City of Andrews

Andrews Economic Development Corporation Move Ahead

Hydrology Study

Well Fields, Florey, University Lands & DCP Land

Prepared by:

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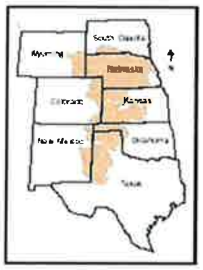
EXECUTIVE SUMMARY

CITY OF ANDREWS HYDROLOGY STUDY

Introduction

City of Andrews, (COA) retained Oller Engineering, Inc., (OEI) to prepare a Hydrology Study of the existing groundwater supply. This study was to identify existing and future sustainable groundwater for the COA for a 50-year period. The study focused on existing well fields, Florey, University Lands and the newest DCP. The following identifies the key elements of the study and the conclusions and recommendations.

Ogallala Groundwater Source



The current well fields are underlain by the Ogallala Aquifer, the largest fresh-water aquifer in the United States. This aquifer is an unconfined aquifer, meaning its upper water surface (water table) is at atmospheric pressure allowing it to rise and fall. This is especially important because unconfined aquifers are more susceptible to drought conditions than confined aquifers. The Ogallala is virtually completely recharged by rainfall and snowmelt. This is exactly the physical conditions that is present in the COA well fields. The wells in each well field average 300-feet deep.

Water Bearing Strata

The groundwater that is produced from the various well fields is held within a layer or strata commonly identified as the water strata or water table. This zone is comprised of sands, silts, clays, and gravel. The more silt and clay present the more difficult to move water through this zone. Clean sand and gravel are ideal mediums for consistent movement of the water to the well hole. However, the geology of the well fields contains silts and clays that retard this movement and cause clogging of the water bearing strata reducing the well yields over time. Over producing wells also cause reduced yields and this is exactly the condition in many of the wells in Florey field today.

Estimation of the Useful Life of Aquifer

The Ogallala has been the main source of water for the High Plains since the early 1940's. Although the northern part, South Dakota & Nebraska experience recharge regularly, the South Plains of Texas does not. Over the years excessive pumping for agricultural use has depleted the aquifer and extended droughts have contributed to its continued decline in available water. The estimated decline in static water levels as measured by Texas Water Development Board (TWDB) and United States Geological Survey (USGS) is -5 to -10 feet in the study area. COA's actual measurements of drawdown and static levels have also indicated a drop in water level over the past 10 years of approximately 2 feet. The current wells are estimated to have adequate water production to approximately 2040. Additional wells and other water resources will be required to meet growth projections from 2040 to 2070. This is further confirmed in the State Water Plan Region F which includes COA.

Current Well Field Yield

The current wellfield yield from all existing wells is approximately 5,699 gpm or 25.18 Ac-Ft/day as measured and recorded by City staff in 2018. Florey well field has experienced declining water levels especially during the summer months and recovery of these wells has not occurred like it has in years past. Florey well field is declining in overall production and due to the age of the existing wells has become a questionable long-term reliable field.

Future Sustainable Water Supply

The COA population is projected to grow from the current of 14,391 to 32,627 in 2070. Projecting future water supply involves numerous variables and unknowns. The Ogallala is a declining resource. The existing wells except for DCP field, are old and have had maintenance issues with well casings and screens reducing the yields and, in many cases, have completely gone dry. All the existing wells are over produced during the summer months of June through September further reducing recovery times for the wells and increasing clogging of the slotted well screens. Using an average pumping time of 10 hours per day per well produces approximately 3,419,400 gpd. June 2020 average day usage was 3,906,0000 gallons. Additional water will be required to meet the projected population growth. COA can maintain supply until approximately 2040 by strategic well field improvements and adding wells to City owned land north of DCP. Additional production will be required to supplement and or replace existing wells in Florey and University by 2040.

Recommendations and Infrastructure Additions

Florey Booster Station is a central booster location between University Lands and DCP. A new 20-inch supply line is currently in design to replace the existing deteriorating 14-inch concrete steel cylinder line from Florey to Mustang Water Treatment Facility. The Florey Booster is the central location for future expansion and transmission of water requires additional storage capacity along with additional booster pumps. The following table are the recommendations to provide sustainability to the COA well field water supply:

Well Field	Recommended Improvement	Year
Florey	500,000 gal GST	2022
	On-site Generator w/Auto Switch	2022
	New 2000 gpm Booster Pump	2022
University	200,000 gal GST	2024
	2000 gpm Booster Pump	2024
	On-Site Generator w/Auto-Switch	
DCP	New Booster Station	2026
	250,000 gal GST	2026
	On-Site Generator w/Auto-Switch	2026
Florey – University Interconnect	Interconnecting Pipeline Approx. 4 miles	2026

Introduction:

The City of Andrews (COA) is a proactive and disciplined City concerning water supply and use. Over the years City management has taken a position of assuring a sustainable water supply for the City that at a minimum assures water for 50 years into the future. This Hydrology Study addresses existing conditions and water use in the City of Andrews and looks 50 years into the future at the current water supply and future needs based on population, growth, existing water use and sustainability of water supply from the 3 developed well fields.

History of Existing Water Supply/Well Fields:

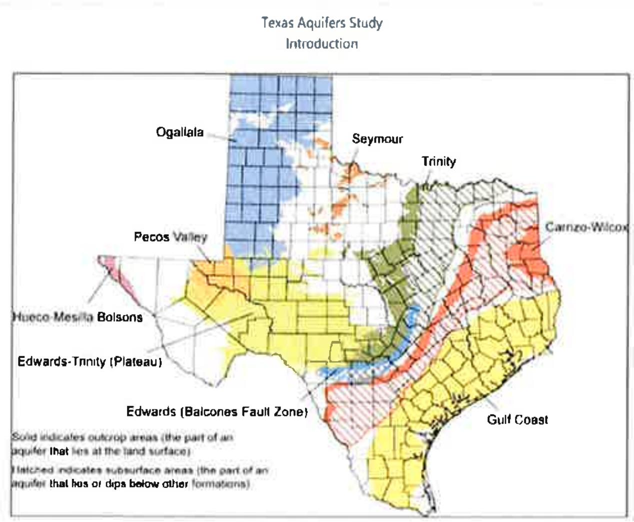
The existing well fields are Florey, University and the newest is DCP. Florey has been the major producer and University field was developed in the mid 1950's. Florey and University fields comprise 19 total operating wells. DCP has 2 existing wells with 2 more currently under construction.

Florey wells have in the past 3 years started showing major maintenance related wear, such as screen plugging and calcium carbonate growth on the internal casing. Pump failure has occurred, and new submersible pumps have been installed. University field has had a few problems with the major issues of wells "sanding in". Both fields are approximately 40 years old, and some wells have completely stopped producing and have been plugged. These wells are shown in Exhibit I in the Appendix of this report.

DCP field was developed in 2017 and supplements the Florey field. The 2 wells in DCP produce approximately 400 gallons per minute (gpm) each and the quality of the water is better than Florey and University wells. DCP water quality contains less Arsenic and Total Dissolved Solids (TDS) than Florey or University water.

Ogallala and Geological Significance of Area:

COA water supply is produced from the Ogallala Aquifer which is an unconfined aquifer that underlies the panhandle of Texas and extends southward to Odessa and Midland. The "Red Beds" as they are commonly referred to, are the Triassic red clays that identify the bottom of the aquifer. The water bearing strata lies on top of these Red Beds and is a mixture of silts, clays, sands, and gravel. Clays found in this water bearing strata tend to reduce the transmissivity of the groundwater. A typical cross-section of actual wells drilled in Florey and at DCP show the structure of the geology typical of the wells in area.



The major significance of the wells found in the COA well fields is the shallow depth of the available groundwater, (surface to water) and the actual structure of the water bearing strata. The water bearing strata is fine sands interlaced with clay lenses and gravel and on average are approximately 50 feet in thickness. This varies across the region and is dictated by the erosional layer of the Red Beds and how they were formed during the glacial retreat.

The average depth from surface to groundwater in the area is approximately 150 – 300 feet. Production of groundwater in the area has varied from 100 gpm to 900 gpm.

Typical Well Bore Hole Geology
Florey and DCP

Depth	Geological Layer/Description	
0 – 12'	Topsoil	
12 – 21'	Caliche	
21 – 45'	Sandstone	Overlying Soil
45' – 78'	Sandy Clay	
78 – 92'	Sandstone Ledges	
92' – 103'	Sandstone/Gravel	
104 – 150'	Gravel/Silt/Water	
150 – 152'	Intermediate Red Clay	
152 – 169'	Gravel/Seashell	
169 – 171'	Blue Clay/Gravel/Water	
171 – 300'	Sand/Gravel/Water	Water Bearing Strata
300 – 310'	Red Bed	

Water Bearing Strata Yield:

The water producing strata is comprised of the sands and gravels that hold the water in the aquifer. The actual composition of these sands and gravels determine the production or "Yield", potential of the aquifer. As previously mentioned, when silts and clays are mixed in the water bearing strata zone the yield of the aquifer is reduced. The larger the gravel size the more water produced or greater yield. Sands can be loose in structure or compacted this also influences the movement of water within the water bearing zone and reduces the yield. The geology varies throughout the area and tends to be reduced in yield potential the farther south along the "fingers" or flattening of the water bearing strata within the study area. Texas Water Development Board (TWDB) and the USGS have monitored the base upper elevations of the saturated zones and have determined that the Ogallala is in decline and has an average loss in overall depth of approximately 10 feet of saturated thickness across the study area.

Influence of Surface Water Interaction and Flows to Other Aquifers:

Depletion of groundwater also occurs from flows into natural bodies of water such as rivers, streams, and lakes. There is minimal surface water interaction within the study area. Some outflow occurs to springs in the area but are not significant. Likewise, flows into other aquifers can occur and the TWDB staff have modeled such action in the Texas Aquifer Study and the estimates of this interaction are shown on Table 5-2 in Exhibit II herein. Note, these flows can go both ways from and to the Ogallala and in Andrews County they are modeled to show movement from the Edwards Trinity Plateau to Ogallala and back and from the Ogallala to the Pecos Valley aquifer. This action attributes some loss of groundwater to recoverable water.

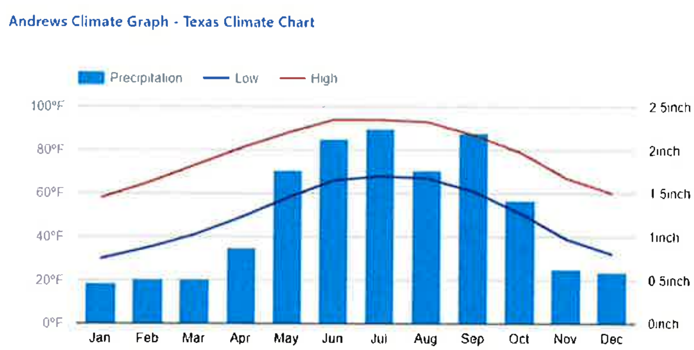
Estimation of Useful Life of Aquifer:

Research has indicated that the Southern Ogallala formation has experienced a decline in saturated thickness of approximately 5 - 10 feet over the past 5 or so years. COA is in the area where a decline in the saturated depth has changed, (Water Level Changes in the Ogallala Aquifer, 1995 to 2015, Texas Aquifer Study, shown in Exhibit II. This has been further substantiated from static drawdown measurements in COA wells in 2018. Florey wells have seen changes in pumping levels and yields. Great Plains has developed a new well field that produces higher volumes of water in Gaines County. Aquifer sustainability will require new farming technology practices, conservation, and watershed management at a minimum to extend the life of the aquifer for all interested parties.

To extend the sustainability of the groundwater supply, COA will need to add more GST's at strategic locations as outlined in this report. Management of the actual watershed will become a key strategic objective for COA. Currently, additional water will be needed by 2030 to meet the projected growth of COA. This will require additional water resources, better well management and maintenance, operating changes to maximize well recovery times and improvement in recharge capabilities by improved land management practices.

Climate and Drought Affects:

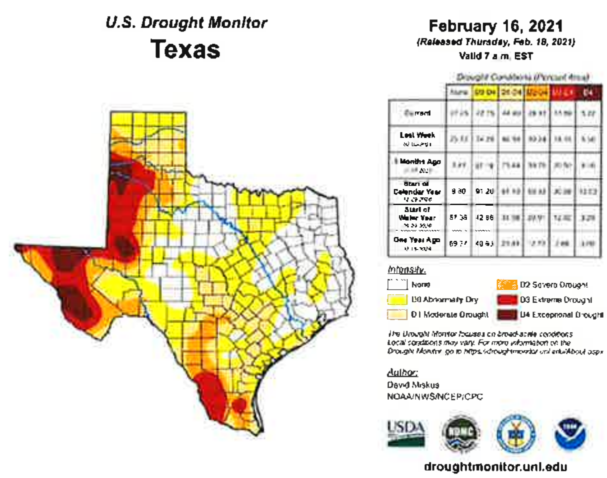
Climate and drought have a direct effect on the amount of groundwater available for capture and use. Over the past 10 years the area has experienced a continual drought even with intermittent periods of significant rainfall, the area has not totally been removed from drought conditions, (see Drought Monitor Map of Texas). The Climate Map also shows the annual cycle for Andrews County indicating the most prolific rainfall occurs during the months with the highest temperature and evaporation rates.



Overall due to the continued drought, agricultural activities have increased the withdrawal of groundwater which in effect has decreased the saturated thickness as measured by the High Plains Underground Water District. Actual measurements in the Andrews fields has not been documented so an average for the area was used to assess the actual saturated thickness in Andrews County. The actual depth from surface to water is approximately 120 feet from well logs in the area and from actual drilling logs at DCP. The saturated thickness averages approximately 50 feet and has declined due to drought conditions over the past 5 years. The amount of decline varies within the region but an average decline of -5 to -10 feet as documented by TWDB, Texas Aquifer Study, is a conservative amount to use for projecting the useful life of the existing well fields.

Aquifer Decline:

Over the past 10-years the area has experienced a continuous drought. Agricultural irrigation has increased in the area because of the extended drought conditions. On average as reported by TWDB the aquifer has declined in overall depth of saturated thickness by 5-10 feet. Andrews well field area comprises approximately 17.5 sections of land. This is approximately 11,200 acres of water rights. Using a conservative average of 7 feet decline over this area equates to a loss of approximately 78,406 ac-ft of possible production. Exhibit II shows water level changes in the aquifer as determined in the Texas Aquifer Study, TWDB.



Recharge of this area has been estimated at approximately 0.01 to 3 inches per year given the soil types and structure in the area. However, during drought conditions there is no recharge occurring.

The typical soils in the area are coarse sands and are underlain by rock layers, caliche and clay deposits. This tends to reduce the infiltration ability reducing and or preventing any substantial recharge. Surface features such as vegetation and woody plants like mesquite capture any available moisture further reducing the likelihood of recharge. Climate changes that occur, specifically extreme changes in normal weather patterns, extended droughts, large rainfall events with high intensity rainfall, extreme winter conditions, do not increase recharge capabilities.

TWDB in their modeling of the aquifer for Groundwater Management Area 2 which covers Andrews County has projected a declining availability from 2020 – 2070 in total ac-ft of groundwater, see Exhibit III.

Existing Well Field Production:

The combination of the 3 well fields, Florey, University Lands and DCP, currently producing groundwater is summarized below:

Wellfield	Existing Production (gpm)	Million Gallons/day (10 hr. period) 600 min.
University	3745	2,247,000
Florey	1250	750,000
DCP (2 existing wells)	704	422,400
TOTAL PRODUCTION		**3,419,400**

Data from City pumping records and OEI archive files.

DCP was added in 2016-17 and replaced two wells that were lost in the Florey Field. Florey has shown increased drawdowns especially during the peak demand months of June through September. Typically, this well field recovers in the winter months. The age of the existing wells is a concern and TV inspections of the well casings have shown tuberculin growth and calcification around the slotted openings reducing the flow from the aquifer into the well. An enhanced well field maintenance program is suggested to preserve the current yield from these wells and to avoid loss of wells during peak demand periods. Raw water is produced from these 3 well fields daily. The raw water is collected in ground storage tanks (GST's) at Florey Booster Station and University Booster station and is pumped into town via 2 pipelines, Florey, and University to Mustang Drive Water Treatment Facility, (WTF). The water is currently transferred by booster pumps as shown below:

Well Field Booster Pump Capacity

Wellfield	Total Well Capacity (gpm)	Booster Pump Capacity (gpm)	Ground Storage Tank Capacity (Gal)	Combined Booster Pump Pumping Capability (gpm) 85% of Combined Rated Capacity	Capacity to Meet Peak w/ Largest Pump Out (gpm)*
Florey	1250	1900/900	200,000	**2380	Incapable
University	3745	3100/3100	200,000	5270	3100
DCP *	704	-	-	-	-

**DCP wells pump to Florey GST and the existing booster pumps at Florey Booster Station deliver the raw water to Mustang Water Treatment Facility. No separate Booster is currently located at DCP although one is proposed for future development. It was originally planned to develop 5 wells at DCP to duplicate Florey's total well production. 2-new wells at DCP are current planned for construction in 2021.*

*** Current booster pumping capacity does not meet requirements to pump the peak demand with the largest pump out of service.*

In June 2020 COA pumped 3.9 MG of water per day. The existing well fields can produce approximately 3.4 MG in a 10-hour period. Typically, wells are sized to run no more than 10 hours a day. Operating wells are also cycled to allow recovery time for each well. Current operating procedure for COA is to operate all the wells in a selected well field, i.e., Florey, and have all the wells in that field coming on simultaneously. This is Not the recommended operating sequence. Adding storage with Ground Storage Tanks, (GST's) provides raw water for peak demands as needed and allows the wells to operate in a cycled sequence thereby not over producing the wells and allowing recovery time for each well after operation.

Additional storage capacity is recommended as shown below:

Location	Existing GST Volume	New GST Volume
University	200,000	250,000
Florey	200,000(remove)	500,000
DCP *	0	250,000
TOTAL WELLFIELD STORAGE		**1,000,000**

* *The additional storage volumes follow the recommendations from the City's Water Master Plan.*

Storage Volume Determination:
5472 connections (2020) x 200 gallons per connection = 1,094,400 gallons (TCEQ minimum storage requirement)

Existing total storage = 3.8M gallons > 1,094,400 gallons as required by TCEQ. (Distribution System)

Existing wellfield storage = Florey & University Fields = 200,000 gal. each = 400,000 gal total.

DCP projected wellfield production = 1400 gpm x 10 hrs x 60 min/hr = 840,000 gpd (4 wells @ 350 gpm each, includes 2 new wells constructed in 2021)

Assuming 2 Additional Wells are added in the Future:
6 wells rated at 350 gpm each = 2100 gpm x 10 hrs x 60 min/hr = 1,260,000 gallons

Florey wellfield production with all wells operating = 1250 gpm or approximately 750,000 gpd using a 10-hour run time with decreasing production in several of the existing wells.

Adding GST's for raw water storage accomplishes 2 key functions:

1. It reduces well production time for moving the water to storage;
2. It provides storage to meet peak demands of the system easily without overproducing the wells.

DCP is a necessary field due to the declining production and unreliability of the Florey field.

**DCP ideally should develop its own GST and booster station. This reduces the over pumping of the groundwater from DCP and provides a backup booster pump system for Florey and University fields.*

Well Field History:

The existing Florey, University and DCP well fields are the source of all drinking water for COA. The combined production from the producing wells in these fields is approximately 5,699 gpm as recorded by City operations staff. DCP has limited available data to develop predictive groundwater production models. Exhibit IV, for DCP land, is a contour map of saturated thickness that was developed from existing well logs in the area and the known elevation of the Red Bed. There is an erosional layer within the Red Beds that is believed to be in the approximate location as shown on this Exhibit. The actual width of these channels is unknown. The production from this area is believed to be high given the data that has been collected over the recent years and from test wells drilled in the area. Yields from this area are in the range of 300-400 gpm depending on the location of the well. The breakdown of this well field yields is shown in the following table:

Existing Well Field Production

Well Field	Well No.	Production Rate, GPM
University	5	250
	6	250
	7	365
	8	300
	9	300
	10	600
	11	900
	12	200
	13	580
Total Production University Field		**3745 gpm**
Florey		
	14	220
	15	434
	16	100
	17	100
	18	396
Total Production Florey Field		**1250 gpm**
DCP		
	#22(DCP-1), L-1	324
	#23 (DCP- 2), L-4	380
Total Production DCP Field		**704 gpm**
TOTAL PRODUCTION IN GPM/AC-FT		**5699 GPM** **25.18 AC-FT/D**

** Data provided by City 2018 records.*

Note:

DCP well field is the primary groundwater development area for COA. Currently, there are two new wells under construction on DCP land. A full development of this field includes additional wells and a GST with booster station.

Drawdown Table of Existing Producing Wells 2018

Well Field	Well No.	Pump Level	Static Level	Drawdown (ft)
University	6	145	125	20
	7	141	130	11
	8	164	149	15
	9	136	125	11
	10	175	154	21
	11	155	137	18
	12	149	143	6
	13	174	151	23
Florey				
	14	No Data		
	15	187	181	6
	16	No Data		
	17	No Data		
	18	205	185	20
	22 (DCP-1) L-1	184	153	31
	23 (DCP-2) L-4	191	158	33

******Drawdown depths from City field measurements 2018*

Drawdown measurements are important from an overall well management perspective. This provides detail of the difference in water level from static to implied stress, or pumping. This gives us a way to determine the actual yield capacity of the well with imposed water level changes. COA has recorded declining static water levels in the Florey wells and this correlates with the loss of production from those wells. The more stress or pumping the more drawdown and the less yield from those respective wells. As part of the well management program semi-annual drawdowns should be taken on all wells to chart the change in water levels.

DCP Lease & Production Royalty:

The City currently has a Lease agreement for the DCP well field that stipulates an annual Lease amount of $50,000 paid in quarterly installments of $12,500. Additionally, a royalty of 20% of the retail price, is added to the water produced from this well field based on the Consumer Price Index to adjust this rate charge annually and is based on the current rate structure of the City's residential water rates.

University Field Royalty:

The existing agreement expires in 2035. The rate charged is $0.60 per 1000 gallons produced. An adjustment is done every 5 years based upon the water rates of area cities.

Calculated Volume of Water Available:

There are several methods available to estimate the volume of water available from the aquifer. The most widely accepted method is the Specific Yield method. This method applies an empirically derived Specific Yield coefficient to the volume of the aquifer in question. It is determined using the following formula:

Area of Study (acres) x Saturated Thickness of Aquifer (feet) x Specific Yield = total acre-feet available

The Specific Yield coefficient used is 14.4 % which is the average for Andrews County as published by the Ogallala Aquifer Program at Texas Tech University. This Specific Yield coefficient falls within the range published by TWDB Report 288 (12%-20%).

"The Ogallala aquifer is an unconfined aquifer; that is, the volume of water in storage changes by the filling and draining of pore or void space in the material that makes up the aquifer." As documented in the report prepared by Saturated Thickness in the Ogallala Aquifer in the Panhandle Water Planning Area— Simulation of 2000 through 2050 Withdrawal Projections. This is significant because the water is free to flow and is impeded by the pore openings or transmissivity of the geology. The finer sands and gravel having smaller pore spaces and thereby less movement or space to store water than the larger granular sediments found in the upper reaches of the High Plains.

Calculated Volume for Each Well Field:

DCP Land:

Area = approximately 2.5 sections = 1635 acres x 50 ft saturated thickness x 14.4% Specific Yield = 772 Ac-Ft Available

Florey:

654 acres x 43 ft saturated thickness x 14.4% specific yield = 4050 Ac-ft Available

** NOTE: Saturated thickness adjusted for declining drawdown levels;*
Florey well field is influenced by Great Plains that maintains an adjoining well field for power plant production in Odessa. There has been a "gentleman's agreement" that the City and Great Plains would not overproduce wells to extend the production for both entities.

Florey is the only well field completely owned by the City and there are no royalties associated with the production of this groundwater. This field has also seen substantial declines in production from all the wells, many of which are now not producing.

University Lands:

14.5 Sections = 9,483 acres

9,483 acres x 50 ft saturated thickness x 14.4% Specific Yield = 68,277 ac-ft available

Population:

COA has maintained a consistent population growth for the past 10 years. Historically, West Texas communities do not have an upward growth curve. Growth is an indication of sound economic development and stability within the City. The table below shows the population growth for the City for the past 10 years:

10-Year Population Record

Year	Population
2010	11,088
2011	11,526
2012	11,683
2013	12,317
2014	13,198
2015	13,765
2016	13,548
2017	13,400
2018	13,762
2019	14,109
2020	14,391

**Freese & Nichols Master Plan COA 2020*

Projected Population,
Service Connections & GPD Water Supply:

Year	Population	Service Connections	Projected Supply (gal)
2020	14,391	5,472	3,828,006
2030	17,543	6,670	4,666,438
2040	21,385	8,131	5,688,410
2050	24,171	9,185	6,429,486
2060	28,082	10,671	7,469,812
2070	32,627	12,398	8,678,782

** Freese & Nichols COA Master Plan 2020*

Current Water Use:

Water use records from utility billing were researched to determine an average and peak water use volume. These records provide the actual amount of water that has been sold to users within the distribution system.

The average daily use for the past 5 years is summarized below:

City of Andrews — **2015 - 2020 Avarage Daily Use of Billed Water**

Water Audit Report (City Data from Water Audit Reports)

	20-Jan	20-Feb	20-Mar	20-Apr	20-May	20-Jun	20-Jul	20-Aug	20-Sep	20-Oct	20-Nov	20-Dec
Total Water Pumped/Billed w/Corrections (1000 of gallons)	41250	36710	36820	52509	100783	117187	119188	106334	98641	76083	54319	42664
Number of Days in Month	31	28	31	30	31	30	31	31	30	31	30	31
Average Daily Water Use (1000 of gallons)	1330.645	1311.071	1187.742	1750.3	3251.065	3906.233	3844.774	3430.129	3288.033	2454.29	1810.633	1376.258
	19-Jan	19-Feb	19-Mar	19-Apr	19-May	19-Jun	19-Jul	19-Aug	19-Sep	9-Oct	19-Nov	19-Dec
Total Wtr (1000 of gallons)	39535	41797	40930	41014	59365	86831	101365	102885	88981	63256	50183	38773
Avg. Daily Water Use (1000 of gallons)	1275.323	1492.75	1320.323	1367.133	1915	2894.367	3269.839	3318.871	2966.033	2040.516	1672.767	1250.742
	18-Jan	18-Feb	18-Mar	18-Apr	18-May	18-Jun	18-Jul	18-Aug	18-Sep	18-Oct	18-Nov	18-Dec
Total Wtr (1000 of gallons)	39706	40102	43398	68473	93435	90928	88591	99861	74264	59613	46223	39611
Avg. Daily Water Use (1000 of gallons)	1280.839	1432.214	1399.935	2282.433	3014.032	3030.933	2857.774	3221.323	2475.467	1923	1540.767	1277.774
	17-Jan	17-Feb	17-Mar	17-Apr	17-May	17-Jun	17-Jul	17-Aug	17-Sep	17-Oct	17-Nov	17-Dec
Total Wtr (1000 of gallons)	35479	36801	39002	60101	71643	85384	97770	86964	77475	57772	56505	40490
Avg. Daily Water Use (1000 of gallons)	1144.484	1314.321	1258.129	2003.367	2311.065	2846.133	3153.871	2805.29	2582.5	1863.613	1883.5	1306.129
	16-Jan	16-Feb	16-Mar	16-Apr	16-May	16-Jun	16-Jul	16-Aug	16-Sep	16-Oct	16-Nov	16-Dec
Total Wtr (1000 of gallons)	34228	34531	43560	55508	70487	74183	88362	105033	63573	53311	53076	33982
Avg. Daily Water Use (1000 of gallons)	1104.129	1233.25	1405.161	1850.267	2273.774	2472.767	2850.387	3388.161	2119.1	1719.71	1769.2	1096.194
	15-Jan	15-Feb	15-Mar	15-Apr	15-May	15-Jun	15-Jul	15-Aug	15-Sep	15-Oct	16-Nov	15-Dec
Total Wtr (1000 of gallons)	38146	38343	34963	59459	70943	66590	77996	98274	88859	58647	53896	41771
Avg. Daily Water Use (1000 of gallons)	1230.516	1369.393	1127.839	1981.967	2288.484	2219.667	2516	3170.129	2961.967	1891.839	1796.533	1347.452

2020 Water Use Records of Billed Water

** The highlighted values are peak water use per month.*

The table above shows that the average usage varies by the time of year and by population. Texas Commission on Environmental Quality (TCEQ) on their Water Watch Website lists COA with an average daily usage of 4.52 million gallons per day or approximately 314 gallons per capita per day (GPCD). TWDB and the Region F Water Plan have used 266 gpcd for planning purposes.

Historical Water Demands & Peaking Factor

Year	Overall Population	Avg. Daily Demand (MGD)	Avg. Per Capita Demand (gpcd)	Max. Day Demand (MGD)	Max Day/Avg Day Peaking Factor
2014	13,198	2.20	166	-	-
2015	13,765	2.13	155	-	-
2016	13,548	2.22	164	4.33	1.95
2017	13,400	2.36	176	4.21	1.78
2018	13,762	2.66	193	4.16	1.56
2019	14,109	2.51	178	4.07	1.62
	Average	**2.31**	**171**	**4.23**	**1.77**

City of Andrews Mater Plan by Freese & Nichols 2020
**TCEQ Peaking Factor is 2.4 Average Daily Use. City's factor is 1.77 approx. ½ of the design factor used by TCEQ*
Gpcd average = 171, which is lower than the State Water Plan Region F value of 266.

The gpcd values vary based on conservative planning objectives and actual real billed/metered water values. The region and climate influence this gpcd number. When compared to other similar sized cities in the state and in different regions this gpcd is average. TWDB rates usage by utility size and number of meter connections. COA is a Medium utility with 3,300-16,000 connections. This equates to approximately 232 gpcd. Water rates and conservation measures also contribute to water usage on a per capita basis. It is recommended that an average gpcd of 266 be used by the City in determining required raw water supply. This is the same gpcd value that is used in the State Region F Water Plan for the City.

Key Infrastructure to Extend Wellfield Life

In previous studies of the well fields and the development of DCP Well Field, several key infrastructure improvements were noted. Specifically, additional Ground Storage Tanks (GST's) have been recommended as noted in this report. Both Florey and University fields have infrastructure investment, wells, booster pumps and GST's. Florey was the largest ground storage tank location for many years until the in-ground storage deteriorated beyond reasonable repair costs and was taken out of service. Currently, as stated previously, the available storage at Florey is 200,000 gallons. Additionally, this booster station does not have enough pumping capacity to pump the peak flow and does not meet current TCEQ pumping requirements. A new 20-inch transmission line is being designed to replace the existing 14-inch concrete steel cylinder line that has been leaking for years. A completely new discharge header piping is also being designed to accommodate higher flows from the existing booster station. To both meet the peak demand pumping capability and to provide extended operation to supply the City, additional GST storage is recommended. The recommended size for this storage is 500,000 gallons of GST capacity.

There are valid reasons to increase the storage at all the current well fields. Currently, the well pumps are being used to transfer water a long distance, some over 1 mile. To transfer this pumped water, the well pump continues running, continues to pull the available groundwater around the well down toward the pump and in so doing increases the velocities in the water bearing strata and increases the zone of influence. This action damages the aquifers' ability to produce the desired rates from the wells and further depletes the available water. Rather, wells should be used to lift the water from the aquifer and delivery it to a GST, thereby not over producing the well and allowing adequate time for the wells to recover completely before they are needed to produce again. This creates a more sustainable well and increases its longevity. Well run times are also a key factor when optimizing well operations. Staging of the start and stop of the wells allows wells to be off for a period of time and recover from previous pumping cycles while others produce. Cycling this operation correctly is easily done using the existing SCADA (Supervisory Control and Data Acquisition) system. This can extend the useful life and production of all the wells.

DCP Field is similar in character as Florey and the groundwater being produced from DCP is currently pumped more than 1 mile by well pumps to the Florey GST. This field includes plans for a GST and booster station to transfer the groundwater produced to Florey. DCP supply line was designed with 2 stub-outs on either side of Highway 385 for an eventual 24-inch supply line placed in the Right-of-Way of Highway 385 into Mustang Station GST's. This gives the City several options to bring raw water into town as well field development expands.

Currently, Florey and University have 2 separate transmission lines from the respective well fields into Mustang Drive Water Treatment Plant. Having 2 separate transmission lines provides flexibility in meeting high demand periods and provides the City with redundancy. Interconnecting Florey and University well fields provide flexibility in transferring water between the 2 major booster stations in the system. This also provides the City a means of delivering water should one station be out of service.

University Field currently has a 200,000-gallon GST and 2-booster pumps. This station should increase the storage capacity up to a minimum of 400,000 gallons and add an additional booster pump. All the booster stations should add an on-site standby generator with auto-switch to completely power the stations and key wells in the event of a catastrophic event or major power outages.

Recommended Improvements

Florey Well Field:

- New GST 500,000-gallon
- New Booster Pumps
- Backup Generator with Auto Switch
- New Discharge Header (Construction in 2021)

University Field:

- Add 200,000-gallon GST
- New Booster Pump
- Backup Generator with Auto Switch

DCP Field:

- New 250,000-gallon GST initial build
- New Booster Station & Pumps

- Chlorination Facility
- Backup Generator with Auto Switch

Future Groundwater

The City should always be looking for new water resources for acquisition to ensure continued supply and growth. To accomplish this, additional wells will be required in DCP and University. Florey is compromised by Great Plains and its proximity to Florey and the historic over production of this field has severally depleted the well production from Florey. In the past several years Great Plains has acquired additional groundwater rights in Gaines County to supplement their production from Florey well field.

DCP will become a key well field for future supply for the City of Andrews. Likewise, University Field will also become important in maintaining a reliable supply for increased demands. Additional wells will be required in future years to supplement existing wells that are nearing their useful life in University Field.

One strategy moving forward would be to develop additional wells on City owned land north of DCP and connect this production into a local GST and booster station at DCP. (see Exhibit I, area in Yellow North of DCP Land) A second strategic approach would be to develop DCP fully. It would be in the City's best interest to own this tract of land especially since the City owns a ½ section north of DCP. Having ownership of the land eliminates royalties and solves issues related to sanitary control easements as required by TCEQ. Exhibit IV is provided to show the detail and stratigraphy of DCP and the 2 existing wells.

Gaines County has more saturated thickness and in many cases higher yielding wells. Gaines County also has an Underground Water District (Llano Estacado) that controls the development and production of groundwater within the defined limits of the district. This is an option but has infrastructure costs and additional compliance requirements to develop and produce groundwater.

A longer-term sustainable project would be Aquifer Storage and Recovery (ASR) using treated wastewater. Wastewater Reuse is targeted as a necessary resource in the State Water Plan Region F. All State Water Plans have identified wastewater as the "New Water" that is recommended to be incorporated into future water supplies especially in West Texas. The ASR option would require enhanced wastewater treatment and then the water would be injected through injection wells into the ground and pumped out as required for use. (El Paso has been using wastewater reuse for 30 plus years successfully.) The geology provides additional treatment beyond the physical treatment prior to injection. These projects are approved by the Executive Director of TCEQ on a case-by-case basis.

City of El Paso has used ASR for the past 30 years to supplement their groundwater supply. The City is currently proposing a Direct Potable Reuse. Advanced treatment will treat wastewater for drinking water. Pilot plant studies are currently underway for this sustainable and drought-proof alternative.

Future Capability of the Existing Well Fields to Provide a Sustainable Supply for the Next 50 Years:

Florey Well Field:

Well No.	Current Yield	Casing Age Factor (% clogged)	Aquifer Yield Depletion %	Estimated Future Yield 50 Yrs. (gpm)
14	220	40	15	88
15	434	40	15	174
16	100	40	15	40
17	100	40	15	40
18	396	40	15	158
Total Projected Yield				**500**

**Estimated Future Yield is calculated using Casing age factor of the existing well and the transmissivity for an unconfined aquifer. Transmissivity is a function of aquifer thickness; in the Andrews area this averages approximately 50 ft thickness.*

University Field

Well No.	Current Yield (gpm)	Casing Age Factor (% clogged)	Aquifer Yield Depletion %	Estimated Future Yield 50 Yrs. (gpm)
6	250	40	10	90
7	365	40	10	131
8	300	40	10	108
9	300	40	10	108
10	600	40	10	216
11	900	40	10	324
12	200	40	10	72
13	580	40	10	209
Total Projected Yield				**1258**

DCP Field

Well No.	Current Yield (gpm)	Casing Age Factor (% clogged)	Aquifer Yield Depletion %	Estimated Future Yield 50 Yrs. (gpm)
22	324	0	10	275*
23	380	0	10	323*
24(New)	350	0	10	298
25(New)	350	0	10	298
Total Projected Yield				**1194**

**These wells have stainless screens installed that provide a level of protection from calcification and tuberculin growth. Well #'s 24 & 25 are scheduled to be added to DCP Field summer of 2021.*

In estimating the future well yields, age of the wells are a major controlling factor. This approach estimates the overall condition of the casing supporting the well. Additionally, slots or holes that are cut into the casing in the saturated zone to allow groundwater to enter the borehole/casing, become clogged with age and poor maintenance. Over time these holes or slots calcify and clog reducing the rate of flow into the casing and thereby reducing the overall yield from the well. A reduced yield factor based on age is used to estimate the well yields.

Total Estimated Population in 2070 = 32,627

Projected gpcd State Water Plan Region F = 266 gpcd

Projected Water Demand = 32,627 persons * 266 gpcd = 8,678,782 gallons per day or 6,026 gpm, 26.64 Ac-Ft

Current Well Field Yield from all Fields = **5699 gpm** (COA recorded value)

Required additional supply = 6,026 – 5699 = 327 gpm (This will be covered by adding the 2 new wells at DCP in 2021)

Projected decline of existing wells from age of casing and maintenance related issues and the natural aquifer decline due to use from agricultural practices results in an overall estimated well yield of approximately 2952 gpm from all existing well fields.

Projected deficiency in supply = 6,026 gpm – 2952 gpm = (3074 gpm Total Projected Production from Existing Well Decline)

Projected Water Supply Requirements Next 30 Years

Year	Population	Water Req'd GPD
2020	14,391	3,828,006
2030	17,543	4,666,438
2040	21,385	5,688,410
2050	24,171	6,429,486

Conclusions & Recommendations

The existing well fields are currently capable of producing approximately 5699 gpm from all the operating wells. Florey well field is the only well field totally owned by the City and its production is not subject to any production royalty's. This has been the primary supply source to the City for that reason. Florey is also the well field with the most decline in operating wells and in available groundwater. Numerous wells are no longer producing and have been plugged and abandoned.

Based on current well production and the addition of the DCP field, the City can provide the needed supply out to approximately 2030 - 2035 provided no wells are lost from those producing currently. Climate and agricultural practices will also play a significant factor in the sustainability of the aquifer in years to come. Drought will increase irrigation in the area which will have a direct effect on the groundwater available for water supply.

Additional wells and water resources should be pursued by the City. Direct ownership of DCP well field is highly recommended to provide control by the City over the field like Florey has been. Owning the field allows the City to improve the recharge ability by removing water intensive plants such as Mesquite and Cedar. Sanitary Control Easements are not required on land owned by the City.

Next development after DCP wells 24 and 25, should be on City owned land north of DCP. A booster station with ground GST is recommended for DCP as outlined previously.

Florey is the central booster station and requires new GST and new booster pumps.

University booster station needs additional storage of a minimum of 200,000 gallons.

All booster stations are required to have backup power and due to their location (10 plus miles out of City) it is recommended that these generators be on-site with auto-switches to automatically operate when there is a power outage.

Connecting all well fields between the booster stations has been proposed for numerous years. This is a beneficial improvement allowing water to be transferred as needed between booster pumping stations for backup delivery into the City. An eventual line between Florey and University is recommended, (See Exhibit V for proposed connecting pipeline). DCP wellfield is currently connected to Florey, (See Exhibit V).

10 – Year Capital Improvement Plan

The 10-Year Capital Improvement Plan for Water Supply is detailed on the following page.

10-year Plan for Major Infrastructure Projects

Wellfield Development *(OEI Wellfield Development Plan)*

CURRENT 10-YEAR PLAN

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Drill 2 new wells on DCP Block 19 (carryover)	420,000									
	Construct 24" pipeline from Florey to City Limits	3,200,000									
1	Construct 24" pipeline from City Limits to WTP		1,500,000								
2	Add 400K gallon ground storage tank at Florey			520,000							
3	Add 3 booster pumps at Florey			600,000							
4	Add 1 booster pump at University				200,000						
5	Add 400K gal storage tank & booster pump bldg at DCP						1,065,865				
6	Add 3 booster pumps at DCP						299,675				
7	Drill 2 new wells north of DCP & connect in							965,440			
	FY2021 10 Year Plan	3,620,000	1,500,000	1,120,000	200,000	-	1,365,540	965,440	-	-	-

1 Continue 24" pipeline from Florey transmission line from City Limits to Water Treatment Plant (addresses 8" and 14" lines currently running underneath houses in NE Andrews)
2 Adding a 400K gallon ground storage tank at Florey reduces the pumping time for all the wells collecting water at Florey. The existing Florey GST is nearing life expectancy.
3 Adding 3 booster pumps at Florey provides additional pumping capacity needed at Florey, especially with a new supply line. The existing high service booster pump at Florey is not operational.
4 Adding a booster pump at University increases University's pumping capacity.
5-7 Increase DCP storage and volume capacity by adding a storage tank and 2 new wells.

REVISED 10-YEAR PLAN

		2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	
	Drill 2 new wells on DCP Block 19 (carryover)	470,000										
	Phase 1: Construct 20" pipeline from Florey to ???	2,950,000										
	New booster station discharge header line	250,000										
	Phase 2a: Construct 20" pipeline from ??? to Ave K & Airport		3,050,000									
	Phase 2b: Construct 30-36"pipeline from Ave K to WTP		1,300,000									<- pursue 20 year Private Issue Certificate of Obligation (2022 items)
2	Add 500K gallon ground storage tank at Florey		650,000									
3	Add 3 booster pumps at Florey			600,000								pay out of AEDC Budget if possible
5	Add 400K gal storage tank & booster pump bldg at DCP				1,065,865							
6	Add 3 booster pumps at DCP				299,675							pursue 20 year Certificate of Private Issue Obligation (items 5-7)
7	Drill 2 new wells north of DCP & connect in					965,440						
	Tie Florey and University wellfields together (~ 3 miles)										2,755,566	
	FY2021 10 Year Plan	3,670,000	5,000,000	600,000	1,365,540	965,440	-	-	-	-	2,755,566	
	Anticipated debt payment at 3% interest rate		336,079		156,678							
	Anticipated debt payment at 4% interest rate		95,656		171,518							

Exhibit I

COA Water Rights Land

COA Existing Water Well Network

S:\Engineering\Andrews\1000.21.01 – Andrews DCP Well Addition\09.00_CAD\09.02_Drawings\09.02.02_Sheet Files\GROUNDWATER RIGHTS MAP.dwg

City of Andrews Water Well Network Map

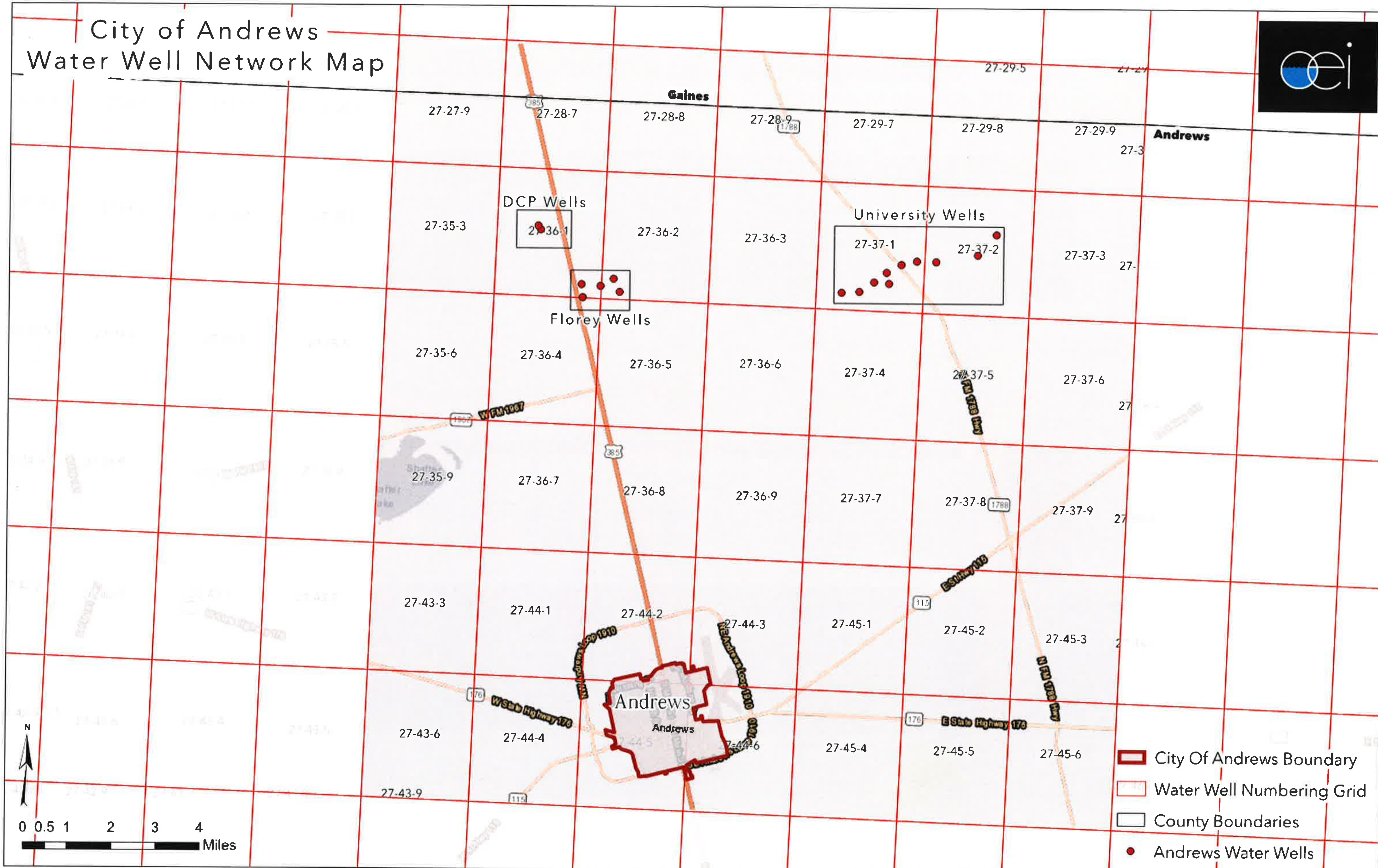


Exhibit II

Inter-Aquifer Transfers

Aquifer Water Level Changes 1995-2015

Table 5-2. Detailed modeled estimates of inter-aquifer flows between major and minor aquifers in Texas counties.

County	From aquifer	To aquifer	Average annual net flow (acre feet per year)	Groundwater availability model (GAM)	Comments
Andrews	Dockum	Ogallala	16	High Plains Aquifer System GAM v1.01	
Andrews	Dockum	Edwards-Trinity (Plateau)	11	High Plains Aquifer System GAM v1.01	
Andrews	Edwards-Trinity (Plateau)	Ogallala	1,085	Edwards Trinity (Plateau) and Pecos Valley GAM v. 1.01	Different models show flow reversal
Andrews	Ogallala	Pecos Valley	182	High Plains Aquifer System GAM v1.01	
Andrews	Ogallala	Edwards-Trinity (Plateau)	212	High Plains Aquifer System GAM v1.01	Different models show flow reversal
Andrews	Pecos Valley	Ogallala	0	Edwards Trinity (Plateau) and Pecos Valley GAM v. 1.01	
Armstrong	Ogallala	Dockum	2,174	High Plains Aquifer System GAM v1.01	
Baily	Ogallala	Edwards-Trinity (High Plains)	396	High Plains Aquifer System GAM v1.01	
Bandera	Edwards-Trinity (Plateau)	Trinity	12,911	Edwards Trinity (Plateau) and Pecos Valley GAM v. 1.01	
Bandera	Trinity	Edwards (Balcones Fault Zone)	2,621	Edwards Trinity (Plateau) and Pecos Valley GAM v. 1.01	
Bandera	Trinity	Edwards-Trinity (Plateau)	1,430	Draft Llano Uplift GAM	
Bell	Edwards (Balcones Fault Zone)	Trinity	352	Northern Trinity Woodbine GAM v2.01	

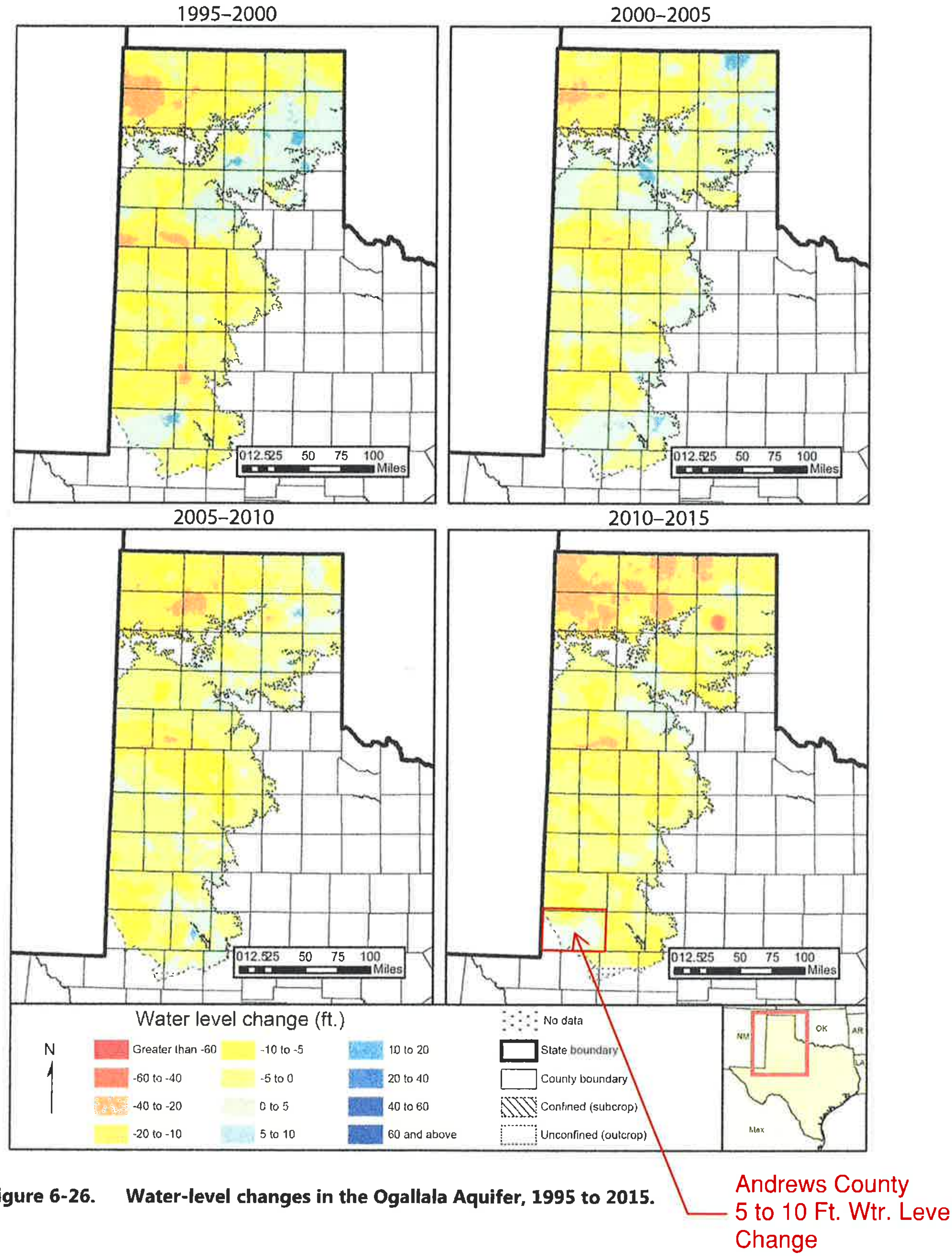


Figure 6-26. Water-level changes in the Ogallala Aquifer, 1995 to 2015.

Exhibit III

Groundwater Availability

Texas Aquifer Study Model 2020 - 2070

Groundwater Management Area 2 – Desired Future Conditions

Aquifer	County	Regional Water Planning Area	River Basin	Modeled Available Groundwater						TWDB Report
				2020	2030	2040	2050	2060	2070	
Ogallala and Edwards-Trinity (High Plains)	Andrews	F	Colorado	24,937	21,375	19,795	18,774	18,040	17,474	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Andrews	F	Rio Grande	0	0	0	0	0	0	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Bailey	O	Brazos	97,679	67,307	51,199	42,704	37,858	34,815	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Borden	F	Brazos	842	699	635	597	572	555	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Borden	F	Colorado	5,080	3,940	3,433	3,140	2,849	2,657	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Briscoe	O	Red	29,022	17,637	11,907	9,053	7,445	6,451	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Castro	O	Red	107,563	72,432	43,208	25,577	17,236	12,970	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Castro	O	Brazos	159,730	112,038	61,892	32,048	19,950	14,535	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Cochran	O	Brazos	26,117	21,555	18,919	17,399	16,483	15,900	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Cochran	O	Colorado	75,645	57,597	45,584	38,008	31,376	26,775	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Crosby	O	Red	3,693	3,503	3,068	2,373	1,888	1,567	GR16-028 MAG
Ogallala and Edwards-Trinity (High Plains)	Crosby	O	Brazos	162,630	108,077	68,110	46,363	35,547	29,723	GR16-028 MAG

Exhibit IV

DCP Land Red Bed Contours

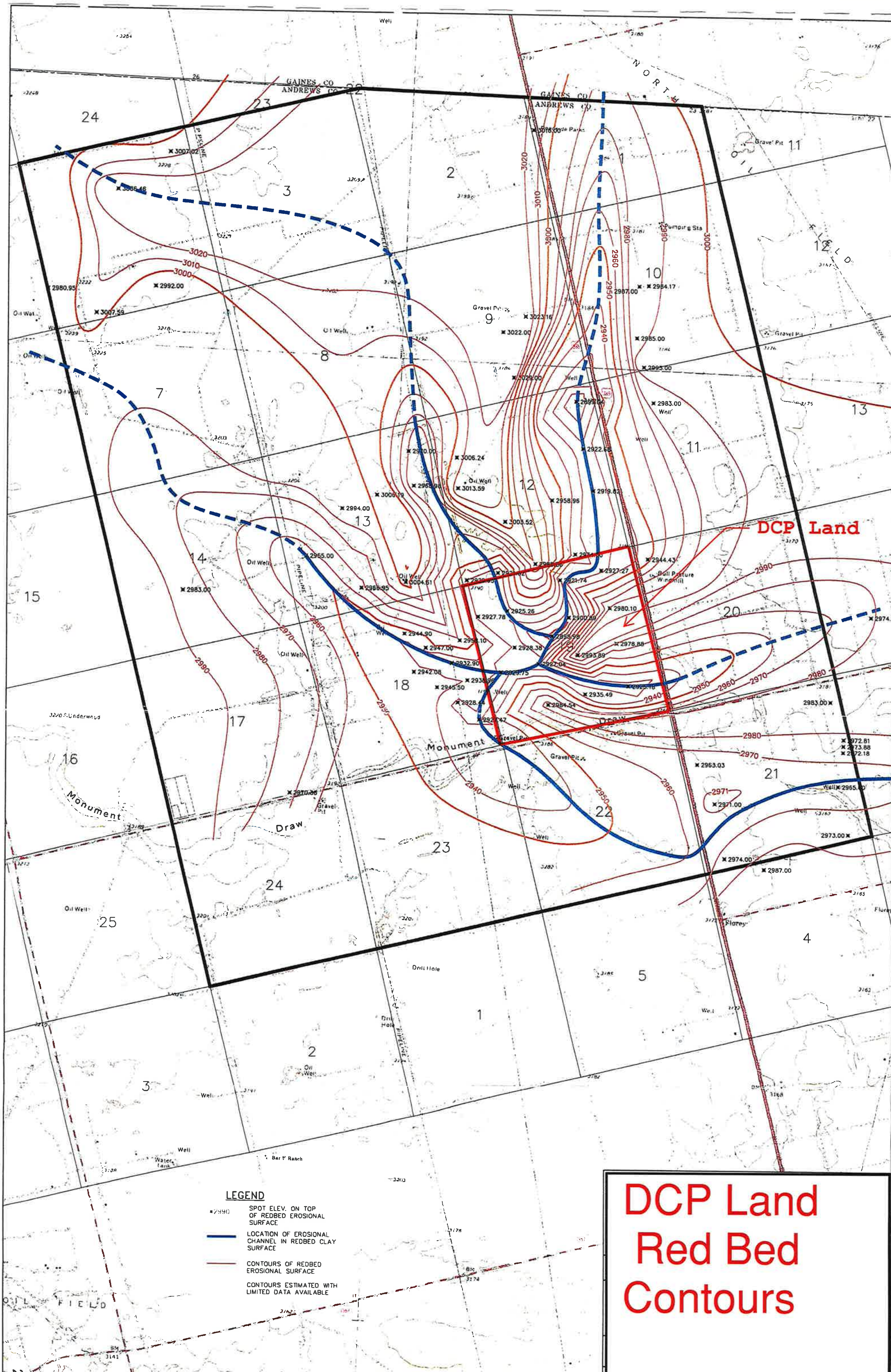

DCP Land
Red Bed
Contours
DCP Land
LEGEND
SPOT ELEV. ON TOP OF REDBED EROSIONAL SURFACE
LOCATION OF EROSIONAL CHANNEL IN REDBED CLAY SURFACE
CONTOURS OF REDBED EROSIONAL SURFACE
CONTOURS ESTIMATED WITH LIMITED DATA AVAILABLE
Monument Draw

Exhibit V

DCP Land Site Plans & Stratigraphy

LEGEND:

FLOREY FIELD

DCP FIELD

MBCO Engineering, LLC.
MOSS | BLETSCH | CRENEK | OLLER
1212 13th St, Ste. 202 | Lubbock, Texas 79401
TBPE Reg. No. F16850 | TBPLS Reg. No. 10194112
PHONE: 806-993-6226 | www.mbcoengineering.com

ANDREWS WELL FIELD
EXPANISION-PHASE 1

DCP & FLOREY WELL FIELDS

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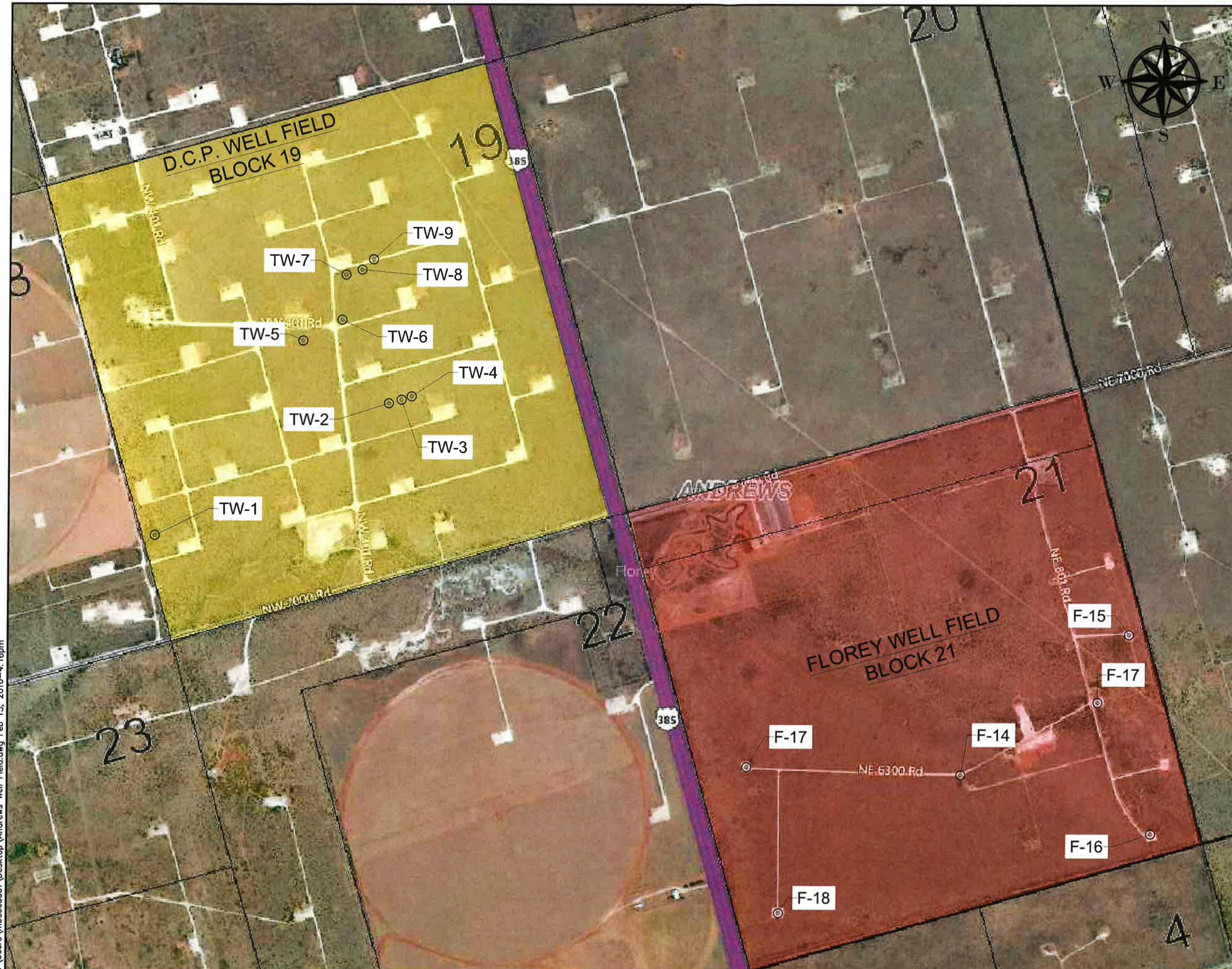
Checked By: R.M.O.		OF	06



LEGEND:

FLOREY FIELD

DCP FIELD

TW-# TEST WELL LOCATION

MBCO Engineering, LLC.

MOSS | BLETSCH | CRENEK | OLLER

1212 13th St, Ste. 202 | Lubbock, Texas 79401
TBPE Reg. No. F16850 | TBPLS Reg. No. 10194112
PHONE: 806-993-6226 | www.mbcoengineering.com

ANDREWS WELL FIELD
EXPANISION-PHASE 1

DCP WELL FIELD & FLOREY FIELD
WELL LOCATIONS

Date: 2/15/16	Job No.: 0021.15.6020	SHEET 03 OF 06
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Checked By: R.M.O		

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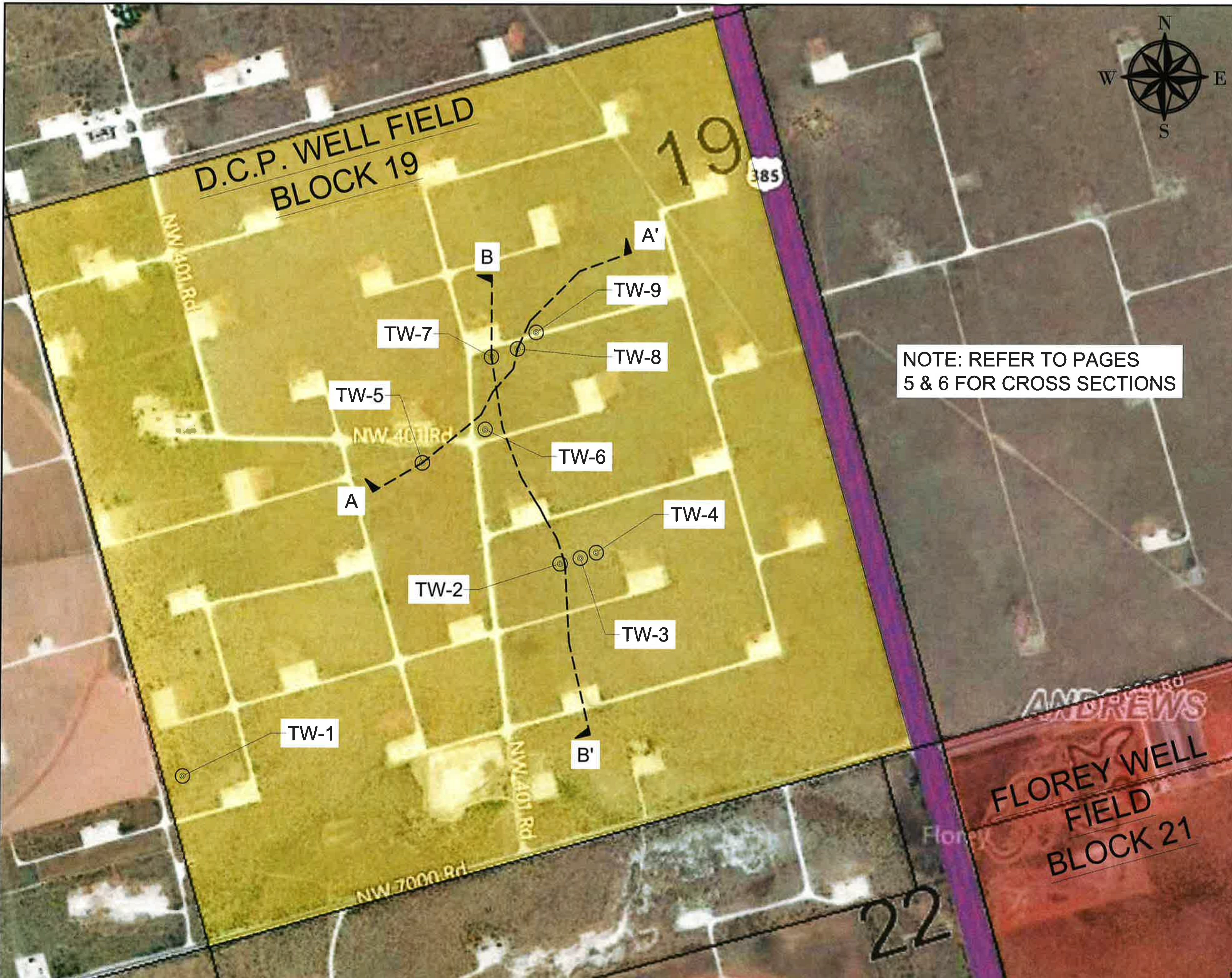

LEGEND:

FLOREY FIELD

DCP FIELD

TW-# TEST WELL LOCATION

CROSS SECTION LOCATION

MBCO Engineering, LLC.
MOSS | BLETSCH | CRENEK | OLLER
1212 13th St, Ste. 202 | Lubbock, Texas 79401
TBPE Reg. No. F16850 | TBPLS Reg. No. 10194112
PHONE: 806-993-6226 | www.mbcoengineering.com

ANDREWS WELL FIELD
EXPANISION-PHASE 1

DCP WELL FIELD WELL
CROSS SECTION LOCATIONS

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Checked By: R.M.O.			

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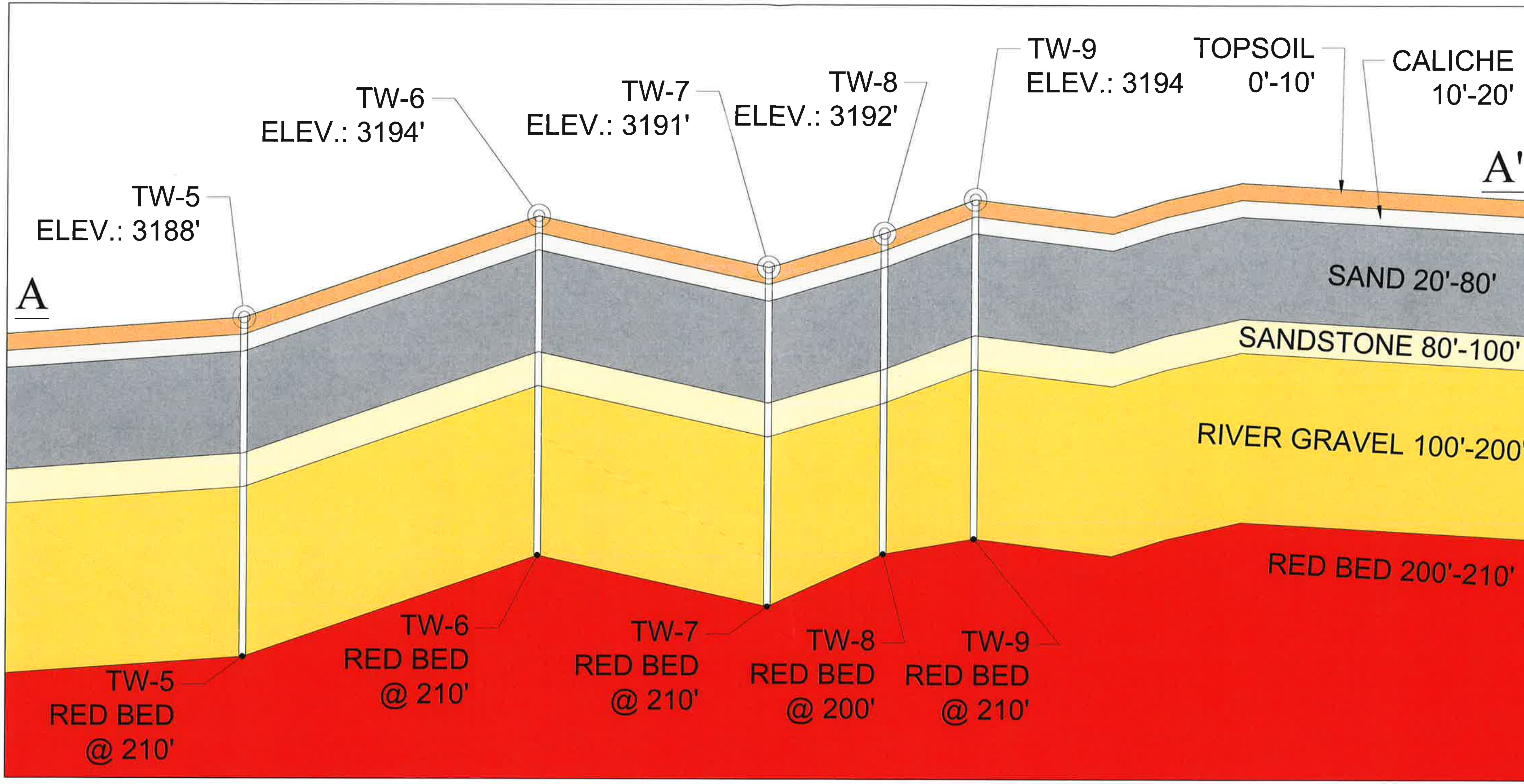

CROSS SECTION A-A'

NOTE: REFER TO SHEET 4 FOR CROSS SECTION LOCATIONS

MBCO Engineering, LLC.
MOSS | BLETSCH | CRENEK | OLLER
1212 13th St, Ste. 202 | Lubbock, Texas 79401
TBPE Reg. No. F16850 | TBPLS Reg. No. 10194112
PHONE: 806-993-6226 | www.mbcoengineering.com

ANDREWS WELL FIELD
EXPANISION-PHASE 1

DCP WELL FIELD CROSS SECTION
CROSS SECTION A-A'

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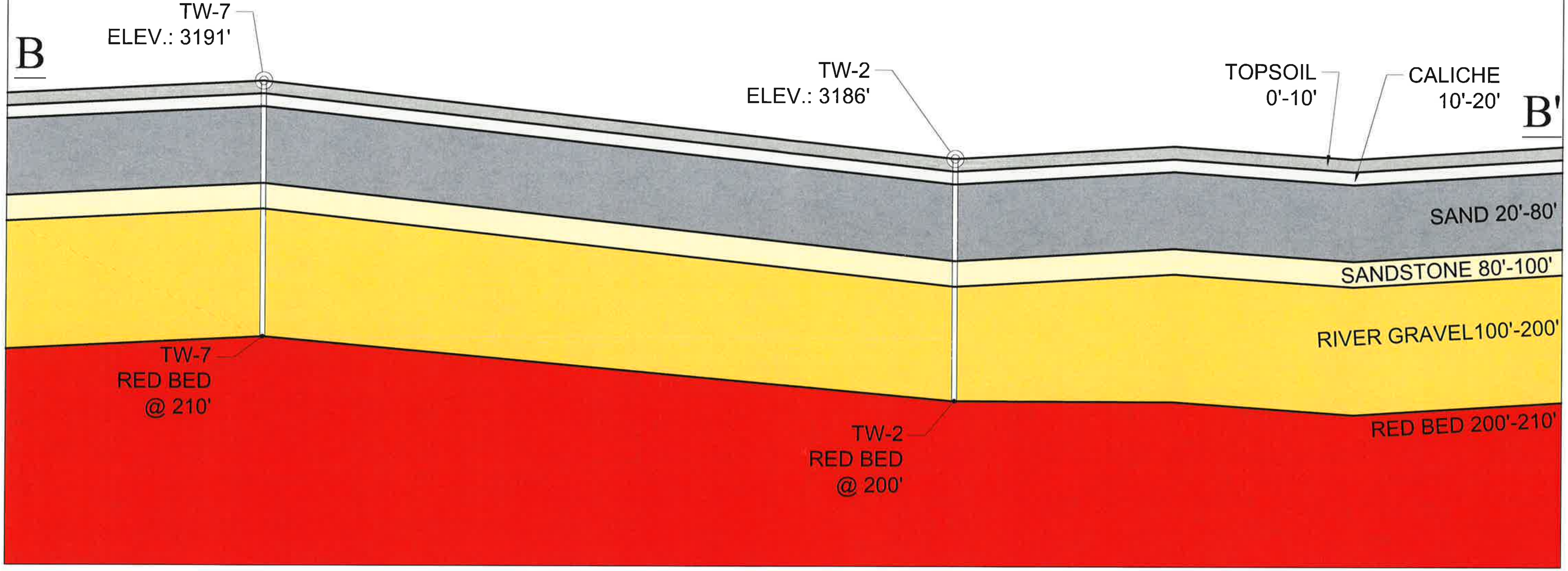
Checked By:	R.M.O.		OF 06



CROSS SECTION B-B'

NOTE: REFER TO SHEET 4 FOR CROSS SECTION LOCATIONS

MBCO Engineering, LLC.
1212 13th St, Ste. 202 | Lubbock, Texas 79401
TBPE Reg. No. F16850 | TBPLS Reg. No. 10194112
PHONE: 806-993-6226 | www.mbcoengineering.com

ANDREWS WELL FIELD
EXPANISION-PHASE 1

DCP WELL FIELD CROSS SECTION
CROSS SECTION B-B'

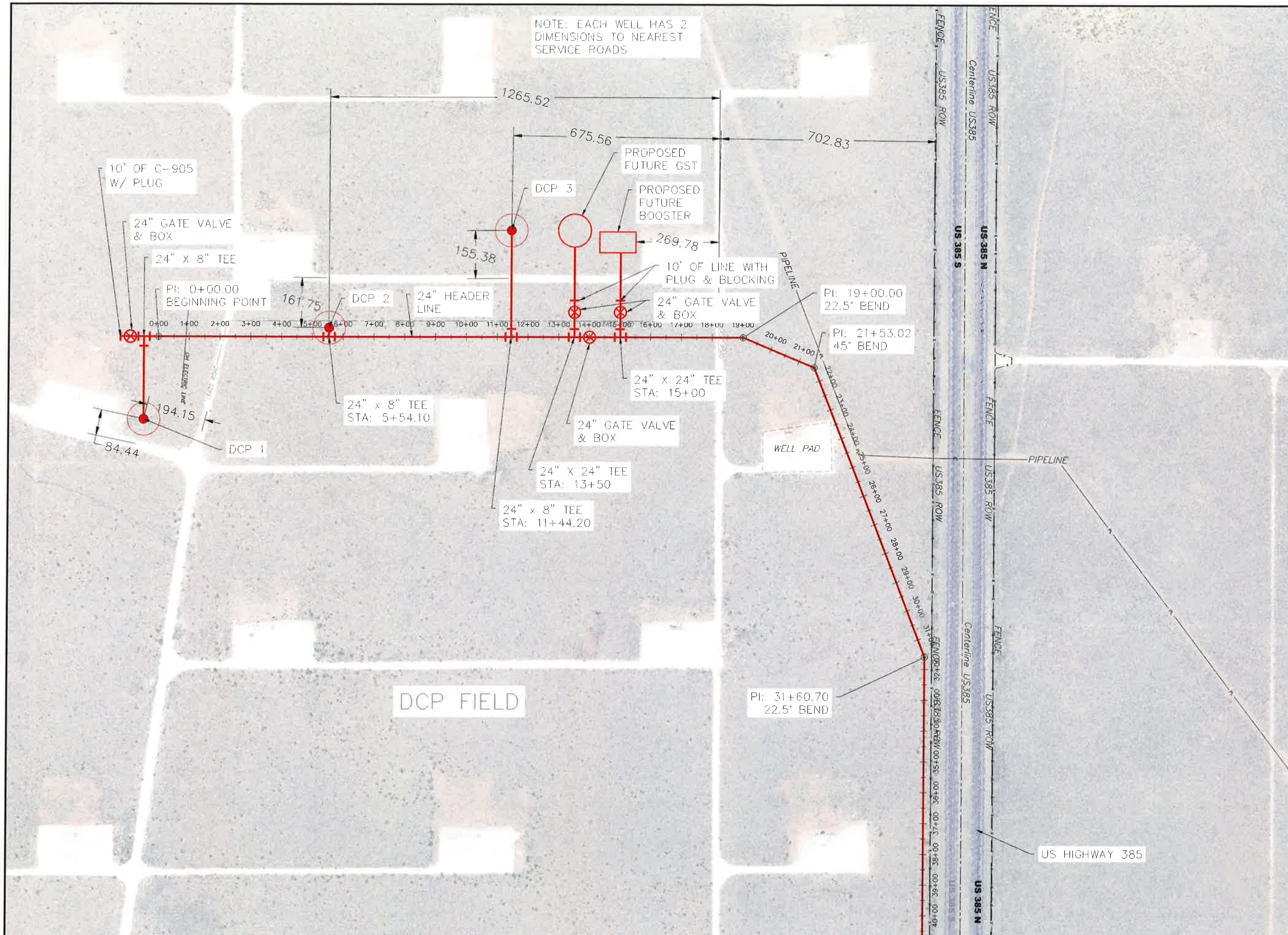
Date:	2/15/16	Job No.: 0021.15.6020	SHEET
Drawn By:	C.C.C.	Scale:	06
Checked By:	R.M.O.		OF 06

Description of Soils/Formation									
Depth/Location	TW-1	TW-2	TW-3	TW-4	TW-5	TW-6	TW-7	TW-8	TW-9
O'-10'	Topsoil	Topsoil	Topsoil	Topsoil	Topsoil	Topsoil	Topsoil	Topsoil	Topsoil
10'-20'	caliche layer @18' ; poorly sorted	Caliche gravel-like; poorly sorted	Caliche & Gravel; poorly sorted	Caliche & Gravel; poorly sorted	Caliche & gravel; poorly sorted	Caliche & gravel; poorly sorted	Calich, gravel-like; poorly sorted	Caliche or "rock-like" formation	Calich, gravel-like; poorly sorted
20'-40'	fine silt, soft, light pinkish-brown; "powder-like"	Transition to sand; brown color	Find Sand; brown color	Sand & rock; sand fine-brown color	Fine Sand; brown color	Fine Sand; brown color	Very fine sand	Fine sand; "sugar sand"	Very fine sand
40'-60'	clayer fine sand @50'; reddish brown;well sorted	Sand & little rock; very fine sand; brown color	Very fine sand; brown color	Very fine sand; some rock; brown color	Very fine sand; lighter brown color	Very fine sand; brown color	Very fine sand	Fine sand; "sugar sand"	Very fine sand
60'-80'	**VERY fine sand; caving in w/ air-rotary;"sugar sand"	Very fine sand; little caliche-well sorted	Very fine sand; lighter brown color	Very fine sand; little rock	Very fine sand; lighter brown color	Very fine sand; lighter brown color	Very fine sand; well sorted; reddish-brown color	Mix of sand & sandstone @ approx 73'	Very fine sand; well sorted; reddish-brown color
80'-100'	harder formation; sandstone & chert/calich @ approx 85'	Sand & Sandstone; lighter brown; poorly sorted	Sand & Sandstone; lighter brown; poorly sorted	Fine sand & sandstone; lighter brown; poorly sorted	Sand & sandstone; poorly sorted	Very Fine Sand & Sandstone; lighter brown; poorly sorted	Medium gravel; poorly sorted mix w/ sandstone @ 75'; sandstone	sandstone; poorly sorted	Medium gravel; poorly sorted mix w/ sandstone @ 75'; sandstone
100'-120'	sugar sand;started mud-drilling; diff to define formation	River gravel @ 100'; well sorted	River gravel; Well sorted	River gravel @100'; well sorted	River gravel @ 100'; well sorted; @120' rock change to bigger white rock	River gravel @ 105'; well sorted	River gravel; well sorted; sample taken @ 100'	River gravel @ 100'	River gravel; well sorted; sample taken @ 100'
120'-140'	reddish-brown color	River gravel @ 100'; well sorted	River gravel; Well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted
140'-160'	reddish-brown color	River gravel @ 100'; well sorted	River gravel; Well sorted	River gravel mix w/ Red Bed; well sorted @ 155'	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted
160'-180'	small, poorly sorted gravel; @ 170' reached water bearing strata	River rock & Red Bed; kept drilling @175' to 190'	River gravel/Red bed mix; kept drilling; Red Bed @170'	Red Bed @ 165'; stopped drilling	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted
180'-200'	small river gravel; redbed @	Red Bed @200'; couldn't penetrate further	---	---	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted	River gravel; well sorted
200'-220'	---	---	---	---	Red Bed @ 210'	Red Bed @ 210'	Red Bed @ 210'	Red Bed @ 205'	Red Bed @ 210'

Appendix A

DCP Land Proposed Buildout

DCP/Florey/University Wellfield Interconnection



Texas 811 — Know what's below. Call before you dig.

STATE OF TEXAS — RICH OLLER — 61831 — REGISTERED PROFESSIONAL ENGINEER

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1212 13th St, Ste. 202 | Lubbock, Texas 79401
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CITY OF ANDREWS
DCP WELLFIELD EXPANSION
PHASE 1-WELLFIELD SUPPLY LINE

DCP HEADER DETAIL

Date: SEPTEMBER 2016	Job No.: 0021.15.0020	SHEET
Drawn By: C.C.C.	Scale: Horiz: 1"=150'	3
Checked By: R.M.O. & W.A.R.		


U.S. 385
PROPOSED 3 NEW WELLS FOR DCP WELLFIELD (PHASE I)
D.C.P. WELL FIELD BLOCK 19
TW-8
TW-9
TW-6
PROPOSED 24" PIPELINE (PHASE I)
DCP WELL
FISHER ROAD
FLOREY WELL FIELD BLOCK 21
EXISTING 16" HEADER
F-21
F-20
F-15
F-14
F-17
F-19
F-16
F-18
16" PIPE LINE TIE IN TO EXISTING
NE 6000
PROPOSED NEW BOOSTER GST @ EXISTING FLOREY STATION (PHASE IA)
PROPOSED NEW BOOSTER PUMP @ EXISTING FLOREY STATION (PHASE I)
RUN 24-INCH PIPELINE TO UNIVERSITY WELL FIELD PHASE III
UNIVERSITY WELL FIELD BOOSTER STATION
NEW BOOSTER PUMP (PHASE II)
EXISTING 14" & 8" LINES TO THE CITY
NEW 24-INCH INTERCONNECTING LINE (PHASE IV)
FUTURE 24" PIPE LINE
NE 2001
U.S. 385
LEGEND
PHASE I
PHASE IA
PHASE II
PHASE III
PHASE IV
PHASE V
EXISTING 16" LINE
EXISTING 8" & 14" LINE