

Developing New Operating Policies in Tarrant Regional Water District Model, and Integration with Hydraulics and Cost Optimization Models

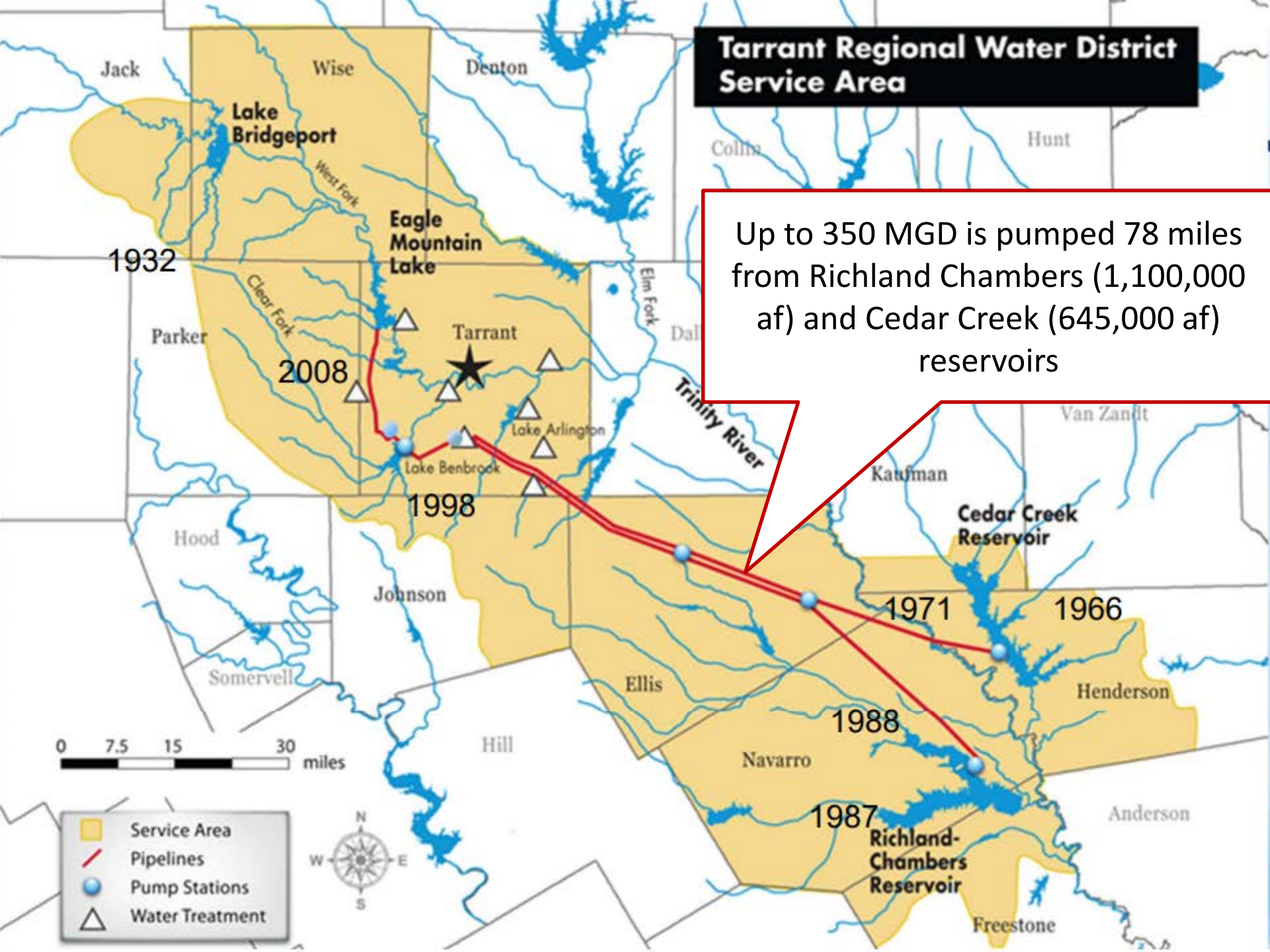
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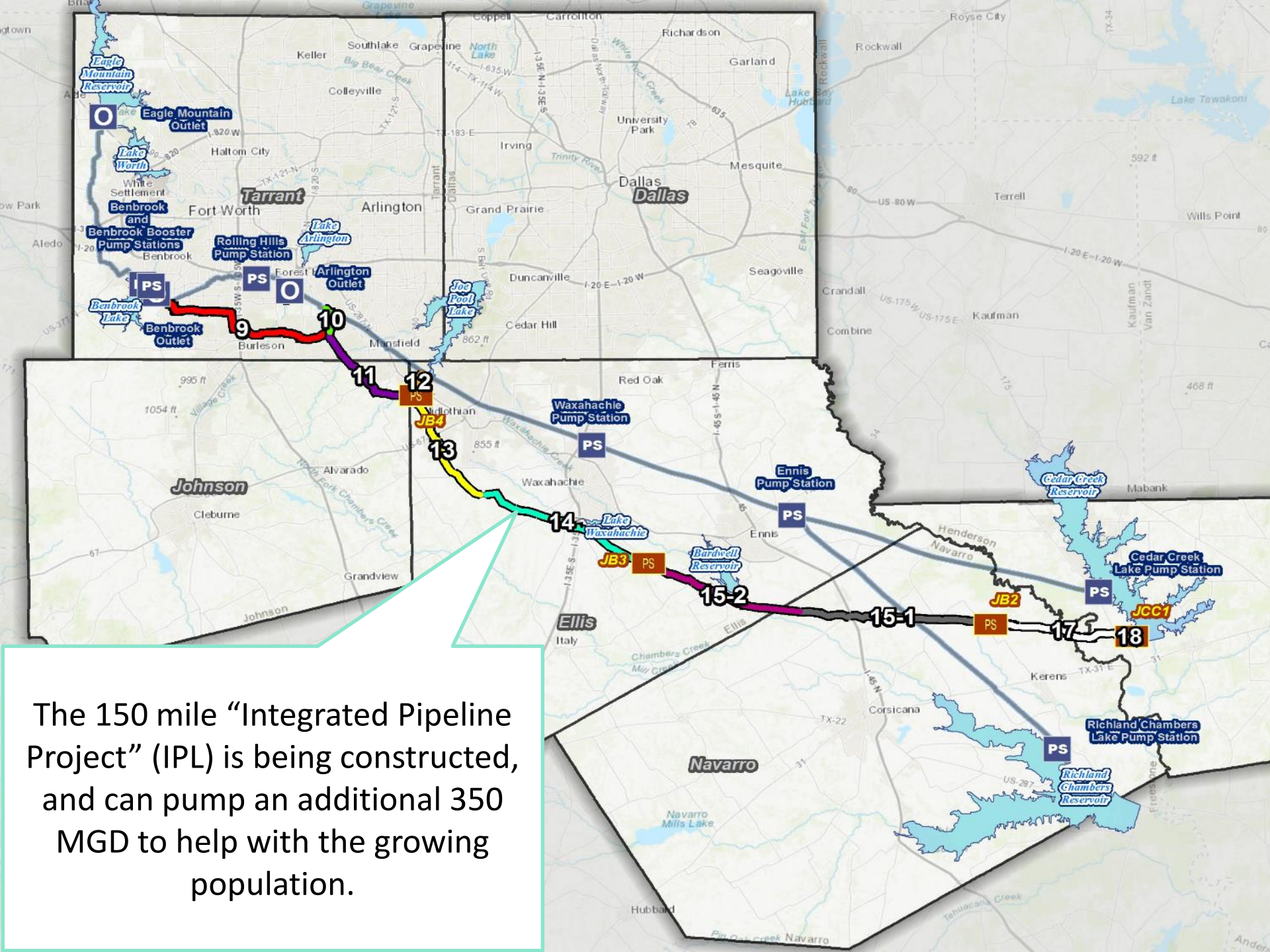


Tarrant Regional Water District Service Area

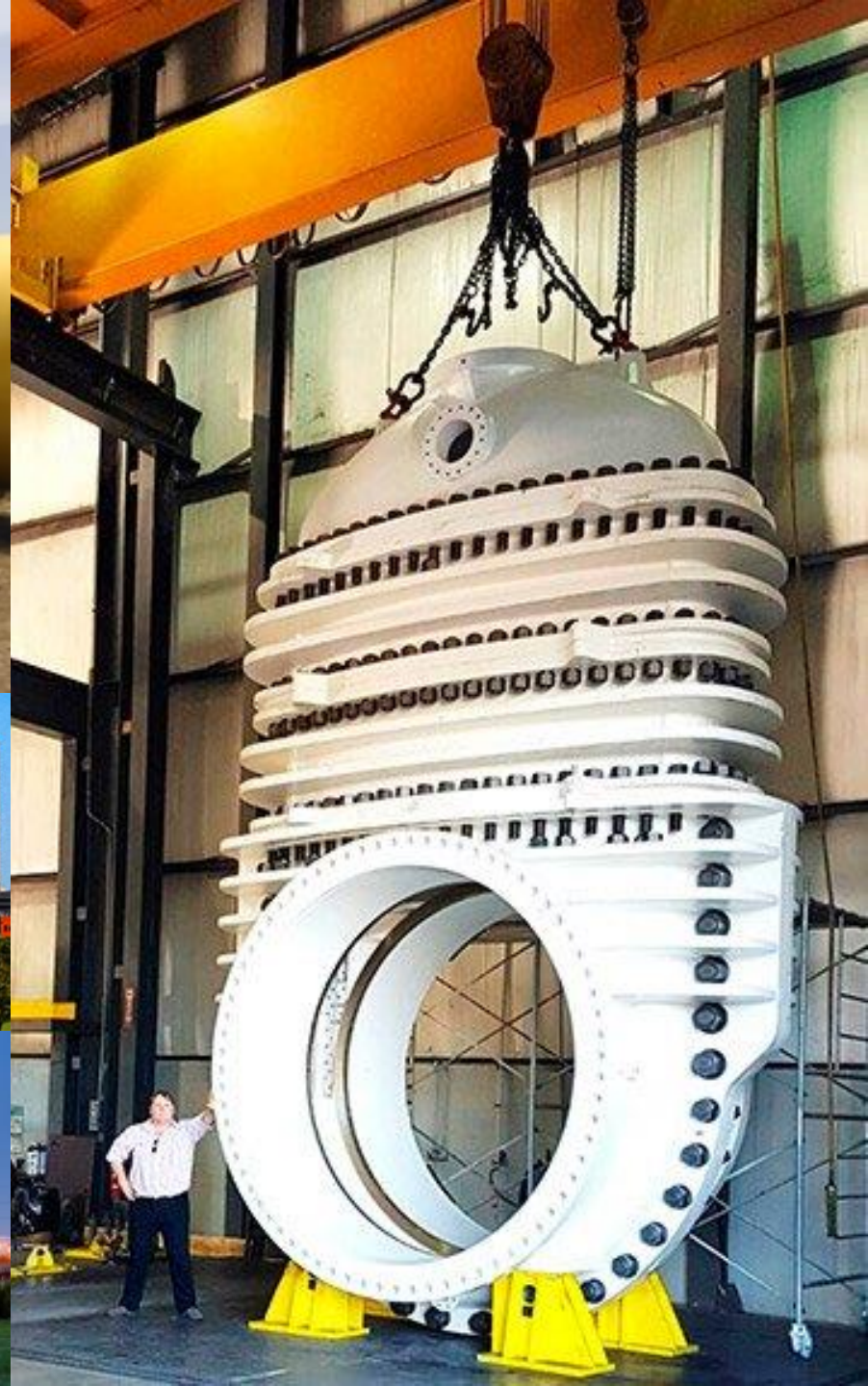
Up to 350 MGD is pumped 78 miles from Richland Chambers (1,100,000 af) and Cedar Creek (645,000 af) reservoirs

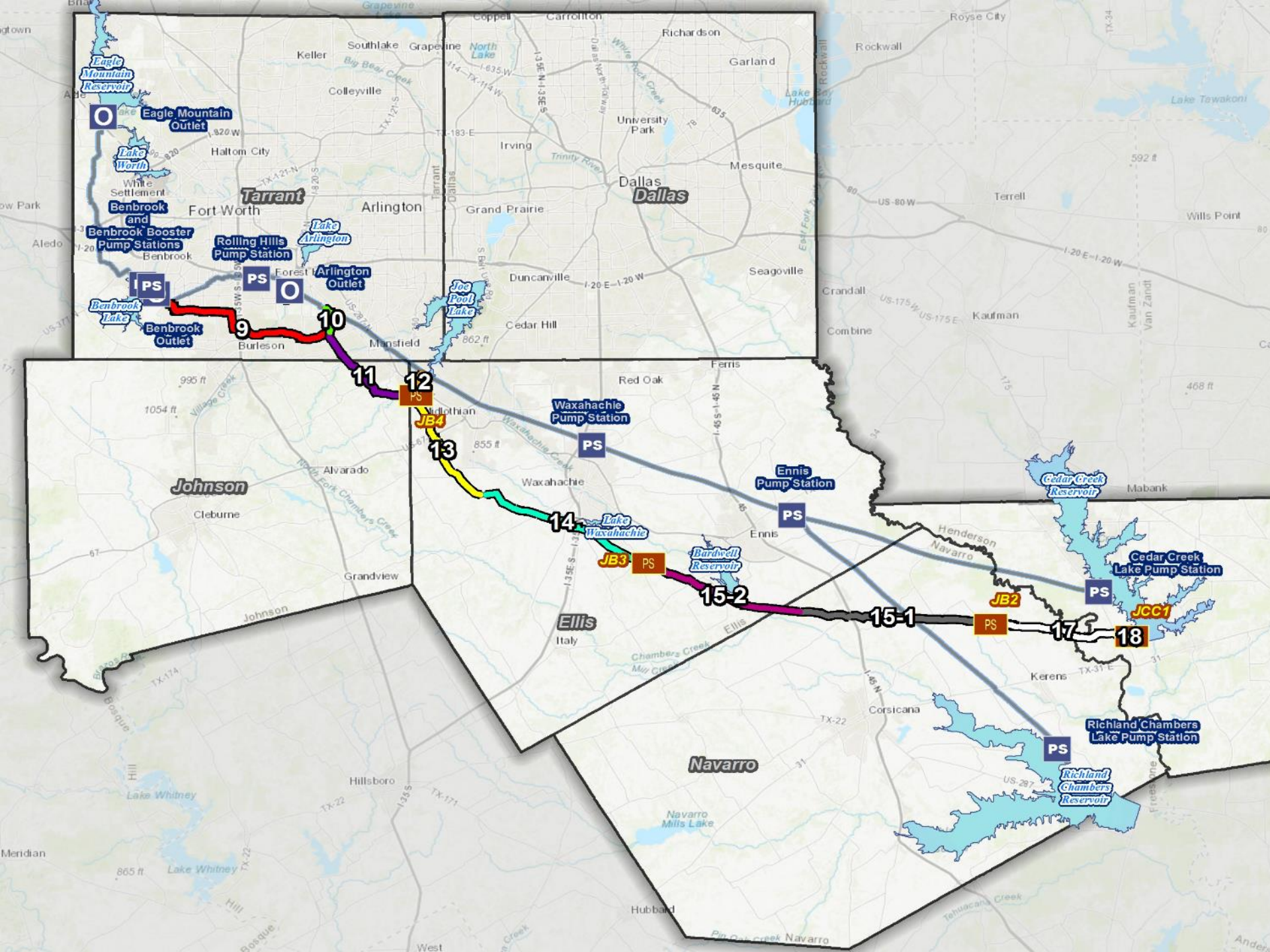


- Service Area
- Pipelines
- Pump Stations
- Water Treatment



The 150 mile “Integrated Pipeline Project” (IPL) is being constructed, and can pump an additional 350 MGD to help with the growing population.





Tarrant

- Eagle Mountain Reservoir
- Eagle Mountain Outlet
- Lake Worth
- Benbrook and Benbrook Booster Pump Stations
- Rolling Hills Pump Station
- Arlington Outlet
- Benbrook Outlet
- Benbrook Lake
- Benbrook
- Forest
- Joe Pool Lake
- Mansfield

Dallas

- North Lake
- University Park
- Mesquite
- Grand Prairie
- Duncanville
- Cedar Hill
- Seagoville

Johnson

- Waxahachie Pump Station
- Waxahachie
- Ennis Pump Station
- Ennis
- Cedar Creek Reservoir
- Cedar Creek Lake Pump Station
- JCC1
- Richland Chambers Lake Pump Station
- Richland Chambers Reservoir

Johnson

- 1054 ft
- 995 ft
- Village Creek
- Alvarado
- Grandview
- Johnson
- Cleburne

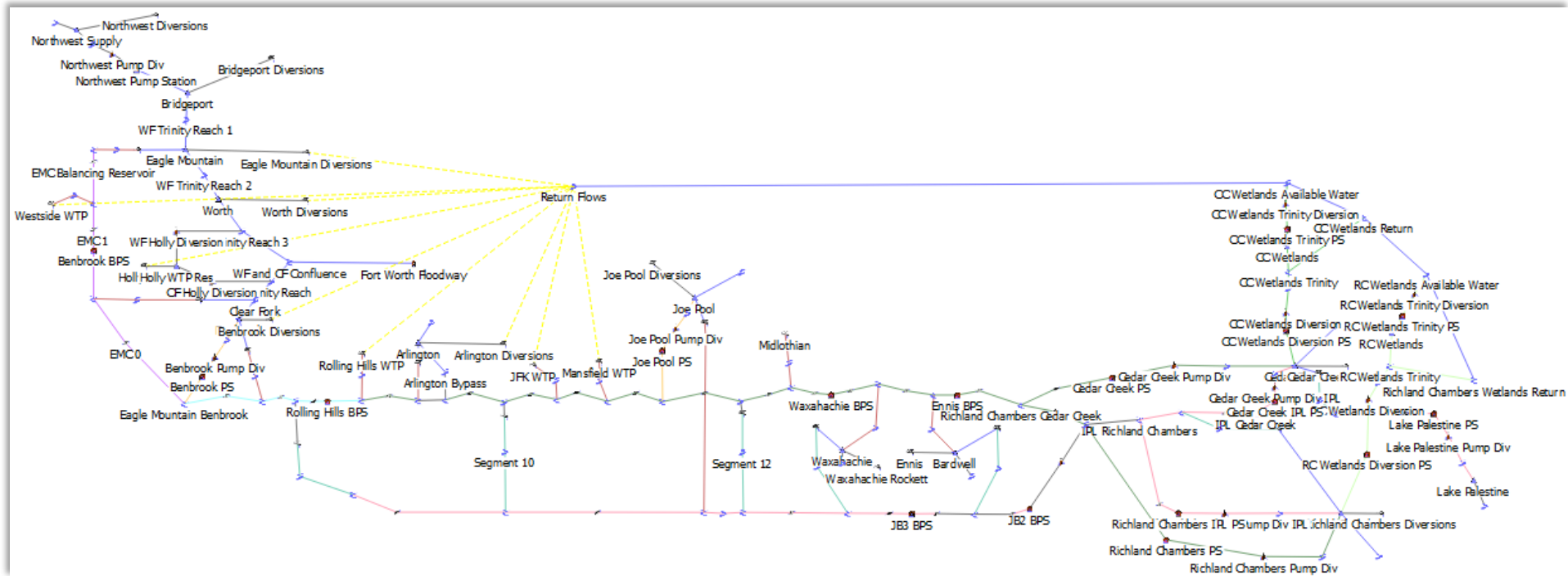
Ellis

- 11
- 12
- 13
- 14
- 15-2
- 15-1
- 17
- 18
- Italy
- Chambers Creek
- Hubbard

Navarro

- Ennis
- Ennis Pump Station
- PS
- Richland Chambers Lake Pump Station
- Richland Chambers Reservoir
- Hubbard
- Navarro Mills Lake

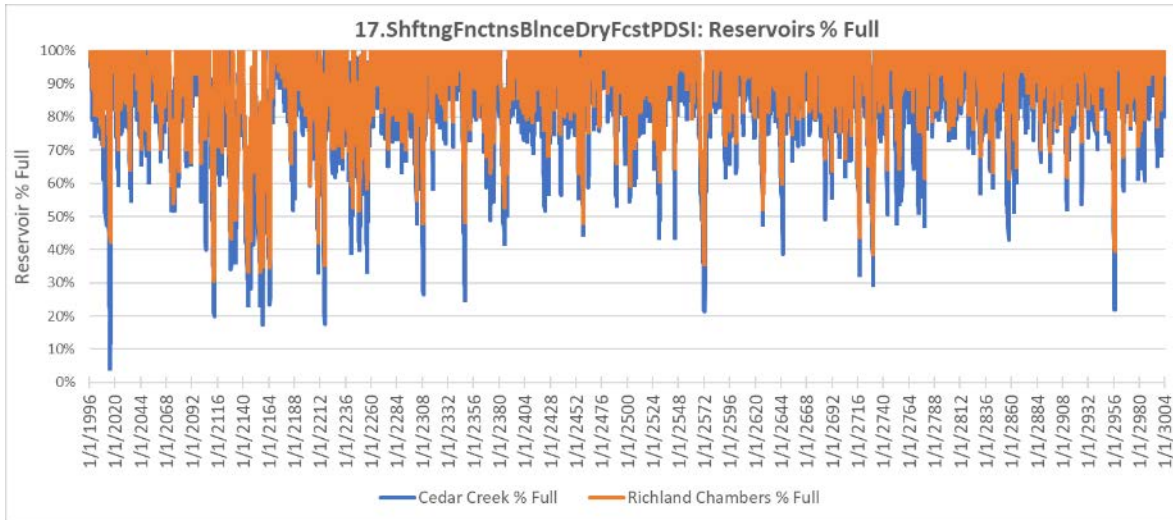
TRWD used their RiverWare long-term monthly planning model to test various operating schemes for their new IPL system, and analyze tradeoffs.



Tradeoff Analysis

	Policy #	POR (1941-2017) Statistics																		
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
Metric	Actual (1990-2017 data)	Current RiverWare Policy	IPL Phase 2 Table	Balance RC and CC % Full	Balance RC and CC % Permit Remaining	Balance RC and CC % Full AND % Permit Remaining	Allow CC % Full to go 10% below RC % Full	Allow CC % Full to go 10% below RC % Full, unless Eastern System forecast is Dry, then Balance	Allow CC % Full to go 10% below RC % Full, unless Entire System forecast is Dry, then Balance	Allow CC to go 3' below RC	Allow CC to go 3' below RC, unless Eastern System fcst for next 3mo., otherwise keep Permit % remaining within 10% of each other	Allow CC to go 3' below RC, unless Dry fcst for next 3 mo. then keep Permit % remaining within 10% of each other	Allow CC to go 3' below RC, unless Dry fcst for next 3 mo. then keep Physical % remaining within 10% of each other	When CC drawdown <3', pump 67:33 CC:RC. When CC drawdown >3', pump 50:50. Ramp up RC pumping as Drawdown Differential Increases	When CC drawdown <3', pump 67:33 CC:RC. When CC drawdown >3', pump 50:50. Ramp up RC pumping as Drawdown Differential Increases. If Dry East Forecast for next 3 months, Balance.	Pump 67:33 CC:RC. When drawdown diff >3', pump 33:67 CC:RC. If Dry East Forecast for next 3 months, Balance.	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If drawdown diff STILL >1/2' or EVER >2', pump 33:67 CC:RC.	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If Dry East Forecast for next 3 months, Balance.	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If Dry East Forecast for next 3 months, Balance.	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If Dry East Forecast for next 3 months, Balance.
CC Total Pumping (MAF)	1.5	5.7	10.6	6.1	6.0	6.0	9.7	8.9	8.1	11.1	7.2	10.9	11.0	8.9	8.5	9.3	9.1	8.8	8.9	
RC Total Pumping (MAF)	3.5	11.5	6.2	10.8	10.9	10.9	7.1	7.9	8.8	5.7	9.6	5.9	5.8	8.1	8.5	7.7	7.9	8.2	8.1	
Total Pumping (MAF)	5.0	17.2	16.8	16.9	16.9	16.9	16.8	16.8	16.9	16.8	16.9	16.8	16.8	17.0	17.0	17.0	17.0	17.0	17.0	
CC pumping %	30%	33%	63%	36%	36%	36%	58%	53%	48%	66%	43%	65%	66%	52%	50%	55%	54%	52%	52%	
RC pumping %	70%	67%	37%	64%	64%	64%	42%	47%	52%	34%	57%	35%	34%	48%	50%	45%	46%	48%	48%	
Average annual Pipeline Shortage (AF)		0	39	0	0	0	2	0	0	3	0	0	3	0	0	1	0	0	0	
Avg. % Full Difference	3%	3%	9%	1%	3%	2%	6%	4%	3%	8%	4%	7%	7%	5%	4%	5%	5%	4%	4%	
Avg. % Permit Remaining Difference		5%	31%	14%	1%	8%	29%	22%	18%	35%	10%	34%	33%	19%	16%	21%	19%	17%	17%	
Avg. LA Elev (ft)		545.8	545.3	544.7	544.7	544.7	544.6	544.6	544.7	544.6	544.7	544.6	544.6	544.6	544.6	544.5	544.6	544.6	544.6	
Avg. BB Elev (ft)		690.5	690.5	689.9	689.9	689.9	689.8	689.9	690.0	689.9	690.0	689.9	689.9	690.7	690.7	690.7	690.7	690.7	690.7	
Avg. EM Elev (ft)		647.0	646.5	647.1	647.1	647.1	646.8	646.9	647.1	646.8	647.1	646.8	646.8	647.0	647.0	647.0	647.0	647.0	647.0	
% of months CC and RC % full differ by >10% from each other	9	6%	35%	1%	6%	1%	11%	5%	3%	41%	10%	36%	37%	19%	11%	20%	19%	11%	16%	
% of months CC and RC % full differ by >15% from each other	3	2%	24%	0%	2%	0%	1%	0%	0%	23%	3%	17%	17%	7%	3%	11%	4%	2%	4%	
% of months CC and RC % full differ by >20% from each other	1	0%	15%	0%	0%	0%	0%	0%	0%	1%	0%	1%	0%	1%	0%	2%	0%	0%	0%	
Avg. CC drawdown (ft)	1.5	1.8	3.1	1.7	1.9	1.7	2.5	2.3	2.1	2.9	2.0	2.8	2.8	2.4	2.2	2.4	2.4	2.3	2.3	
Max. CC drawdown (ft)	7.8	16.2	19.5	21.3	18.7	20.7	19.9	20.7	22.2	19.6	20.4	19.0	19.3	22.0	21.9	21.5	22.2	21.9	22.0	
Avg. RC drawdown (ft)	2.1	2.2	1.3	2.1	2.1	2.1	1.6	1.8	1.9	1.5	2.0	1.6	1.5	1.7	1.8	1.7	1.7	1.8	1.8	
Max. RC drawdown (ft)	11.4	22.9	15.3	20.8	22.5	21.1	18.0	19.6	20.2	17.3	21.5	17.9	17.3	19.2	19.3	18.1	19.4	19.5	19.5	
% of months CC drawdown is 3' or more	21%	21%	38%	19%	23%	20%	34%	29%	24%	41%	25%	39%	40%	31%	27%	30%	33%	29%	30%	
% of months RC drawdown is 3' or more	27%	24%	11%	25%	23%	24%	19%	21%	23%	16%	22%	17%	17%	19%	21%	19%	19%	22%	20%	
% of months CC and RC drawdown differs by 3' or more	10%	7%	23%	1%	7%	3%	0%	1%	1%	8%	4%	9%	6%	4%	2%	9%	4%	1%	2%	
Avg. # months for CC and RC % Full to get within 10% of each other if next 3 month Forecast Dry		0	6	0	1	0	2	0	0	8	1	5	5	5	1	3	3	1	2	
Avg. # months for CC and RC % Permit Remaining to get within 10% of each other if next 3 month Forecast Dry		0	7	1	0	1	1	3	3	5	1	3	5	0	2	2	3	2	2	

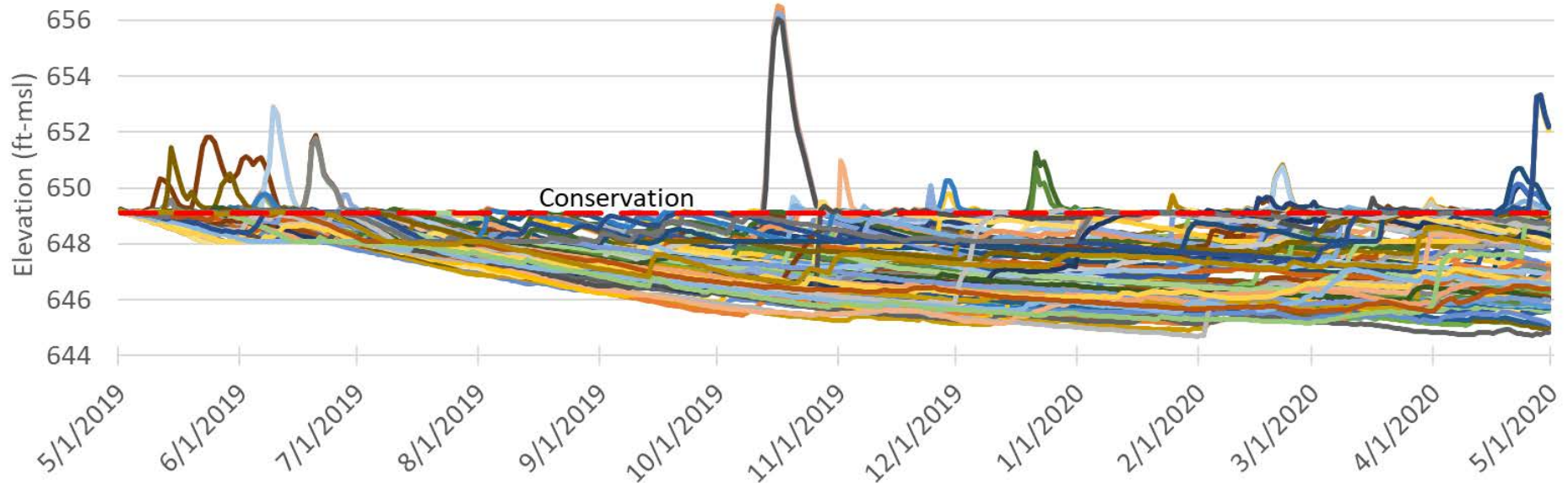
TRWD also tested the various operating schemes using their 1,000-year PDSI tree-ring hydrology



	Policy #	PDSI Statistics (1996-3003)		
		16	17	18
Metric	Actual (1990-2017 data)			
		Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If drawdown diff STILL >1/2' or EVER >2', pump 33:67 CC:RC	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If drawdown diff >2', pump 33:67 CC:RC. If Dry East Forecast for next 3 months, Balance.	Pump 67:33 CC:RC. When drawdown diff >1/2' & CC Drawdown >3', pump 50:50 CC:RC. If drawdown diff >2', pump 33:67 CC:RC. If Dry East Forecast for next 3 months, Balance.
CC Total Pumping (MAF)	1.5	128.1	123.6	124.7
RC Total Pumping (M\AF)	3.5	118.3	123.1	122.0
Total Pumping (MAF)	5.0	246.4	246.7	246.7
CC pumping %	30%	52%	50%	51%
RC pumping %	70%	48%	50%	49%
Average annual Pipeline Shortage (AF)		0	0	0
Avg. % Full Difference	3%	6%	5%	5%
Avg. % Permit Remaining Difference		19%	16%	16%
Avg. LA Elev (ft)		544.4	544.4	544.4
Avg. BB Elev (ft)		690.8	690.8	690.8
Avg. EM Elev (ft)		646.6	646.6	646.6
% of months CC and RC % full differ by >10% from each other	9	22%	15%	17%
% of months CC and RC % full differ by >15% from each other	3	8%	6%	6%
% of months CC and RC % full differ by >20% from each other	1	4%	3%	3%
Avg. CC drawdown (ft)	1.5	3.2	3.0	3.0
Max. CC drawdown (ft)	7.8	31.6	31.3	31.4
Avg. RC drawdown (ft)	2.1	2.4	2.5	2.5
Max. RC drawdown (ft)	11.4	23.2	24.1	23.9
% of months CC drawdown is 3' or more	21%	39%	37%	37%
% of months RC drawdown is 3' or more	27%	28%	29%	29%
% of months CC and RC drawdown differs by 3' or more	10%	7%	6%	6%
Avg. # months for CC and RC % Full to get within 10% of each other if next 3 month Forecast Dry		3	1	1
Avg. # months for CC and RC % Permit Remaining to get within 10% of each other if next 3 month Forecast Dry		3	2	2

- TRWD staff selected a final operating policy, which is now used for short-term Operation Forecasting runs
- Used in conjunction with 100 hydrologic traces
- The result is a cloud of probability of lake elevations, diversion volumes from each of the source supply reservoirs, and more.

Eagle Mountain Lake Elevations for 100 RiverWare Model Runs



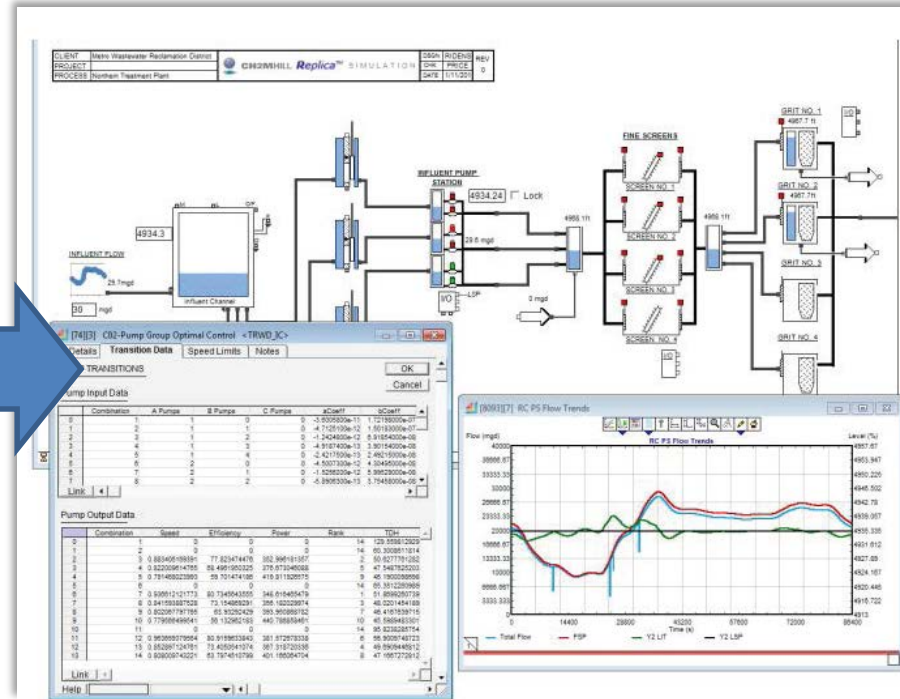
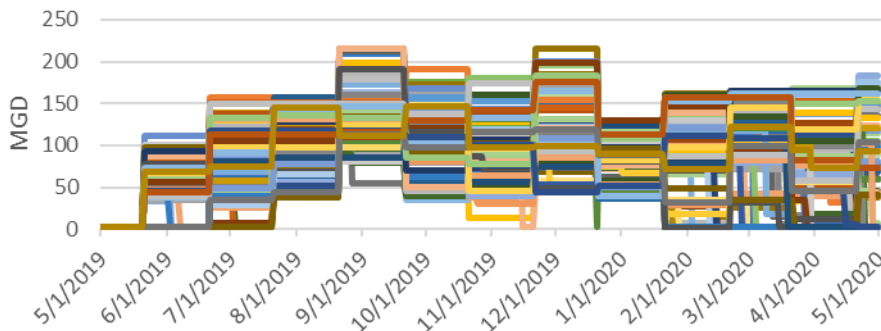
The 100 sets of diversion outputs are run through Jacobs Engineering's SupplyOpt model, which determines how the diversion volumes from RiverWare will be hydraulically moved through the system.



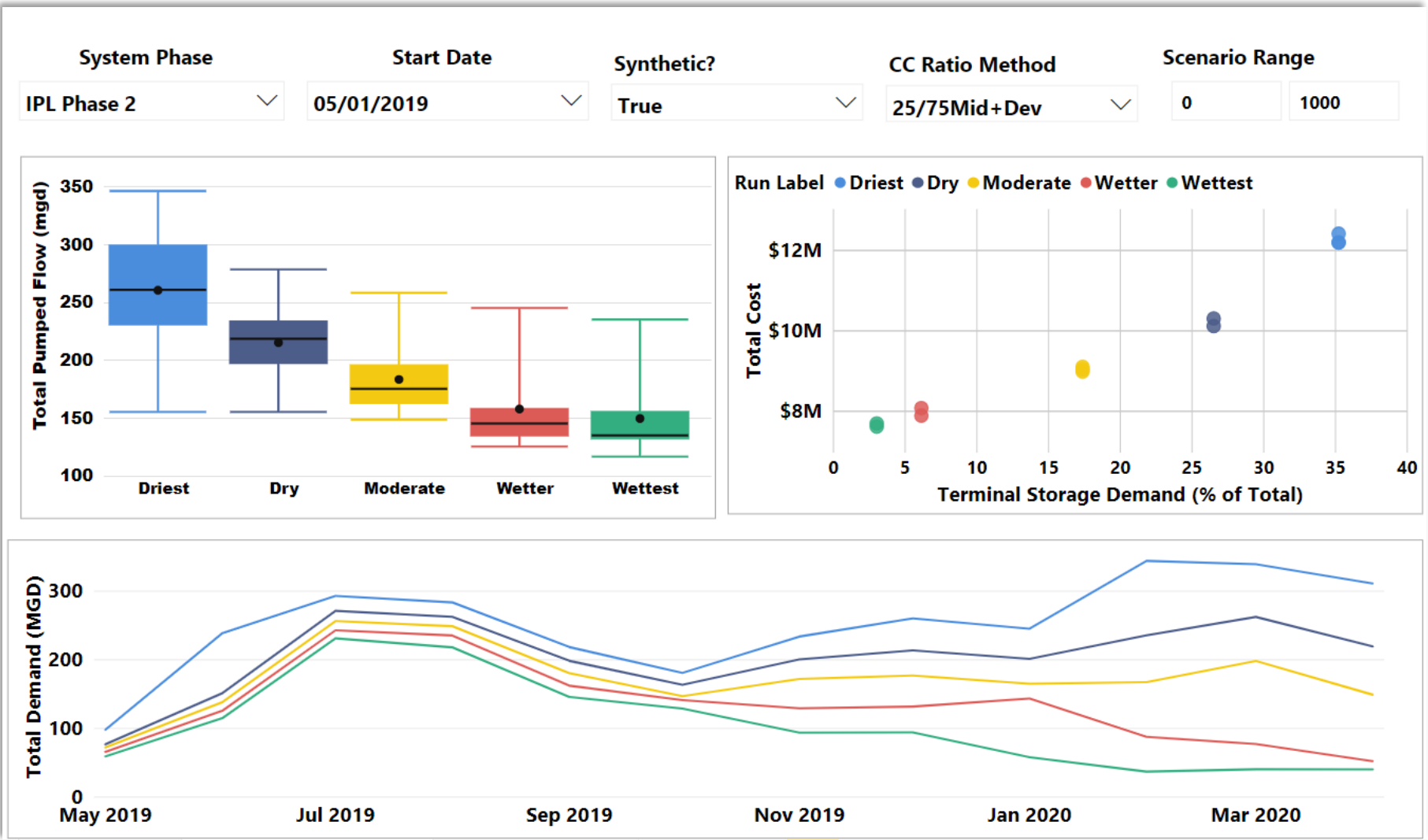
Diversions from Richland Chambers for 100 RiverWare Model Runs



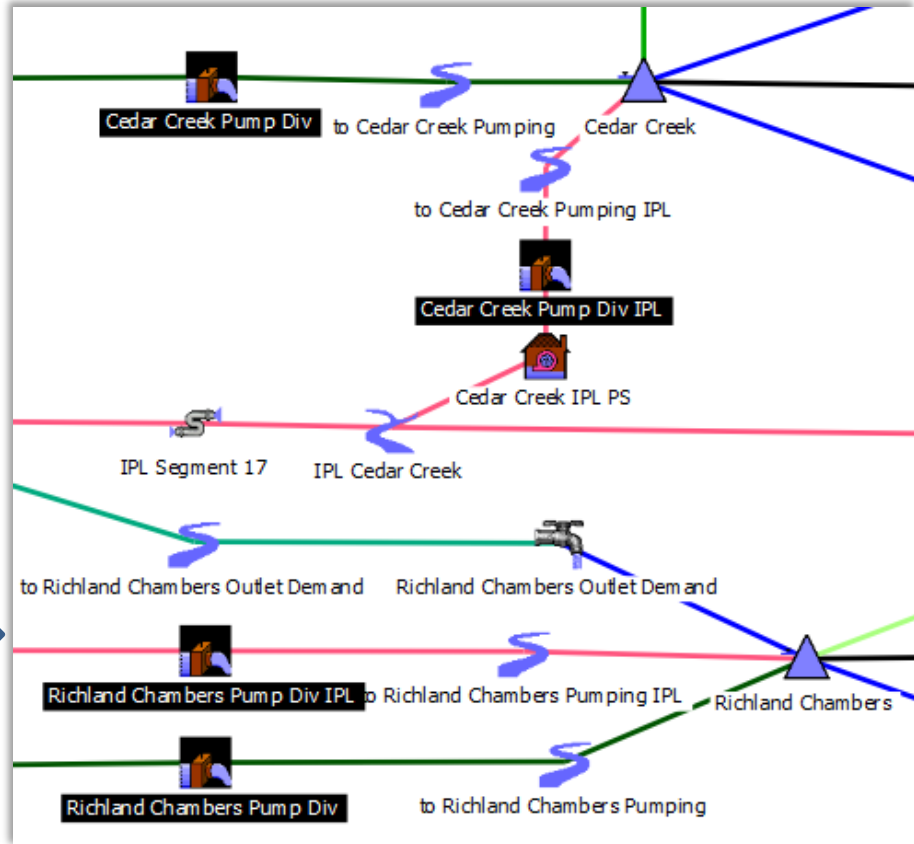
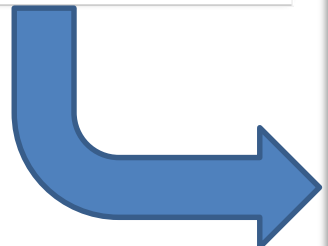
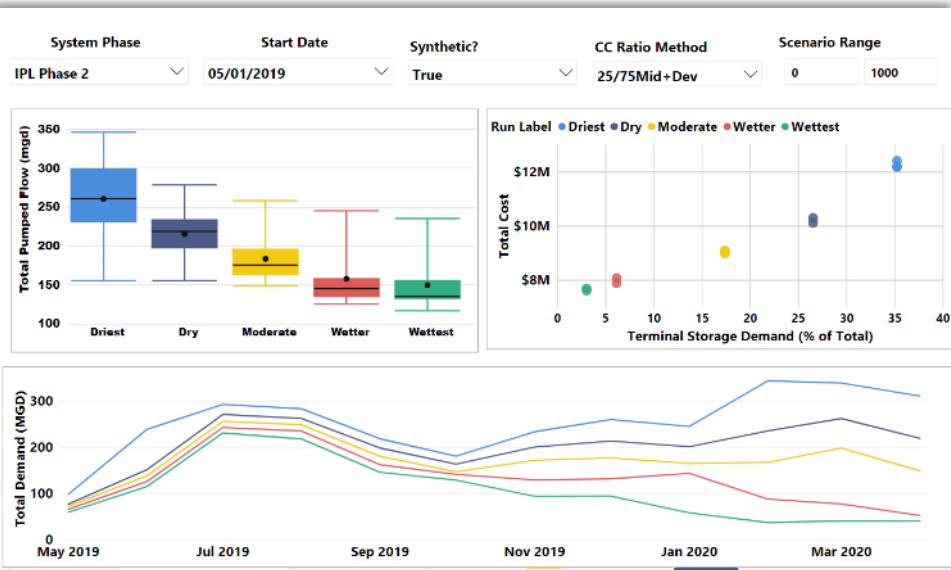
Diversions from Cedar Creek for 100 RiverWare Model Runs



- SupplyOpt's cost optimization model then alters the pumping schemes slightly to minimize costs.



- Several cost-optimized pumping schemes for the next 3 months are fed back into RiverWare, and tested against all 100 hydrologic traces.



- TRWD evaluates the risks associated with each cost-optimized pumping scheme, and decides which to use for operations over the next 3 months

- Risks include:
 - Spill from reservoirs
 - Shortages to customers
 - Low reservoir elevations



	SupplyOpt Pumping Scheme					
	135_0	135_3	136_0	136_1	140_0	140_3
Date Range	5/1/19 - 7/20/19					
Successful RiverWare traces	100%	100%	100%	100%	100%	100%
% of days with Customer Pipeline Demand	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%
Min Daily Customer Pipeline Demand Shortage (MGD)	0	0	0	0	0	0
Mean Daily Customer Pipeline Demand (MGD)	0.0	0.0	0.3	0.0	0.0	0.0
Max Daily Customer Pipeline Demand (MGD)	0	0	32	0	0	0
Min Richland Chambers elevation (ft)	313	313	313	313	313	313
Mean Richland Chambers elevation (ft)	315	315	315	315	315	315
Max Richland Chambers elevation (ft)	316	316	316	316	316	316
Min RC Pumping (MGD)	67	67	67	67	67	67
Mean RC Pumping (MGD)	79	67	67	67	79	67
Max RC Pumping (MGD)	115	67	67	67	115	67
% of days with spill at Richland Chambers	36%	36%	36%	36%	36%	36%
Mean Daily Spill at Richland Chambers (MGD)	491	493	493	493	491	491
Max Daily Spill at Richland Chambers (MGD)	33,799	33,799	33,799	33,799	33,799	33,799
Min Cedar Creek elevation (ft)	320	320	320	320	320	320
Mean Cedar Creek elevation (ft)	322	322	322	322	322	322
Max Cedar Creek elevation (ft)	323	323	323	323	323	323
Min CC1 Pumping (MGD)	0	0	29	29	29	29
Mean CC1 Pumping (MGD)	26	23	35	43	37	43
Max CC1 Pumping (MGD)	52	52	52	52	52	52
Min JCC1 Pumping (MGD)	40	40	0	0	60	60
Mean JCC1 Pumping (MGD)	97	105	62	67	104	104
Max JCC1 Pumping (MGD)	150	150	160	120	150	150
Min JB3 Pumping (MGD)	40	40	0	0	60	60
Mean JB3 Pumping (MGD)	97	105	62	67	104	104
Max JB3 Pumping (MGD)	150	150	160	120	150	150
% of days with spill at Cedar Creek	17%	17%	19%	18%	15%	15%
Mean Daily Spill at Cedar Creek (MGD)	234	233	246	239	221	221
Max Daily Spill at Cedar Creek (MGD)	22,831	22,831	22,831	22,831	22,831	22,831
Min Lake Arlington elevation (ft)	549	548	546	547	549	549
Mean Lake Arlington elevation (ft)	550	550	550	550	550	550
Max Lake Arlington elevation (ft)	560	560	560	560	560	560
% of days LA Elevation below 535'	0%	0%	0%	0%	0%	0%
% of days (between 6/1 and 9/30) LA Elevation	0%	0%	0%	0%	0%	0%

Next Steps

- Better connection between RiverWare & SupplyOpt
 - SQL database connection to RiverWare

Questions?