama, and along the Cuyama River near SR 33 through Ventucopa. Additionally, there has recently been new agricultural development in the western part of the Basin.

### CBRWM Platform

The CBWRM was developed based on the Integrated Water Flow Model (IWFM) software platform. The IWFM is an open-source, finite element simulation code that supports triangular and quadrilateral elements (Dogrul et al., 2017b). IWFM was specifically designated in the Sustainable Groundwater Management Act (SGMA) regulations as a model supported by the California Department of Water Resources (DWR) for evaluation of the integrated surface water and groundwater resources a basin, including detailed water budget development that meets SGMA requirements. IWFM has been used throughout California for planning and management of water resources, including GSP development. IWFM is also used for DWR's California Central Valley Groundwater-Surface Water Simulation Model

(C2VSim), which is the fine-grid version that is being refined and enhanced by DWR to support SGMA activities throughout the Central Valley at the regional scale (DWR, 2018).

The IWFM Demand Calculator (IDC) is the stand-alone root zone component of IWFM that simulates land surface and root zone flow processes (Dogrul et al., 2017b). It calculates agricultural and urban water demands using inputs including climatic conditions, soil hydrologic conditions, and land use types and cropping patterns. The IDC can be used as a stand-alone model, or it can be combined with IWFM. When combined, the full IWFM model simulates the integrated system of land surface processes and groundwater system and the stream system, as well as interaction among these systems.

## CBWRM Development

### Model Input Data

The CBWRM historical model simulates Basin hydrologic conditions on a daily time step from water year 1995 through water year 2017 (i.e., October 1, 1994 through September 30, 2017). Table C-1 lists CBWRM files and corresponding major data sources.

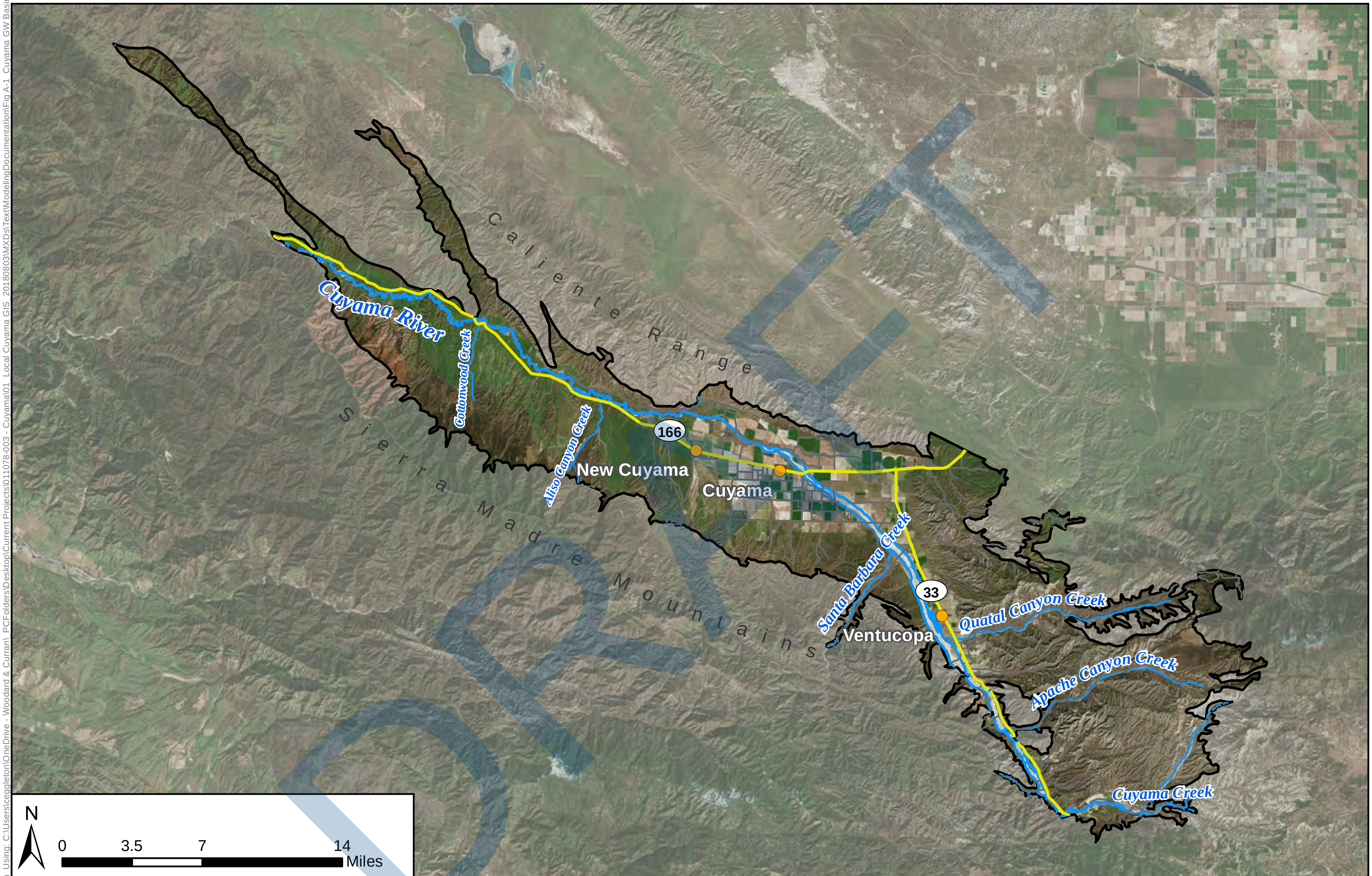


**Figure C-1 - Cuyama Valley Groundwater Basin**

Cuyama Basin Groundwater Sustainability Agency

Cuyama Valley Groundwater Basin Groundwater Sustainability Plan

April 2019

WOODARD & CURRAN

*Legend*

- Towns
- Cuyama Basin
- Highways
- Local Roads
- Cuyama River
- Streams/Creeks

**Table C-1: CBWRM Major Model Data**

| Major Data Category | Minor Data Category | Data Source |
|---|---|---|
| Hydrogeological Data | Geologic Stratification | Diblee Maps and Cuyama Valley Hydrologic Model (CUVHM) |
| Stream Data | Stream Configuration | National Hydrography Dataset (NHD) |
| | Streamflow Records | United States Geological Survey (USGS) and California Data Exchange Center (CDEC) Stream Gages |
| Hydrological Data | Precipitation | Parameter-Elevation Relationships on Independent Slopes Model (PRISM) |
| Agricultural Water Demand | Land Use and Cropping Patterns | • DWR<br>• Private Landowners<br>• CBGSA-developed data |
| | Evapotranspiration | California Irrigation Management Information System (CIMIS) |
| | Soil Properties | Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) |
| Urban Water Demand | Population | United States Census Bureau |
| | Per Capita Water Use | Cuyama Community Services District (CCSD) Local Information |
| Water Supply | Groundwater Pumping | CCSD |
| Other | Initial GW Level Conditions | • DWR Water Data Library<br>• Private landowners |
| | Small Watersheds | NHD |
| | GW Level Records for Calibration Wells | • DWR Water Data Library<br>• Private landowners |

Analysts developed the 50-year hydrologic period of water years 1968 through 2017 for use in CBWRM to meet SGMA requirements for long-term water budget representation for current and projected Basin conditions.

## CBWRM Grid

Analysts developed the finite element grid using the Groundwater Modeling System (GMS) software' the grid development module. The model grid network is composed of a combination of quadrilateral and triangular elements, which allows a detailed representation of various hydrologic, geologic, and jurisdictional features required for development of information about land and water use, water supply, groundwater conditions, and water budget. The CBWRM grid and the specific features used in grid development are shown in Figure C-2. These features include the following:

- The Basin boundary as defined in DWR's Bulletin 118 (DWR, 2004)
- Hydrologic and hydrogeologic features (i.e., Cuyama River and minor streams, faults, and outcroppings)
- The Cuyama Community Services District (CCSD) boundary
- Cuyama Water District boundary

The CBWRM grid contains 6,582 elements with an average element area of 36.8 acres. Primary objectives during grid development were to maintain a manageable number of elements and nodes for model computational performance, to optimize resolution for data analysis, and to contain relatively finer resolution along rivers, which allows for better simulation of stream-aquifer interaction to optimize the model run time and to streamline model output.

## Stream Configuration and Watersheds

The CBWRM surface hydrology is represented by nine model stream reaches, representing the Cuyama River. The USGS has two active gages that record flows in the Cuyama River watershed upstream of Lake Twitchell. These include one gage on the Cuyama River downstream of the Basin (ID 11136800), which is located just upstream of Lake Twitchell. This gage has 58 recorded years of streamflow measurements from 1959 to 2017. The other active gage is south of the city of Ventucopa along Santa Barbara Canyon Creek (ID 11136600), and this partial record is limited to seven years (i.e., from 2010 to 2017).

The inflow from upper watershed areas originates from ungaged watersheds. Figure C-3 shows the upper watershed areas included in the model. Flows from ungaged watersheds surrounding the Basin are estimated using a simplified rainfall runoff module incorporated in the small watersheds module of the CBWRM. This module simulates the surface water and groundwater contributions from the small watersheds using daily precipitation rates and runoff and infiltration characteristics assigned to each ungaged watershed. The portion of flow from the small watershed that enters the model domain as surface runoff is directed to drain into simulated streams. The portion of flow from small watersheds that infiltrates to ground contributes to the main groundwater system as boundary flows.

All subsurface inflows from these small watersheds are routed to model Layer 1 along specified groundwater nodes, with a user-defined maximum percolation rate at each node. Excess flows that do not infiltrate to groundwater enter the simulated streams at user-specified locations. The hydrologic conditions of these small watersheds used to estimate the subsurface and surface flows are represented using parameters (e.g., precipitation, surface layer soil parameters, runoff coefficient) for each watershed.

## Precipitation

Rainfall data for the CBWRM area are derived from the PRISM database (PRISM Climate Group, 2018). The database contains monthly precipitation data starting from 1895 and daily precipitation data from December 1, 1981 on a 4-kilometer grid throughout the model area. To develop data for the daily time step of the CBWRM, monthly precipitation data for the 1968 to 1981 time period was downscaled to daily temporal resolution with a similar water year type analysis using the recorded Cuyama River flows. Each of the model elements was mapped to the nearest PRISM reference node, which are uniformly distributed across the model domain. The resulting average annual precipitation is shown in Figure C-4.

Figure C-5 shows the Basin averaged annual rainfall in the model area and the cumulative departure from mean, which is an indication of long-term rainfall trends in the area. The average annual precipitation during the 50-year hydrologic sequence from October 1967 to September 2017 was 13.1 inches, which ranges from an annual average of 11.4 inches in the valley floor to 14.8 inches in the upper watershed areas.

Attachment 1 describes the climate change scenarios analyzed for projected future conditions, and the modifications made to the precipitation data to reflect the effects of climate change.

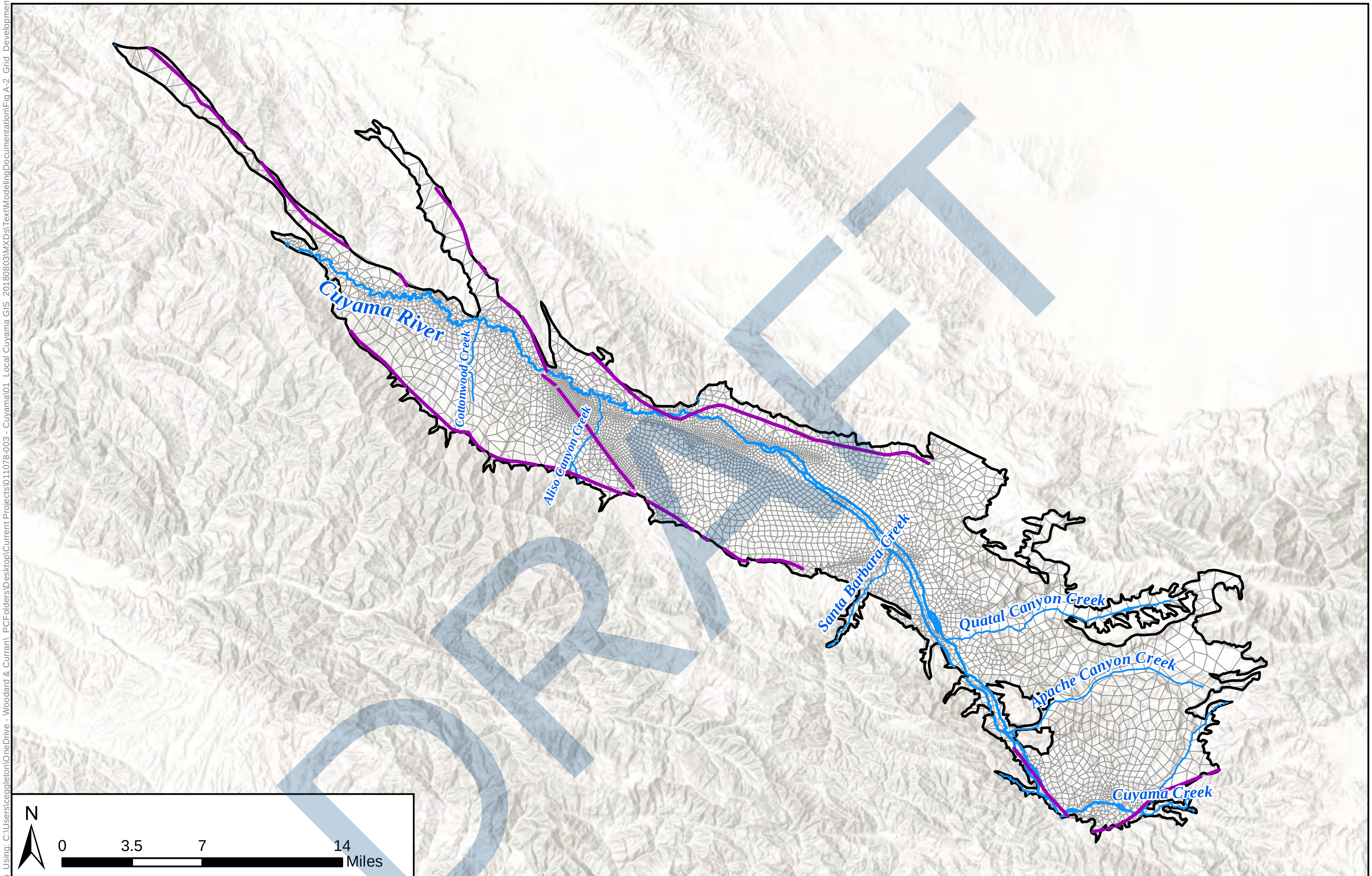


**Figure C-2 - Cuyama Valley Groundwater Basin IWFM Grid Development Features**

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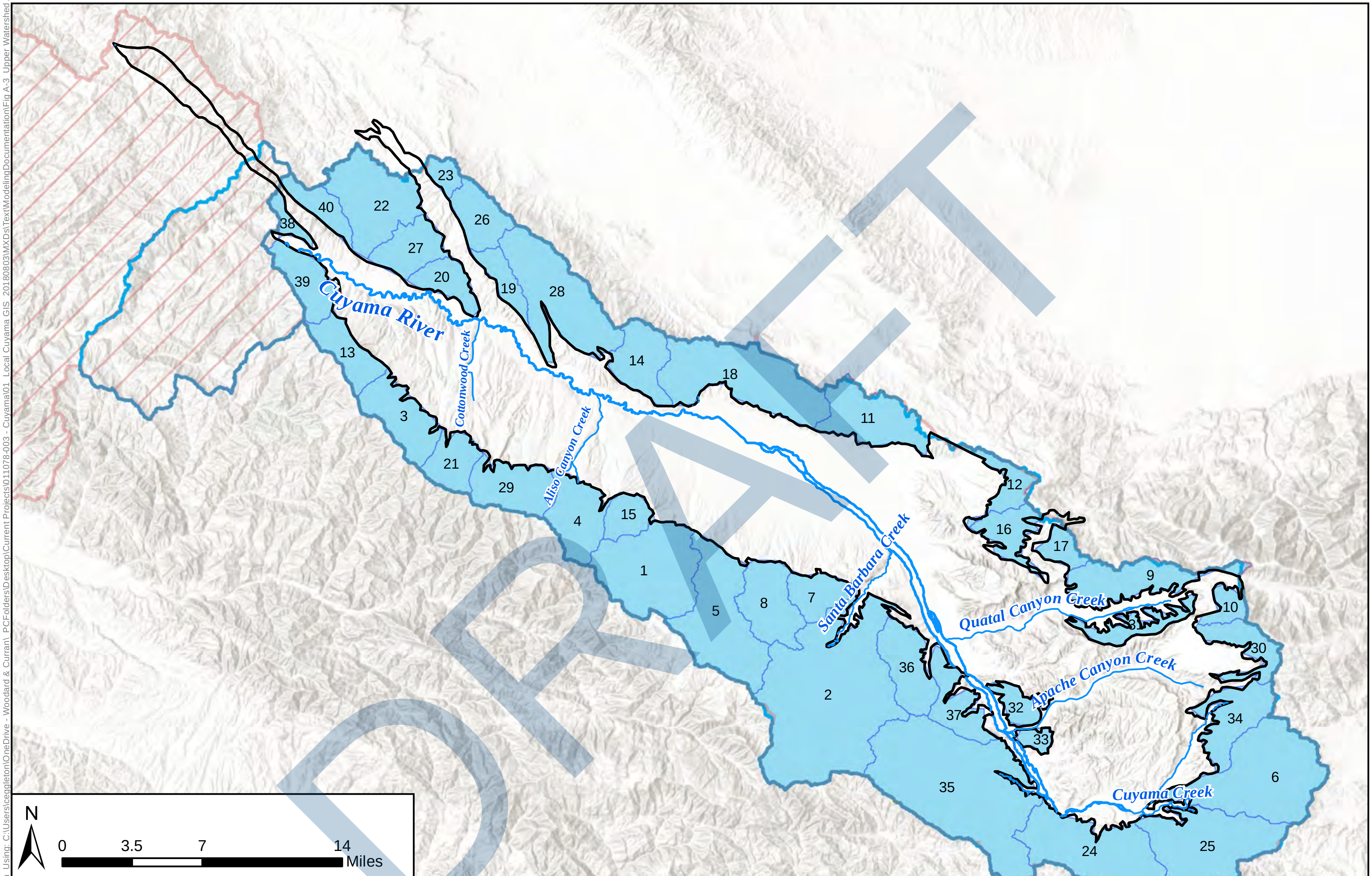


**Figure C-3 - Cuyama Valley Groundwater Basin Upper Watershed Areas in the IWFM Model**

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Legend

- Cuyama Basin
- Cuyama River
- Streams/Creeks
- Contributes to Cuyama GW Basin
- Does Not Contribute to Cuyama GW Basin
- Watershed
- Small Watersheds (HUC 12)

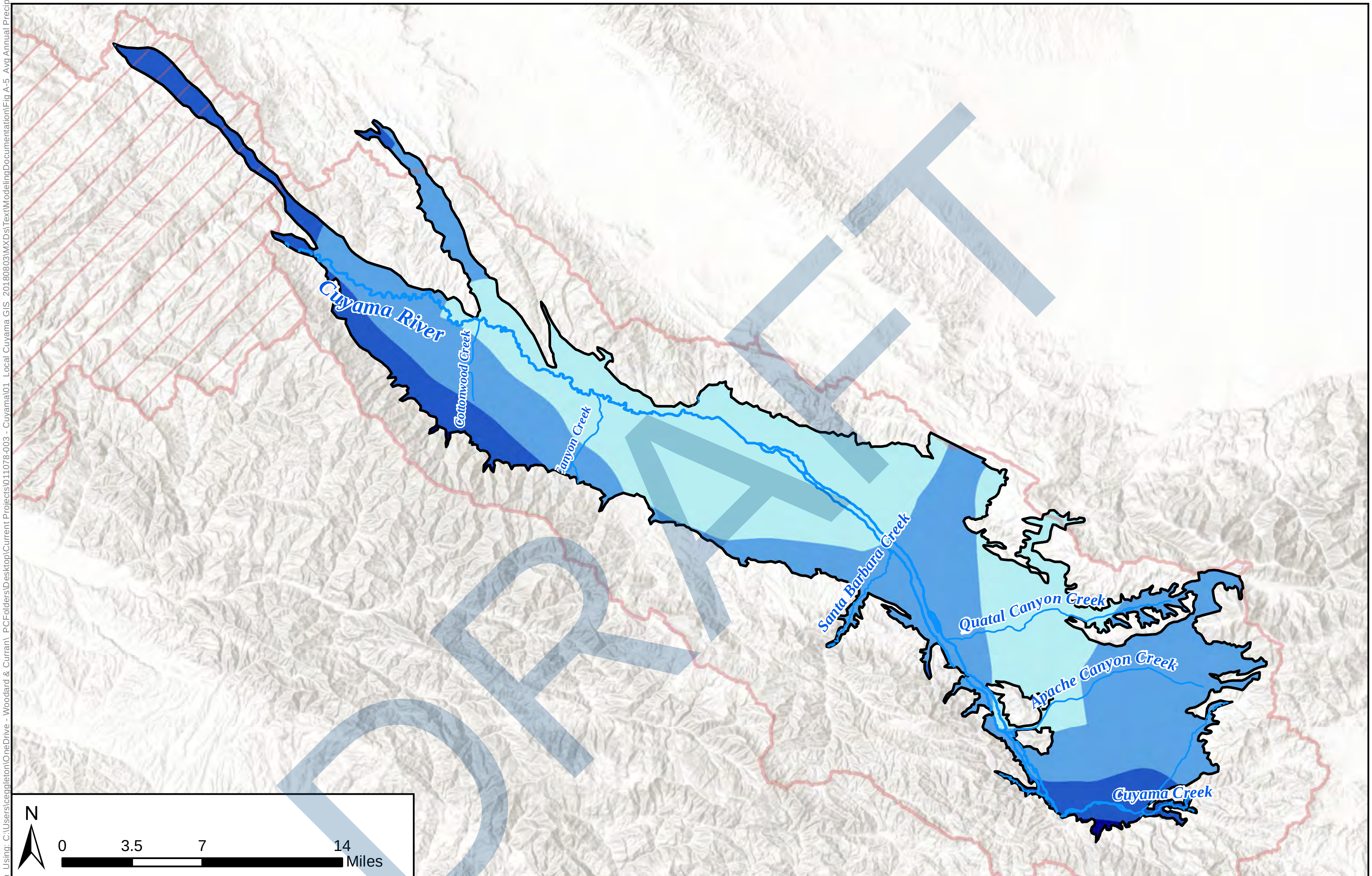




**Figure C-4 - Cuyama Valley Groundwater Basin Average Annual Precipitation**

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*Legend*

- Cuyama Basin
- Cuyama River
- Streams/Creeks
- Contributes to Cuyama GW Basin
- Does Not Contribute to Cuyama GW Basin

**Average Annual Precipitation (.in)**

- 5.1 - 10
- 11 - 15
- 16 - 20
- 21 - 25

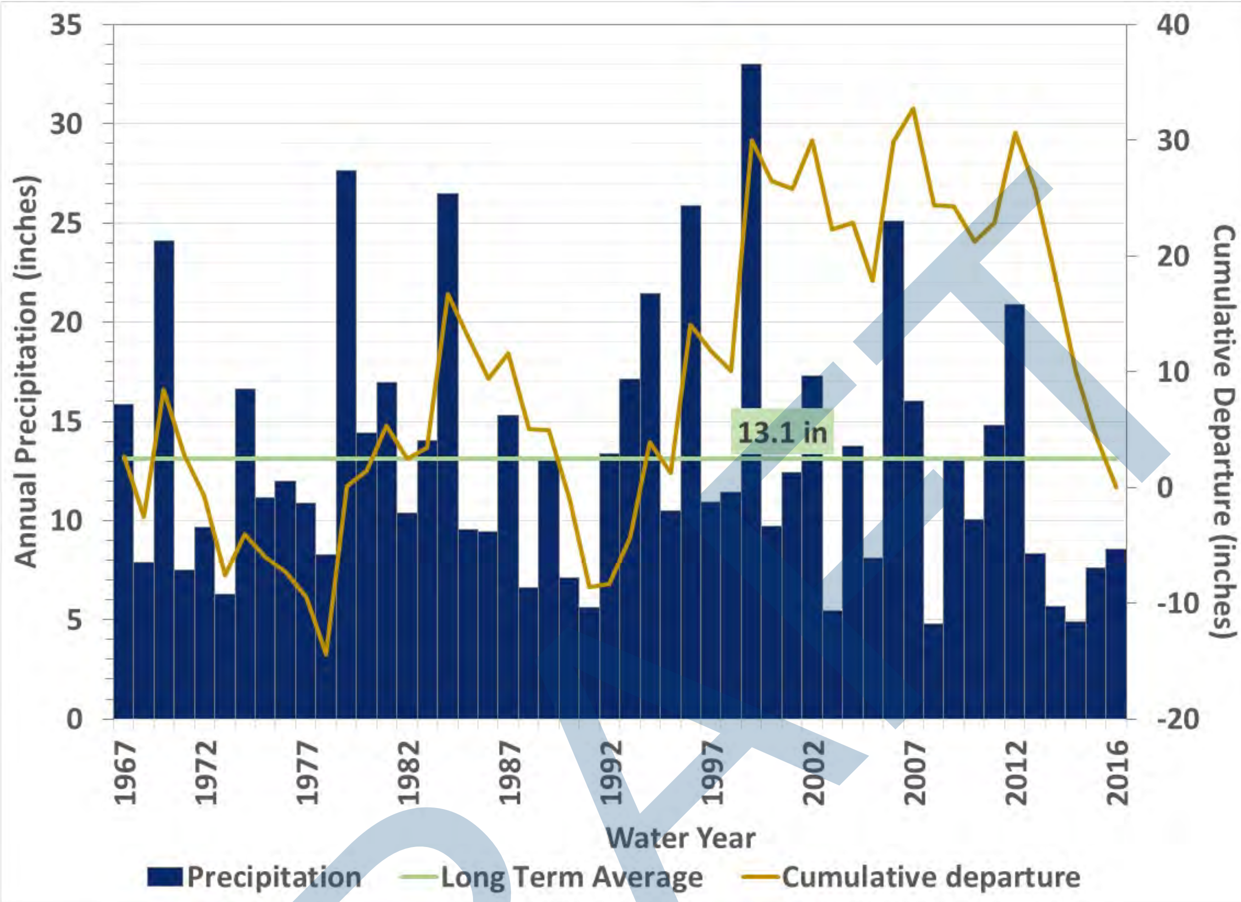

Figure C-5: 50-Year Historical Precipitation and Cumulative Departure from Mean Precipitation

## Root Zone Soil Parameters

Soil properties specified in the CBWRM are field capacity, wilting point, total porosity, saturated hydraulic conductivity, and pore size distribution index. These soil properties are specified for each model element, and were used to calculate runoff and infiltration from both rainfall and applied water at each model time step.

DWR's IWFM Soil Data Builder (DWR, 2017) was used in conjunction with the SSURGO (USDA, 2017a) soil data to determine the five soil parameters for each model element. The IWFM Soil Data Builder extracts the SSURGO data relevant to the model area and associates it with each model grid element. For the elements where SSURGO data was incomplete, analysts used the USDA's Digital General Soil Map of the United States (STATSGO2) data (USDA, 2017b) to complement SSURGO parameters.

CBRWM elements are associated with the four hydrologic soil groups according to their runoff potential and infiltration characteristics. NRCS defines these hydrological soil groups as follows (NRCS, 2009):

- **Group A** – Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- **Group B** – Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 and 20 percent clay and 50 to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- **Group C** – Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- **Group D** – Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential.

## Land Use and Cropping Patterns

Land use and cropping patterns are key data sets that support estimation of monthly agricultural water requirements over the period of model simulation. Consistent with the DWR's C2VSim, the CBWRM includes 23 irrigated crop categories and four general land use categories. The general land use categories include urban landscape (e.g., residential areas, school fields, roads, etc.), water surface (e.g., streams, lakes, and reservoirs), riparian vegetation (e.g., native vegetation in the vicinity of surface water), and native vegetation. The 23 irrigated crop categories are combined into six summary-level crop group with similar water use and/or irrigation practices, which also provides a simpler representation of crop group types for planning and policy purposes. Table C-2 lists the land use categories.

**Table C-2: Land Use Categories**

| Land Use Type | Model Category | Grouped Categories |
|---|---|---|
| Irrigated Crops | • Apple<br>• Berry<br>• Citrus<br>• Olive<br>• Pistachio<br>• Misc. Deciduous<br>• Misc. Subtropical Fruits | Fruit and Nut Trees |
| | Vineyards | Vineyards |
| | • Alfalfa<br>• Mixed Pasture | Alfalfa and Irrigated Pasture |
| | • Misc. Grain<br>• Misc. Grass<br>• Wheat | Grain |
| | • Dry Beans<br>• Corn<br>• Misc. Field Crops<br>• Safflowers | Field Crops |
| | • Carrot<br>• Cole<br>• Mixed Greens<br>• Lettuce<br>• Melons<br>• Onion<br>• Potatoes<br>• Misc. Truck Crops | Truck Crops |
| | Idle and Fallow Lands | Idle |
| Other Land Use | • Urban Landscape<br>• Water Surface<br>• Riparian Vegetation<br>• Native Vegetation | |

Spatial land use data were used to specify land use types and crop acreages for each model element for each year of simulation. The following data sources were used:

- 1996 data from historical DWR county land use surveys[1]
- 2014 and 2016 data that were developed for DWR using remote sensing data by LandIQ[2]
- 2000, 2003, 2006, 2009, 2012 data that were developed for the CBGSA using remote sensing data; development of these datasets is documented in Attachment 2.
- Data provided by private landowners for portions of the Basin between 1992 and 2017

Figure C-6 shows the spatial distribution of the major land use categories in the Basin for 2016.[3] Estimated land use in 2016 includes approximately 36,500 acres of irrigated land use. Figure C-7 shows the historical trend of land use categories in the Basin and the projected assumed annual land use pattern for the 50-year hydrologic period used for the projected condition model scenario. The projected annual land use categories are developed based on the 2017 crop categories as the basis, with annual variability developed based on an autoregressive moving average model that uses the historical land use data sets.



[1] https://www.water.ca.gov/Programs/Water-Use-And-Efficiency/Land-And-Water-Use/Land-Use-Surveys
[2] https://gis.water.ca.gov/app/CADWRLandUseViewer/
[3] Figures for other years can be found in Chapter 1

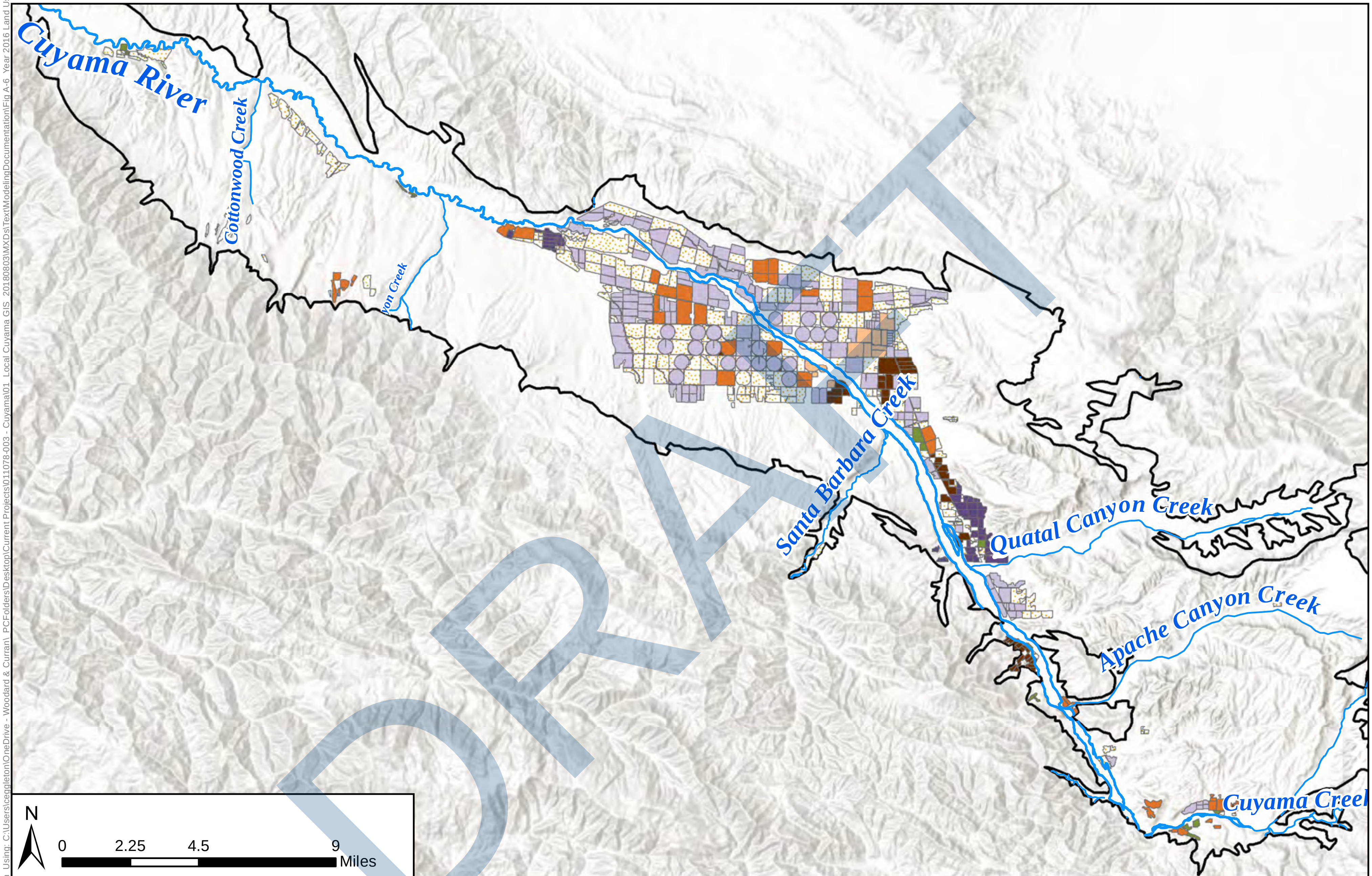


**Figure C-6 - Cuyama Valley Groundwater Basin Year 2016 Land Use**

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*Legend*

- Cuyama Basin
- Cuyama River
- Streams/Creeks

**Land Use from 2016 Crop Mapping**

- Alfalfa and Irrigated Pasture
- Fruit and Nut Trees
- Field Crops
- Truck Crops
- Vineyard
- Grain
- Idle

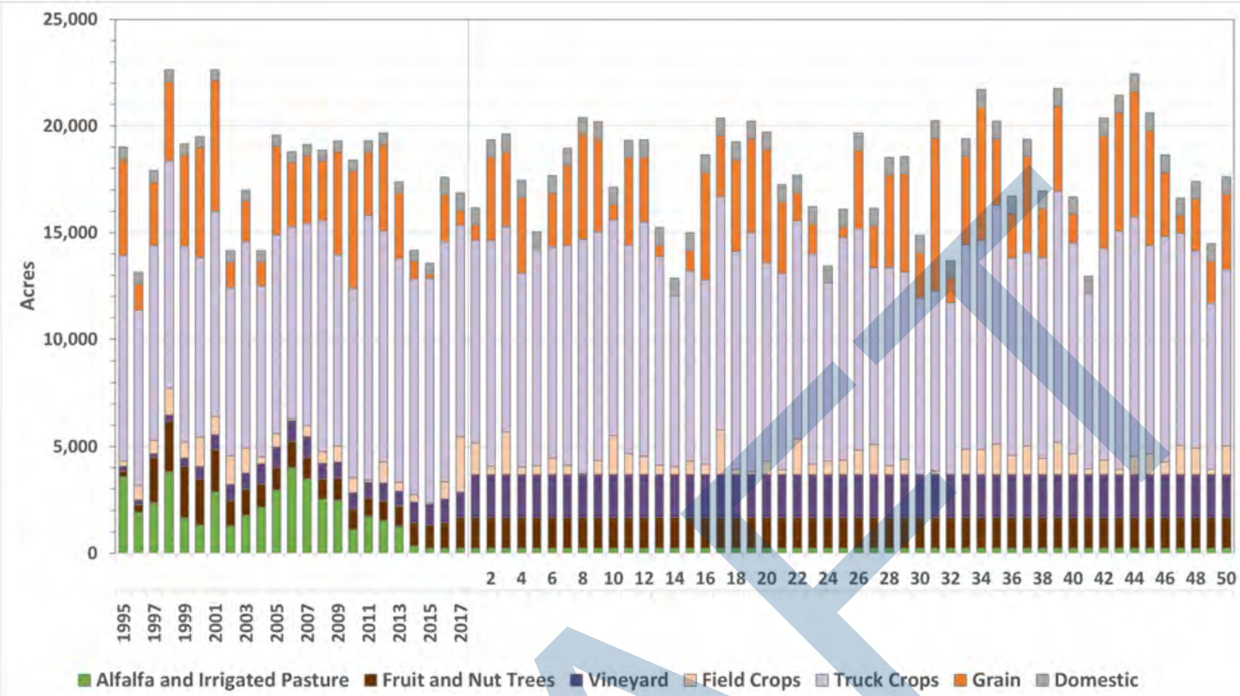



**Figure C-7: Historical and Projected Land Use in the Basin**

## Evapotranspiration

The crop evapotranspiration (ET) requirement is an important factor in agricultural demand estimation. Every land use category must have evapotranspiration assigned for the simulation period. Due to changes in cropping patterns and irrigation practices over time during the historical calibration period, the ET data are specified as a time series during the entire calibration period. ET values are based on the reference evapotranspiration data from Cuyama CIMIS Station. The reference evapotranspiration was converted to crop evapotranspiration using crop coefficients, supplemented by information developed using the Mapping EvapoTranspiration at High Resolution with Internalized Calibration (METRIC) methodology (as described in Attachment 3). Crop coefficients for each land use category were developed using the Remote Sensing Root Zone (RSRZ) model. The RSRZ Model is driven by the Landsat Normalized Difference Vegetation Index (NDVI) data set, which was originally developed for the Kaweah Delta Water Conservation District in Tulare and Kings counties. The RSRZ model simulates the rootzone processes on a daily time step, and using remote sensing data, it can capture changes in the timing and intensity of cropping over time.

In the CBWRM, ET represents the net vertical water flux from the land surface and root zone through the upper model layer. Figure C-8 shows the range in annual evapotranspiration rates for each crop category. For climate change scenarios analyzed for projected future conditions, evapotranspiration rates were modified to reflect the effects of anticipated temperature change (Attachment 3).

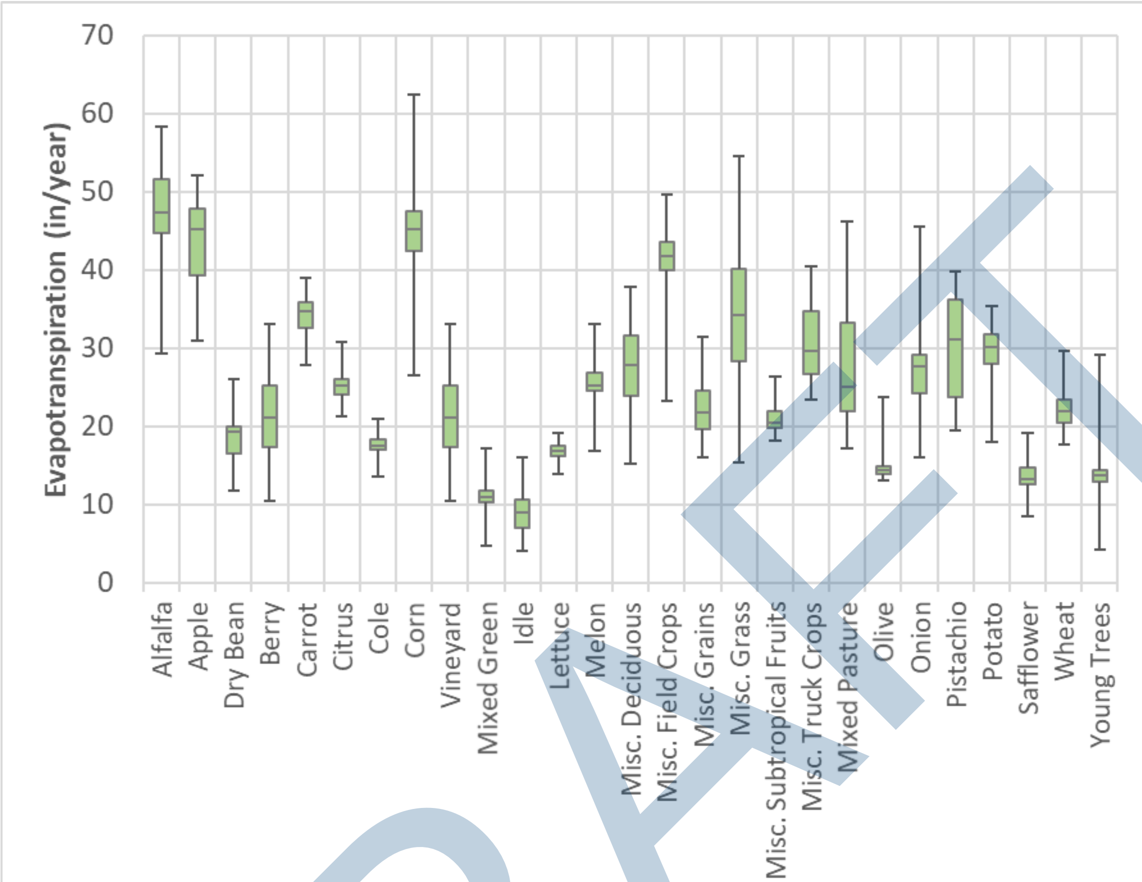


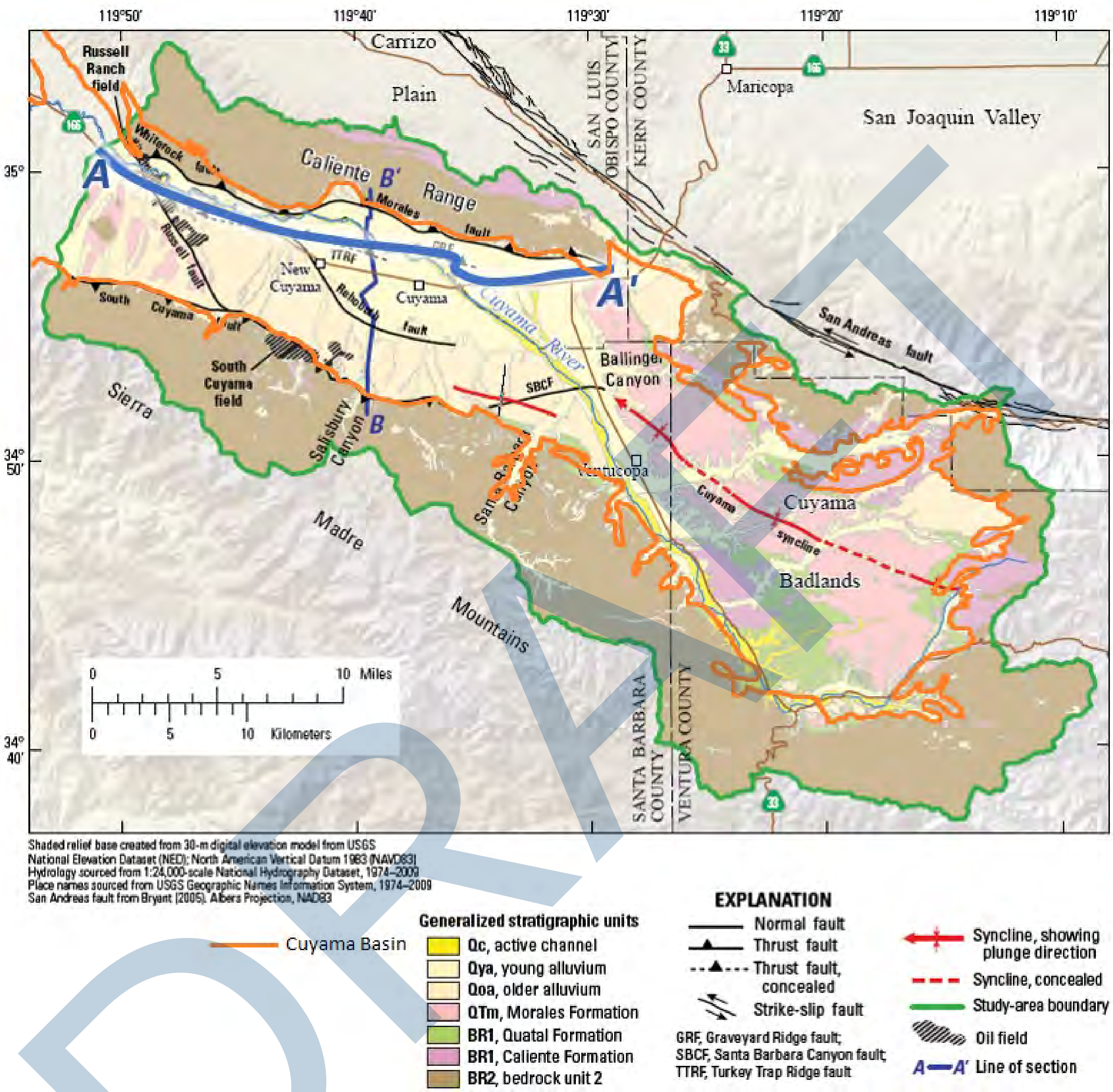

**Figure C-8: Annual Evapotranspiration for Each Land Use Type**

## CBWRM Layering

The CBWRM subsurface zone is characterized by the following three model layers, representing geologic stratification from ground surface to bedrock (listed from top to bottom below) as follows:

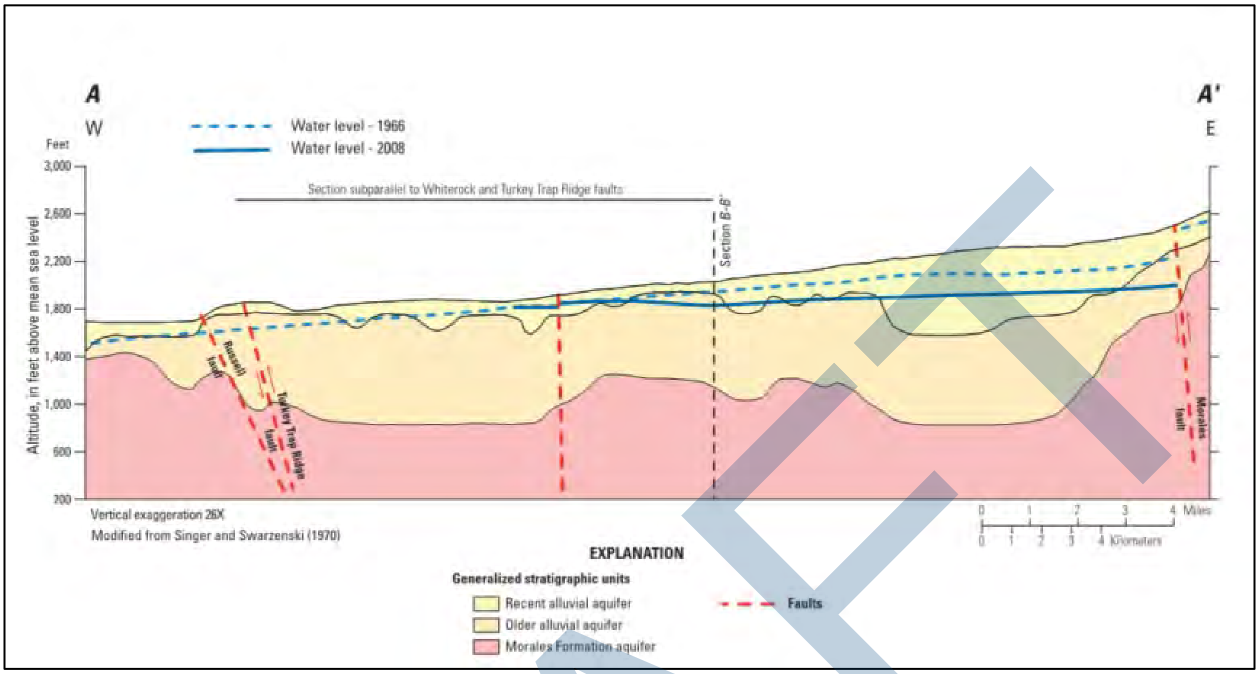
- Layer 1: Recent Alluvial aquifer
- Layer 2: Older Alluvial aquifer
- Layer 3: Morales Formation aquifer

These layers are primarily based on geologic stratification as defined by the USGS (USGS, 2015). They were refined using additional data sets as described in Chapter 2, Section 2.1 of the GSP. Figure C-9 shows the locations of cross sections across the central portion of the Basin as prepared by the USGS in 2013 (USGS, 2013). Figure C-10 shows a west-east cross section that runs near the towns of New Cuyama and Cuyama labeled A-A' (Figure C-11), and a south-north cross section labeled B-B' (Figure C-12).



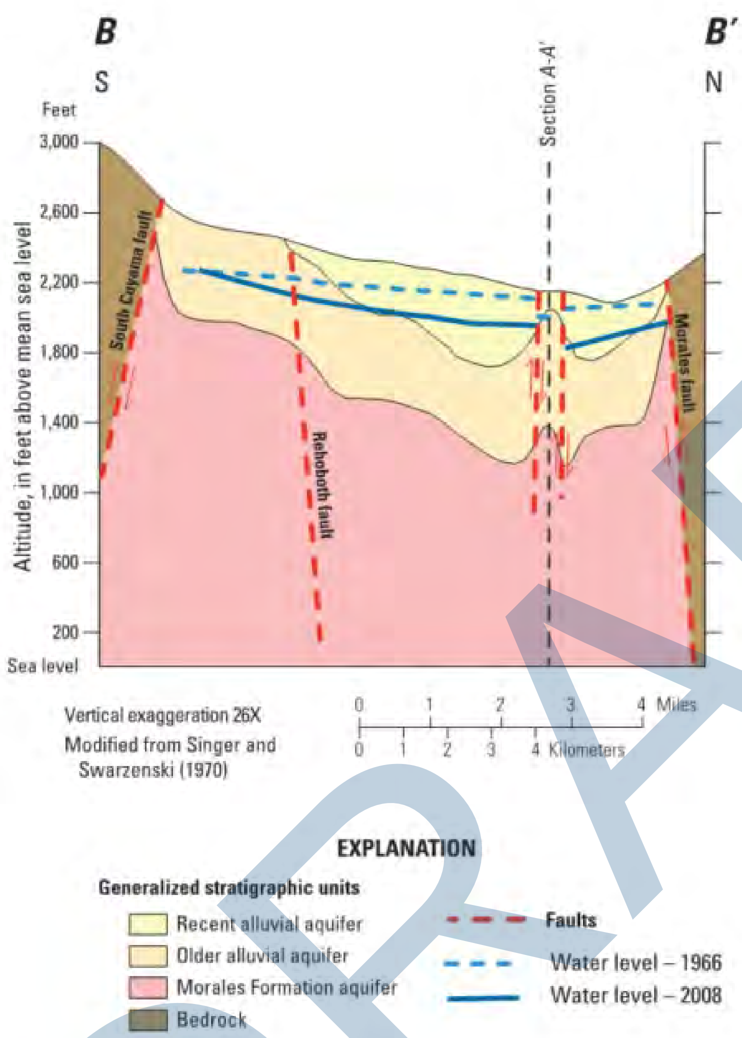

*Source: USGS, 2015.*

**Figure C-9: Location of USGS 2015 Cross Sections**




Source: USGS, 2015

**Figure C-10: USGS Cross Section A-A'**




*Source: USGS, 2015*

**Figure C-11: USGS Cross Section B-B'**

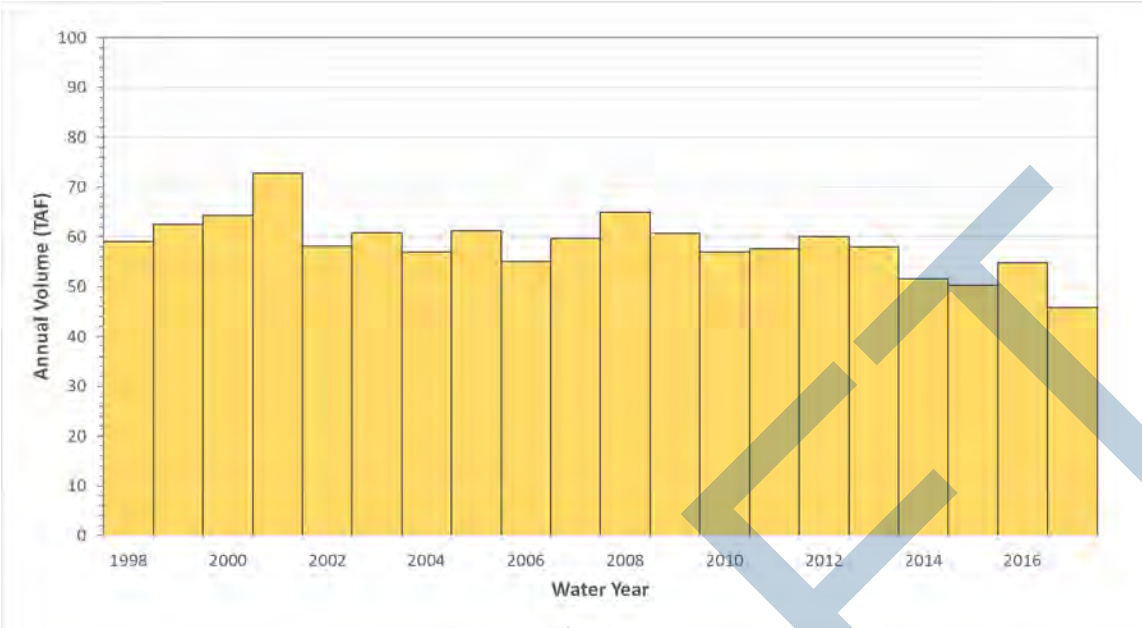



**Figure C-12: Annual Agricultural Water Demand**

### Boundary Conditions

As discussed in the previous section, both surface and subsurface inflows within the ungaged watershed areas tributary to the main Basin are simulated using small watersheds module of the CBWRM. No flow boundary conditions were assumed for the rest of the domain boundary.

### Initial Conditions

Groundwater heads for each model node and each layer at the beginning of the historical simulation (i.e., October 1, 1994) were developed using groundwater level data described in Chapter 2, Section 2.2. Due to the lack of information on well depth and/or perforation for many of the wells used, groundwater heads for each model layer are assumed to be the same. During the calibration process, some refinements were made by layer, as needed. This assumption, however, results in the use of first few years of simulation for start-up period to stabilize the simulated groundwater levels. Therefore, the model calibration period effectively ends up to be the 18-year period of water years 1998 through 2015.

## Water Supply and Demand Data

The following sections describe the data and methodology for the CBWRM water demand and supply calculations. Agricultural water demands were calculated in the IDC portion of IWFM. Agricultural and domestic supplies are specified in the CBWRM's groundwater pumping data.

## Agricultural Water Demand

Agricultural water demand is the amount of irrigation water that is required to satisfy the crops' evapotranspiration requirement after rainfall. The IDC is designed to estimate the agricultural water demand for each model element through consumptive use methodology. The IDC calculations rely on model input data for historical crop acreage, irrigation practices, soil moisture requirements, effective rainfall (the portion of rainfall available for crop consumptive use), crop evapotranspiration, and localized soil parameters. This data was compiled, analyzed, synthesized, and processed for input into CBWRM.

## Domestic Water Use

IDC calculates urban water demand based on population and per capita water use, and the breakdown of indoor versus outdoor water use by month. For the Basin, the per capita water use was estimated using historical pumping estimates provided by the CCSD (CCSD 2010 to 2017) and population records published for the CCSD service area. Domestic water use during the historical period ranges between 100 and 200 acre-feet per year (AFY).

# CBRWM Calibration

The goals of CBRWM calibration were as follows:

- Achieve a reasonable water budget for each component of the hydrologic cycle modeled (i.e., land and water use, soil moisture, stream flow, and groundwater) that is acceptable by the stakeholders to support the development of the GSP
- Maximize the agreement between simulated and observed groundwater levels at select well locations, and simulated and observed streamflow hydrographs at select gaging stations

These objectives are achieved through verification of model input data and adjustment of model parameters.

CBRWM calibration begins after data analysis and input data file development are completed. The calibration effort can be broken down into subsets that align with packages within the IWFM platform. As an integrated surface water and groundwater model, the results of each part of the simulation are dependent on one another. The model calibration can be considered a systematic process that includes the following activities:

- Calibrate water demand estimates for agricultural and urban sectors
- Calibrate surface water features, including the small watershed runoff, boundary flows, and streamflows
- Calibrate overall water budgets for the model area, and model subregions
- Calibrate simulated groundwater levels to observed groundwater levels
- Compare calibration performance with the calibration targets
- Conduct additional refinements to model as necessary

The CBWRM was calibrated to historical groundwater elevation data, with the calibration informed by local data provided by private landowners and other stakeholders.

Due to uncertainty in the initial conditions, a one-year warm-up period was included to allow groundwater levels to stabilize. Thus, the model calibration period for the CBWRM is October 1995 through September 2015, or water years 1996 through 2015 (i.e., 20 years).

### Calibration of IDC and Root-Zone Parameters

The goal of IDC calibration is to estimate a reasonable urban and agricultural demand and develop the components of a balanced root zone budget. IDC calibration serves as the foundation of IWFM calibration as demand estimates directly affect the estimates of groundwater pumping. This part of the calibration effort focused primarily on refining individual budget items, while maintaining reasonable root zone parameters.

The calibrated IDC was used to estimate monthly agricultural water demand at each model element during the model hydrologic period. To adjust agricultural demand, elemental root zone parameters were adjusted in accordance with the hydrologic soil group. Figure C-12 shows estimates of annual agricultural water demand in the Basin from water year 1998 to water year 2017. The average annual agricultural water demand during these years is estimated to be approximately 59,000 AFY. The year-to-year variability in estimated agricultural demand reflects the variabilities in land use, precipitation, and temperature experienced historically in the Basin.

### Calibration of Surface Water Features

As discussed above, small watersheds were used to simulate inflows into the model from ungaged watersheds. The small watershed were split between surface water runoff that enters the stream system, percolation that occurs during transport to the streams, and baseflow entering the groundwater system at the model boundary.

As discussed above, limited streamflow data are available to perform calibration on surface water flows in the model. One USGS gage is available on the Cuyama River downstream of the Basin (ID 11136800), which is located just upstream of Lake Twitchell. The flows from this gage were adjusted to estimate flows at the downstream boundary of the Basin. These adjusted flows were then compared to the flows resulting from the model calibration process.

### Calibration of Water Budgets

The aim of the calibration process is to ensure an accurate representation of the hydrologic characteristics of the Basin, confirmed through the analysis of the resulting water budgets. A water budget balances all supplies, demands, and any subsequent change in storage occurring within that specific portion of the hydrologic cycle. IWFM automatically outputs budgets at the subregion scale for processes involving groundwater, the surface layer, streams, the root zone, and small watersheds. IWFM can output select budget information down to a single element or any specific grouping of elements. This feature was used during the calibration process to prepare water budget information by certain geographic areas for planning and comparison purposes.

During this step of the calibration process, CBRWM results are reviewed and summarized into monthly and annual (by water year) budgets. Two key hydrologic components that were reviewed most frequently during the calibration process were the groundwater budget and the land and water use budget. During extensive analysis of water budgets, key model datasets and parameters were adjusted (including parameters related to soil and root zone, small watershed and boundary flows, stream system, and aquifer system), to better match the conceptual understanding of the Basin. CBWRM water budget results are summarized in the following sections.

### Land Surface Water Budget

The following components are included in the land surface water budget:

- Inflows:
  - Precipitation
  - Applied Water
- Outflows:
  - Evapotranspiration (Agricultural and Native Vegetation)
  - Domestic Water Use
  - Deep Percolation
  - Runoff

Figure C-13 shows the annual time series of historical land surface inflows and outflows during the calibration period. The Basin experienced about 282,000 AF of inflows each year, of which 223,000 AF is from precipitation and the remainder is from applied water. About 223,000 AFY was consumed as evapotranspiration and domestic use, with the remainder either recharging the groundwater aquifer as deep percolation, stream seepage or leaving the Basin as river flow.

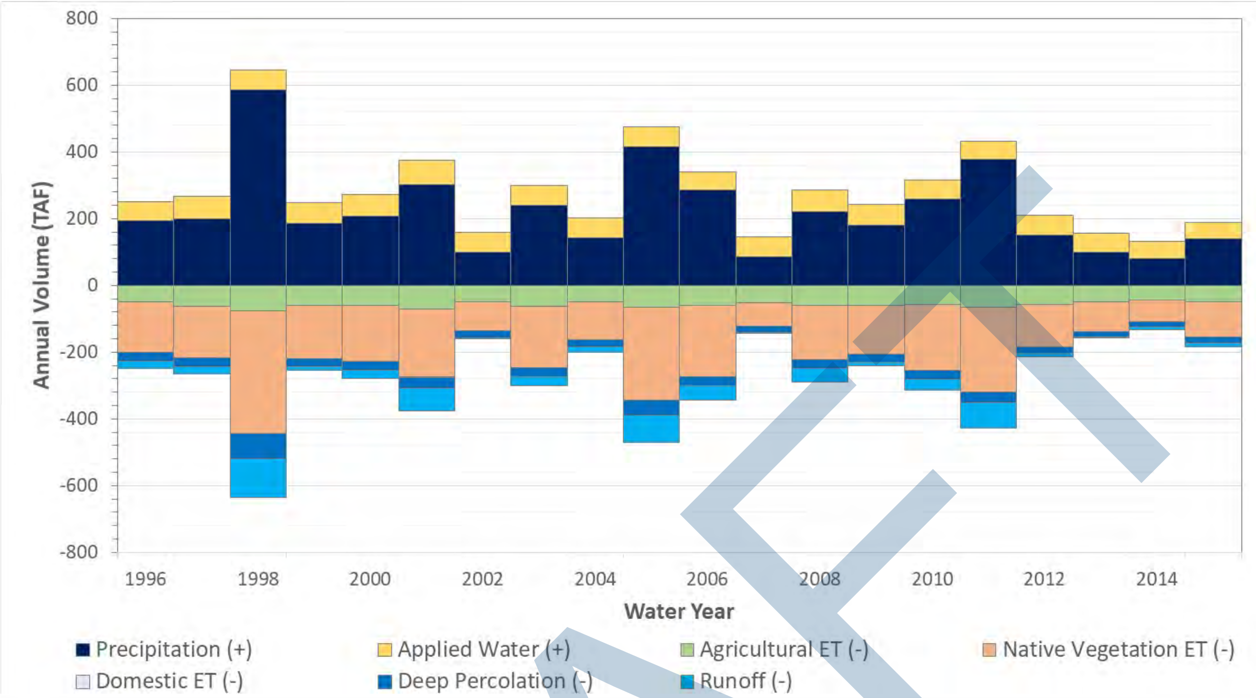



**Figure C-13: Land Surface Water Budget Annual Time Series in the Calibration Period**

## Groundwater Budget

The following components are included in the groundwater water budget:

- Inflows:
  - — Deep percolation
  - — Stream seepage
  - — Subsurface inflow
- Outflows:
  - — Groundwater pumping

Figure C-14 shows the annual time series of groundwater inflows and outflows during the calibration period. The Basin average annual historical groundwater budget has greater outflows than inflows, leading to an average annual deficit in groundwater storage of 23,000 AF. The groundwater storage decreases consistently over time, despite year-to-year variability in groundwater inflows.

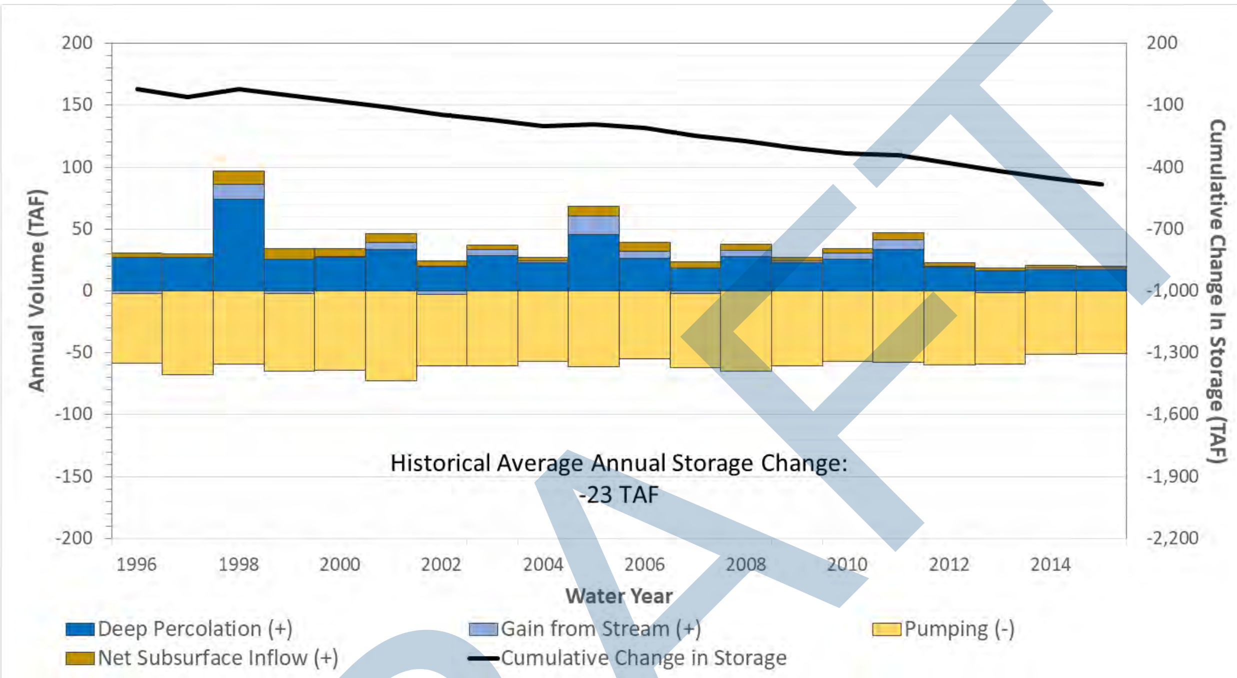



**Figure C-14. Groundwater Budget Annual Time Series in the Calibration Period**

## Groundwater Level Calibration

The goal of groundwater level calibration is to achieve reasonable agreement between the simulated and observed values (in this case, groundwater levels at the calibration wells). Within the CBWRM, 139 wells were used to evaluate the model calibration at both a regional and local scale. These wells are included in the CBGSA's Opti data management system. The calibration wells were selected based on their period of record and availability of observation data, spatial distribution across the model, and trends of nearby wells. These calibration wells are shown in Figure C-15.

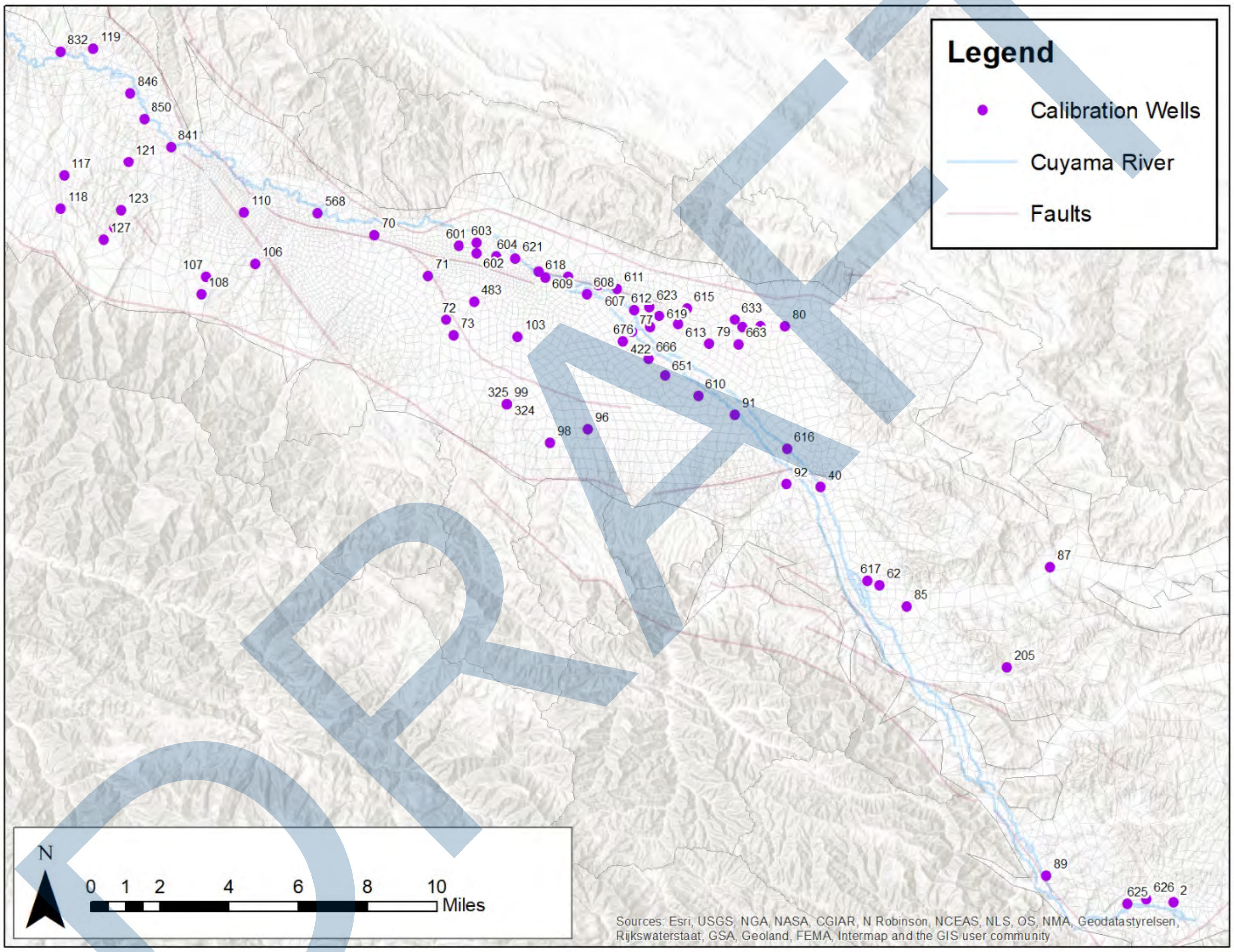



**Figure C-15. Location of Calibration Wells**

Simulated groundwater levels were calibrated to observed levels through systematic adjustments to aquifer parameters including hydraulic conductivity, specific storage, and specific yield. The goal of groundwater level calibration is to achieve the maximum agreement between simulated and observed groundwater elevations at calibration wells while maintaining aquifer parameters within reasonable range. The groundwater level calibration is performed in two stages as follows:

- The initial calibration effort is focused on the regional scale to verify hydrogeological assumptions made during model data development and confirm the accuracy of general groundwater flow directions. During this stage, simulated groundwater elevation trends, flow directions, and groundwater gradients are compared to those that can be synthesized form the reported data.
- The second stage of calibration of groundwater levels is to compare the simulated and observed groundwater levels at each calibration well. This comparison provides information on the overall model performance during the simulation period. The simulated groundwater elevations at the calibration wells were compared with corresponding observed values for concurrence in long-term trends as well as seasonal fluctuations.

The results of the groundwater level calibration indicate that CBWRM reasonably simulates long-term hydrologic responses under various hydrologic conditions, and the short-term monthly or seasonal fluctuations. Attachment 3 shows a selection of calibration wells with their resulting groundwater level hydrographs.

Figures C-16 and C-17 show a statistical comparison of the final simulated and observed groundwater levels across the entire Basin. As shown in these figures, the model results show a strong correlation with the observed data.

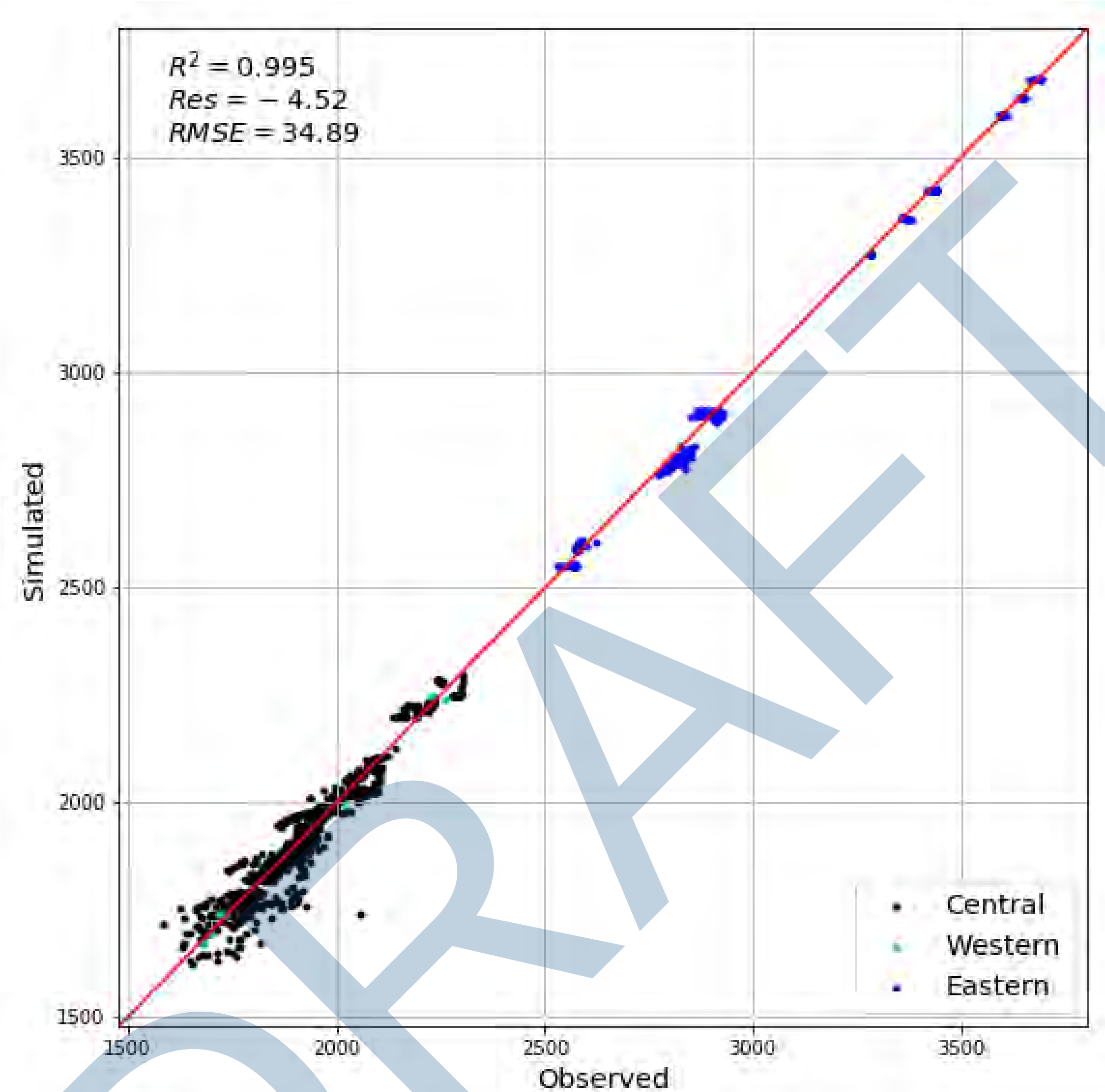



**Figure C-16: Comparison of Simulated and Observed Groundwater Levels**

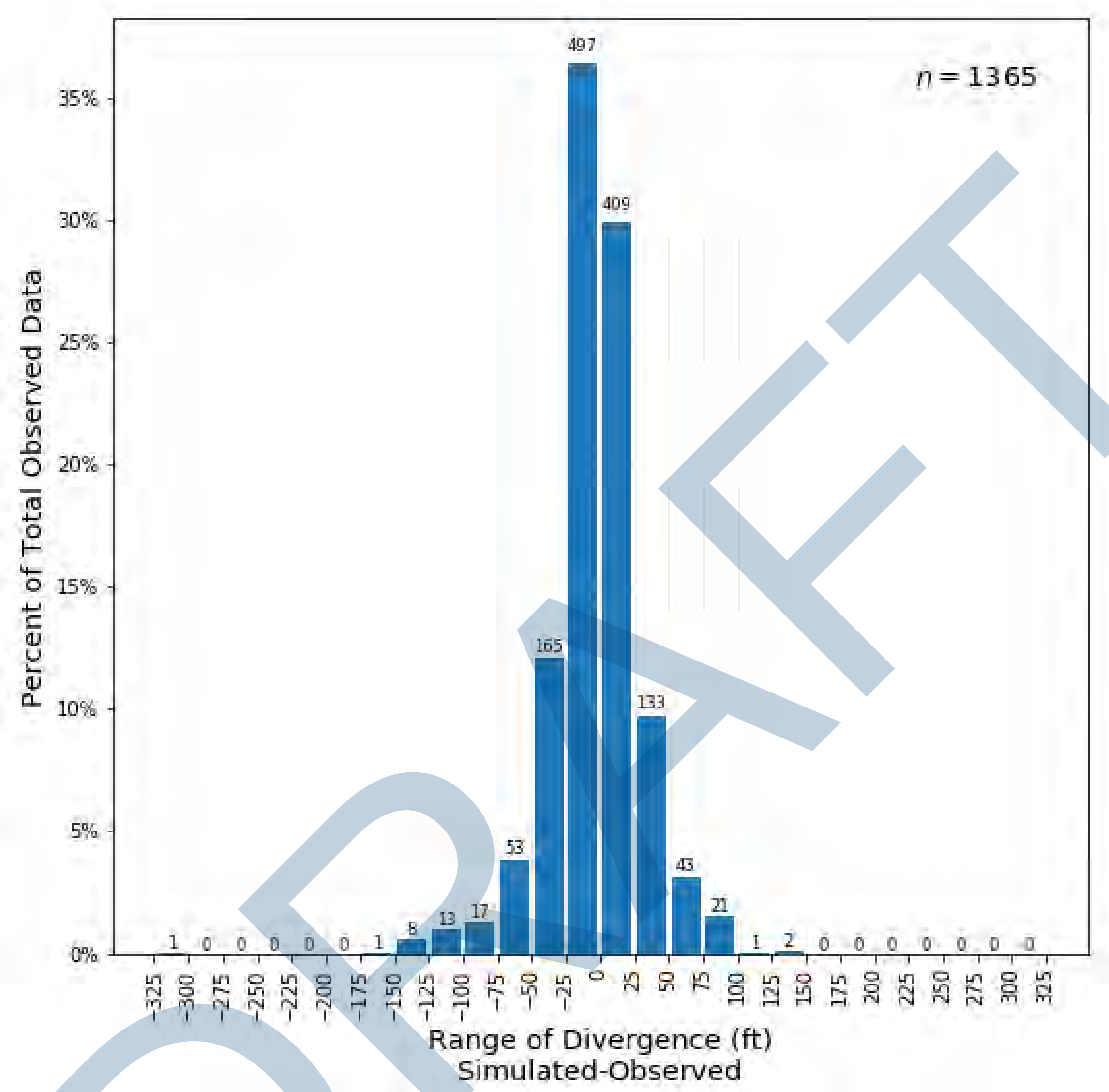



**Figure C-17: Histogram of Divergence of Simulated Groundwater Levels from Observed Data**

## Uncertainty Assessment

To incorporate the uncertainty that originates from various model inputs such as hydraulic parameters, land use, irrigation practices and agricultural demand, an ensemble of perturbed simulation results were analyzed to quantify the overall effect on the groundwater storage change over the historical simulation period.

Accounting for these uncertainties, the upper and lower bounds for the cumulative groundwater storage change are presented in Figure C-18 below. The upper and lower bounds for the average groundwater storage change were estimated to range from 21,000 to 26,000 AFY.

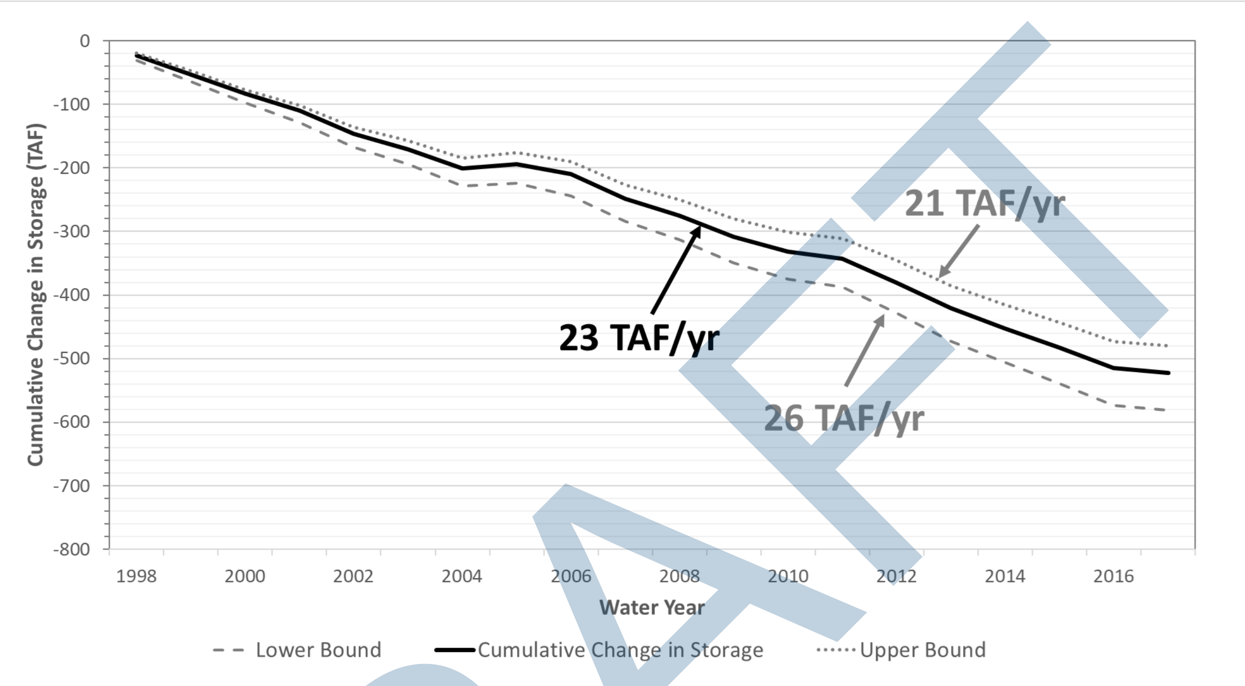



**Figure C-18: Lower and Upper Bounds for the Groundwater Storage Change**

## Conclusions and Recommendations

The CBWRM is the latest analytical model based on DWR's state-of-the science modeling platform, IWFM. The CBWRM has relied on data sets from various sources, and was developed to support GSP development with the primary purpose of assessing hydrologic and groundwater conditions in the Basin during the recent historical period from water 1998 to water year 2017. CBWRM also assesses hydrologic and groundwater conditions under the Basin's current level of development and under projected conditions.

Based on analysis, the following conclusions are made:

1- CBRWM is reasonably calibrated, and reflects a reasonable representation of the Basin's hydrologic and hydrogeologic conditions

2- CBRWM calibration meets the intended need to support GSP development

3- GSP stakeholders and the Technical Forum have reviewed model development and calibration results, and have agreed that the CBWRM, as it stands, is a strong analytical tool to be used for assessment of and planning for sustainable groundwater conditions in the Basin.

The following recommended actions would support future model updates:

- **Continue engagement with local stakeholders**. Continue working with local agencies and groundwater users in the Basin to further understand the local operations of the groundwater system and improve representation of groundwater users in the model by collecting additional data. Specific data to be considered are irrigation practices outside the main District areas, groundwater level data, information on the well profiles and characteristics.
- **Perform additional hydrogeological conceptualization.** Specific areas can benefit from additional hydrogeologic investigations. These include eastern art of the basin in the vicinity of the Ventucopa area, as well as the western part of the model, downgradient from the Russel Fault. In addition, data about effectiveness of the fault system in the area are very sparse. Additional targeted groundwater exploration and/or groundwater level monitoring should focus on the areas near the fault systems.
- **Improve streamflow record collection.** Currently, there are no long-term streamflow gaging stations within the CBWRM. As part of GSP implementation, at least two streamflow gaging stations should be installed and monitored regularly, so that Basin inflows and outflows are properly monitored.
- **Improve representation of small watersheds.** Surface water flow from and evapotranspiration losses in the ungaged watersheds represent a relatively large portion of the Basin water budgets. Additional investigations on the native vegetation ET, and runoff conditions in the ungaged watersheds can improve model representation of this feature.
- **Develop groundwater pumping estimates.** As groundwater pumping is the primary outflow from the groundwater system, an accurate representation of outflow significantly improve CBWRM performance. A pilot project is recommended to monitor and measure groundwater use and well discharge for select parcels based on cropping patterns and geographic location relative to the river and relative to other hydrologic features, such as faults.
- **Incorporate future data into model calibration.** Data will be collected using the CBGSA's groundwater monitoring network, and should be used to re-assess and improve CBWRM calibration, especially in areas of the Basin where little or no data exist currently.

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# Attachment C-1

## Land Use and Consumptive Water Use of Cuyama Groundwater Basin for Water Years 1996 Through 2016

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## TECHNICAL MEMORANDUM – DRAFT

# LAND USE AND CONSUMPTIVE WATER USE OF CUYAMA GROUNDWATER BASIN FOR WATER YEARS 1996 THROUGH 2016

| | |
|---|---|
| To: | Woodard & Curran |
| From: | Land IQ |
| Date: | July 27, 2018 |

## INTRODUCTION

Accurate and current information on constantly changing consumptive water use for crops is critical not only to water rights administration, but also to sustainable groundwater management, agricultural irrigation management, and to environmental and water quality protection. Land IQ has been contracted by Woodard & Curran to analyze consumptive water use in the Cuyama Groundwater Basin for these purposes and overall Groundwater Sustainability Plan (GSP) development data resources.

This memorandum provides methods and results of crop type identification for selected water years (1996, 2000, 2003, 2006, 2009, 2012, 2014 & 2016) during the 20 year time period. Multiple sources of data are used in the identification of each field. These sources include aerial imagery, satellite photography, DWR land use surveys and ground survey information.

This documentation also provides estimates of crop evapotranspiration (ET) for the 1996 and 2016 water years (10/1/1995 – 9/30/1996, 10/1/2015 – 9/30/2016). The surface energy balance model, METRIC (Mapping Evapotranspiration with high Resolution and Internalized Calibration), is applied to estimate monthly and annual evapotranspiration. The input data include CIMIS weather station data and USGS Landsat 5 & 8 satellite images.

## DETERMINING LAND USE

Land use is one of the most influential inputs to a consumptive use or groundwater model. The most common land use in the Cuyama Groundwater Basin is agriculture production. Crop type information optimizes estimations of evapotranspiration, applied water, deep percolation return flows and other water balance input data requirements.

### LAND USE DATA SOURCES

Available resources for crop mapping in recent years are more refined and accurate than in past years. Table 1 shows the types of aerial/satellite imagery as well as data availability for each year. Taking this into account, the accuracy and specificity of crop identification is greatest in the most recent mapping years (2014 & 2016). In more recent years, data allows individual crop types to be identified, instead of a more general category (e.g. Miscellaneous Truck Crops).

**TABLE 1. SUMMARY OF DATA SOURCES AVAILABLE FOR EACH ANALYSIS YEAR**

| Year | Land Use Survey Data | Google Earth | NAIP Imagery | Landsat |
|---|---|---|---|---|
| **2016** | ✔ | ✔ | ✔ | ✔ |
| **2014** | ✔ | ✔ | ✔ | ✔ |
| **2012** | - | ✔ | ✔ | ✔ |
| **2009** | - | ✔ | ✔ | ✔ |
| **2006** | - | ✔ | ✔ | ✔ |
| **2003** | - | - | ✔ | ✔ |
| **2000** | - | - | - | ✔ |
| **1996** | ✔ | - | - | ✔ |



## Land Use Survey data

The California Department of Water Resources (DWR) publishes land use data for regions on a rotating schedule for all or portions of each California County (DWR, 2018). The Cuyama Valley was last surveyed by DWR in 1996, including >90% of the fields in the Valley. Since then, Land IQ has completed statewide crop mapping for DWR in 2014 and 2016, encompassing the entire Cuyama Valley. In these three years, this data was used as a base layer and updated as needed.

## Google Earth

Google Earth provides high resolution satellite imagery with some temporal variation. Currently, most Google Earth data is provided by DigitalGlobe's WorldView-3 satellite, providing sub-meter resolution (Digital Globe, 2010). The street view function is also very helpful when identifying past years' crops. The street view in this area is very limited, however, and only available in 2008.

## NAIP Aerial Imagery

The National Agriculture Imagery Program (NAIP) captures aerial imagery during the growing season for public use (USDA, 2017). The imagery for the Cuyama Valley was available starting in 2003. NAIP imagery has a fairly high resolution of one meter. This imagery is used to update the field boundary layer for each year because the high resolution allows for the identification of fields that have split or have a different footprint. The drawback to NAIP imagery is that it is only a snapshot in time, with no temporal variation. Figure 1 shows 2009 NAIP imagery of the Cuyama Valley at two different scales to show detail.

**FIGURE 1. NATURAL COLOR COMPOSITE OF NAIP IMAGE, FOR 05/05/2012; 1:300,000 SCALE ON LEFT; 1:9,000 SCALE ON RIGHT.**

## LANDSAT SATELLITE IMAGERY

Landsat satellite imagery is a joint project between the USGS and NASA that collects imagery for public use. Landsat provides lower resolution imagery (30 x 30 meter pixels) but at a much higher frequency than NAIP (USGS, 2007). Depending on year and cloud cover, imagery for an area could be as frequent as every 8 days. This frequency allows for the observation of the crop in all stages of development. All imagery dates during the growing season are used to identify the color and texture changes, to support the crop type identification.

The Cuyama Valley is within Landsat reference system path 42 and row 36. Landsat 5, 7, and 8 were used for appropriate years. All available growing season images were utilized, except those that had cloud contamination. Figure 2 is an example of the agriculture area in Landsat 5 on June 26, 2009.

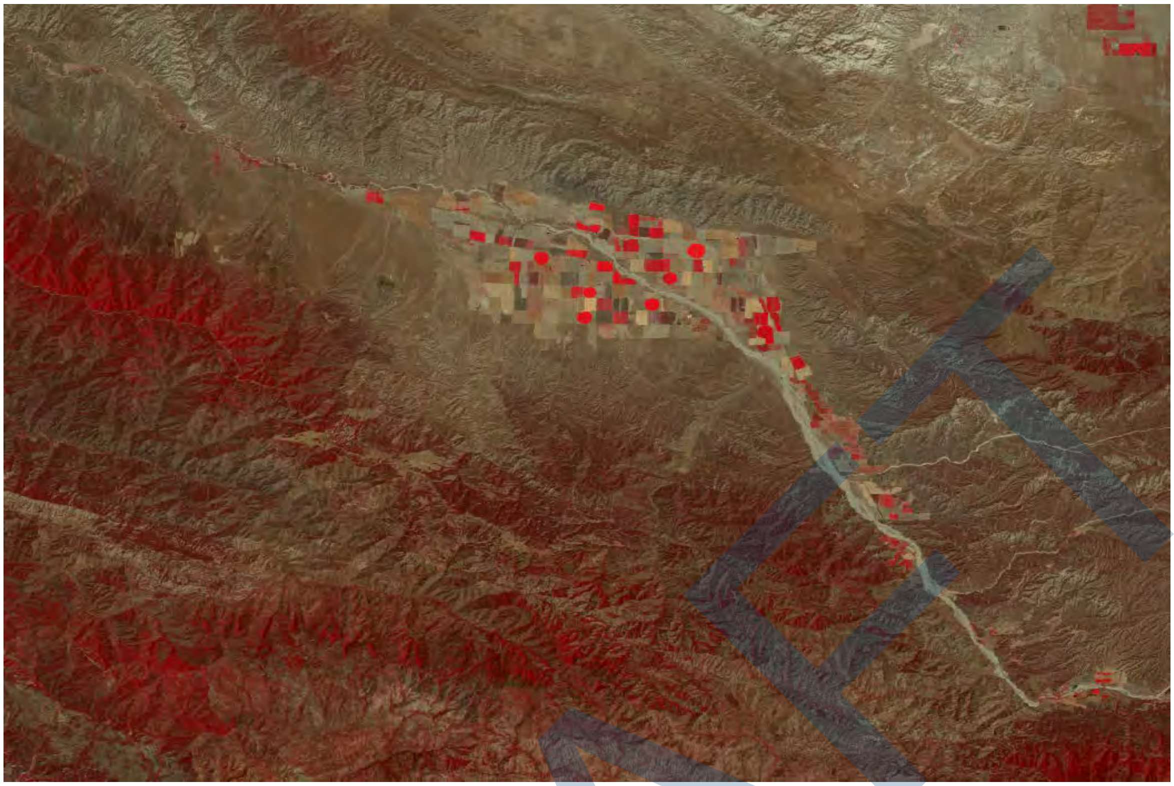

**FIGURE 2. FALSE COLOR COMPOSITE OF LANDSAT 5 IMAGE, PATH 42 ROW 36, FOR 06/26/2009. AGRICULTURE IS IN THE MIDDLE OF THE IMAGE.**

## LAND USE RESULTS

Classification and field boundary updates were completed for each year, using the data sources available. Table 2 summarizes the results of the classification and boundaries. The top 5 crop classes during the 20 year period (excluding idle) were miscellaneous truck, miscellaneous grain and hay, carrots, alfalfa and alfalfa mixtures, and apples.

TABLE 2. SUMMARY OF CROP MAPPING RESULTS

| DWR Crop | 1996 | 2000 | 2003 | 2006 | 2009 | 2012 | 2014 | 2016 |
|---|---|---|---|---|---|---|---|---|
| Alfalfa & alfalfa mixtures | 3,574 | 2,586 | 1,950 | 2,201 | 935 | 1,356 | 168 | 235 |
| Apples | 2,475 | 2,478 | 1,417 | 773 | 518 | 282 | 307 | 331 |
| Beans (dry) | - | 259 | - | - | - | - | 1,064 | - |
| Bush berries | - | - | - | - | - | - | - | 21 |
| Carrots | 4,698 | 843 | 307 | 566 | 5,582 | 6,654 | 2,302 | 5,572 |
| Citrus | - | 2 | 2 | 2 | 4 | 4 | 2 | 2 |
| Cole crops | - | - | 107 | 137 | 292 | 236 | 182 | 383 |
| Corn, sorghum and sudan | - | 185 | 209 | - | 74 | - | 32 | 173 |
| Grapes | 357 | 794 | 768 | 768 | 765 | 853 | 1,303 | 1,241 |
| Greenhouses | - | - | - | - | - | - | - | 5 |
| Idle | - | 8,286 | 9,971 | 12,247 | 9,139 | 8,449 | 15,352 | 13,572 |
| Lettuce/leafy greens | - | - | - | 271 | 212 | 171 | - | 612 |
| Melons, squash, and cucumbers | 12 | - | - | - | - | - | 562 | 50 |
| Miscellaneous deciduous | 12 | 10 | 10 | 16 | 41 | 35 | 10 | 6 |
| Miscellaneous field crops | 114 | - | - | - | - | - | - | - |
| Miscellaneous grain and hay | 7,462 | 5,756 | 5,580 | 4,712 | 8,767 | 6,367 | 851 | 3,198 |
| Miscellaneous grasses | - | 192 | 485 | 192 | 111 | 14 | 22 | - |
| Miscellaneous subtropical fruit and nut | - | - | - | - | - | - | - | 7 |
| Miscellaneous truck | 3,723 | 6,842 | 8,083 | 9,380 | 3,451 | 4,078 | 6,100 | 3,322 |
| Mixed pasture | 737 | 104 | 91 | 398 | 273 | 392 | 97 | 142 |
| Native | - | - | - | - | - | 166 | - | - |
| Olives | - | 4 | 4 | 4 | 4 | 4 | 4 | 517 |
| Onions and garlic | 313 | 10 | 315 | 527 | 983 | 1,231 | 615 | 2,190 |
| Peaches/nectarines | 413 | 348 | 284 | 213 | 75 | - | - | - |
| Pistachios | 676 | 604 | 604 | 757 | 757 | 722 | 802 | 722 |

## DETERMINING CONSUMPTIVE USE

Traditional methods of calculating evapotranspiration can be done quite accurately using weighing lysimeters and eddy correlation monitoring techniques. These methods are limited, however, because they provide point values of ET for a specific location and fail to provide the ET on a regional scale. This limitation has motivated the development of using remotely sensed (RS) data from satellites to evaluate ET over vast areas. Satellite data are ideally suited for deriving spatially continuous ET surfaces that can be pared down to the field scale because of their temporal and spatial characteristics. However, the most accurate use of RS models require calibration to surface measurements.

## SURFACE ENERGY BALANCE CONSUMPTIVE USE ANALYSIS – METRIC MODEL

METRIC estimates surface evapotranspiration (ET) based on the evaluation of the energy balance at the earth's surface. METRIC model processes instantaneous remotely-sensed images and weather data, and estimates the partitioning of energy into net incoming radiation ($R_n$), heat flux into the ground (G), sensible heat flux to the air (H), and latent heat flux (LE). The latent heat flux is computed as a residual in the energy balance, representing the energy consumed by ET. The main advantage of using the energy balance is that the actual ET is computed, rather than a potential ET. A disadvantage of the energy balance approach is in the complexity of calculations and the need for human oversight during calibration. Figure 3 shows a general workflow of the METRIC process.

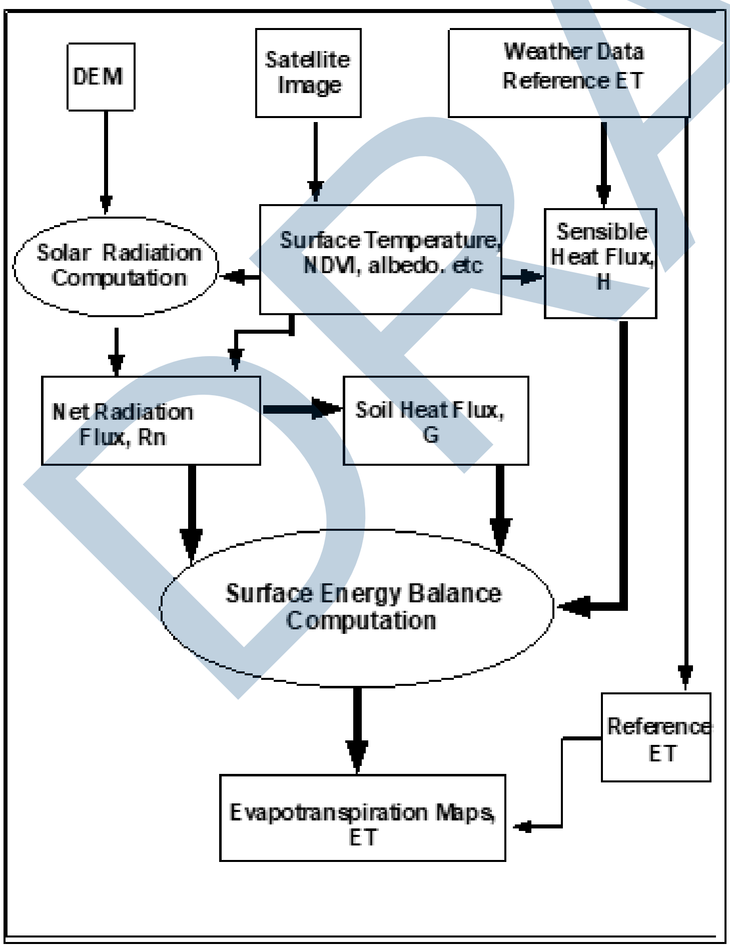


FIGURE 3. GENERAL WORKFLOW OF THE METRIC PROCESS

For the Cuyama Groundwater Basin METRIC application, the Cuyama station (CIMIS station #88) was selected to produce the reference ET (ETo) during calibration. During the internal calibration of sensible heat flux in METRIC, multiple pairs of hot and cold pixels are selected for the model, the one with relative stable result is selected for final calibration. A detailed description of METRIC can be found in Allen et al. (2007a, b; 2008).

## METRIC Input Data – Satellite Images

The Cuyama Groundwater Basin is within Landsat reference system path 42 and row 36. For the 1996 water year, Landsat 5 images were used, and for the 2016 water year, Landsat 8 images were used. All available images were utilized, except those that had cloud contamination.

Tables 3 and 4 provide a list of the images used for each water year. A total of 14 Landsat 5 images were modeled by METRIC for the 1996 water year, and a total of 16 Landsat 8 images were modeled for the 2016 water year. For each image, the METRIC model was used to estimate actual daily ET. Linear interpolation was then used to calculate monthly and annual ET.

**TABLE 3. DATES OF THE LANDSAT 5 SATELLITE IMAGES USED FOR METRIC PROCESSING IN 1996 WATER YEAR**

| # | Date of Landsat | Image Type |
|---|---|---|
| 1 | 9/24/1995 | Landsat 5 |
| 2 | 10/10/1995 | Landsat 5 |
| 3 | 11/11/1995 | Landsat 5 |
| 4 | 11/27/1995 | Landsat 5 |
| 5 | 1/14/1996 | Landsat 5 |
| 6 | 5/21/1996 | Landsat 5 |
| 7 | 6/6/1996 | Landsat 5 |
| 8 | 6/22/1996 | Landsat 5 |
| 9 | 7/8/1996 | Landsat 5 |
| 10 | 7/24/1996 | Landsat 5 |
| 11 | 8/9/1996 | Landsat 5 |
| 12 | 8/25/1996 | Landsat 5 |
| 13 | 9/10/1996 | Landsat 5 |
| 14 | 9/26/1996 | Landsat 5 |

**TABLE 4. DATES OF THE LANDSAT 8 SATELLITE IMAGES USED FOR METRIC PROCESSING IN 2016 WATER YEAR**

| # | Date of Landsat | Image Type |
|---|---|---|
| 1 | 10/1/2015 | Landsat 8 |
| 2 | 11/18/2015 | Landsat 8 |
| 3 | 1/21/2016 | Landsat 8 |
| 4 | 2/6/2016 | Landsat 8 |
| 5 | 3/9/2016 | Landsat 8 |
| 6 | 3/25/2016 | Landsat 8 |
| 7 | 4/26/2016 | Landsat 8 |
| 8 | 5/12/2016 | Landsat 8 |
| 9 | 6/13/2016 | Landsat 8 |
| 10 | 6/29/2016 | Landsat 8 |
| 11 | 7/15/2016 | Landsat 8 |
| 12 | 7/31/2016 | Landsat 8 |
| 13 | 8/16/2016 | Landsat 8 |
| 14 | 9/1/2016 | Landsat 8 |
| 15 | 9/17/2016 | Landsat 8 |
| 16 | 10/3/2016 | Landsat 8 |

## METRIC Input Data – Weather Data

METRIC utilizes reference ET as calculated by the ASCE standardized Penman-Monteith equation (ASCE-EWRI 2005) for calibration of the energy balance process. For our study, grass reference ET (ETo) is used in the modeling process. Hourly weather data time steps are needed to represent ETo at the time of the Landsat overpass for calibration of the METRIC energy balance estimation process. ETo was calculated using the RefET software from the University of Idaho (Allen, 2013). California Irrigation Management Information System (CIMIS) weather station #88 at Cuyama was used to provide hourly weather data for ETo calculation. Figure 4 is an example of weather data for May 21$^{st}$, 1996. Figure 5 shows the annual reference ETo for 1996 and 2016 water years calculated from the CIMIS Cuyama weather station using RefET software.

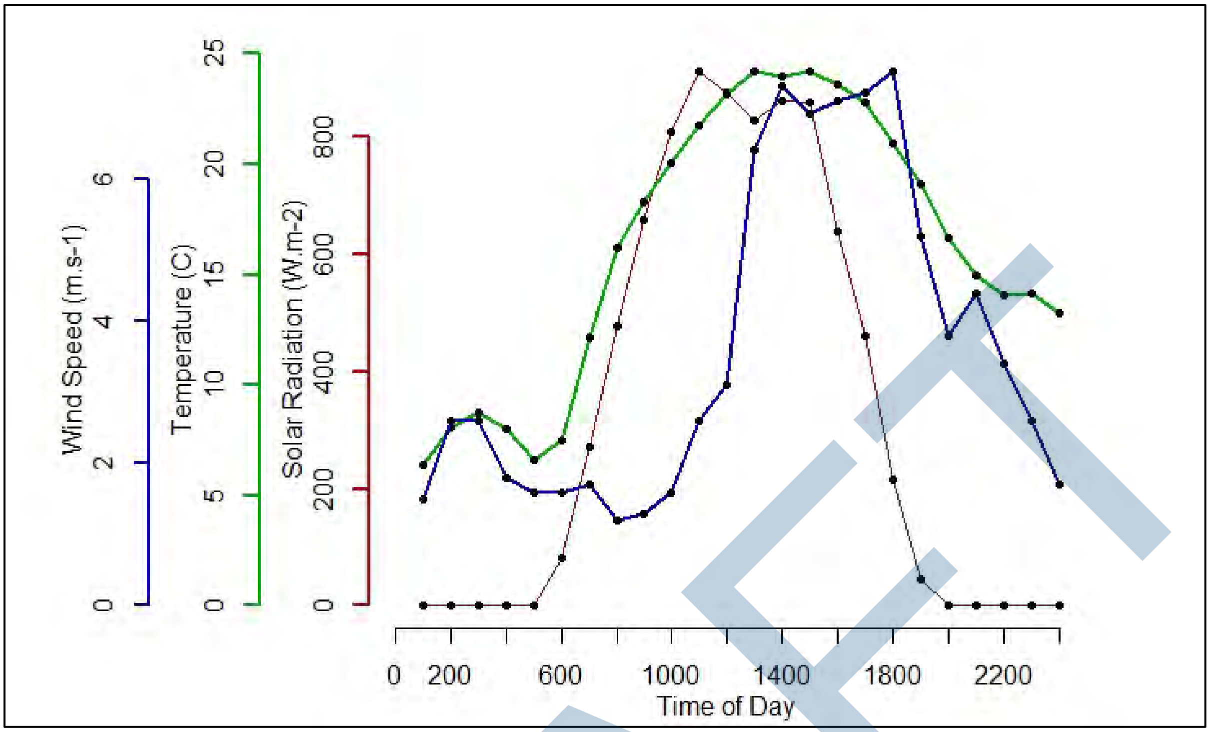


FIGURE 4. CIMIS CUYAMA #88 STATION WEATHER DATA ON MAY 21ST, 1996.

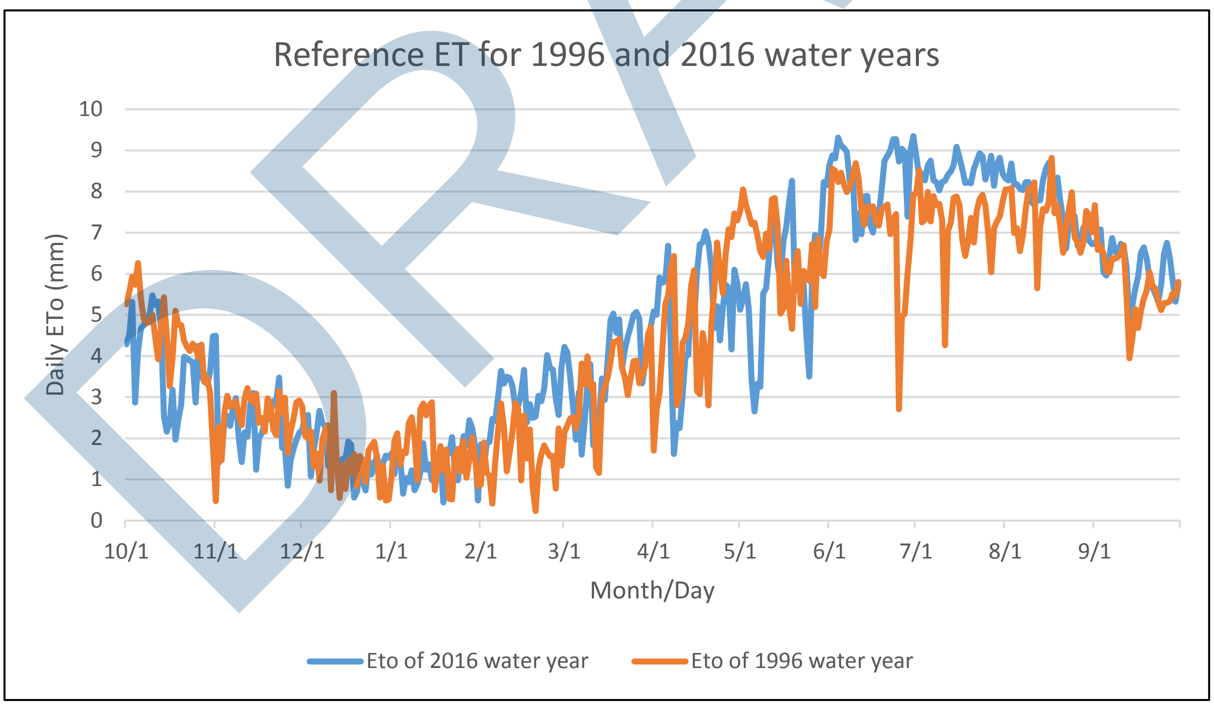


FIGURE 5. REFERENCE EVAPOTRANSPIRATION FOR 1996 AND 2016 WATER YEARS.

## Consumptive Use Results

The annual ET data for the 1996 and 2016 water years are summarized by major crop types within each year. Tables 5 and 6 show the results of average crop actual ET. Major crops, such as alfalfa, apples, and carrots, have relative higher annual ET in 2016 than 1996, and these could be attributed to a number of factors:

- ➔ 2016 total annual ETo is higher than 1996 total annual ETo. As shown in Figure 5, during the month of June and July, ETo is consistently higher in 2016.
- ➔ The underlying crop layers used for generating the statistics are created differently. 2016 crop layer is created by Land IQ while 1996 crop layer is created by DWR.
- ➔ The field boundary of 2016 is more accurate, compared with 1996 field boundary. And this could cause differences in ET stats.
- ➔ Crop variety and irrigation methods are different in those 2 years, making crops evaporate more water in 2016.

Figure 6 shows the overview of 2016 water year ET over the whole Cuyama Basin. The focus and calibration area for METRIC ET evaluations was the agricultural growing region (valley floor) itself. The surrounding mountains with different elevations and aspects may have differing results.

**TABLE 5. SUMMARY OF CROP EVAPOTRANSPIRATION OF 1996 WATER YEAR**

| Crop Types | 1996 Water Year ET (mm) | 1996 Crop Acres |
|---|---|---|
| Alfalfa and Alfalfa Mixtures | 1124 | 3576 |
| Apples | 875 | 2477 |
| Carrots | 713 | 4702 |
| Grapes | 749 | 357 |
| Miscellaneous Grain and Hay | 483 | 7468 |
| Miscellaneous Truck Crops | 519 | 3726 |
| Mixed Pasture | 721 | 737 |
| Onions and Garlic | 447 | 313 |
| Peaches/nectarines | 764 | 414 |
| Pistachios | 584 | 677 |

**TABLE 6. SUMMARY OF CROP EVAPOTRANSPIRATION OF 2016 WATER YEAR**

| Crop Types | 2016 Water Year ET (mm) | 2016 Crop Acres |
|---|---|---|
| Alfalfa and Alfalfa Mixtures | 1366 | 235 |
| Apples | 1224 | 331 |
| Carrots | 1018 | 5572 |
| Grapes | 727 | 1242 |
| Miscellaneous Grain and Hay | 782 | 3198 |
| Miscellaneous Truck Crops | 723 | 3322 |

| | | |
|---|---|---|
| **Mixed Pasture** | 555 | 142 |
| **Onions and Garlic** | 897 | 2190 |
| **Pistachios** | 1253 | 722 |
| **Lettuce/Leafy Greens** | 700 | 613 |
| **Olives** | 617 | 517 |
| **Safflower** | 590 | 810 |

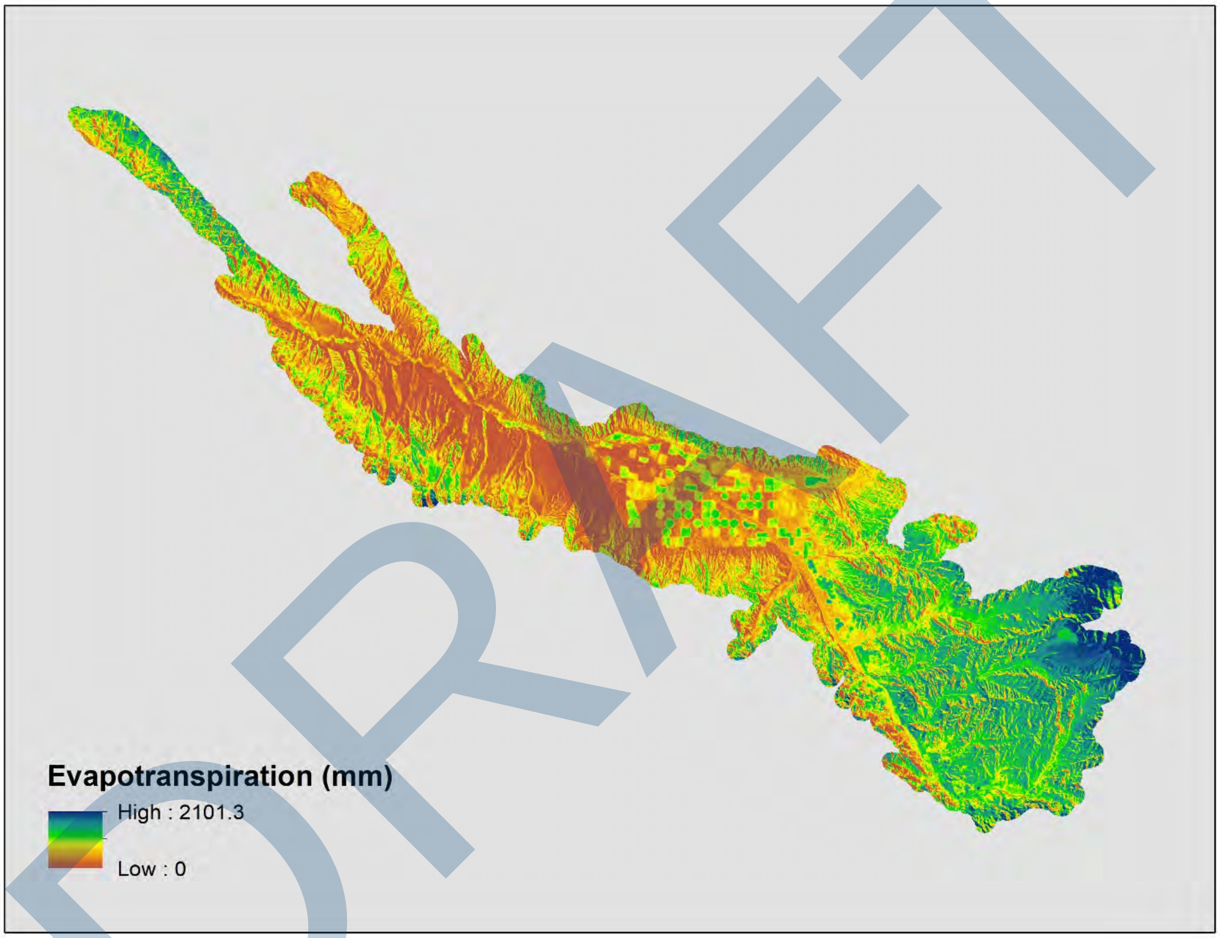


**FIGURE 6. 2016 WATER YEAR EVAPOTRANSPIRATION OF THE CUYMA BASIN.**

# DATA DELIVERABLES

Data delivered as part of the consumptive water analysis efforts are summarized in Table 7.

**TABLE 7. SUMMARY OF CROP MAPPING DATA DELIVERABLES**

| # | File Name | Description |
|---|---|---|
| 1 | CuyamaValley_2016_LandUse_Classification.shp | Crop classification for 2016 water year (attribute: Crop2016) |
| 2 | CuyamaValley_2014_LandUse_Classification.shp | Crop classification for 2014 water year (attribute: Crop2014) |
| 3 | CuyamaValley_2012_LandUse_Classification.shp | Crop classification for 2012 water year (attribute: Crop2012) |
| 4 | CuyamaValley_2009_LandUse.shp | Crop classification for 2009 water year (attribute: Crop2009) |
| 5 | CuyamaValley_2006_LandUse.shp | Crop classification for 2006 water year (attribute: Crop2006) |
| 6 | CuyamaValley_2003_LandUse.shp | Crop classification for 2003 water year (attribute: Crop2003) |
| 7 | CuyamaValley_2000_LandUse.shp | Crop classification for 2000 water year (attribute: Crop2000) |
| 8 | CuyamaValley_1996_LandUse.shp | Crop classification for 1996 water year (attribute: Crop1996) |
| 9 | 1995-10_ETa.tif | Raster image of total evapotranspiration (unit: mm) for October 1995 |
| 10 | 1995-11_ETa.tif | Raster image of total evapotranspiration (unit: mm) for November 1995 |
| 11 | 1995-12_ETa.tif | Raster image of total evapotranspiration (unit: mm) for December 1995 |
| 12 | 1996-01_ETa.tif | Raster image of total evapotranspiration (unit: mm) for January 1996 |
| 13 | 1996-02_ETa.tif | Raster image of total evapotranspiration (unit: mm) for February 1996 |
| 14 | 1996-03_ETa.tif | Raster image of total evapotranspiration (unit: mm) for March 1996 |
| 15 | 1996-04_ETa.tif | Raster image of total evapotranspiration (unit: mm) for April 1996 |
| 16 | 1996-05_ETa.tif | Raster image of total evapotranspiration (unit: mm) for May 1996 |
| 17 | 1996-06_ETa.tif | Raster image of total evapotranspiration (unit: mm) for June 1996 |
| 18 | 1996-07_ETa.tif | Raster image of total evapotranspiration (unit: mm) for July 1996 |
| 19 | 1996-08_ETa.tif | Raster image of total evapotranspiration (unit: mm) for August 1996 |
| 20 | 1996-09_ETa.tif | Raster image of total evapotranspiration (unit: mm) for September 1996 |

| # | File Name | Description |
|---|---|---|
| **21** | 1996_total_ETa_mm.tif | Raster image of total evapotranspiration (unit: mm) for 1996 water year |
| **22** | 2015-10_ETa.tif | Raster image of total evapotranspiration (unit: mm) for October 2015 |
| **23** | 2015-11_ETa.tif | Raster image of total evapotranspiration (unit: mm) for November 2015 |
| **24** | 2015-12_ETa.tif | Raster image of total evapotranspiration (unit: mm) for December 2015 |
| **25** | 2016-01_ETa.tif | Raster image of total evapotranspiration (unit: mm) for January 2016 |
| **26** | 2016-02_ETa.tif | Raster image of total evapotranspiration (unit: mm) for February 2016 |
| **27** | 2016-03_ETa.tif | Raster image of total evapotranspiration (unit: mm) for March 2016 |
| **28** | 2016-04_ETa.tif | Raster image of total evapotranspiration (unit: mm) for April 2016 |
| **29** | 2016-05_ETa.tif | Raster image of total evapotranspiration (unit: mm) for May 2016 |
| **30** | 2016-06_ETa.tif | Raster image of total evapotranspiration (unit: mm) for June 2016 |
| **31** | 2016-07_ETa.tif | Raster image of total evapotranspiration (unit: mm) for July 2016 |
| **32** | 2016-08_ETa.tif | Raster image of total evapotranspiration (unit: mm) for August 2016 |
| **33** | 2016-09_ETa.tif | Raster image of total evapotranspiration (unit: mm) for September 2016 |
| **34** | 2016_total_ETa_mm.tif | Raster image of total evapotranspiration (unit: mm) for 2016 water year |
| **35** | Reference_ETo | Reference ET for 1996 and 2016 water years |
| **36** | Cuyama Consumptive Use Report | Memorandum summarizing consumptive use efforts (this document) |

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# Attachment C-2

## Climate Change Scenario Development

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# 1. CLIMATE CHANGE SCENARIO DEVELOPMENT

## 1.1 Regulatory Background

As prescribed in Section 354.18(d)(3) and Section 354.18(e) of the GSP Regulations, climate change conditions were incorporated into the projected water budgets for the Eastern San Joaquin Groundwater Sustainability Plan.

Section 354.18(d)(3) states:

***"****(d) The Agency shall utilize the following information provided, as available, by the Department pursuant to Section 353.2, or other data of comparable quality, to develop the water budget:*

> *(1) Historical water budget information for mean annual temperature, mean annual precipitation, water year type, and land use.*
> *(2) Current water budget information for temperature, water year type, evapotranspiration, and land use.*
> *(3) Projected water budget information for population, population growth,* ***climate change****, and sea level rise.****"***

Section 354.18(e) states:

***"****(e) Each Plan shall rely on the best available information and best available science to quantify the water budget for the basin in order to provide an understanding of historical and projected hydrology, water demand, water supply, land use, population,* ***climate change****, sea level rise, groundwater and surface water interaction, and subsurface groundwater flow. If a numerical groundwater and surface water model is not used to quantify and evaluate the projected water budget conditions and the potential impacts to beneficial uses and users of groundwater, the Plan shall identify and describe an equally effective method, tool, or analytical model to evaluate projected water budget conditions.****"***

Climate change analysis is an area with continued evolution in terms of methods, tools, forecasted datasets, and the predictions of actual greenhouse gas concentrations in the atmosphere. There is a large number of available combinations of these elements that result in many potential ways to evaluate climate change impacts. For the purposes of this GSP, the method proposed by DWR as a valid method of evaluation in its guidance document was considered adequate (DWR, 2018). Similarly, the "best available information" was deemed the information provided by DWR, customized for the method proposed. The following resources from DWR were used to carry out the climate change analysis:

- SGMA Data Viewer
- Guidance for Climate Change Data Use During
- Sustainability Plan Development and Appendices (Guidance Document)
- Water Budget BMP
- Desktop IWFM Tools

SGMA Data Viewer provides the location for which the climate change forecasts datasets[1] were downloaded for the Cuyama subbasin (DWR, 2019). The guidance document details the approach, development, applications, and limitations of the datasets available from the SGMA Data Viewer (DWR, 2018). The Water Budget BMP describes in more granular detail how projected water budgets should be computed (DWR, 2016). The Desktop IWFM Tools are available to calculate the projected precipitation and evapotranspiration inputs under climate change conditions (DWR, 2018).

Generally, the methods suggested by DWR in the above resources were used, with a few exceptions to ensure the resolution and scale matched that of the historical and current water budgets. Figure C-2-1 shows the overall process consistent with the Climate Change Resource Guide (DWR, 2018) that describes workflow beginning with baseline historical conditions to perturbed 2070 conditions for the projected model run.

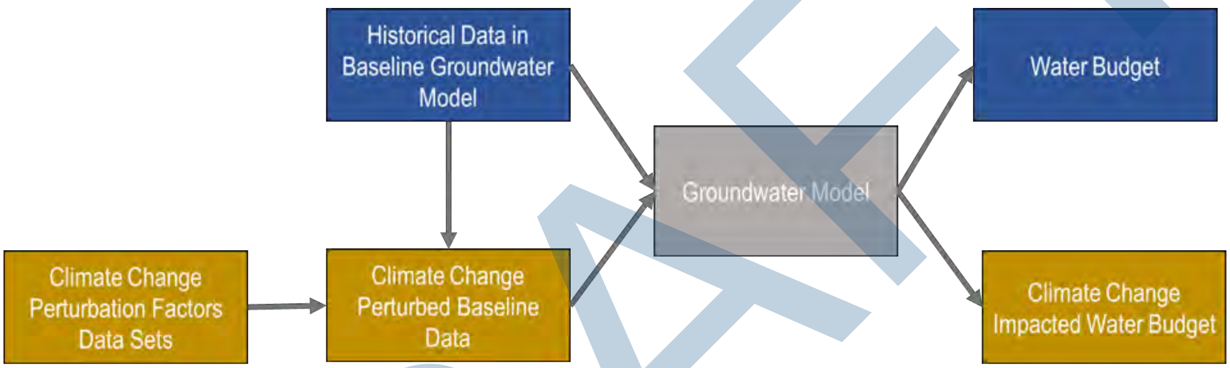


Figure C-2-1

Table C-2-1 below summarizes the forecasted variable datasets provided by DWR that were used to carry out the climate change analysis (DWR, 2019).

Table C-2-1.

| Input Variable | DWR Provided Dataset |
|---|---|
| **Precipitation** | **Change Factors:**<br>VIC model-generated GIS grid with associated change factor time series for each cell |
| **Reference ET** | **Change Factors:**<br>VIC model-generated GIS grid with associated change factor time series for each cell |

[1] In the industry, climate change impacted variable forecasts are sometimes referred to as "data" and their collections are called "datasets." Calling forecasted variable values "data" can be misleading so this document tries to be explicit about when we are referring to data (historical data) vs. forecasts or model outputs.

## 1.2 Climate Change Analysis Methodology

For climate change impacts on groundwater, accepted methods include the assessment of the impacts on the individual water resource system elements that are impacted and directly link to groundwater. These elements include precipitation, streamflow, evapotranspiration and, for coastal aquifers, sea level rise as a boundary condition. For Cuyama, sea level is not relevant. Additionally, in the Cuyama model does not have any stream inflows. For this reason, streamflow under climate change was not perturbed in this analysis.

The methods for perturbing the precipitation and evapotranspiration input files is described in the following sections. Two future scenarios were evaluated in this analysis, according to DWR guidance (DWR, 2018):

- Water Budget under 2030 central tendency conditions to assess near-future impacts of climate change.
- Water Budget under 2070 central tendency conditions to assess impacts of climate change over the long-term planning and implementation period.

### Perturbed Precipitation under Climate Change

Projected precipitation change (perturbation) factors are provided by DWR, calculated using a climate period analysis based on historical precipitation from January 1915 to December 2011 (DWR, 2018). Change factors provided by DWR were calculated as a ratio of the value of a variable under a "future scenario" divided by a baseline. DWR used a macroscale hydrologic model that solves the full water and balance in a watershed, called the Variable Infiltration Capacity (VIC) Model. The baseline data corresponds to the 1995 historical template detrended scenario by the VIC model through global circulation model (GCM) downscaling. The "future scenario" corresponds to VIC outputs of the simulation of future conditions using GCM forecasted hydroclimatic variables as inputs. These change factors are thus a simple perturbation factor that corresponds to the ratio of a future with climate change divided by the past without it. Change factors are available on a monthly time step and spatially defined by the VIC model grid. Supplemental tables with the time series of perturbation factors are available by DWR for each grid cell.

Because the Cuyama model has a daily time step, the historical baseline time series (WY 1960-WY 2017) was aggregated monthly. DWR change factors, or perturbation factors, were then multiplied by historical baseline precipitation to generate projected precipitation under 2030 and 2070 central tendency future scenarios using the Desktop IWFM GIS tool (DWR, 2018). The tool calculates an area weighted precipitation change factor for each model grid geometry. This model grid geometry was generated based on polygons generated around the PRISM nodes that are within the model region.

However, the DWR tool only includes change factors through 2011. The remaining 5 years of the time series were synthesized according to historically comparable water years. The perturbation factor from the corresponding month of the comparable year was applied to the baseline of the missing years (2012-2017) to generate projected values. Months with no precipitation in the baseline were assumed a monthly precipitation of 1mm under climate change to account for increased precipitation that cannot be calculated from a baseline of 0 mm for these synthesized years. Table C-2-2 below shows the comparable water years assigned for each missing year.

Table C-2-2

| WY with Missing Change Factors | Comparable WY on Record | |
|---|---|---|
| | April - Sept | Oct - March |
| 2012 | 1987 | 2009 |
| 2013 | 1990 | 1990 |
| 2014 | 1990 | 1989 |
| 2015 | 2001 | 1990 |
| 2016 | 1990 | 1989 |
| 2017 | 1990 | 1990 |

## Applying Change Factors to Precipitation and ET

DWR datasets include scenarios for 2030 and 2070 timeframes and for conditions similar to historical in terms of precipitation forecasted (central tendency) and conditions wetter and drier. All scenarios available present higher future temperatures. The team selected the 2070 central tendency forecasted conditions for the analysis.

After applying the change factor to the model simulation period (baseline) we obtained the precipitation and evapotranspiration under climate change. The resulting perturbed precipitation values and the baseline precipitation values can be found in Figure C-2-2 below. The exceedance plot for these two times series can be found in Figure C-2-3.

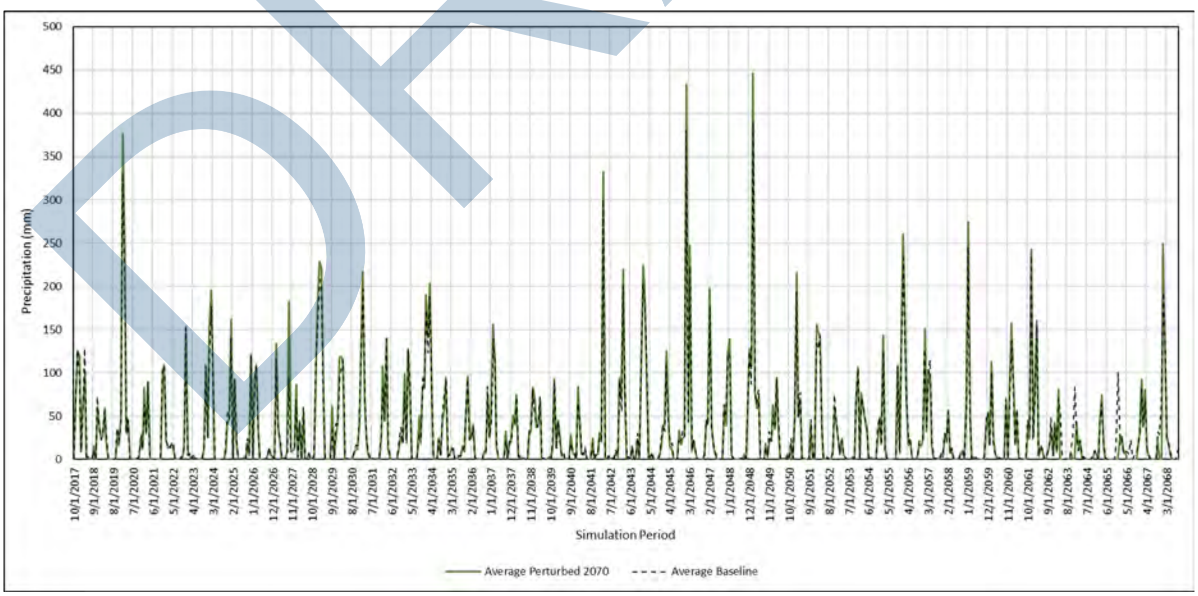


Figure C-2-2. Precipitation Perturbation Factors as Compared to Baseline Values

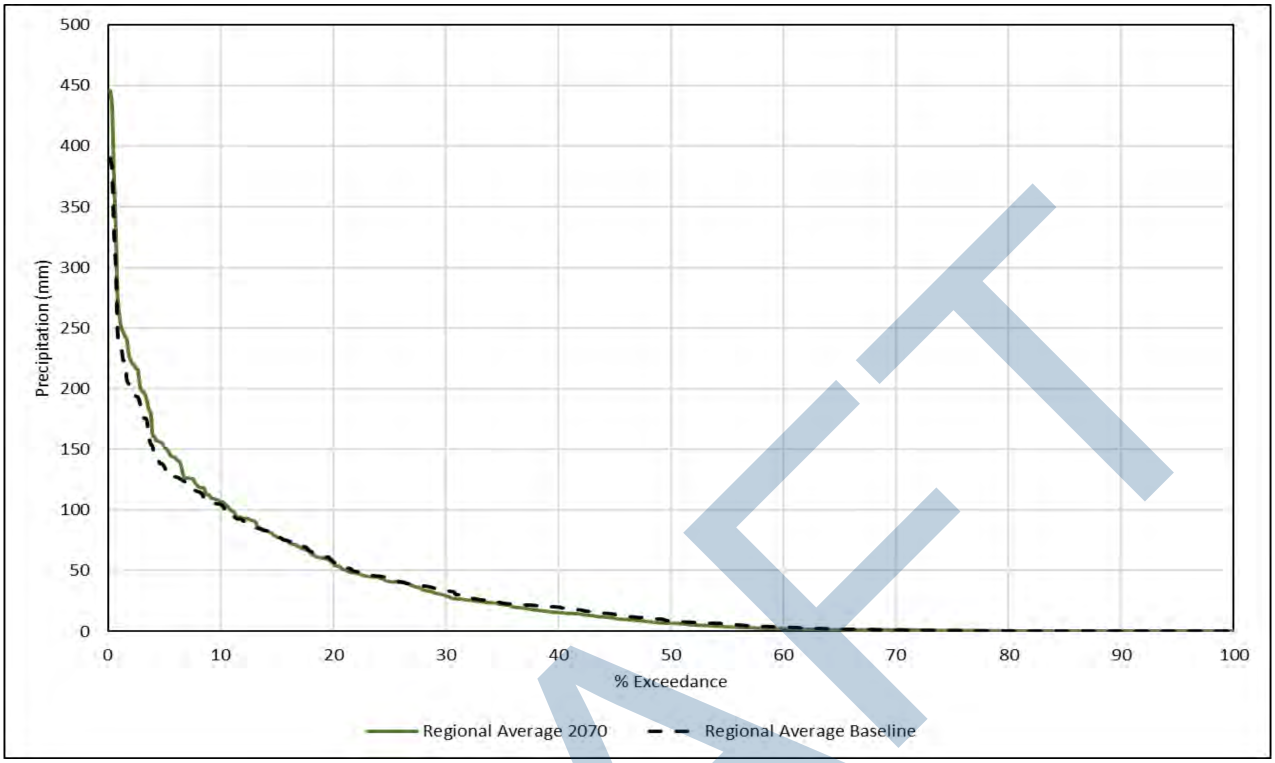


Figure C-2-3. Exceedance of Precipitation Perturbation Factors as Compared to Baseline Values

Figure C-2-4 shows the difference between the regional average under 2070 climate change conditions and the regional average under historical baseline conditions plotted against different amounts of projected monthly precipitation.

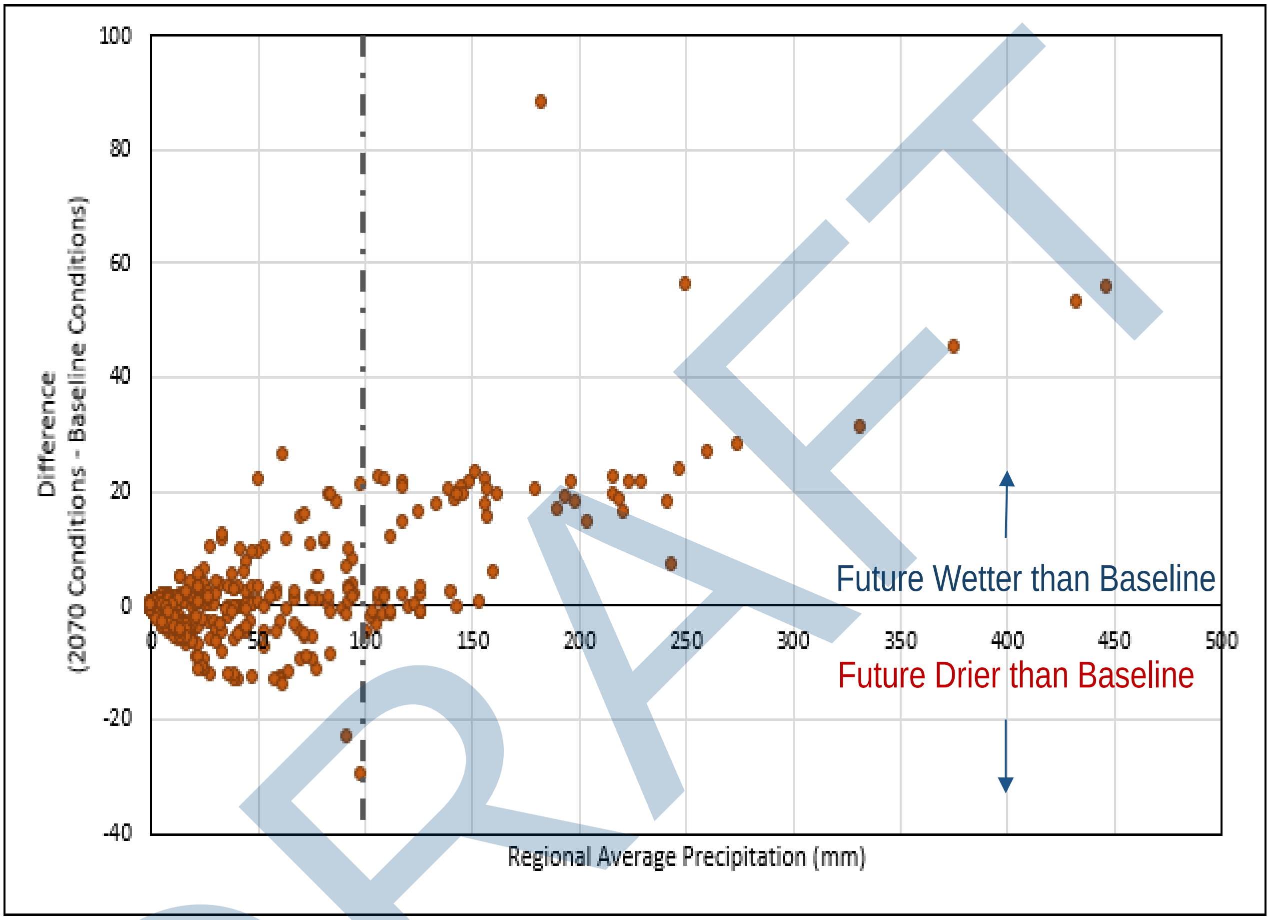


Figure C-2-4. Difference in Monthly Precipitation Estimates as Compared to Baseline Values

This plot demonstrates that in 2070 with climate change added, in low precipitation months, there is approximately equal probability that the month will be wetter or drier than historical conditions. However, under climate change, the 2070 conditions will be always wetter on average in months with precipitation above approximately 100mm. Therefore, under climate change conditions, we can see that the occurrence of low precipitation months will likely not change, but the higher precipitation months will be wetter overall than the baseline.

It is important to note that, while the central tendency scenario shows limited changes in future precipitation compared to historical record, the drier and wetter scenarios do show more variability. Figure 5 shows the exceedance curve for the wet scenario and it shows a larger difference to baseline compared to the central tendency. The use of other scenarios can be explored in future GSP updates.

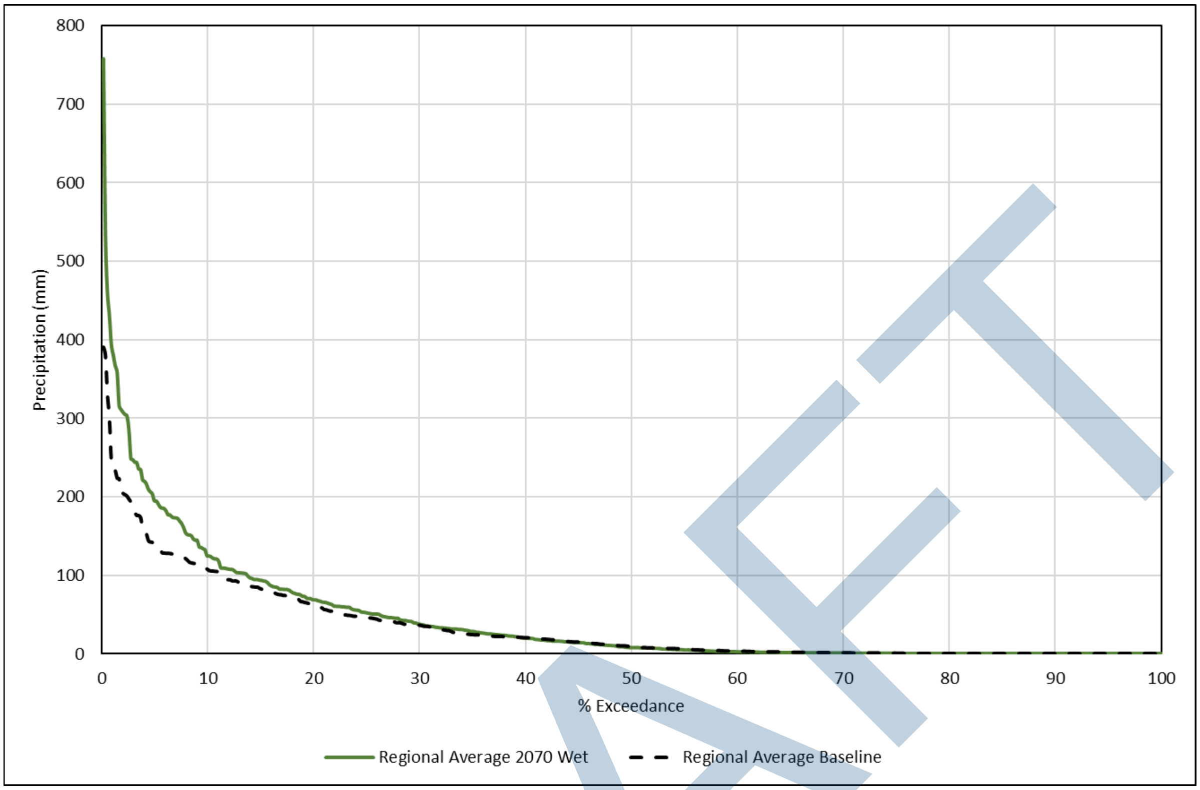


Figure C-2- 5. Exceedance of Wet Scemario Precipitation Estimates as Compared to Baseline Values

## Perturbed Evapotranspiration under Climate Change

Reference evapotranspiration (ET) is differentiated only by crop in the Cuyama model. However, because there is no spatial component to ET, the same crop in a different part of the basin is modeled with the same ET. Change factors for ET are available in the same spatially distributed manner as precipitation, as described above. However, to match the level of discretization with the Cuyama model, an average ET change factor was calculated across all VIC grid cells within the Cuyama Subbasin boundary. Therefore, the tool to process ET provided by DWR was not needed or used. Change factors provided by DWR for WY 1964 through December 1, 2011 were averaged. This average ET change factor was then applied to the baseline ET time series for each crop type. Because the same ET change factor was applied over the entire baseline time series, no synthesis was required in this analysis.

- For 2030, average change factor is: **1.03**
- For 2070, average change factor is: **1.07**

To better show the impact of climate change, a sample of years (1994 & 1995) for one crop (Melons) is included in Figure C-2-6. Figure C-2-7 shows the exceedance curve for these estimates.

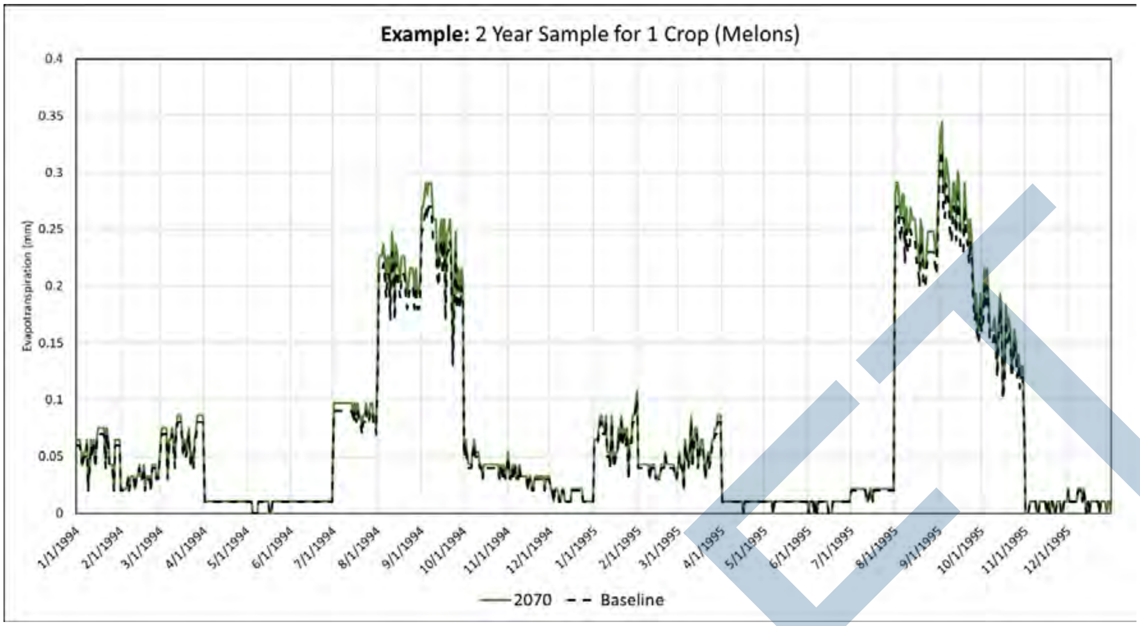


Figure C-2-6. Changes in Melon Evapotranspiration in 1994 & 1995 as Compared to Baseline Values

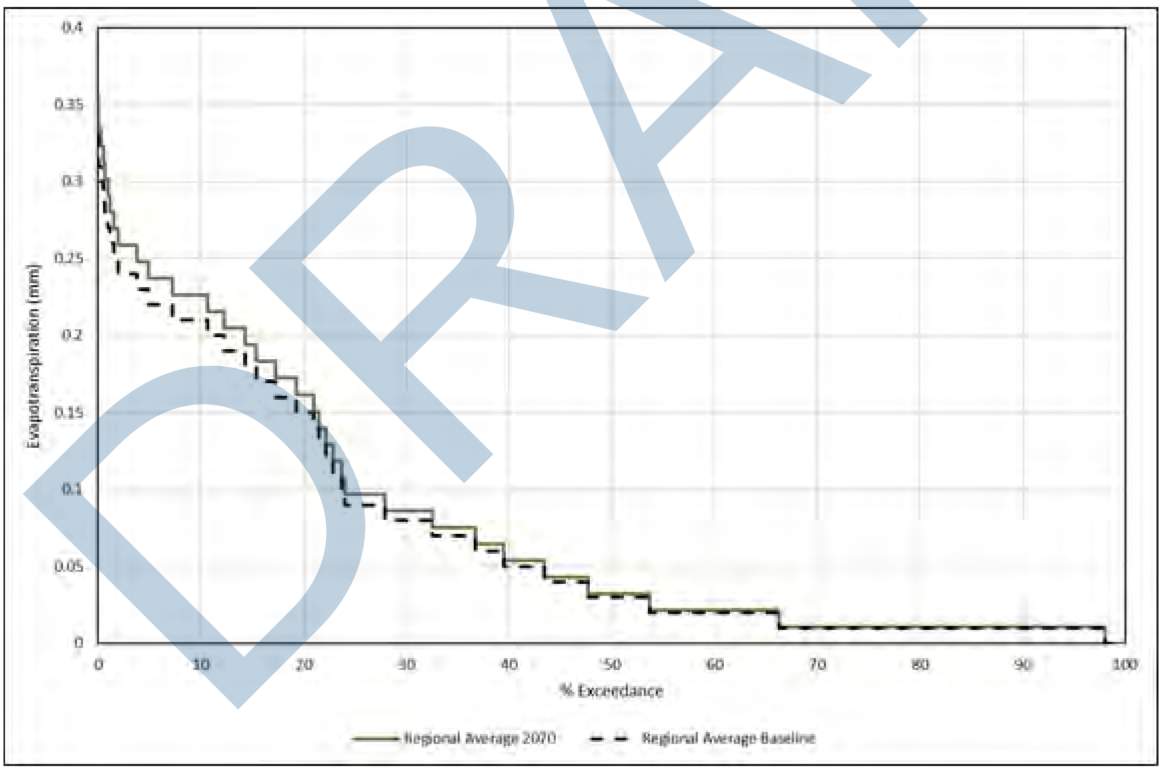


Figure C-2-7. Exceedance of Melon Evapotranspiration in 1994 & 1995 as Compared to Baseline Values

## Considerations for this Analysis

By using DWR's climate change datasets, this GSP has chosen to use a climate period analysis. A "period of analysis" method is what DWR proposes since it provides an intuitive way to compare the past and future conditions, preserving historical temporal trends. Under a period of analysis (sometimes referred to as the "delta method") precipitation and Crop ET patterns from the past are mirrored into the future and shifted either higher or lower in magnitude (DWR, 2018). When using a period of analysis method, any difference between the baseline historical conditions and the projected conditions can be attributed only to climate change.

Using a climate period analysis in contrast to a transient analysis, however, brings also some disadvantages. While a significant advantage of this method is that the climate change signal can be isolated from signals of other impacts, temporal changes in the water resources system are ignored in favor of adopting the temporal trends of the past. In a continuously changing and variable climate in California, this approach incurs significant disadvantages. Inter-annual variability in the climate period analysis follows the exact patterns of the historical period it references. Shifting seasonality of precipitation, peak snowmelt, and temperature, are important climate impacts expected through the GSP planning horizon that are not captured in the projected water budget (Langridge, Sepaniak, Fencl, & Mendez, 2018) (PPIC, 2019). Longer drought period than have been recorded historically are also expected according to many climate experts (PPIC, 2019). These changes are also not captured.

## Opportunities for Future Refinement

The regulations dictate that GSPs reflect the best available science to make climate change projections. For future GSP updates, climate change analysis incorporation should build off of this baseline work to continually improve projections into the future. Some refinements or modifications may include:

- Use other scenarios (dry and wet) in addition to the central tendency scenario
- Use a transient method as opposed to a period of record method
- Incorporate paleohydrology observations and make inferences about the impacts of longer droughts captured in the paleorecord

## 1.3 References

DWR. (2016). *Best Management Practices for the Sustainable Management of Groundwater Water Budget.*

DWR. (2018). *DWR-Provided Climate Change Data and Guidance for Use During Groundwater Sustainability Plan Development.*

DWR. (2018). *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development.*

DWR. (2018, December 13). *SGMA Climate Change Resources*. Retrieved from https://data.cnra.ca.gov/dataset/sgma-climate-change-resources

DWR. (2019). *SGMA Data Viewer*. Retrieved from https://sgma.water.ca.gov/webgis/?appid=SGMADataViewer

Langridge, R., Sepaniak, S., Fencl, A., & Mendez, L.-E. (2018). Adapting to Climate Change and Drought in Selected California Groundwater Basins: Local Achievements and Challenges. *California's Fourth Climate Change Assessment*.

PPIC. (2019). *Climate Change.* Public Policy Institute of California. Retrieved from https://www.ppic.org/wp-content/uploads/californias-future-climate-change-january-2019.pdf

# Attachment C-3

## Groundwater Level Hydrographs for Calibration Wells

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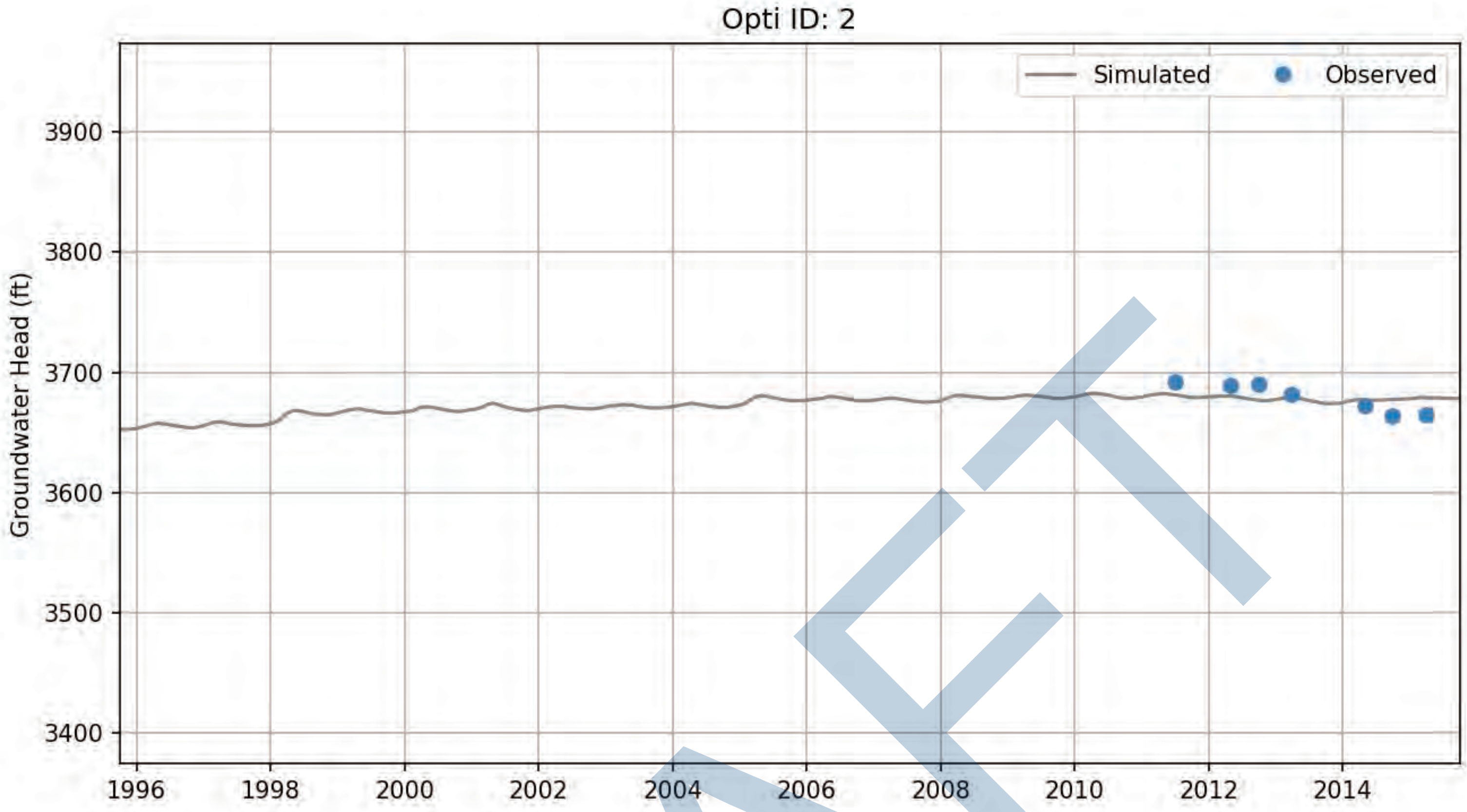
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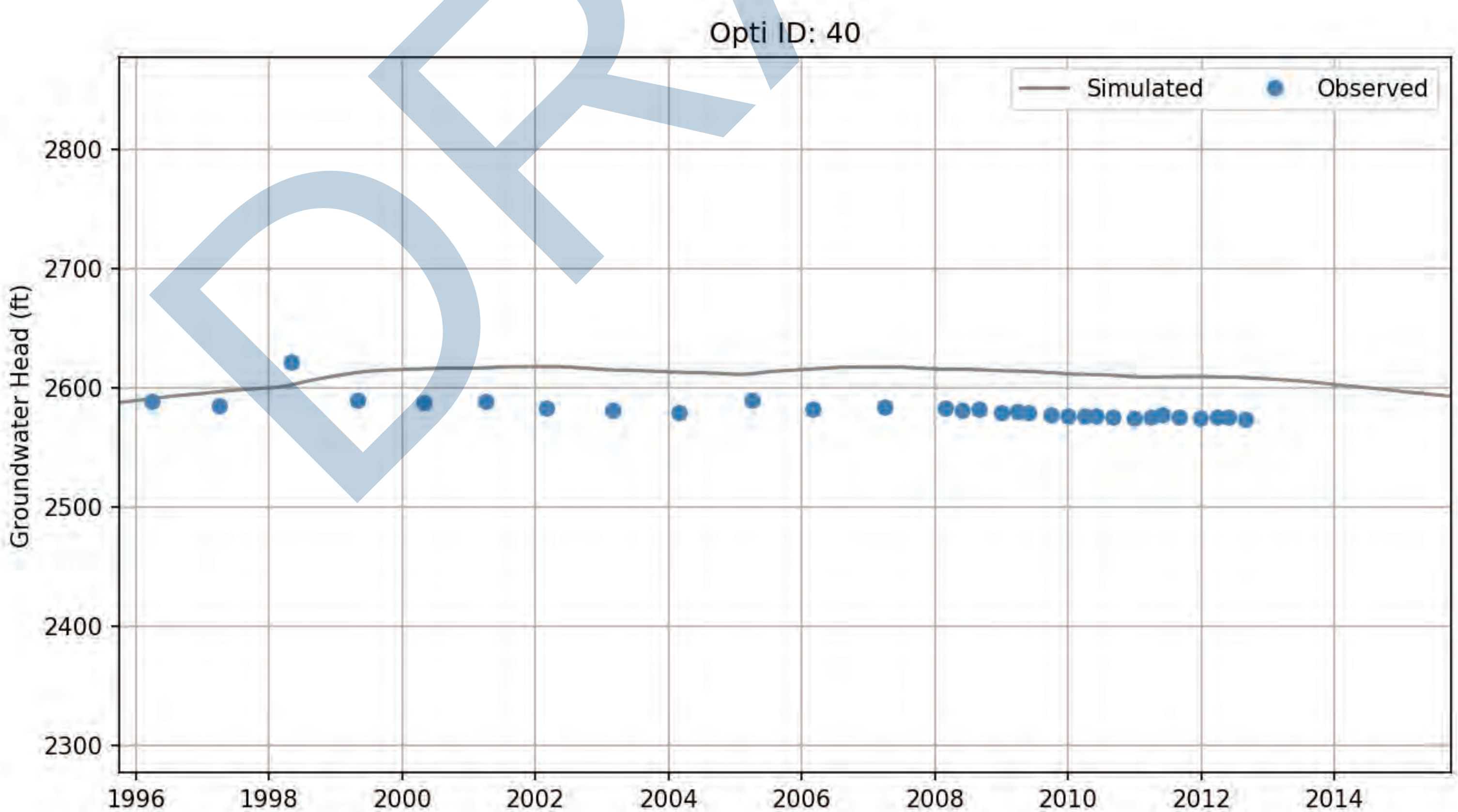
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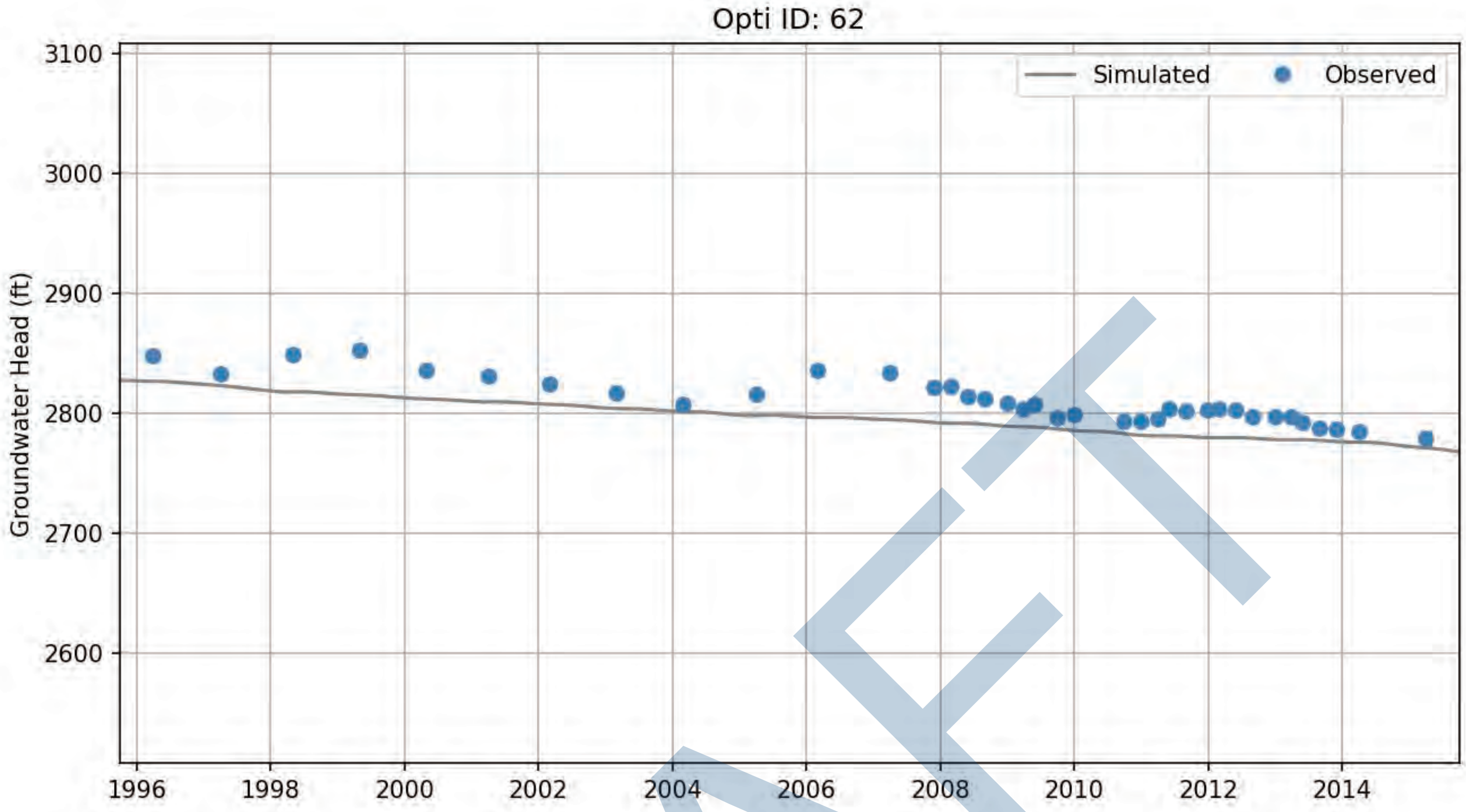
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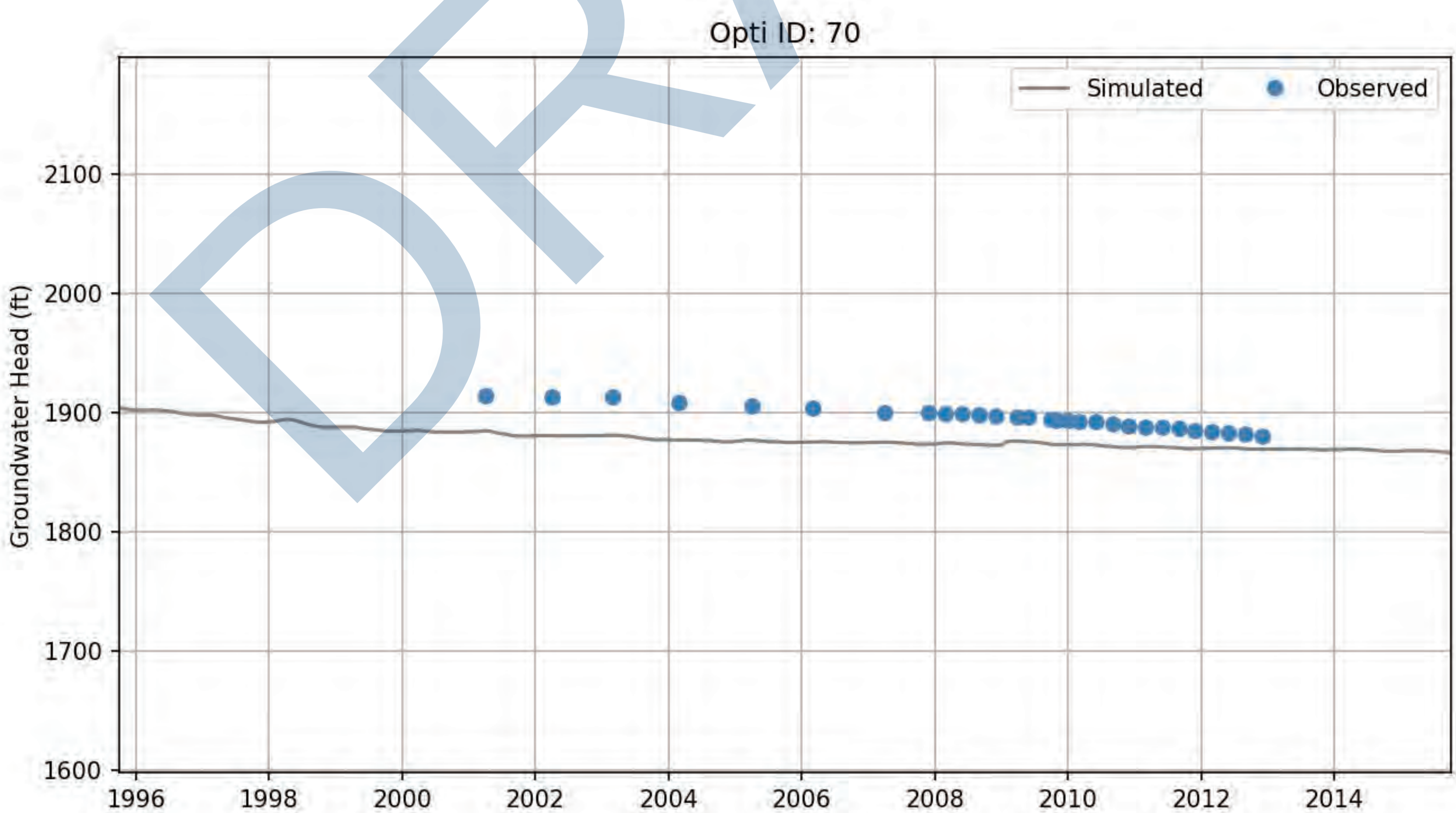
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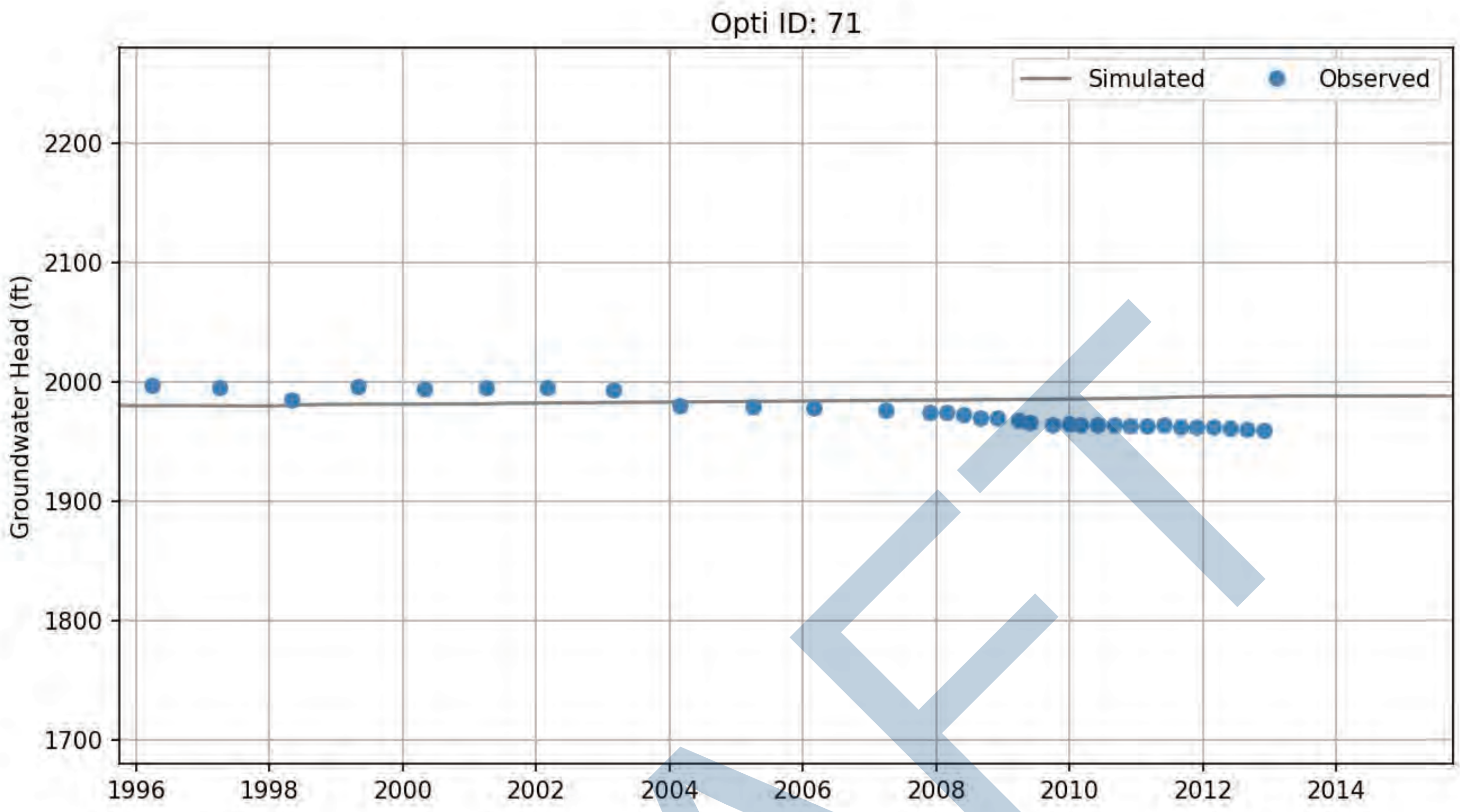
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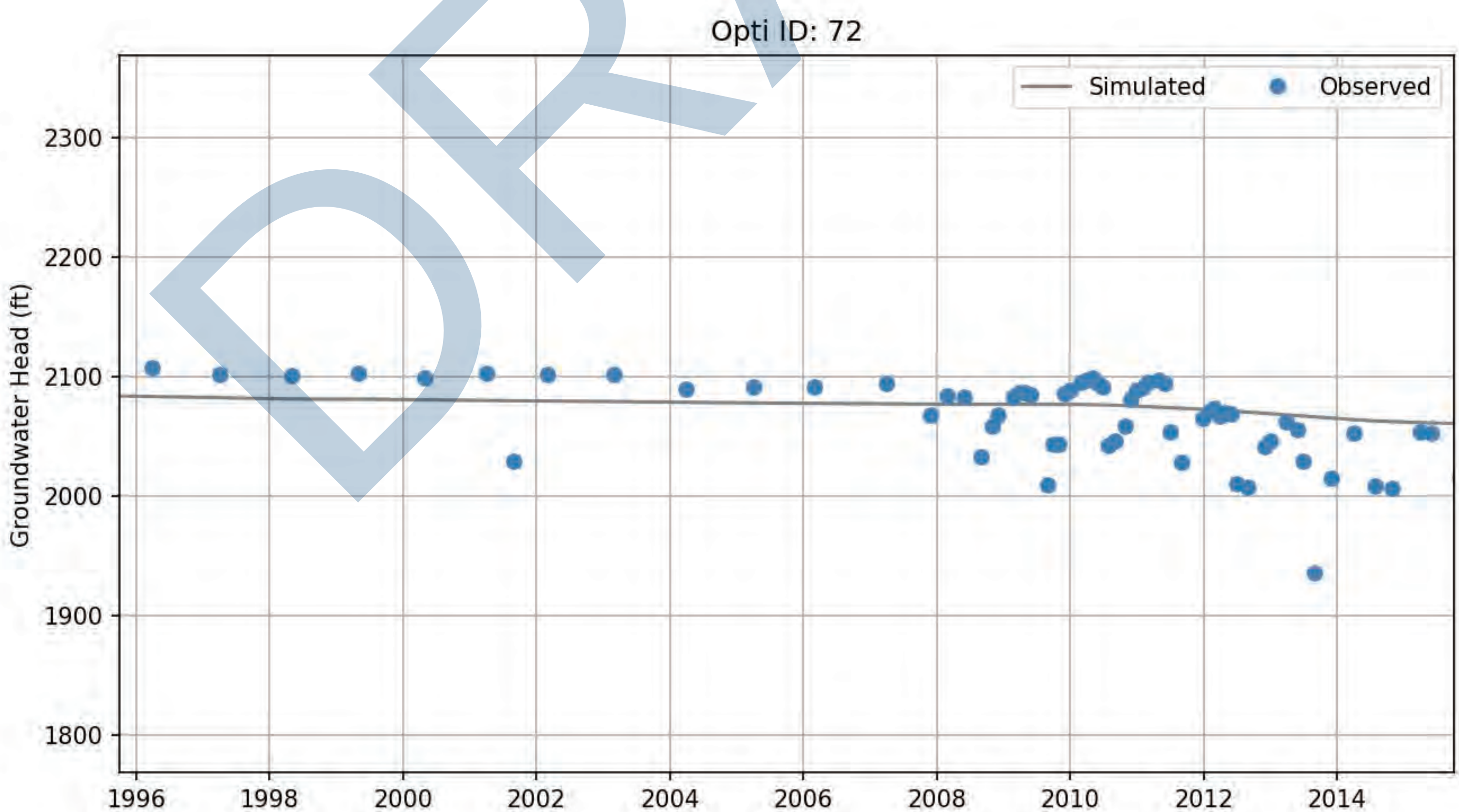
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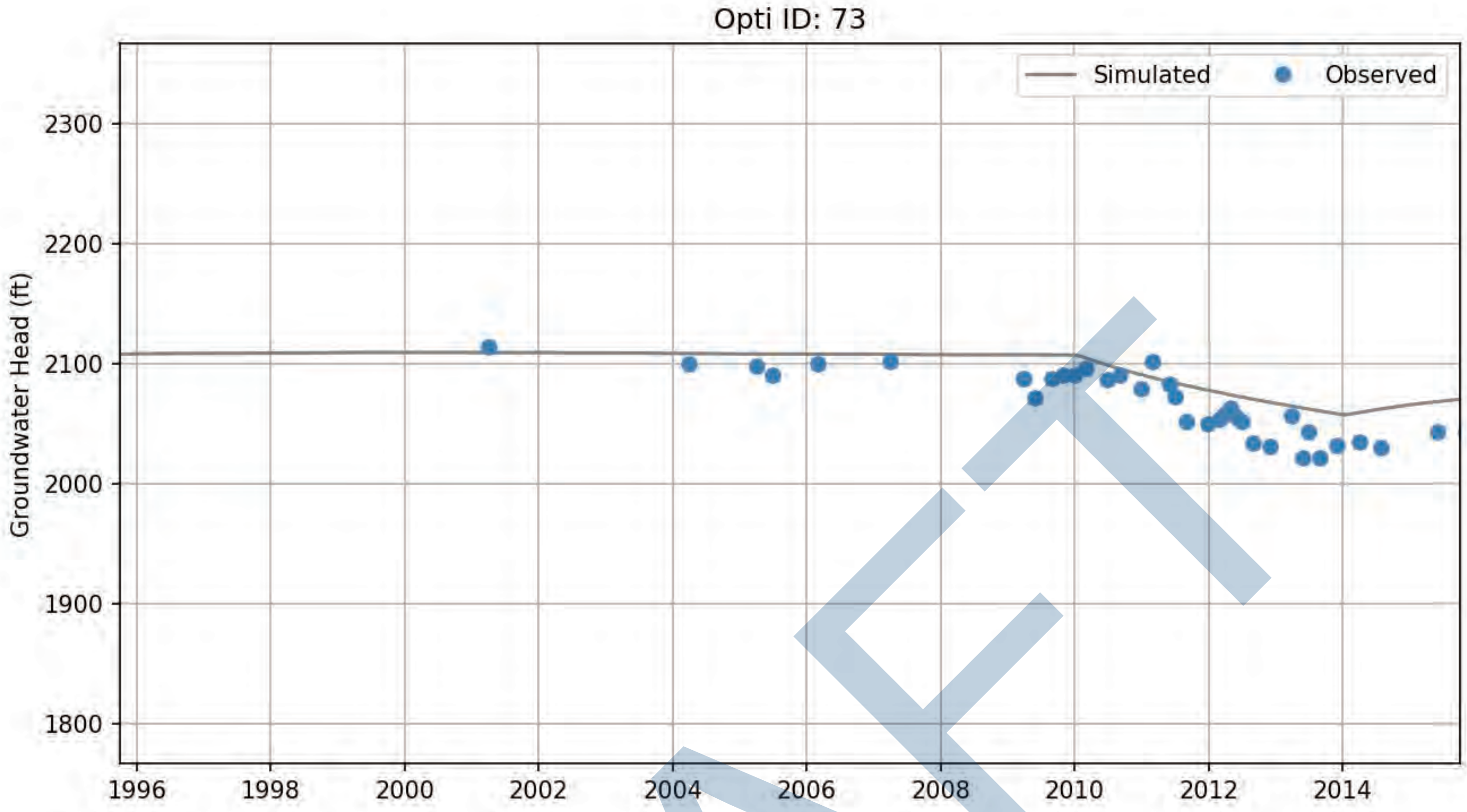

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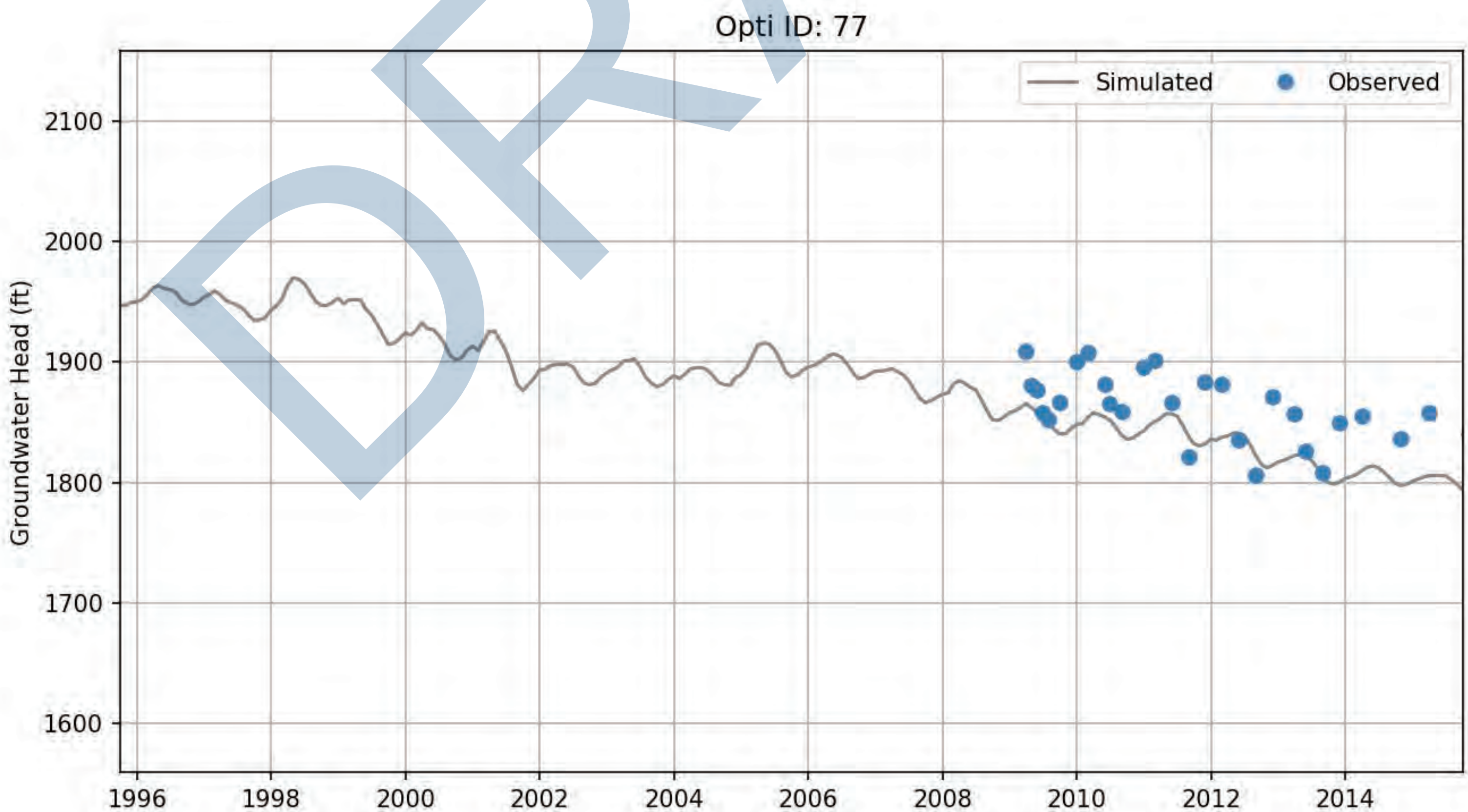

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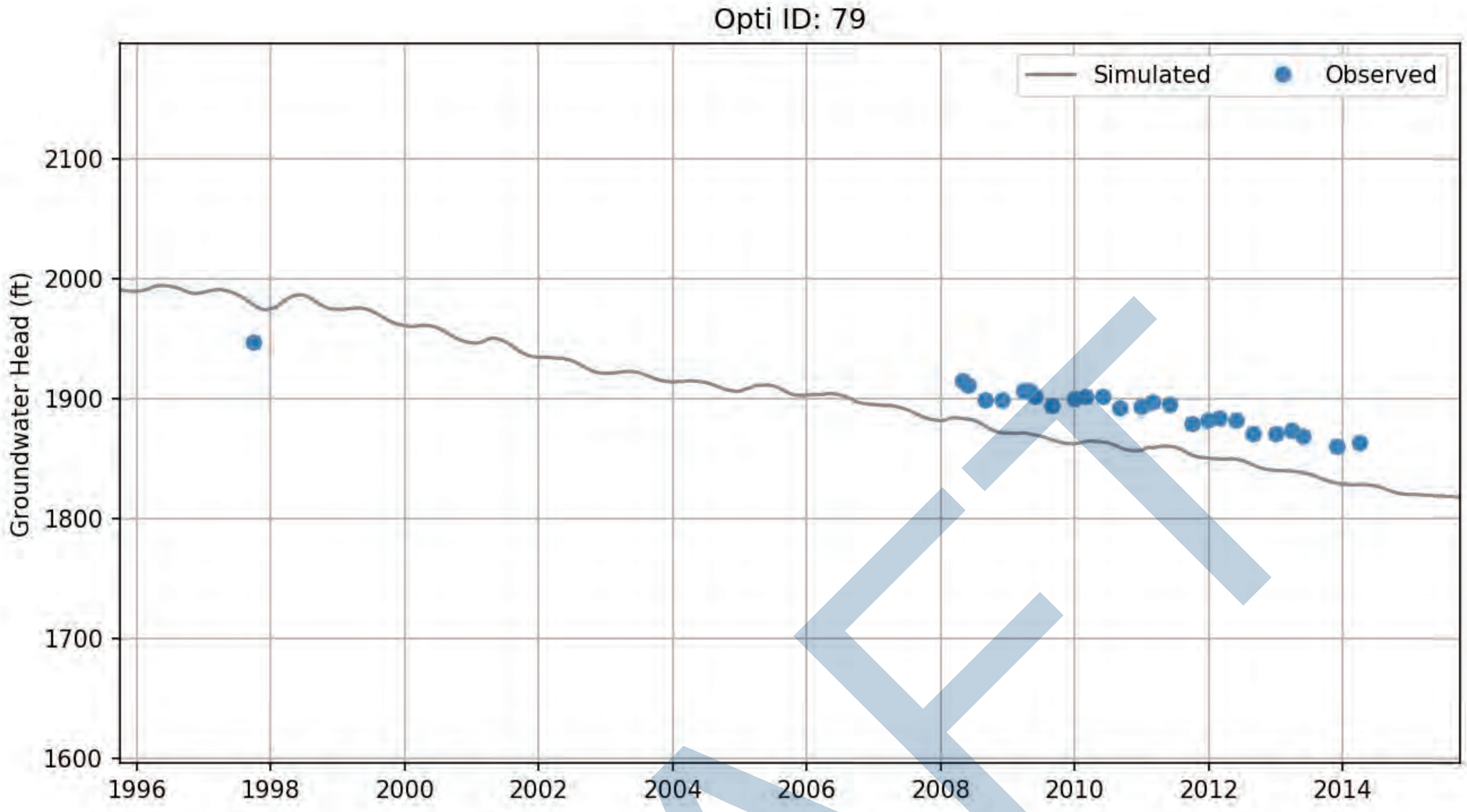
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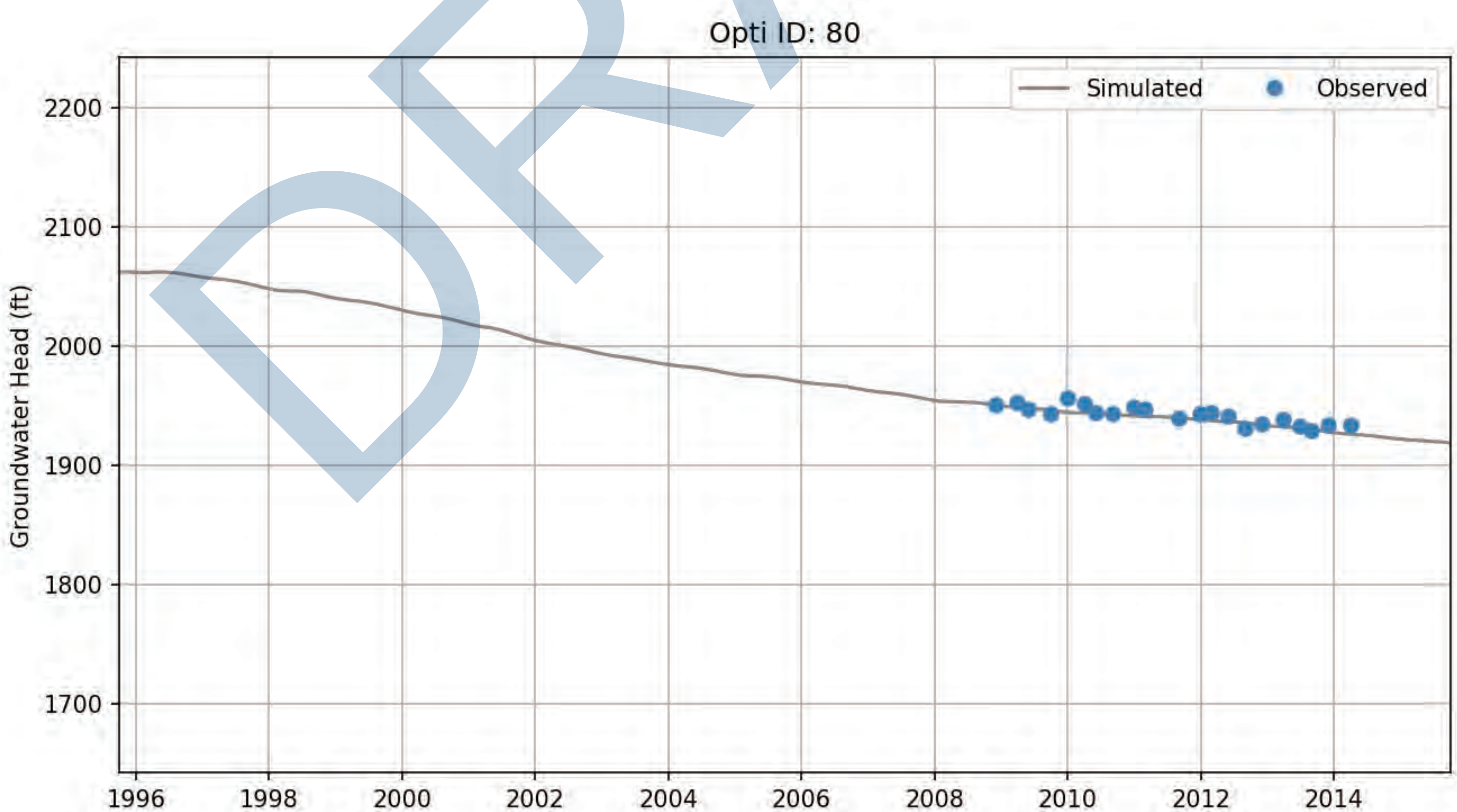
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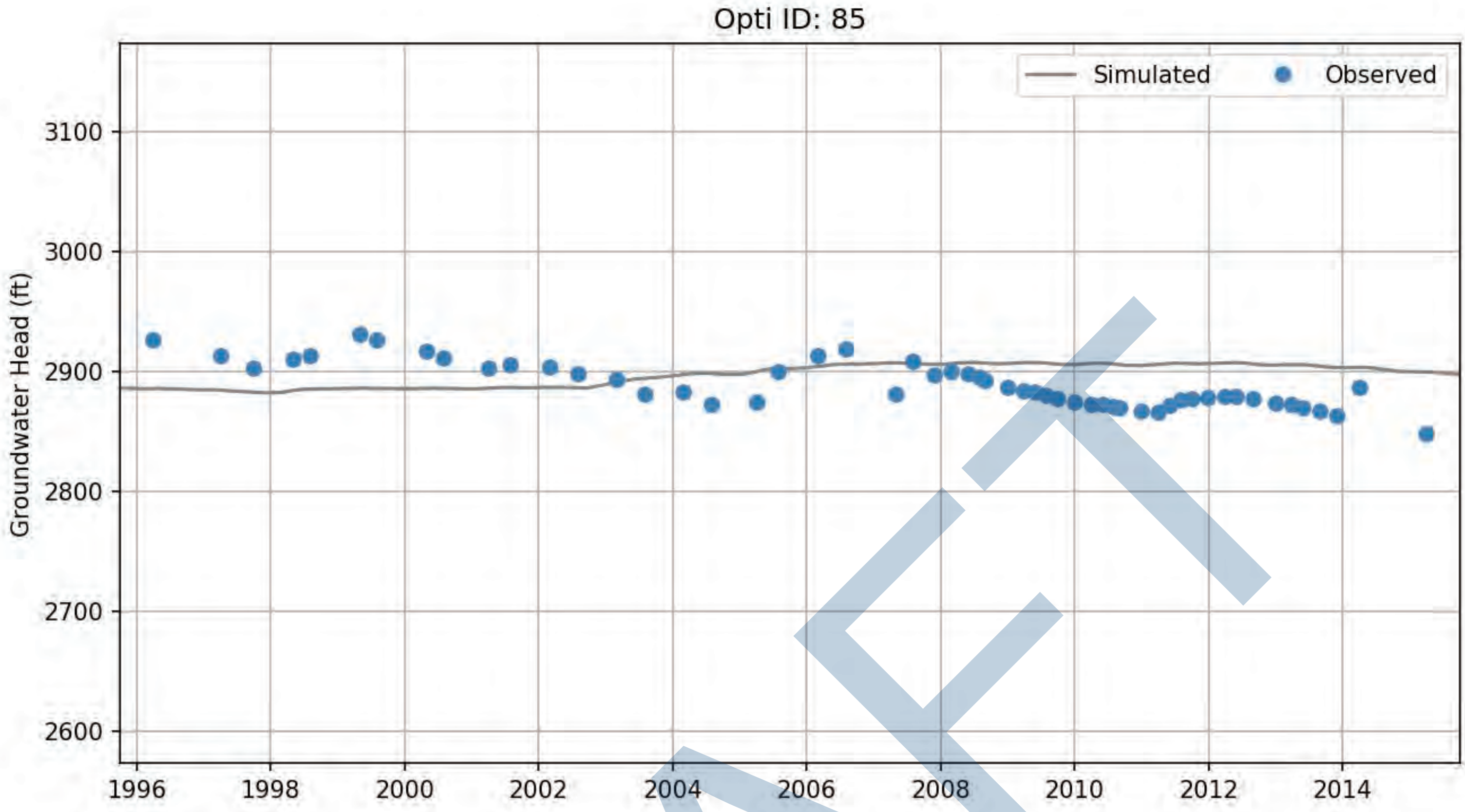
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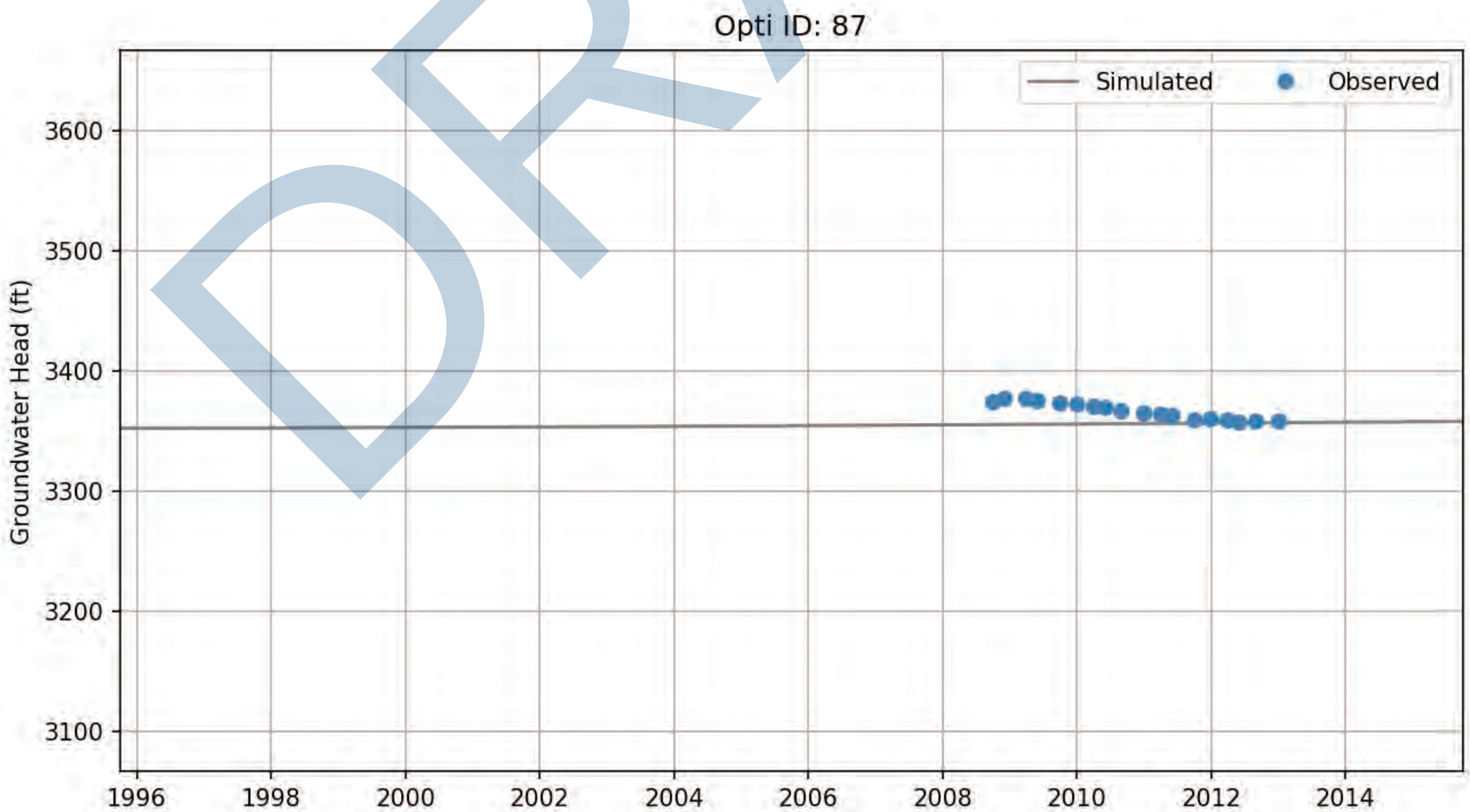
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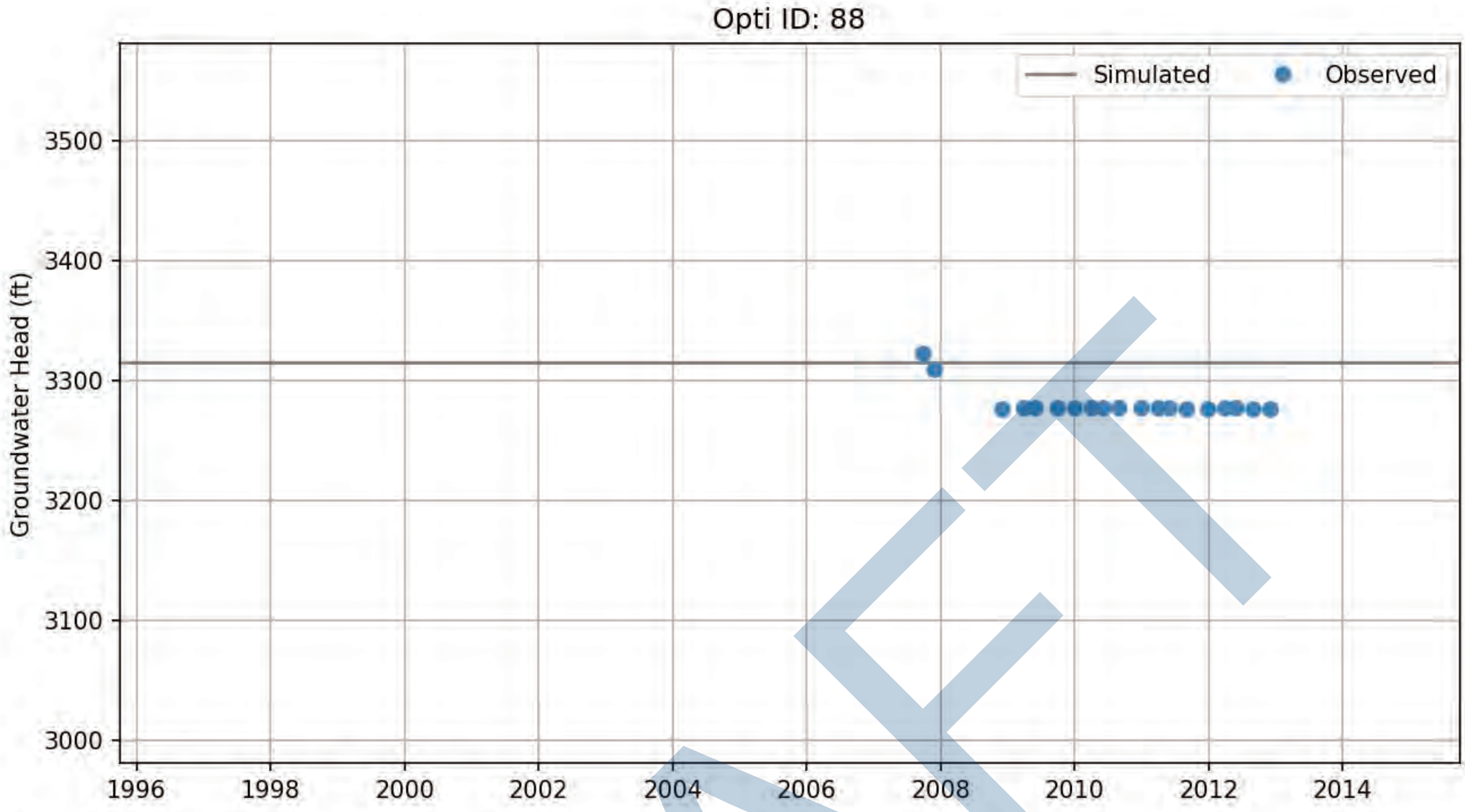
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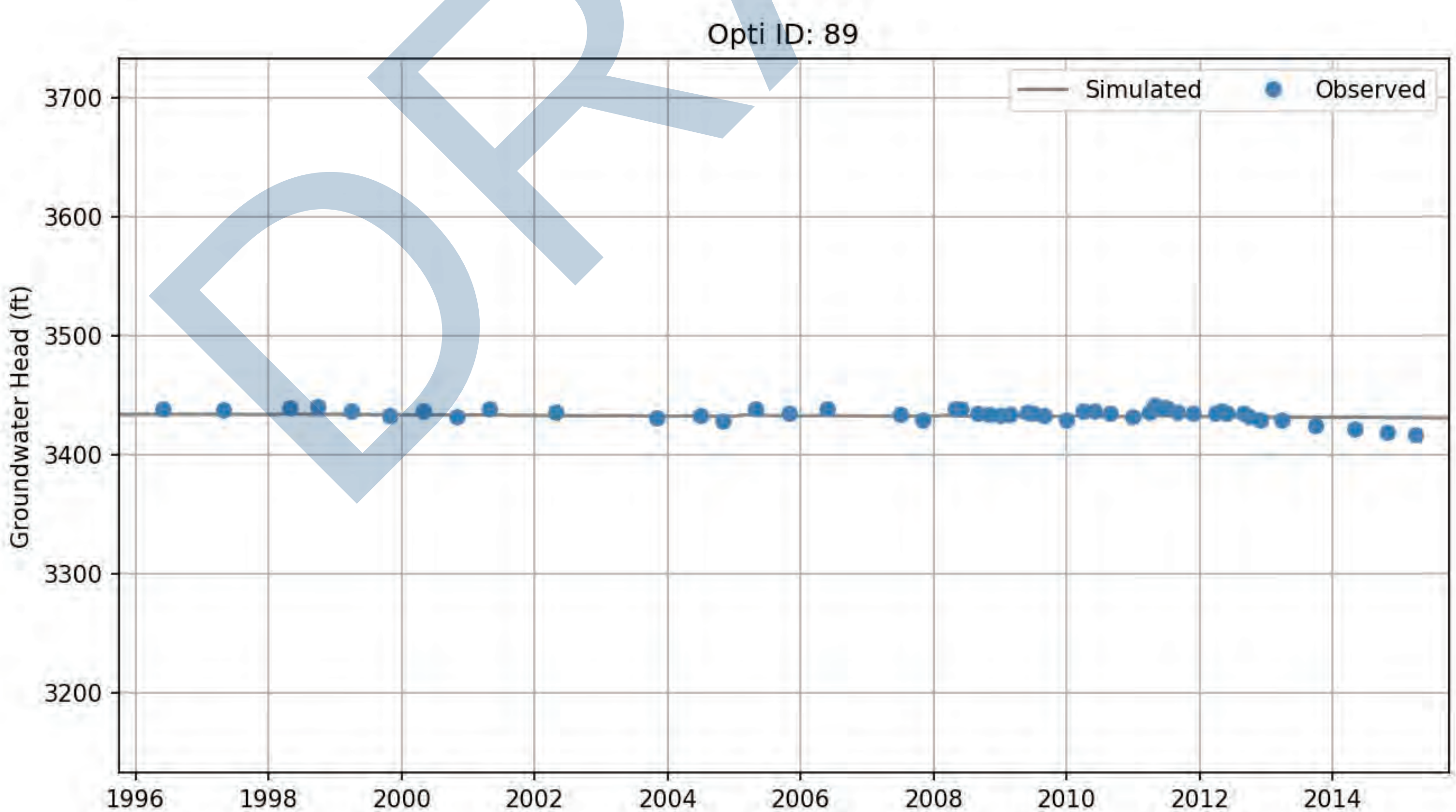
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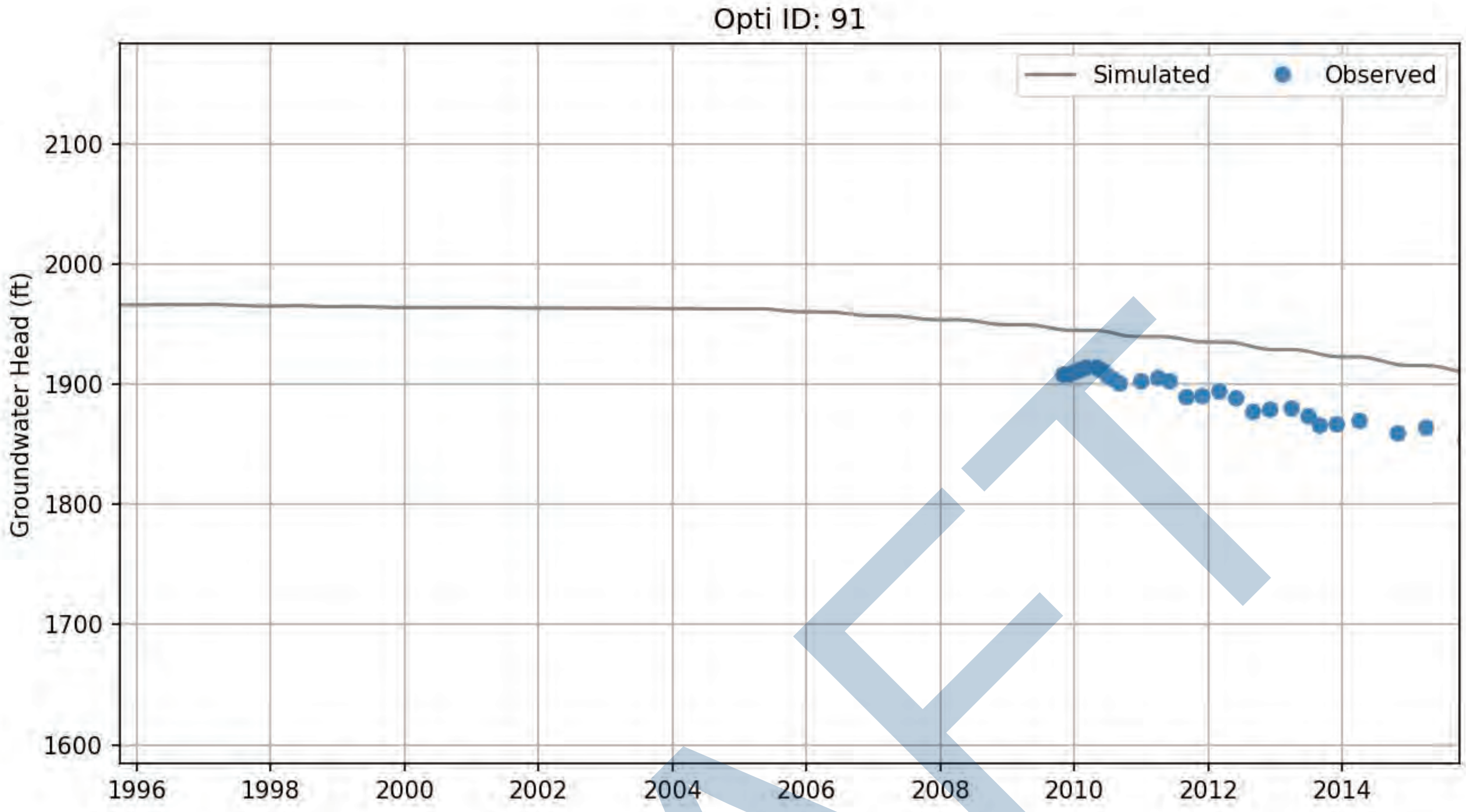

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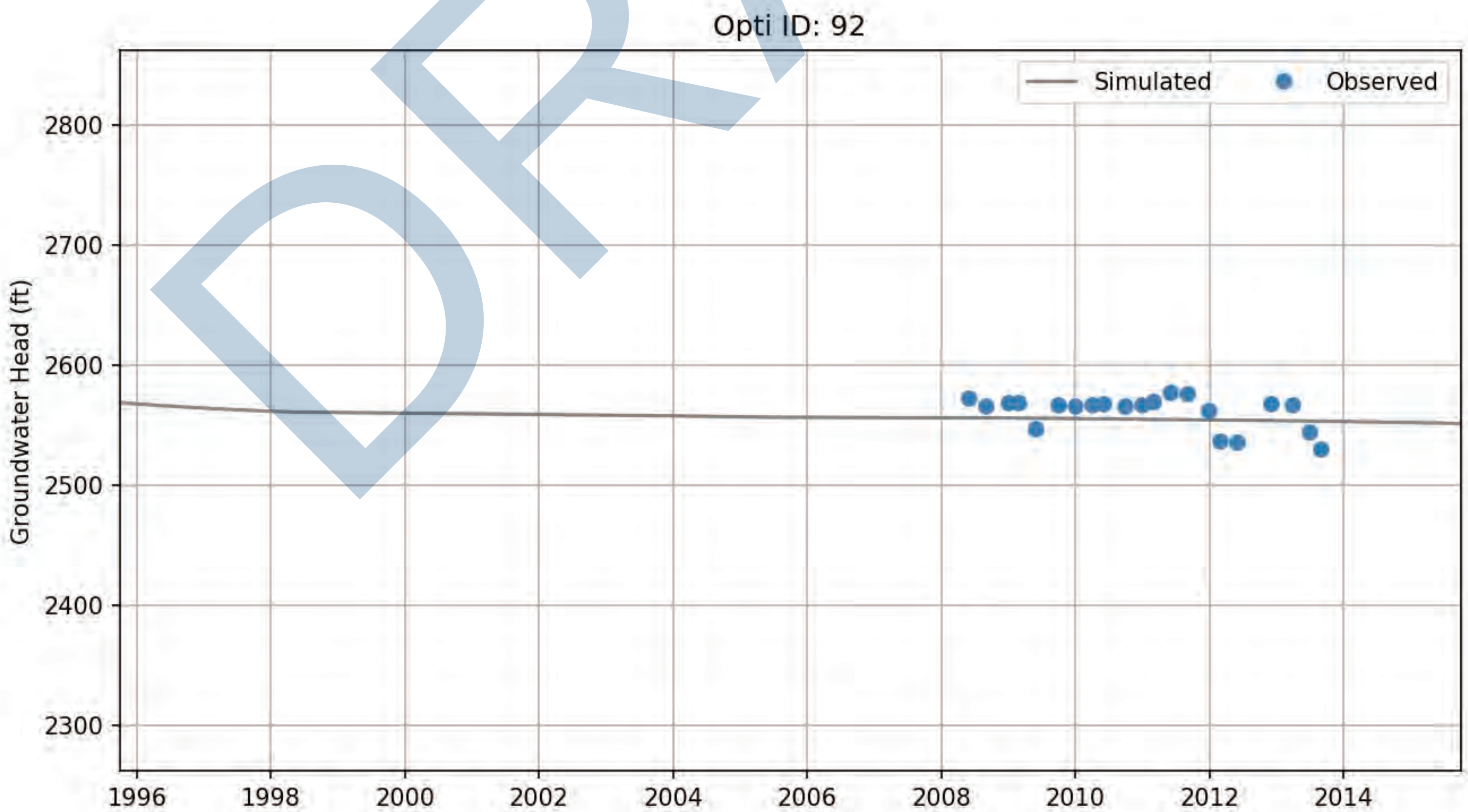

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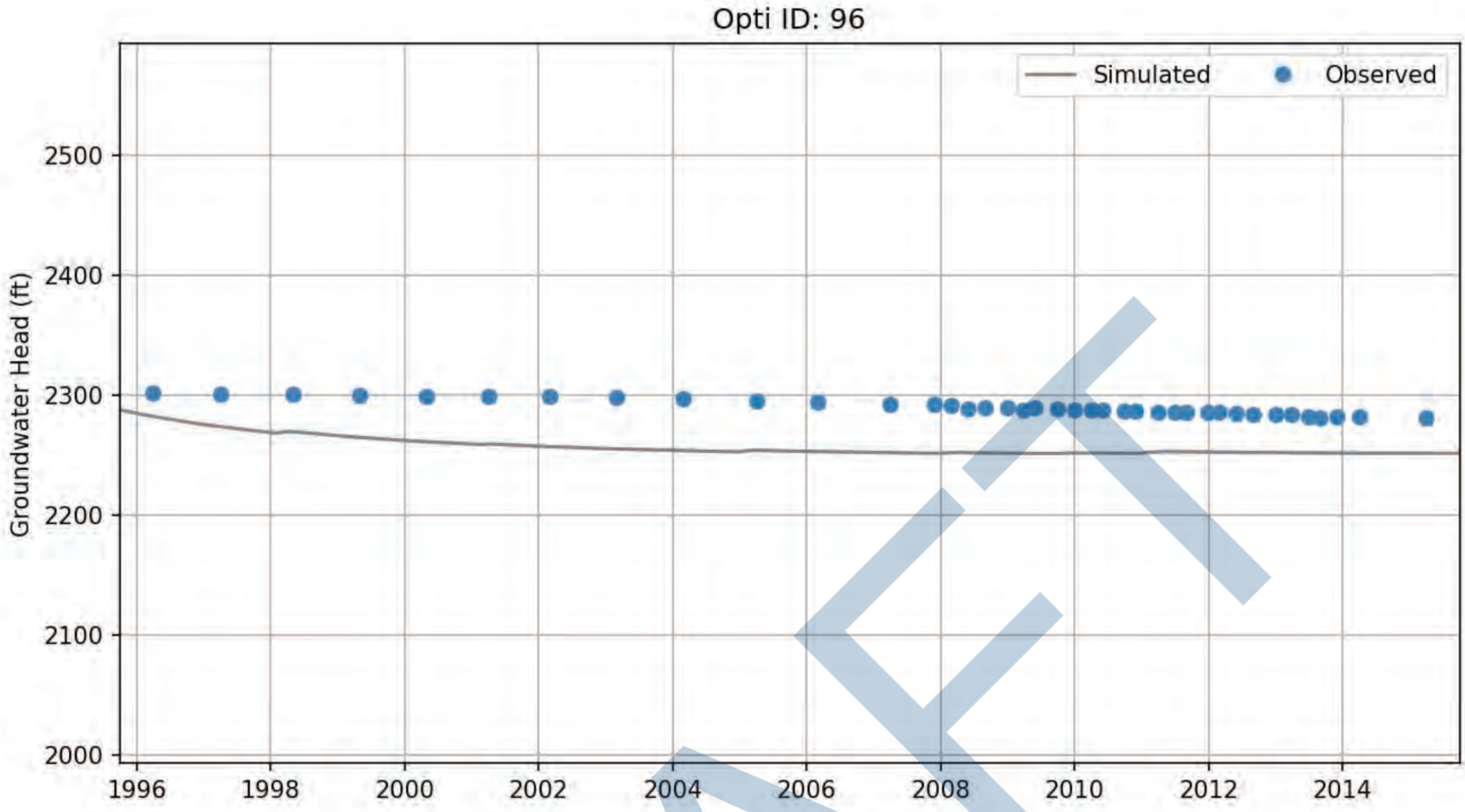
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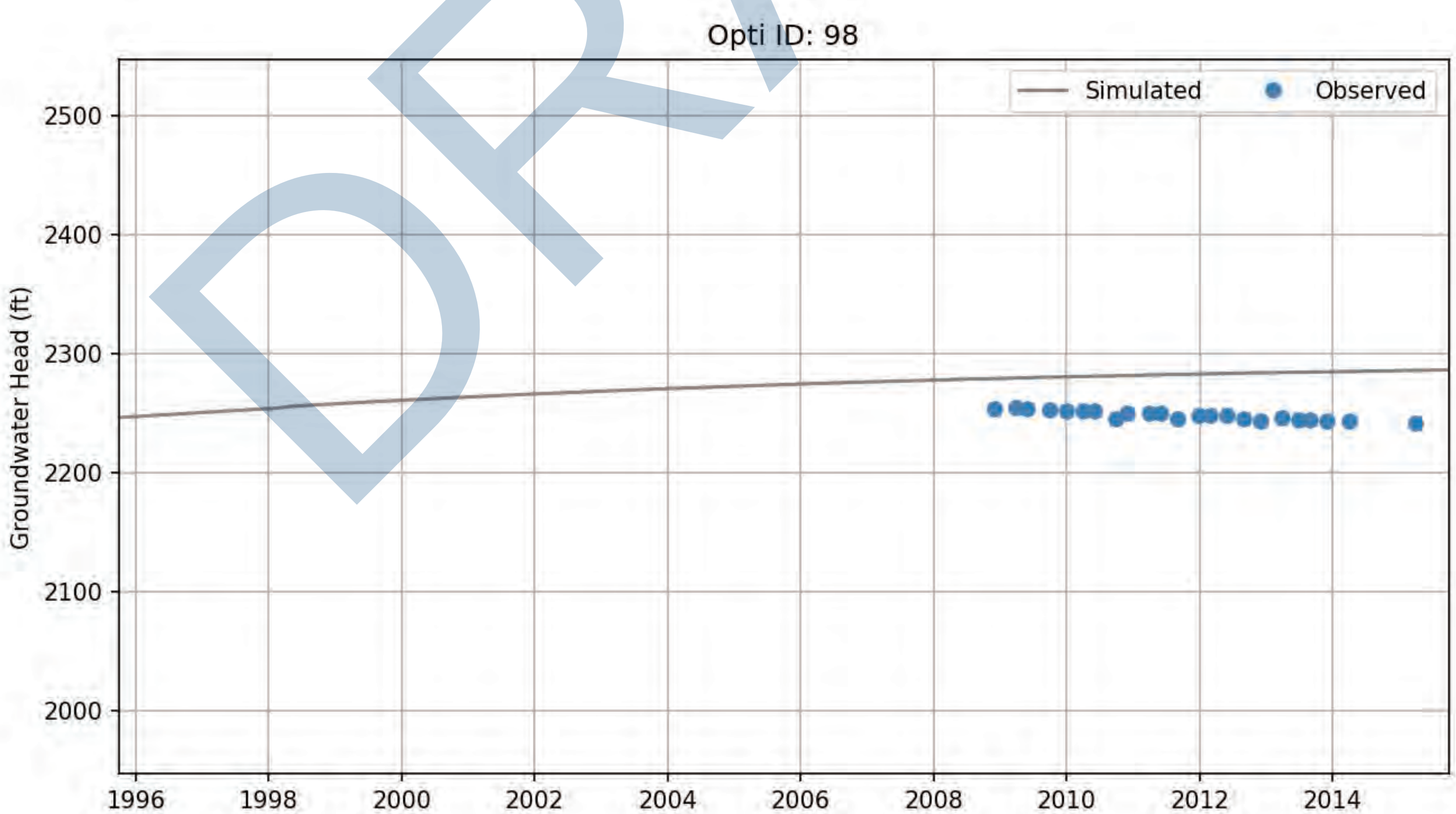
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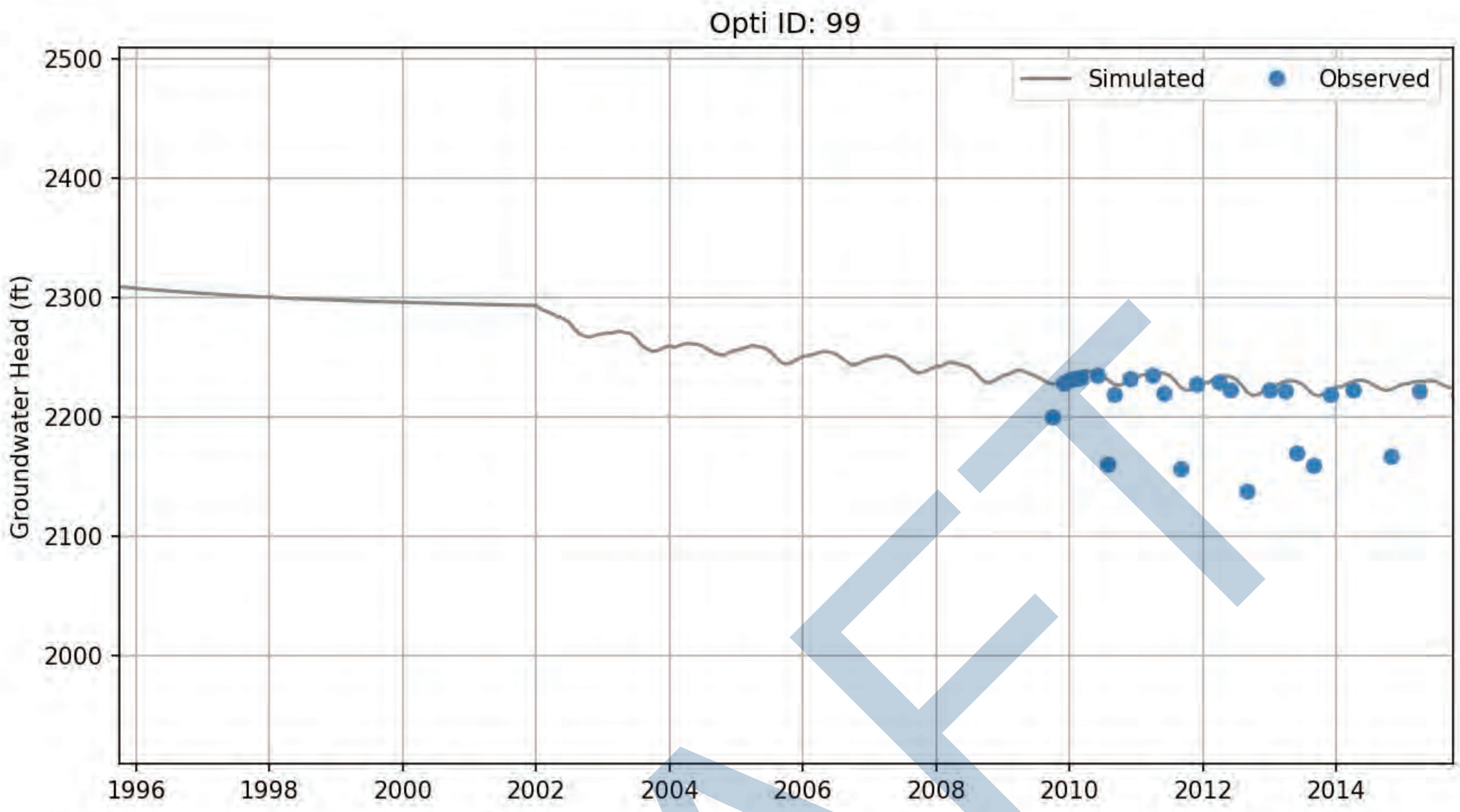
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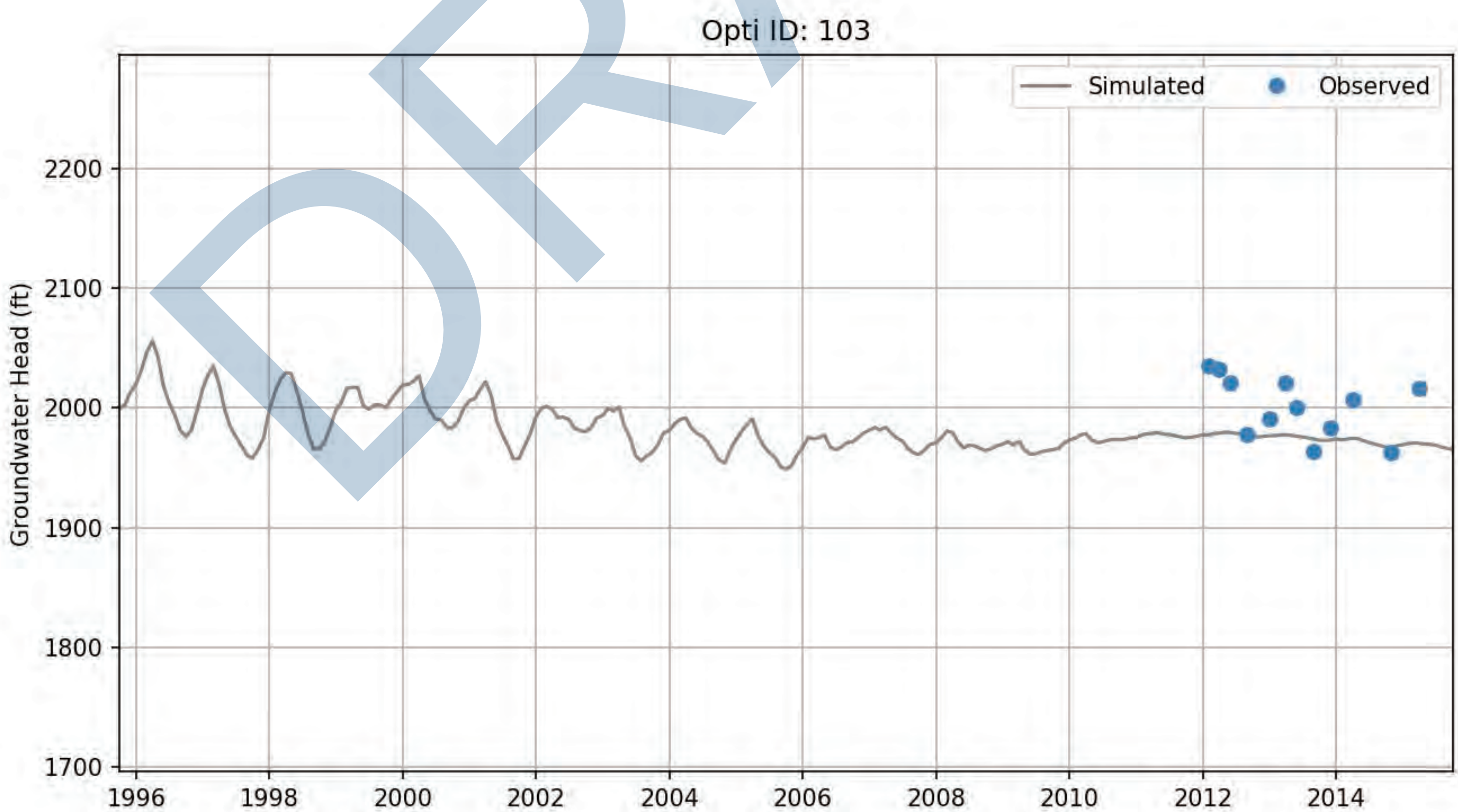
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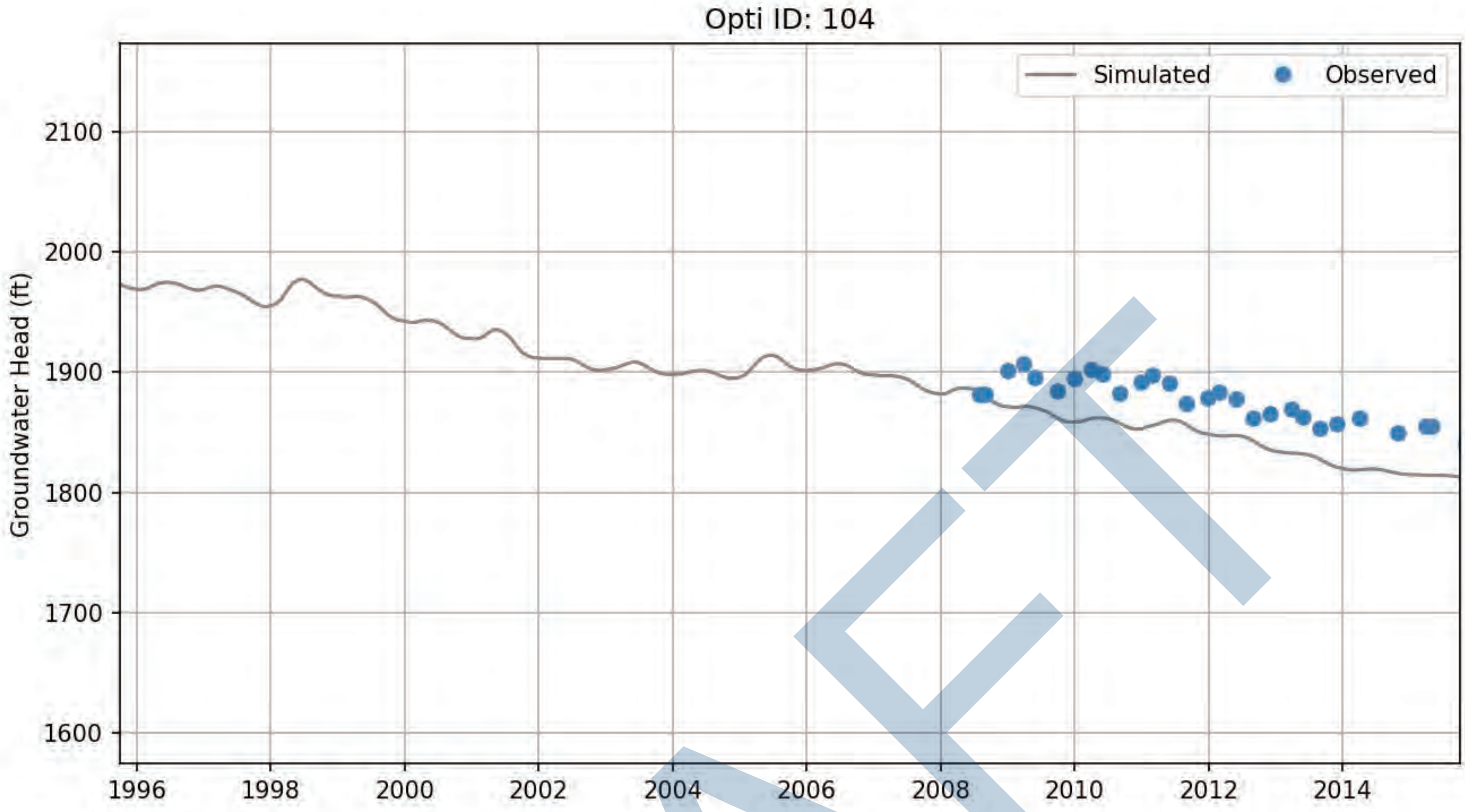
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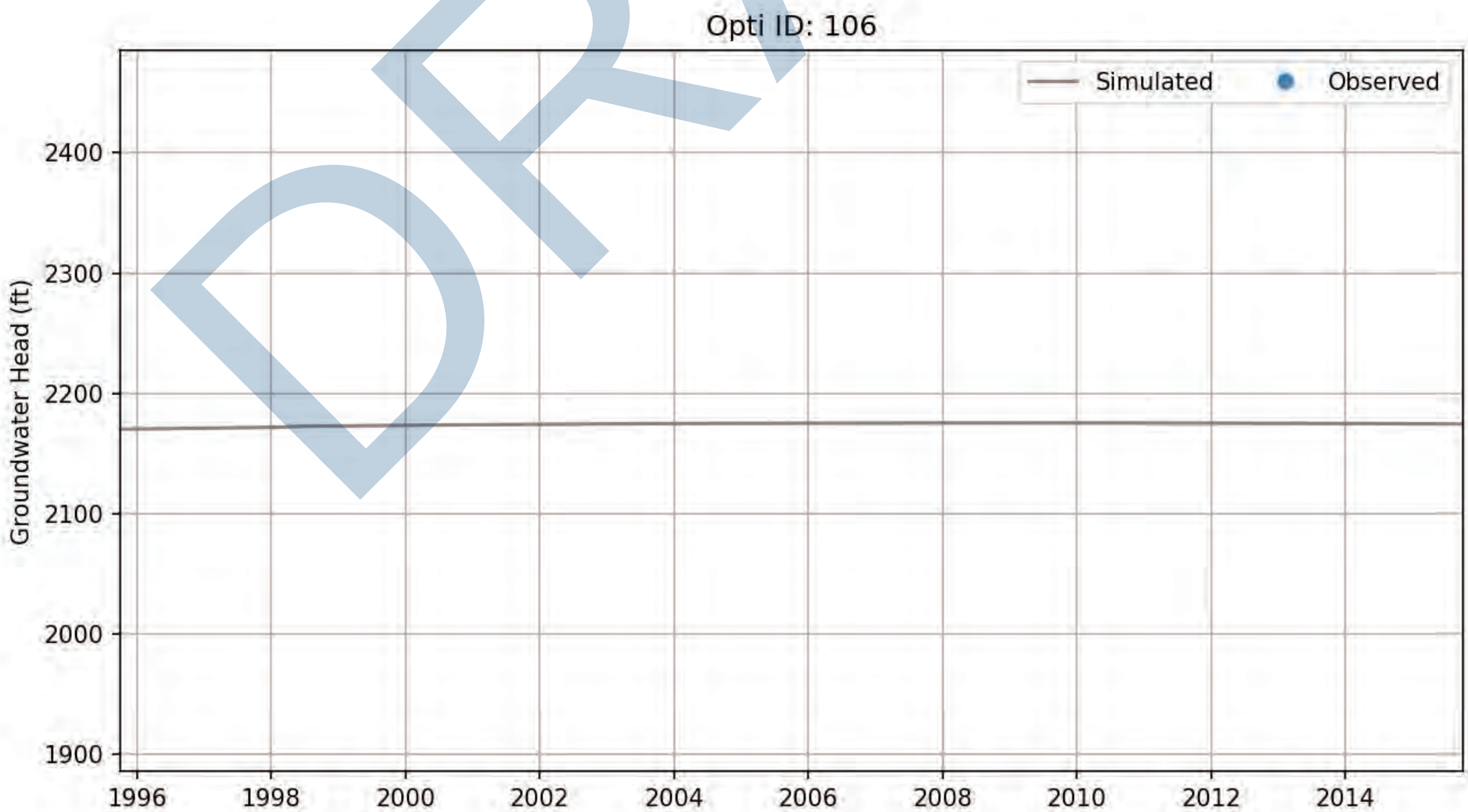
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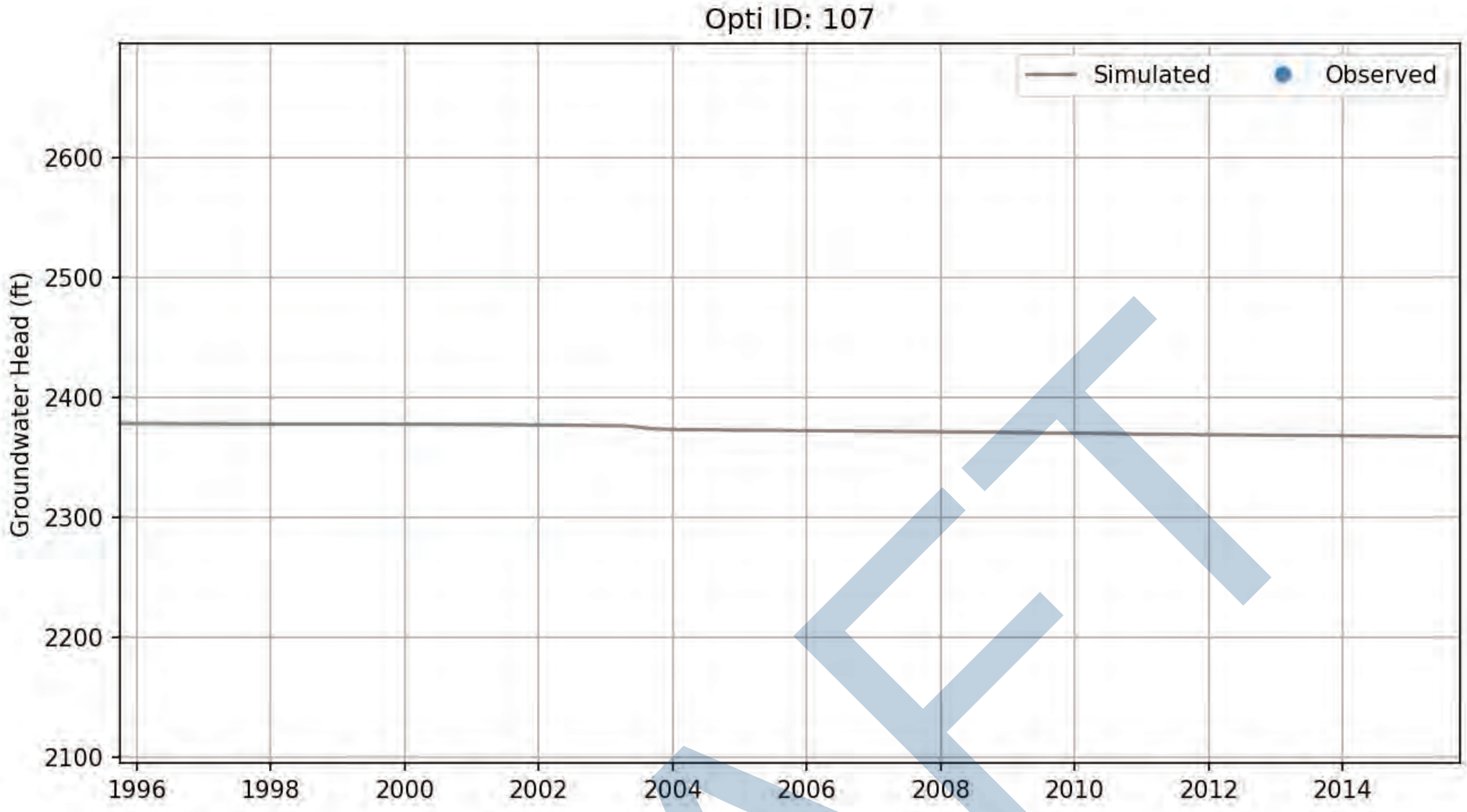

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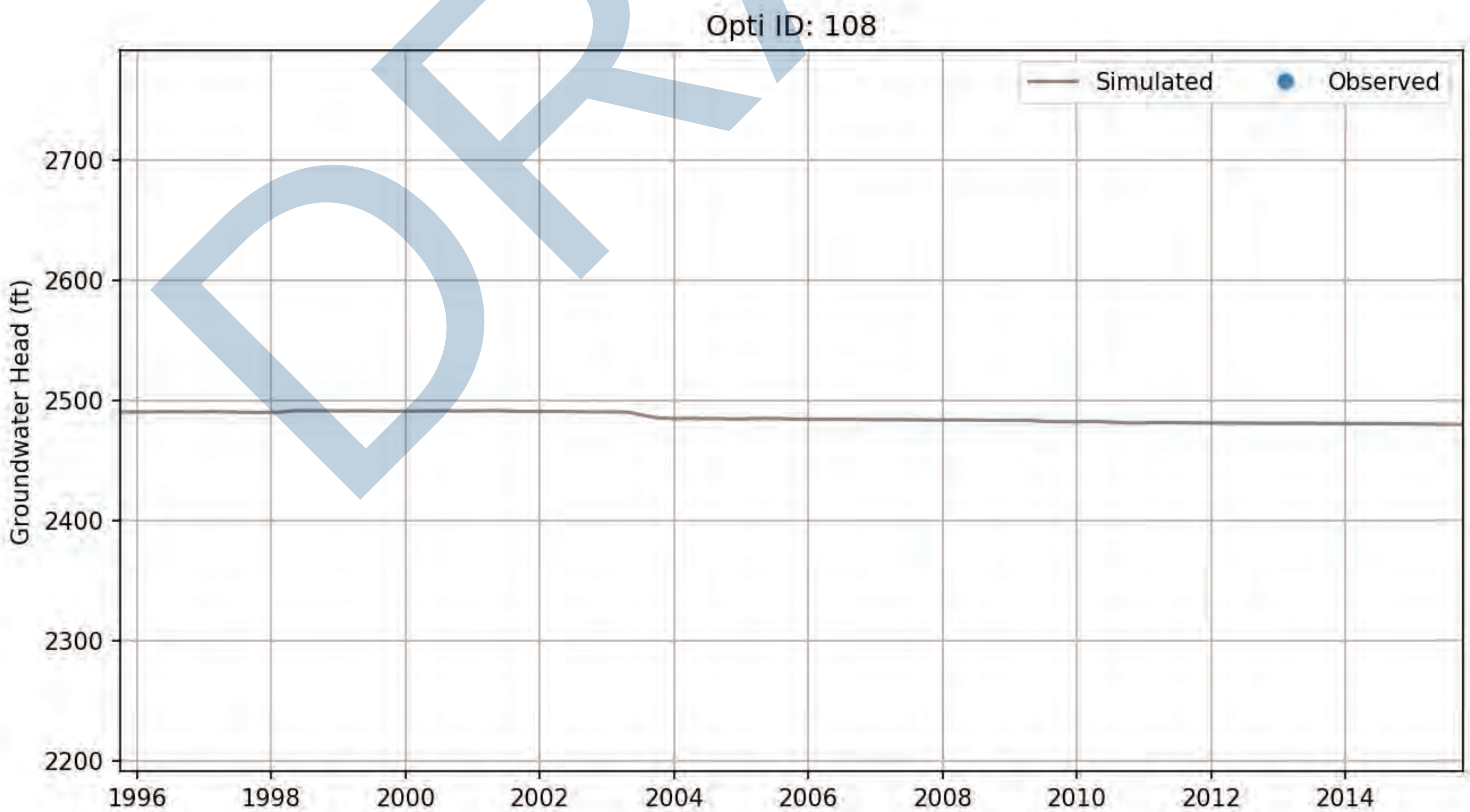
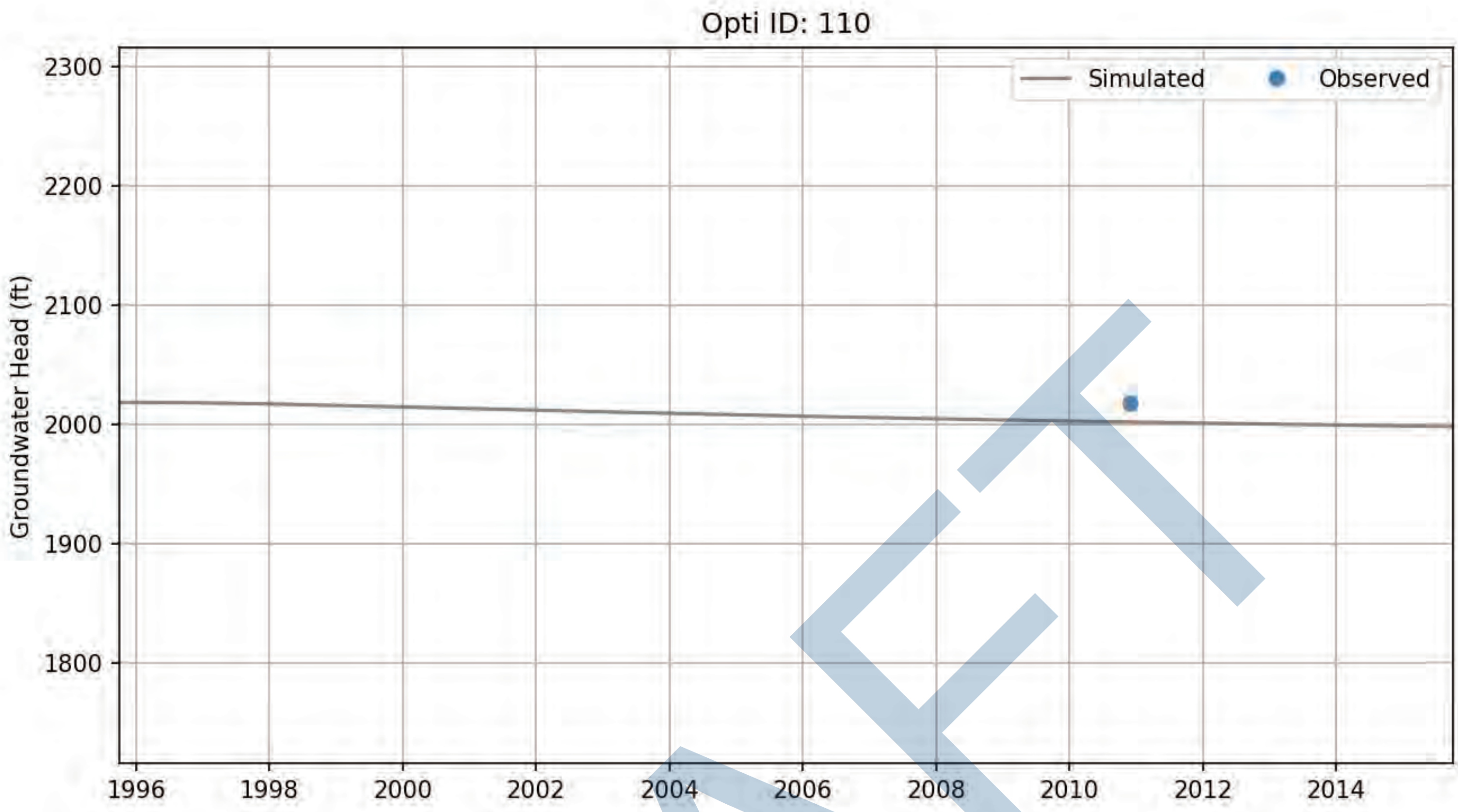
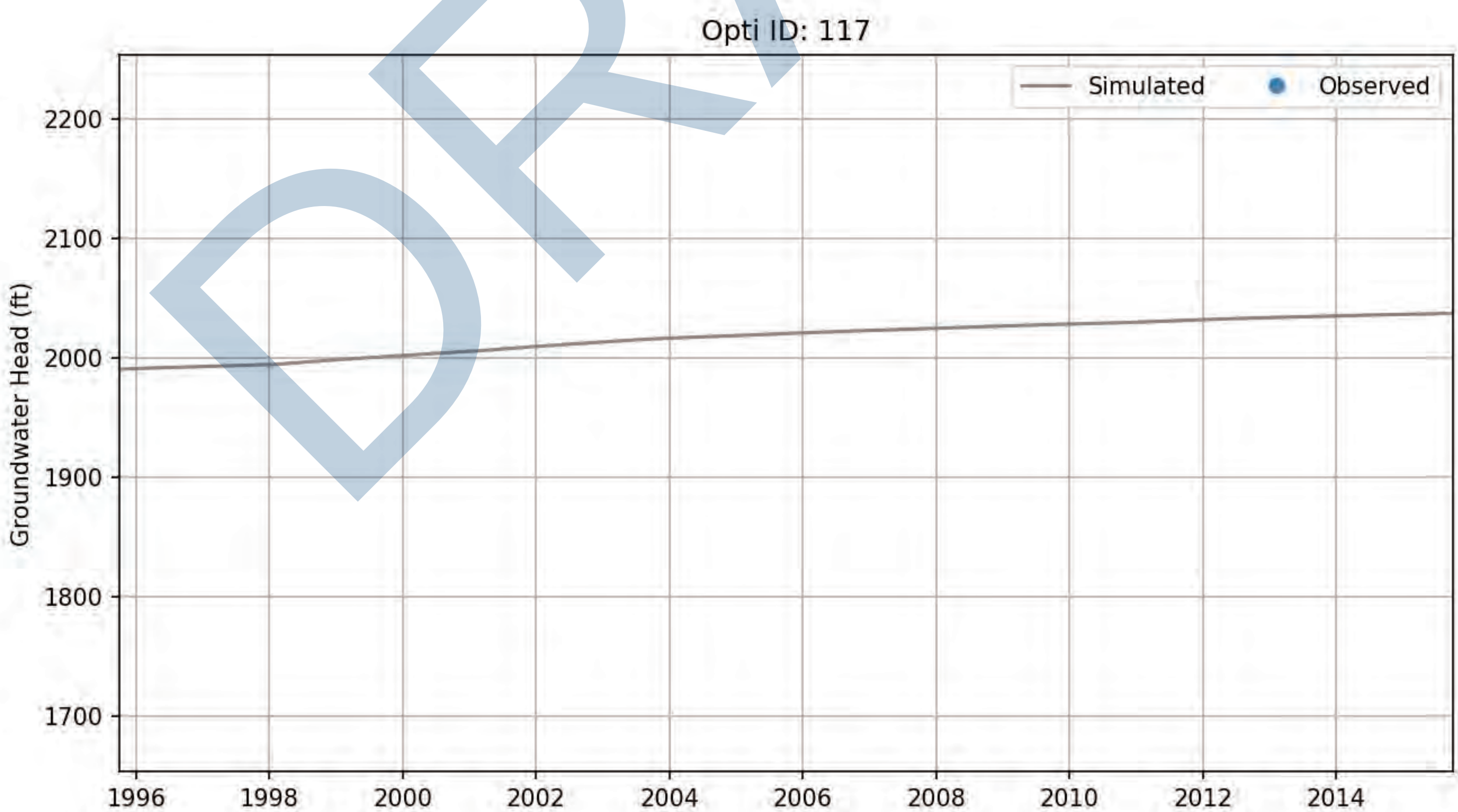
2012
2014

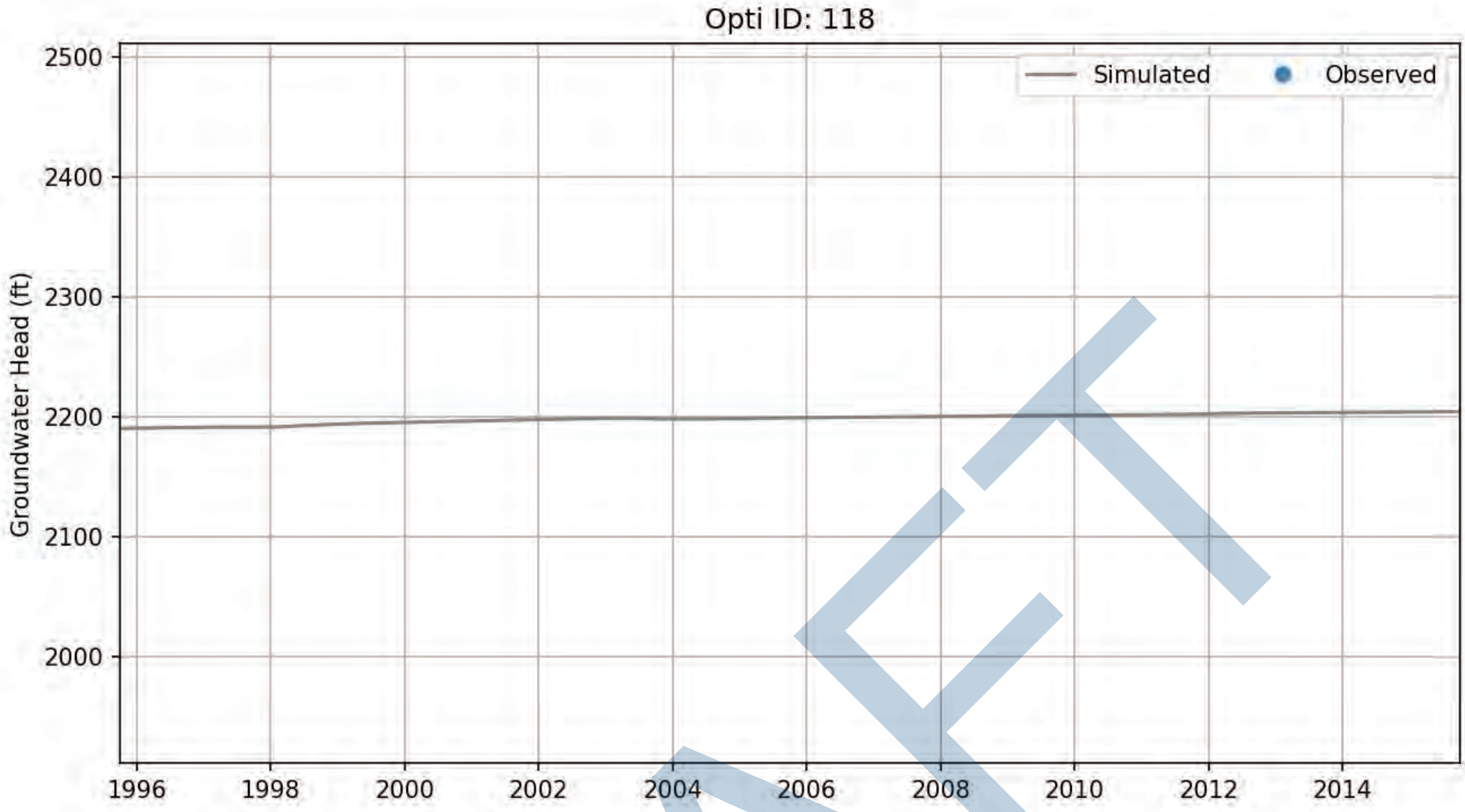
Opti ID: 108
Simulated
Observed
Groundwater Head (ft)
2200
2300
2400
2500
2600
2700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

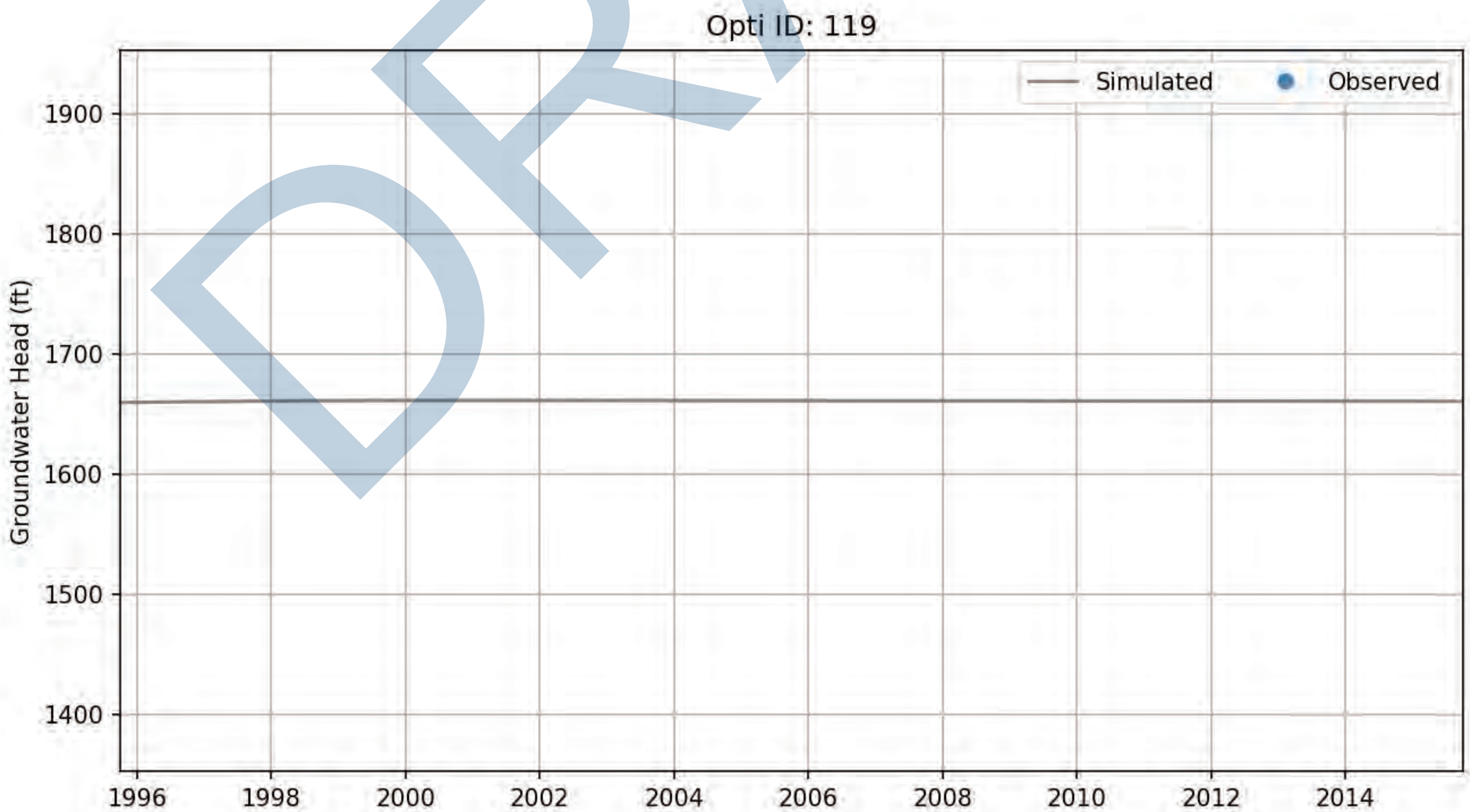


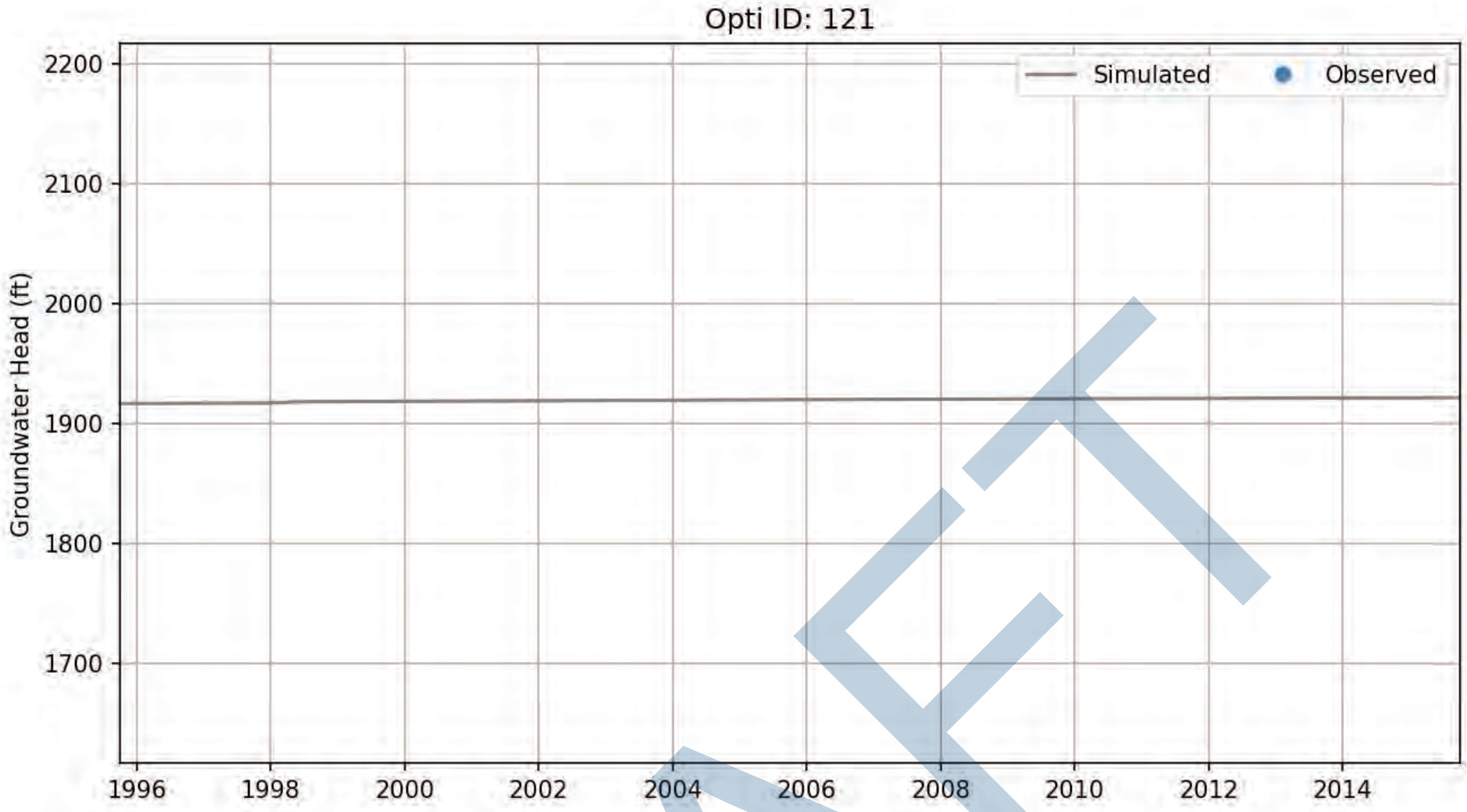
Opti ID: 110
Simulated
Observed
Groundwater Head (ft)
2300
2200
2100
2000
1900
1800
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

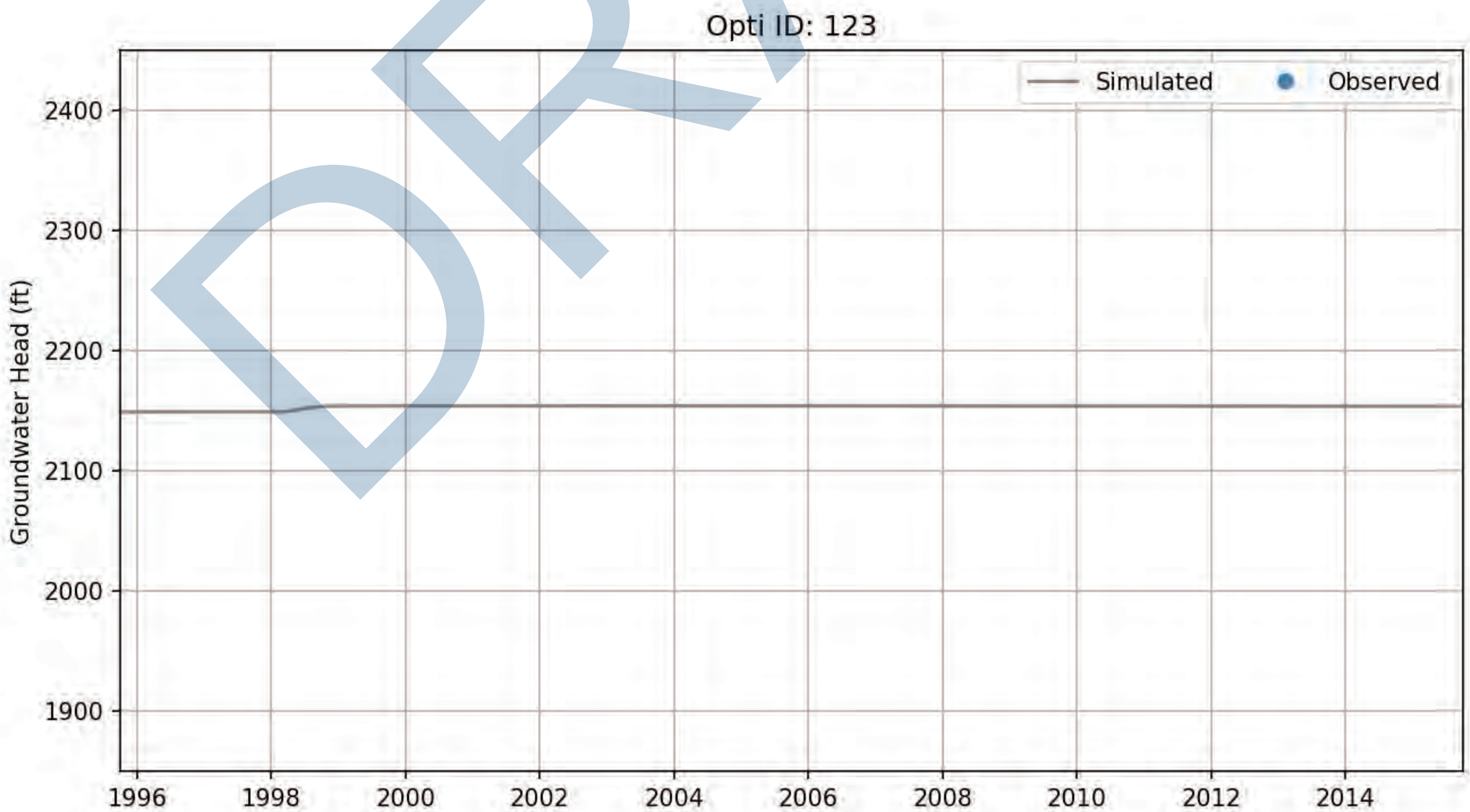



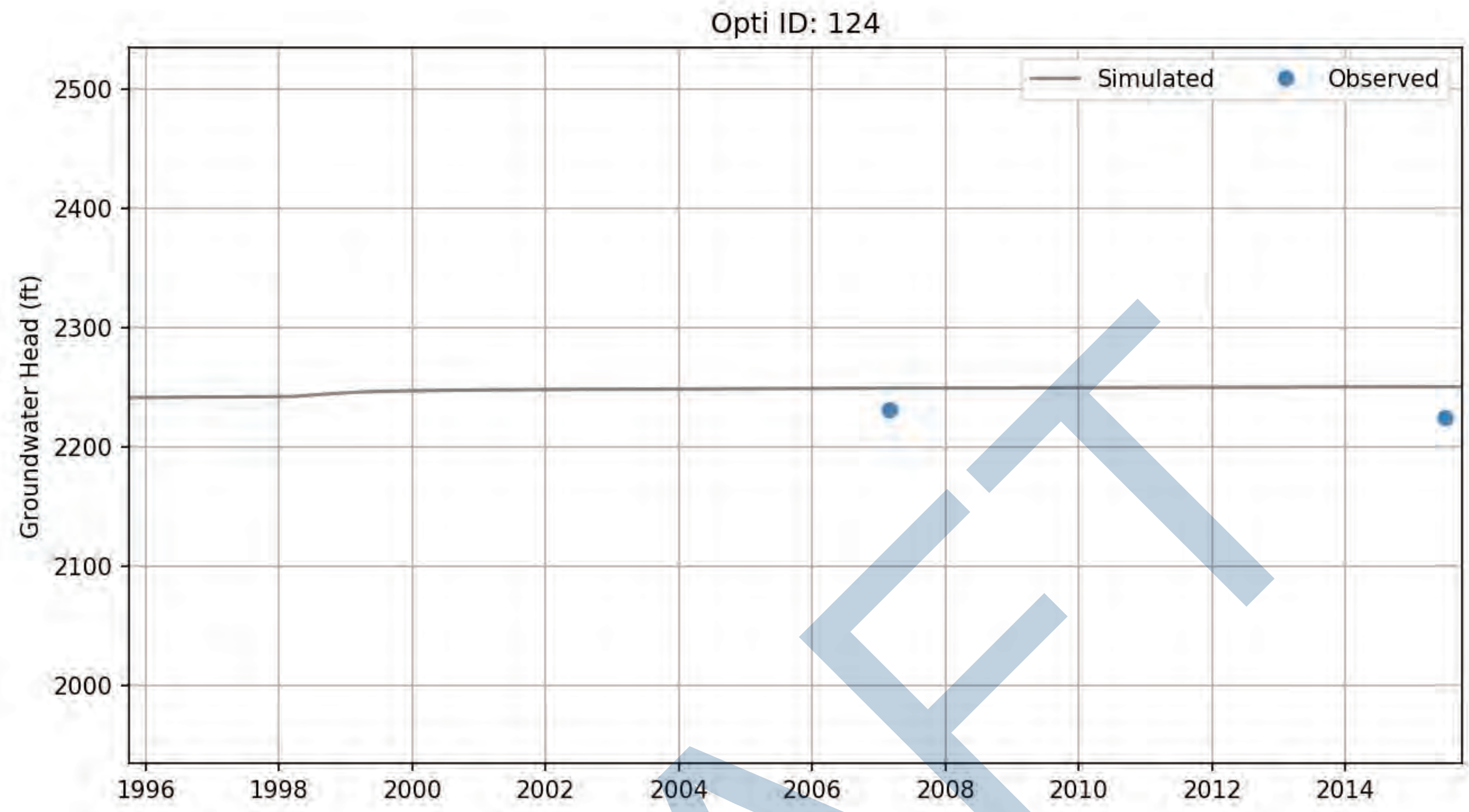
Opti ID: 117
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 118
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

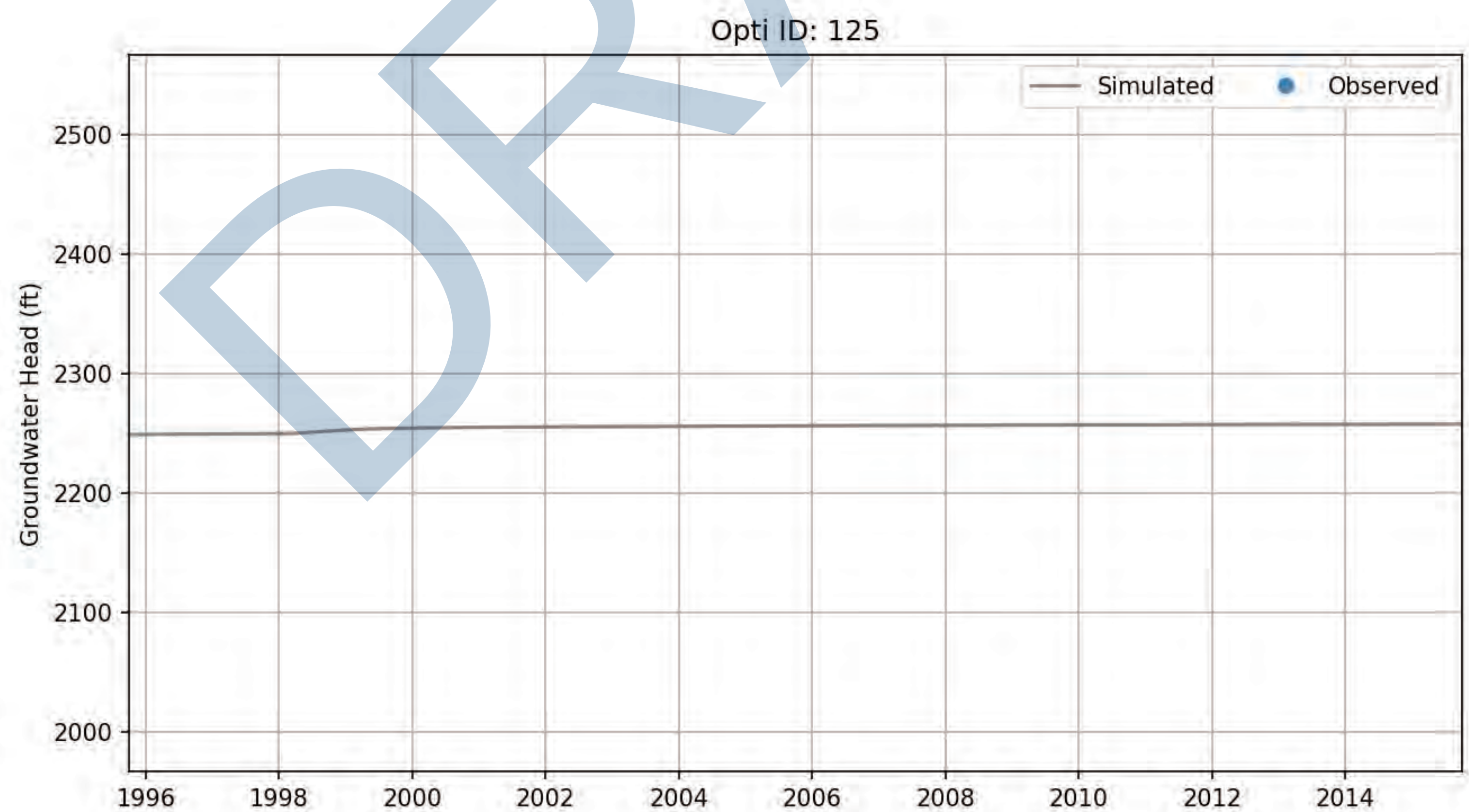

Opti ID: 119
Simulated
Observed
Groundwater Head (ft)
1900
1800
1700
1600
1500
1400
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 121
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

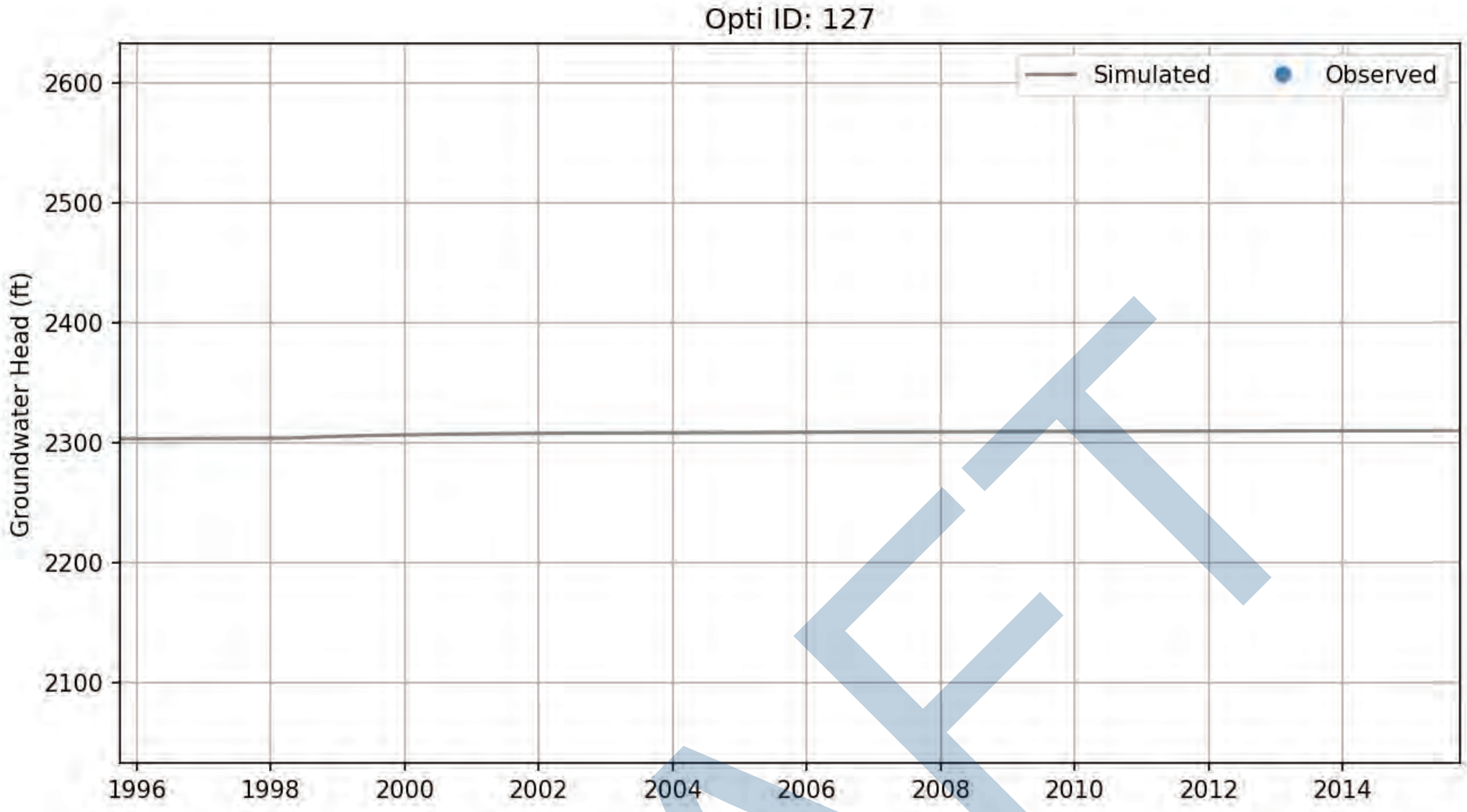

Opti ID: 123
Simulated
Observed
Groundwater Head (ft)
2400
2300
2200
2100
2000
1900
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014



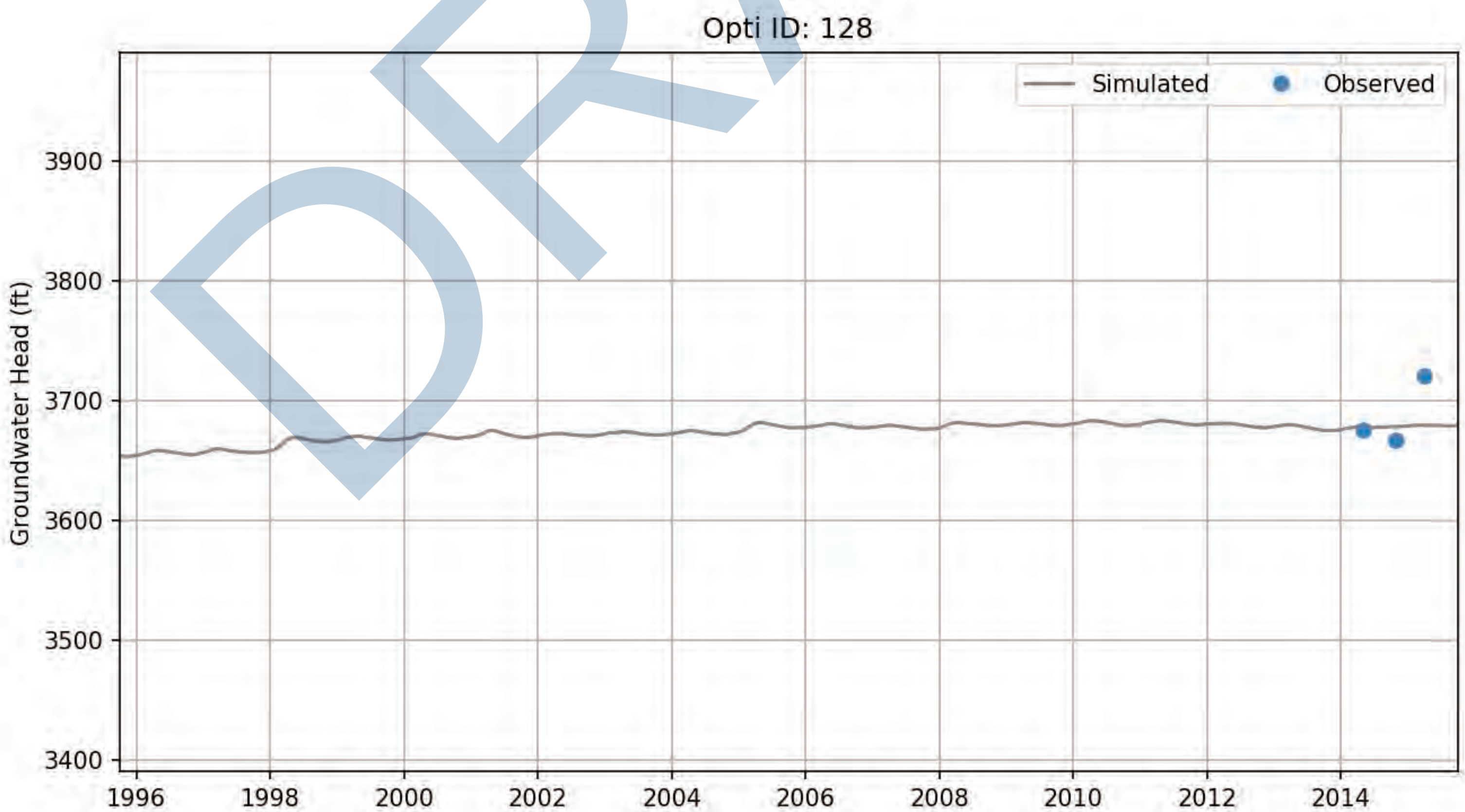
Opti ID: 124
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

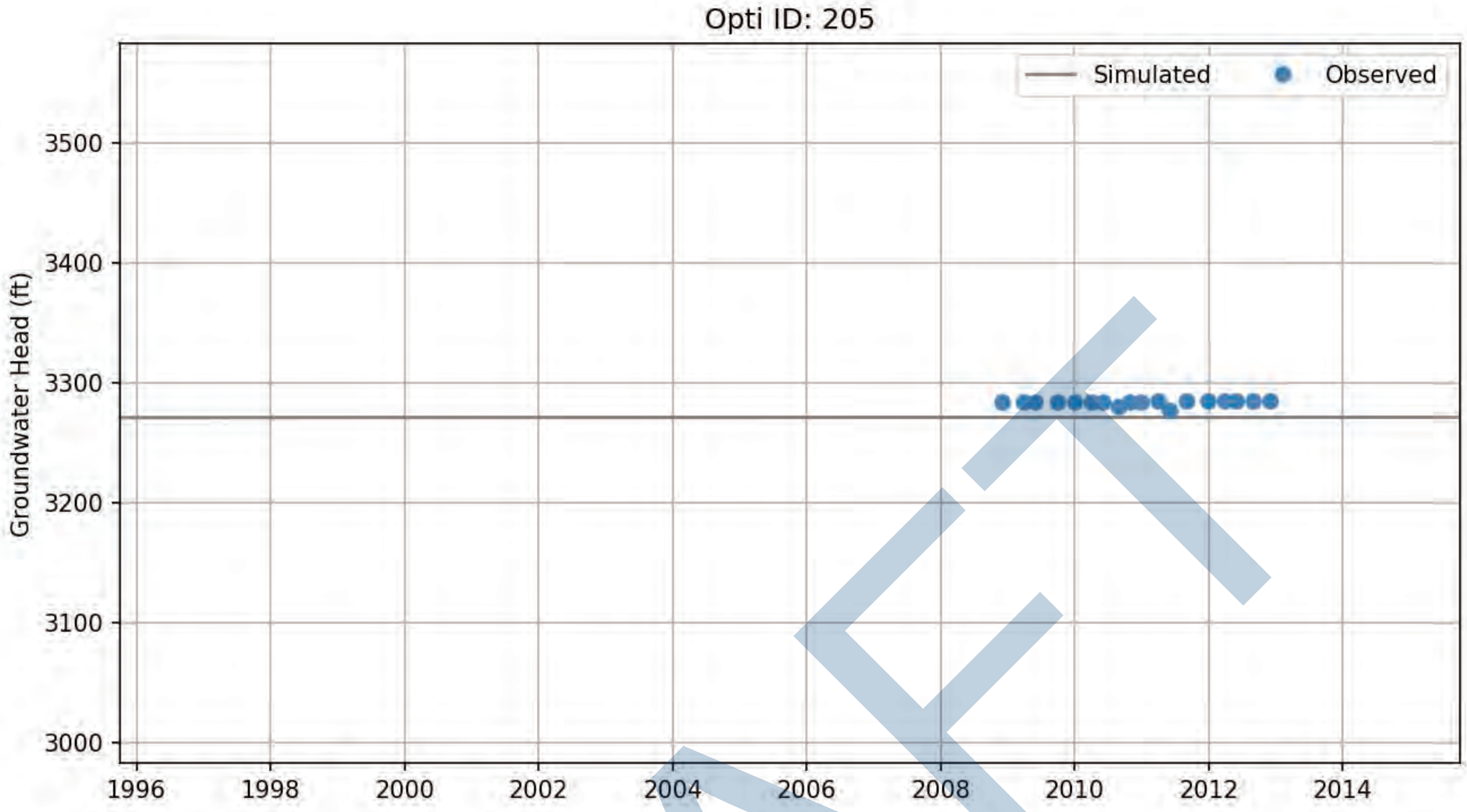
Opti ID: 125
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

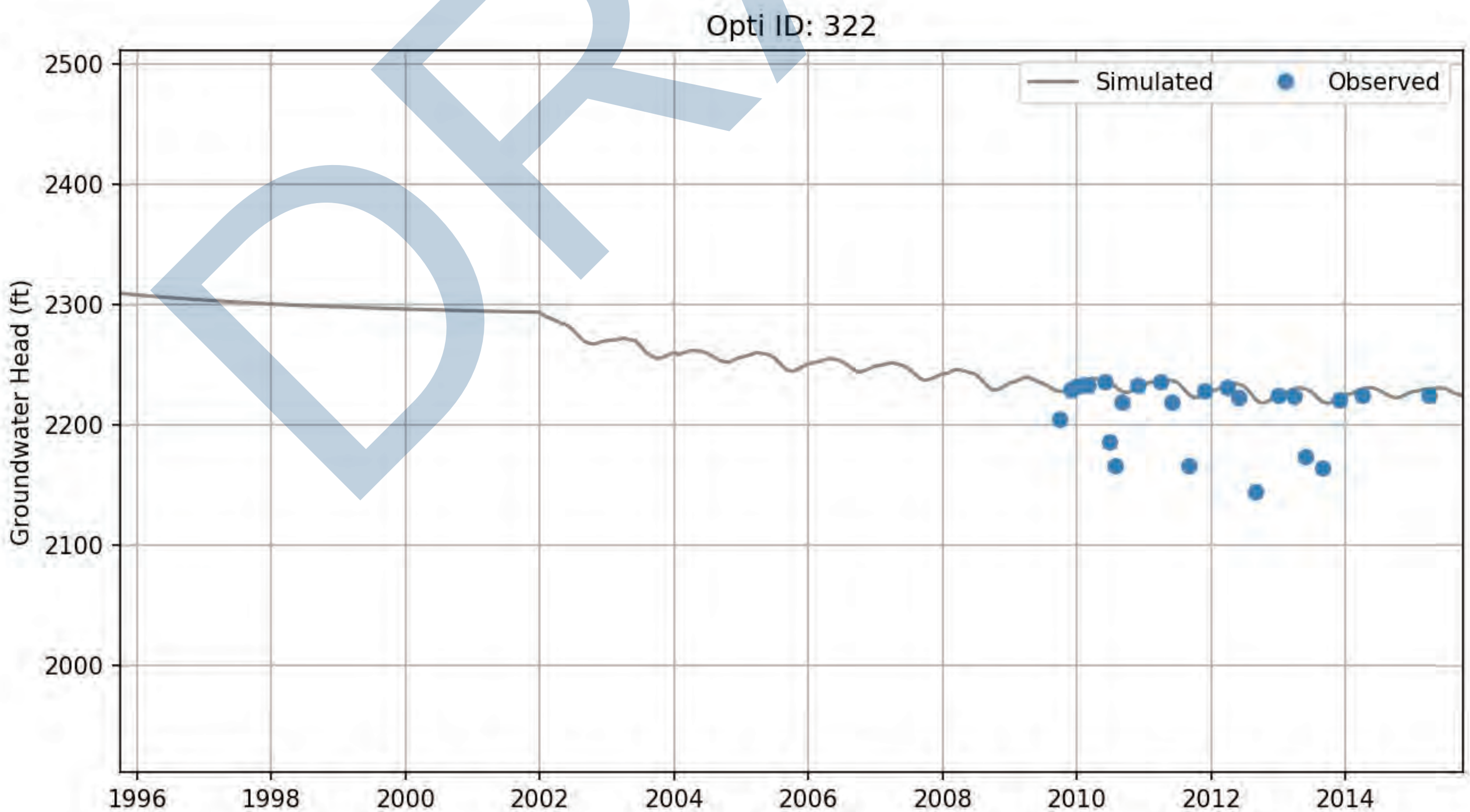


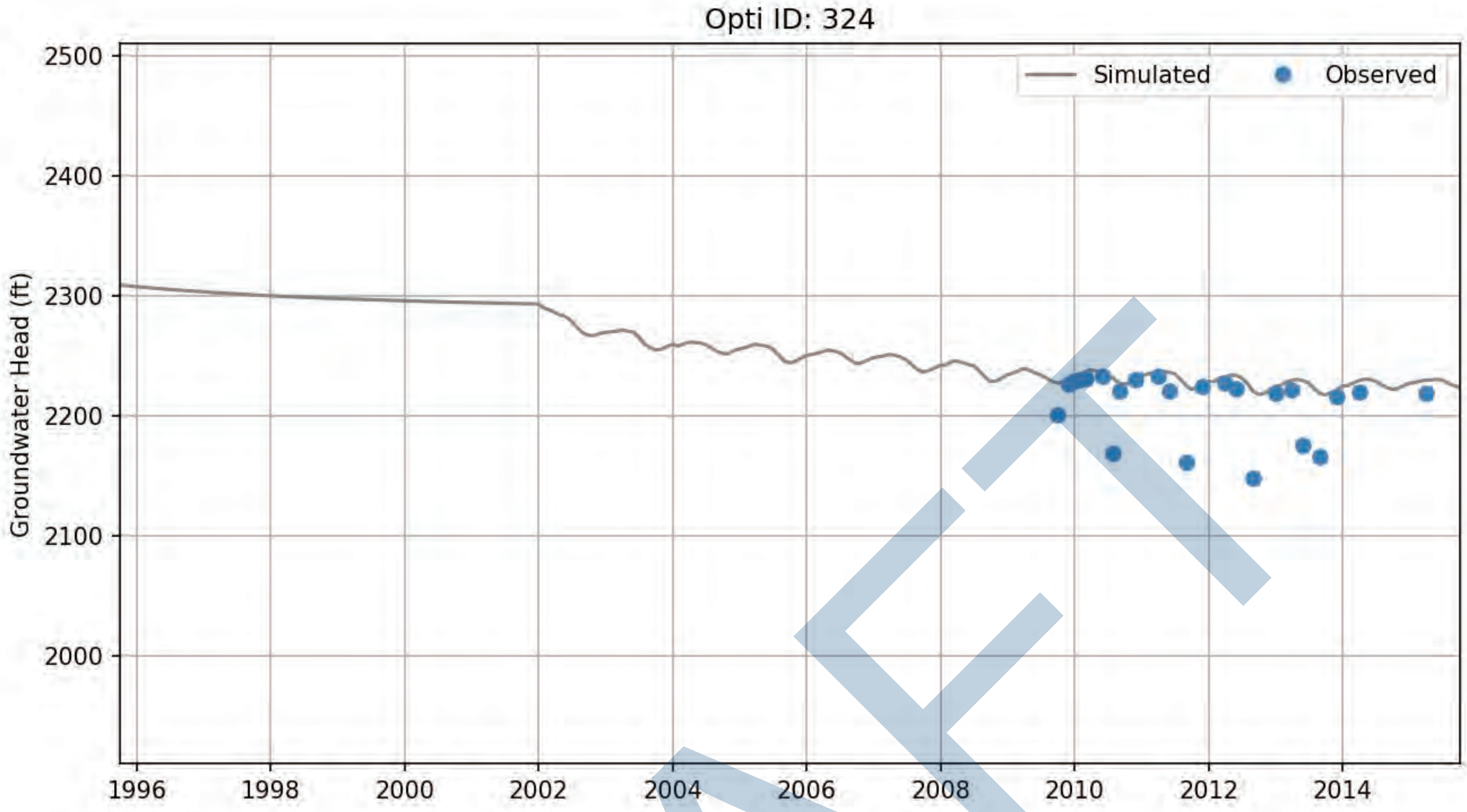
Opti ID: 127
Simulated
Observed
Groundwater Head (ft)
2600
2500
2400
2300
2200
2100
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

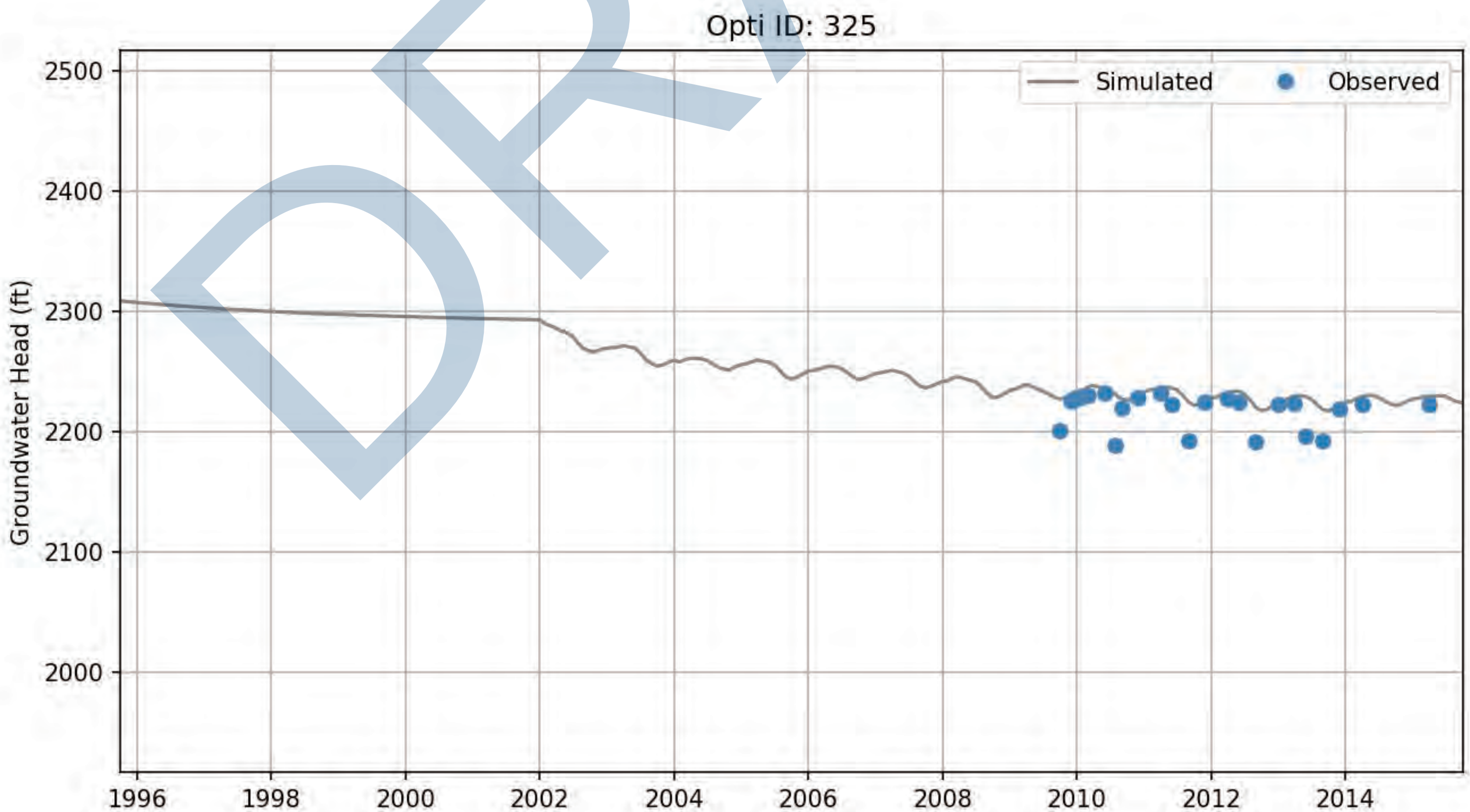
Opti ID: 128
Simulated
Observed
Groundwater Head (ft)
3900
3800
3700
3600
3500
3400
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 205
Simulated
Observed
Groundwater Head (ft)
3500
3400
3300
3200
3100
3000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

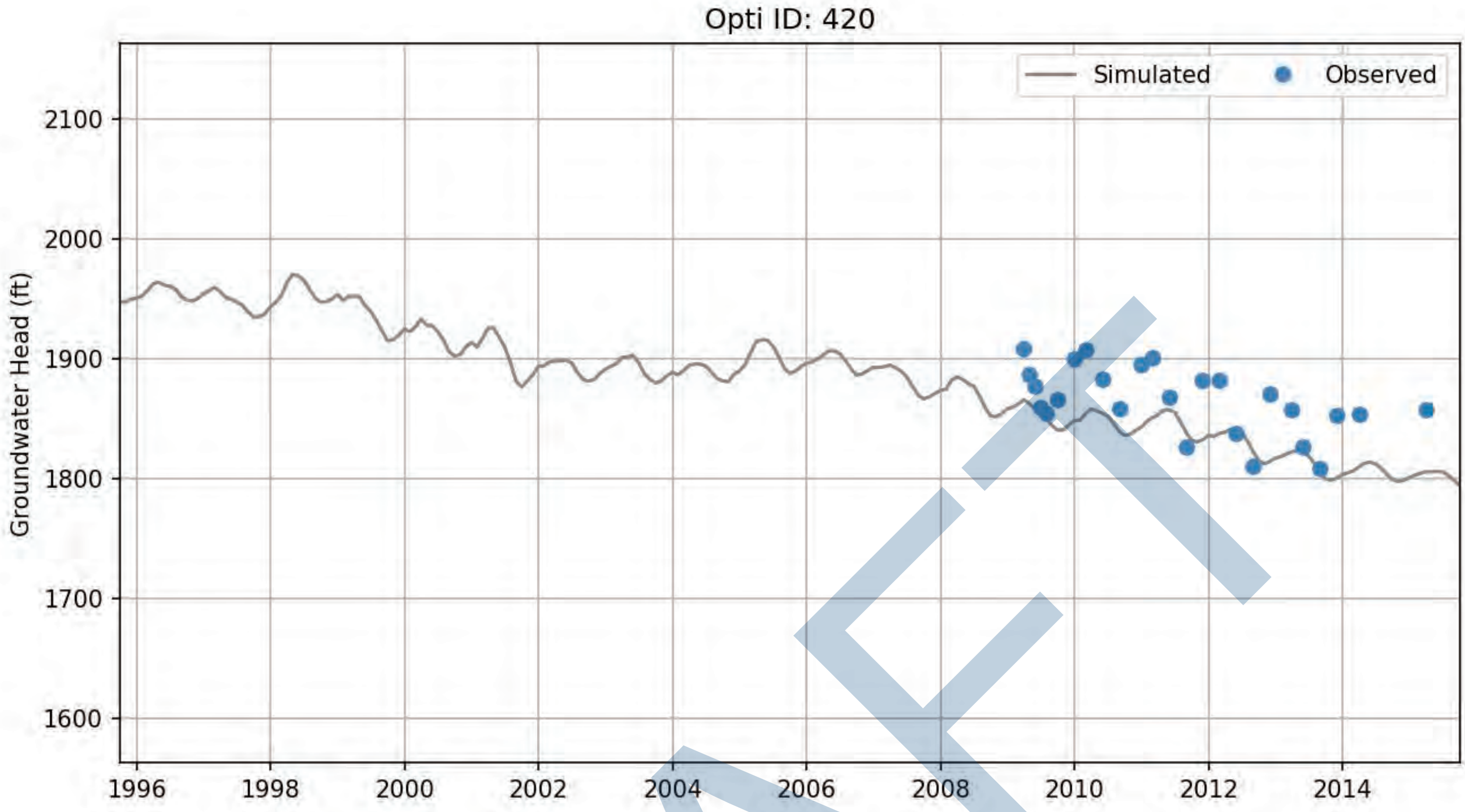

Opti ID: 322
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

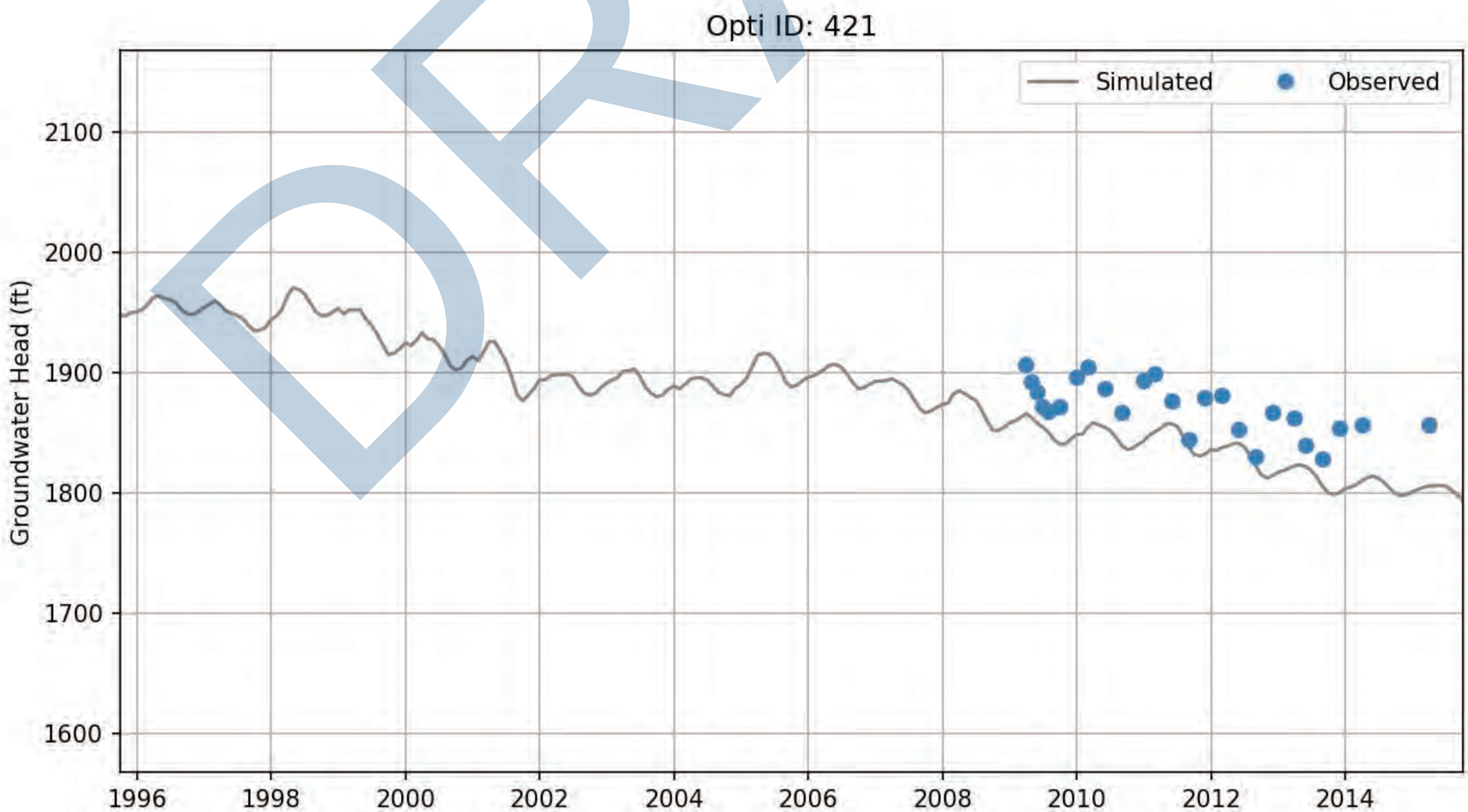


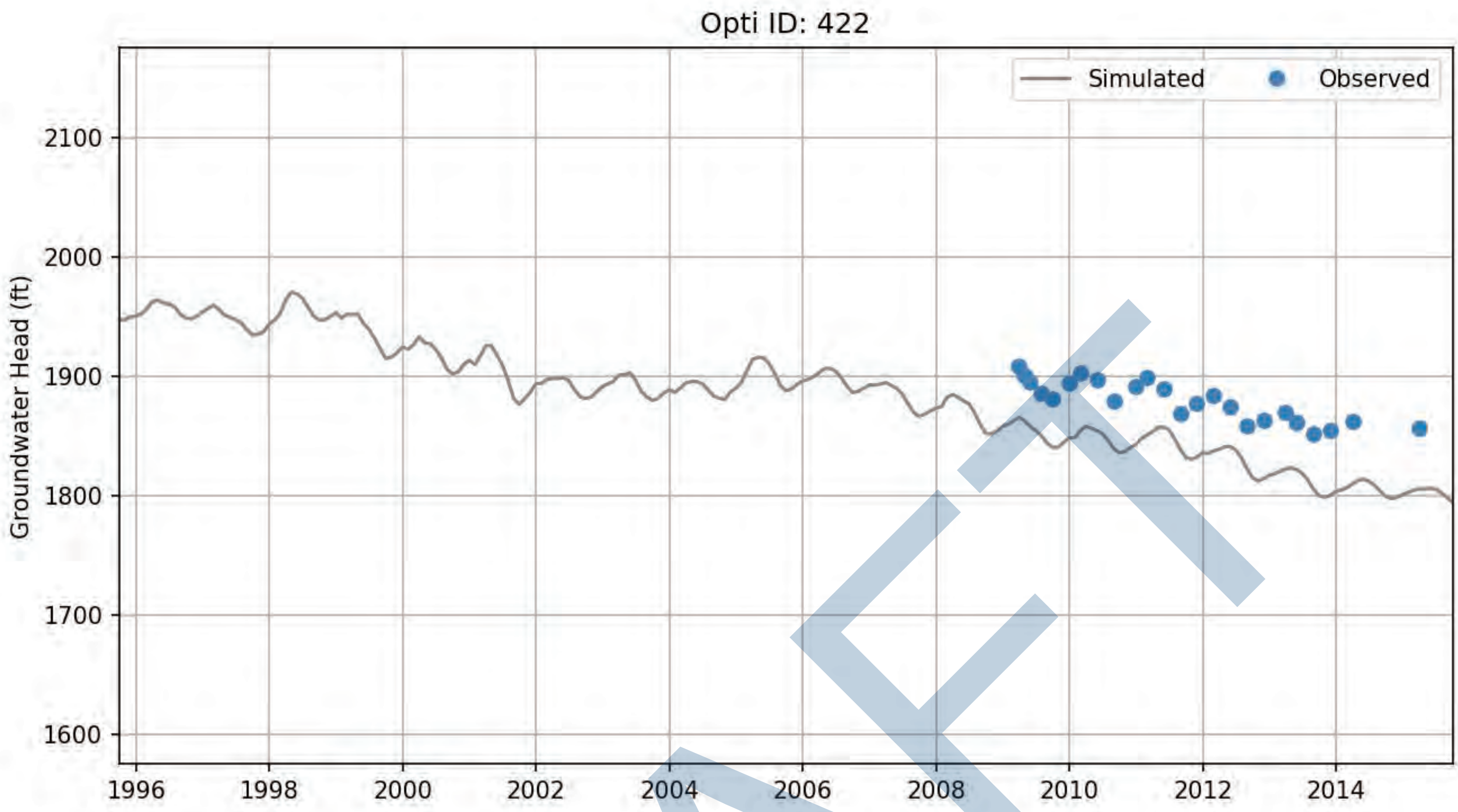
Opti ID: 324
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

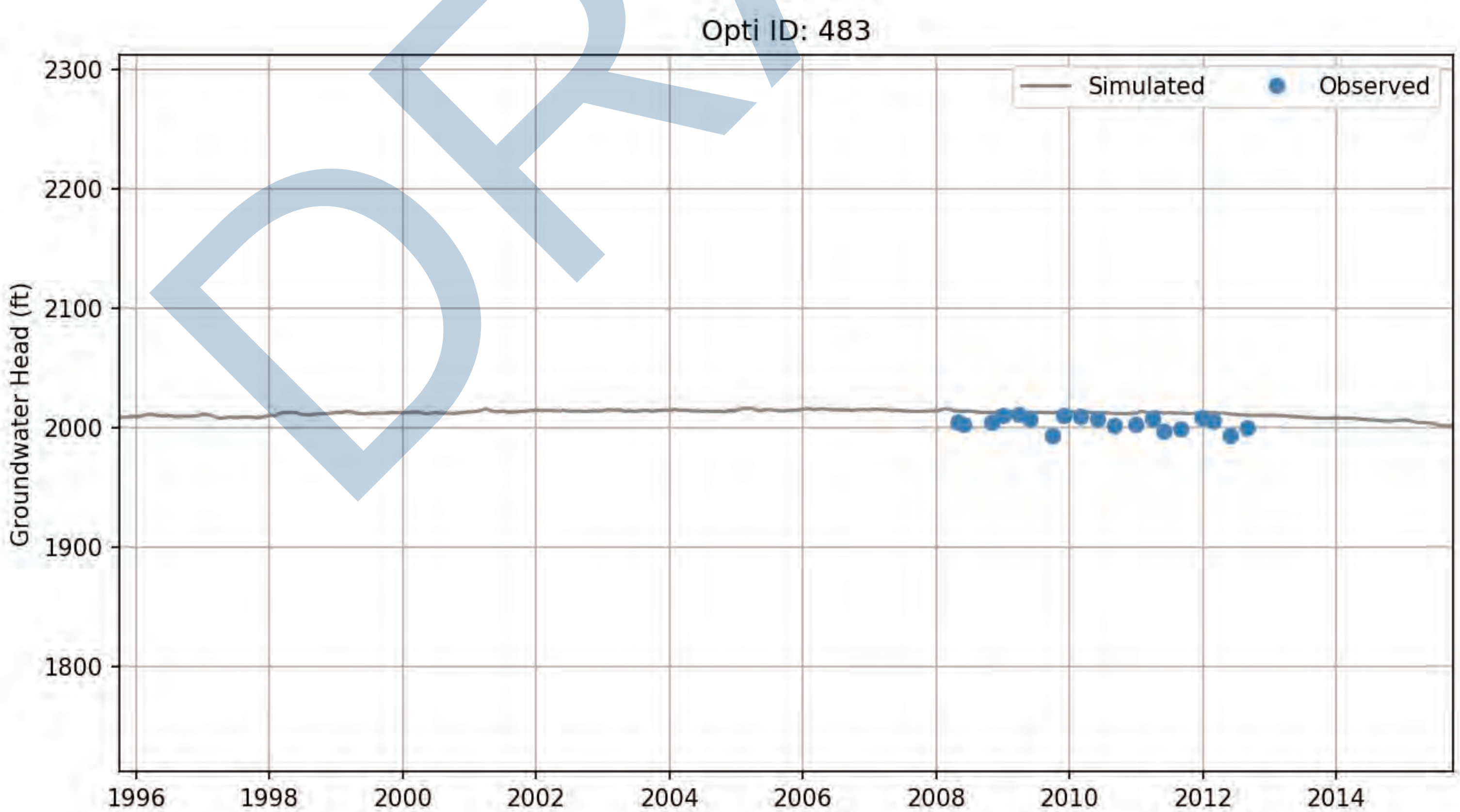



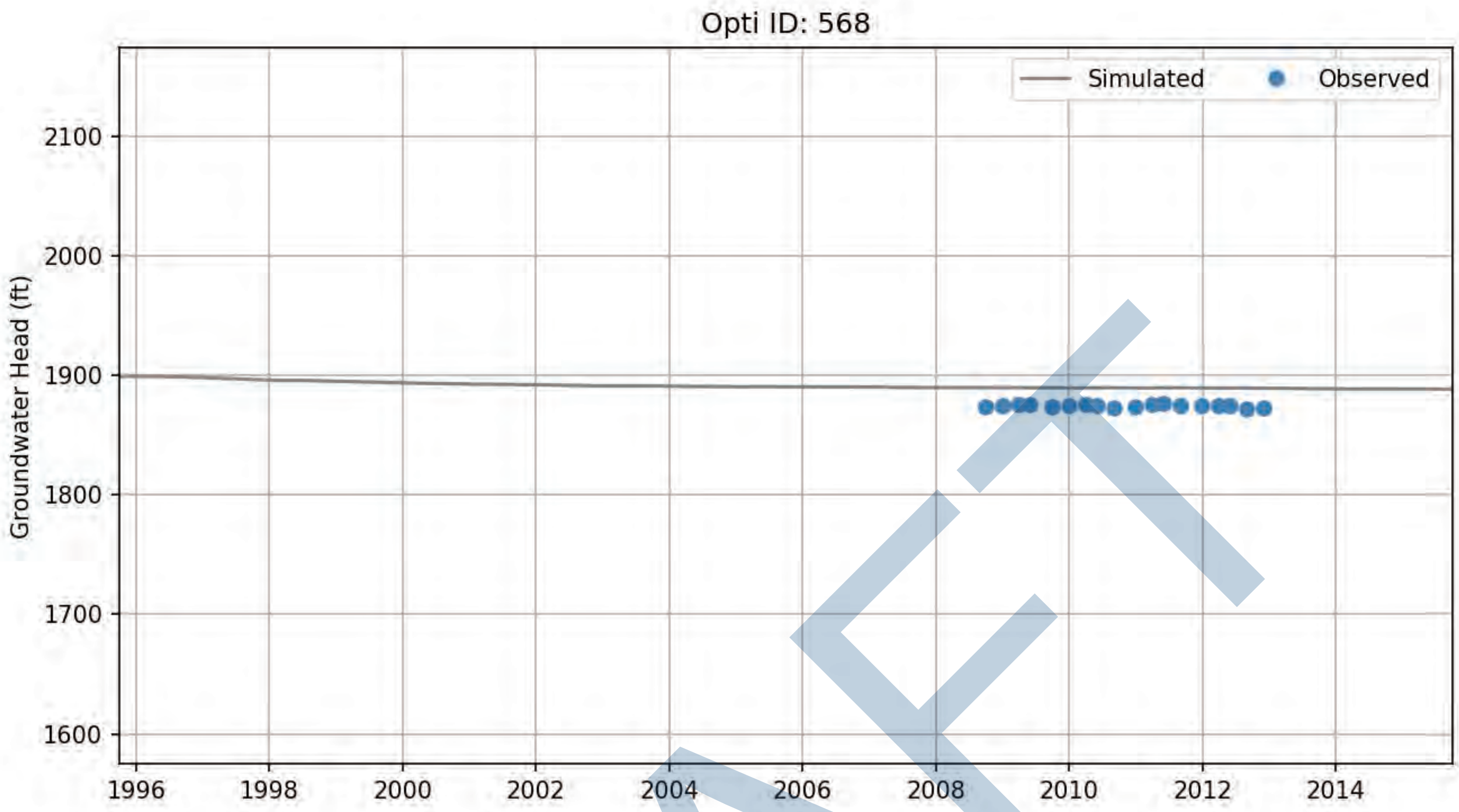
Opti ID: 325
Simulated
Observed
Groundwater Head (ft)
2500
2400
2300
2200
2100
2000
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 420
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

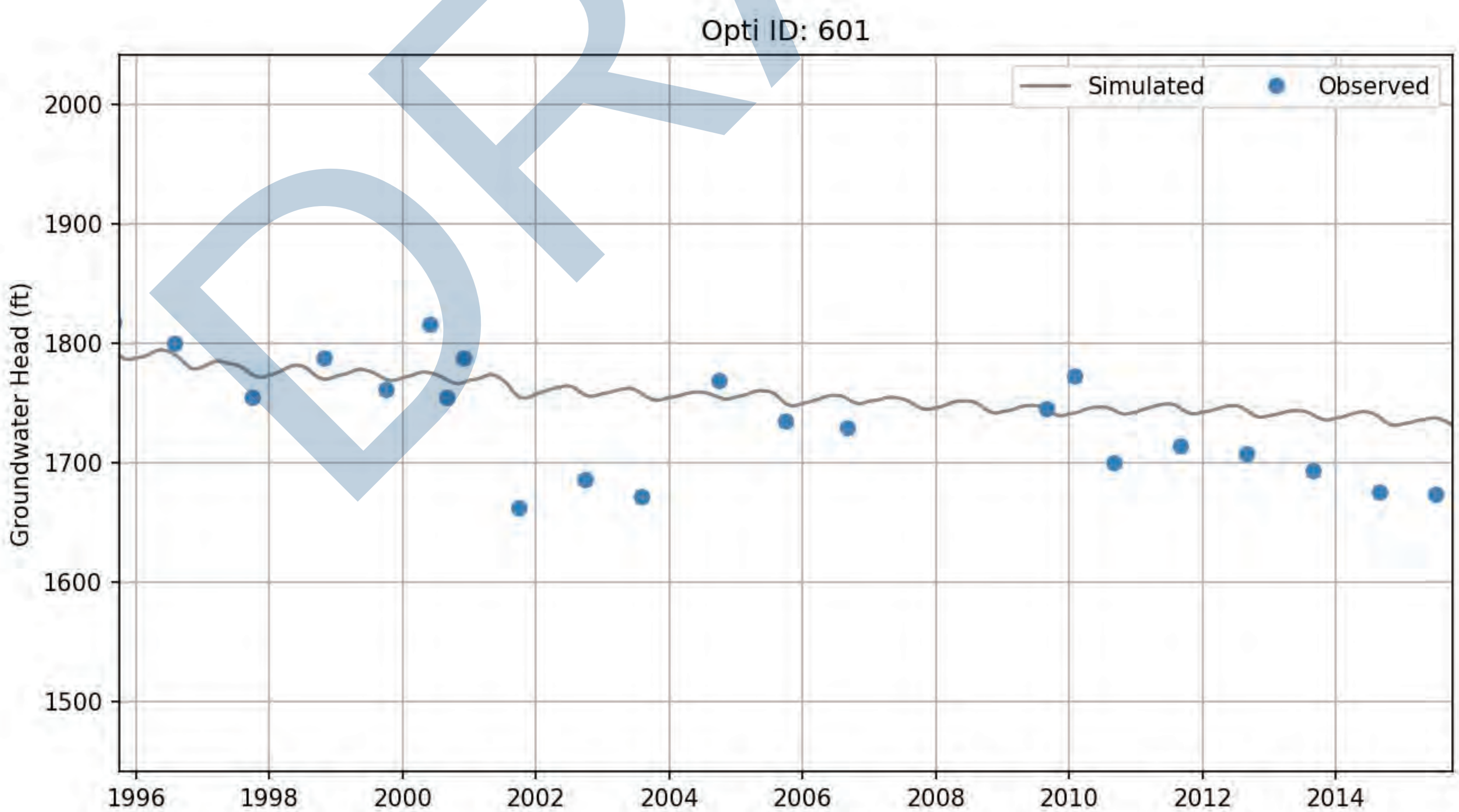

Opti ID: 421
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 422
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

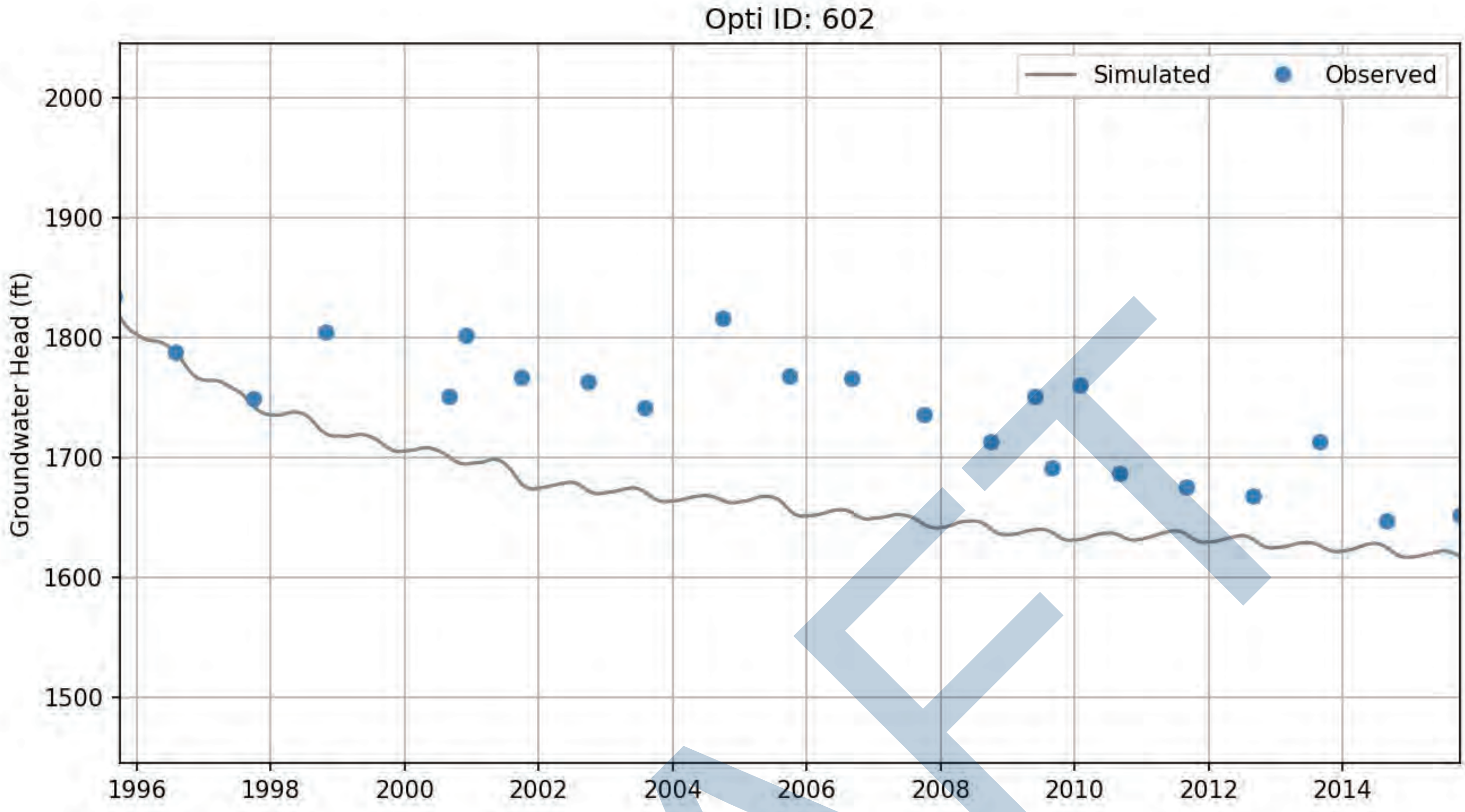

Opti ID: 483
Simulated
Observed
Groundwater Head (ft)
2300
2200
2100
2000
1900
1800
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

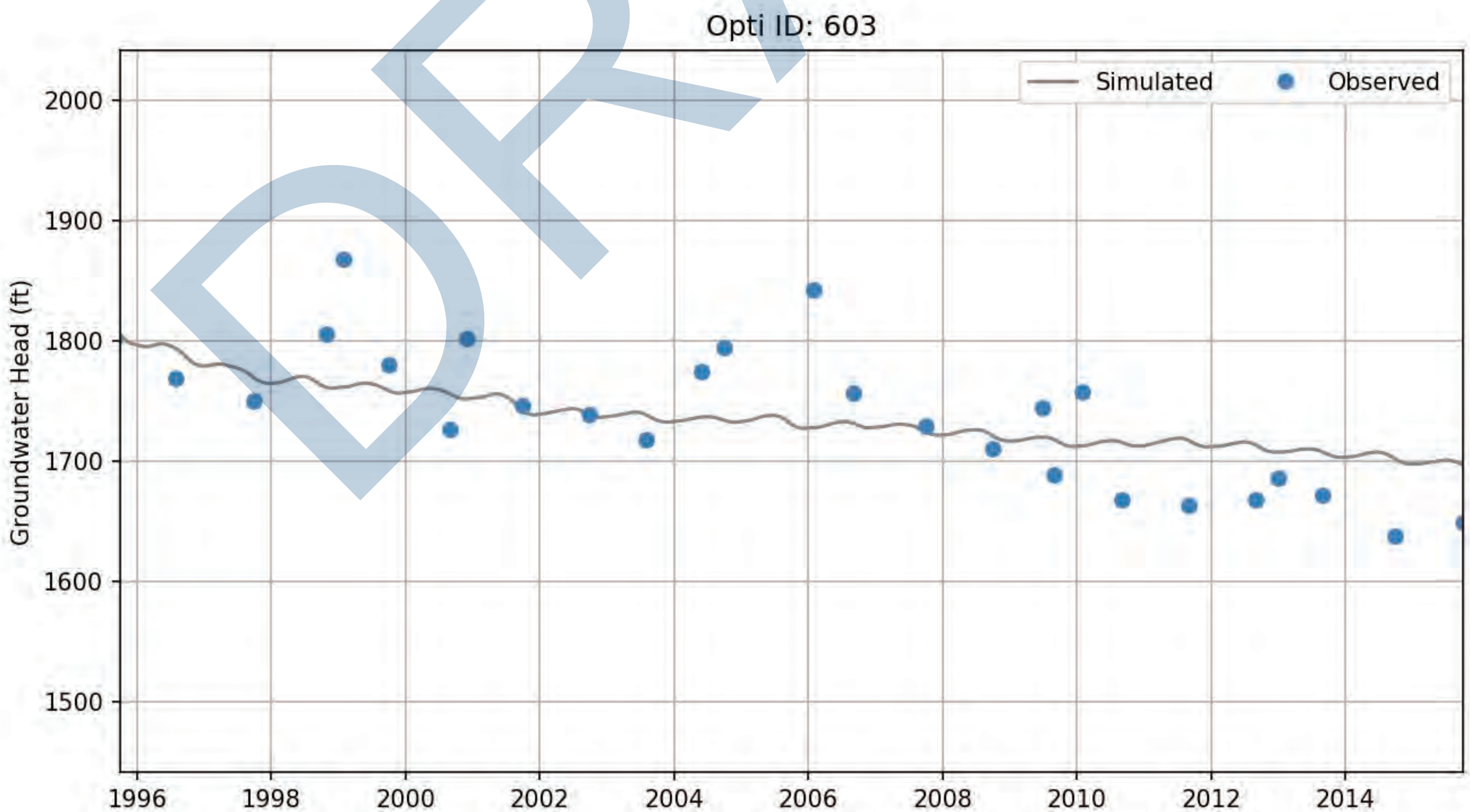


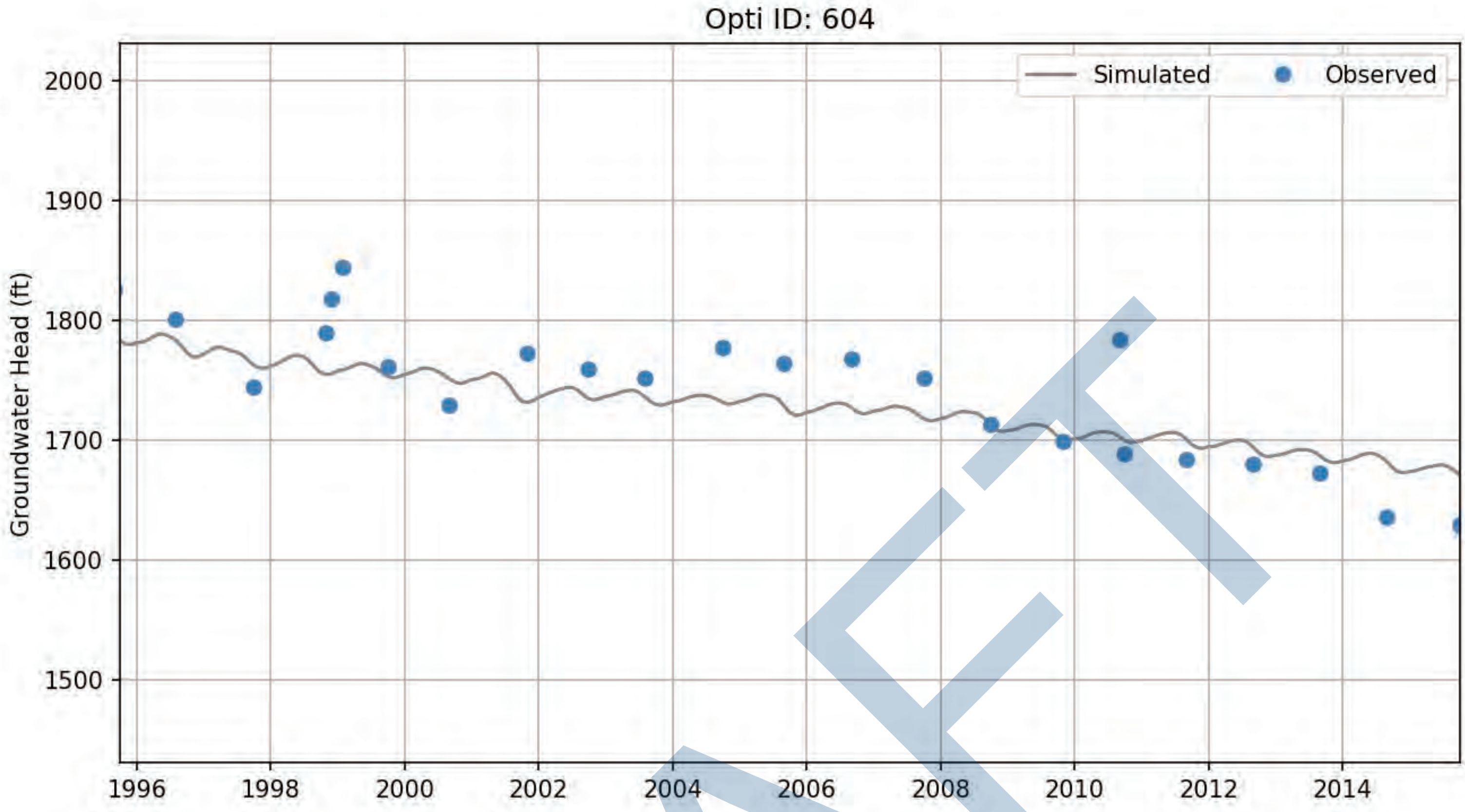
Opti ID: 568
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

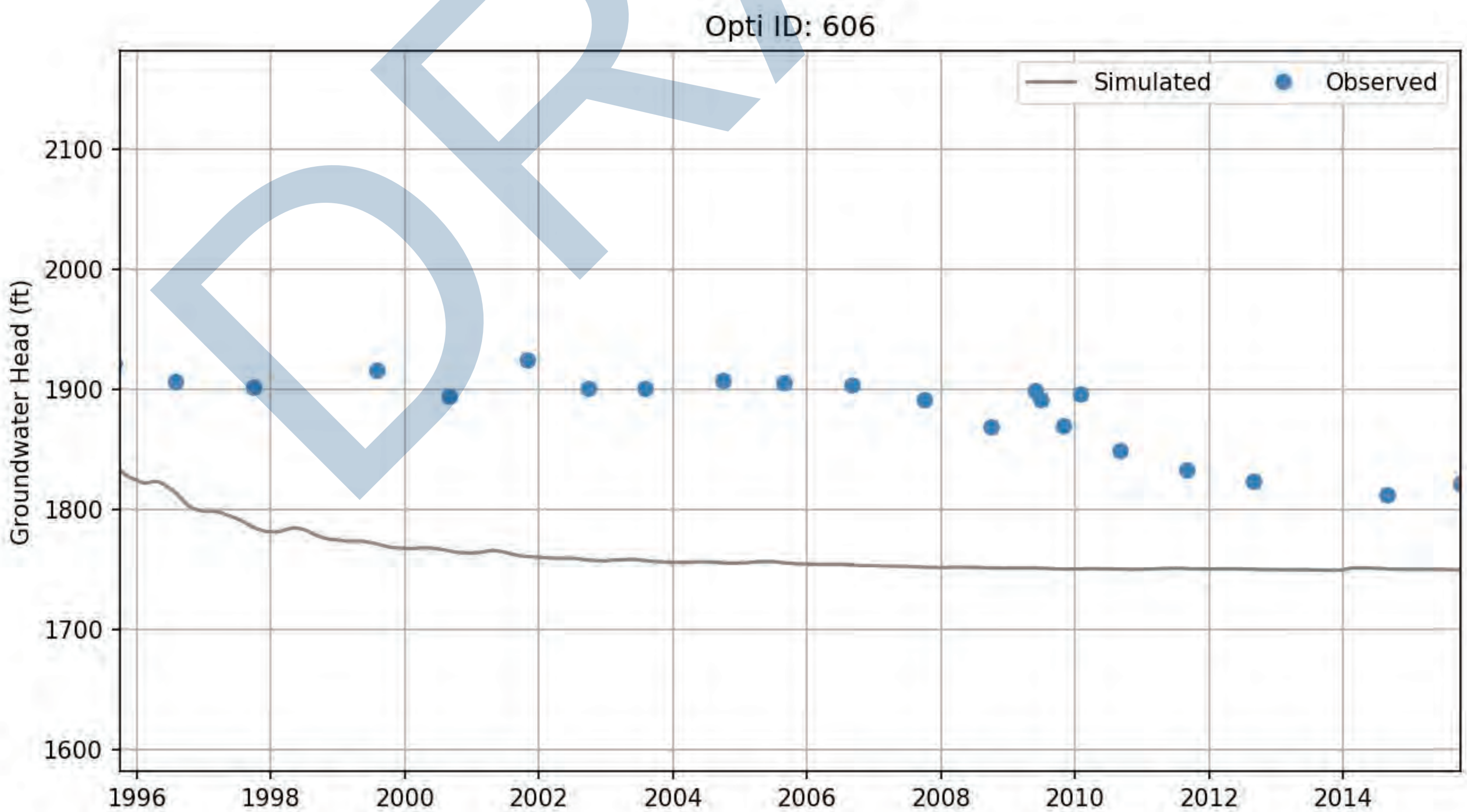
Opti ID: 601
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 602
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

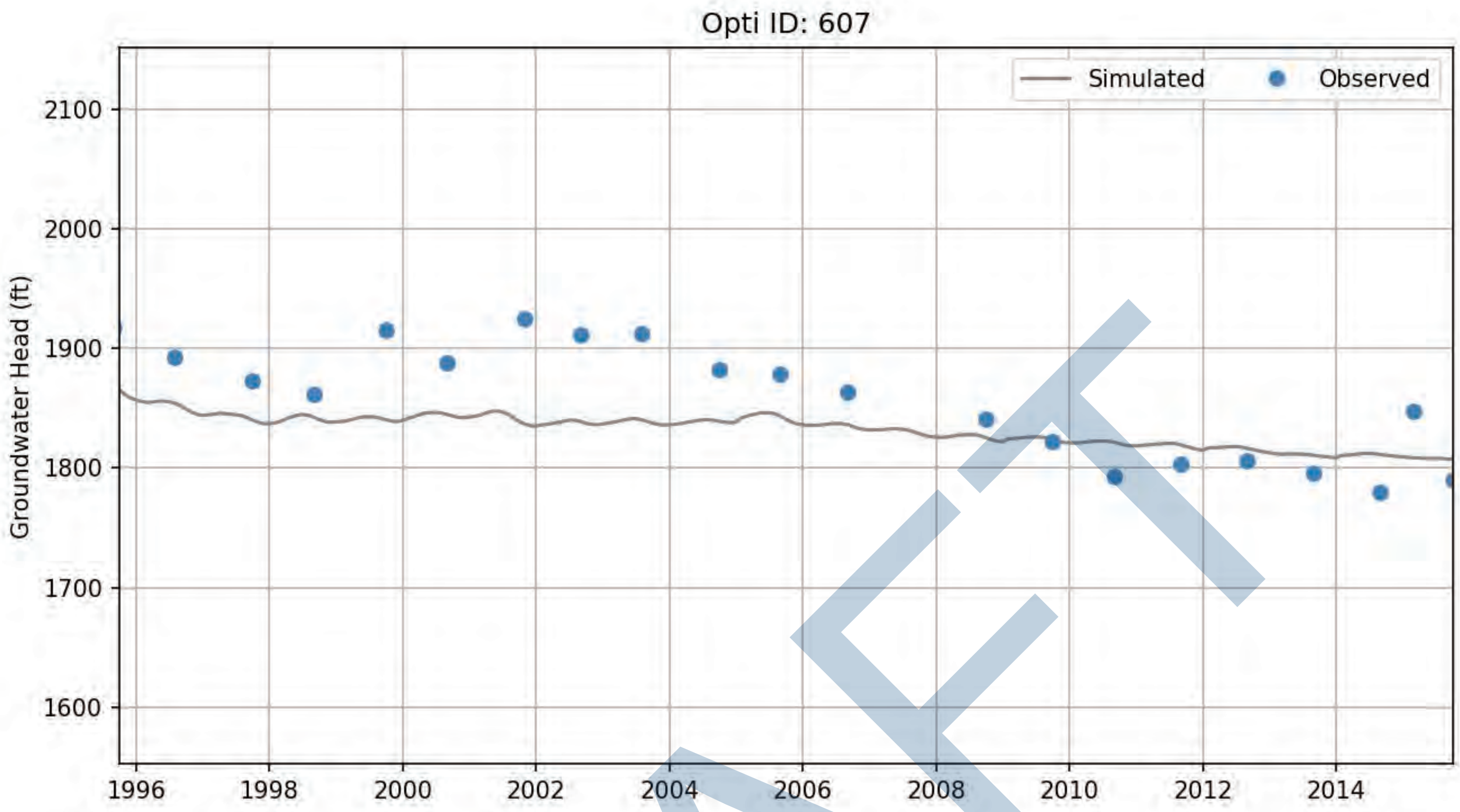

Opti ID: 603
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014



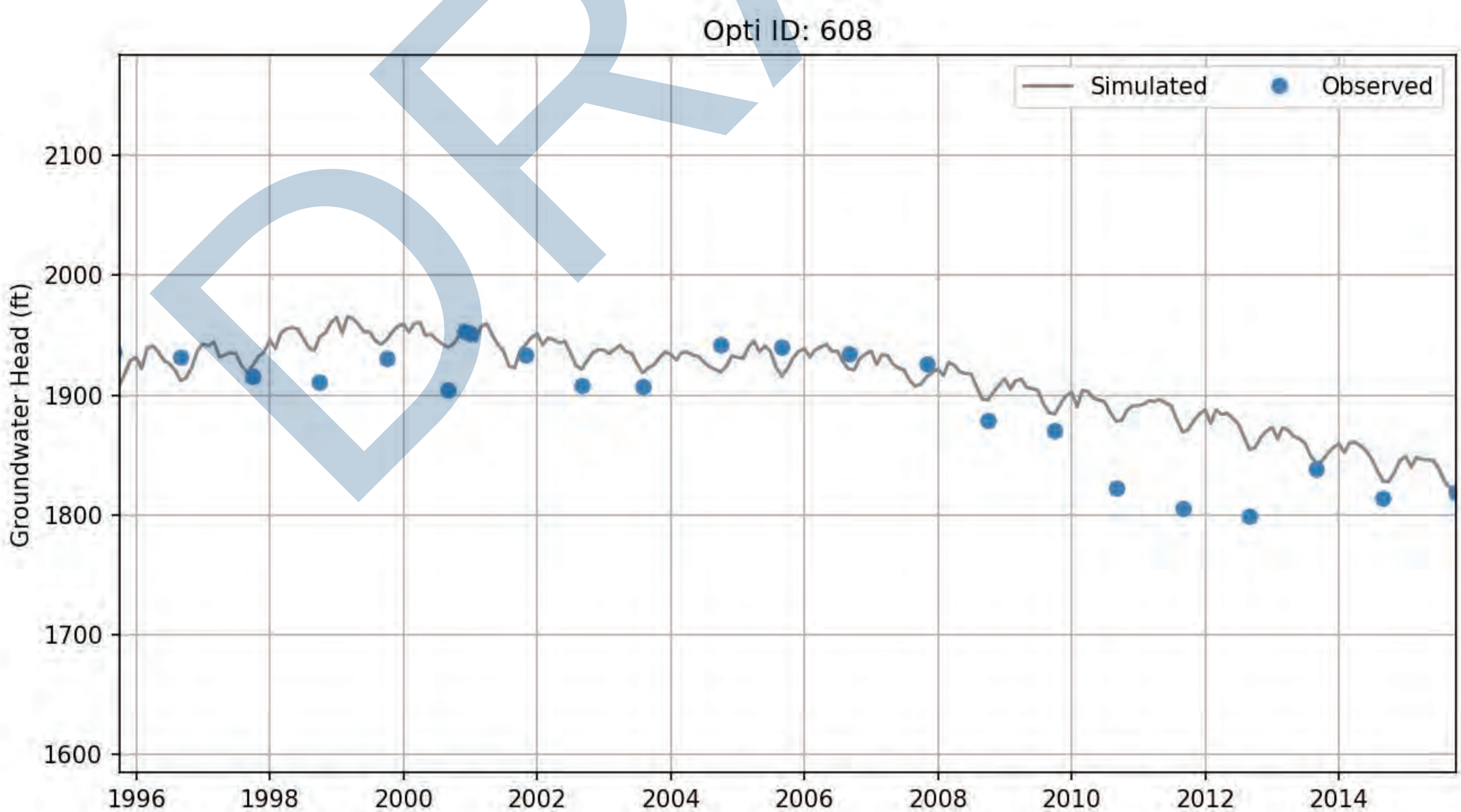
Opti ID: 604
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

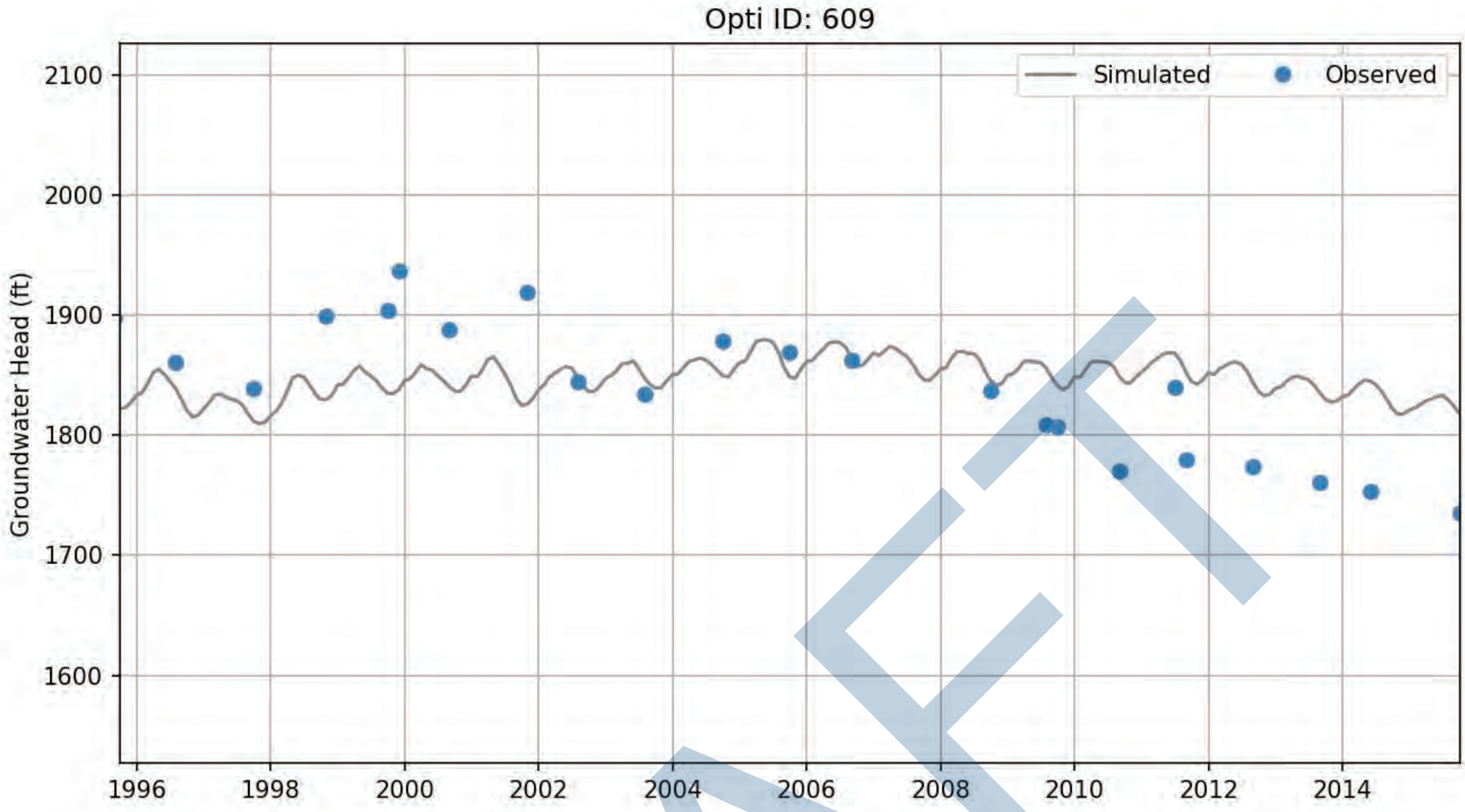
Opti ID: 606
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

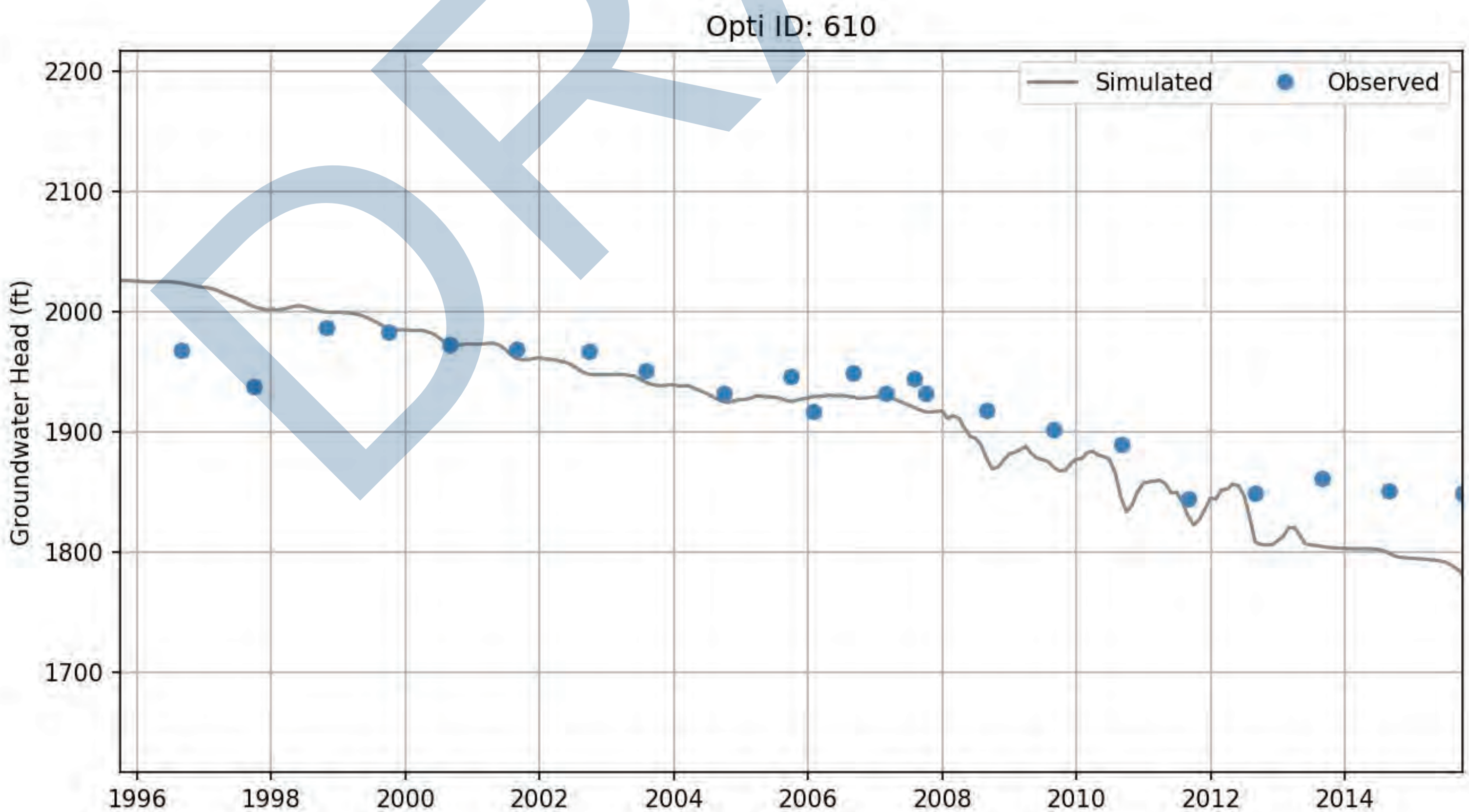


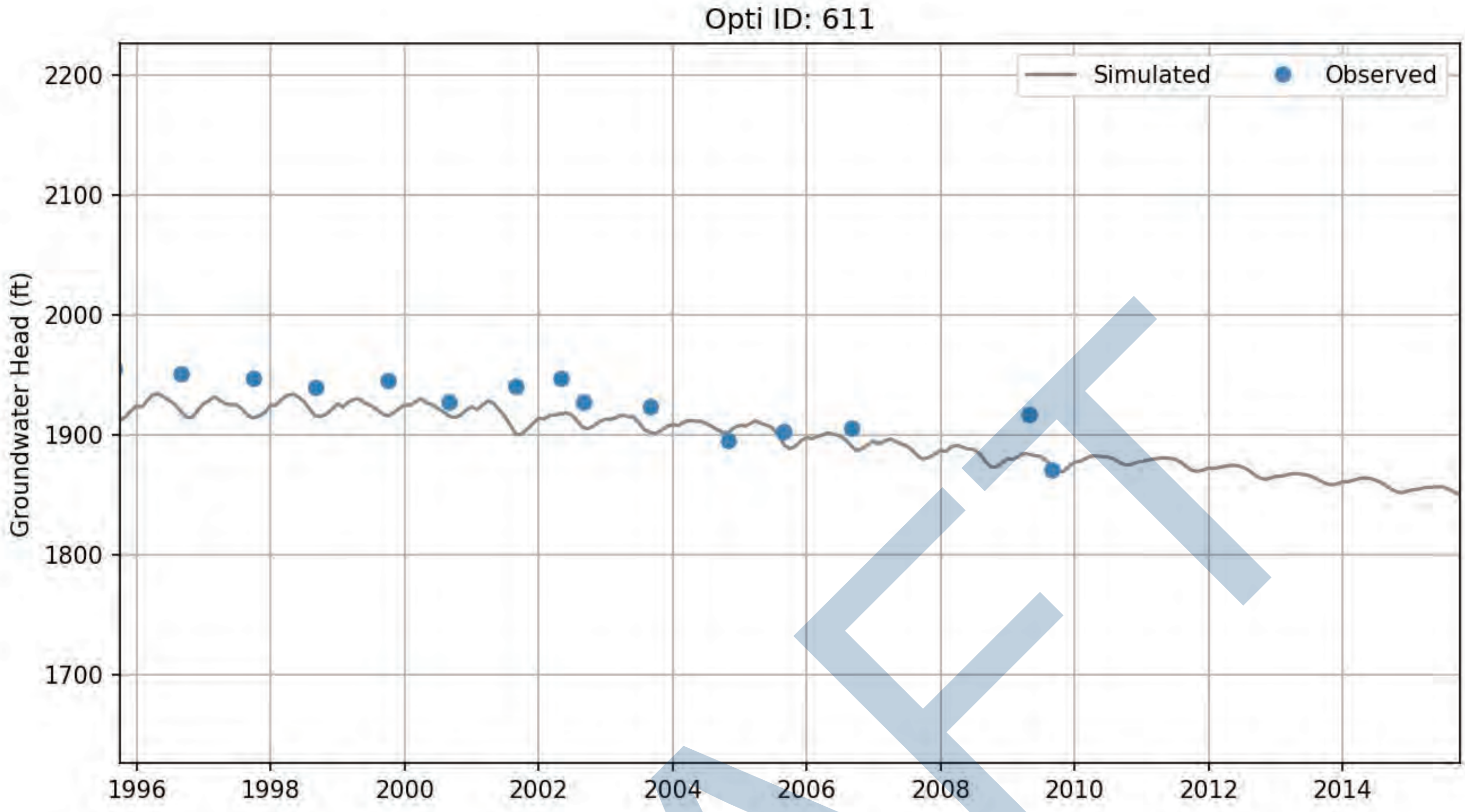
Opti ID: 607
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

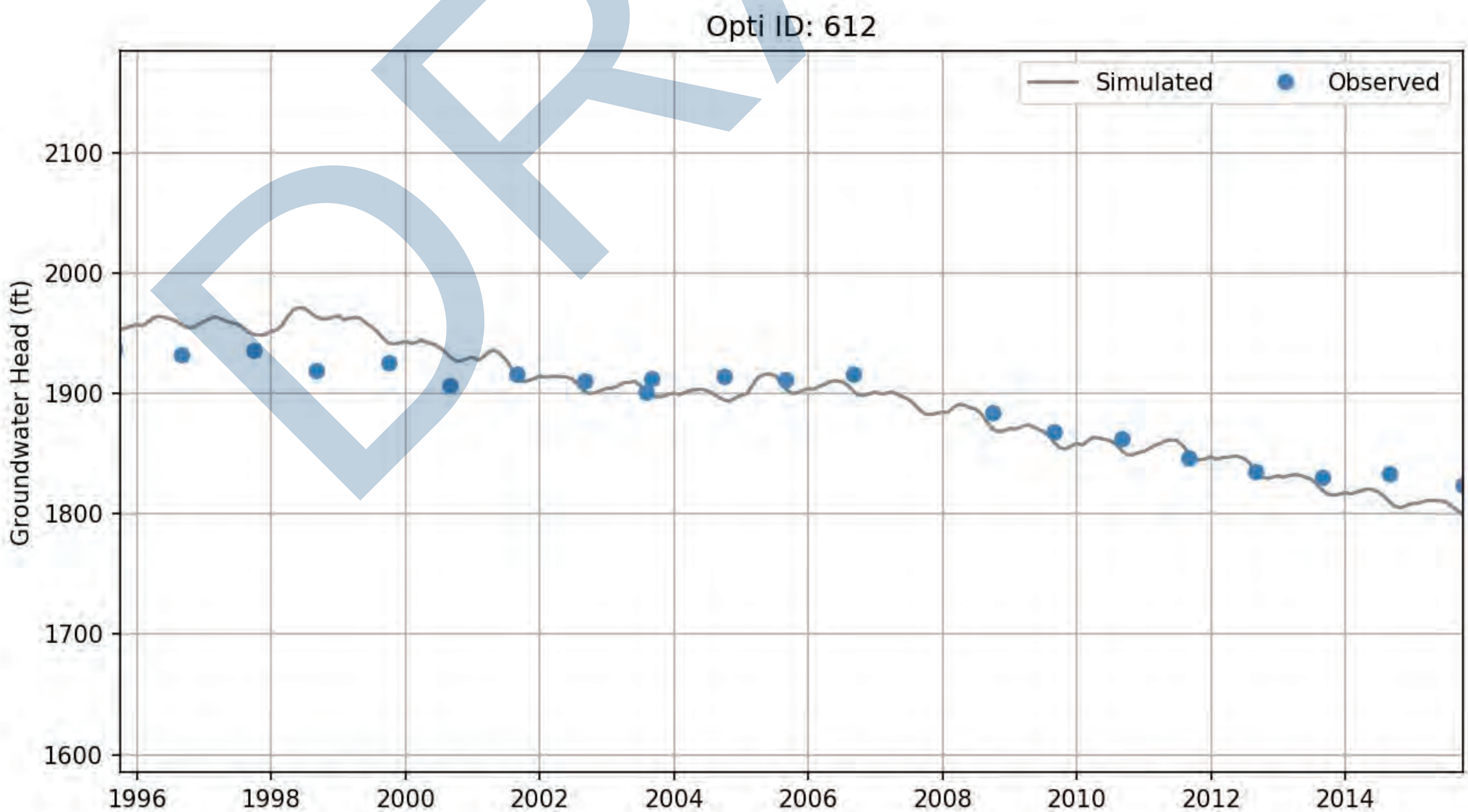
Opti ID: 608
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 609
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

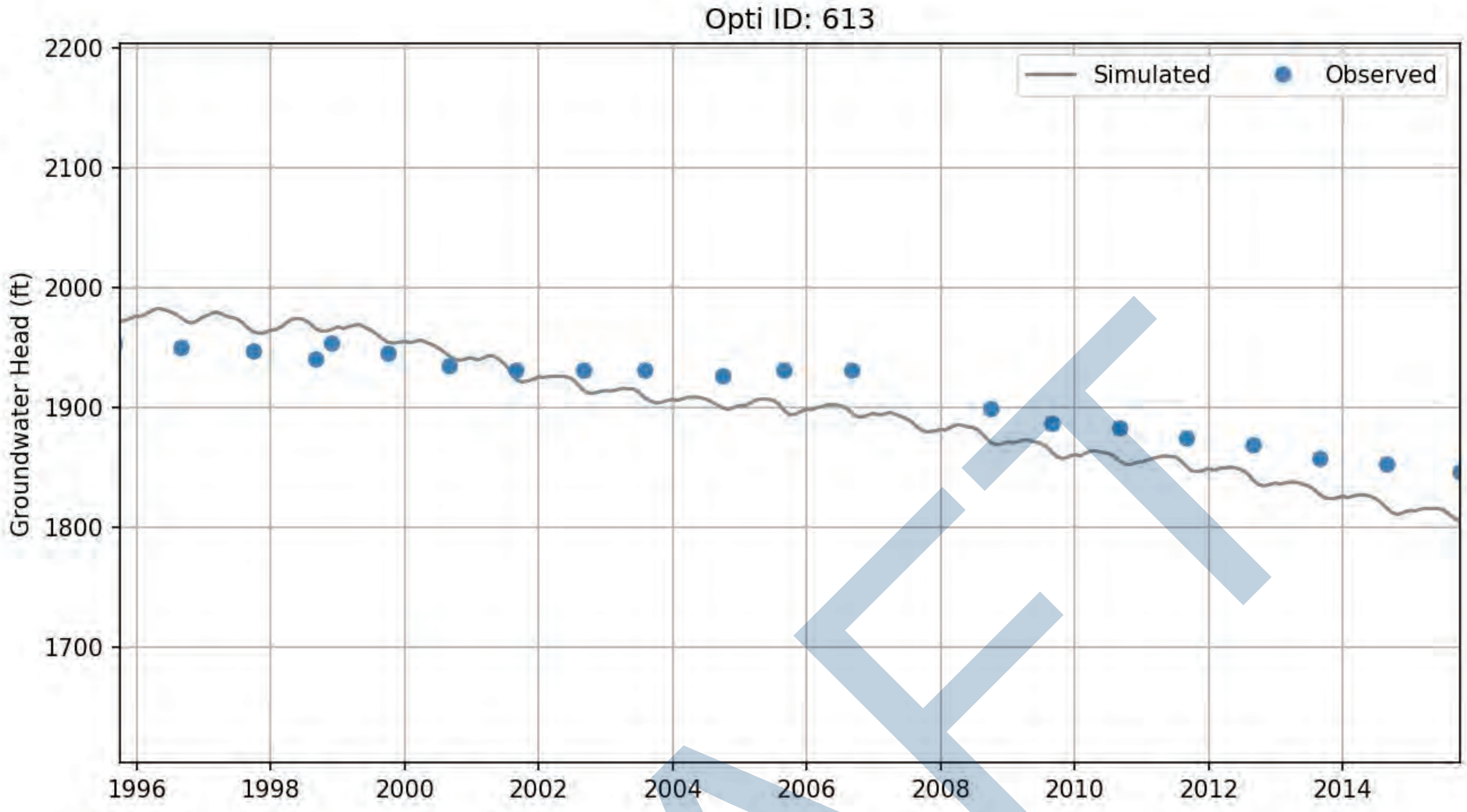

Opti ID: 610
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014



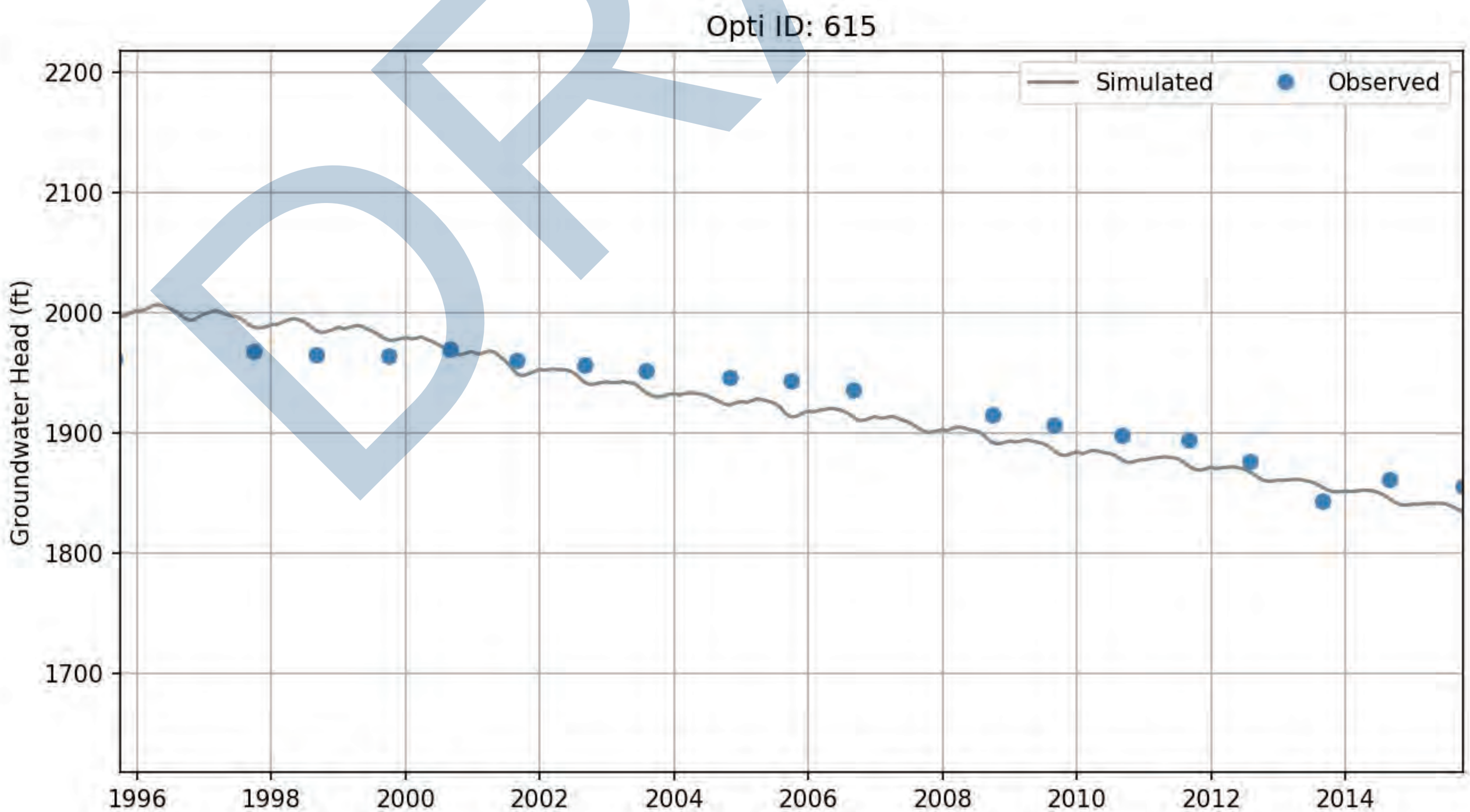
Opti ID: 611
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

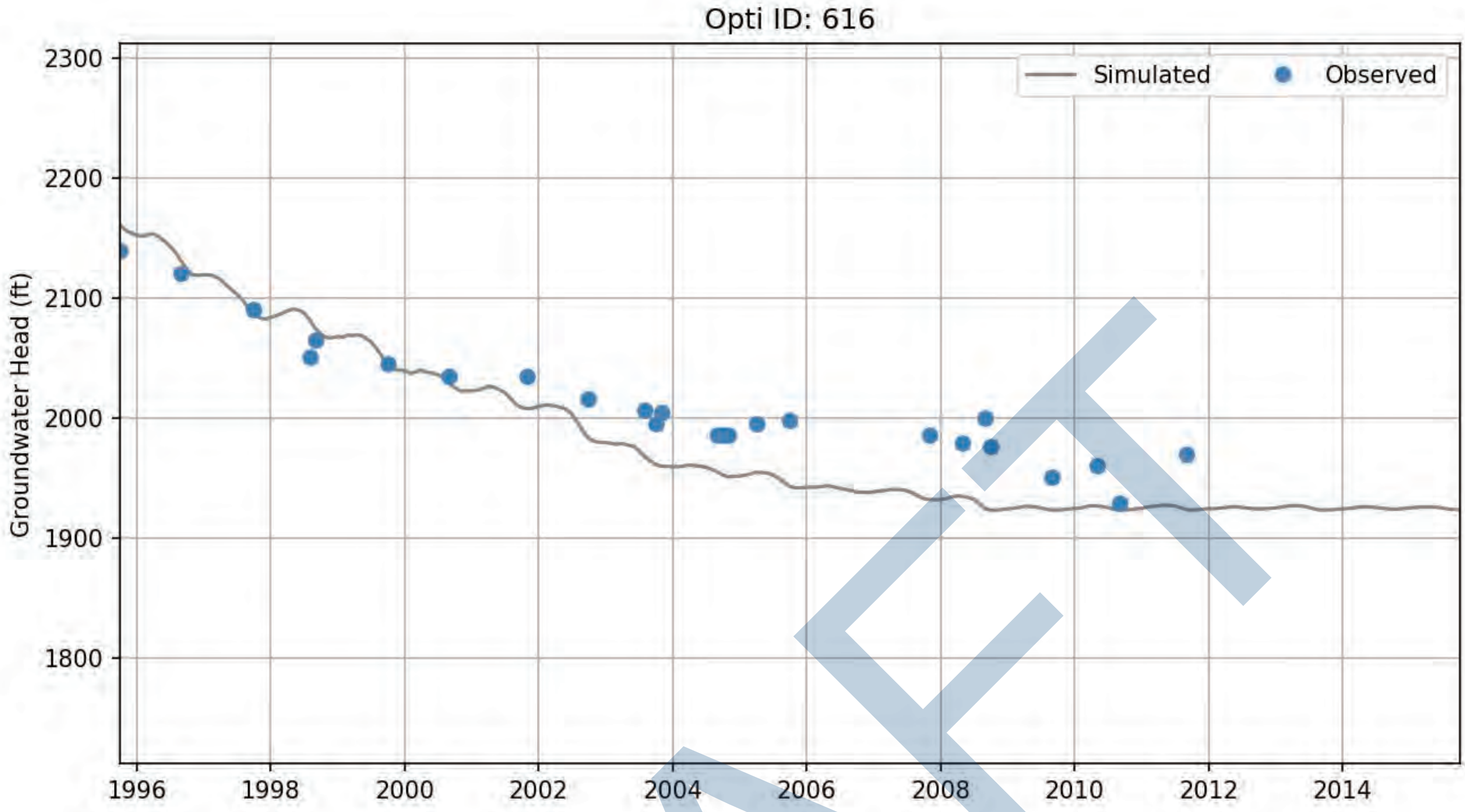
Opti ID: 612
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

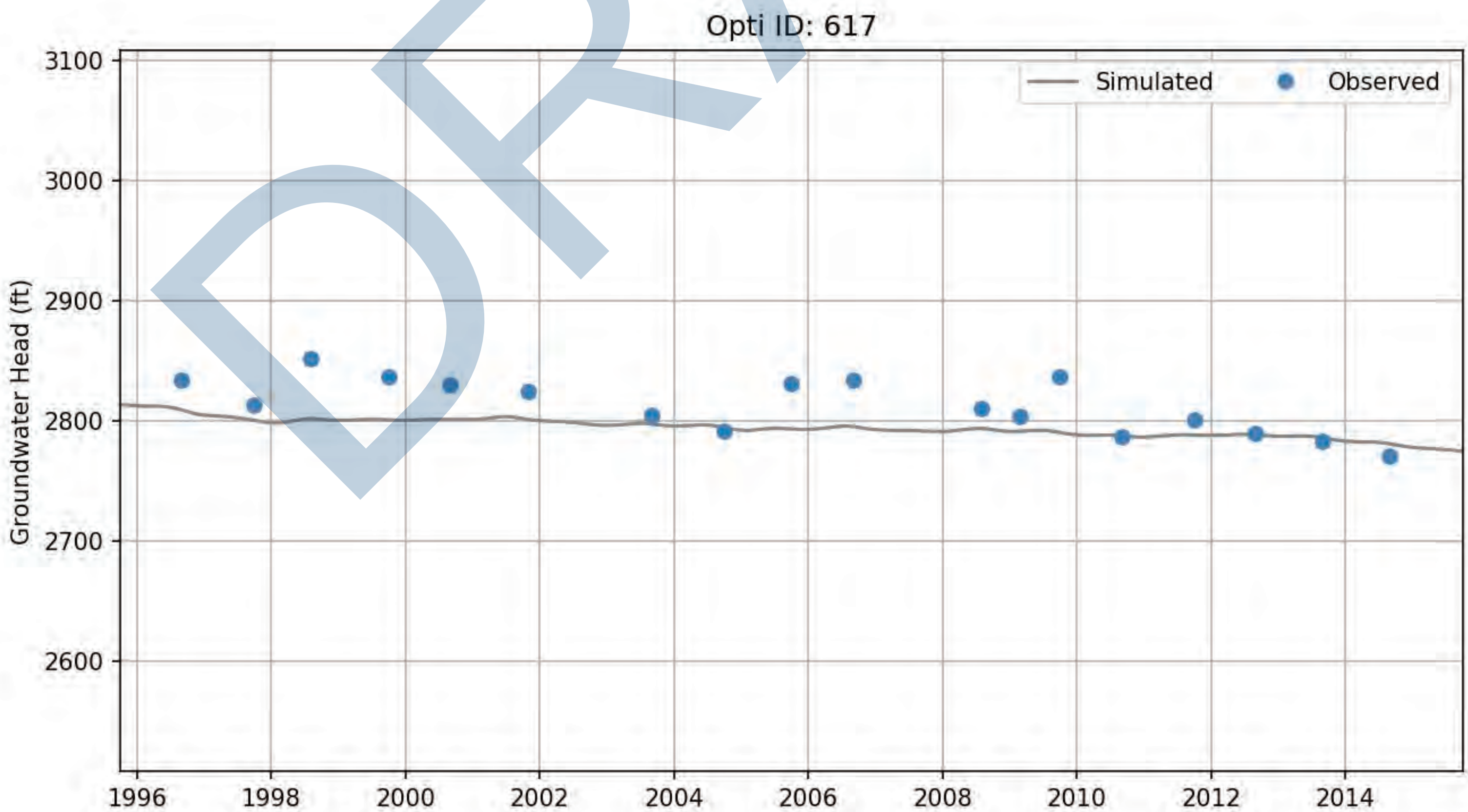


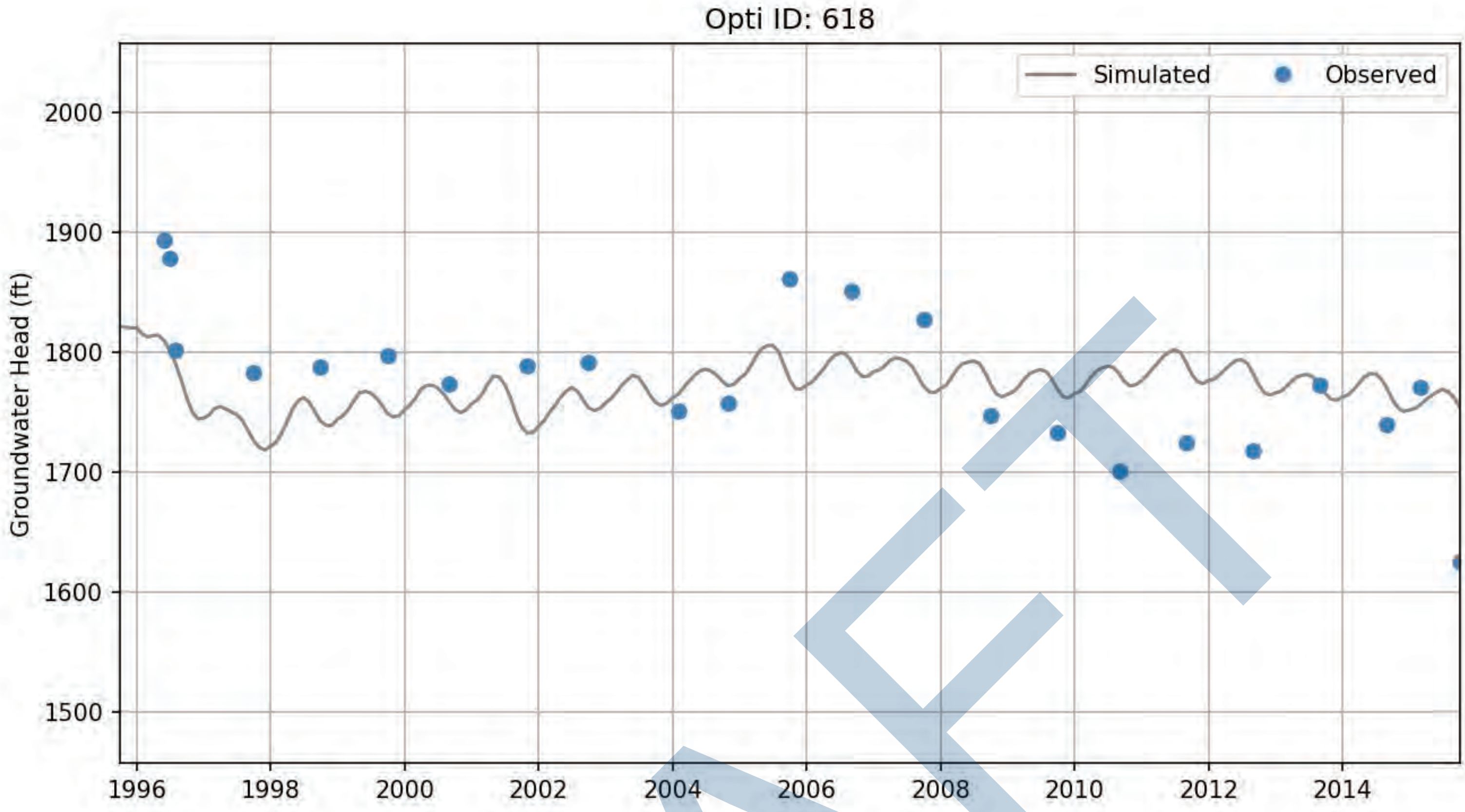
Opti ID: 613
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

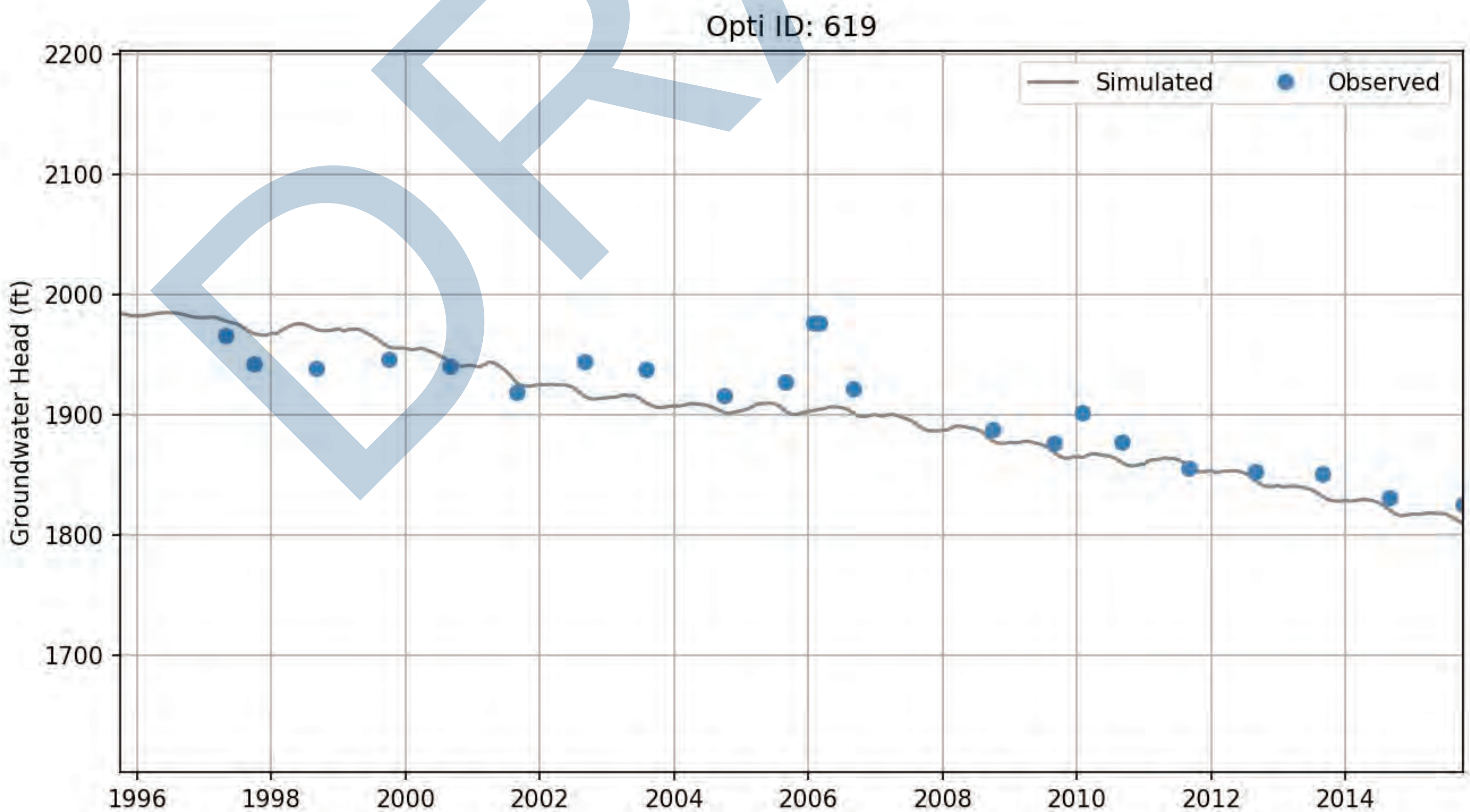



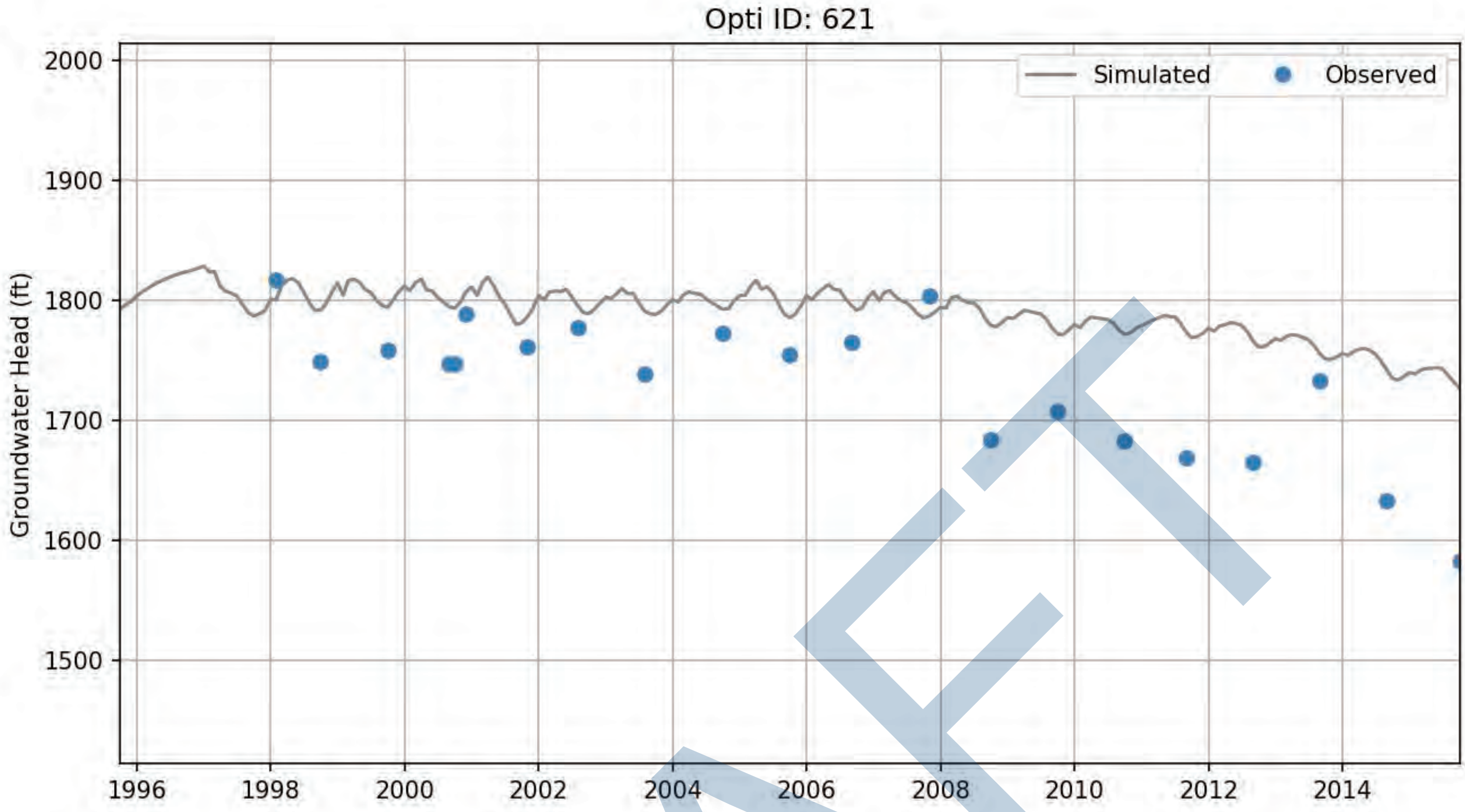
Opti ID: 615
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 616
Simulated
Observed
Groundwater Head (ft)
2300
2200
2100
2000
1900
1800
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

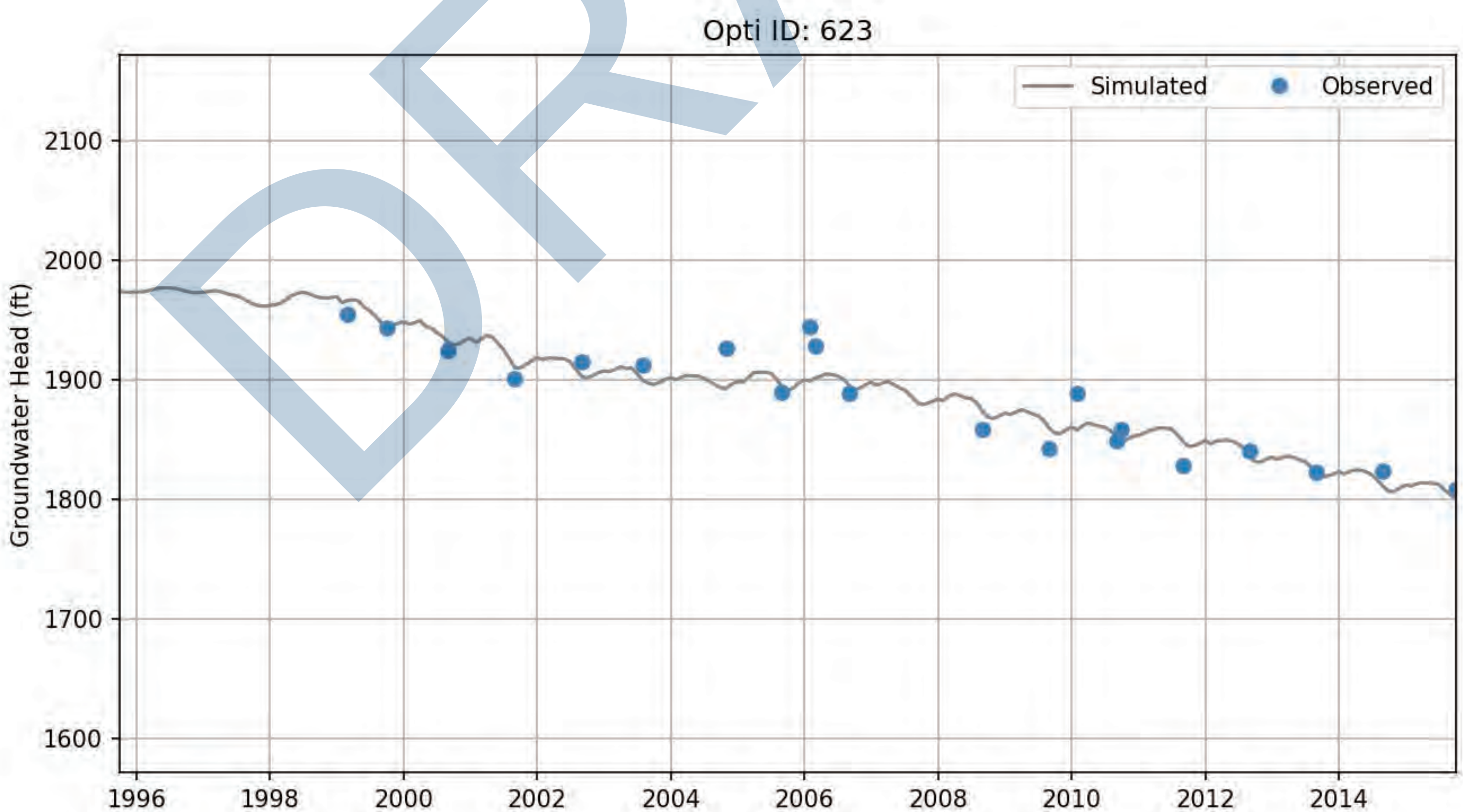

Opti ID: 617
Simulated
Observed
Groundwater Head (ft)
3100
3000
2900
2800
2700
2600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 618
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

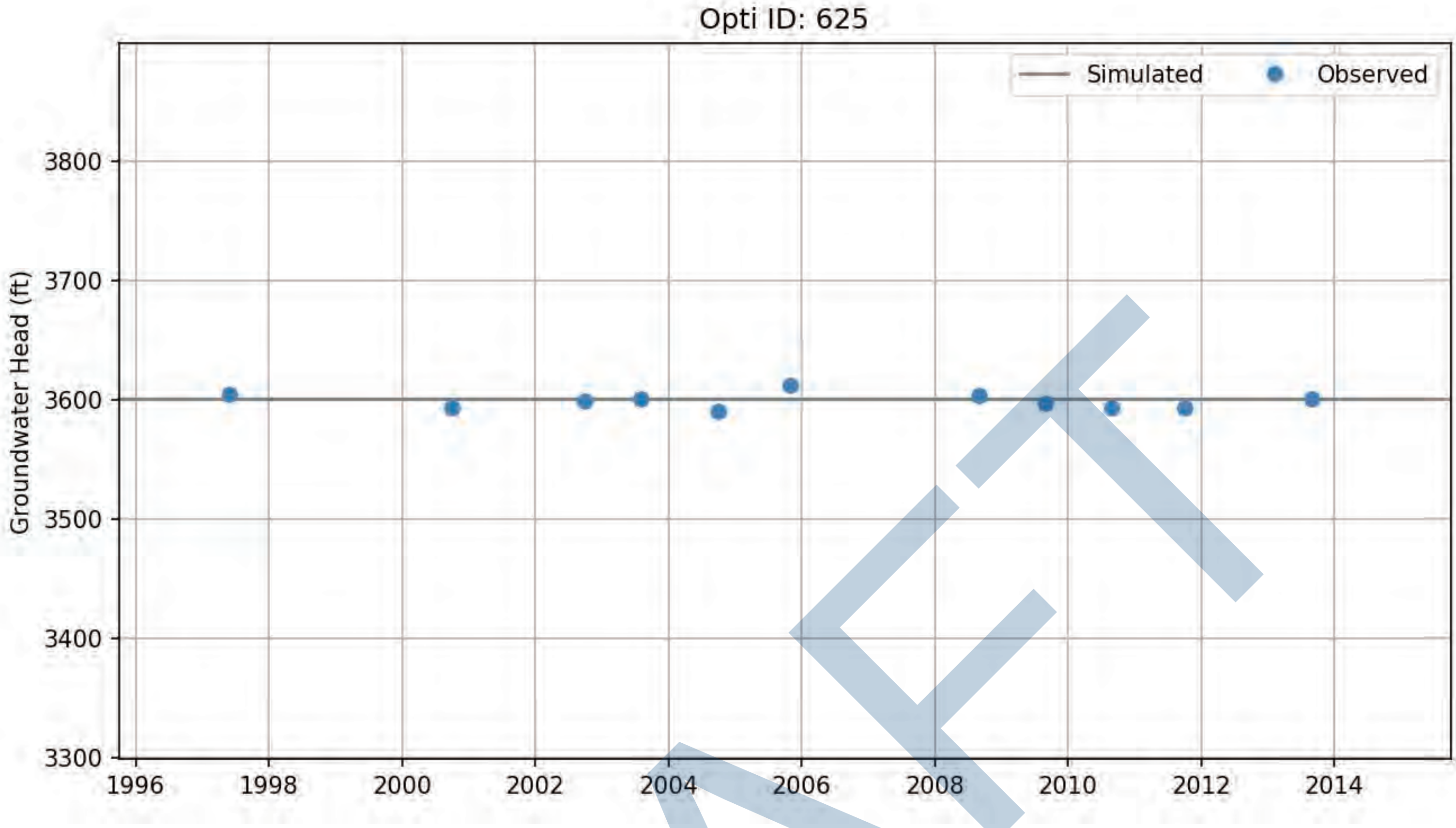

Opti ID: 619
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

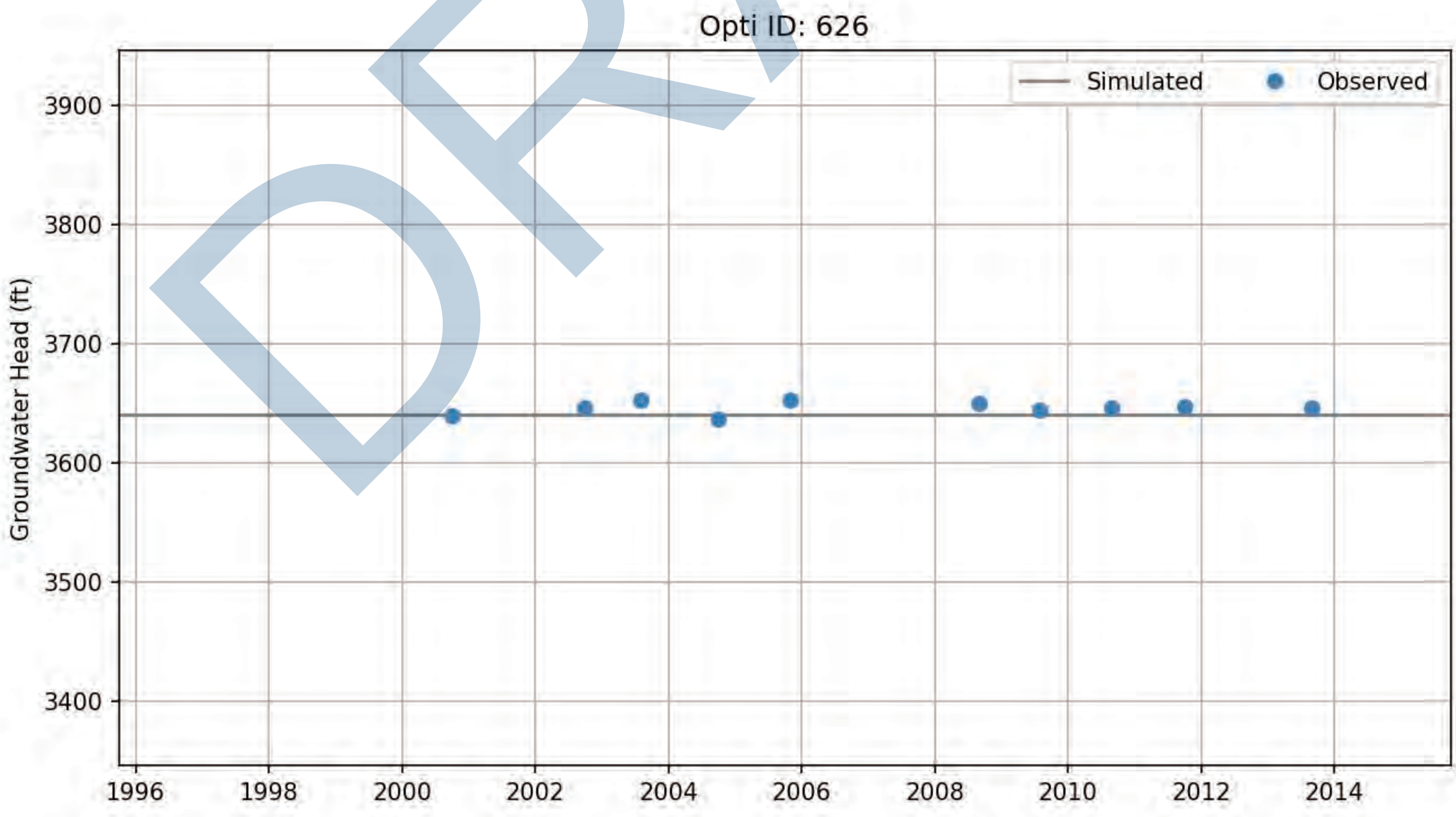


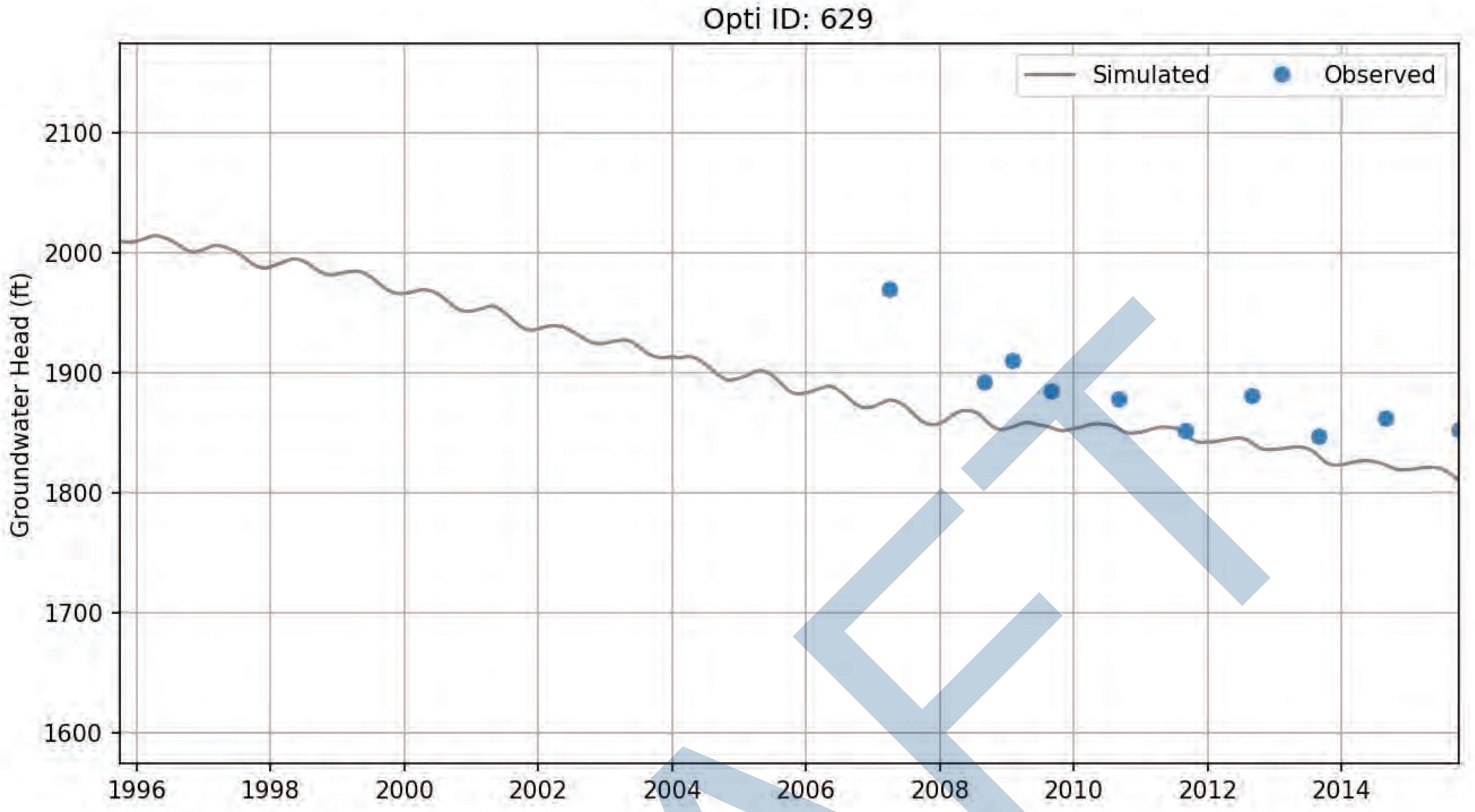
Opti ID: 621
Simulated
Observed
Groundwater Head (ft)
2000
1900
1800
1700
1600
1500
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

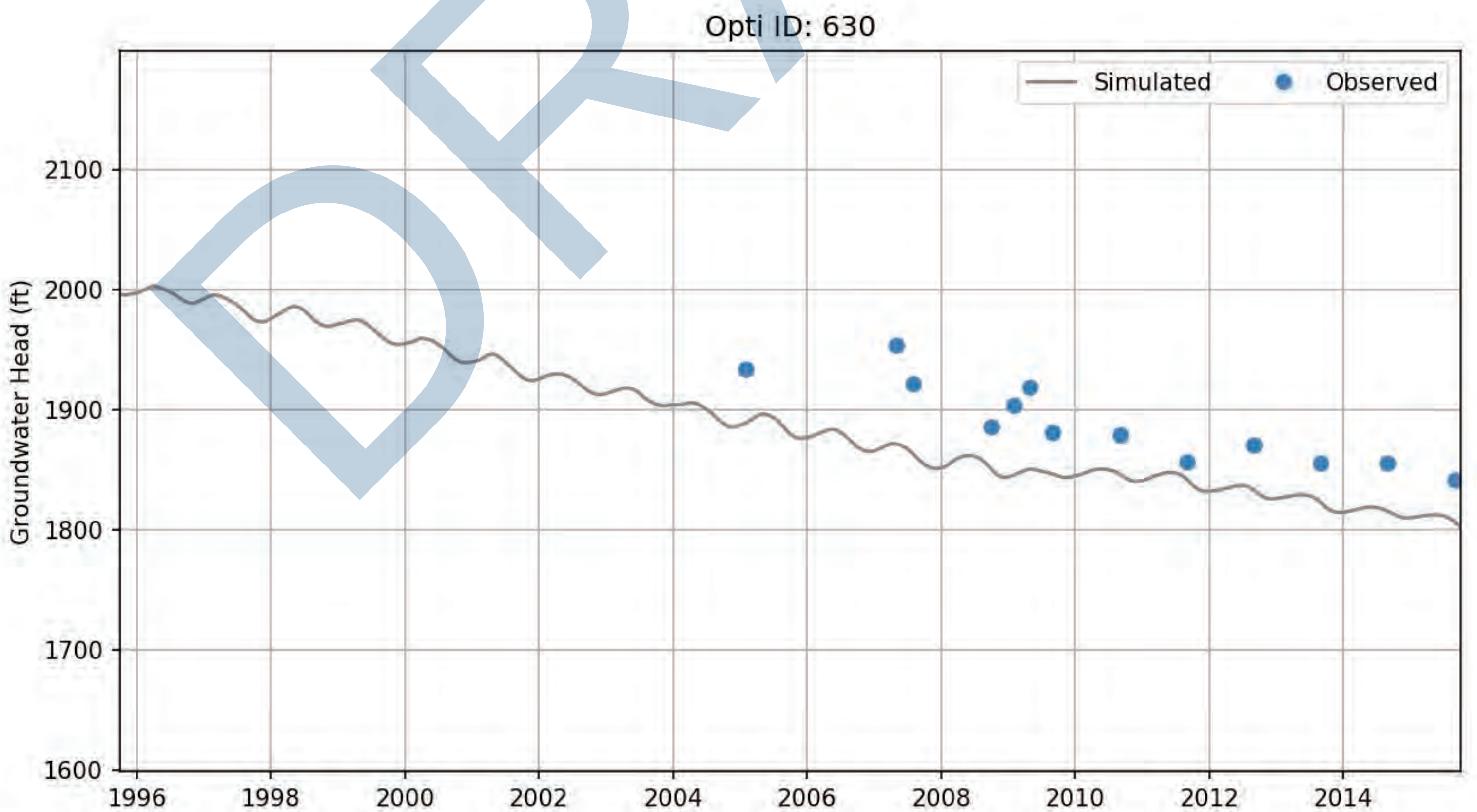



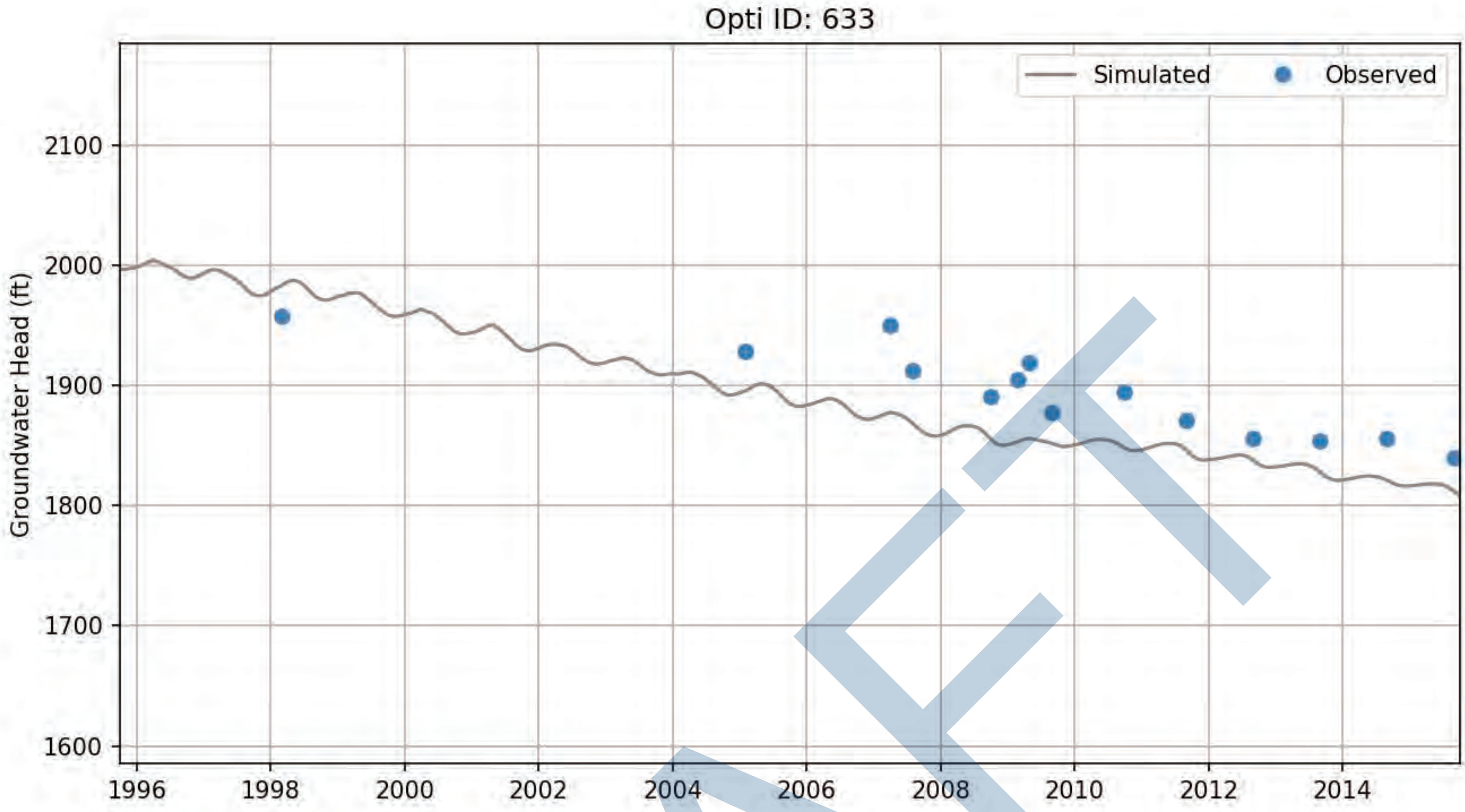
Opti ID: 623
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

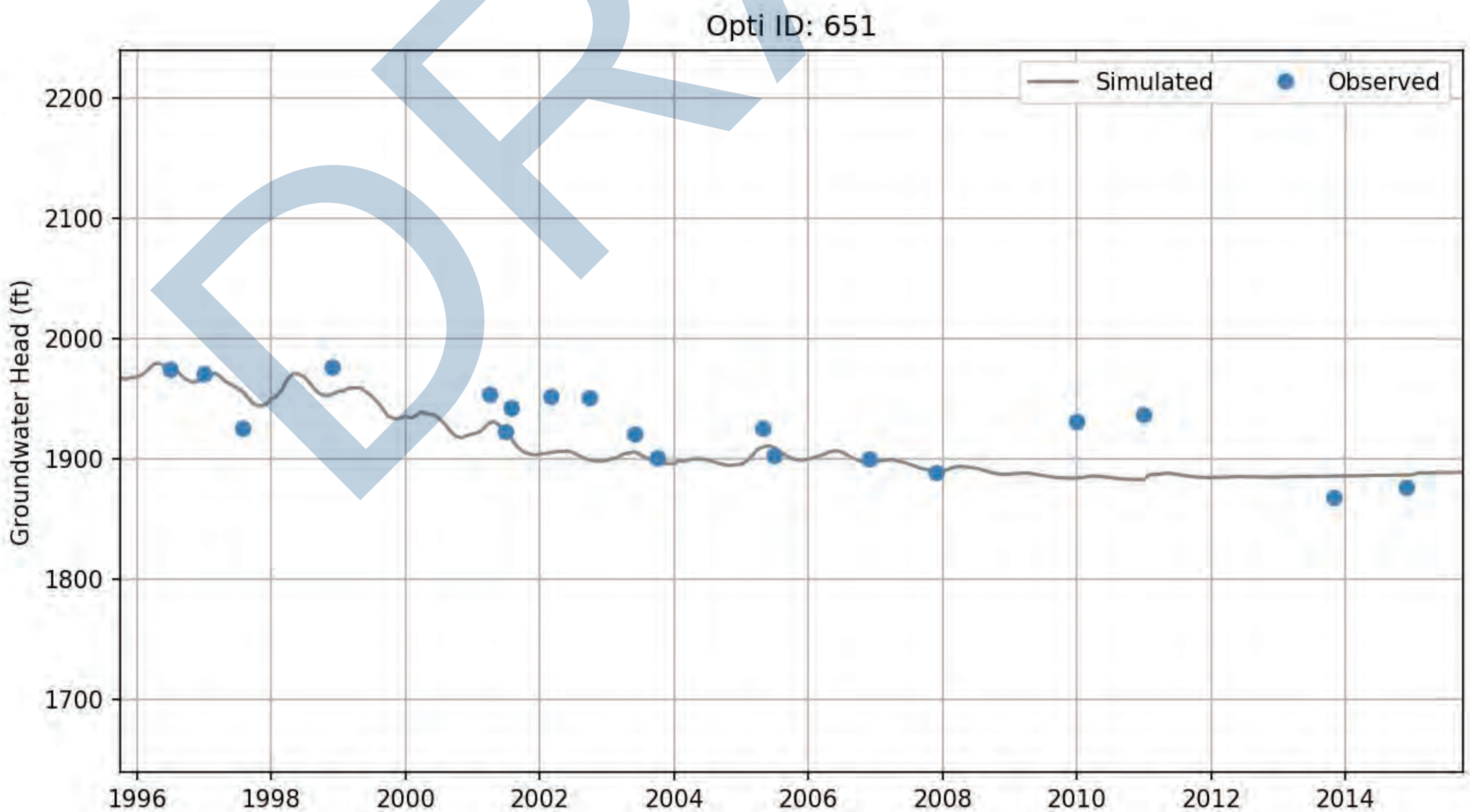

Opti ID: 625
Simulated
Observed
Groundwater Head (ft)
3800
3700
3600
3500
3400
3300
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

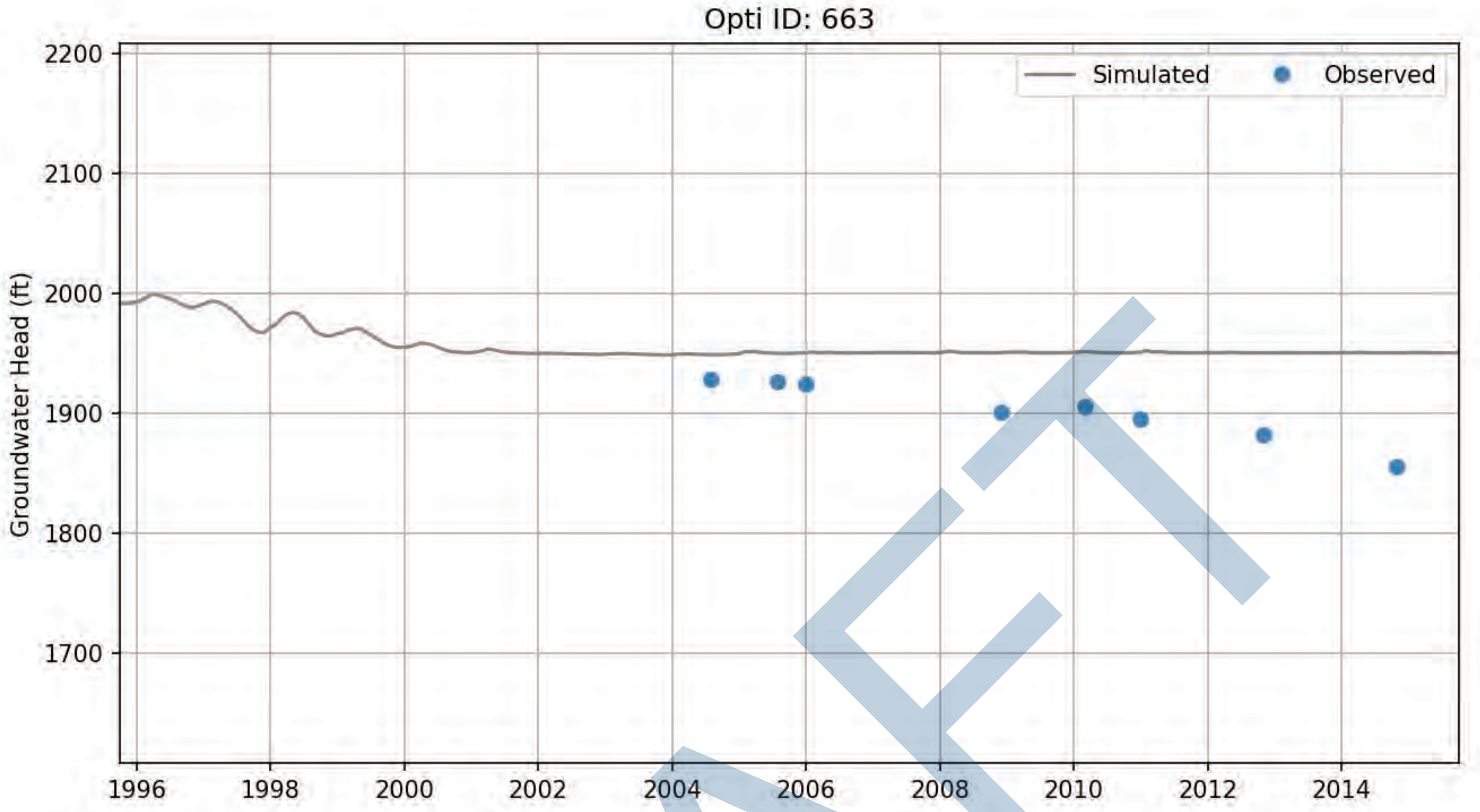

Opti ID: 626
Simulated
Observed
Groundwater Head (ft)
3900
3800
3700
3600
3500
3400
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

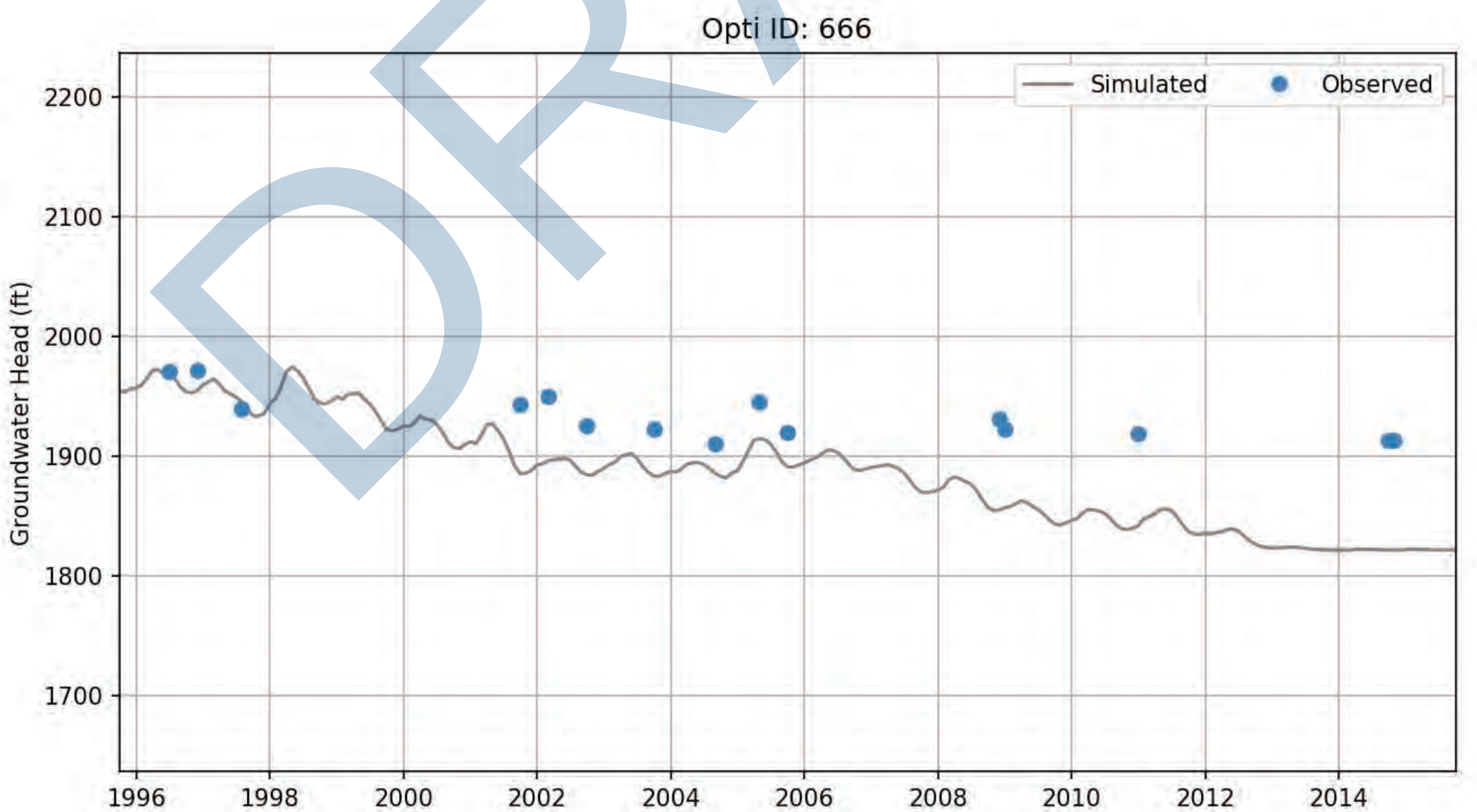

Opti ID: 629
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 630
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 633
Simulated
Observed
Groundwater Head (ft)
2100
2000
1900
1800
1700
1600
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 651
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014


Opti ID: 663
Simulated
Observed
Groundwater Head (ft)
2200
2100
2000
1900
1800
1700
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014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Observed
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1800
1700
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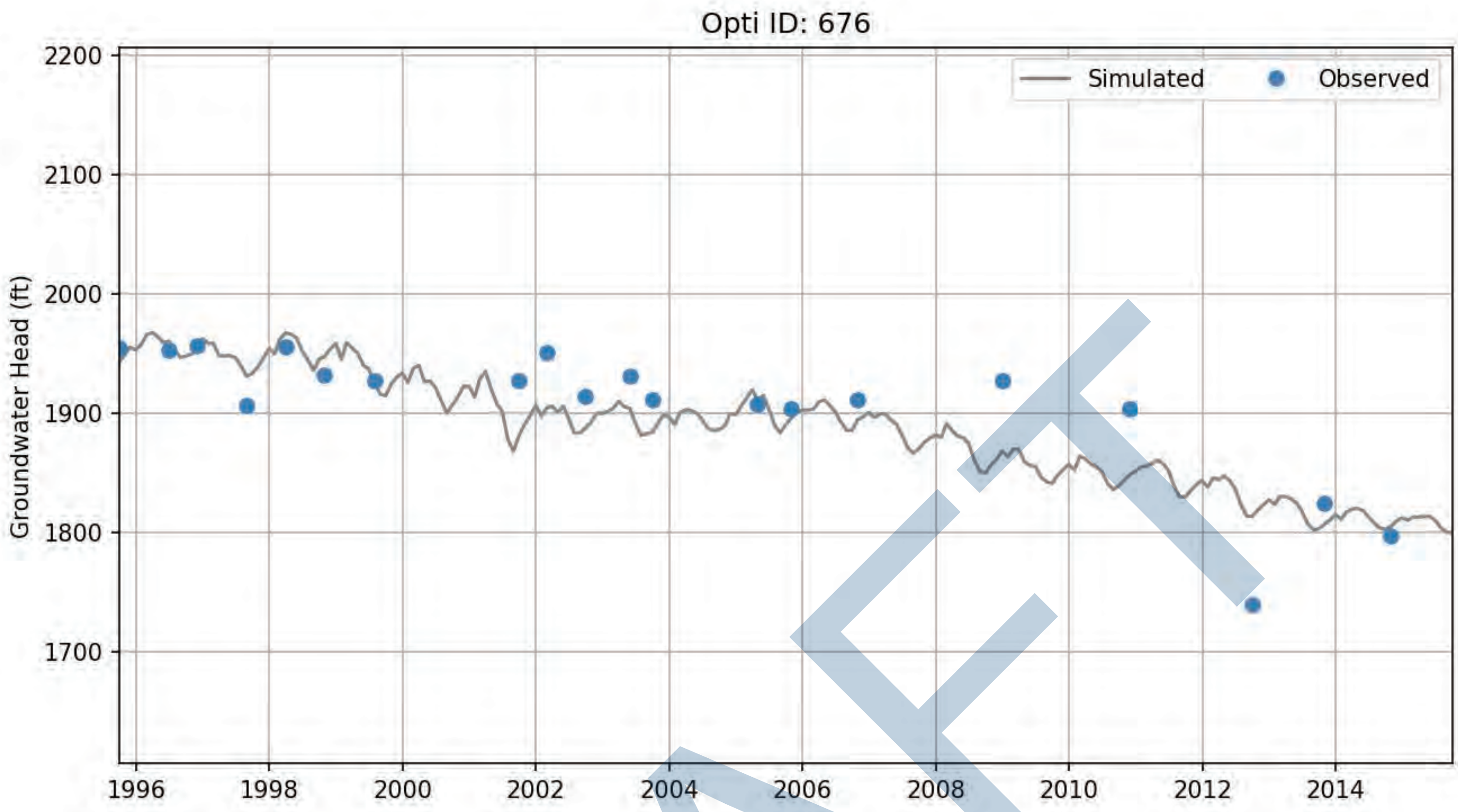
2006
2008
2010
2012
2014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2000
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1800
1700
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2006
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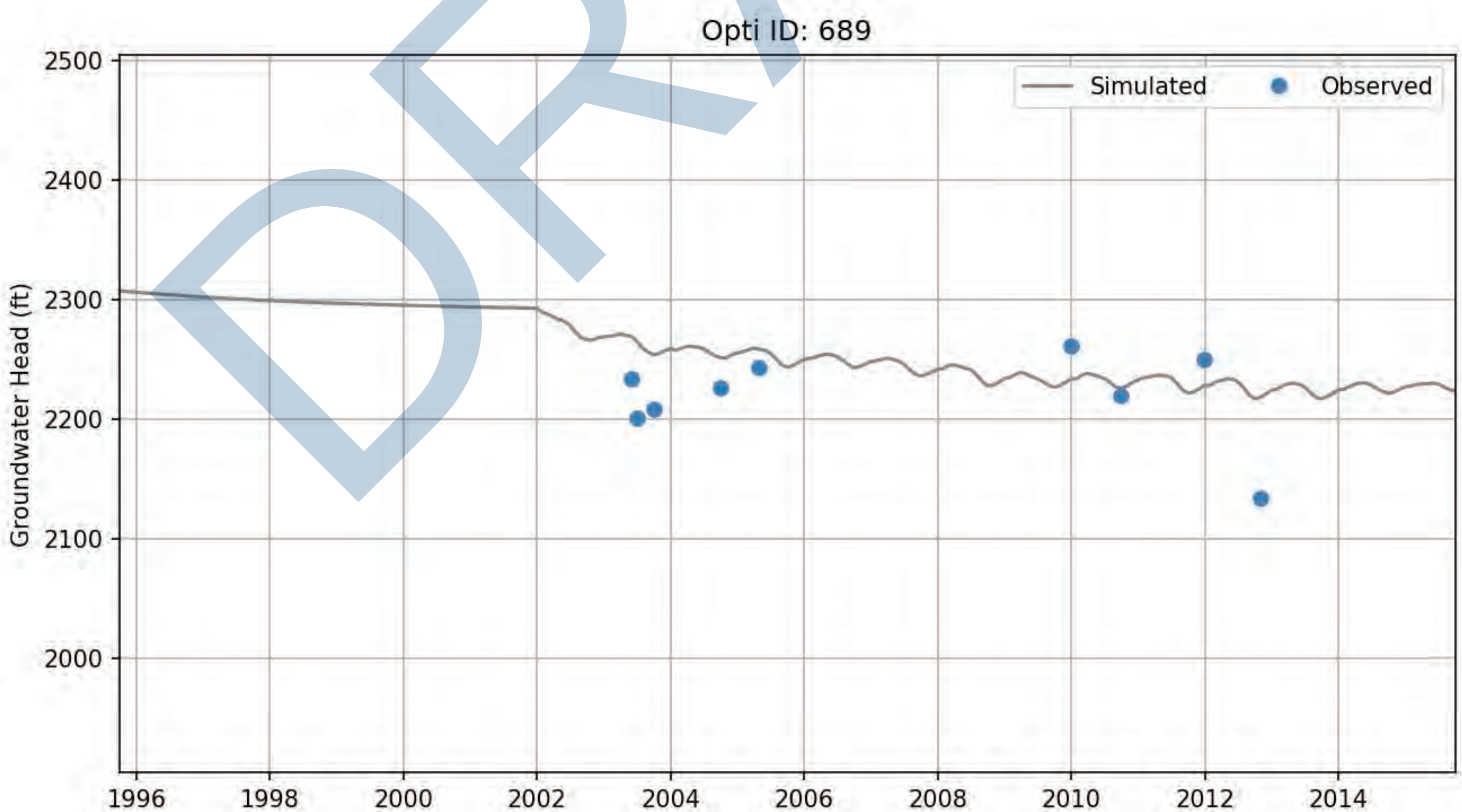
2010
2012
2014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2300
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2100
2000
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2006
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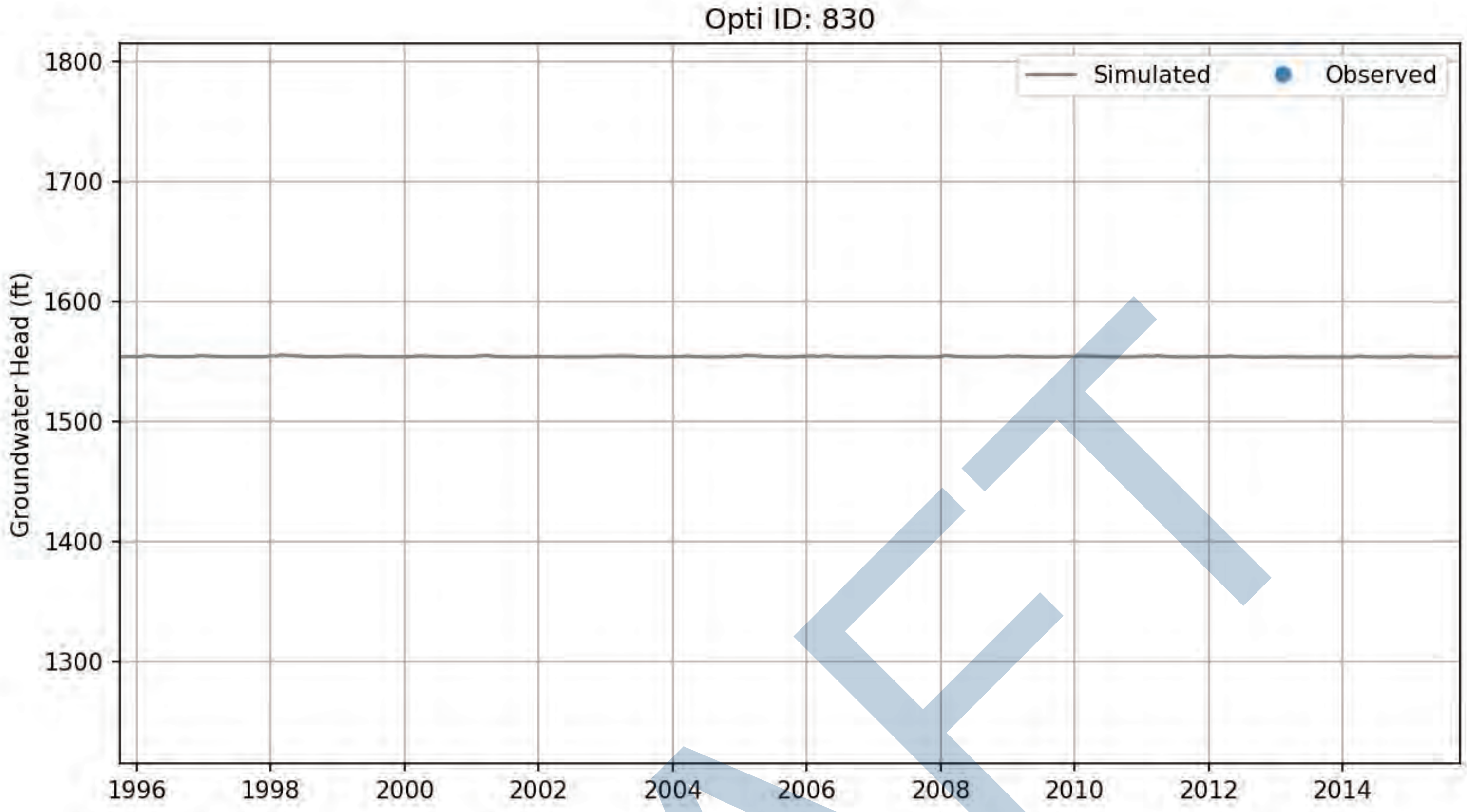
2010
2012
2014



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Observed
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1600
1500
1400
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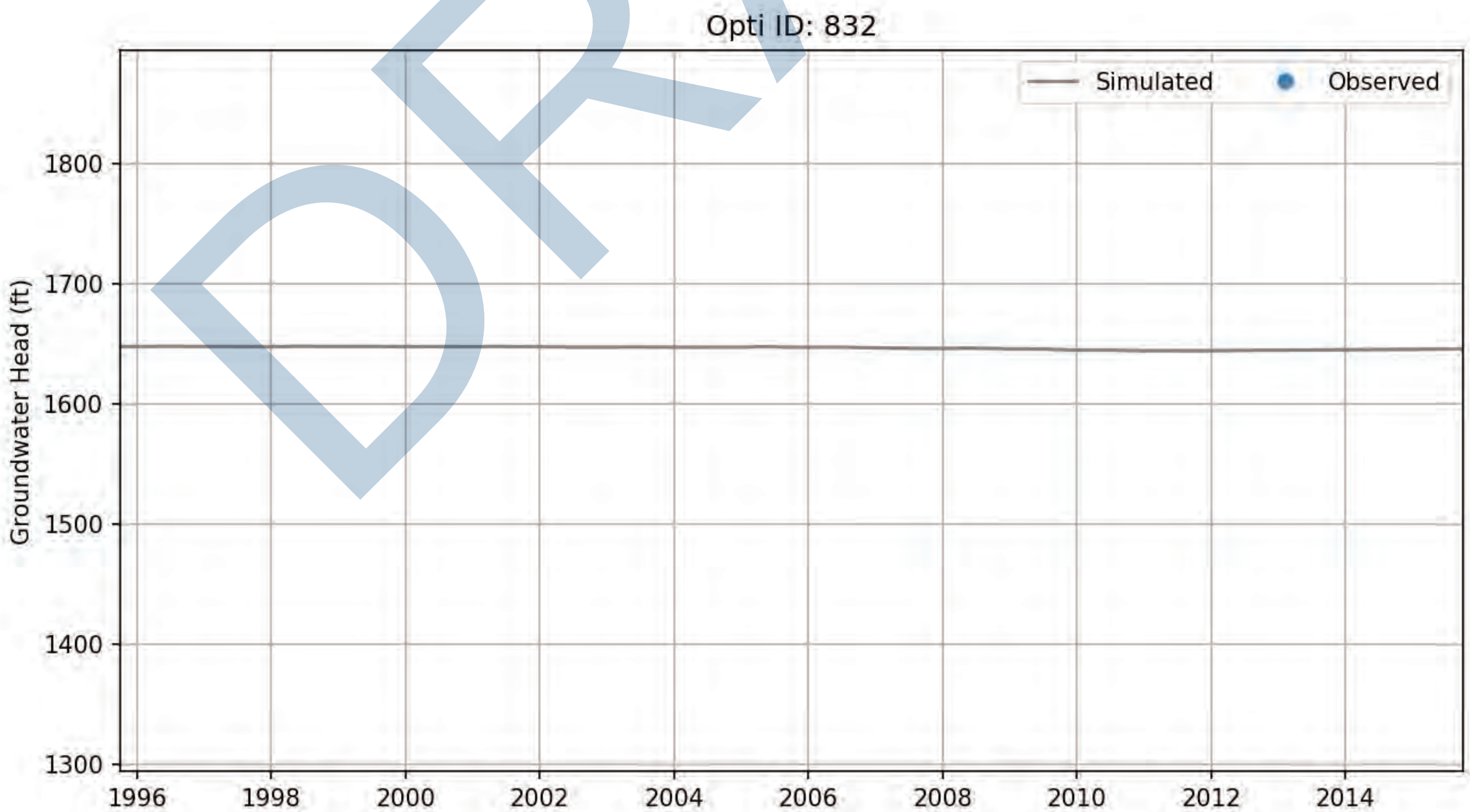
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014

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Observed
Groundwater Head (ft)
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1600
1500
1400
1300
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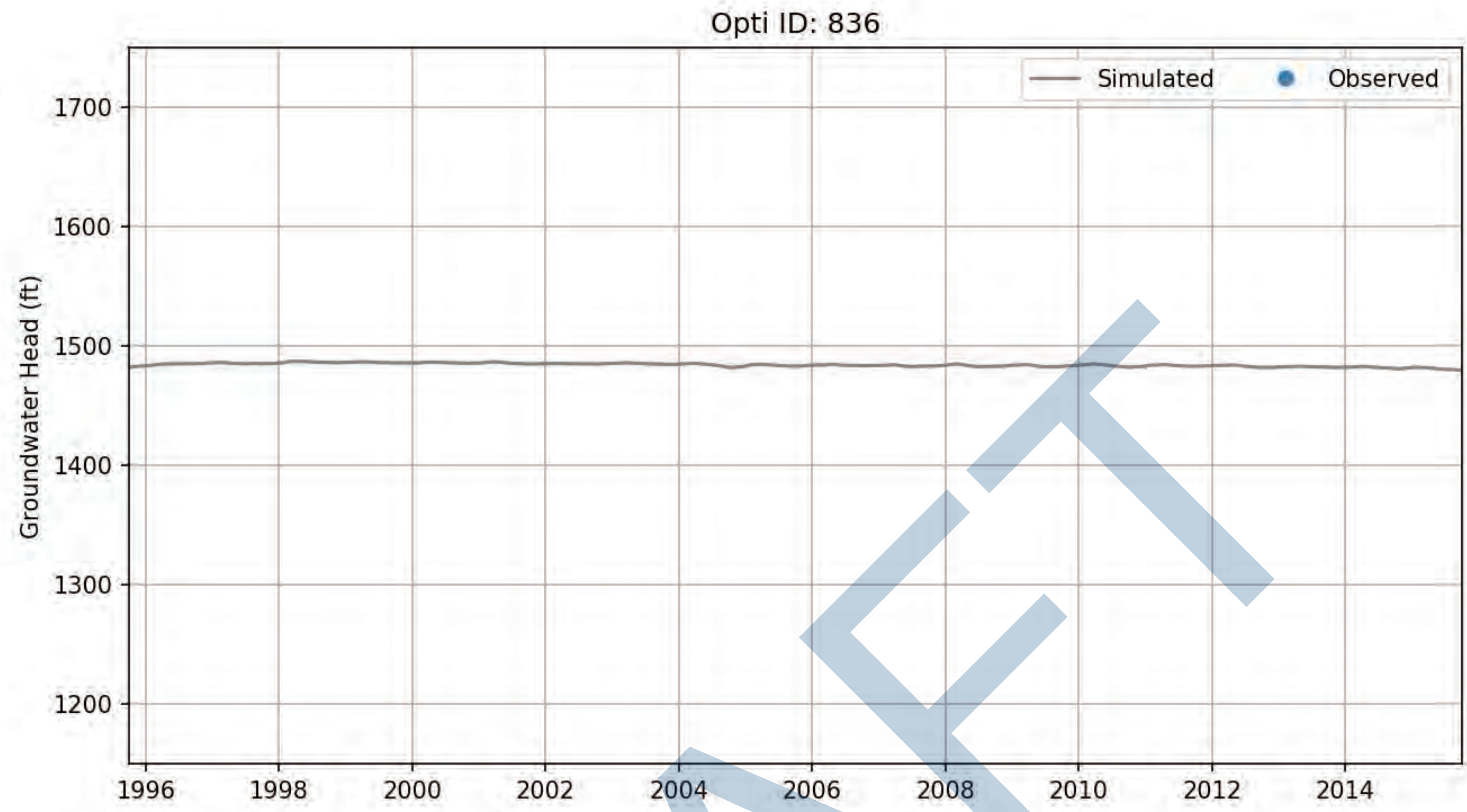
2008
2010
2012
2014



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Observed
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1500
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1300
1200
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1998
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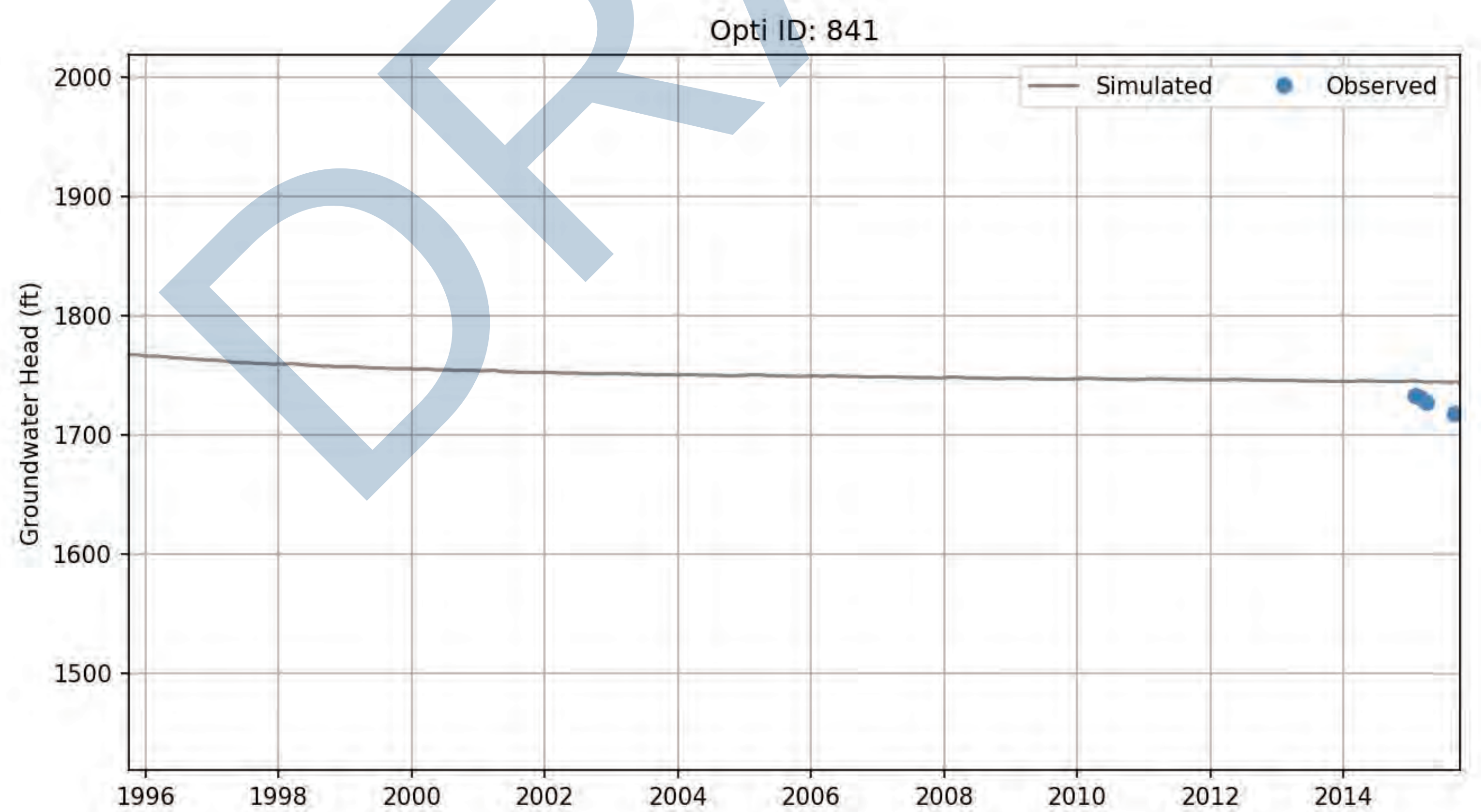
2004
2006
2008
2010
2012
2014

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Observed
Groundwater Head (ft)
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1900
1800
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1600
1500
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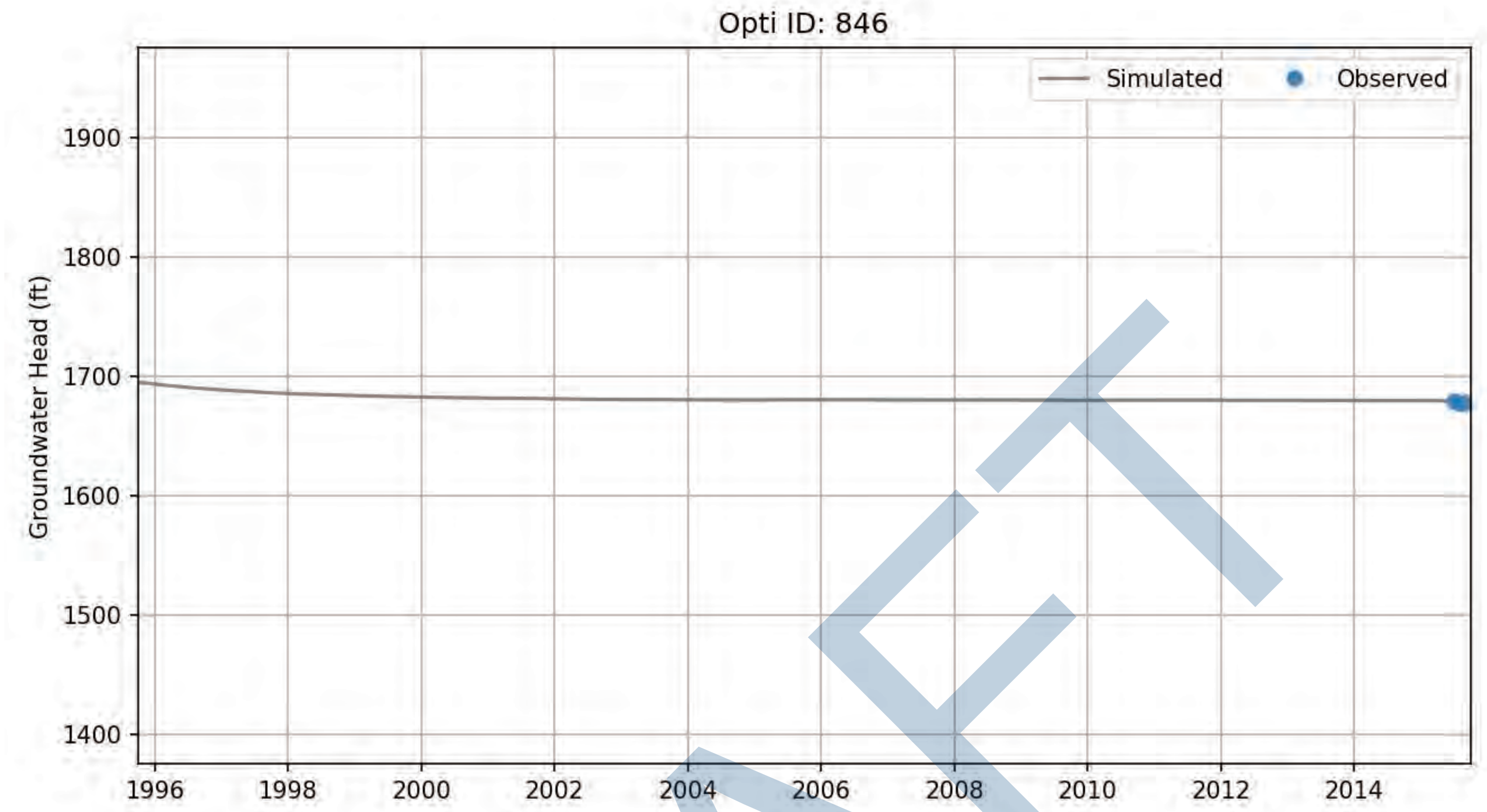
2012
2014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Observed
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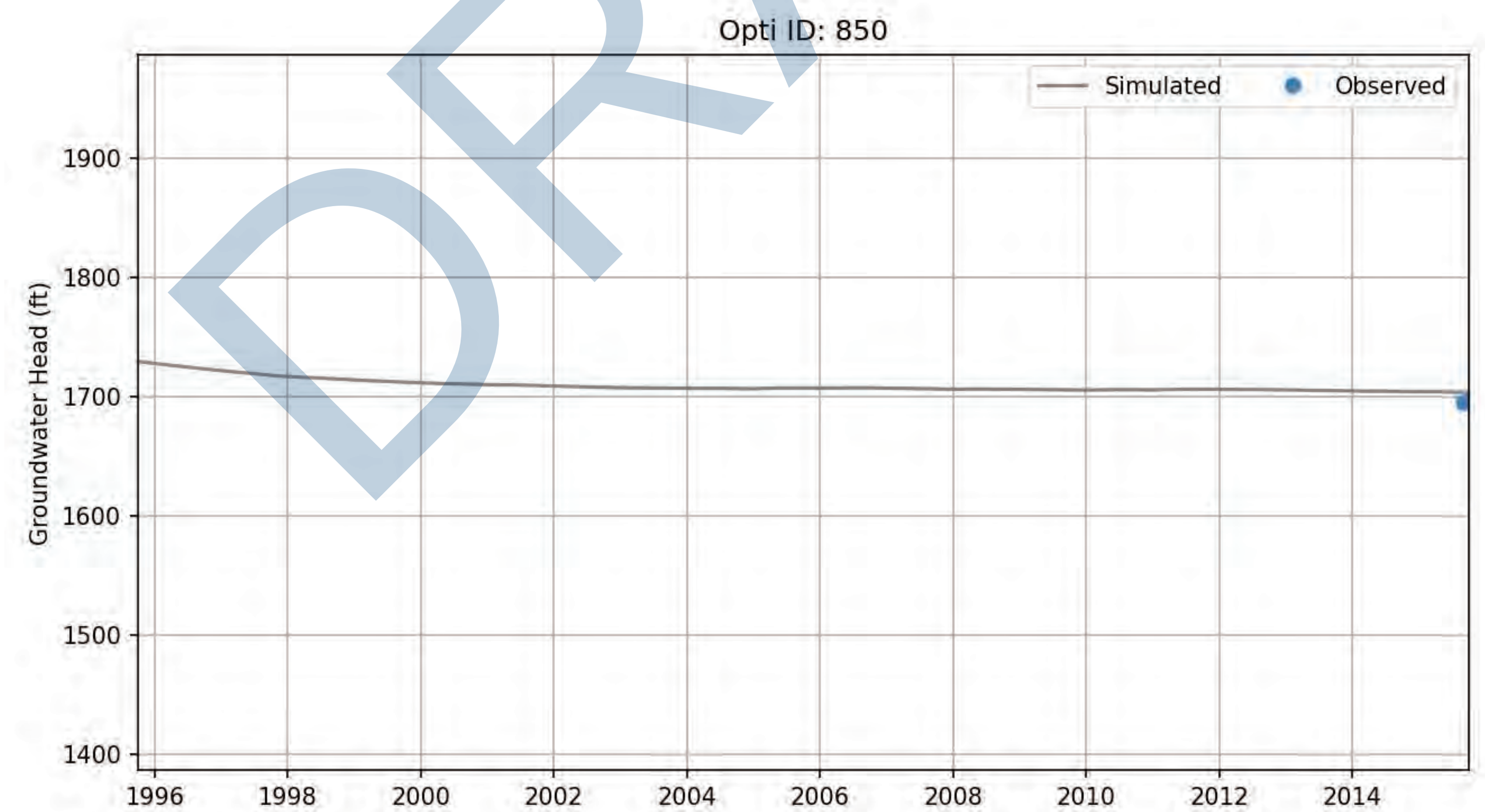
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Observed
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1900
1800
1700
1600
1500
1400
1996
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2000
2002
2004
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2008
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2012
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# Appendix D

## Technical Memorandum: Verification of NCCAG-Identified Locations

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WOODARD
&CURRAN

# TECHNICAL MEMORANDUM


TO: Cuyama Groundwater Sustainability Agency

CC: Brian Van Lienden, Woodard & Curran PM

PREPARED BY: William L. Medlin, PWS, ENV SP

REVIEWED BY: John Ayres and Micah Eggleton

DATE: February 15, 2019

RE: Cuyama GSP Groundwater Dependent Ecosystems Study



As part of the California Sustainable Groundwater Management Act (SGMA), Groundwater Sustainability Agencies (GSAs) are required to develop a Groundwater Sustainability Plan (GSP) to help ensure that groundwater is available for long-term, reliable water supply uses. SGMA was put into place and is enforced by the California Department of Water Resources (DWR). Once implemented, each GSP must address certain key elements such as a baseline groundwater assessment, monitoring, establishing best management practices (BMPs), and setting new regulations with the goal of defining a pathway to achieve sustainable groundwater management within 20 years (DWR 2018).

Within the GSP, a baseline assessment of groundwater conditions must be completed, and part of that assessment includes identification of groundwater dependent ecosystems (GDEs) and an assessment of potential impacts on GDEs. SGMA defines GDEs as “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface.” The identification and determination of GDEs within a groundwater basin is the responsibility of the GSA that governs the basin. This study specifically focuses on GDEs identified within the Cuyama Valley groundwater basin.

## 1. CUYAMA VALLEY GROUNDWATER BASIN ECOLOGICAL SETTING

The Cuyama Valley groundwater basin encompasses multiple California ecoregions (Griffith et al. 2016). In terms of land area, the dominant ecoregion is the Central California Foothills and Coastal Mountains (6), sub-ecoregion Cuyama Valley (6am). This ecoregion is characterized by its Mediterranean climate with hot, dry summers and cool, moist winters. Typical vegetative communities consist of chaparral and oak woodlands; grasslands are present at some lower elevations and pine forests are observed at high elevations. Most of the region is comprised of open, low mountains and foothills with some irregular plains and narrow valleys in certain locations. More specifically, the Cuyama Valley is a narrow valley with significant agricultural production. The mainstem Cuyama River flows through the center of the valley from southeast to northwest.

A minor part of the Cuyama Valley ground water basin is in the Southern California Mountains (8) ecoregion, in the Northern Transverse Range (8g) sub-ecoregion. This ecoregion, like other California ecoregions, is characterized by a Mediterranean climate of hot, dry summers and cool, moist winters. Chaparral and oak woodland vegetative communities are still ever-present, however the elevations in this ecoregion are higher generally leading to cooler summers and greater rainfall which result in denser vegetation and large areas of coniferous forests. There is a slope effect that causes some significant ecological differences in the Transverse Range. South-facing slopes receive more annual precipitation (30-40 inches) than the northern-facing slopes (15-20 inches), yet evaporation rates contribute to the development of chaparral communities. While on the northern-facing side of parts of the ecoregion, lower temperatures and evaporation coupled with slow snow melt allow for a coniferous forest that transitions to desert montane habitat. Some areas of severe erosion are common where vegetation has been removed via fire, overgrazing, or other land clearing practices. Many areas in this ecoregion are National Forest public land (Griffith et al. 2016). The Cuyama River headwaters (Quatal Canyon Creek, Apache Canyon Creek, and Cuyama Creek) flow through this ecoregion. Figure 1 (Attachment A) illustrates the general location of the Cuyama Valley groundwater basin in the context of the Ecoregions of California.

## 2. GDE ASSESSMENT AND FIELD VALIDATION

Using Geographic Information Systems (GIS), Woodard & Curran completed a preliminary desktop analysis of the California DWR *Natural Communities Commonly Associated with Groundwater* (NCCAG) geospatial data set. Woodard & Curran attempted to identify NCCAG polygons that appeared to be "probable GDEs" based on the following observations:

- Presence of a mapped USGS spring or seep
- Inundation visible on aerial imagery
- Saturation visible on aerial imagery
- Dense riparian and/or wetland vegetation visible on aerial imagery

Areas that did not exhibit the above characteristics (or similar) were considered "probable non-GDEs" for purposes of this study. Reference Figure 2 (Attachment A) for geospatial representation of our basin-wide GDE desktop assessment.

In addition to the preliminary desktop analysis of the NCCAG data set, Woodard & Curran also completed a preliminary GDE field validation study throughout portions of the Cuyama Valley groundwater basin. The field study was conducted only on publicly accessible lands (including the Los Padres National Forest) where the NCCAG data set indicated potential presence of GDEs. Field observations were made at NCCAG-mapped seeps, springs, and at other riparian habitats to document plant communities, aquatic or semi-aquatic wildlife, indicators of surface and subsurface hydrology, presence of hydric soils, and other relevant ecological and hydrological data. Photographs were taken in the four cardinal directions (north, east, south, west) at each field validation assessment location, and additional photographs were taken of plant species and other relevant ecological data. Global Positioning System (GPS) points were also collected using a sub-meter Trimble Geo 7x GPS unit at the field validation assessment locations. Preliminary determinations were made at these field assessment locations as to whether an area would be classified as a GDE. Figure 3 (Attachment A) shows the locations of GDE field validation assessment data collection points.

## 3. RESULTS

Out of 486 NCCAG-mapped polygons (128 GDE_wetland and 358 GDE_vegetation), the preliminary desktop analysis yielded 123 "probable GDEs" and 275 "probable non-GDEs" based on the above-described methodology. Individual polygons were not assessed due to time constraints, but rather groupings of similarly-situated riparian areas or clusters of polygons were assessed via GIS for probability of GDE classification.

The preliminary GDE field validation study assessed six (6) locations in the field on publicly accessible lands. All field assessment sites were in the Los Padres National Forest public lands. One (1) location was along the upper mainstem of the Cuyama River, and the other five (5) locations were in the Apache Canyon Creek watershed. Table 1 below describes each of the field assessment sites in more detail.

## Table 1: GDE Field Validation Data Collection Sites

| GPS Data Point Name | Latitude / Longitude | NCCAG-Mapped Polygon? | NCCAG Vegetation / Wetland Type | Dominant Plant Species Observed | Other Notes |
|---|---|---|---|---|---|
| probable Non-GDE 1 | 34.760116 N, 119.419661 W | Yes | Vegetation - Riversidean Alluvial Scrub | *Hesperoyucca whipplei, Arctostaphylos glauca, Lepidospartum squamatum, Ericameria nauseosa, Eriogonum fasiculatum, Bromus carinatus* | Soils at data point are sandy, dry and friable; would not stay in soil auger. This location does not appear to be a GDE. |
| probable Non-GDE 2 | 34.761994 N 119.375711 W | Yes | Vegetation - Scalebroom | *Lepidospartum squamatum, Ericameria nauseosa, Eriogonum fasiculatum* | Soils at data point are dry and friable; Some pines and junipers are growing in the riparian zone adjacent to river bed; no evidence of hydrology that persists beyond flashy storm events. This location does not appear to be a GDE. |
| GDE 1 | 34.778902 N 119.341961 W | No | N/A | *Juncus xiphoides, Juncus patens, Typha domingensis, Scirpus microcarpus, Salix exigua, Salix laevigata, Castilleja sp., Isoetes howellii* | A small stream is flowing at this location and hydrophytic vegetation is present throughout the channel; brown algae observed in flowing stream; crystallized salt or other calcic material observed on stream channel sediments; soils are saturated to the surface in this area. This location appears to be a GDE. |
| GDE 2 | 34.801748 N 119.293979 W | Yes | Wetland - Palustrine, Scrub-Shrub, Seasonally Saturated | *Clematis ligusticifolia, Juncus effusus, Salix laevigata, Urtica dioica* | Data point is located at US Forest Service Nettle Springs Campground; USGS mapped spring indicated at data point; groundwater is seeping out of the hillside at this data point; soils sampled on hillslope are hydric and saturated at the surface; water flows in a small channel for approximately 300-500 feet downstream of the spring before drying up. This location appears to be a GDE. |
| GDE 3 | 34.772312 N 119.346965 W | No | N/A | *Salix lasiolepis, Baccharis salicifolia, Baccharis pilularis Distichlis spicata, Artemisia californica,* | Data point is located within a small floodplain depression willow thicket. Hydrophytes are present and soils are saturated at |

| | | | | | |
|---|---|---|---|---|---|
| | | | | *Juncus patens, Anemopsis californica, Leymus triticoides* | the surface by what appears to be groundwater. Soils are hydric. This location appears to be a GDE. |
| GDE 4 | 34.773548 N 119.346732 W | Yes | Vegetation - Riparian Mixed Shrub | *Salix laevigata, Juncus patens, Leymus triticoides, Anemopsis californica, Melilotus sp., Isoetes howellii* | A small stream is flowing at this location and hydrophytic vegetation is present throughout the channel; crystallized salt or other calcic material observed on stream channel sediments; soils are saturated to the surface in this area. This location appears to be a GDE. |

# 4. CONCLUSIONS

The Cuyama Valley groundwater basin is a significantly stressed aquifer due to several factors including climate, industrial-scale agriculture, oil and gas exploration and production, ranching, and other land uses. The combination of these factors has drawn the groundwater down to greater than 600 feet below the ground surface in some locations, and this affects GDEs by limiting the amount of groundwater available to ecological communities living at the surface. Especially affected is the Cuyama River mainstem which was observed to be dry throughout much of its reach that was visible during our preliminary GDE field validation study.

However, there do appear to be some GDEs present within the Cuyama Valley groundwater basin as indicated in Table 1. All these areas (GDE 1 – 4) were located within the headwaters of the Cuyama River along Apache Canyon Creek and its floodplain. Areas mapped by the NCCAG data set as seeps and/or springs and the immediately downstream riparian corridors were among the GDEs that were assessed in the field. These locations had hydrophytic vegetation and other near-surface hydrologic indicators that would suggest that the ecological community is dependent on groundwater being present for significant durations during the growing season each year.

Due to access limitations because of private property restrictions, further study should be done along the mainstem of the Cuyama River (and other select tributaries) to determine if GDEs are present within the channel or riparian area.

# 5. REFERENCES


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Cowardin, L. M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 131pp.

Griffith, G.E., Omernik, J.M., Smith, D.W., Cook, T.D., Tallyn, E., Moseley, K., and Johnson, C.B., 2016, Ecoregions of California (poster): U.S. Geological Survey Open-File Report 2016–1021, with map, scale 1:1,100,000, http://dx.doi.org/10.3133/ofr20161021.

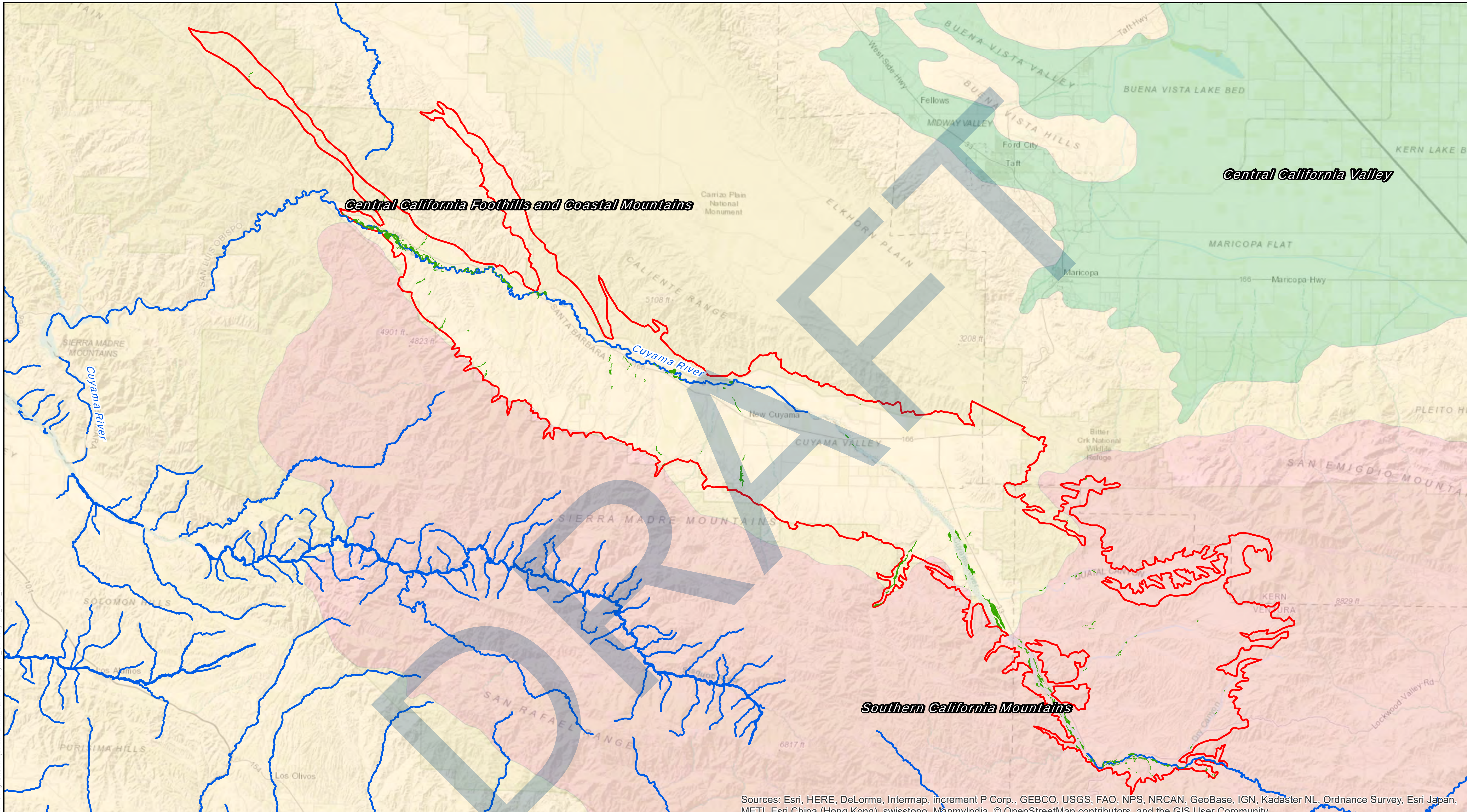
Ritter, Matt. 2018. California Plants: A Guide to Our Iconic Flora.

Rhode, M. M., Matsumoto, J. Howard, S. Liu, L. Riege, and E. J. Remson. 2018. Groundwater Dependent Ecosystems under the Sustainable Groundwater Management Act: Guidance for Preparing Groundwater Sustainability Plans. The Nature Conservancy, San Francisco, California.

United States Department of Agriculture, Natural Resources Conservation Service. 2018. PLANTS Database website. http://plants.usda.gov/java/

Ventura County (CA) Planning Division. 2006. Guide to Native and Invasive Streamside Plants: Restoring Riparian Habitats in Ventura County & along the Santa Clarita River in Los Angeles County.

# ATTACHMENT A: FIGURES




# Figure 1:
# California Ecoregions

Cuyama Valley Groundwater Basin

Kern, San Luis Obispo, Santa Monica, and Ventura Counties, CA

**Legend**

- NCCAG Groundwater Dependent Ecosystem
- USGS NHD Streams
- Cuyama Valley Groundwater Basin
- Central California Foothills and Coastal Mountains
- Central California Valley
- Southern California Mountains

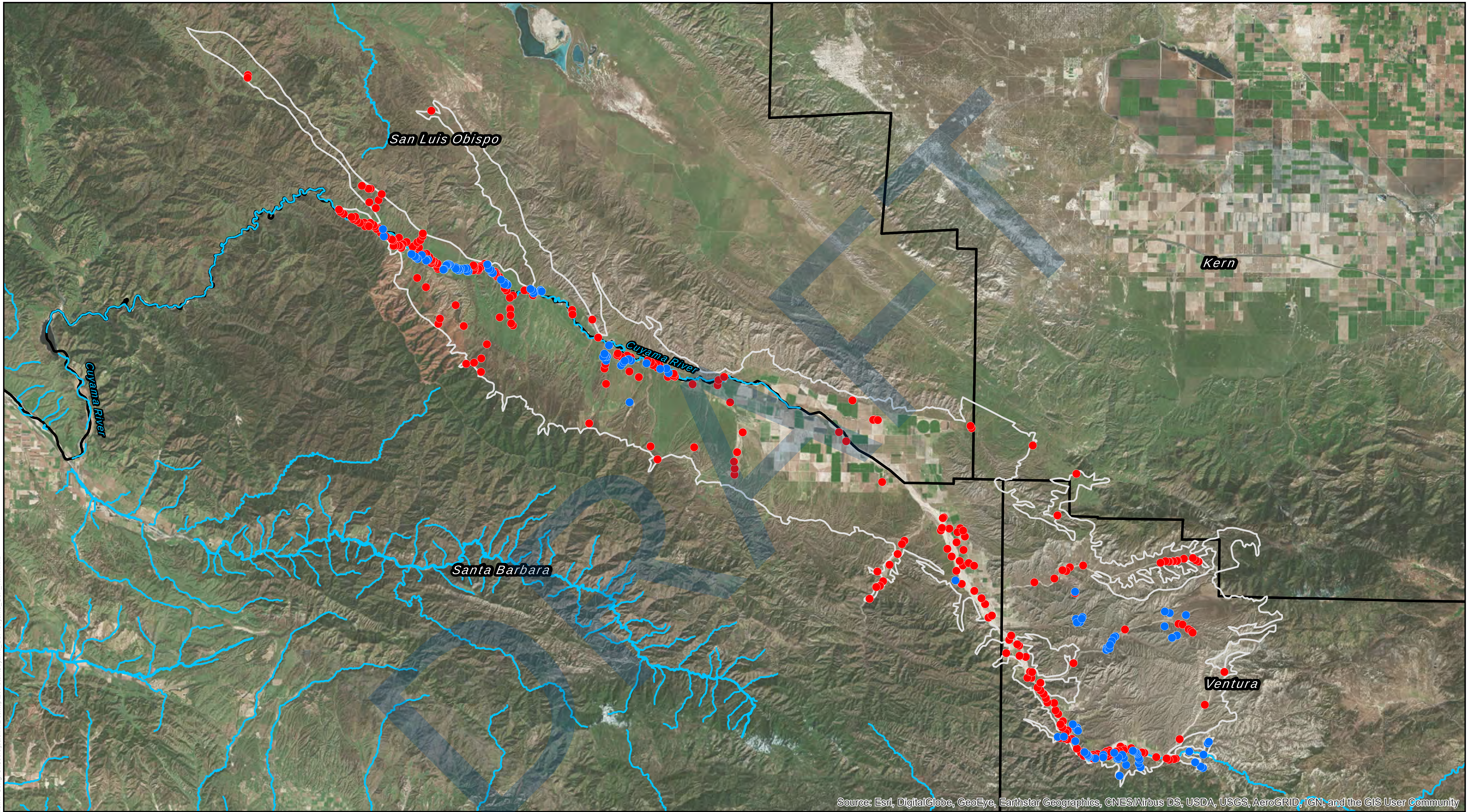
0 1.25 2.5 5 Miles

N

WOODARD & CURRAN

Project #: 0011078.01
Map Created: February 2019

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein is solely at the users' sole risk. **Data Sources: USEPA Level III Ecoregions of California(2016), USGS NHD**




# Figure 2: Basin-Wide Groundwater Dependent Ecosystem (GDE) Desktop Assessment

Cuyama Valley Groundwater Basin

Kern, San Luis Obispo, Santa Monica, and Ventura Counties, CA

**Legend**

- Probable GDE
- Probable Non-GDE
- Streams
- Cuyama Valley Groundwater Basin
- County Boundary

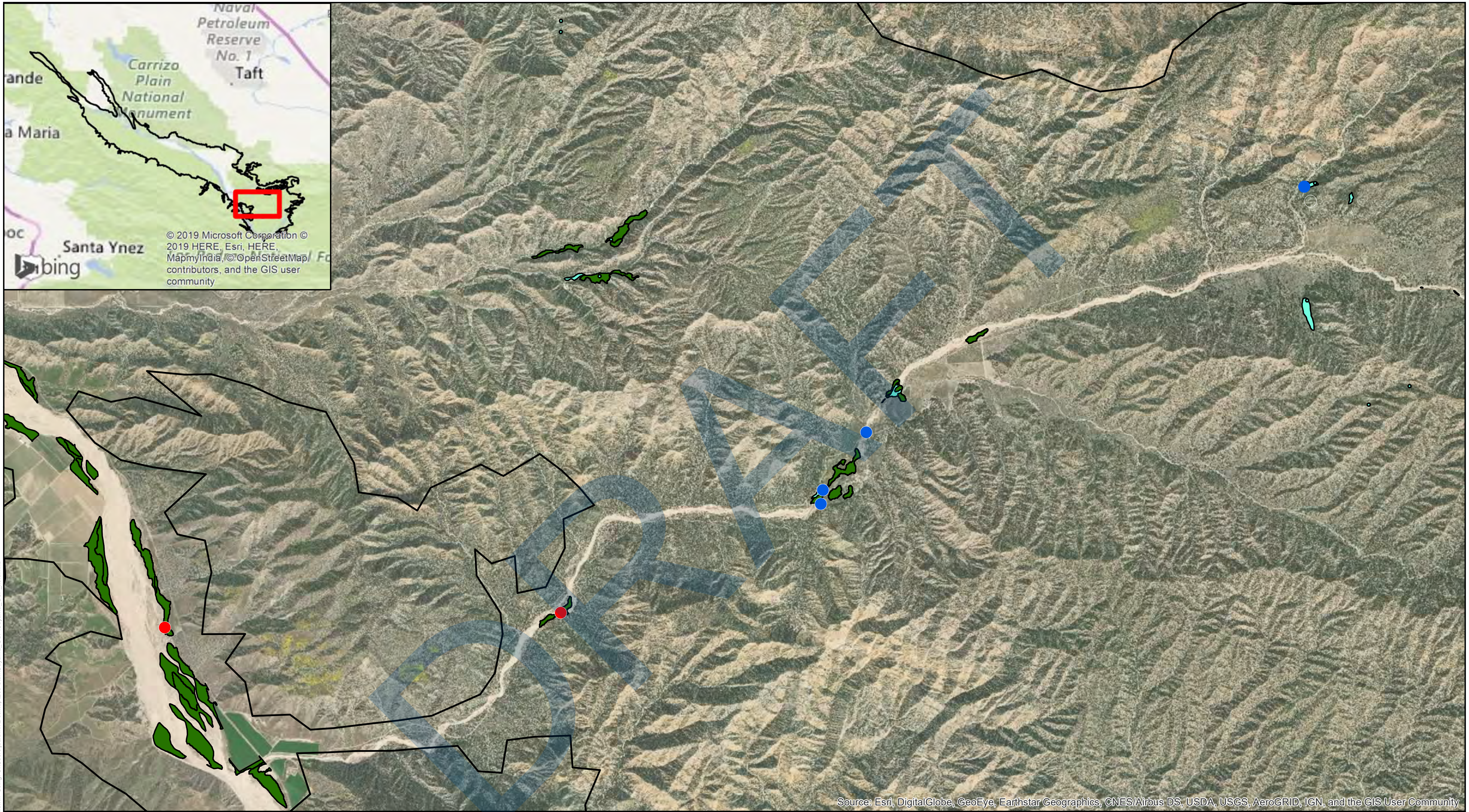
0 1.25 2.5 5 Miles

N

WOODARD & CURRAN

Project #: 0011078.01
Map Created: February 2019

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions. Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: USGS NHD**




# Figure 3: Groundwater Dependent Ecosystem (GDE) Field Validation Sites

Cuyama Valley Groundwater Basin

Kern, San Luis Obispo, Santa Monica, and Ventura Counties, CA

*Legend*

- Confirmed GDE Data Point
- Probable Non-GDE Data Point
- NCCAG GDE Wetland
- NCCAG GDE Vegetation
- Cuyama Valley Groundwater Basin

1 inch = 3,000 feet

0 1,500 3,000 6,000 Feet

N

WOODARD & CURRAN

Project #: 0011078.01
Map Created: February 2019

Third Party GIS Disclaimer: This map is for reference and graphical purposes only and should not be relied upon by third parties for any legal decisions.
Any reliance upon the map or data contained herein shall be at the users' sole risk. **Data Sources: CADWR - Natural Communities Commonly Associated with Groundwater(2018)**

# ATTACHMENT B: PHOTOGRAPHS

**Photo Number: 1 | View Direction: North | Date: October 23, 2018**
**Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "probable non-GDE 1".**

**Photo Number: 2 | View Direction: South | Date: October 23, 2018**
**Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "probable non-GDE 1".**

**Photo Number: 3 | View Direction: North | Date: October 23, 2018**
**Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "probable non-GDE 2".**

**Photo Number: 4 | View Direction: South | Date: October 23, 2018**
**Description: Representative photograph taken of potential incorrectly mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "probable non-GDE 2".**

**Photo Number: 5** | **View Direction: North** | **Date: October 23, 2018**

**Description:** **Representative photograph taken of unmapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 1".**

**Photo Number: 6** | **View Direction: South** | **Date: July 26, 2018**

**Description:** **Representative photograph taken of unmapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 1".**

**Photo Number: 7** | **View Direction: North** | **Date: October 23, 2018**

**Description: Representative photograph taken of field-verified mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 2".**

**Photo Number: 8** | **View Direction: South** | **Date: July 26, 2018**

**Description: Representative photograph taken of field-verified mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 2".**

**Photo Number: 9** | **View Direction: North** | **Date: October 23, 2018**

**Description: Representative photograph taken of unmapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 3".**

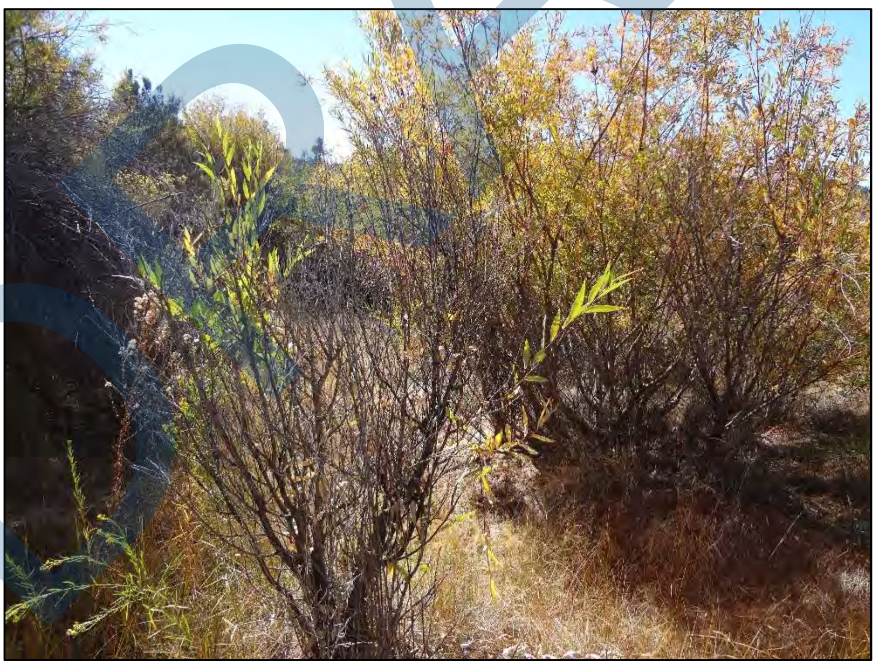


**Photo Number: 10** | **View Direction: South** | **Date: October 23, 2018**

**Description: Representative photograph taken of unmapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 3".**

**Photo Number: 11** | **View Direction: East** | **Date: October 23, 2018**

**Description:** **Representative photograph taken of field-verified mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 4".**

**Photo Number: 12** | **View Direction: South** | **Date: October 23, 2018**

**Description:** **Representative photograph taken of field-verified mapped groundwater dependent ecosystem (CA DWR NCAG dataset 2018). Photo taken a GPS point "GDE 4".**