Estimated of Depth-to-Water Beneath Vegetation Reinventory Parcels, 1985-2003

Robert F. Harrington
Inyo County Water Department

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1. Introduction.

The relation between groundwater dependent vegetation conditions and water table fluctuations is central to goals of the Inyo/Los Angeles Long-Term Water Agreement. Vegetation conditions were inventoried by LADWP throughout the Owens Valley during 1984 through 1987, and this inventory forms the baseline conditions that define the standard for evaluating vegetation change under the Agreement. To determine whether vegetation conditions are meeting these baseline standards, subsets of the inventoried parcels have been reinventoried by the Water Department annually since 1991 (Manning, 2002). Relating observed vegetation conditions to water table fluctuations requires an estimate the depth to water (DTW) beneath areas of groundwater dependent vegetation. Shallow monitoring wells on LADWP land provide point-measurements of DTW, however these wells are generally not collocated with reinventory parcels, and even if a well is located within a reinventoried parcel, it is not necessarily representative of DTW across the extent of the parcel. To estimate DTW beneath vegetation parcels, point-measurements of DTW must be interpolated to the location and extent of each reinventory parcel. The purpose of this report is to estimate the DTW hydrograph for the period 1985 through 2002 beneath each reinventoried vegetation parcel and assess the uncertainty and reliability of the estimated hydrograph.

This effort, as well as previous similar efforts by the Water Department, used geostatistical methods to estimate DTW on a regular grid for each year, and then the average DTW for vegetation parcels was computed by averaging the DTW values of grid cells that fell within each parcel, resulting in a time-series of DTW for each parcel. In these previous efforts, several deficiencies were apparent, including inaccuracies due to the relative locations of monitoring wells and vegetation parcels, temporal step-changes in parcel hydrographs due to changes in the network of monitoring wells, inaccuracies due to relationships between topography and DTW that were not accounted for in the geostatistical computations, and unrealistic error assessments due to the use of kriging variance as an estimate of error. The work presented here uses space-time ordinary kriging (OK), space-time kriging with an external drift (KED), and sequential Gaussian simulation to remedy these deficiencies.

Section 2 describes the data set used for this analysis, the kriging methods employed to generate DTW estimates, and the simulation methods used to estimate the uncertainty in the estimates. Section 3 presents cross validation statistics for space-time and non-space-time versions of OK and KED, the estimated DTW for each reinventory parcel using space-time OK and KED, and a simulation of the uncertainty of the OK estimate for 2002 using sequential Gaussian simulation. Section 4 contains a discussion of the relative merits and reliability of OK and KED, and provides recommendations for future improvements in DTW estimation. Appendix I presents hydrographs for each reinventory parcel and a narrative evaluation of the hydrographs; Appendix II summarizes the evaluations provided in Appendix I.

2. Methods

Data. This work is based on shallow piezometer water level data collected by LADWP, measured periodically throughout the Owens Valley. A digital set of these data up through June 2003 was transmitted to the Water Department by LADWP. The data consist of LADWP's monthly well reports that contain DTW, water table elevations (WTE), well reference point (RP) elevations, land surface elevations, dry-well indicators, and other comments. The data set spans the period 1971-2003, but many of the wells were constructed later than 1971 resulting in a general increase through time in the number of available data (Table 1). LADWP has also provided total-depth information for piezometers from their database. LADWP's total-depth information was supplemented with well soundings conducted by ICWD. The monthly well reports were imported into a Microsoft Access database and merged with the UTM coordinates (zone 11, NAD 27) of each well (McGhie, 1997). For wet wells (i.e., wells extending below the water table), DTW was computed as land surface elevation minus water table elevation. For dry wells, because the water table elevation was not explicitly in the raw data files, depth to the bottom of the well was computed as depth from RP minus RP elevation plus ground surface elevation. Any well less than 40 ft deep was used for DTW mapping, and if a well was deeper than 40 ft, but nearby lithologic logs indicate that it did not penetrate any significant confining layers, it also was used for DTW mapping.

If the above criteria were met, data were extracted from the database at a resolution of 0.1 ft for April of each year 1985-2003, with each record consisting of UTM easting, UTM northing, April DTW (feet below land surface), and station ID. Dry wells were flagged and exported as separate data sets, with each record consisting of UTM easting, UTM northing, depth of the bottom of well below land surface (feet), and station ID. WTE was calculated as described below. If a well was not measured in April, it was not used for estimating DTW.

Several sources of error are present in the DTW data. Wells reads made by e-tape and RP elevations generally are given with a resolution of 0.01 ft. It is unknown how accurately the RP's were surveyed with respect to mean sea level, but it should be noted that the differential nature of DTW measurements means that only the error in the e-tape measurement is imparted to the DTW measurement. The land surface corrections used to determine land surface elevation from RP elevation were considered accurate to 0.1 ft. due to roughness of the land surface around the perimeter of the well casing. For wells deemed suitable for DTW mapping, the first water level measurement made during the month of April was used. DTW mapping procedures treat all measurements for a single year as having occurred simultaneously; therefore there is some error due to treating noncontemporaneous measurements as representing a single point in time. Examination of well hydrographs suggests that this error may be as much as a few tenths of a foot. Well locations were taken from LADWP global positioning system measurements (McGhie, 1997), which have a horizontal resolution of 3.28 ft (1 m). In general, as will be shown later, the uncertainty in DTW estimates due to measurement error is small compared to the standard deviation of the kriging errors in DTW estimates; therefore, measurement error was not incorporated into the assessment of uncertainty of DTW estimates. The number of wells used for kriging for each year is given in Table 1.

Table 1. Number of wells used for kriging.

		Dry wells used		Total wells used	
Year	Wet wells	OK	KED	OK	KED
1985	160	4	4	164	164
1986	222	11	10	233	232
1987	248	9	8	257	256
1988	252	43	35	295	287
1989	255	53	38	308	294
1990	248	51	40	299	288
1991	247	61	47	308	294
1992	255	56	39	311	294
1993	261	52	42	313	303
1994	279	42	26	321	305
1995	276	39	30	315	306
1996	288	30	21	318	309
1997	299	26	19	325	318
1998	308	21	13	329	321
1999	315	15	8	330	323
2000	305	21	12	326	317
2001	306	21	15	327	321
2002	317	29	20	348	339
2003	299	32	23	331	322

The KED method used the USGS 10 m digital elevation model (DEM) as an external drift function. This DEM has a vertical resolution of 0.328 feet (0.1 m). It is necessary that WTE used for KED be consistent with the DEM. To achieve such consistency, WTE was calculated as DEM elevation minus DTW. An alternative would have been to use the surveyed RP elevation as the datum for computing WTE, but this would have resulted in discrepancies where the DEM and the RP elevations conflicted. Any inaccuracies in WTE that resulted from this process were nullified when WTE was converted back to DTW (by subtraction from the DEM) after the kriging was completed.

Kriging. Previous efforts at DTW estimation have used OK to produce estimates.
In the work presented here, water levels were interpolated using two different methods of kriging: ordinary kriging (OK) and kriging with an external drift (KED) (Deutsch and Journel, 1998; Goovaerts, 1997). OK models the estimate of the primary variable (DTW) at an unobserved location as a linear combination of observations of the primary variable.

KED models the estimate as a linear combination of observations of the primary variable, in this case WTE, and an 'external drift' term defined by a secondary variable, in this case land surface elevation. After the WTE grid was computed, gridded DTW was derived by subtracting the WTE grid from the DEM grid of land surface elevations. Advantages of OK are that it has less tendency to produce water table estimates above the land surface and variogram development is more straightforward. Disadvantages are that it is hard to incorporate land surface elevation data, and interpolation of DTW is insensitive to topographic features that often influence DTW. KED has the advantage that it incorporates information from a secondary variable into the estimate, and WTE is possibly a more smoothly varying quantity than DTW. Disadvantages of KED are that it has a greater tendency than OK to produce water tables above the land surface, and variograms must be developed from the residual of the drift variable and the primary variable. In this case, variogram development for KED was not an obstacle, because the residual is simply DTW. This allowed the same variogram to be used for both OK and KED. The linear correlation coefficient between land surface elevation and WTE was 0.996, assuring that the relation between these two variables is sufficiently linear for the use of KED (Goovaerts, 1997).

Temporal interpolation and the use of land-surface elevation as secondary data have not previously been used by ICWD in developing DTW maps, however both of these ideas have been used previously in other geostatistical models of water table surfaces. Rouhani and Hall (1989) and Rouhani and Wackernagel (1990) applied spatio-temporal kriging to water table surfaces, and concluded that the additional temporal component improved their estimates compared to simple kriging. Elevation data have been used as secondary data to improve estimates of the water table elevation using cokriging (Hoeksema et al., 1989) and using trend models (Volpi and Gambolati, 1978; Desbarats et al., 2002).

Estimating DTW at the dry well locations incorporated dry well data by a two-step process, where DTW was estimated using wet wells only, and if the estimated DTW was less than the depth of the dry well, the dry well was added to the kriging data set with DTW set as the well depth. While this may result in underestimation of DTW at locations influenced by the dry well, it provides a better estimate of DTW than would otherwise be obtained, and typically fixes the water table below the shrub root zone. The number of dry wells used for kriging is given in Table 1.

The space-time covariance was modeled with a geometric-anisotropic spherical variogram, using the product-sum model of De Cesare et al. (2002) to combine the spatial and temporal components. The parameters for the variogram model were derived by fitting the experimental variogram to the model using weighted least squares (Table 2), where the weight for each experimental variogram bin was the number of data in the bin divided by the square of the mean lag.

Table 2. Spatial-temporal covariance model.

Spherical variogram parameters	
Nugget (feet squared)	0.4
Sill (feet squared)	140.3
Major axis range (meters)	2520.2
Minor axis range (meters)	1933.1
Major axis orientation	345^{o}
Temporal sill (years squared)	19.4
Temporal range (years)	9.3
Search parameters	
Maximum spatial search radius (meters)	4000
Maximum temporal search radius (years)	1
Maximum data	15
Minimum data	3
Maximum data per octant	15

Although there is an obvious geometric equivalence between WTE and DTW based on the land surface elevation, these two variables behave differently when interpolated or extrapolated across the landscape. When DTW is extrapolated from a well to higher topography, it tends to be underestimated because the deepening of the water table beneath the higher land is not incorporated in the model. Interpolation of WTE accounts for topographic variability, but is nonstationary on the regional scale modeled here, hence the use of KED to account for the nonstationarity of WTE. By implementing these two methods, more confidence can be placed in results where the two methods agree, though agreement between the methods is neither necessary nor sufficient for accurate estimates.

The global performance of OK and KED was assessed using cross validation, and the local performance (i.e. at individual parcels) was assessed by examining the hydrographs of nearby monitoring wells, the configuration of wells relative to the parcel, the topography in the vicinity of the parcel, and any nearby hydrologic features that might affect the water table.

Cross validation is widely used for testing kriging estimates by comparing them to known data. Cross validation proceeds by removing one point from the data set, using the remaining data to compute an estimate at the location of the removed point, determining the difference between the estimate and the observation (the residual), and repeating this process for all points in the data set. This process generates a residual for each point in the data set.

It is useful to examine both the residuals, $z_i^* - z_i$, and the normalized residuals, $(z_i^* - z_i)/s_z$, where z_i^* is an estimate of the primary variable, z_i is the observed primary variable at the same location, and s_z^2 is the error variance predicted by the kriging procedure. The residuals provide an assessment of error in terms of the same units as the data, whereas the normalized residuals also have the property that they should have zero mean and unit variance, which provides an assessment of how closely the kriging variance represents the actual variability of the errors. Cross validation results were analyzed in terms of mean absolute error, the mean normalized error,

$$S_1 = \frac{1}{n}\sum_{i=1}^{n}\frac{z_i^* - z_i}{s_z}$$

which should be close to zero, and the variance of the normalized residuals,

$$S_2 = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{z_i^* - z_i}{s_z}\right)^2$$

which should be close to 1.0 (Kitanidis, 1993). *n* is the number of observations of the primary variable.

Sequential Gaussian simulation. Interpolation with kriging furnishes an unbiased optimal estimate of DTW; however, due to the spatial averaging nature of the kriged estimate, the resulting grid of is less variable than the original observed data and does not reproduce the experimental variogram. In contrast to kriging, sequential Gaussian simulation (SGS) is a geostatistical technique aimed at reproducing the spatial statistics (i.e., variogram) of the sample data set. This provides a better estimate of uncertainty than the kriging variance, because the kriging variance embodies only the spatial configuration of the data, whereas SGS embodies both the spatial configuration and the variability of data values into its estimate of uncertainty (Deutsch and Journel, 1998; Goovaerts, 1997). SGS is based on sequential addition of kriged estimates to the data set, which then contribute to subsequent estimates until the entire grid is filled in with simulated values. Rather than using the optimal estimates provided by OK or KED, SGS uses the optimal estimate plus a random component based on the kriging variance to fill in the grid. SGS was applied here to the 2002 DTW data to generate a grid of prediction variance for that year. Thirty realizations were generated to compute cell variances. Only one year was simulated due to time and disk space limitations.

Parcel DTW and uncertainty. Maps of the reinventory parcels were overlaid with the kriged DTW grids, and average DTW extracted by averaging all grid cells for which the cell centroid fell within the parcel boundaries. Parcel mean DTW hydrographs for 147 reinventory parcels are shown in Appendix I.

The uncertainty of the estimate for each parcel is a combination of the variability of DTW grid cells within the parcel, and the uncertainty of the estimated DTW for each grid cell. The standard error of the parcel mean DTW was calculated

$$s_p = \sqrt{\frac{1}{N}\sum_{i=1}^{N}((z_i^* - \bar{z}_p)^2 + s_i^2)} \qquad (1)$$

where s_i^2 is the simulated variance of grid cell *i*, z_i^* are the gridded estimates within the parcel, $\bar{z}_p$ is the mean of the gridded estimates within the parcel, and *N* is the number of grid cells in the parcel. The first term in the summation in (1) is related to the variability of DTW grid cells within the parcel; the second term is related to the uncertainty of each DTW grid cell.

In order to assist in the joint analysis of vegetation and DTW information, a qualitative assessment of the uncertainty or reliability of the parcel hydrographs accompanies the parcel hydrographs presented in Appendix I. The purpose of this assessment was to evaluate the utility of each parcel hydrograph for relating water table fluctuations to vegetation conditions. Relevant questions to this assessment are: what water table conditions prevailed during the baseline mapping period?, following the drought of the late-1980's and early-1990's, when and to what degree has the water table recovered to baseline water levels?, and are current estimates of DTW accurate? This assessment was made by comparing the kriged hydrographs with the hydrographs of nearby monitoring wells, consideration of the relative topographic positions of the parcel and nearby wells, the continuity of record of nearby monitoring wells, and the influence of nearby of surface water. Appendix II summarizes the reliability of each parcel hydrograph for assessing baseline DTW, relative recovery to baseline, and current DTW.

3. Results

Comparison of cross validation results for OK and KED (Table 3) reveals that KED yields a slight but consistent reduction in mean error over OK for each single-year cross validation. The cross validation using space-time kriging (all years, in Table 3) yielded a slightly lower mean absolute error for OK. The lower mean absolute error for space-time kriging of all years is due to temporal interpolation of the data from previous and subsequent years for the same well. This reduction in mean absolute error is artificially low; a more meaningful cross validation would remove the data for each well for all years. Inasmuch as the single-year cross validation was sufficient to assess the relative merits of OK and KED, the more rigorous space-time cross validation was deemed unnecessary. The increase in KED mean error for 2002 was due to a single well, 844T, in the Baker Meadow area, for which the KED cross validation residual was 516 ft versus 34 ft for OK. The mean normalized residual (S_1) had a slight negative bias for both OK and KED The variance of normalized residuals (S_2) differed from year to year, but for each year, it was less for KED than for OK. This was probably related to the relatively smaller absolute errors of KED, though since S_2 ranged above and below 1.00, the spatial covariance model appears equally applicable to either OK or KED.

Table 3. Cross validation of OK and KED.

	KED of WTE			OK of DTW		
year	mean absolute error	S_1	S_2	mean absolute error	S_1	S_2
1985	4.15	-0.026	1.36	4.49	-0.031	1.67
1986	4.51	-0.014	0.89	5.07	-0.012	1.12
1987	3.91	0.012	0.86	4.44	-0.021	1.05
1988	4.11	-0.001	0.69	4.71	-0.003	0.84
1989	4.21	-0.009	0.74	4.73	-0.007	0.92
1990	4.67	-0.012	0.74	5.23	-0.002	0.89
1991	4.45	-0.008	0.93	4.90	-0.005	1.07
1992	4.14	-0.002	0.71	4.74	-0.009	0.85
1993	3.92	0.003	0.58	4.53	-0.010	0.72
1994	3.65	-0.008	0.58	4.40	-0.007	0.81
1995	3.59	-0.004	0.58	4.21	-0.020	0.76
1996	3.65	-0.020	0.51	4.41	-0.010	0.74
1997	3.59	-0.010	0.59	4.85	-0.020	0.89
1998	3.97	-0.010	0.97	4.68	-0.020	1.14
1999	3.76	-0.020	0.89	4.37	-0.009	1.07
2000	3.88	-0.000	1.20	4.57	-0.015	1.37
2001	3.79	0.001	1.03	4.19	-0.020	1.13
2002	4.17	-0.020	0.55	4.19	-0.009	0.81
2003	3.53	-0.008	0.87	4.40	-0.030	1.17
all years	1.00	0.000	1.07	0.93	-0.004	1.07

Though the cross validation results suggest that KED is a modest global improvement over OK, both methods were used to generate DTW grids and parcel hydrographs so that each method could be evaluated on a parcel by parcel basis. In Appendix I, each hydrograph is accompanied by a narrative assessment of its accuracy and utility. Considerations entering into this assessment were consistency of the kriged hydrograph with hydrographs of nearby monitoring wells, distance to wells contributing to the kriged estimate, history of the well network, topography and land use (e.g. irrigation), and presence of nearby surface water. Though this assessment is subjective, the methods and data used here are not sufficiently robust to automatically produce useful hydrographs.

To facilitate use of the parcel hydrographs in assessing causes of vegetation change, the utility of each parcel hydrograph is summarized in Appendix II, wherein the validity of the estimated baseline DTW, relative recovery to baseline subsequent to the drought, and accuracy of estimated 2002 DTW is designated as either reliable or not reliable.

4. Discussion and Conclusions.

Though KED resulted in a global reduction in mean absolute error (Table 3), examination of the hydrographs in Appendix I revealed that the relative superiority of OK or KED was location dependent. Depending on the configuration of the well network relative to the parcel, topography, and surface water, either OK or KED may provide the better estimate of DTW for a given parcel. Congruency of the OK and KED parcel hydrographs was neither necessary nor sufficient for a reliable hydrograph, but it was often the case that the most reliable hydrographs were the ones where the two methods produced similar results. KED proved to be very unstable when extrapolated over relatively long distances up alluvial fans, e.g. BIS019 and BLK029, however when extrapolated over modest distances, KED appears to provide useful estimates, e.g. PLC239 and PLC240.

Given the importance that the Agreement places on temporal changes in vegetation conditions, it is critical that temporal changes in the water table be estimated accurately. Kriging the temporal component was done conservatively with a radius of only one year so as to avoid letting the temporal kriging have significant influence outside of interpolating past single-year instances of missing data. This resulted in the temporal kriging having little influence on the overall results.

The dearth of water level data during the baseline period (Table 1) is a serious obstacle to generating reliable parcel hydrographs, particularly when the purpose is to compare recent and baseline water levels. Obviously, the lack of monitoring well data during the baseline years cannot be remedied by installation of additional wells today. Indeed, many of the wells installed during early-2001 produced step-changes in nearby parcel hydrographs, indicating that the prior hydrograph was inaccurate. A better approach than the empirical geostatistical approach used here may be to incorporate a physically-based water table model into the analysis such that the baseline and recent water levels were estimated with similar amounts of information and could thus be legitimately compared. Numerical models such as the USGS Owens Valley regional groundwater flow model could be so adapted.

In theory, sequential Gaussian simulation produces error estimates that are better than those provided by kriging variance as was done by Harrington and Howard (2000), because simulation accounts for both the spatial configuration of the data and the variability in data values, whereas the kriging variance accounts only for the spatial configuration of the data. Yet, the parcel DTW standard errors listed in Appendix II are still large, due to both varying DTW within each parcel and error associated with each estimated DTW grid cell estimate. The variation in DTW within parcels may account for some of the within-parcel heterogeneity in vegetation conditions that is present. Users of the hydrographs in Appendix II should recognize the high degree of uncertainty in the estimated hydrographs, and apply them accordingly.

5. References.

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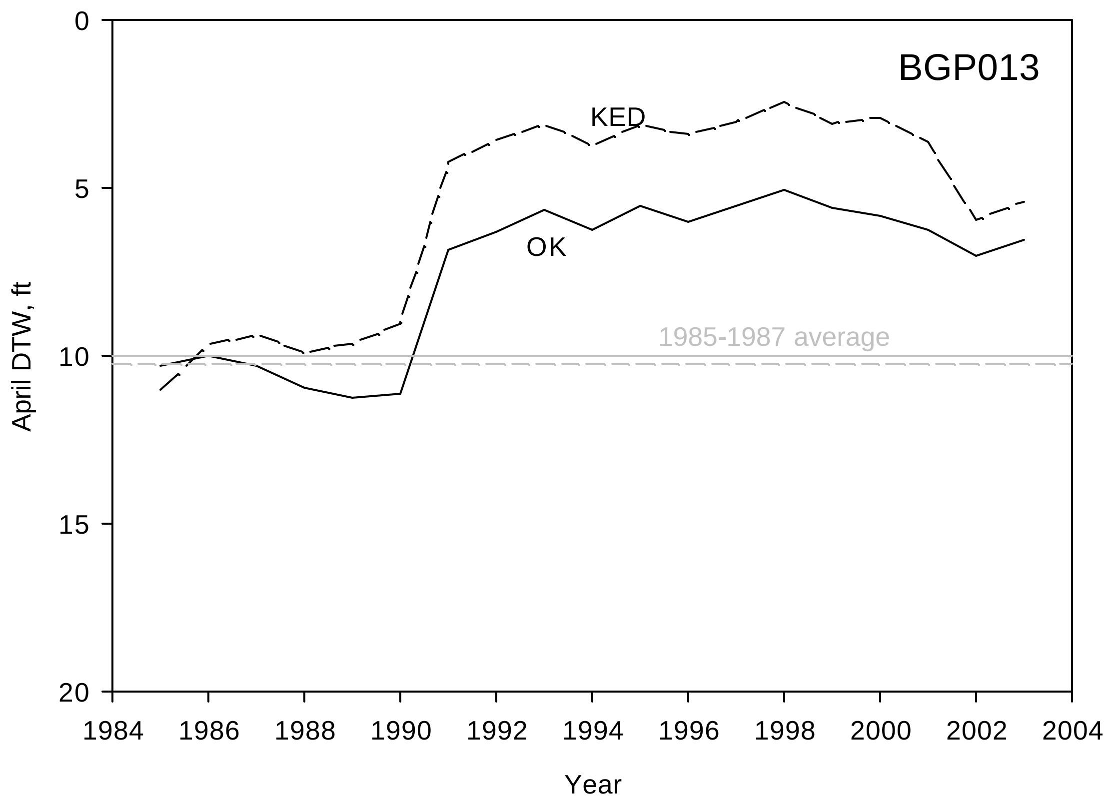
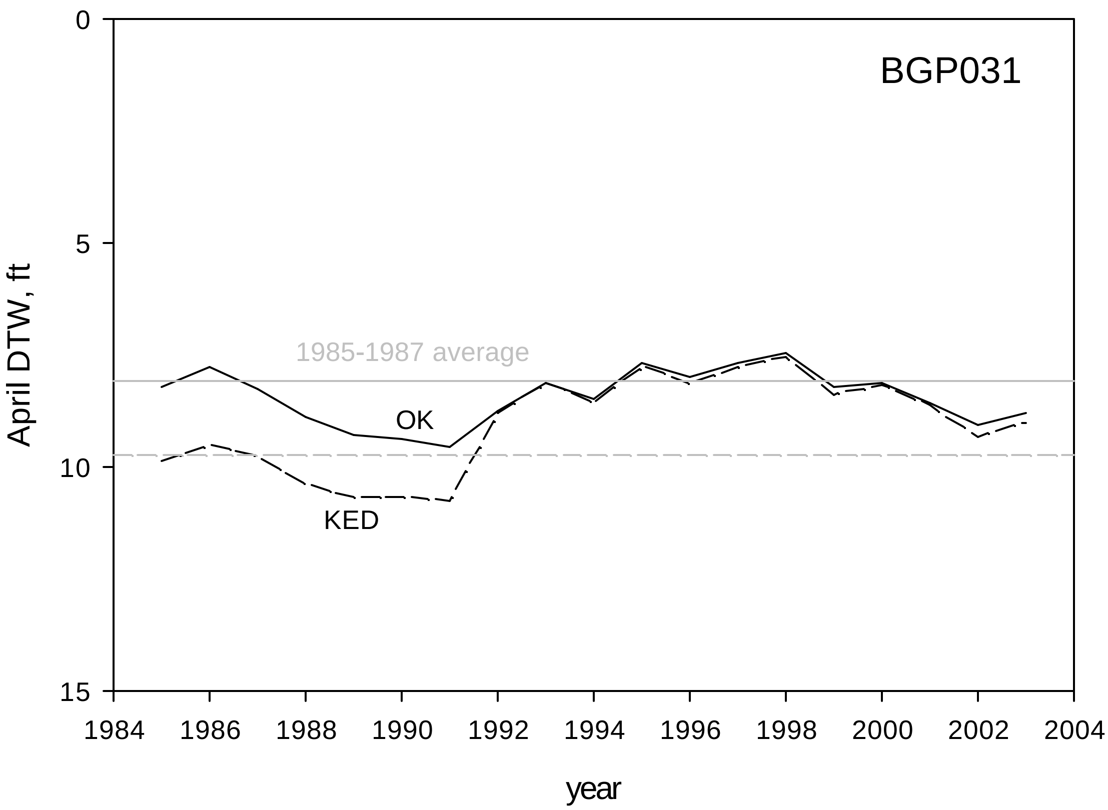
Appendix I. Parcel DTW history.

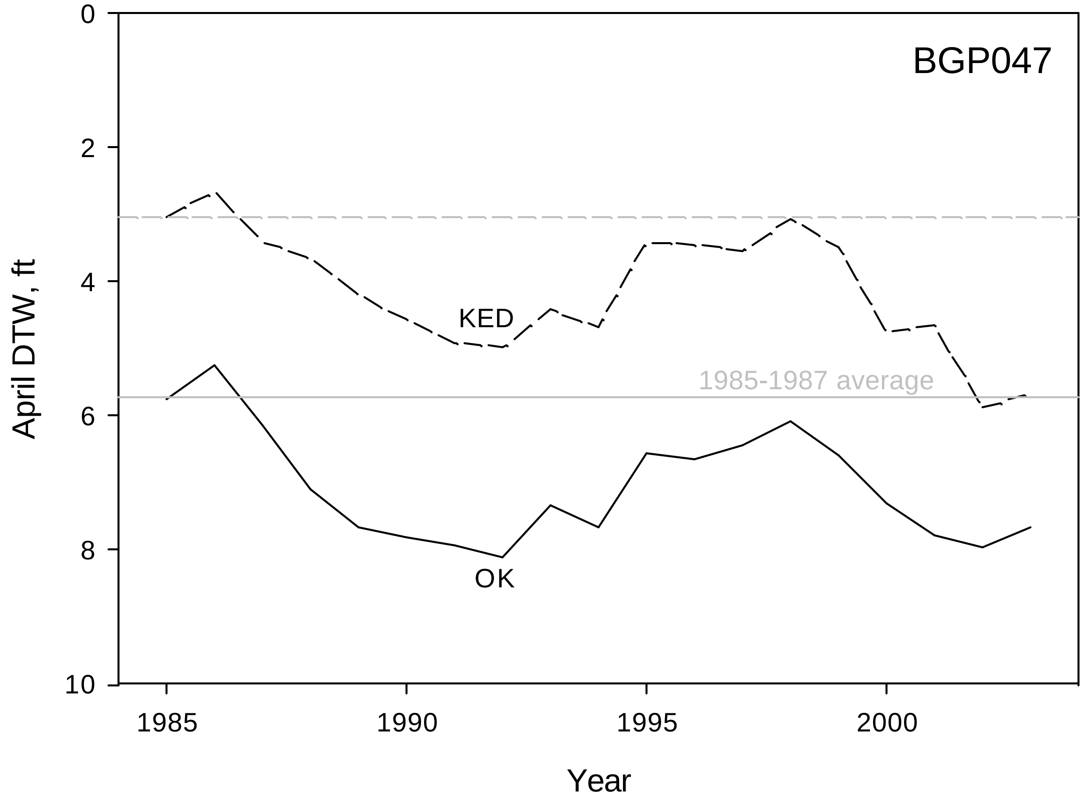
Appendix I contains hydrographs of April depth-to-water (DTW) for reinventoried vegetation parcels. Baseline is defined as the average April DTW for 1985 through 1987. OK indicates hydrographs modeled using ordinary kriging; KED indicates hydrographs modeled using kriging with an external drift. Figure captions discuss the reliability of the hydrographs. See Appendix II for a summary of the usefulness of the hydrographs for estimating baseline, relative recovery to baseline, and 2002 DTW.



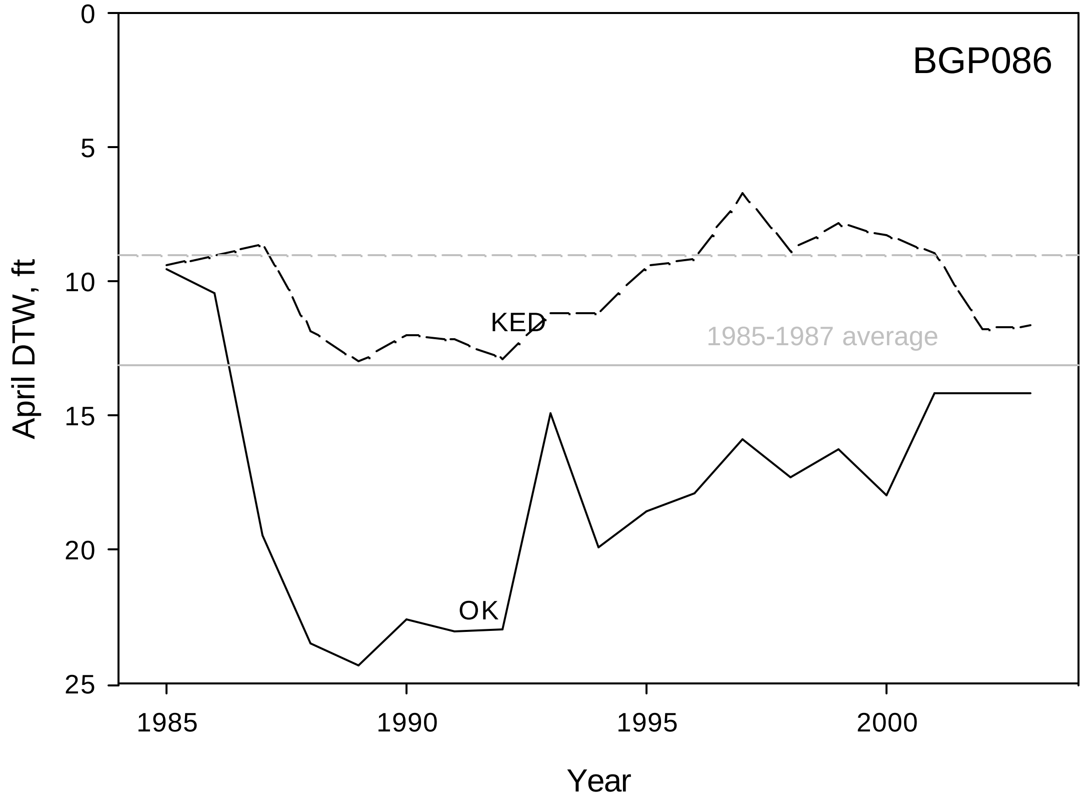
BGP013. KED and OK have similar patterns, stepping up ~4 ft in 1991 due to the appearance of 478AT in the record in 1992. The resulting hydrographs are not consistent with the combined hydrographs of 478T and 478AT. The estimates of baseline and relative recovery are unreliable. The parcel receives tailwater from the west, so 478AT may not be representative of the parcel.



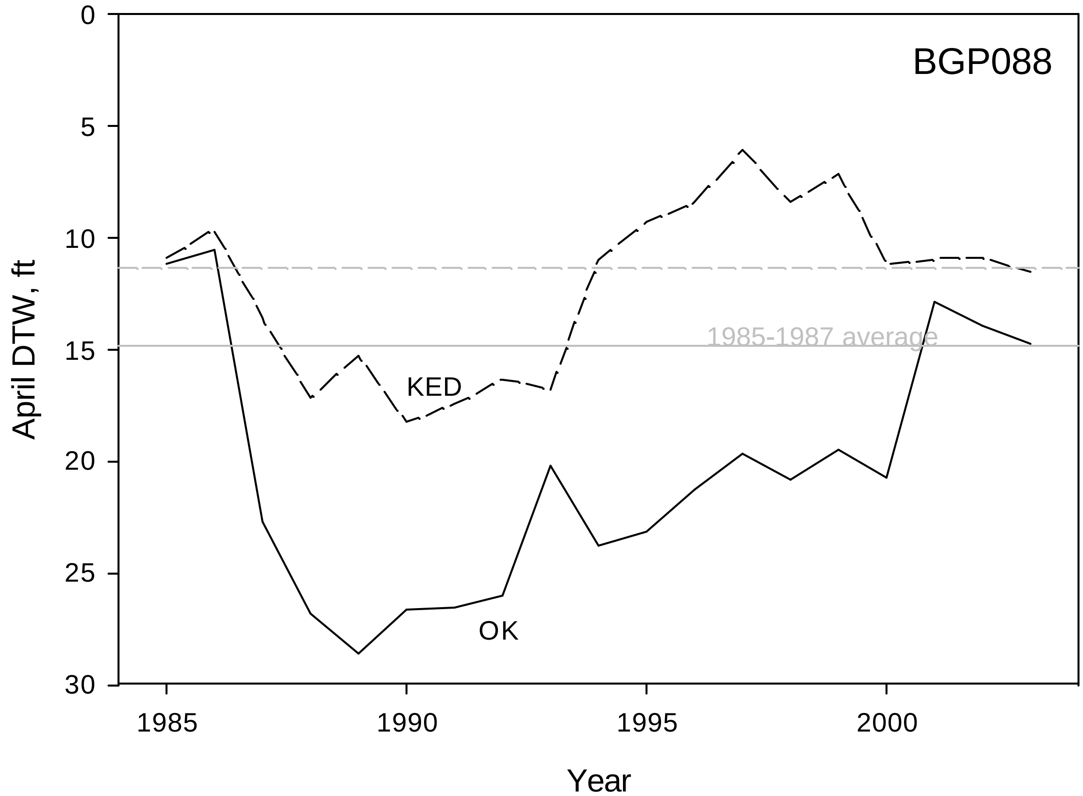
BGP031. KED is ~2 ft deeper than OK prior to 1992; both hydrographs coincide thereafter. The OK hydrograph is consistent with 474T, indicating that the OK hydrograph provides a reasonable assessment of baseline and relative recovery, but due to sparse well coverage, actual 2003 DTW is uncertain.



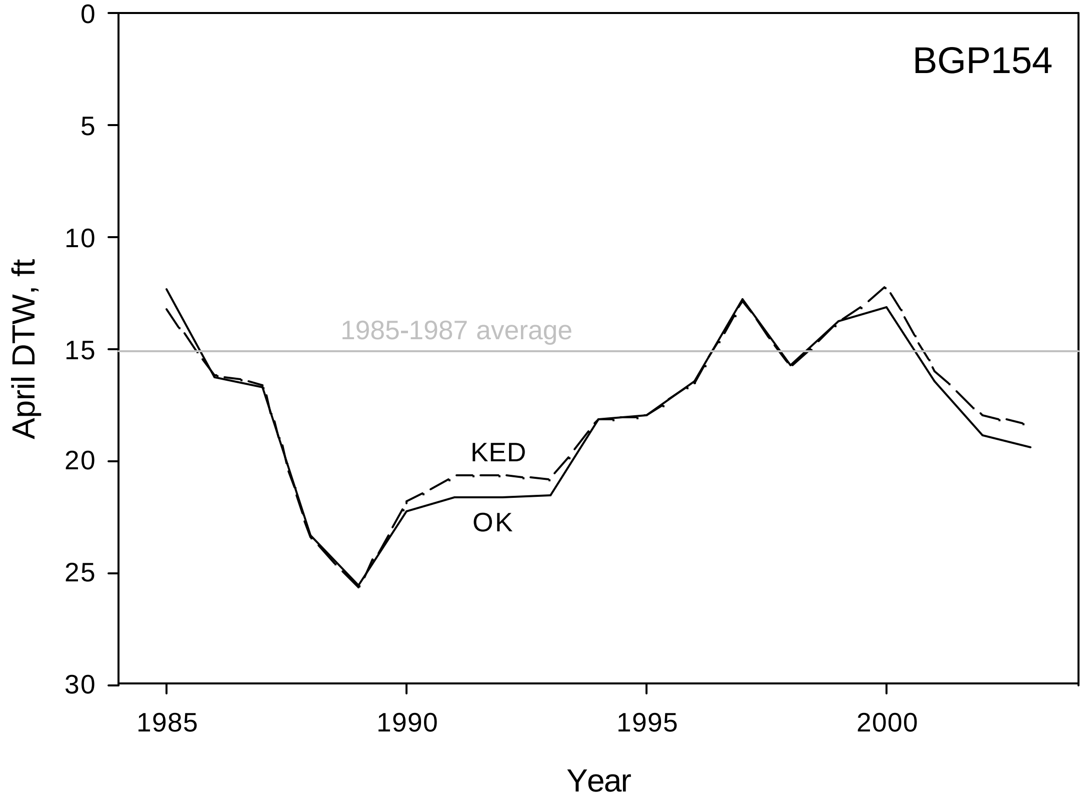
BGP047. The well network around this parcel is sparse. The kriged hydrographs are parallel, but KED is ~3 ft shallower that OK. The parcel lies in the northeasterly continuation of the fault-bounded sag that forms Klondike Lake. The hydrographs are consistent with 473T and 474T. Due to the parcel's low-lying situation, it is likely that the KED hydrograph is the more accurate. The KED hydrograph provides a reasonable estimate of baseline, relative recovery, and 2002 DTW.



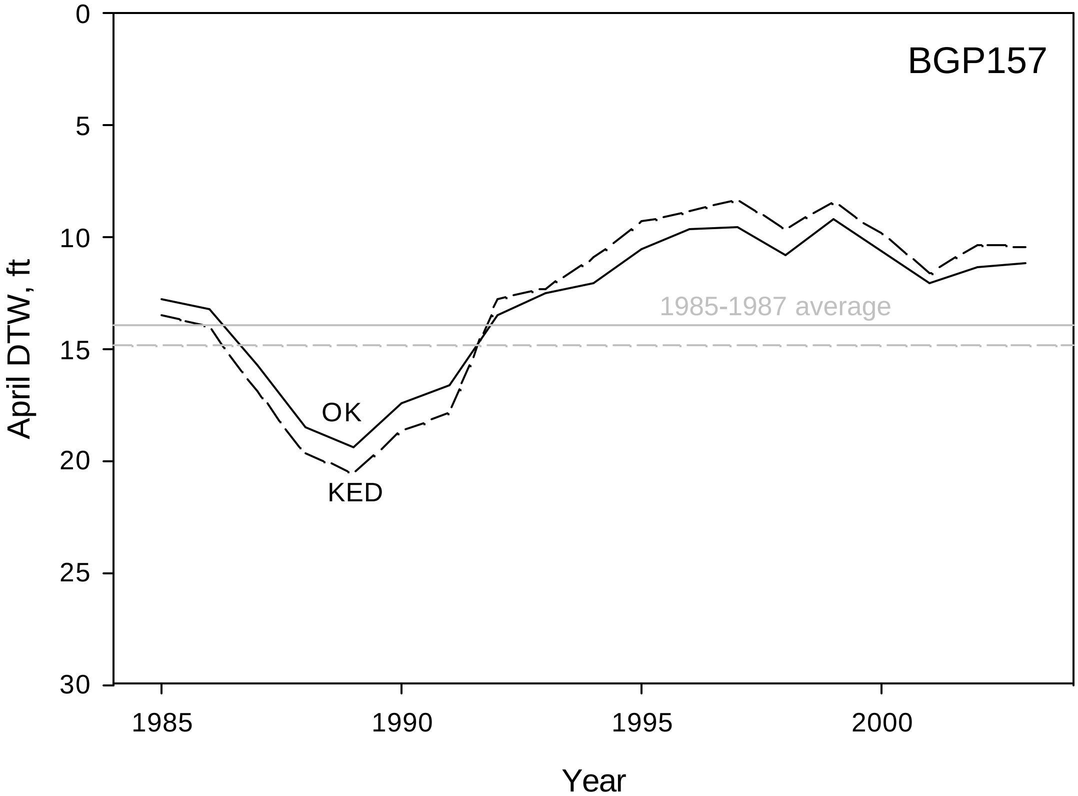
BGP086. The well network around this parcel was sparse prior to the installation of 843T in 2001, and DTW likely along the parcel-axis as it slopes to the Owens River. KED and OK hydrographs are quite different, with OK showing much greater drawdown during the early-1990's and an anomaly due to the intermittency of 686T in the OK data set is present in the OK hydrograph during 1993. The advent of 843T results in a decline in KED in 2002, however KED is more consistent with 428T, 429T, and 689T and is the more representative hydrograph. The sparse network extant in the 1980's indicates that the estimate of baseline by either method is questionable, however the relative recovery of the KED hydrograph is reasonable and the best estimate of the water table history of this parcel. The estimated DTW for 2002 is reasonable, as 843T is situated so as to capture the mean condition of the parcel.



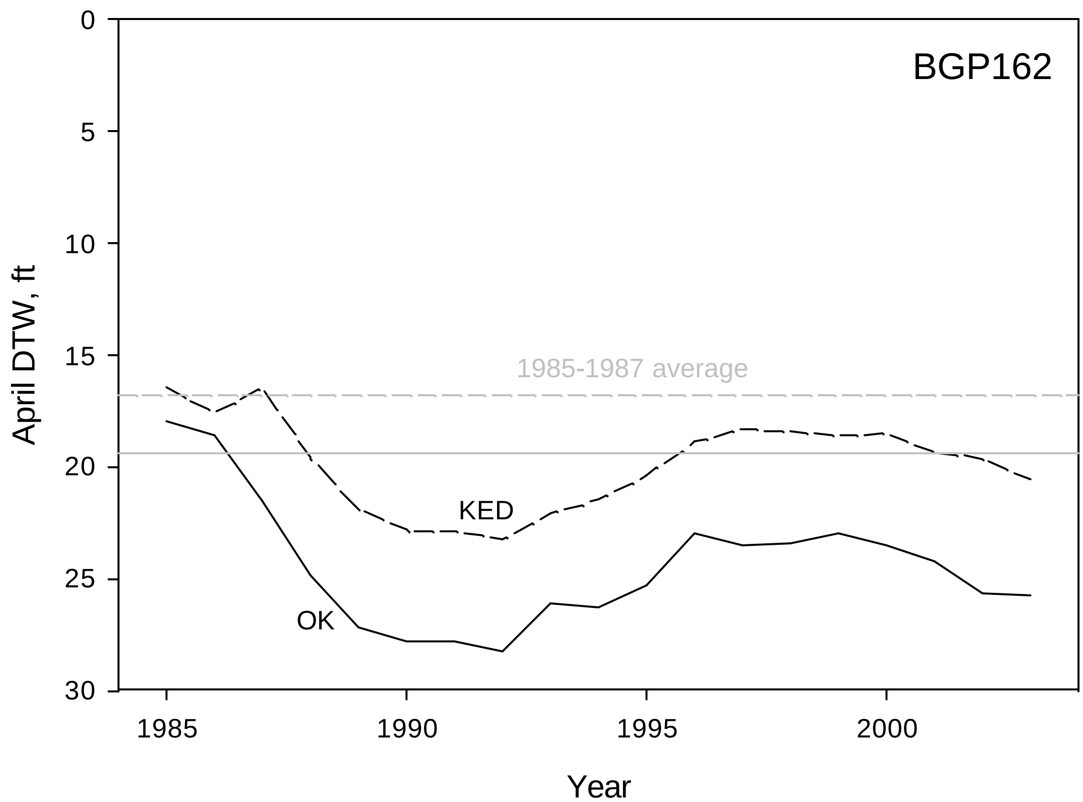
BGP088. The KED and OK hydrgraphs for this parcel are quite different. KED corresponds with 572T better than OK does. OK has an anomaly in 1993 due to the absence of 686T from the OK data set that year, and a sharp rise in 2001 due to the appearance of 843T in the data set. KED has a sharp decline in 2001, again due to the appearance of 843T. KED and OK provide similar baselines, but neither appears to provide a reliable hydrograph.



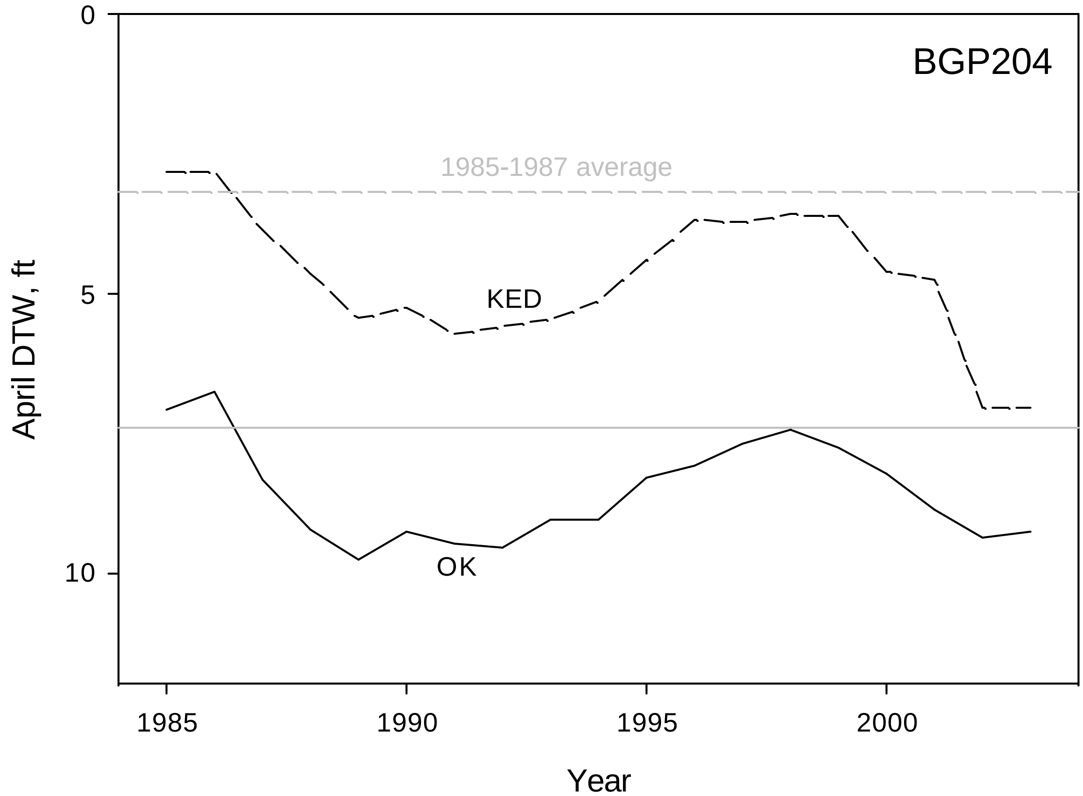
BGP154. KED and OK hydrographs are similar and consistent with 572T but 1-2 ft lower. The estimated 1985 water level may be too shallow, as wells 687T and 688T enter the record in 1986. Though several wells have been constructed in the area post-baseline, the kriged baseline, relative recovery, and recent DTW appear reliable.



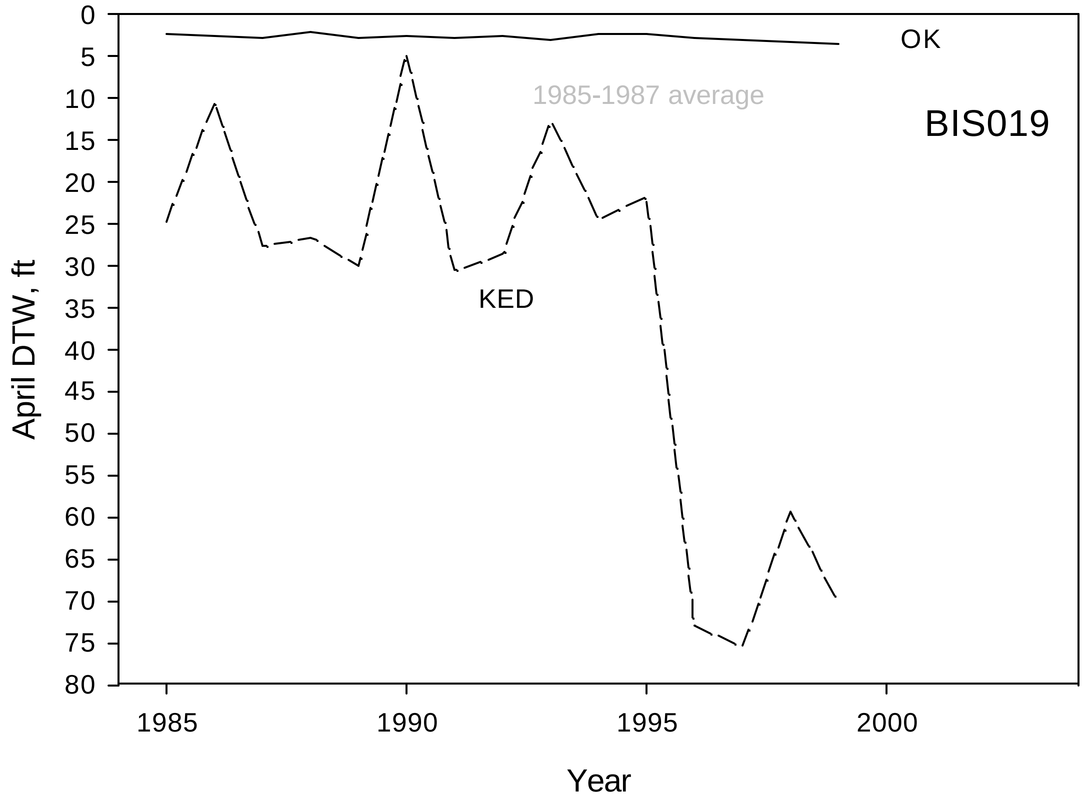
BGP157. KED and OK hydrographs are similar and consistent with wells 428T and 429T. Baseline, relative recovery, and 2003 DTW are reliable for both hydrographs.



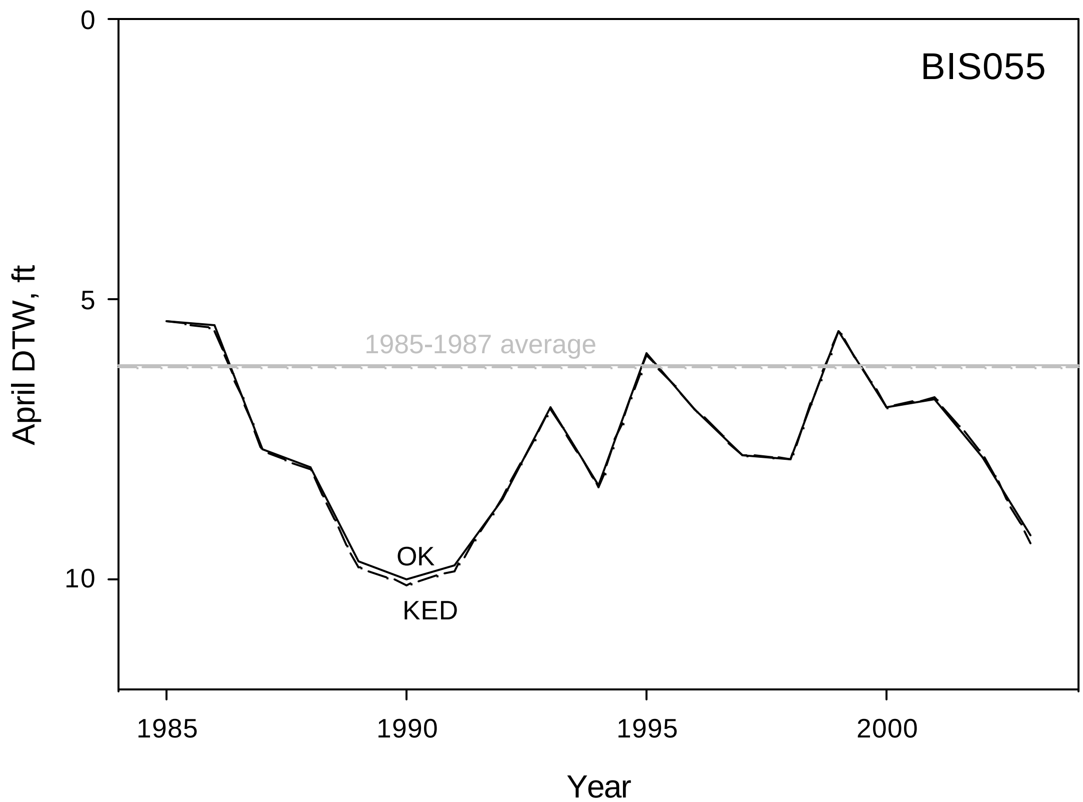
BGP162. This large parcel contains both Owens River flood plain and older terraces, has over 40 ft of topographic relief, is adjacent to irrigated areas, is the location of two production wells, and has adjacent irrigation to the west, thus DTW is expected to range widely within this parcel. KED and OK are parallel with KED ~1-5 ft shallower than OK. KED shows more relative recovery, which is consistent with V014GC and 571T. KED provides a reasonable baseline, relative recovery, and mean DTW for this parcel, though DTW undoubtedly is variable within this parcel.



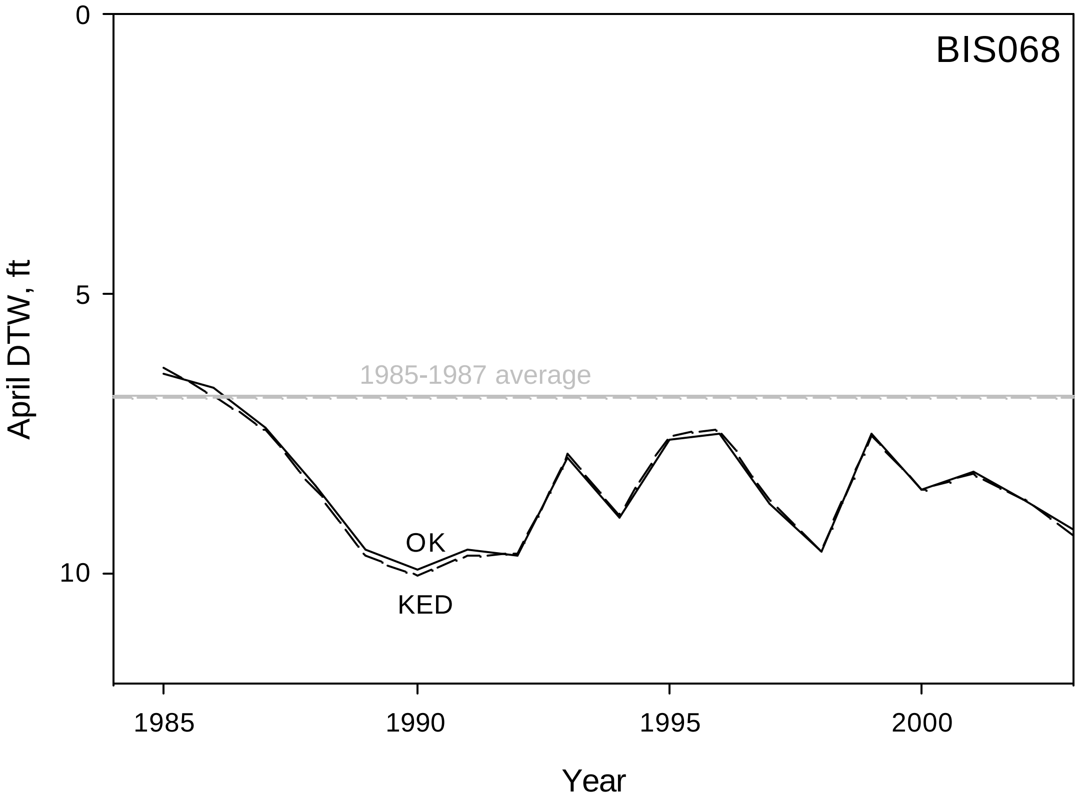
BGP204 and BGP205. Well coverage for these parcels is poor and the Owens River lies between the nearest test well and the parcels. KED and OK hydrographs are parallel with KED ~3 ft shallower than OK. Baseline, relative recovery, and recent DTW are unreliable for these parcels.



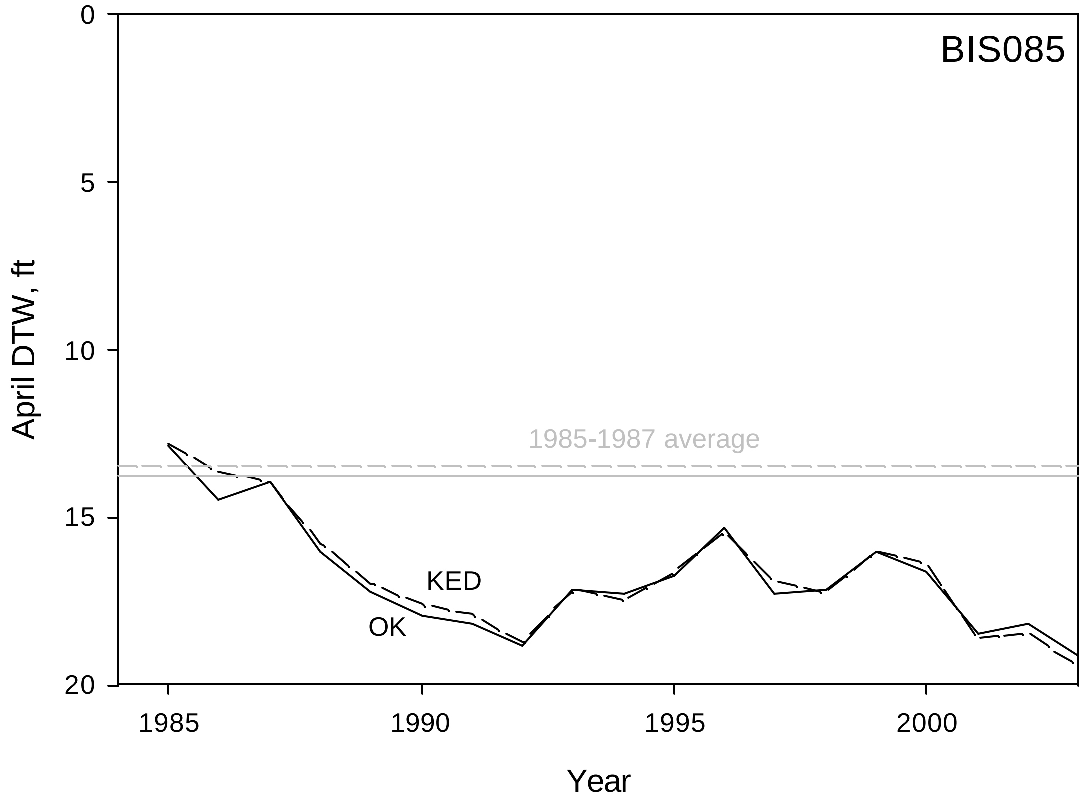
BIS019. The hydrographs for this parcel are unusable due to its poor well coverage. Note the instability of KED in extrapolation.



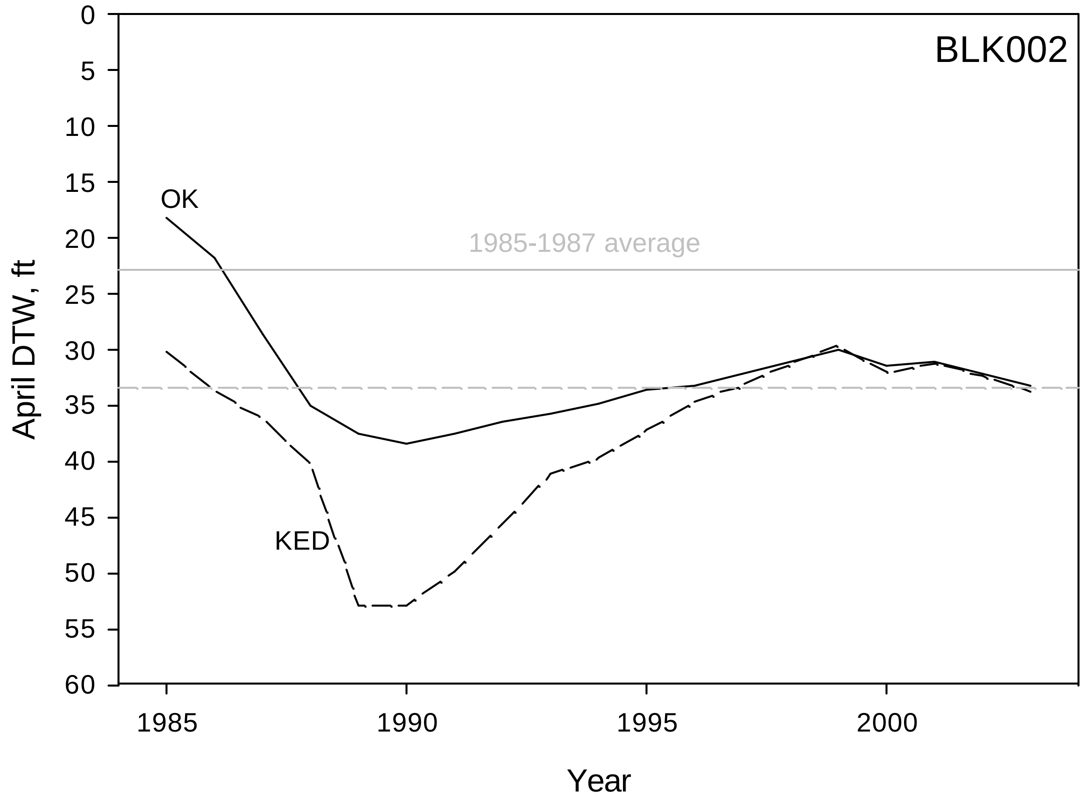
BIS055. KED and OK hydrographs are congruent and consistent with 304AT and 202V. The hydrographs provide a reasonable estimate of baseline, relative recovery, and recent DTW. The trend from shallower to deeper water table easterly across the parcel is consistent with the location of the parcel being bounded on the west by the Bishop Creek Canal.



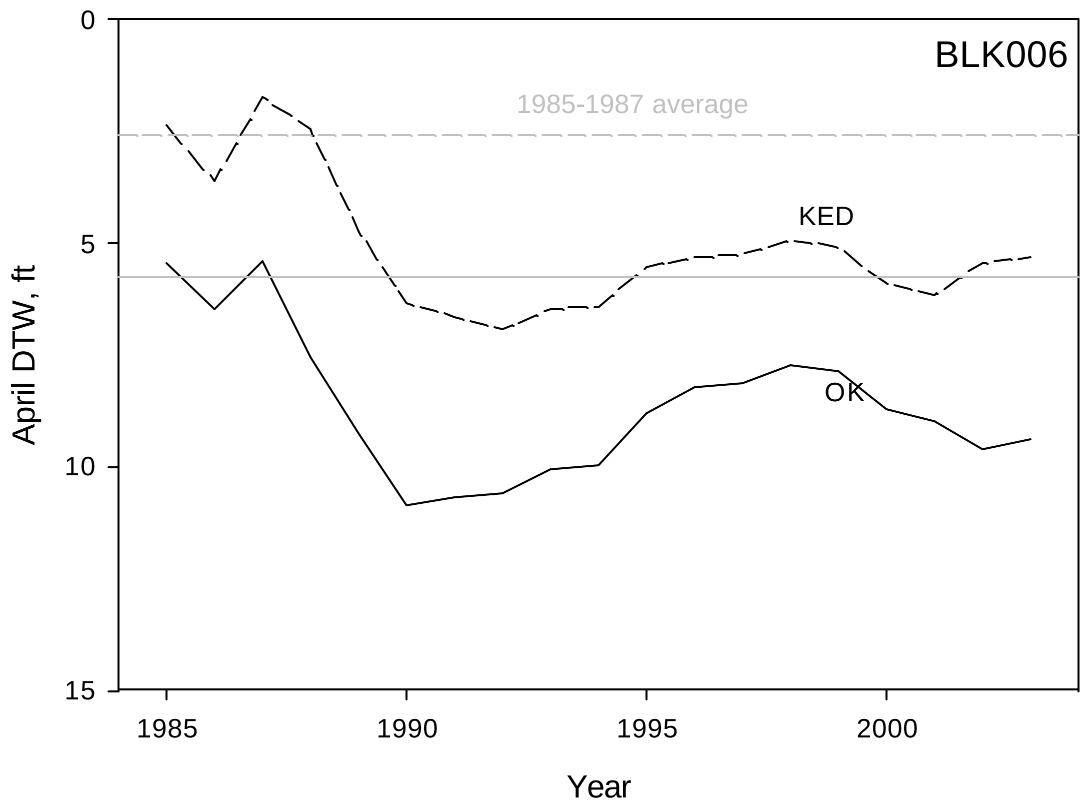
BIS068. KED and OK provide congruent hydrographs that are consistent with wells 432T and 499T, indicating that the hydrographs provide a reliable estimate of baseline, relative recovery, and 2003 DTW in the parcel.



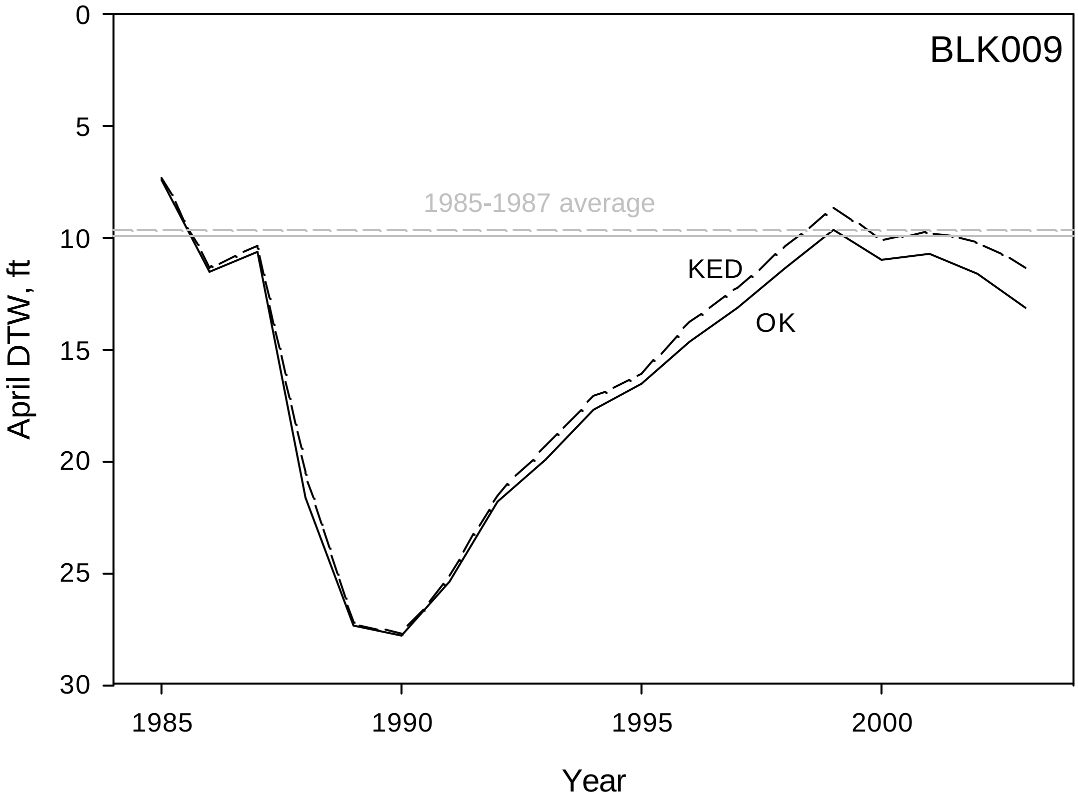
BIS085. KED and OK hydrographs are nearly congruent and consistent with 430T. Baseline, relative recovery, and DTW are reliable.



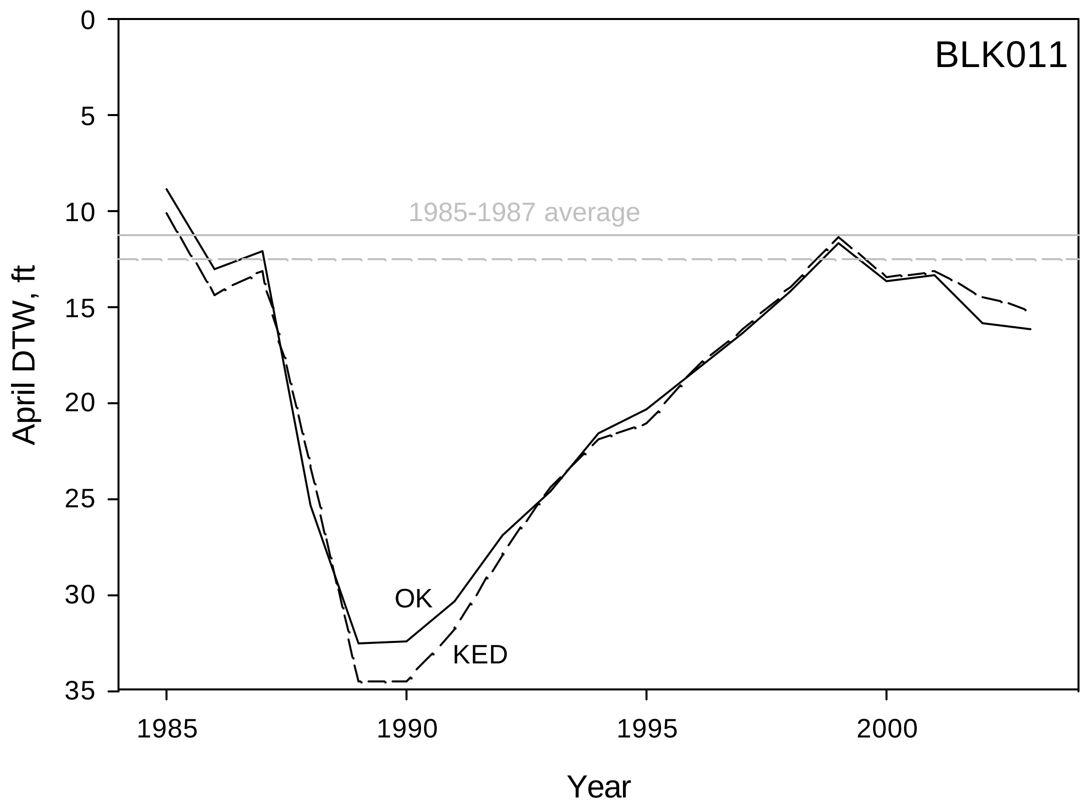
BLK002. KED and OK are different, with OK providing a shallower baseline and less relative recovery. Both hydrgraphs converge after 1998. Well 671T enters the kriging data set in 1995 and wells 801T and 802T enter the record in 1988. The difference between KED and OK appears related to the addition of these wells to the record post-baseline. Based on comparison with 421T, actual relative recovery has probably been less than KED and greater than OK. The shallowness of the OK baseline is due to the influence of 420T, which is located downslope near the Owens River. 421T is undoubtedly more representative of the parcel, therefore the KED baseline is more reliable, but relative recovery must still be considered uncertain because of the changes in well configuration since baseline.



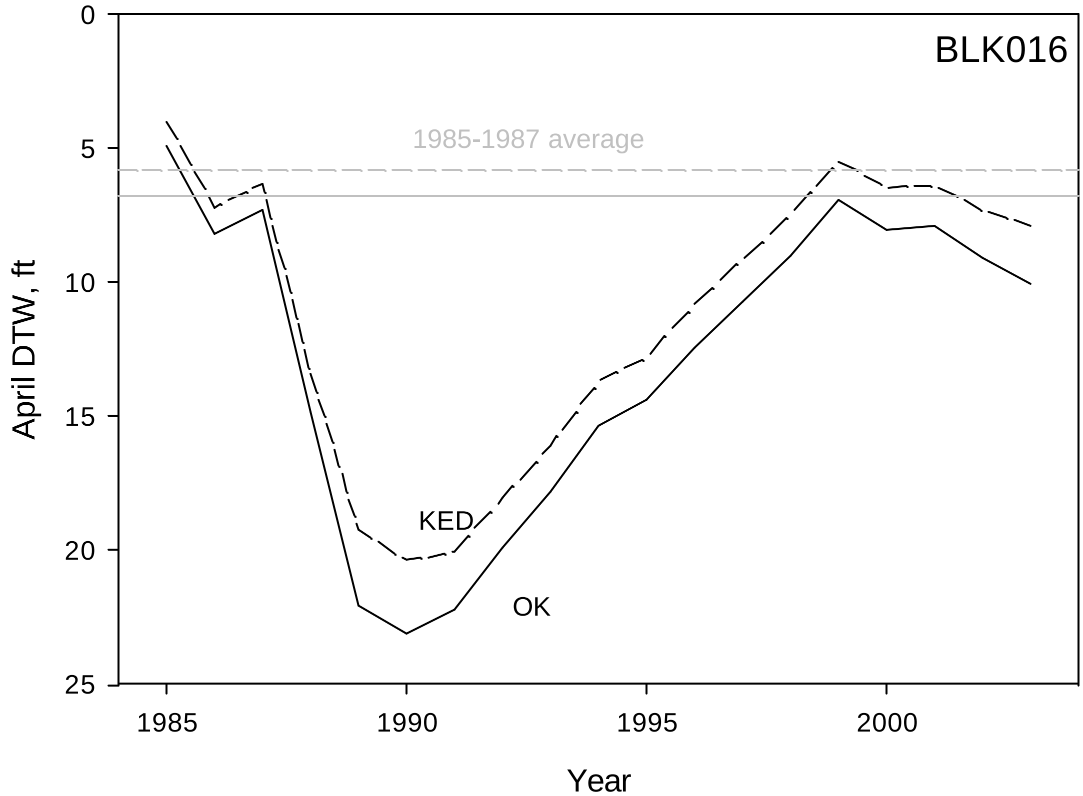
BLK006. KED and OK are parallel, with KED ~3 ft shallower. KED's shallower aspect is probably because most of the parcel lies at lower elevation than 420T, so interpolation of WTE results in a shallower water table than interpolation of DTW. The two hydrographs diverge in 2002, probably due to the addition of 846T to the data set. KED's apparent recovery in 2002 is an artifact of the addition of 846T. OK is similar to 420T. OK baseline, relative recovery, and DTW are reliable.



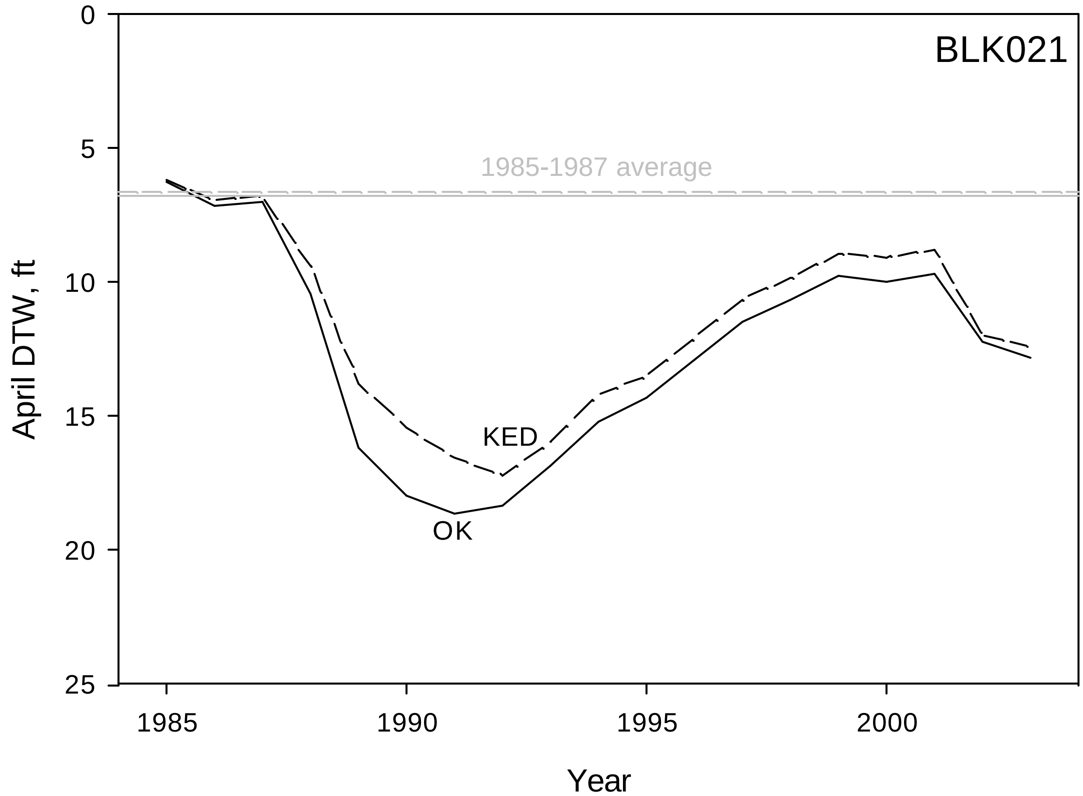
BLK009. KED and OK are nearly congruent, and consistent with 504T and 586T. Both methods produce reliable baseline, relative recovery, and DTW.



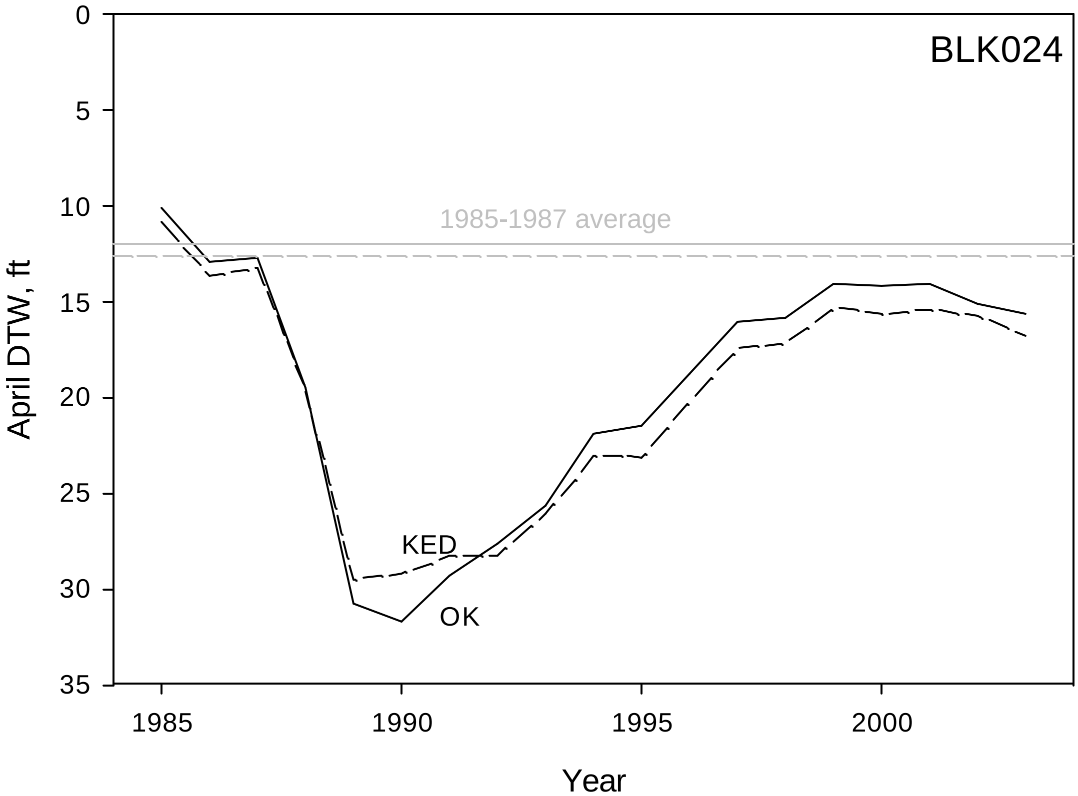
BLK011. KED and OK are nearly congruent, and consistent with 504T and 586T. The greater decline in OK in 2002 is due to the addition of 847T. Both KED and OK produce reliable baseline, relative recovery, and DTW.



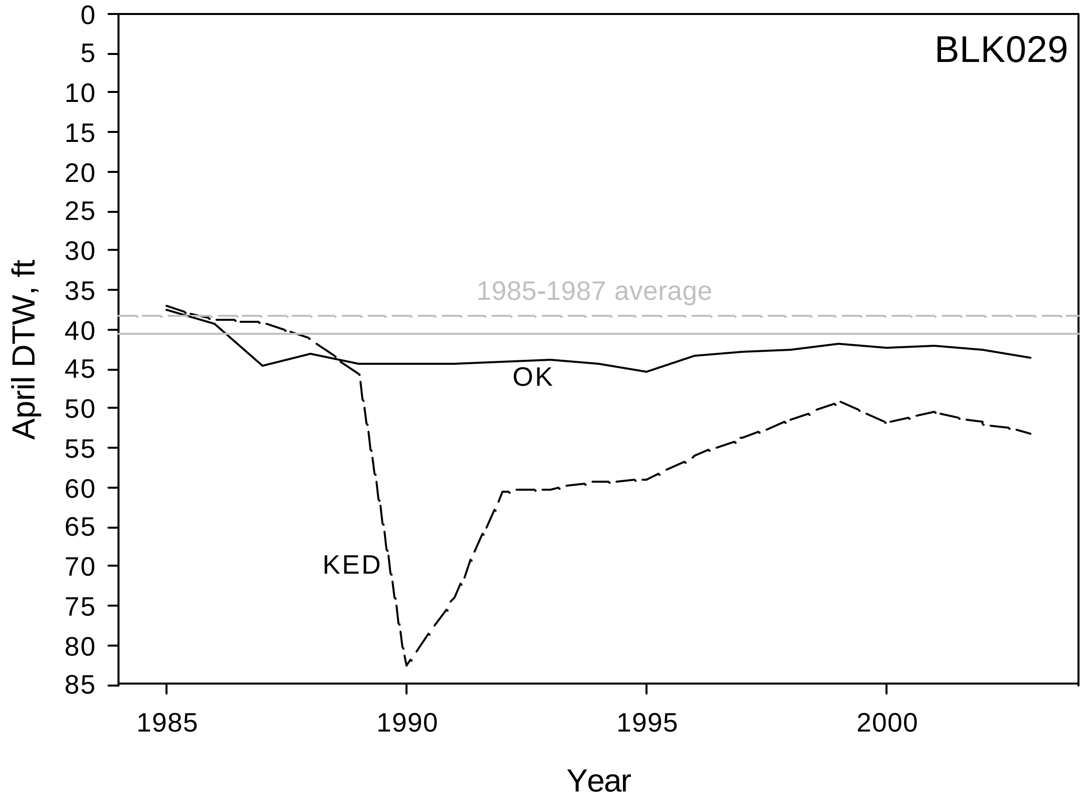
BLK016. KED and OK are parallel with KED ~1 ft shallower. Both hydrographs are consistent with 418T, 419T, and 586T. Either method produces reliable estimates of baseline, relative recovery, and DTW.



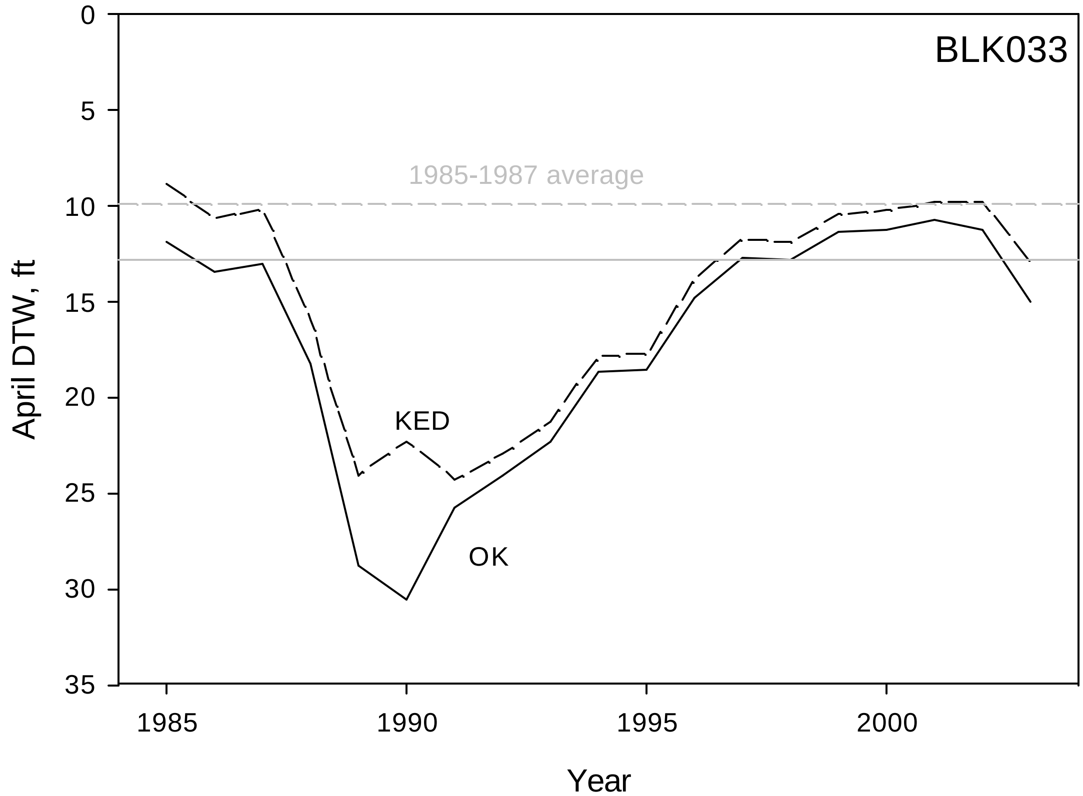
BLK021. KED and OK produce similar baselines and 2002 water levels, but during the rest of the period KED is 1-3 ft shallower. Both hydrographs are consistent with 418T, 455T, and 585T up until 2002, when they decline anomalously due to the addition of 848T to the record. Relative recovery is probably well rendered by both hydrographs, however it is likely that the actual baseline and DTW is deeper than given in the 1985-2001 hydrograph.



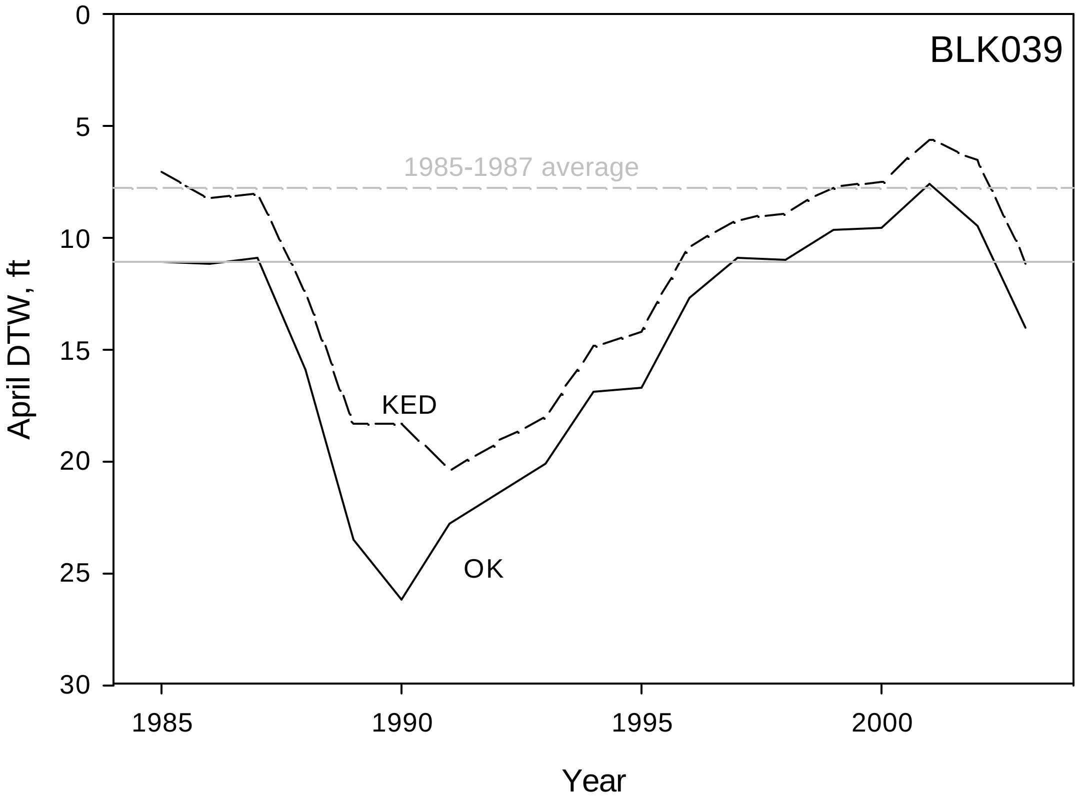
BLK024. KED and OK are similar, and consistent with 505T, 585T, 803T, and 849T. The absence of an anomaly in 2002 due to the addition of 849T indicates that the hydrographs are robust throughout the modeling period. Both methods produce reliable baseline, relative recovery, and DTW.



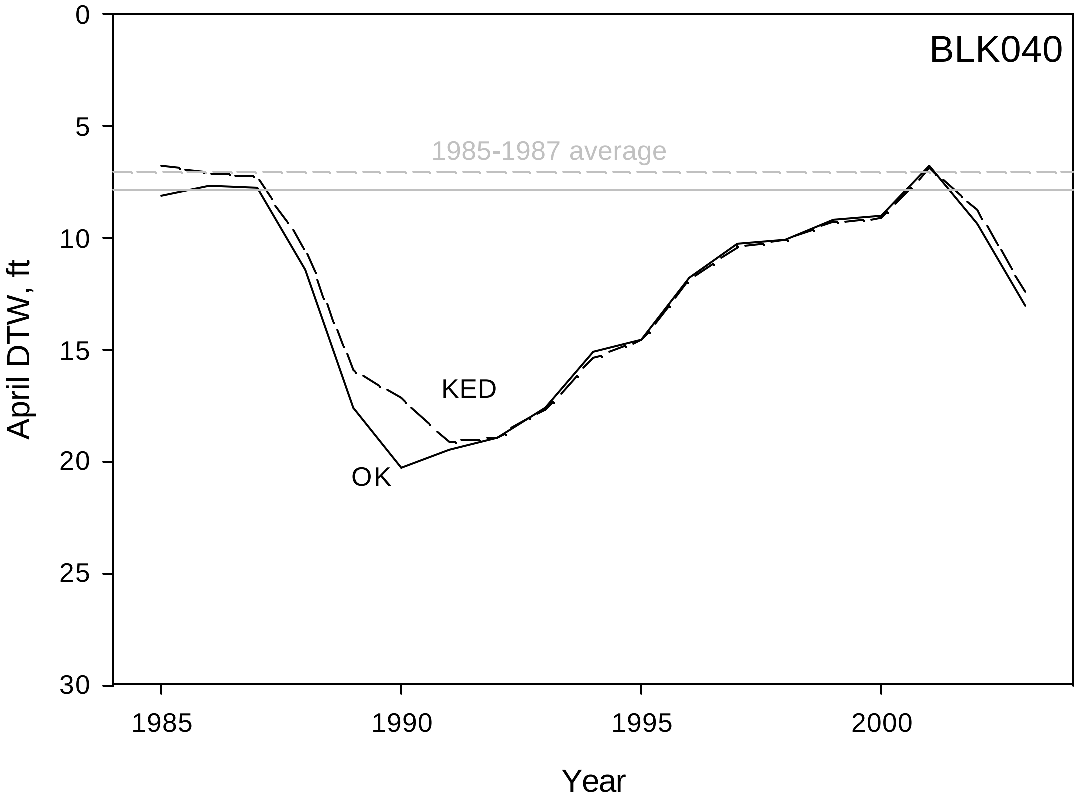
BLK029. KED and OK are drastically different; well coverage is poor both spatially and temporally. Neither hydrograph is reliable.



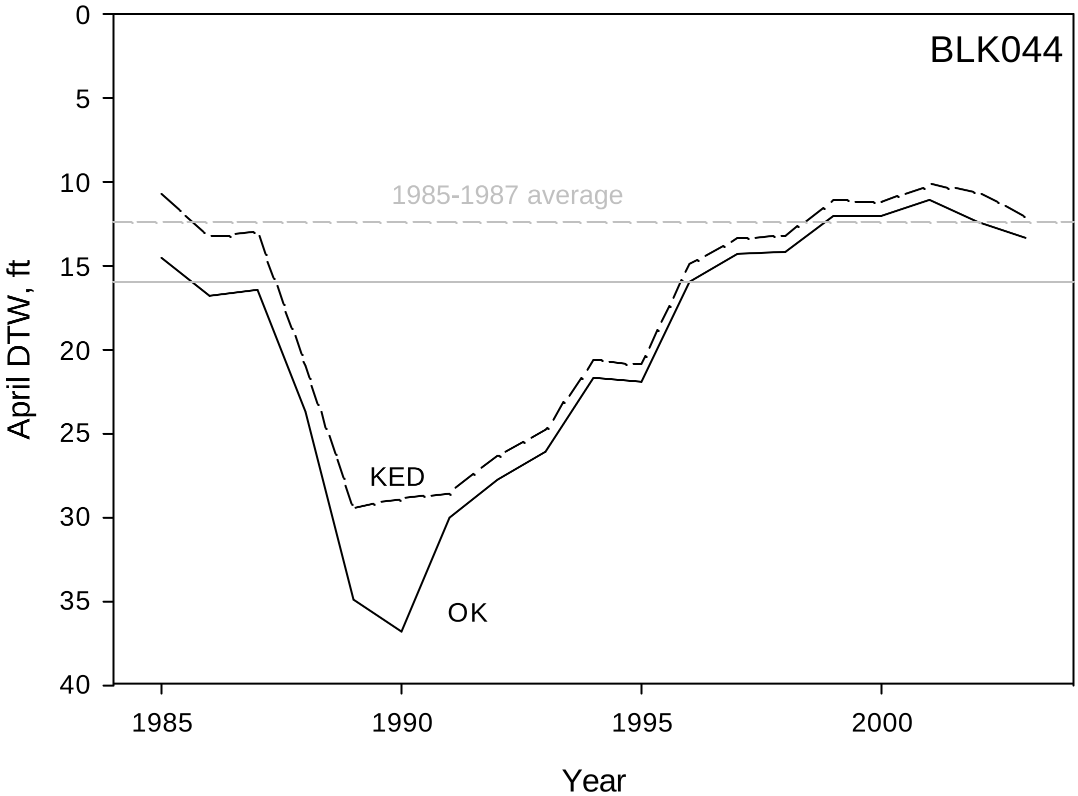
BLK033. KED and OK are parallel with KED 1-3 ft shallower, except during 1989-1991 when KED is 6-8 ft shallower. Both KED and OK show more relative recovery to baseline than 417T or 505T, probably due to 803T. 803T was dry until 1992, which resulted in it entering into the KED data set in 1989 and the OK data set in 1991, based on the jackknife results for dry wells for each method. Both methods probably estimate too much relative recovery to baseline, and the decline in 2003 is an artifact of missing data for 417T and 455T.



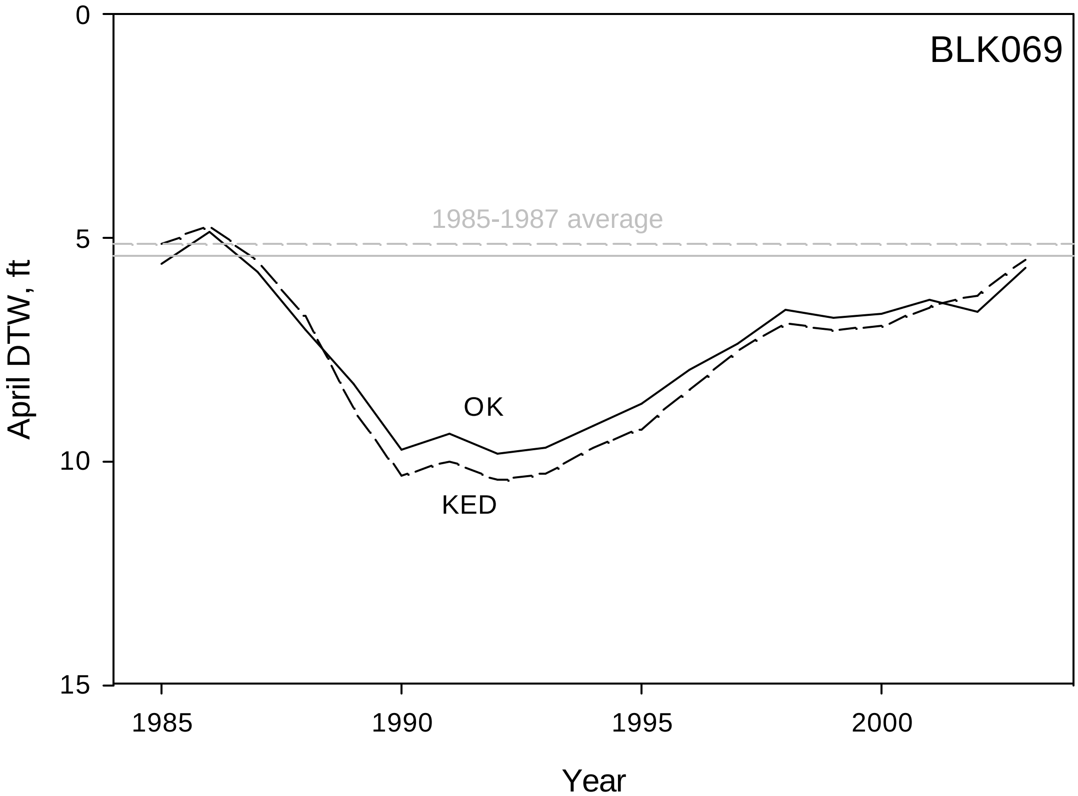
BLK039. KED and OK are parallel with KED 3-5 ft shallower than OK. Relative recovery is greater than 455T and 505T due to entry of 803T into the kriging data set. Relative recovery of both methods is too great, and 2003 DTW is probably unreliable to the absence of 417T and 455T in the data set.



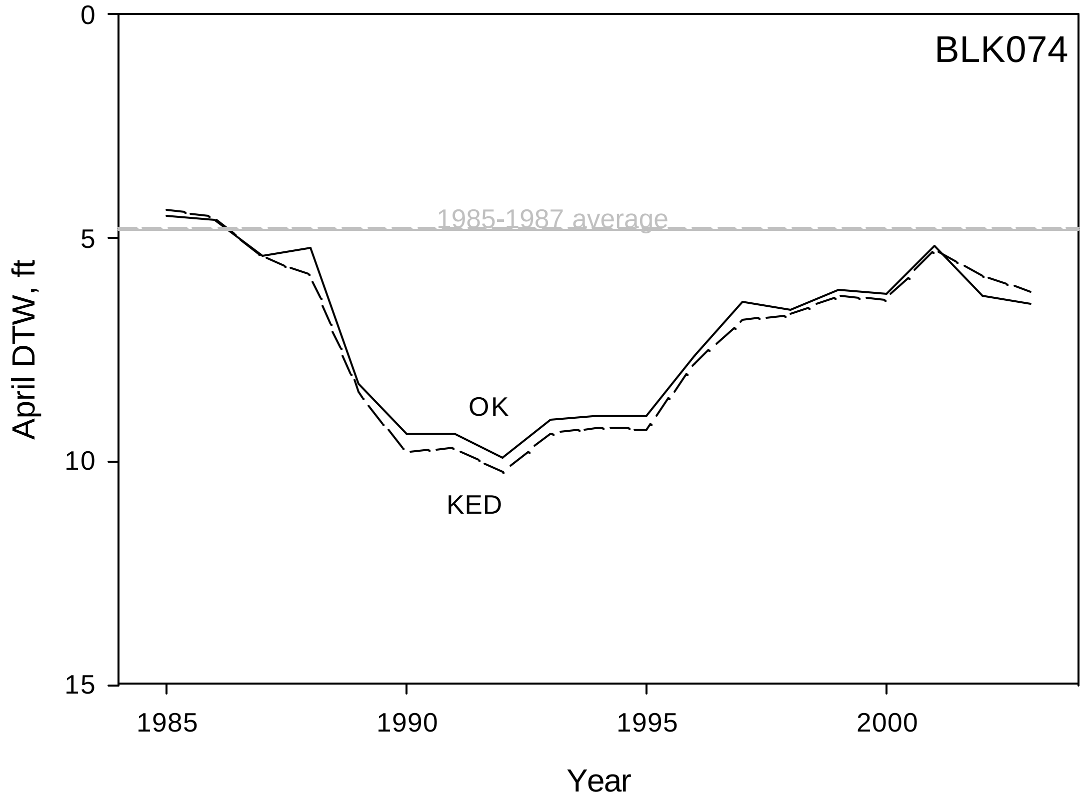
BLK040. KED and OK are similar, especially after 1992 when they are nearly congruent. Relative recovery to baseline is overestimated compared to 455T and V006G, similar to BLK033 and BLK039, but 2003 DTW is unreliable due to the absence of data for 417T and 455T.



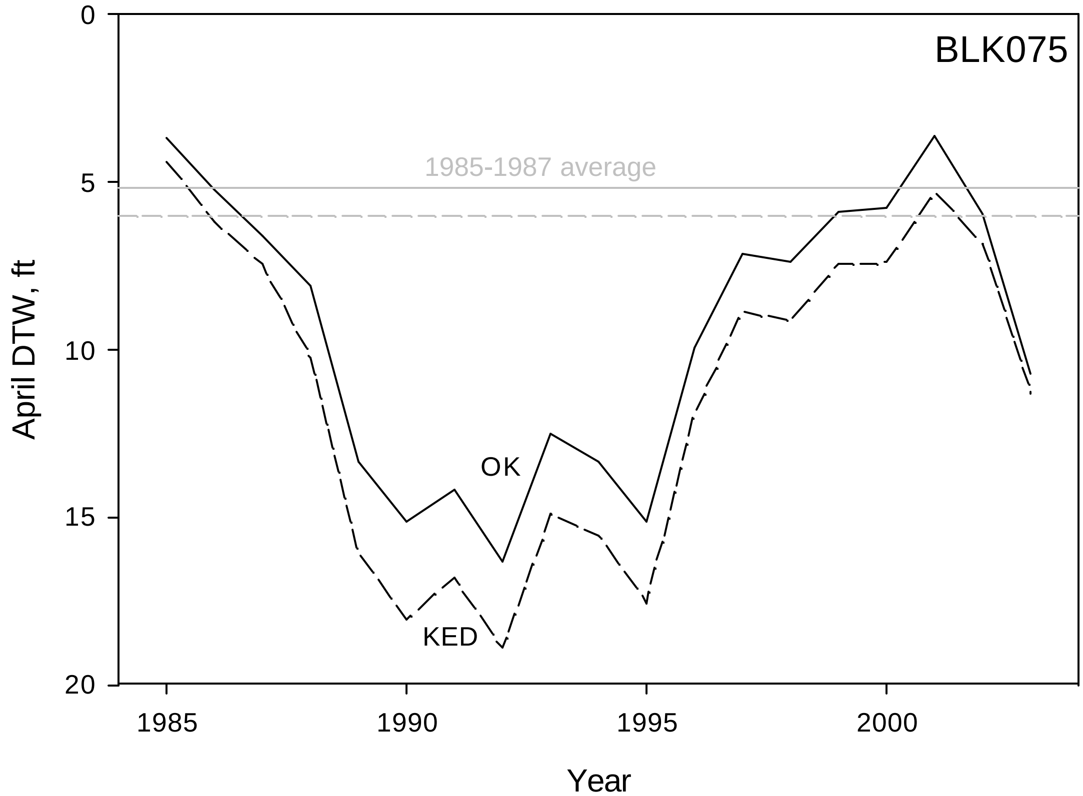
BLK044. Similar comments to BLK033, BLK039, and BLK040.



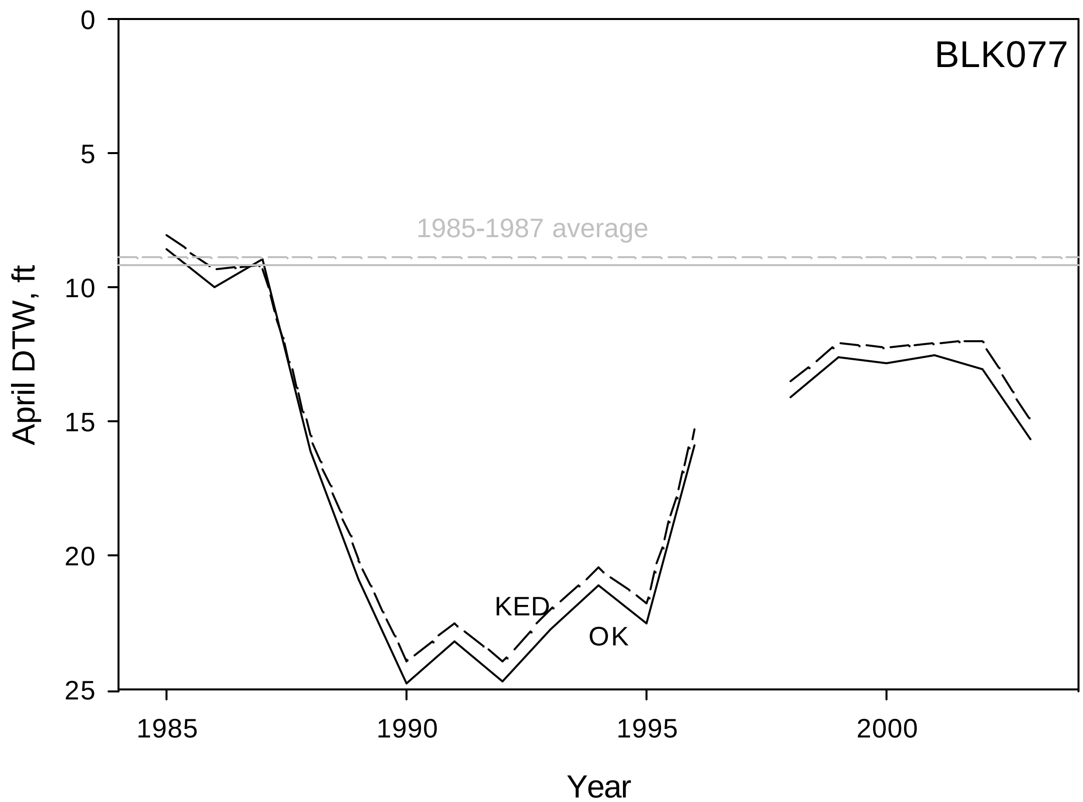
BLK069. KED and OK are nearly congruent and consistent with 507T and 584T. Baseline, relative recovery, and DTW are reliable best estimates.



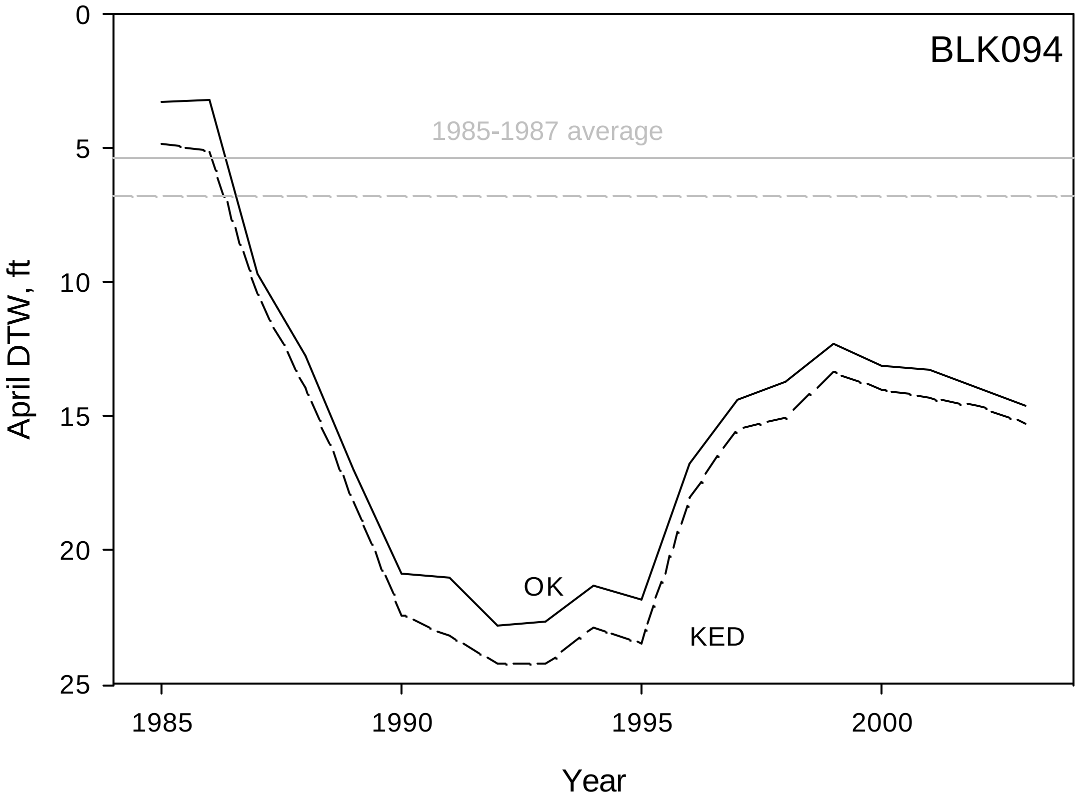
BLK074. KED and OK are nearly congruent and consistent with 507T. Baseline, relative recovery, and DTW are reliable.



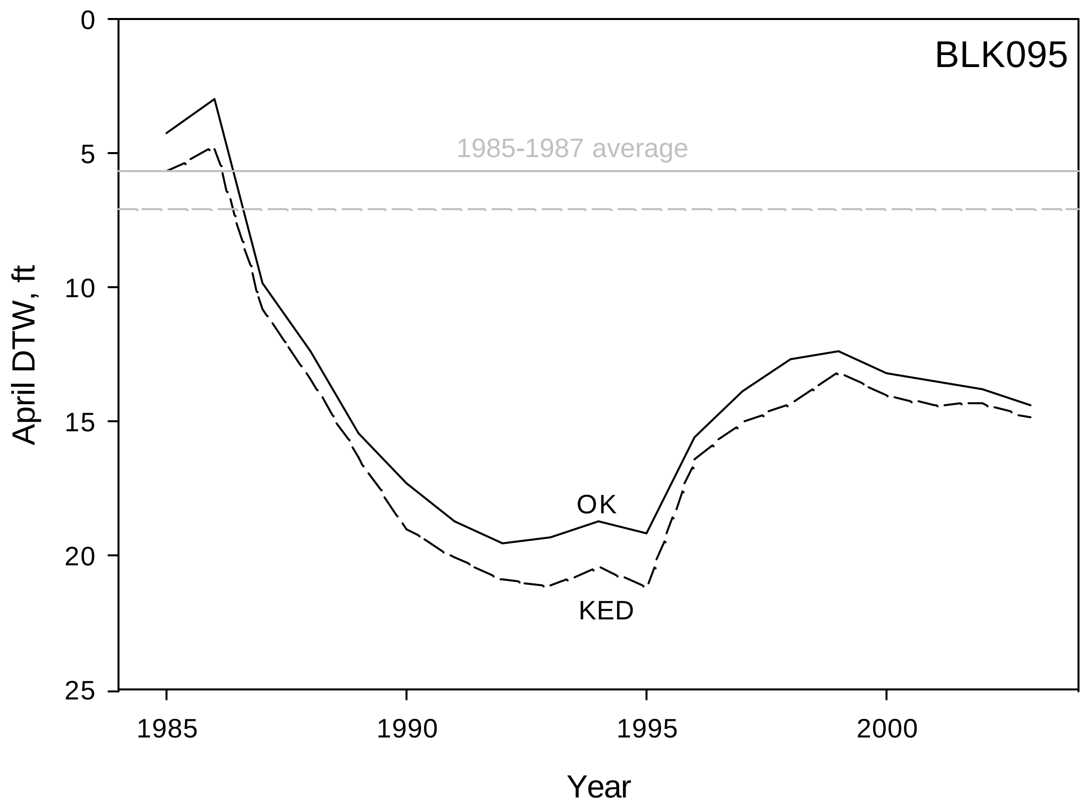
BLK075. KED and OK are parallel with OK 1-2 ft shallower than KED. Relative recovery for both KED and OK is consistent with 416T but greater than 506T, and it is unclear which of these wells is more representative of the parcel. The sharp drop in 2003 is due to the absence of 416T. 2003 DTW, baseline and relative recovery are unreliable.



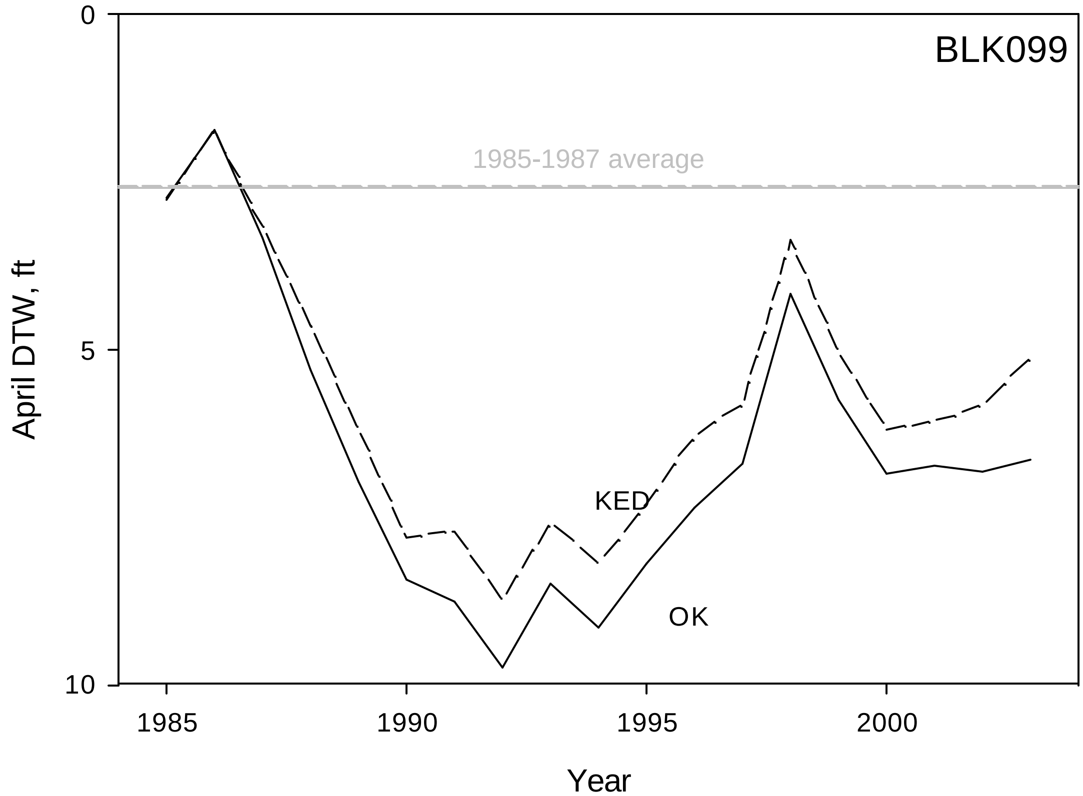
BLK077. KED and OK are nearly congruent; both have an anomaly (removed) in the record at 1997 because for well 415T the first well read for April of that year was blank due to 'County recorder on well.' Otherwise, both hydrographs are consistent with 415T. Baseline, relative recover are reliable, but recent decline is anomalous due to 416T missing from the data set.



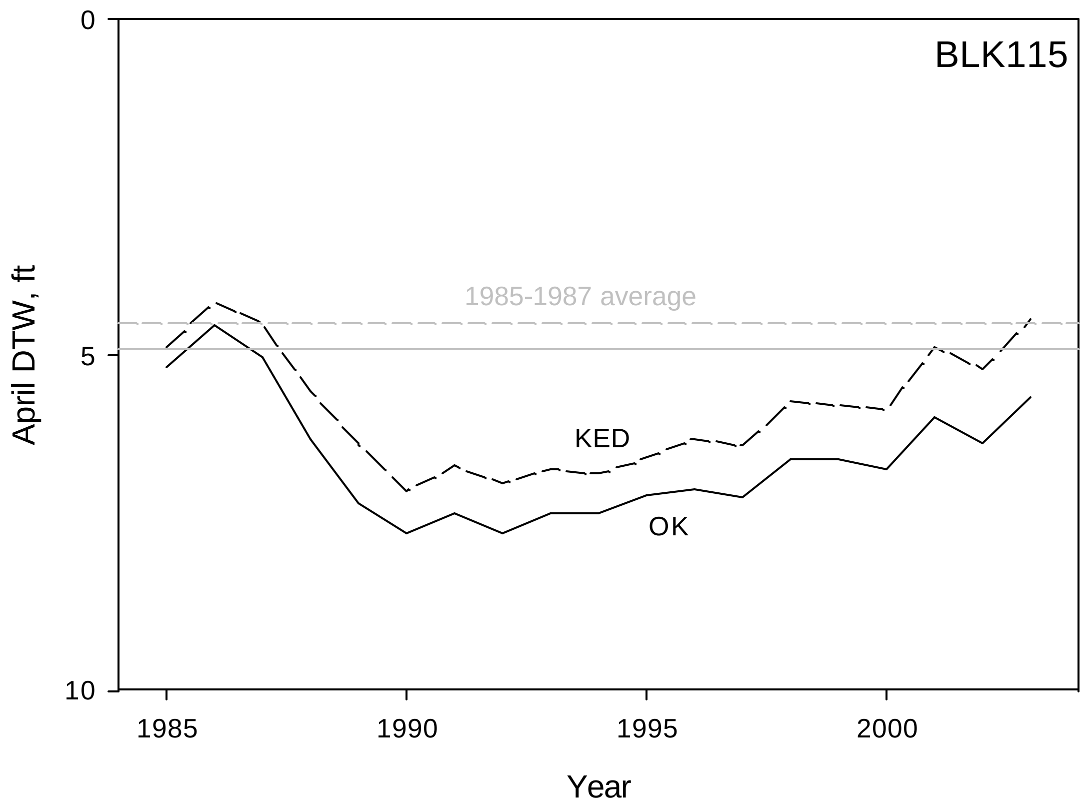
BLK094. Depth to water undoubtedly varies significantly under this parcel due to over 40 ft of relief and tail-water recharge from Eight-mile Ranch. KED and OK hydrographs are parallel with OK 1-2 ft shallower than KED. Both model hydrograph are consistent with the combined hydrographs of 582T and 806T, despite many wells having entered the record since baseline. Baseline, relative recovery, and DTW are reliable.



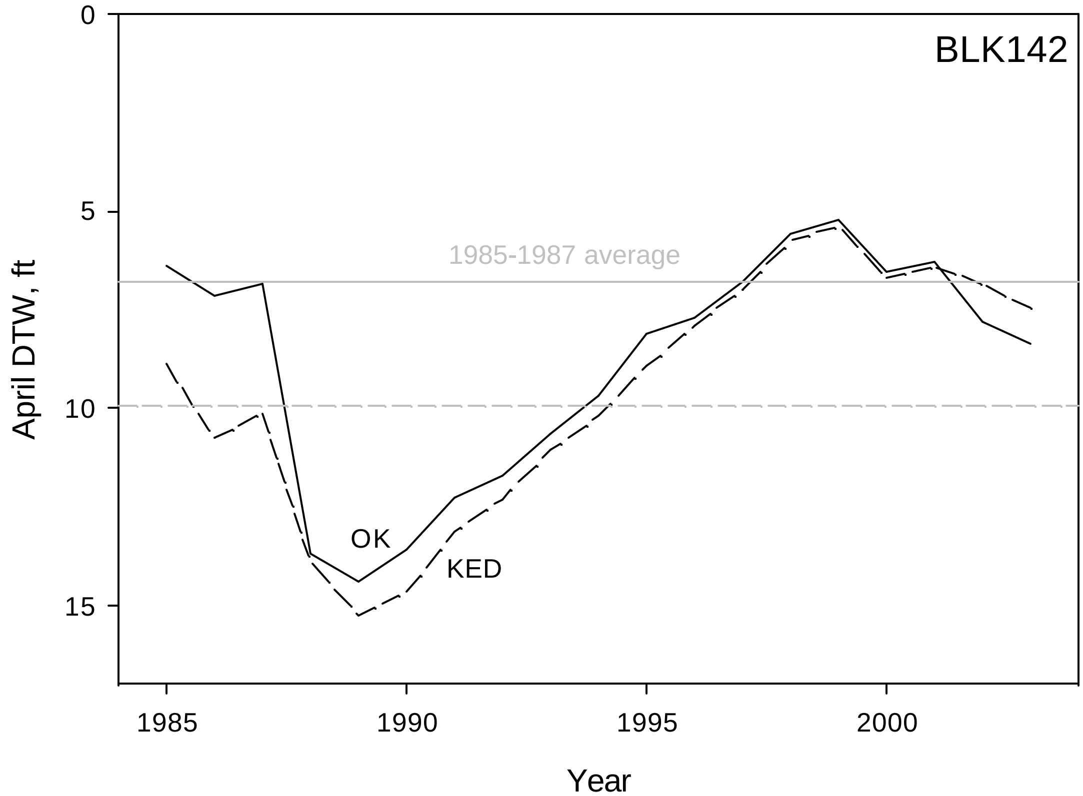
BLK095. This parcel extends across the slope break at the toe of the Thibaut-Sawmill alluvial fan to the LAA and has over 40 ft of relief, which results in variable DTW beneath the parcel. Both KED and OK are consistent with V158, but many wells have entered the record since baseline, possibly invalidating assessments of relative recovery. Baseline, relative recovery, and DTW are reliable.



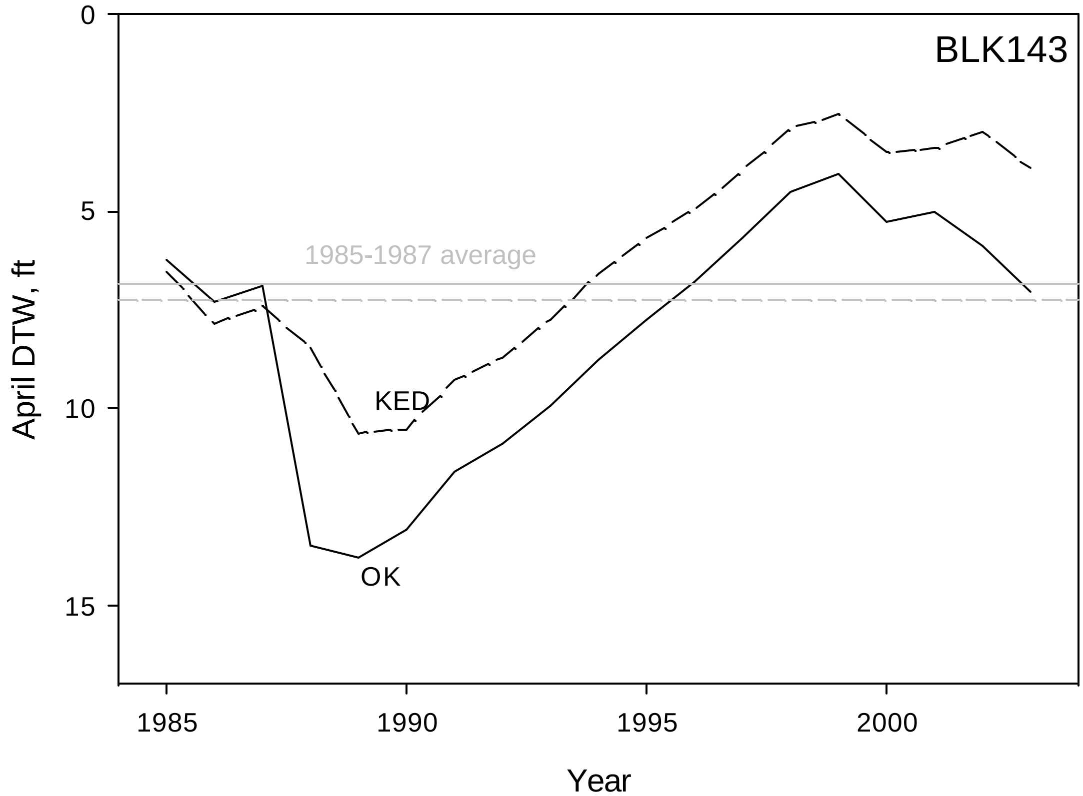
BLK099. KED and OK are parallel with KED 0-2 ft shallower than OK and are consistent with 414T and 581T. The relatively shallow water table compared to BLK094 and BLK095 reflects the lower topographic position and proximity to the LAA of this parcel. Baseline, current DTW, and the current state of relative recovery are reliable, however it is uncertain how representative the local maximum in 1998 is of the whole parcel. Extensive water spreading occurred that year in this parcel, as reflected in the hydrographs for 414T and 581T. Baseline, relative recovery, and current water levels are reliable.



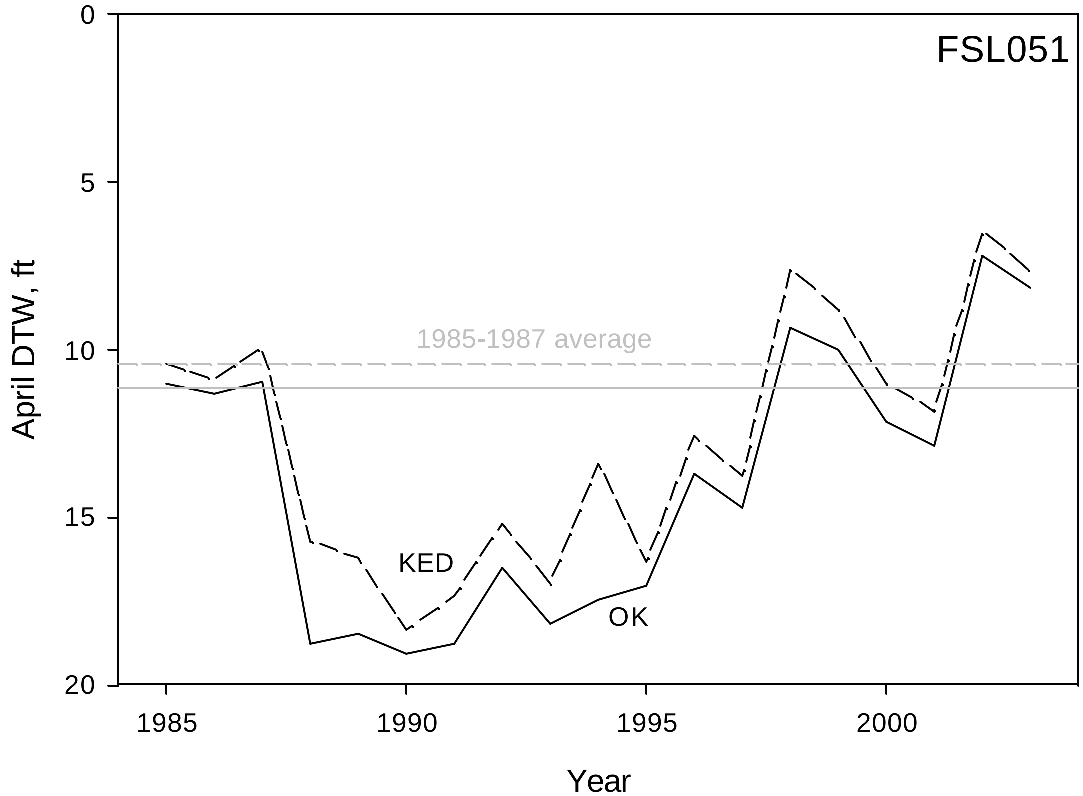
BLK115. KED and OK are parallel with KED ~1 ft shallower than OK. There are no wells near this parcel, but the well configuration stays the same throughout the modeling period. The hydrographs are consistent with 507T and 460T; 458T is more influenced by Blackrock Drain than the parcel is. Baseline and 2002 DTW may be inaccurate due to the sparse well network, but relative recovery of the OK hydrograph is probably reliable.



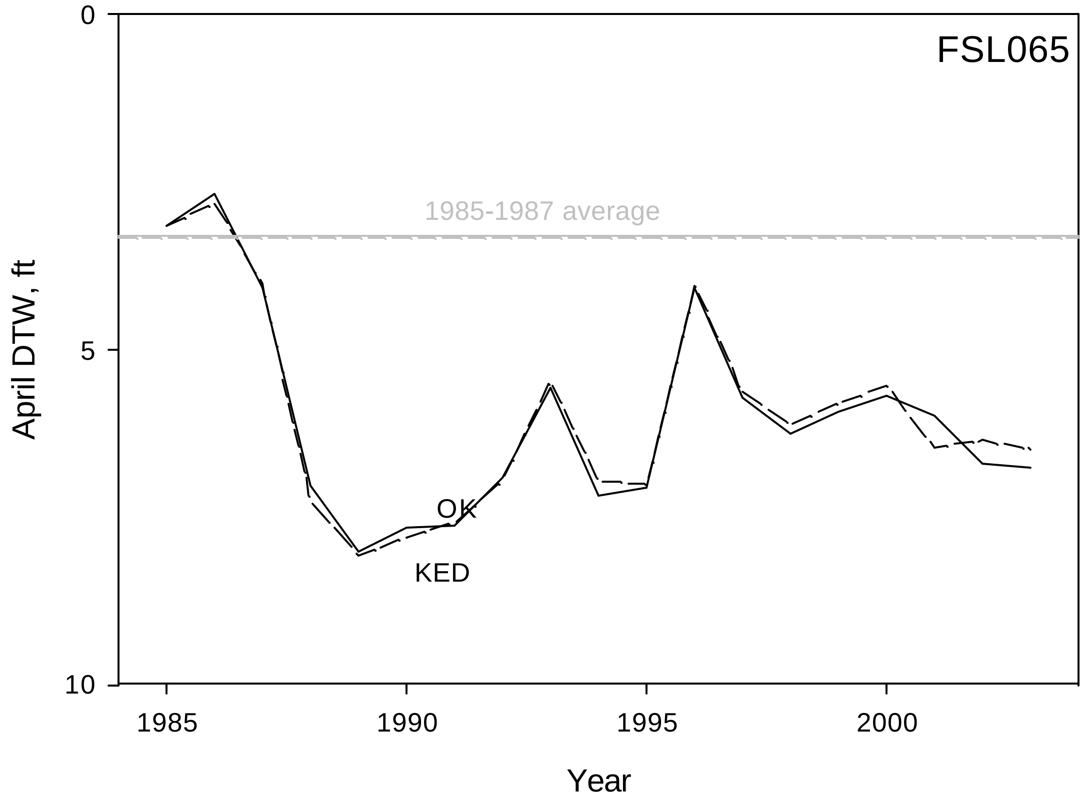
BLK142. KED and OK are different during baseline with KED ~3 ft below OK, and are congruent thereafter. Wells 801T and 802T enter the data set in 1989 and there are not other wells east of the Owen River in the vicinity. Recent DTW is reliable; baseline and relative recovery are unreliable due to absence of wells in the area during baseline.



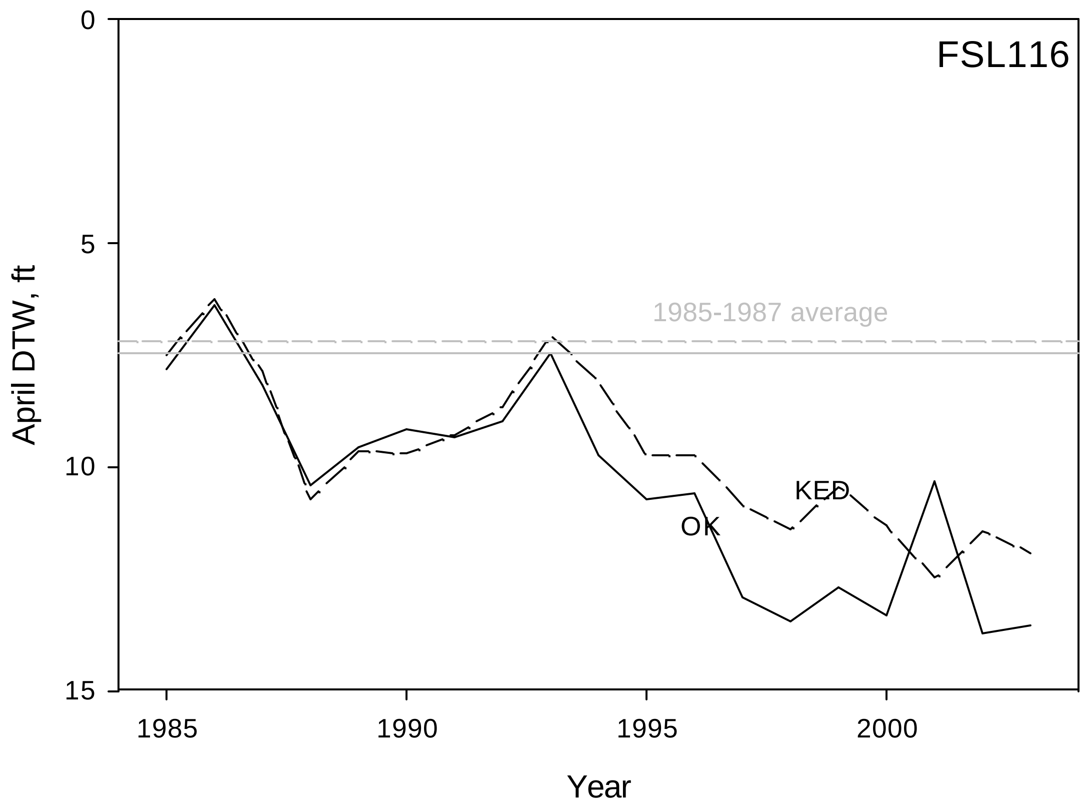
BLK143. KED and OK are similar during baseline, and parallel thereafter with KED 2-4 ft shallower than OK (cf. BLK142). OK corresponds to recent record of 802T. Rise in KED for 2002 is probably due to the addition of 846T. OK DTW is reliable, but baseline and relative recovery are unreliable due to absence of wells in the area during baseline.



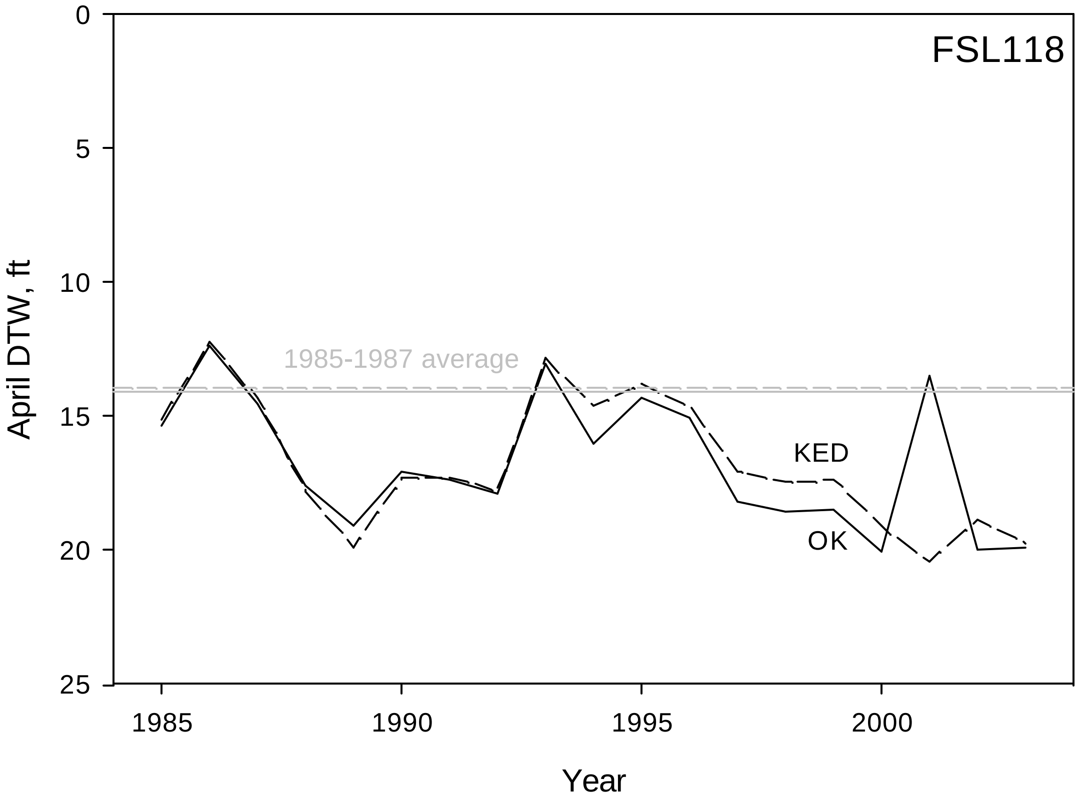
FSL051. KED and OK are parallel with KED 1-2 ft shallower than OK. The modeled hydrographs show greater recovery to baseline than 576T or 438T, probably due to the addition of several monitoring wells at the gravel plant west of the parcel. Baseline and relative recovery are invalidated by changes in the well network configuration; the actual DTW is probably shallower due to the proximity of the Owens River.



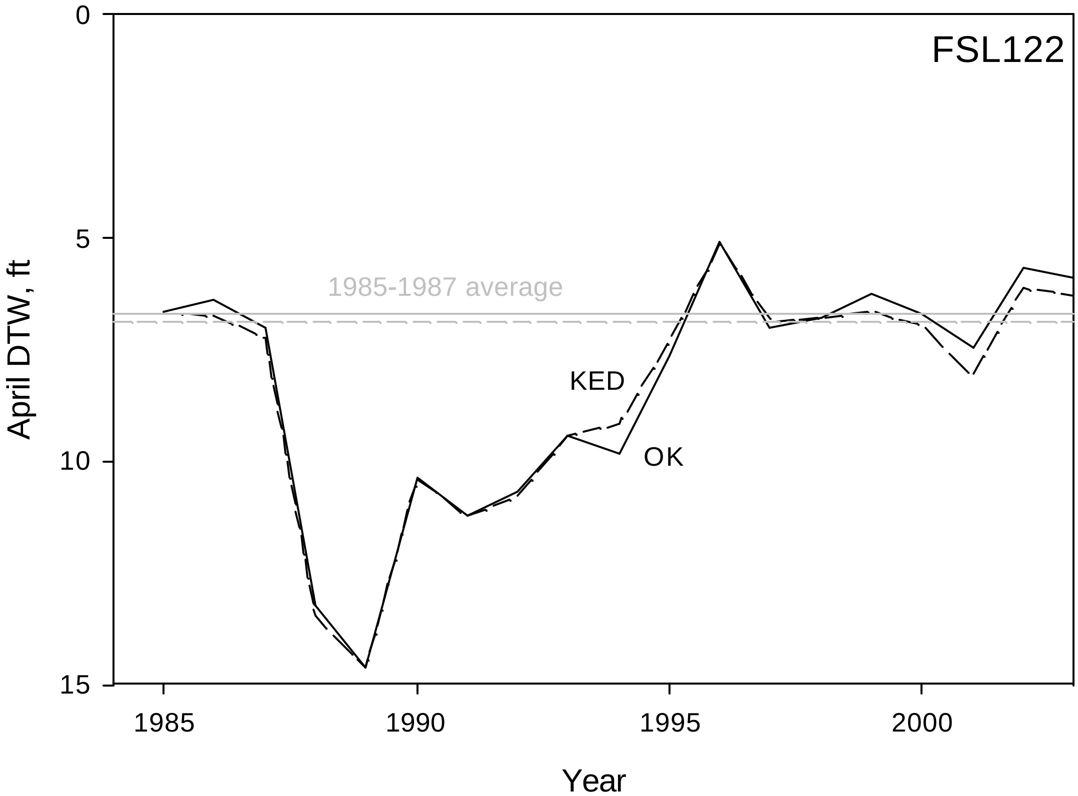
FSL065. KED and OK are congruent and are consistent with 498T. The addition of 838T to the well network in 2002 did not cause a step-change in either KED or OK. Baseline, relative recovery, and DTW are reliable.



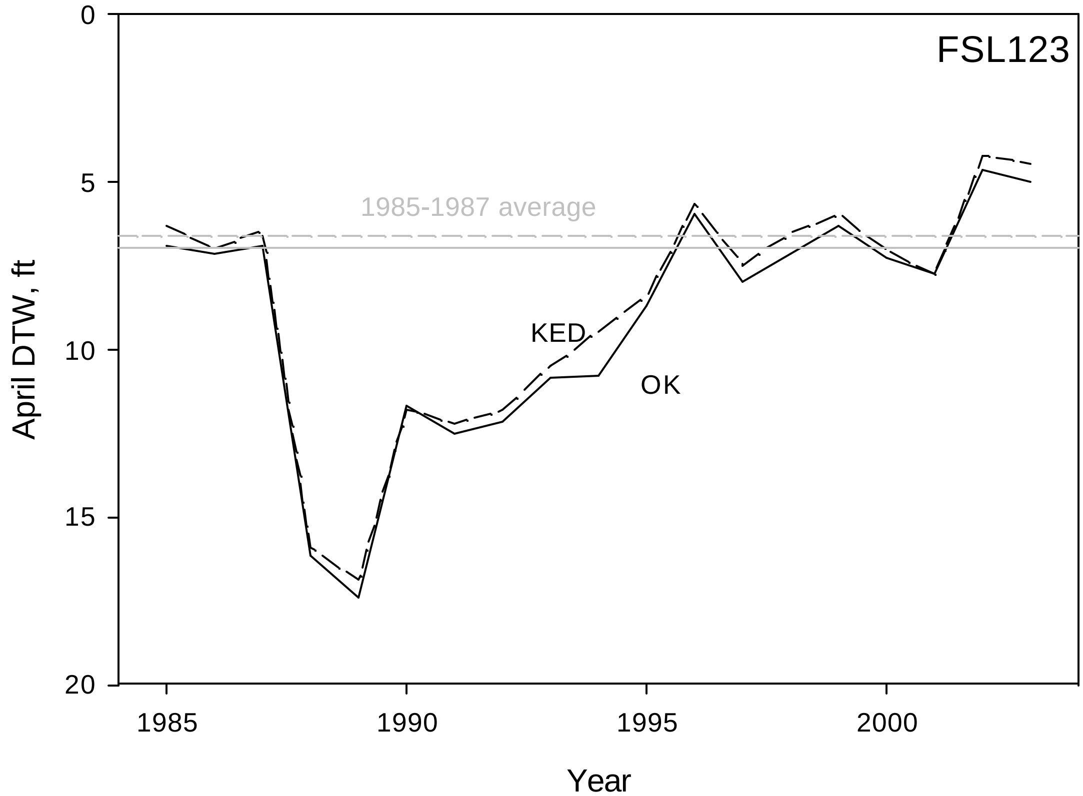
FSL116. KED and OK are similar until 1993, after which KED is shallower than OK by a few ft. After 2000, the two methods have different trends due to 372T drying up. Neither method is consistent with 372T or 384T. This parcel has ~27 ft of relief and is near various water conveyances and irrigated areas, which results in variable depth to water. Baseline, relative recovery, and DTW are unreliable.



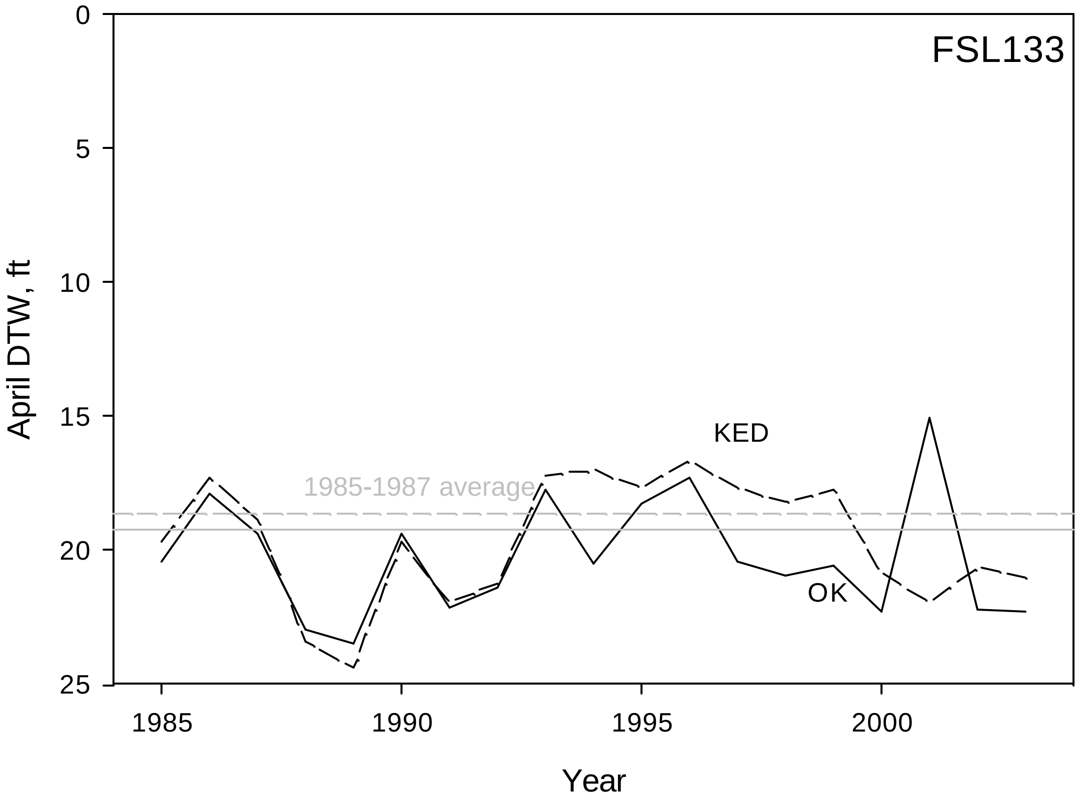
FSL118. Similar comments to FSL116.



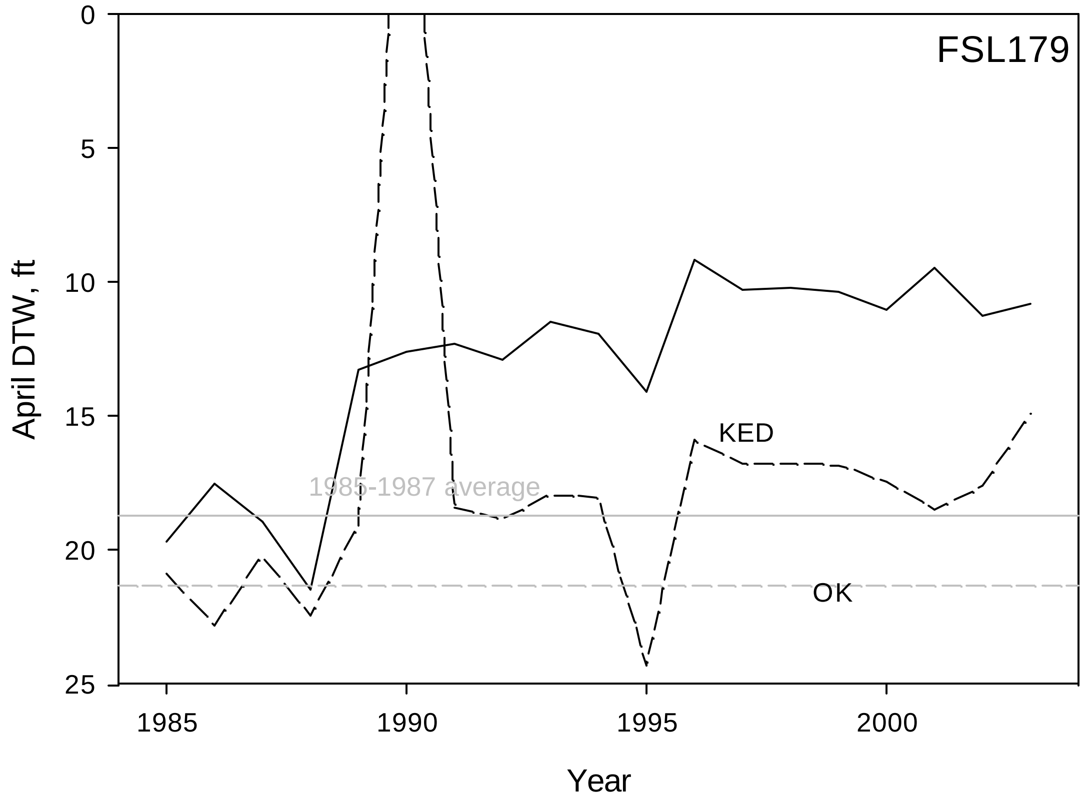
FSL122. KED and OK are nearly congruent, but inconsistent with 498T. The configuration of the well network has changed during the modeling period: 756T entered the record in 1989; 825T, 826T, 827T, 828T and 829T entered the record in 1994; and 838T entered the record in 2002. Baseline and relative recovery are not meaningful, but recent DTW is a reliable best estimate.



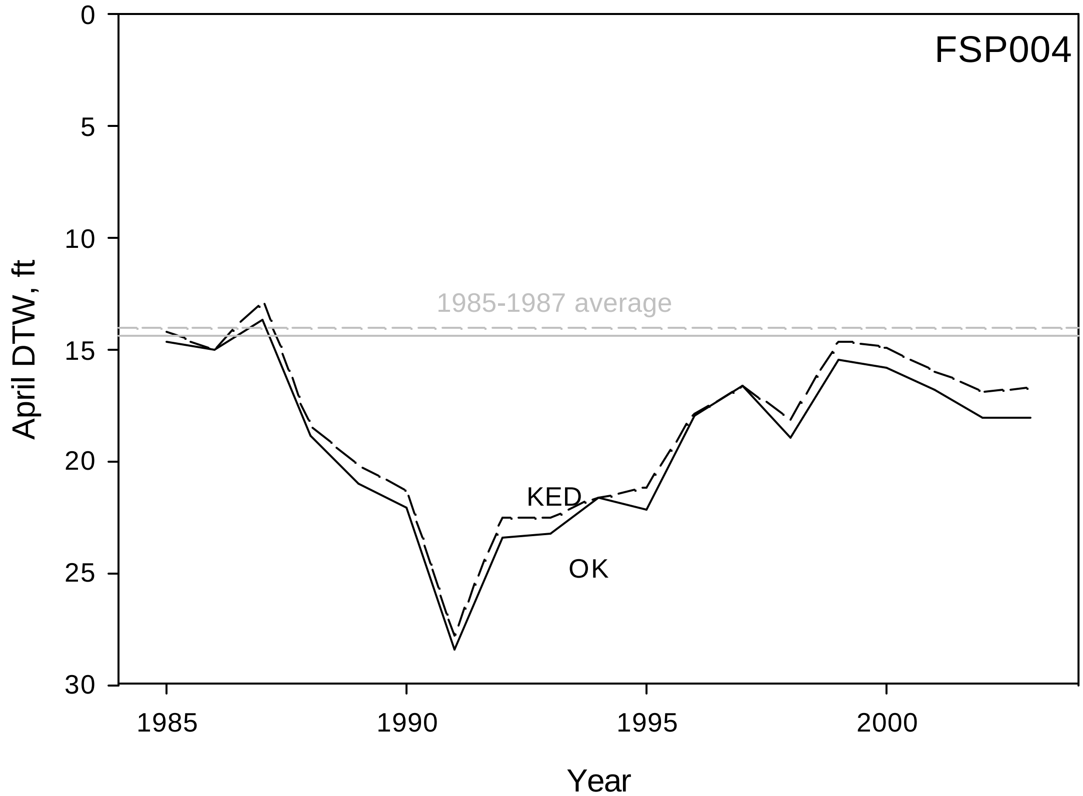
FSL123. Similar comments to FSL122.



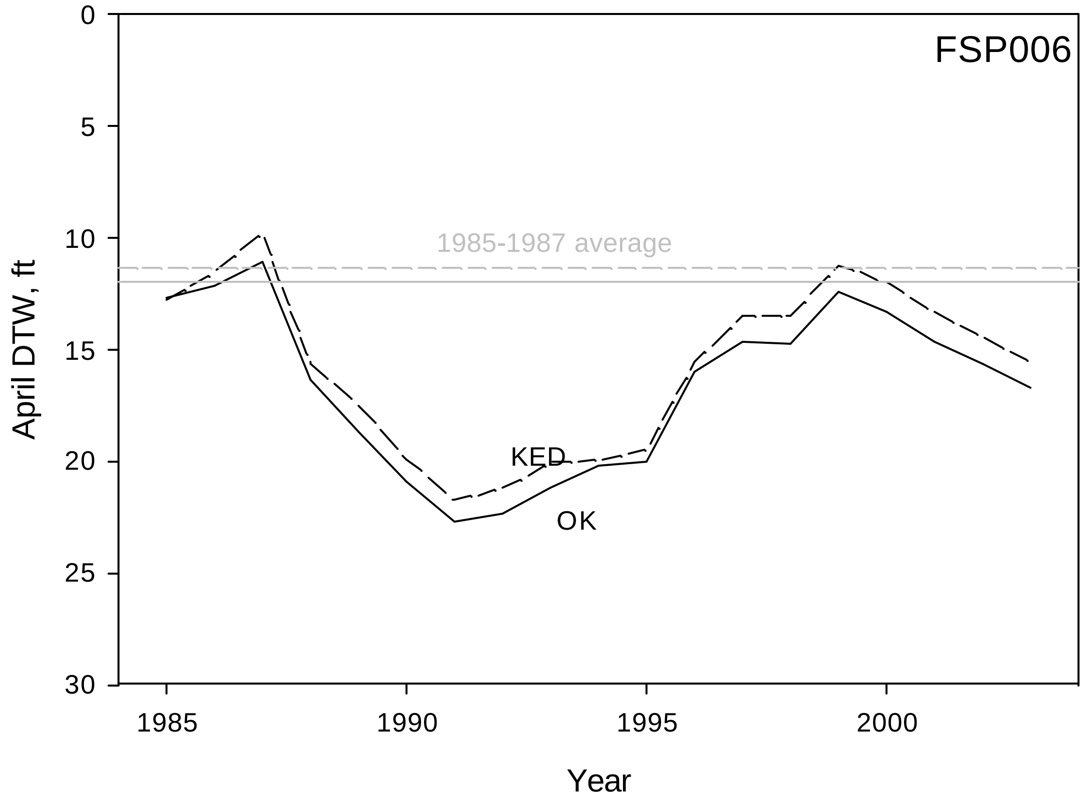
FSL133. KED and OK are similar until 1994, when 825T, 826T, 827T, 828T and 829T entered the record. The discrepancy in 2001 is due to 372T drying up (cf. FSL118). Due to changes in the configuration of the well network, baseline, relative recovery, and recent DTW are not reliable.



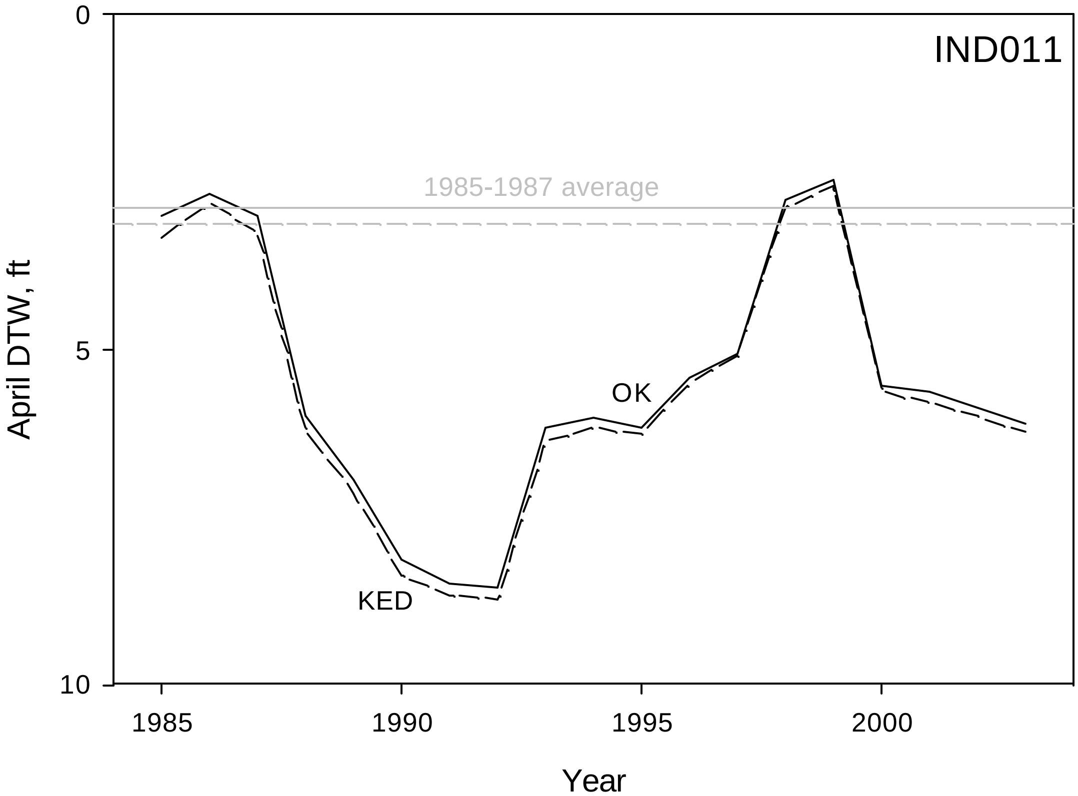
FSL179. KED and OK are both erratic; parcel is barely in kriging domain. Baseline, relative recovery, and DTW are unreliable.



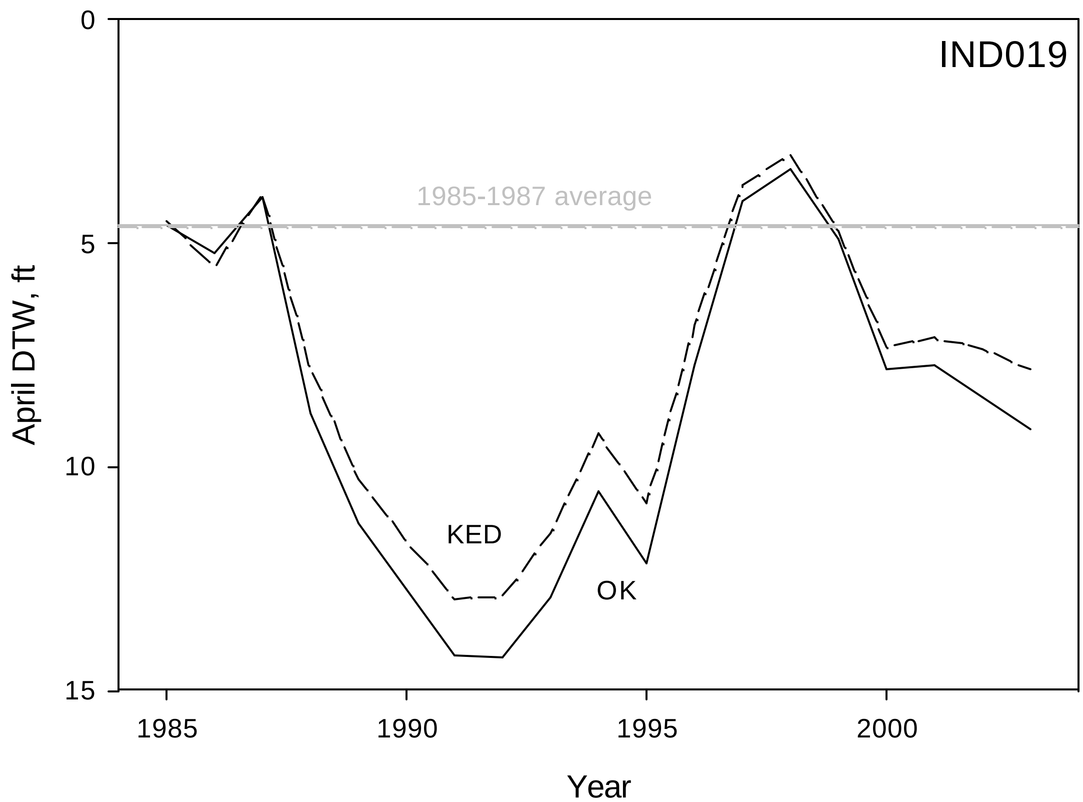
FSP004. KED and OK are nearly congruent, and consistent with 468T and 567T. The well network configuration is similar throughout the modeling period, except for 1985 and 1986 when 681T and 682T are not yet in the kriging data set. Both hydrographs provide a meaningful assessment of relative recovery, but baseline and recent DTW may be shallower than estimated due to the influence of irrigation and tail-water to the north and northwest.



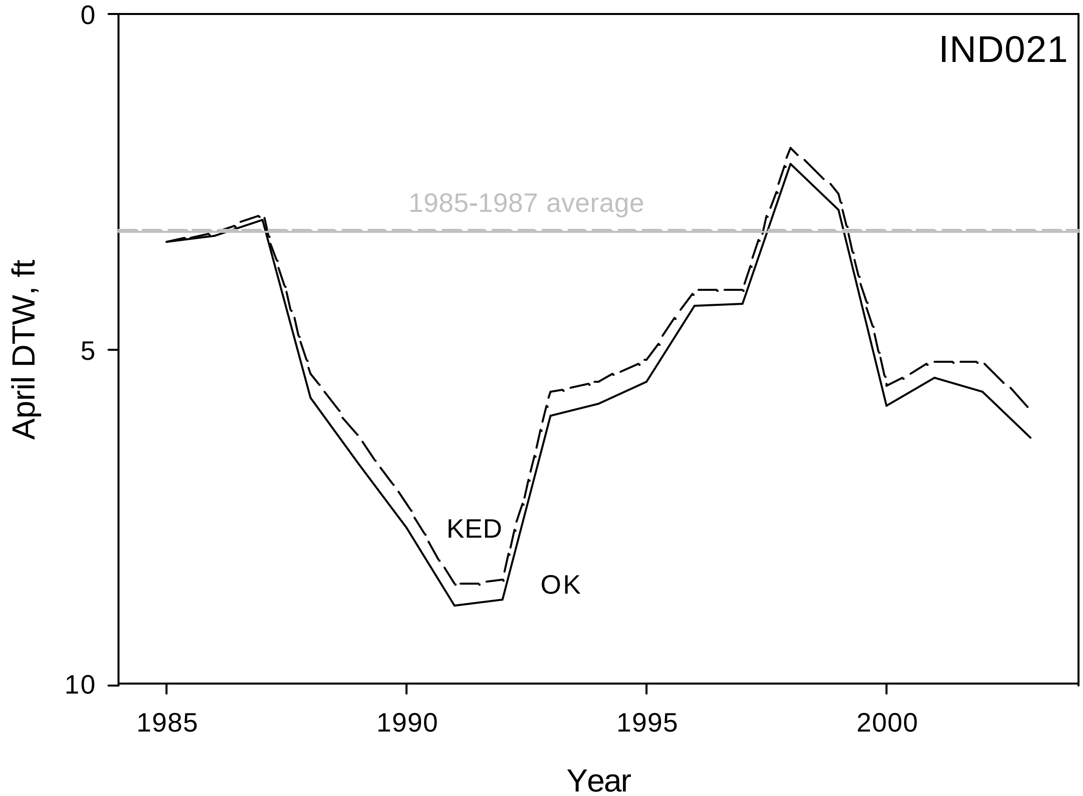
FSP006. Similar comments to FSP004, except influence of irrigation is less. Baseline, relative recovery, and DTW are reliable.



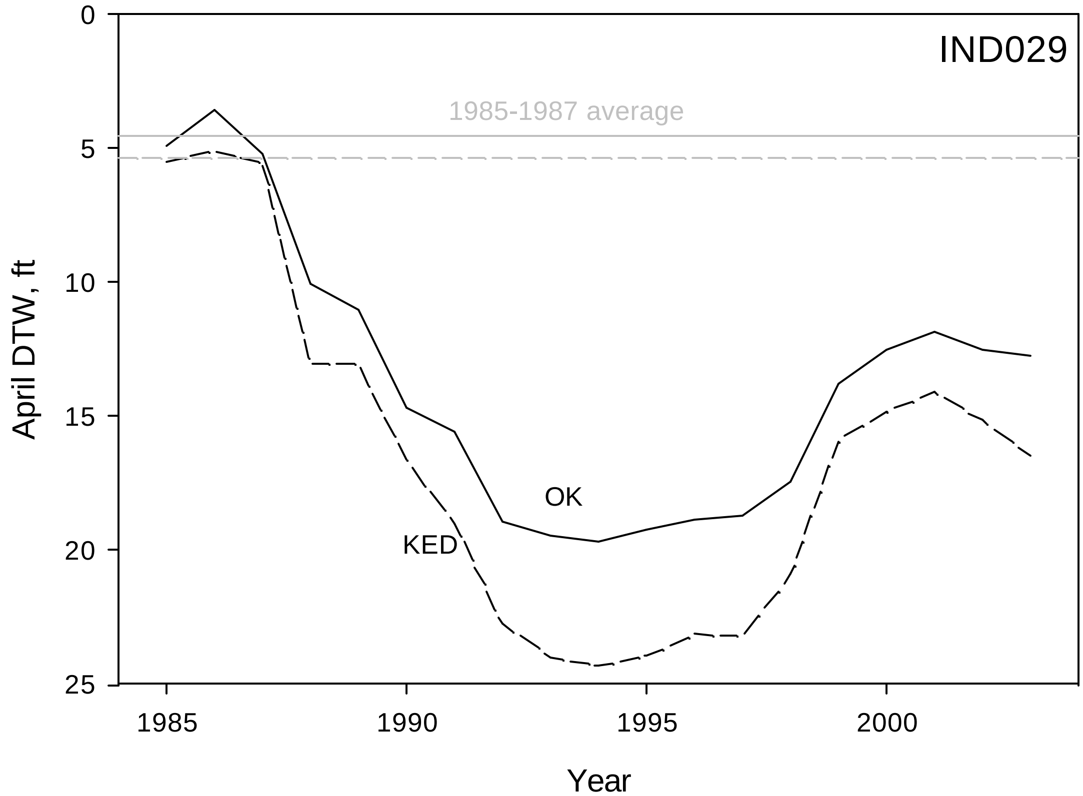
IND011. KED and OK are congruent, and consistent with 411T and 412T. The well network configuration has remained the same, except 554T and 809T enter the data in 1986 and 1990 respectively. Baseline, relative recovery, and DTW are reliable.



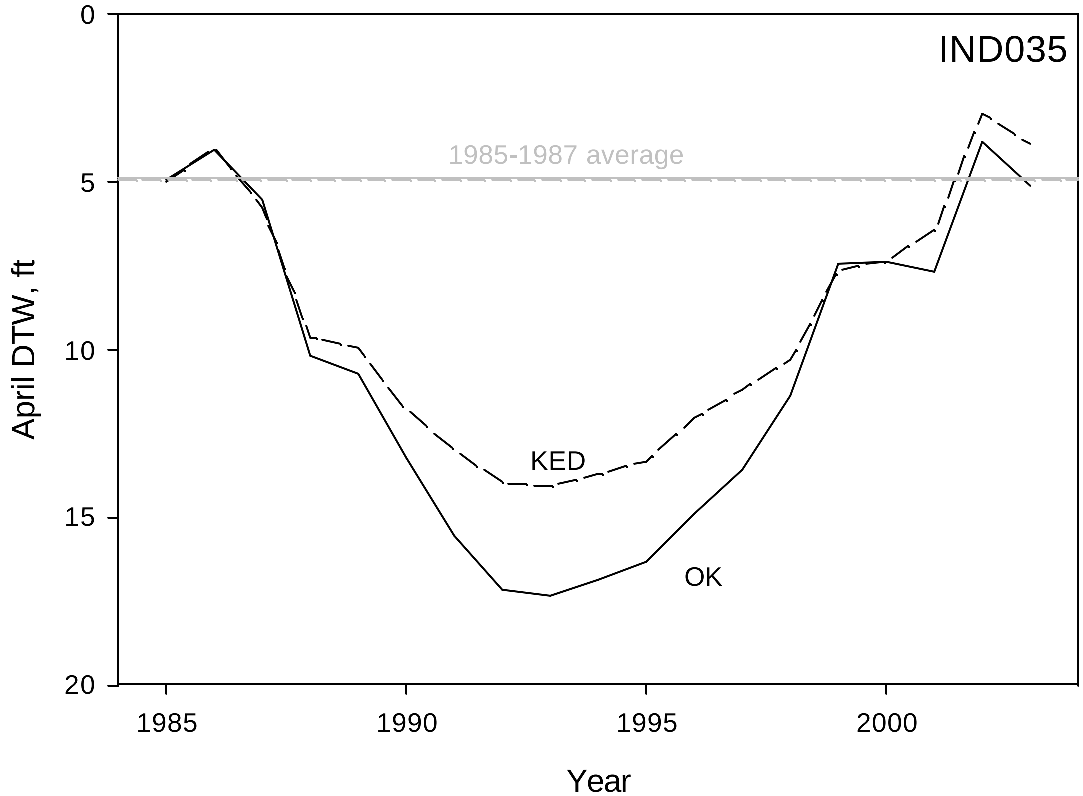
IND019. KED and OK are parallel, with KED 0-2 ft shallower. The estimates are primarily reliant on and consistent with 453T, and the well network configuration remained similar throughout the modeling period. DTW is probably variable in this parcel, as it spans the LAA, nevertheless baseline, relative recovery, and DTW are reliable.



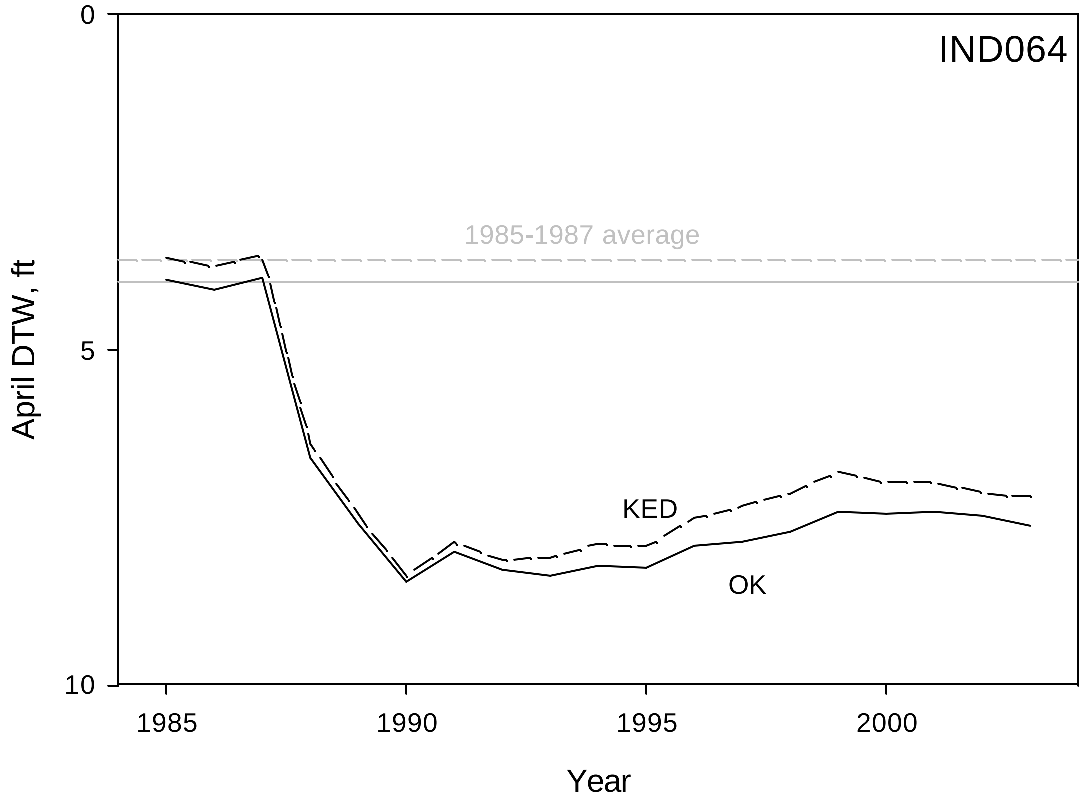
IND021. Similar comments to IND011 and IND019.



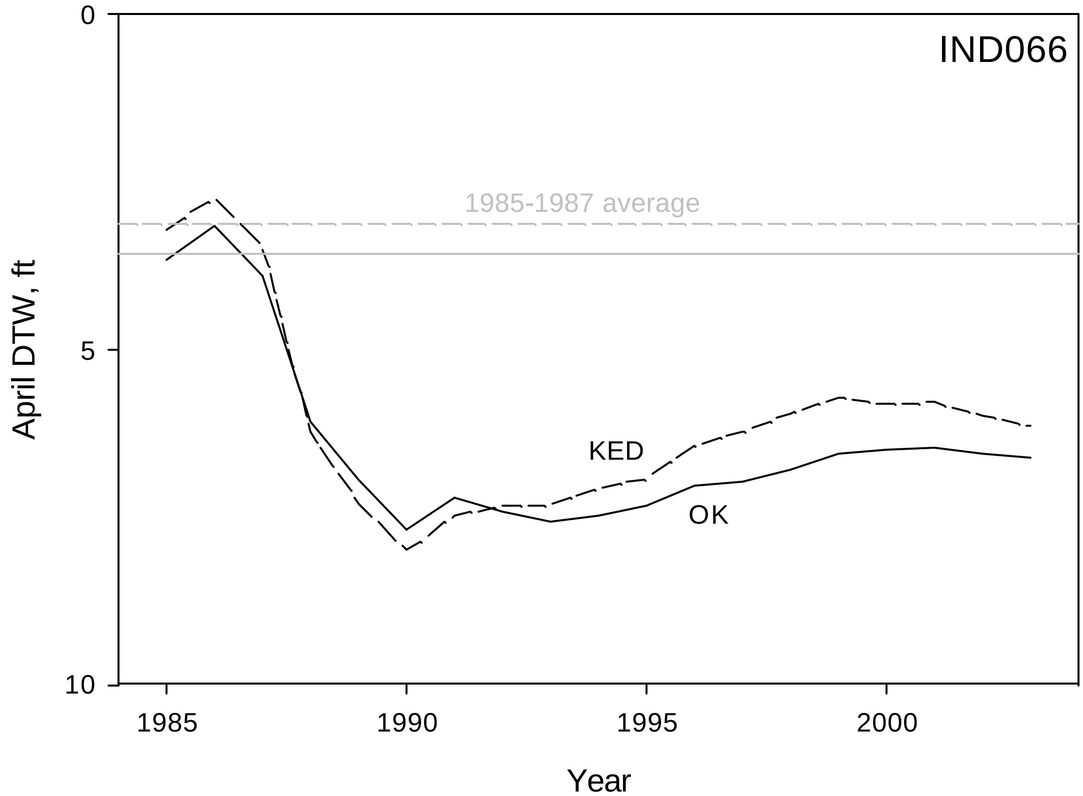
IND029. KED and OK are parallel, with KED 1-5 ft deeper than OK; both are consistent with 52AT. Hydrographs are a good assessment of relative recovery, but because the parcel slopes up from 52AT, the actual baseline and DTW are probably deeper than estimated.



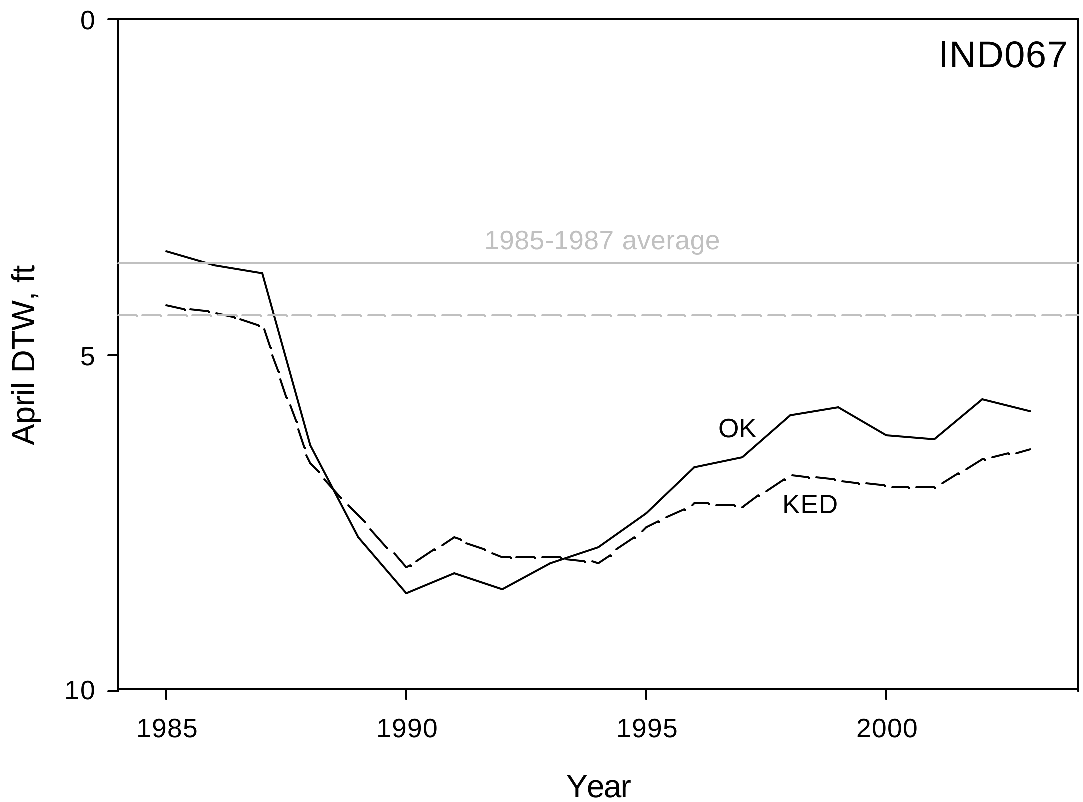
IND035. KED and OK are similar except during early-nineties low stand when OK is ~4 ft deeper than KED. 808T enters the data in 1990, but causes no obvious anomaly; 852T enters the data in 2002, and causes a sharp rise. DTW is undoubtedly variable under this sloping parcel that spans the aqueduct. Baseline, relative recovery, and DTW are not reliable.



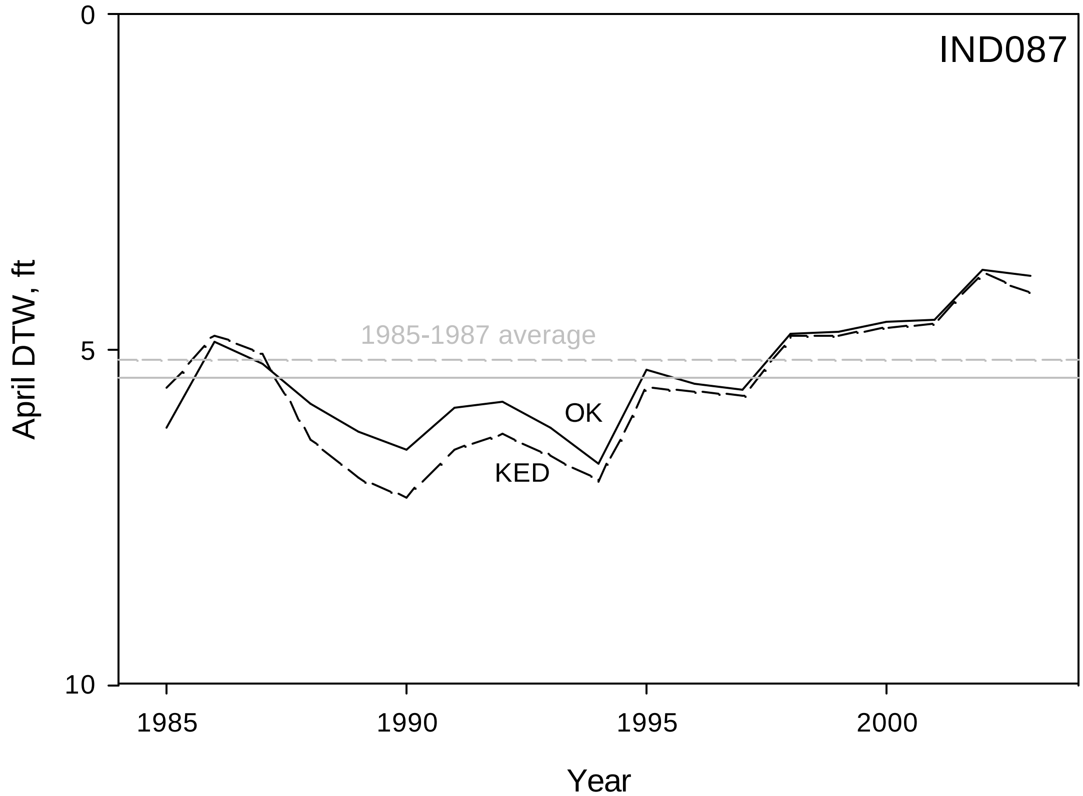
IND064. KED and OK are nearly congruent, and consistent with 374T and 382T. Baseline, relative recovery, and DTW are reliable.



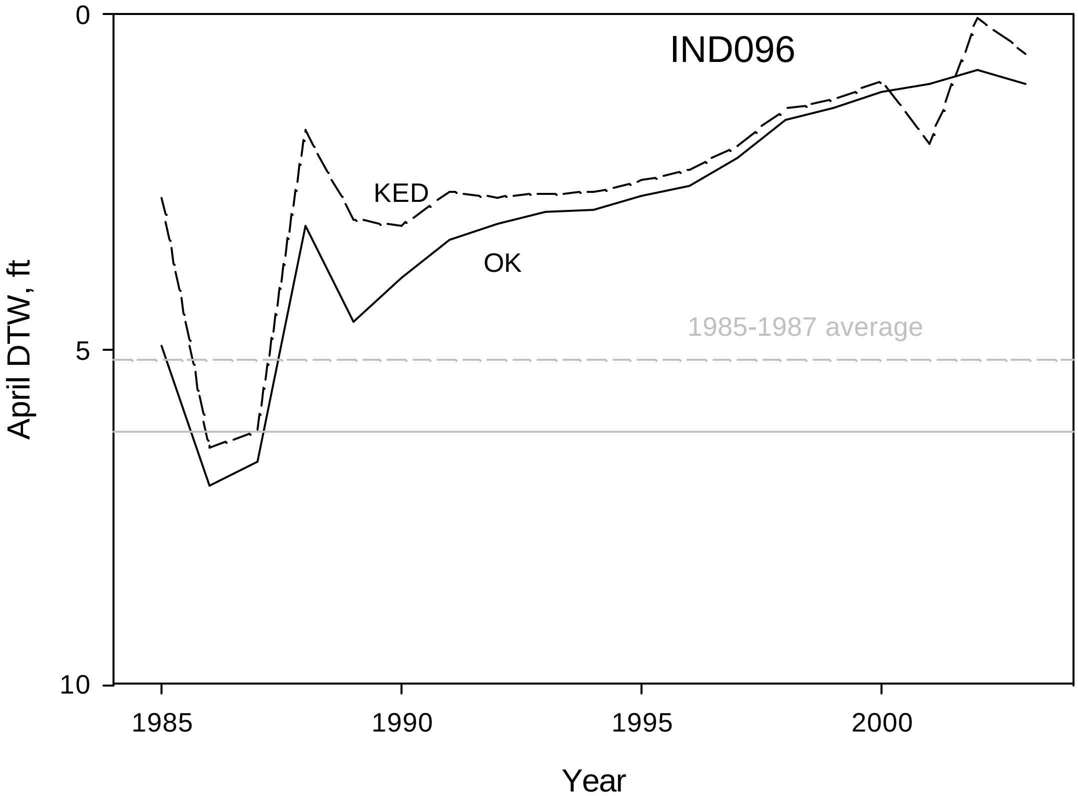
IND066. KED and OK are similar and consistent with and primarily reliant on 450T. Baseline, relative recovery, and DTW are reliable.



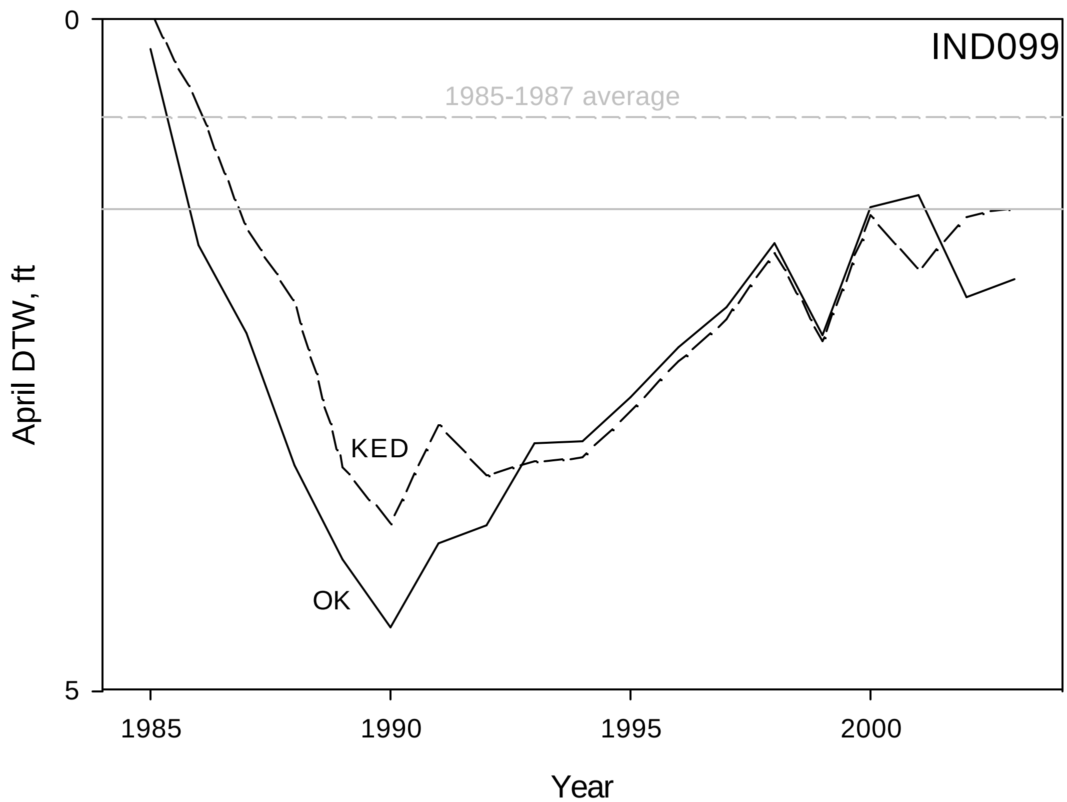
IND067. KED and OK are similar and consistent with 450T and 382T. Well coverage is sparse, but network configuration has not changed during modeling period. Baseline, relative recovery, and DTW are reliable.



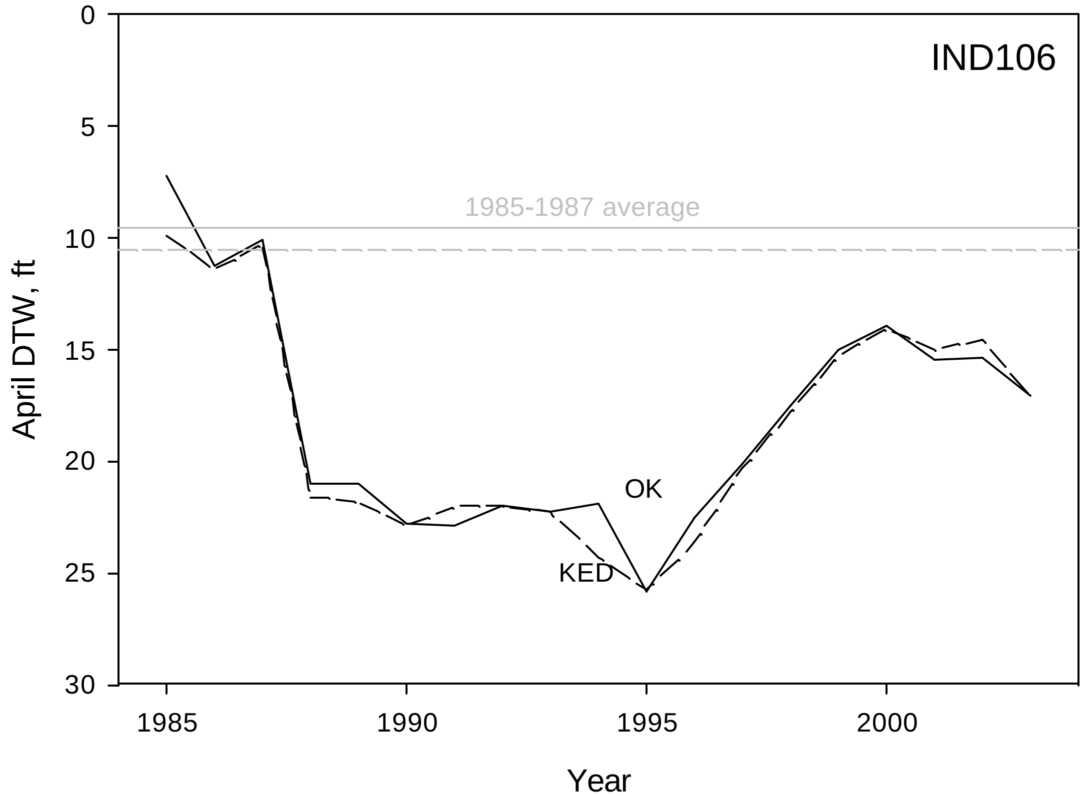
IND087. KED and OK are similar, but inconsistent with 451T. Well network configuration is similar, except in 1985 when V007G is missing and 2002 when 853T is added to the data. Baseline and relative recovery are unreliable, but 2002 DTW is reliable.



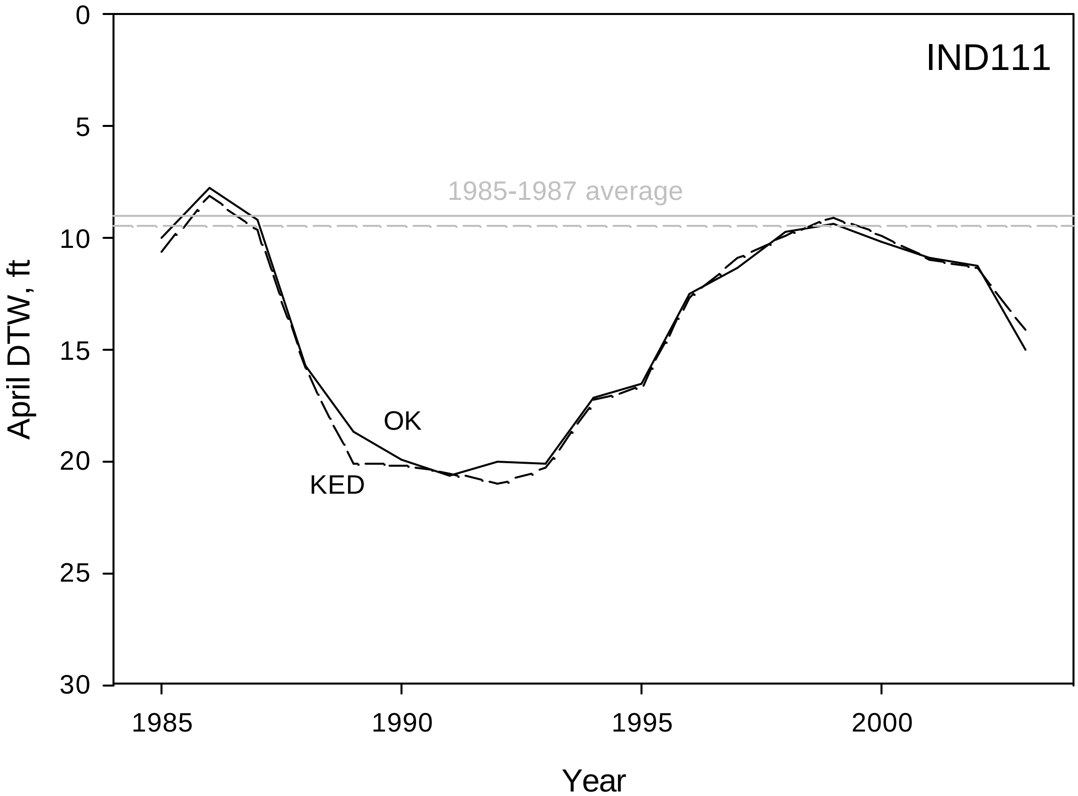
IND096. KED and OK are parallel, except for 2001 and 2002 when KED is erratic. KED is unreliable in this area; it produces negative DTW values. Well network configuration has changed during the modeling period: V007G and 550T enter in 1986, and drawdown site 8 wells enter in 1992. Kriged hydrographs are not consistent with 405T, 406T, or 509T. Baseline and relative recovery are not reliable, but recent OK DTW probably is reliable.



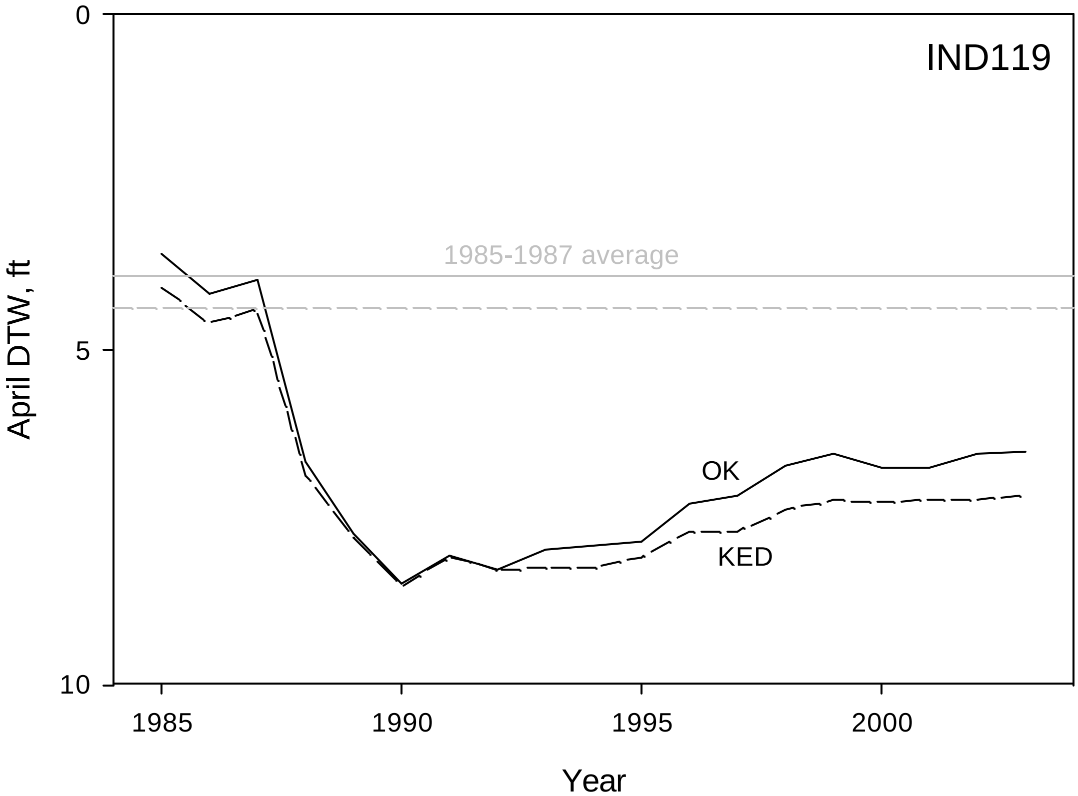
IND099. Similar to IND096 in that both KED and OK provide unreliable baseline, and KED is generally unreliable. Inconsistent with 405T and 406T. Baseline, relative recovery and recent DTW are unreliable.



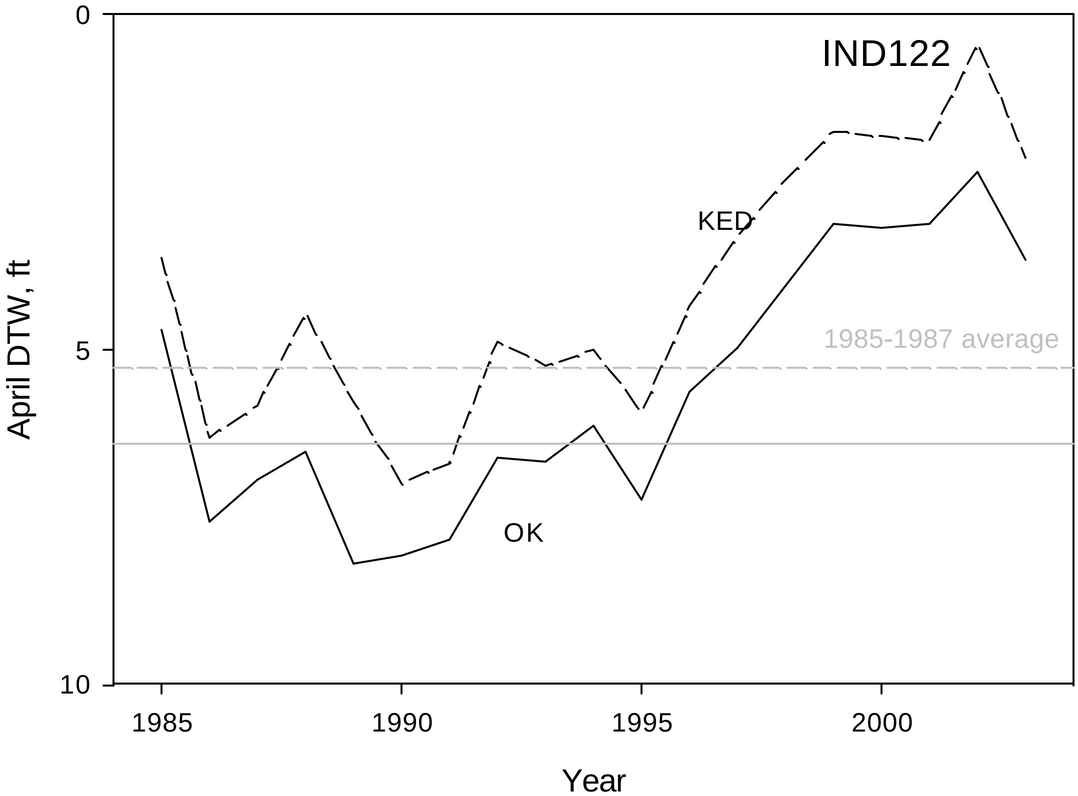
IND106. KED and OK are nearly congruent. This area has dense well coverage, but variable DTW. The entry of well 854T into the data in 2002 does not cause an anomaly because its DTW and WTE fall in the middle of the range spanned by other nearby wells. Though 548T, 556T, and 558T are missing from the 1985 estimate, baseline is consistent with other wells. Baseline and relative recovery are probably reliable, recent DTW is reliable.



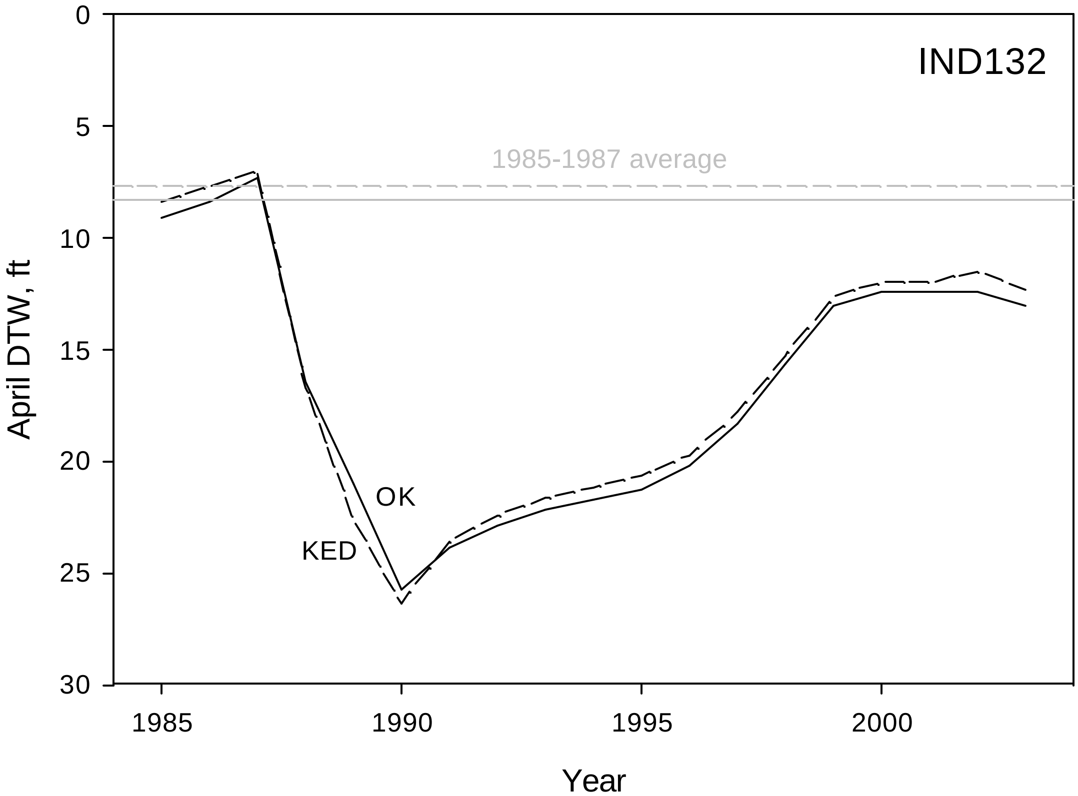
IND111. KED and OK are congruent, and consistent with 412T, 546T, 651T, and 809T. Baseline, relative recovery, and DTW are reliable.



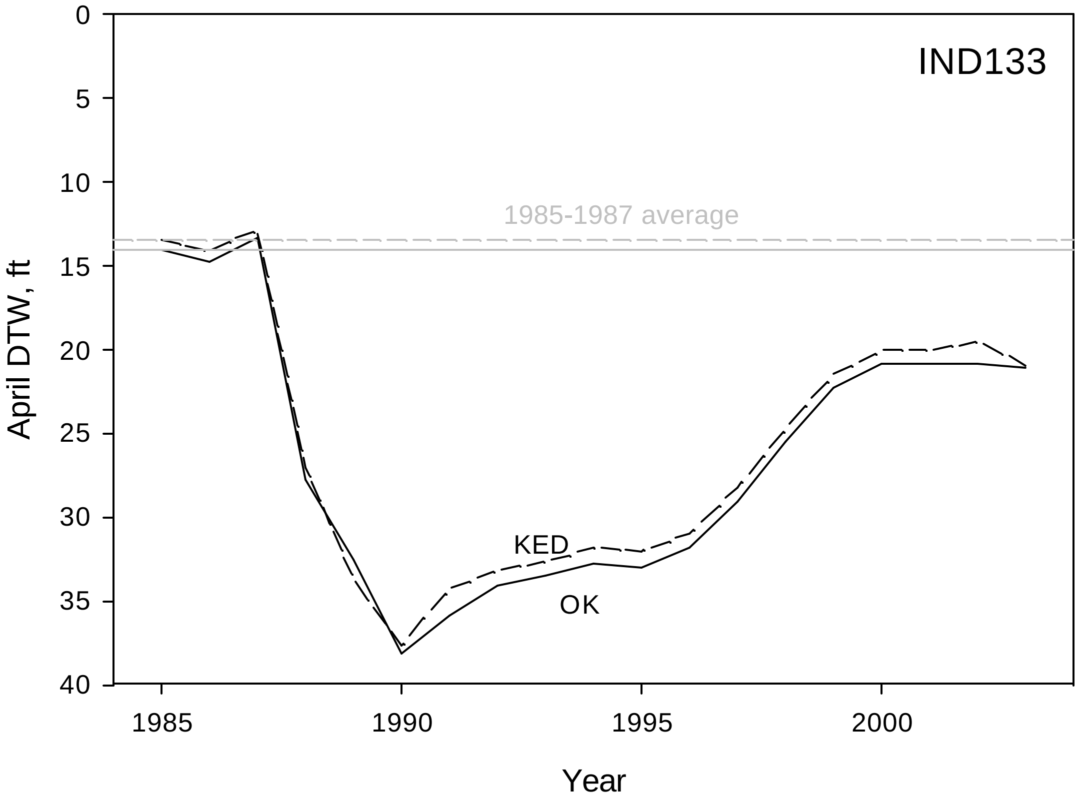
IND119. KED and OK are nearly congruent and consistent 382T. Despite sparse well coverage, baseline, relative recovery, and DTW are probably reliable.



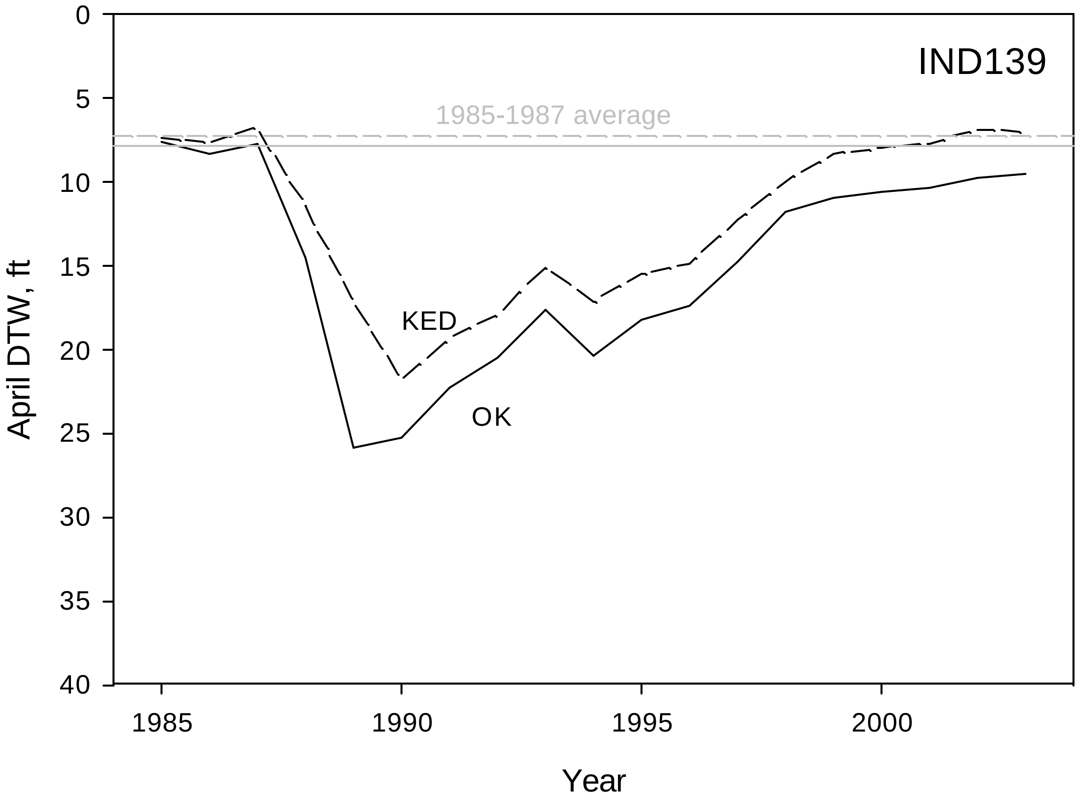
IND122. KED and OK are parallel with KED 1-2 ft shallower than OK. KED produces negative DTW in this region. Both hydrographs are inconsistent with 407T, 548T, and 550T. Baseline and relative recovery are unreliable; OK DTW for 2002 is probably reliable.



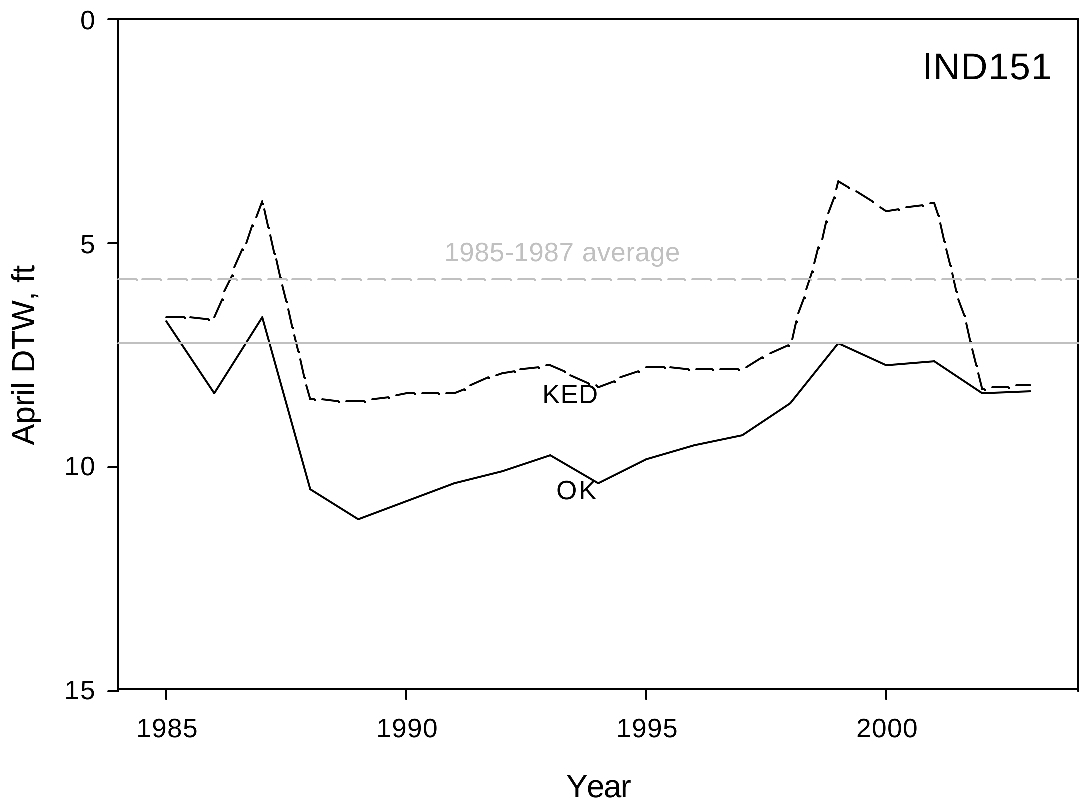
IND132. KED and OK are congruent and consistent with V009G, 407T, and 547T. V009G, 407T, and 547T have a favorable configuration for estimating DTW in this parcel, and indicate that DTW varies as the parcel slopes down to the LAA on its eastern boundary. Baseline, relative recovery, and DTW are reliable.



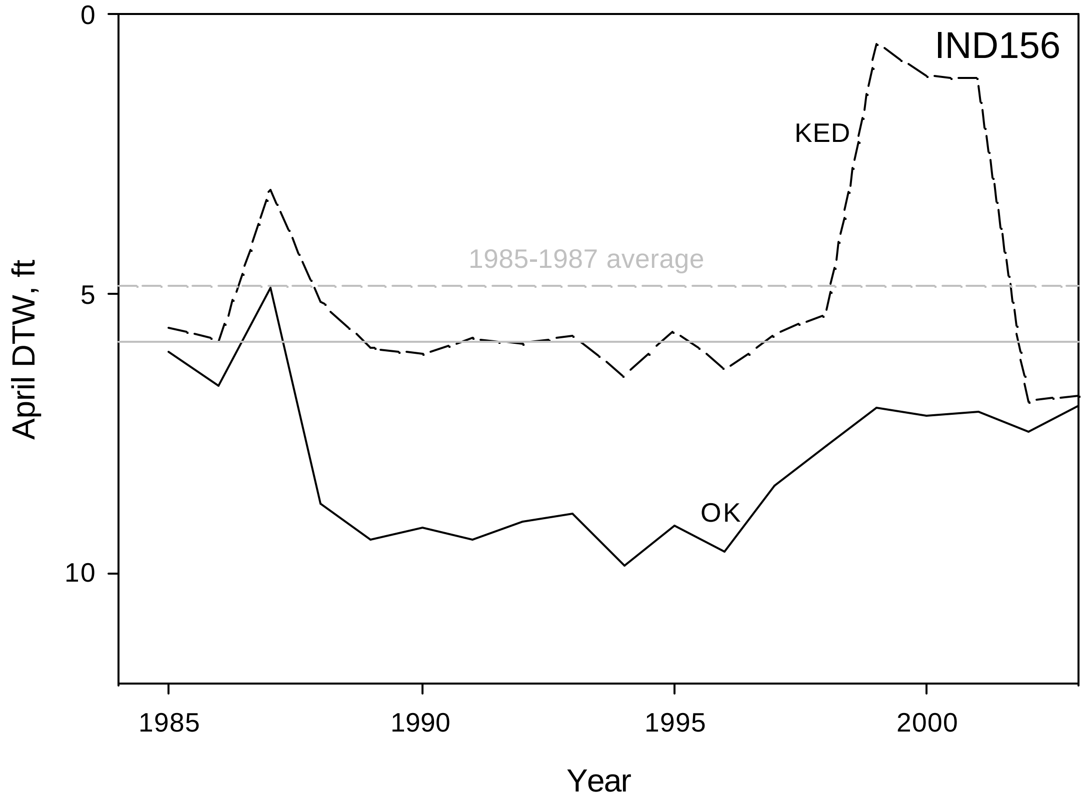
IND133. Similar comments as IND132.



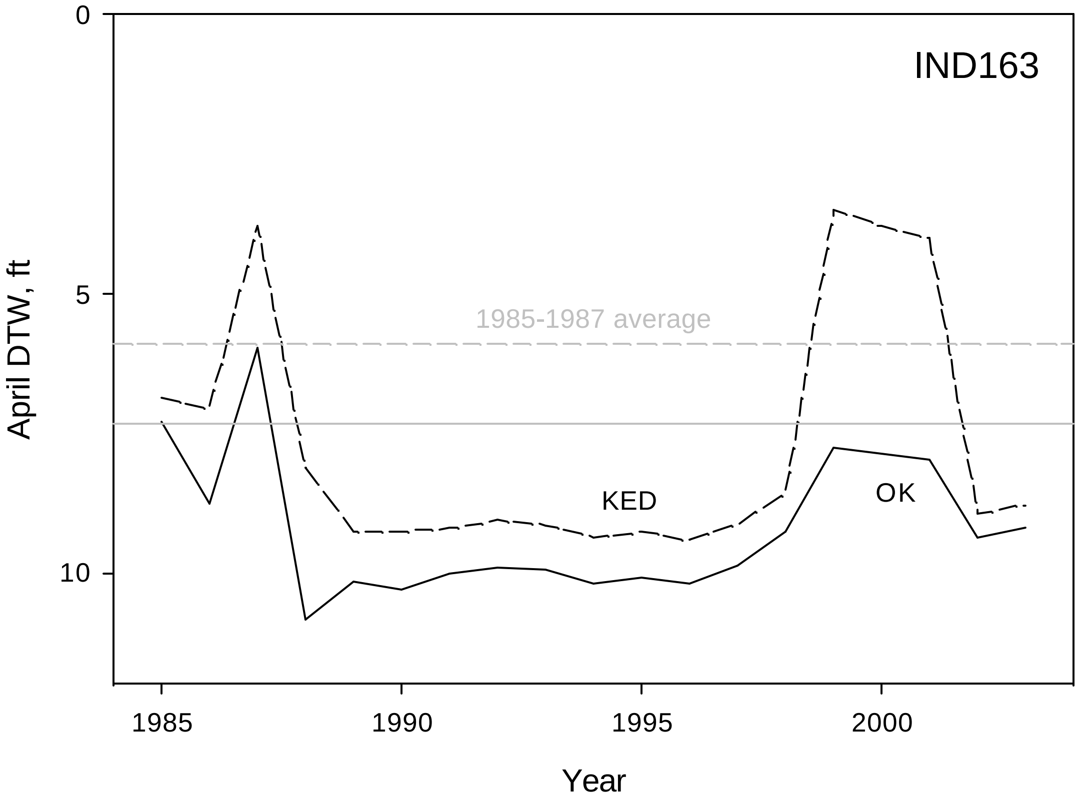
IND139. KED and OK provide similar baselines; thereafter KED is 2-3 ft shallower. KED is consistent with 403T, 561T, and 562T, but OK shows less recovery than these three wells, and is consistent with 404T. The well network in the vicinity of this parcel is favorable for estimation, and reveals that DTW decreases as the parcel slopes eastward to the LAA. Baseline, KED relative recovery, and KED DTW are reliable.



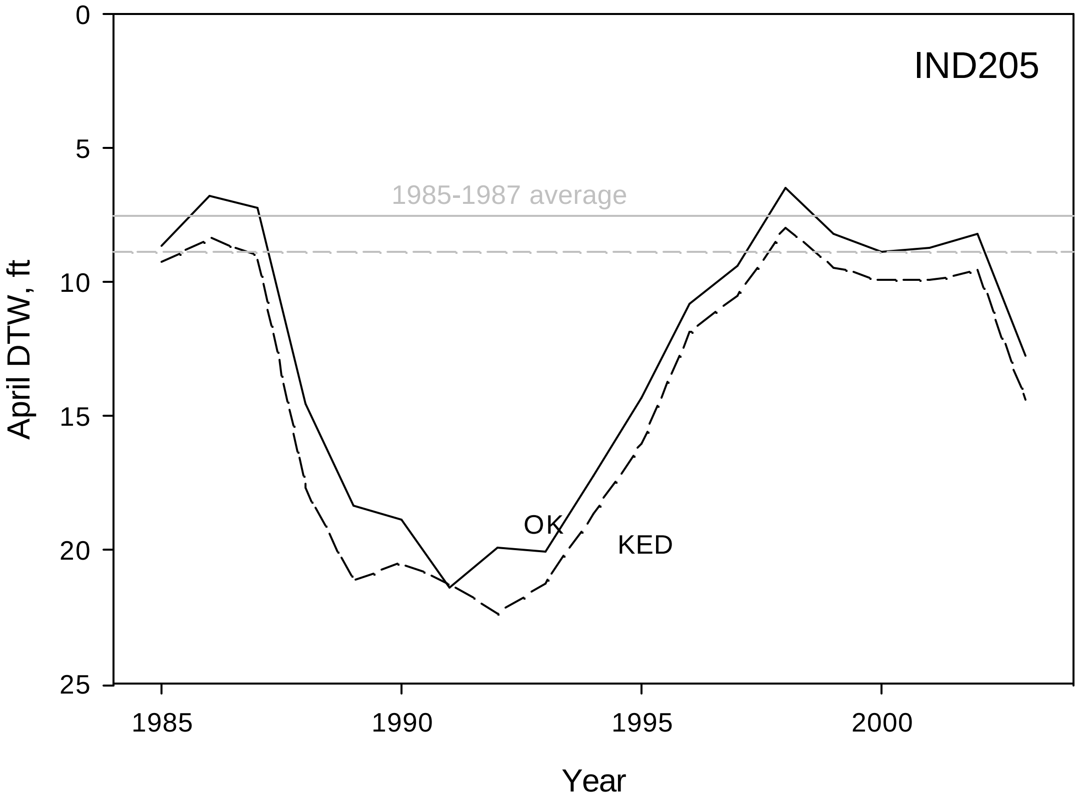
IND151. KED and OK are parallel with KED 2-3 ft shallower than OK, except in 1985 and 2002 when the two methods correspond closely. This parcel is distant from any wells until 855T enters the record in 2002. Both hydrographs drop sharply in 2002 due to the entry of 855T into the data, indicating that baseline and previous estimates of DTW are inaccurate. DTW for 2003 is accurate based on the proximity of 855T and the correspondence of the two methods.



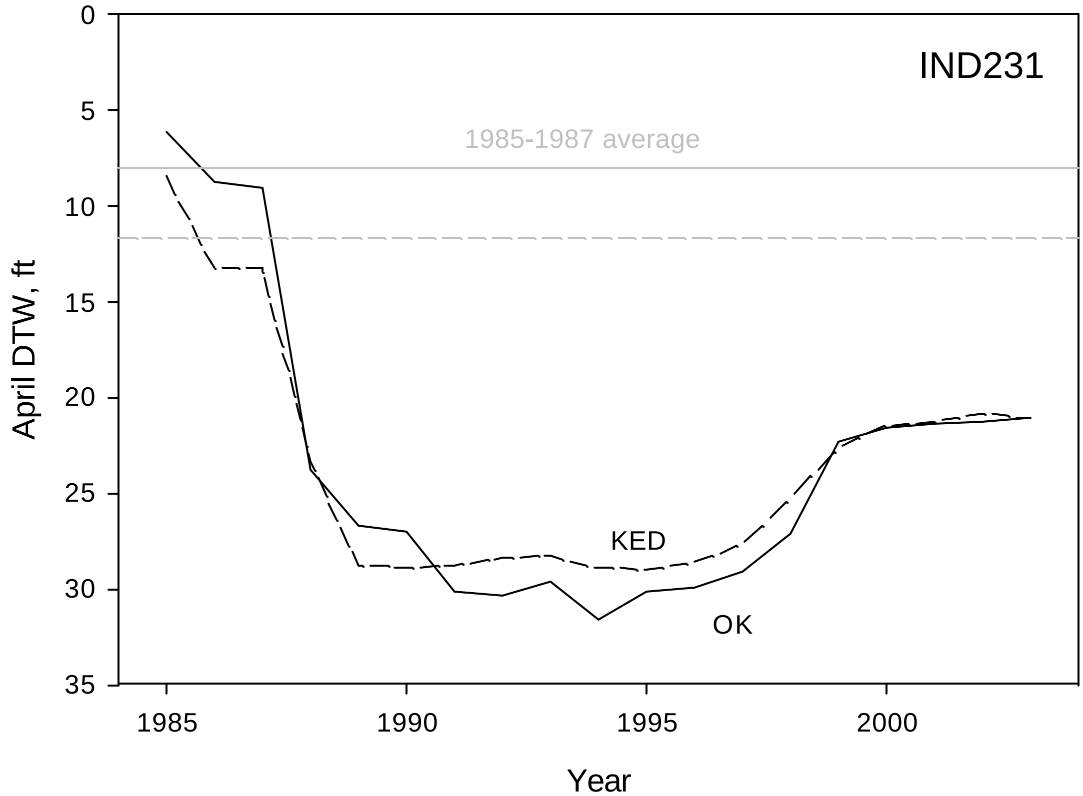
IND156. KED and OK differ. This parcel has poor well coverage and the kriged hydrographs are inconsistent with 441T and 449T. Baseline, relative recovery, and 2002 DTW are unreliable.



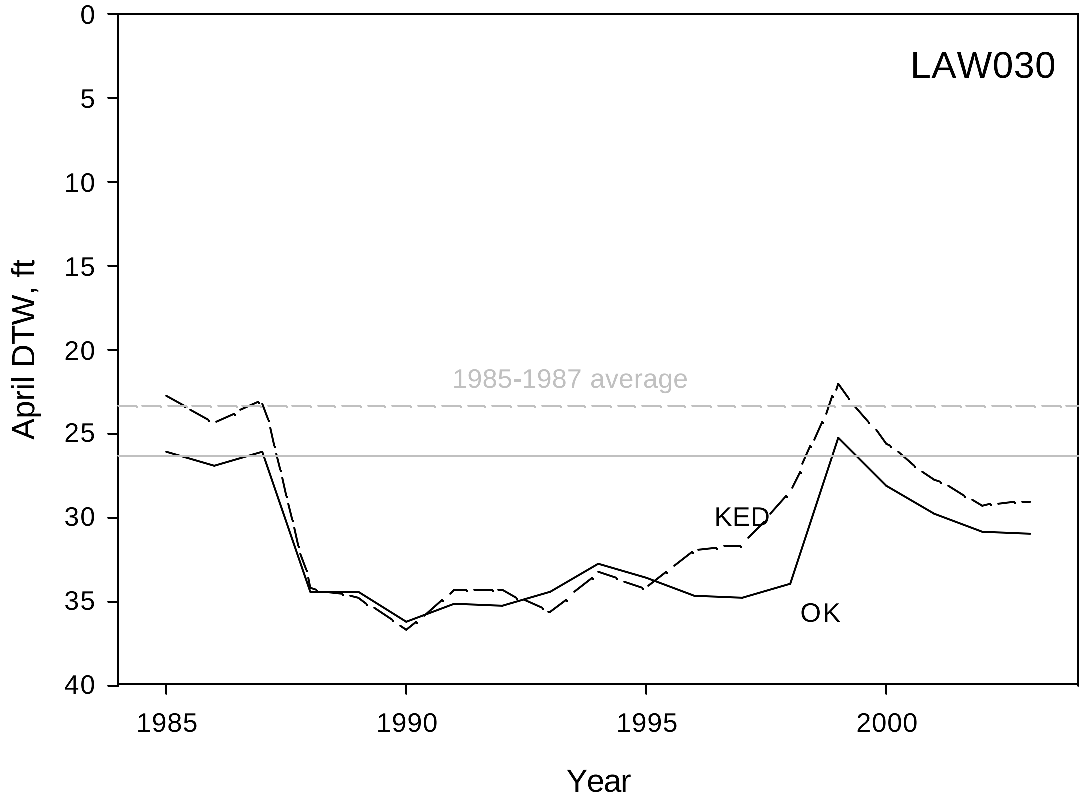
IND163. This is a large parcel with poor well coverage. KED and OK differ, and are inconsistent with 441T. Baseline, relative recovery, and 2002 DTW are unreliable.



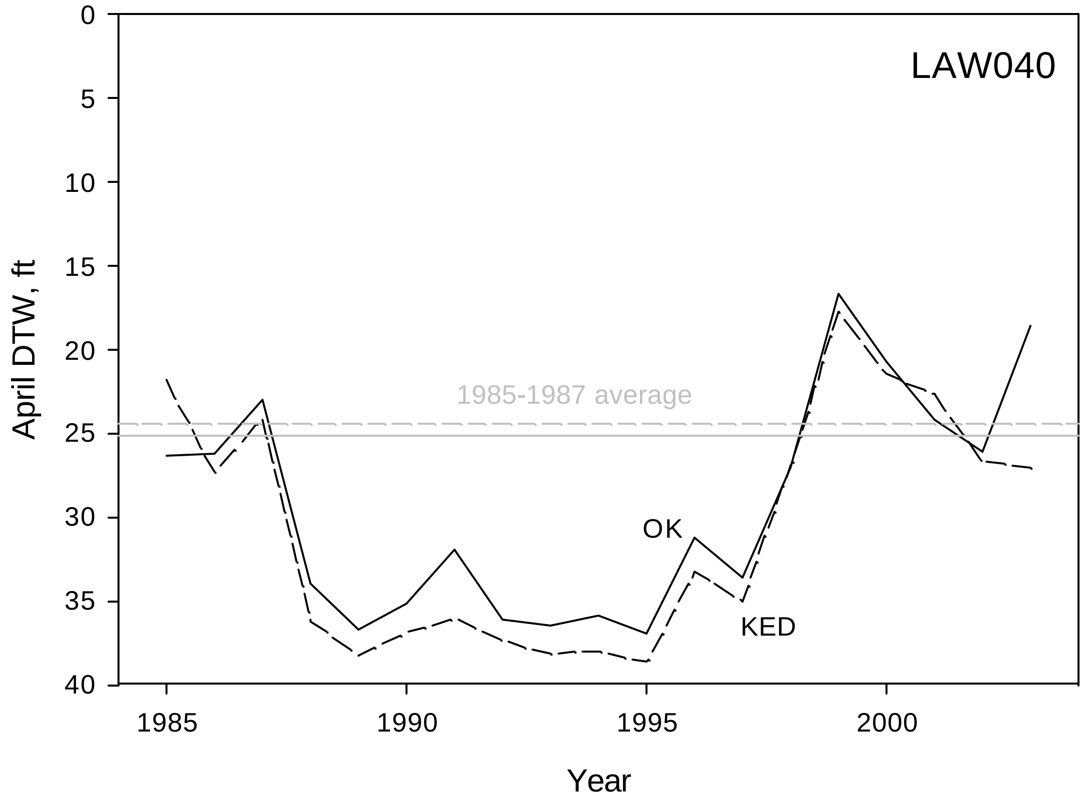
IND205. KED and OK are parallel with OK 0-2 ft shallower than KED, and are consistent with 409T, 546T, 549T, and 552T. No anomalies are apparent in the hydrographs despite the installation of several wells in the area during the modeling period. This parcel is adjacent to irrigated land on the south and east. Relative recovery is accurate; baseline and DTW may be slightly shallower due to the influence of nearby irrigation.



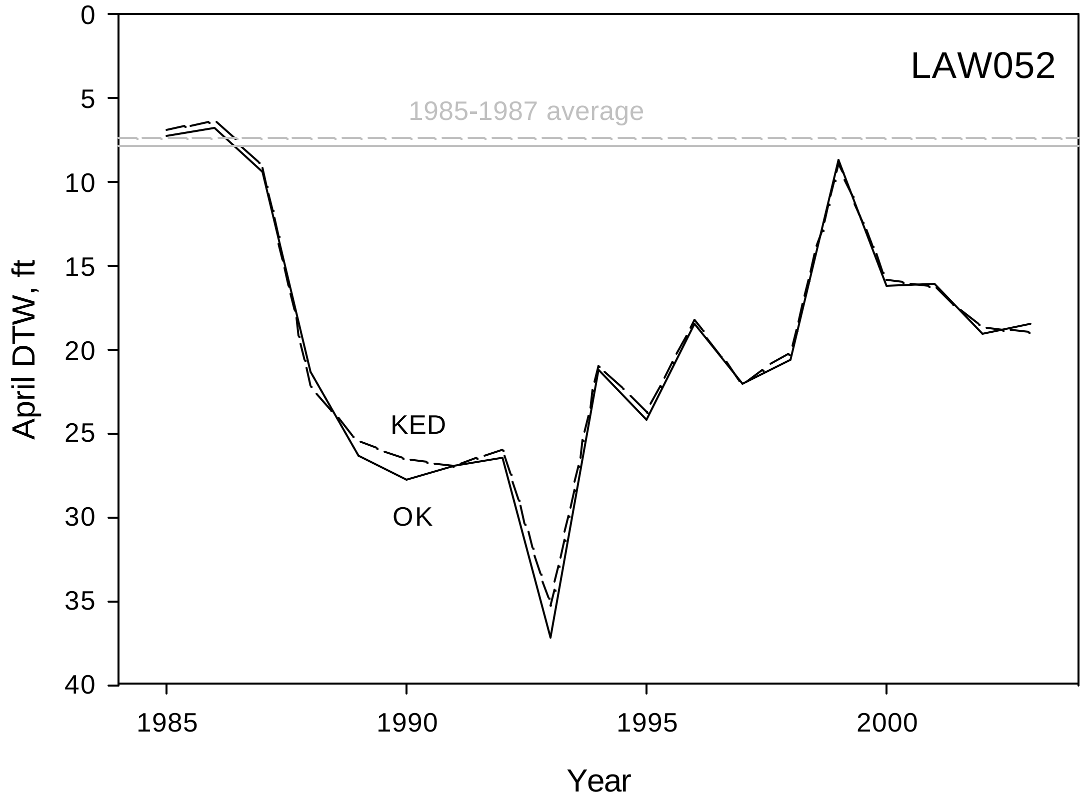
IND231. KED and OK are similar except for during baseline when OK is 2-4 feet shallower. Wells 511T, 646T, and 623T reveal a DTW gradient as the parcel slopes to the LAA. Baseline is uncertain because of sparse well coverage at the time. 646T enters the record in 1988 and provides a reliable DTW thereafter.



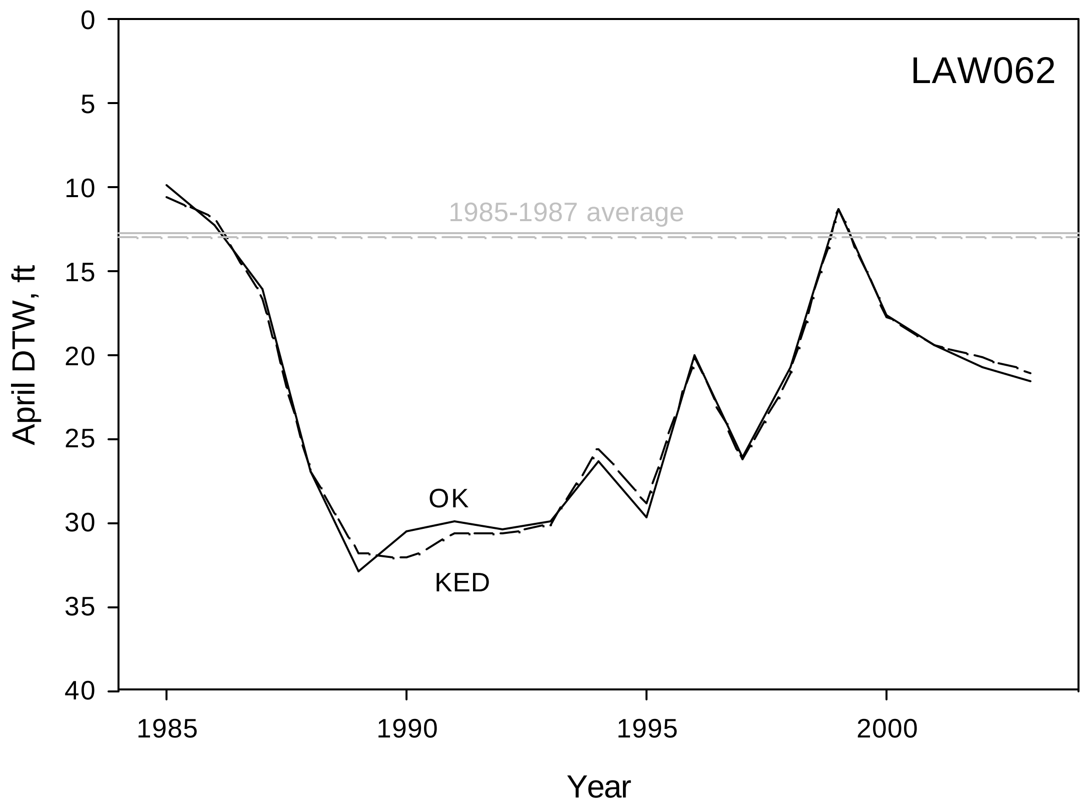
LAW030. KED and OK are similar except for during baseline and recently when KED is a few feet shallower. Well coverage is poor. DTW was underestimated during the early nineties because dry well 579T tends to limit how far the estimated water table can decline. Undoubtedly undergoes large and rapid fluctuations in DTW based on the intermittent operation of the Upper McNally Canal and spreading of Coldwater Creek flows within the parcel. While the estimated relative recovery is consistent with V275 and V286, baseline and 2002 DTW are unreliable due to poor well coverage.



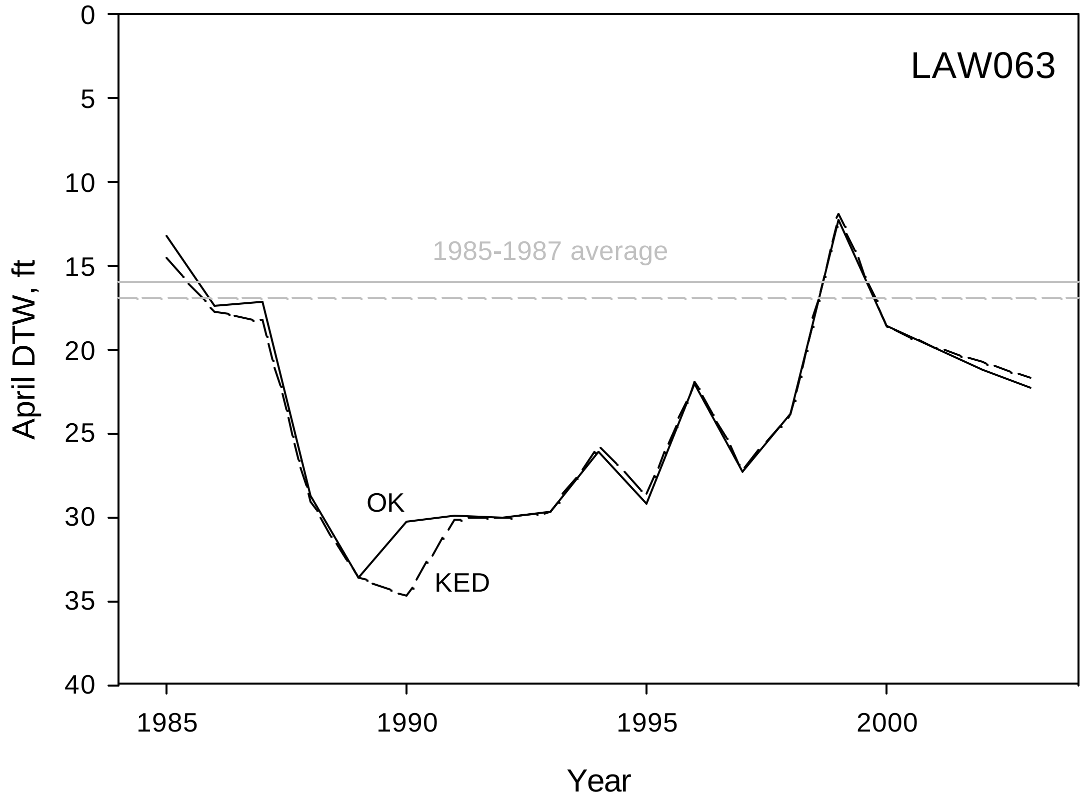
LAW040. KED and OK are similar, but inconsistent with V269, 577T, and 606T. DTW in monitoring wells changes temporally and spatially as parcel crosses Lower McNally Canal and is adjacent to Upper McNally Canal. The yearly time step of the kriged hydrographs does not capture these rapid fluctuations. Baseline, relative recovery, and DTW are unreliable.



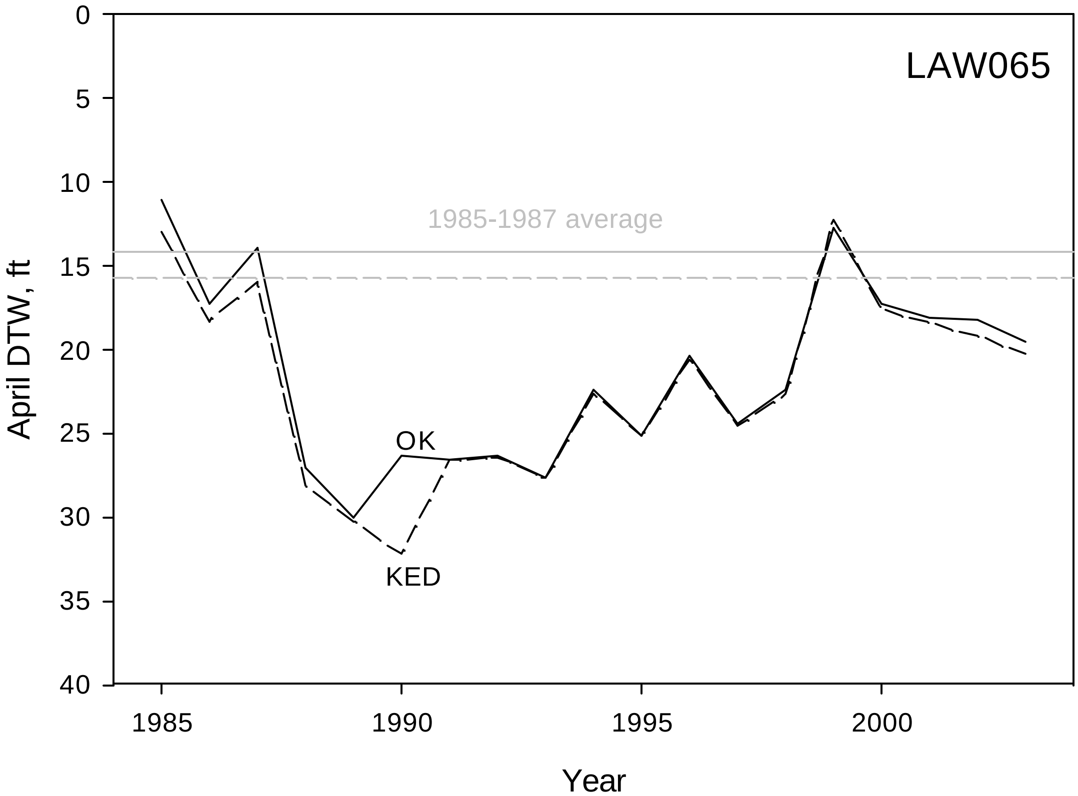
LAW052. KED and OK are congruent and consistent with 313AT, 494T, and 577T. Well network configuration is similar until 835T enters data in 2001. Wells in this vicinity went dry for various periods during the early-1990's, causing the maximum DTW to be unreliable. The entry of 835T into the data does not cause a step-change in the hydrographs, indicating that DTW estimates are robust. Baseline, relative recovery, and DTW are reliable.



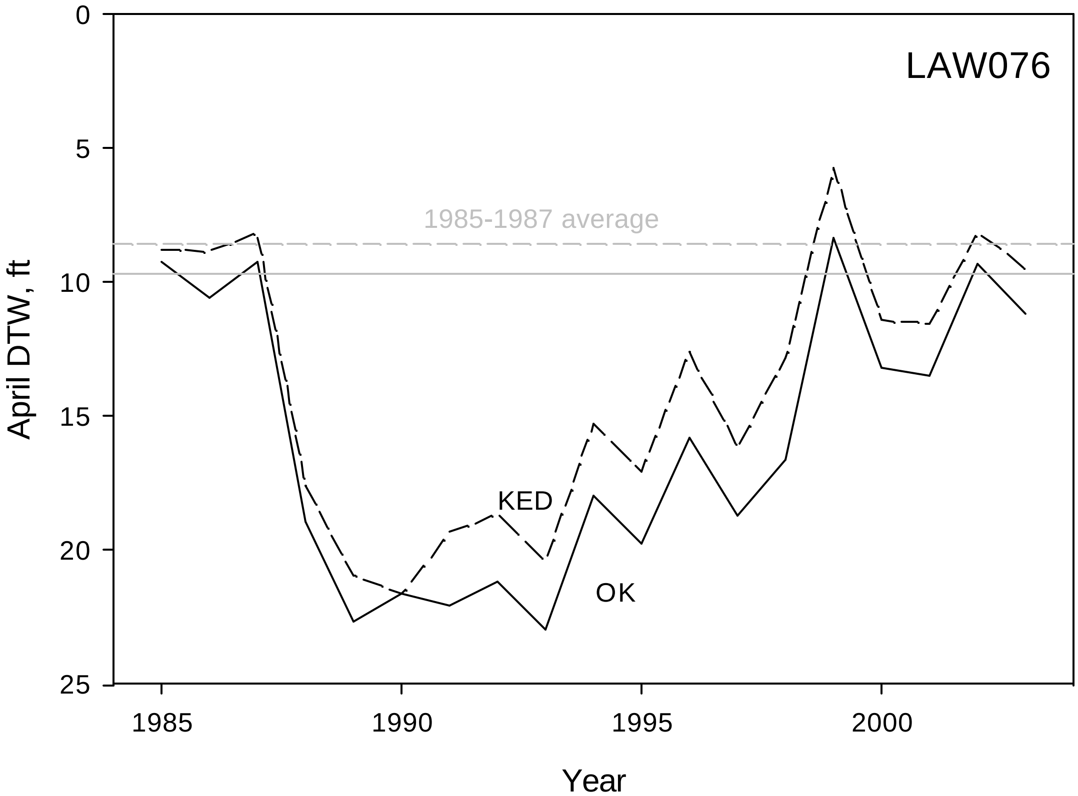
LAW062. KED and OK are congruent and consistent with 577T and V290. Due to its proximity to the Lower McNally Canal, this parcel undergoes rapid changes in DTW that may not be well captured by the yearly time step of the kriged hydrographs. Notwithstanding the yearly time step, baseline, relative recovery, and DTW are reliable.



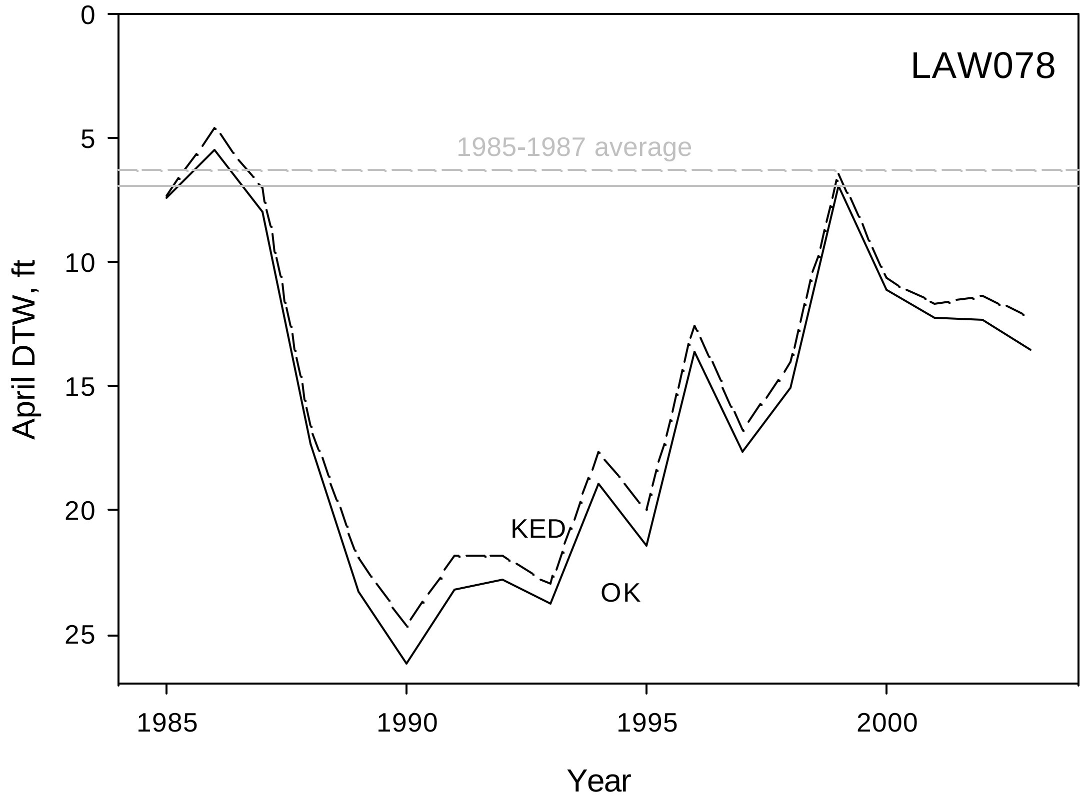
LAW063. Similar comments to LAW062.



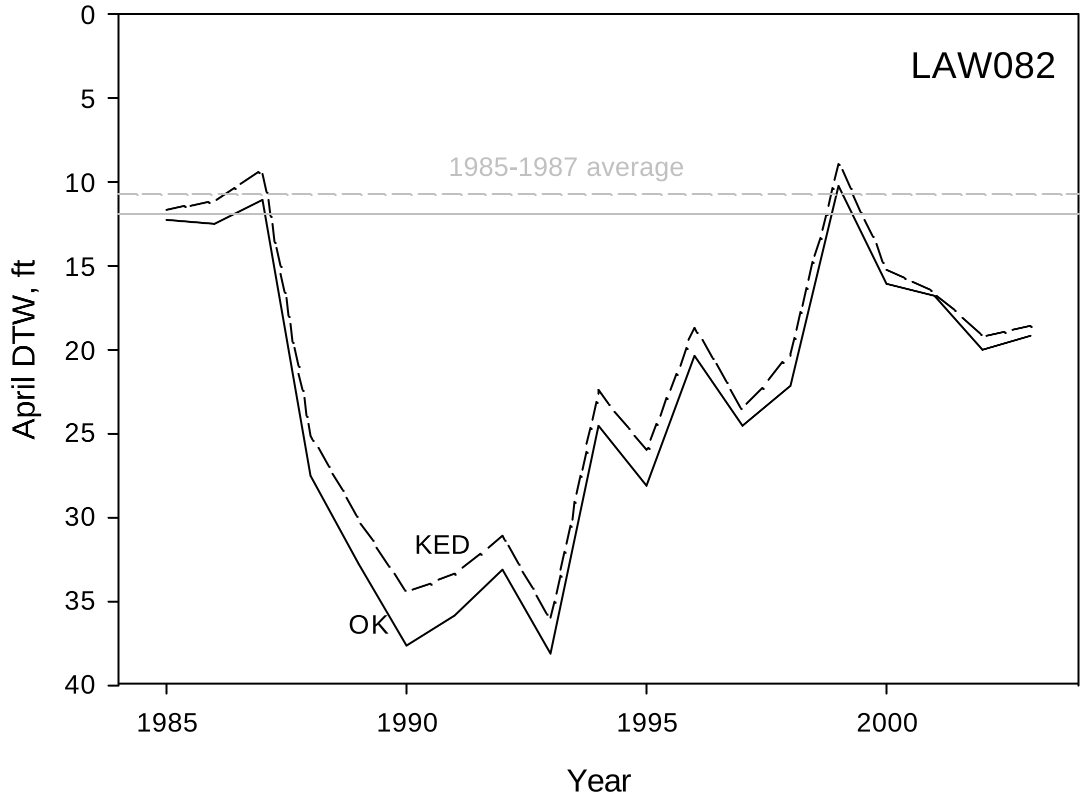
LAW065. Similar comments to LAW062.



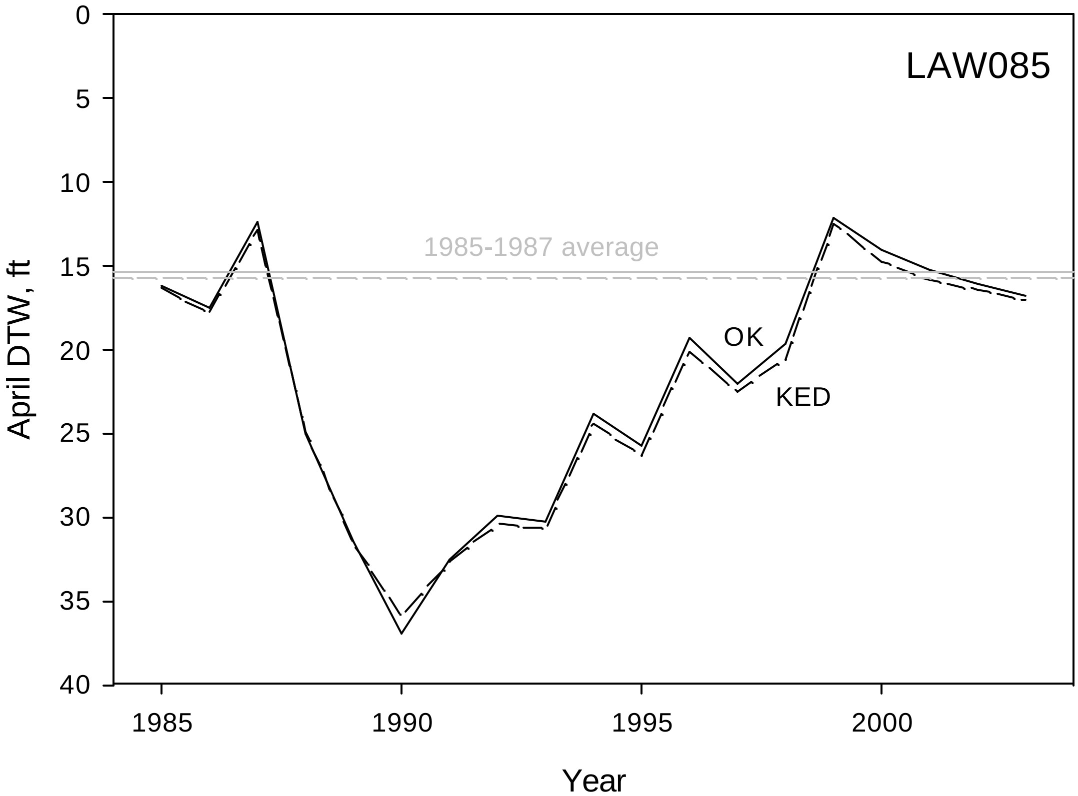
LAW076. KED and OK are similar until 1990; KED is 2-4 ft shallower thereafter. Relative recovery in kriged hydrographs is greater than 435T and 436T. Both hydrographs rise anomalously in 2002 due to the entry of 835T into the data. 835T lies topographically lower than the parcel, which is consistent with a positive anomaly in OK. Baseline, relative recovery, and DTW are unreliable.



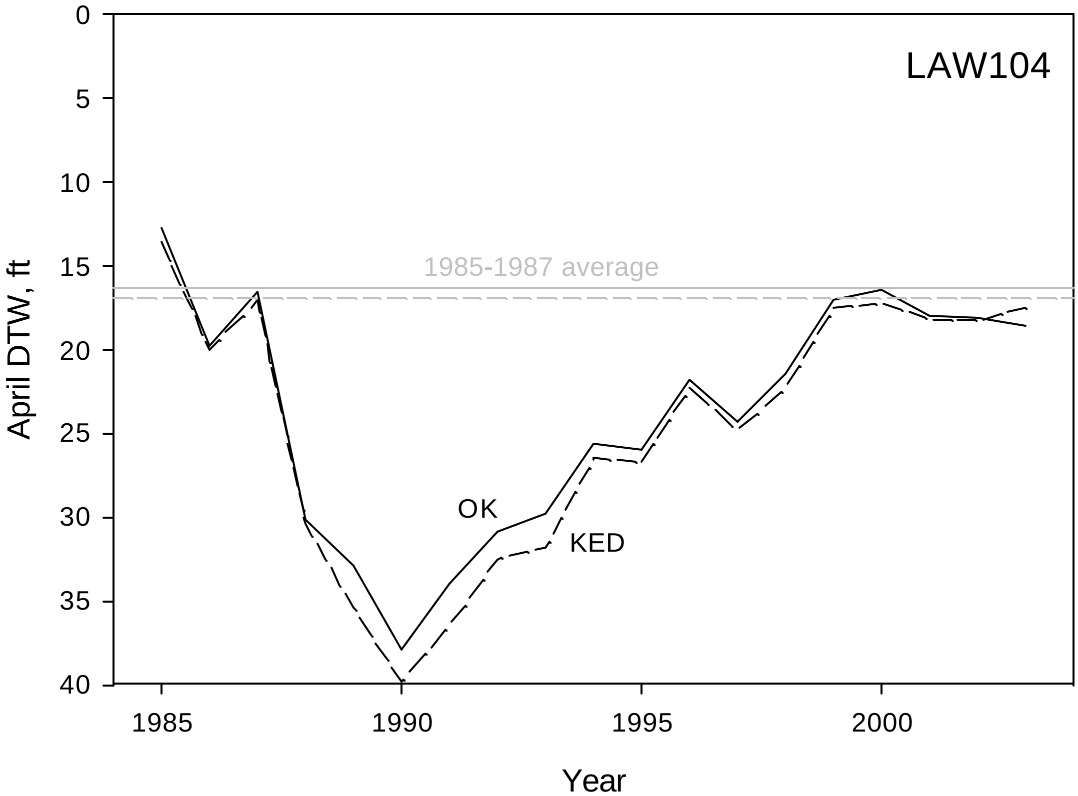
LAW078. KED and OK are parallel with KED ~1 ft shallower and consistent with 435T, 702T and 705T. The entry of 836T into the data does not cause an anomaly in 2002, indicating that both kriged hydrographs are robust. Baseline, relative recovery, and DTW are reliable.



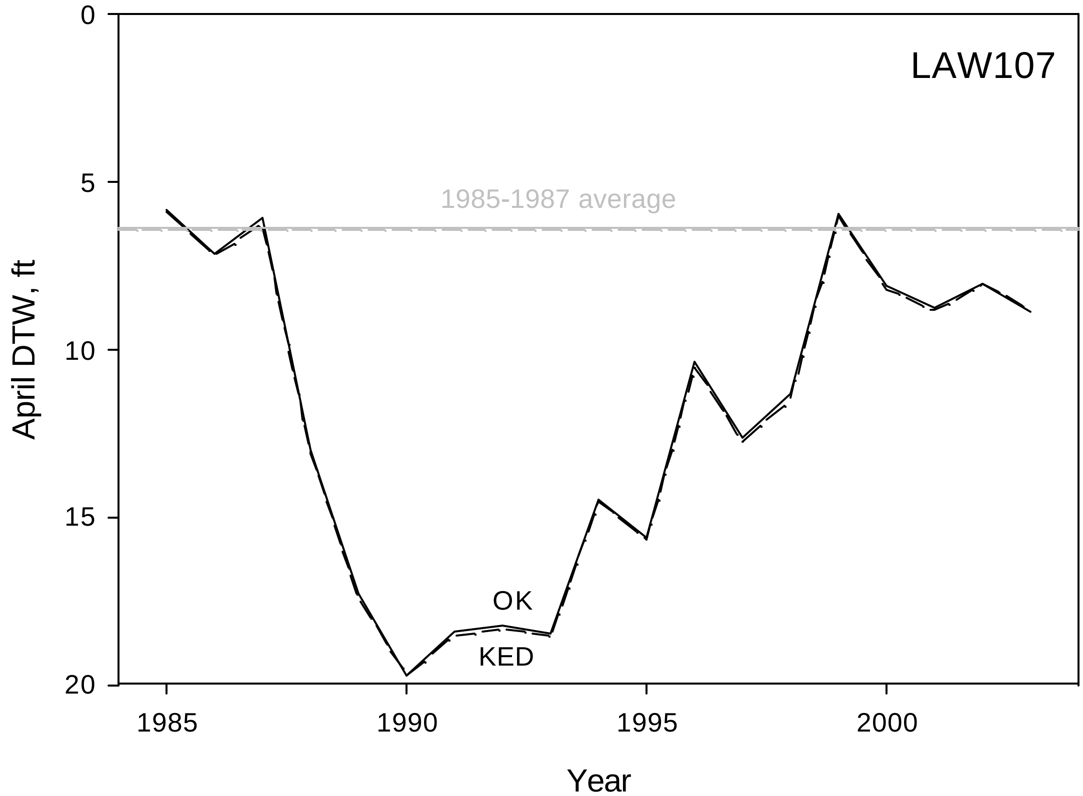
LAW082. KED and OK are parallel with KED ~1 ft shallower and are consistent with V271 and V001G. 702T enters the data in 1987 and 835T enters in 2001, but neither causes a step change in the kriged hydrographs, indicating that the hydrographs are robust. Baseline, relative recovery, and DTW are reliable.



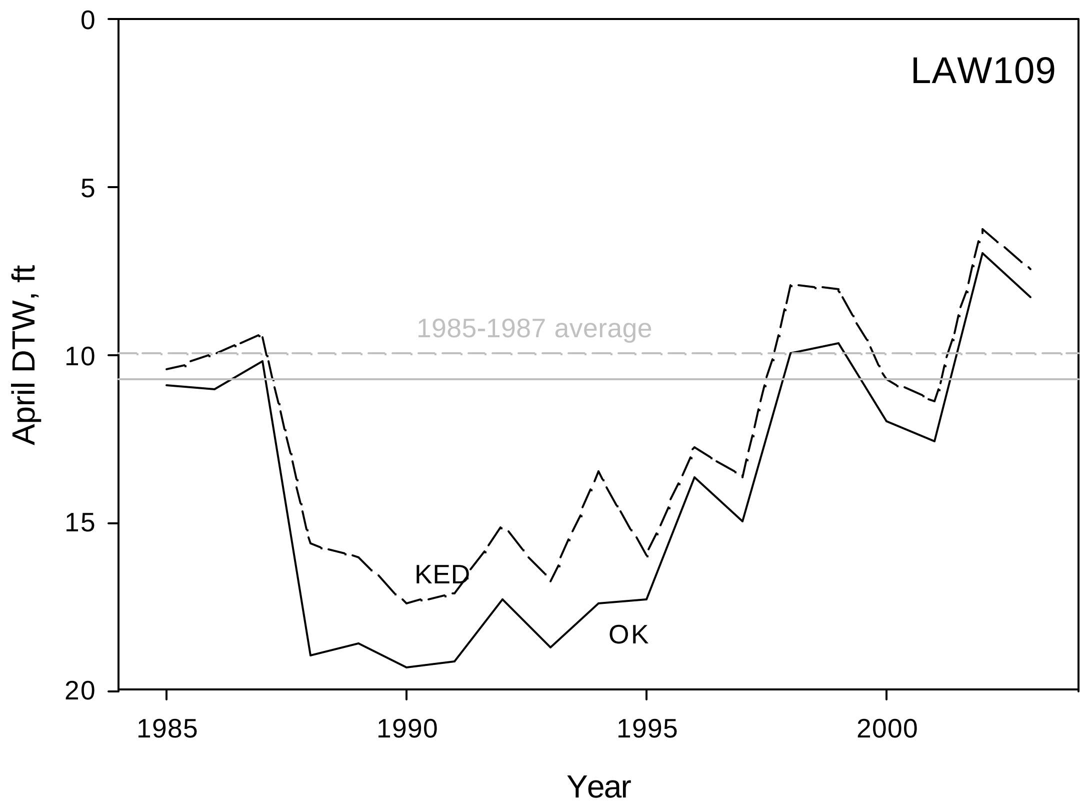
LAW085. KED and OK are congruent. V001G enters the data in 1986, suggesting that the estimated water table for 1985 may be too deep, therefore the baseline average may be slightly too deep. The baseline observations of 435T and 436T support this hypothesis. Baseline and relative recovery are questionable, but recent DTW is reliable.



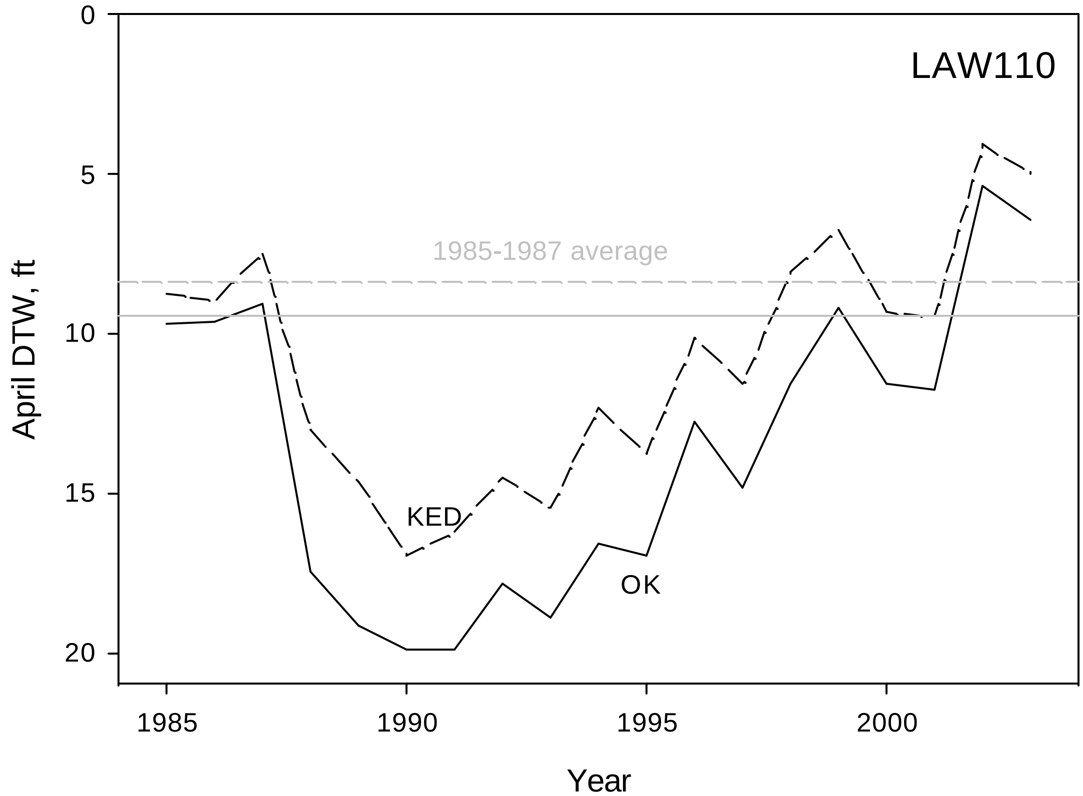
LAW104. KED and OK are nearly congruent. 580T is present for 1986 and 1987 only, making the assessment of relative recovery possibly questionable, however the kriged hydrographs are consistent with 436T and 437T. Baseline, relative recovery, and DTW appear reliable.



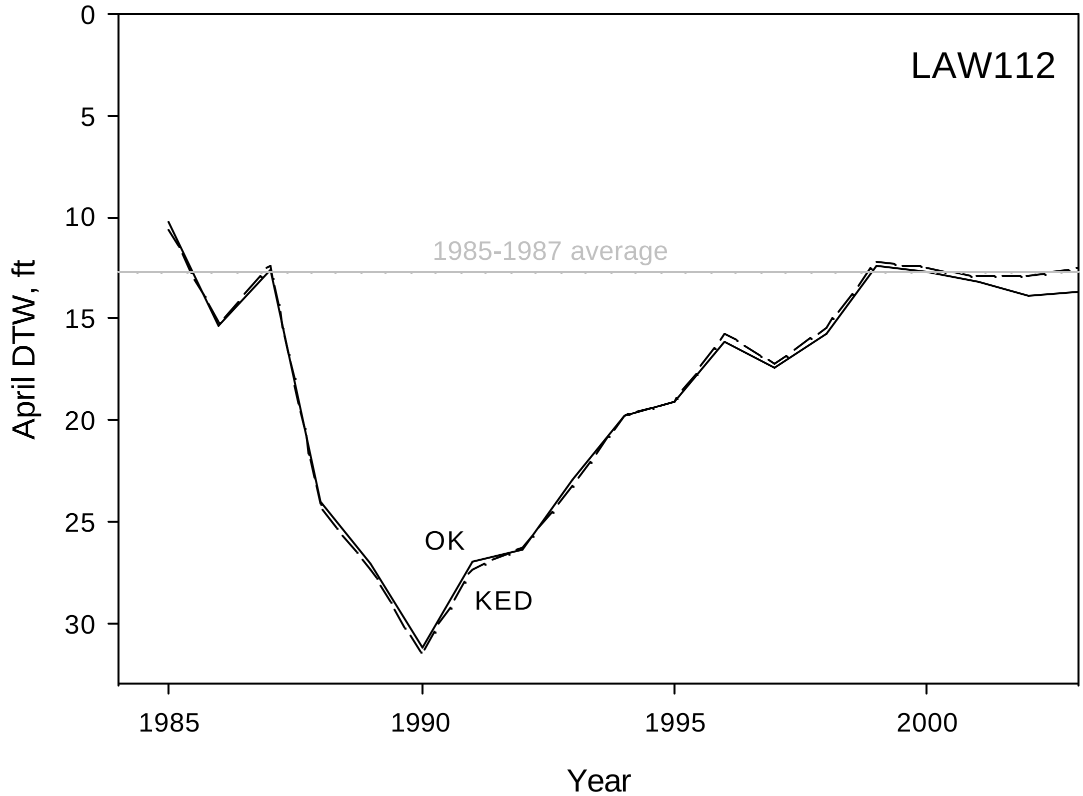
LAW107. KED and OK are congruent and consistent with 435T, 436T, 437T, and 705T. The increase in water level in 2002 is an artifact of the addition of 836T to the well network. Baseline, relative recovery, and DTW are generally reliable, though the slight anomaly due to 836T suggests the hydrographs should be ~1 ft shallower throughout.



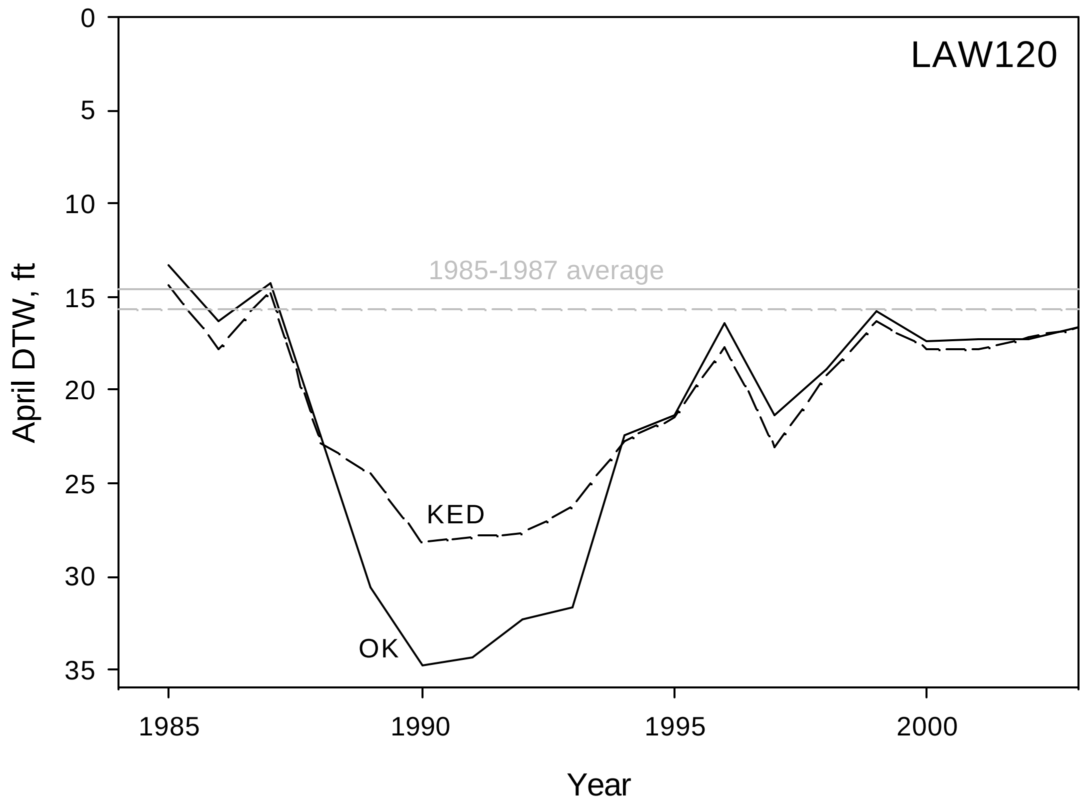
LAW109. KED and OK are parallel with KED 1-3 ft shallower than OK. The sharp rise in 2002 is due to the entry of 837T into the data. This rise suggests that the estimates for 1985-2001 are too deep. The parcel's proximity to the Owens River and the routing of drainage from the gravel pit through he parcel supports this hypothesis. Baseline and relative recovery are unreliable, but DTW for 2002 is reliable.



LAW110. Similar comments and anomalies as LAW109.

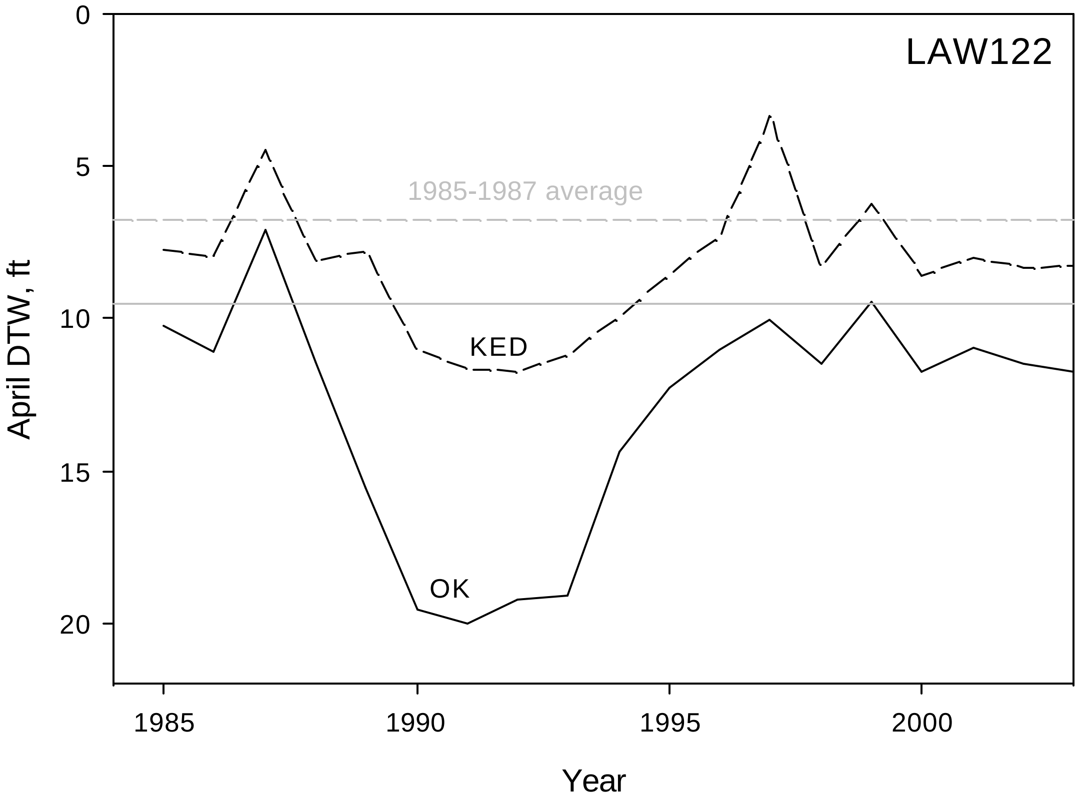


LAW112. KED and OK are congruent and consistent with 434T, 503T, and 575T. Baseline, relative recovery, and DTW are reliable.

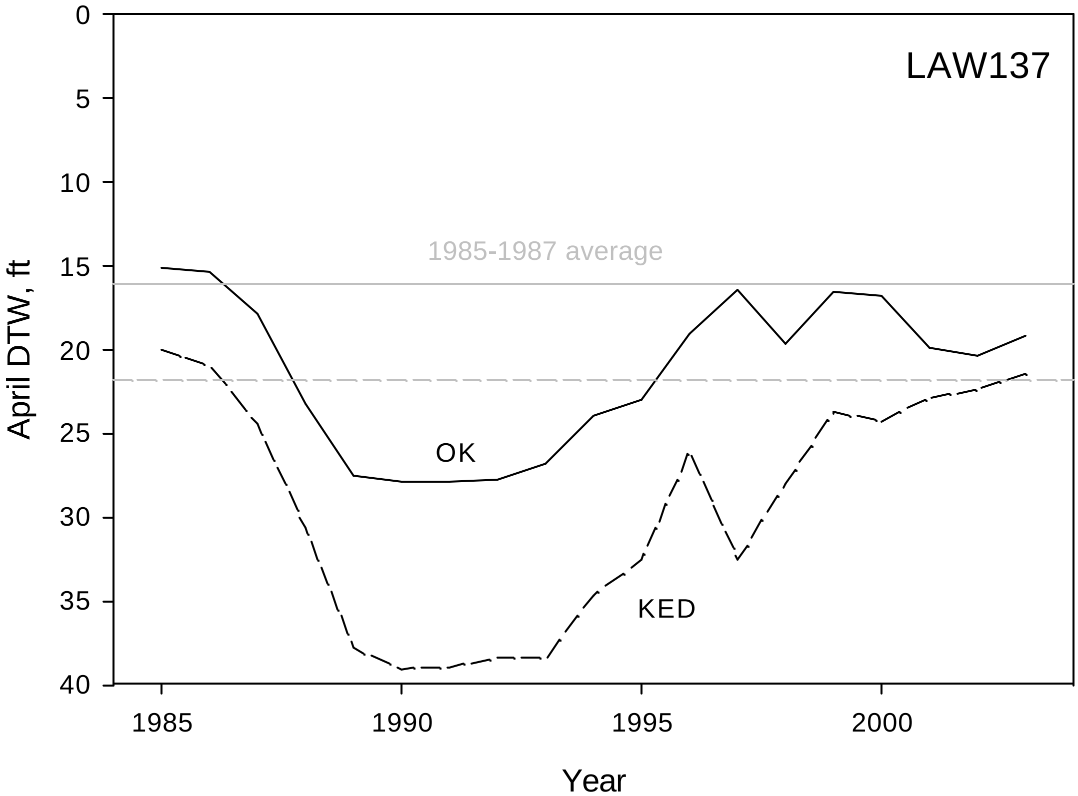


L

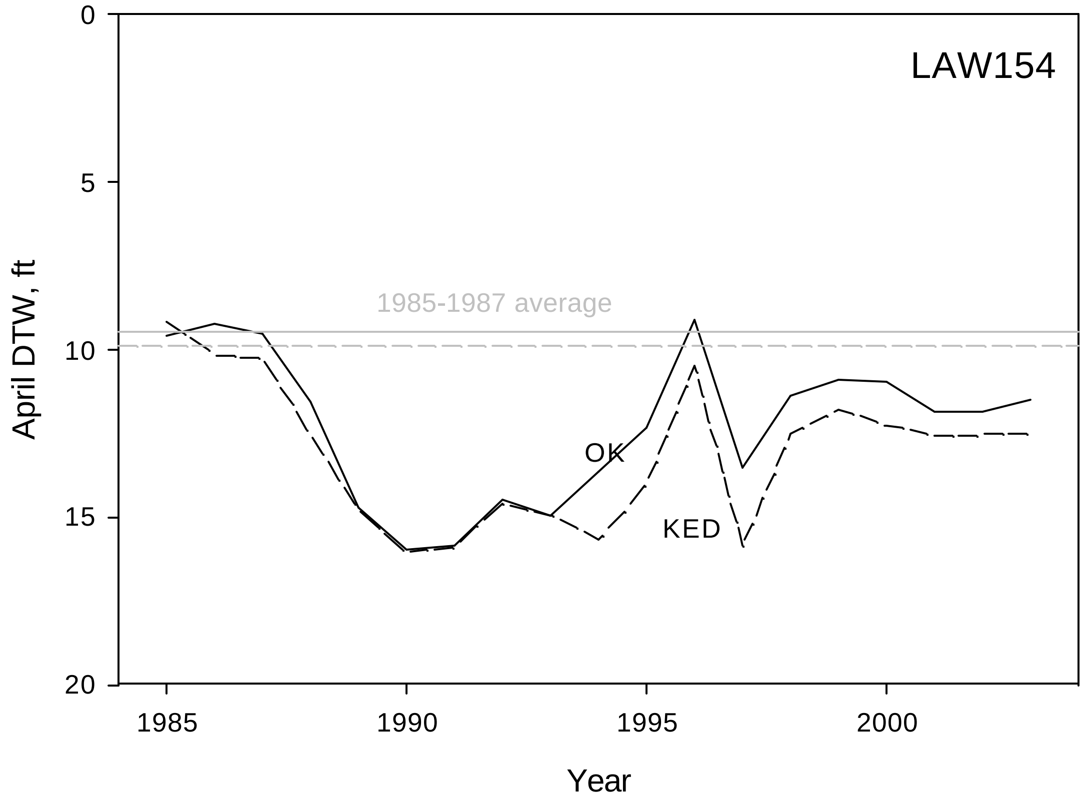
LAW120. OK and KED are nearly congruent during baseline and after 1994; KED is up to ten feet shallower from 1988 through 1993. Baseline is consistent with 496T; relative recovery is reliable and 2002 DTW is reliable. Hydrographs of nearby wells 574T and 496T have erratic fluctuations suggesting the influence of managed surface water. 574T and 496T were dry for various periods of time in the early 1990's, which renders the maximum drawdown at that time unreliable, however baseline, relative recovery, and recent DTW are reliable.



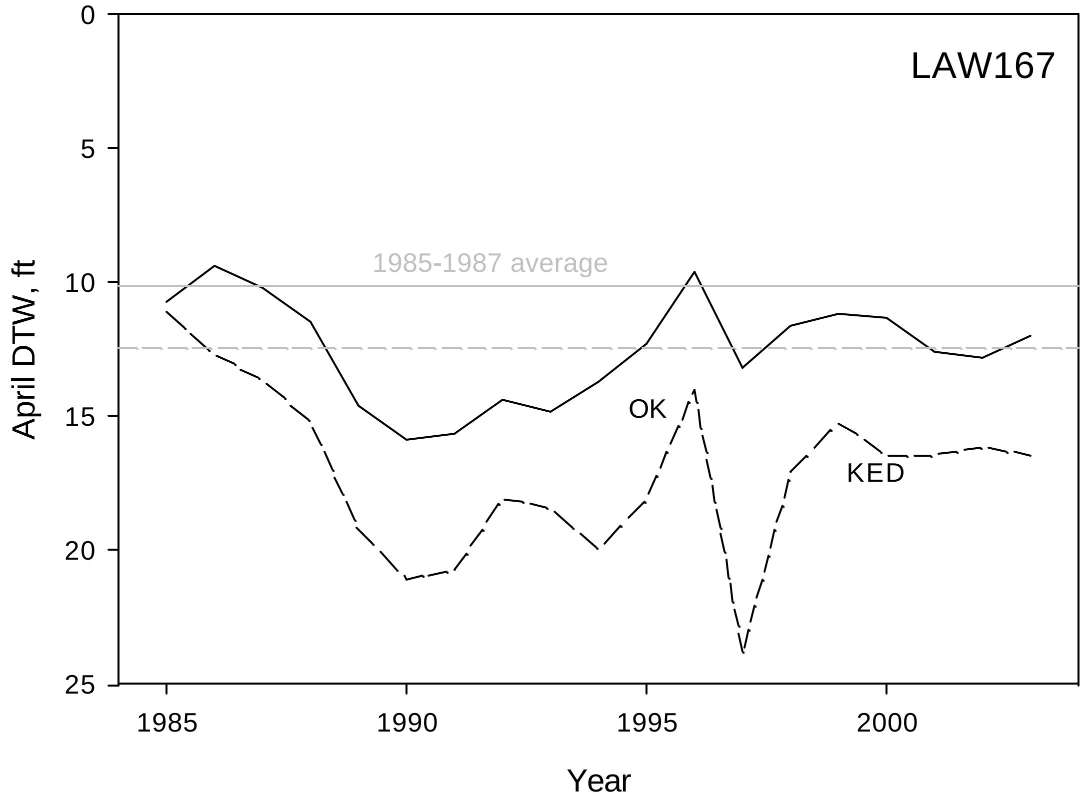
LAW122. This parcel flanks the east side of the Owens River flood plain. The nearest wells, 574T and 490T, are up-slope, suggesting that the OK estimate may be too deep. KED appears reasonable, but sparse well coverage makes the estimate of baseline, relative recovery, and recent DTW unreliable.



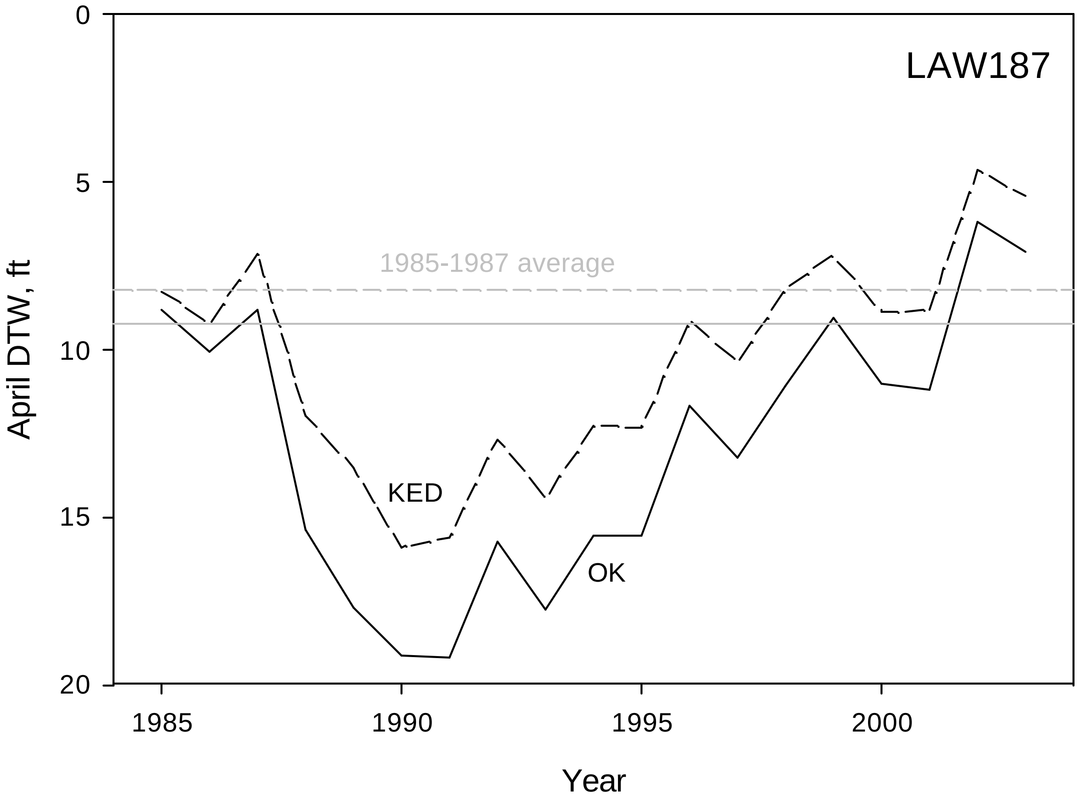
LAW137. KED and OK are different. Well coverage near this parcel was sparse until 841T enters the data in 2002. The hydrographs converge in 2002 due to the addition 841T. DTW in this parcel probably varies within this parcel depending on canal operations. Baseline and relative recovery are unreliable, but 2002 DTW is reliable.



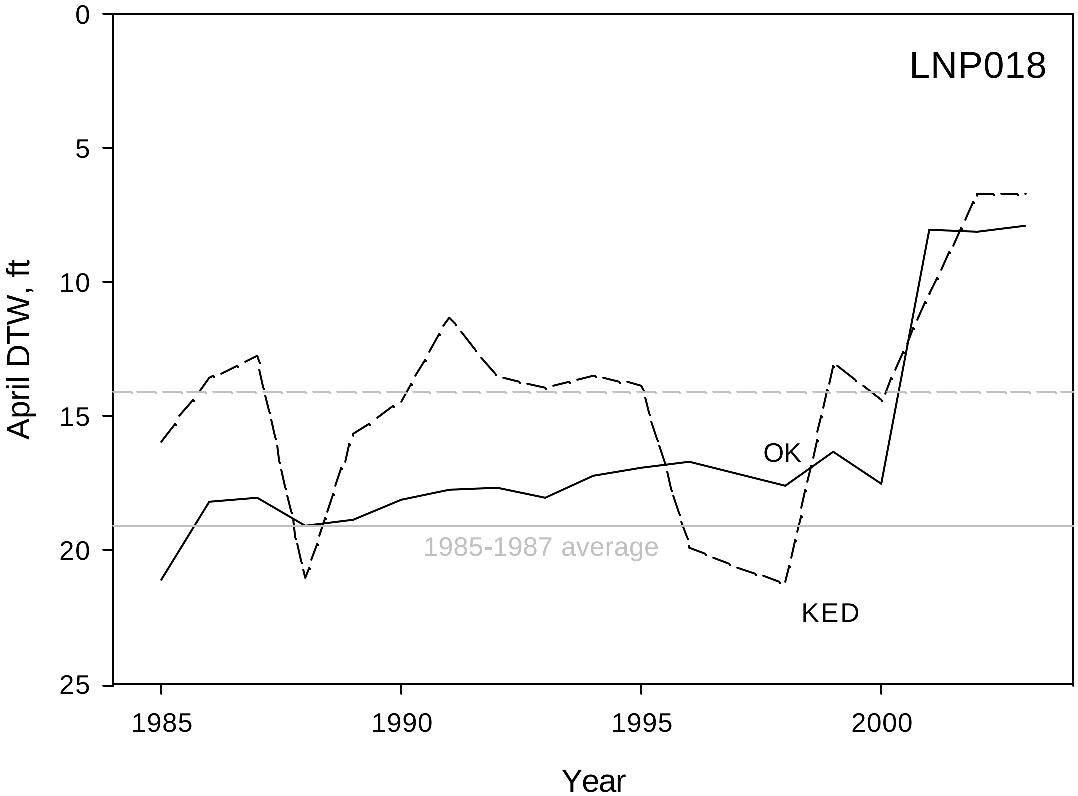
LAW154. KED and OK are erratic. Well network is sparse near this parcel. Baseline, relative recovery, and 2002 DTW are very uncertain.



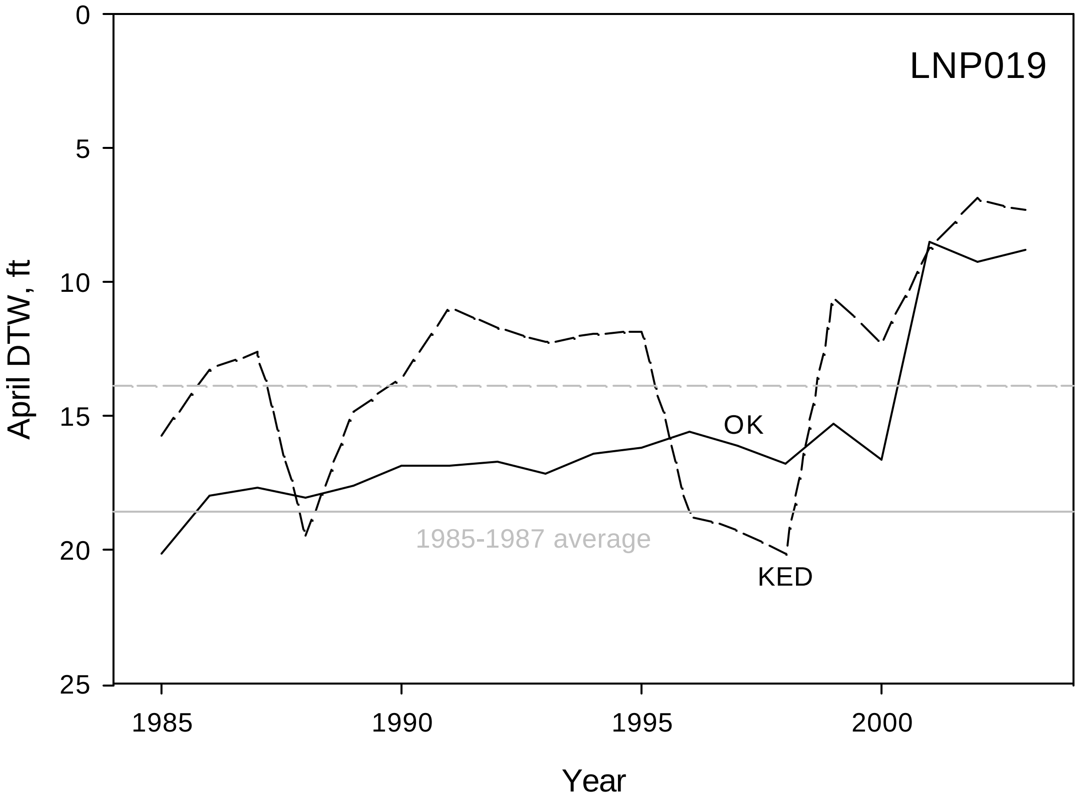
LAW167. Same comments as LAW154.



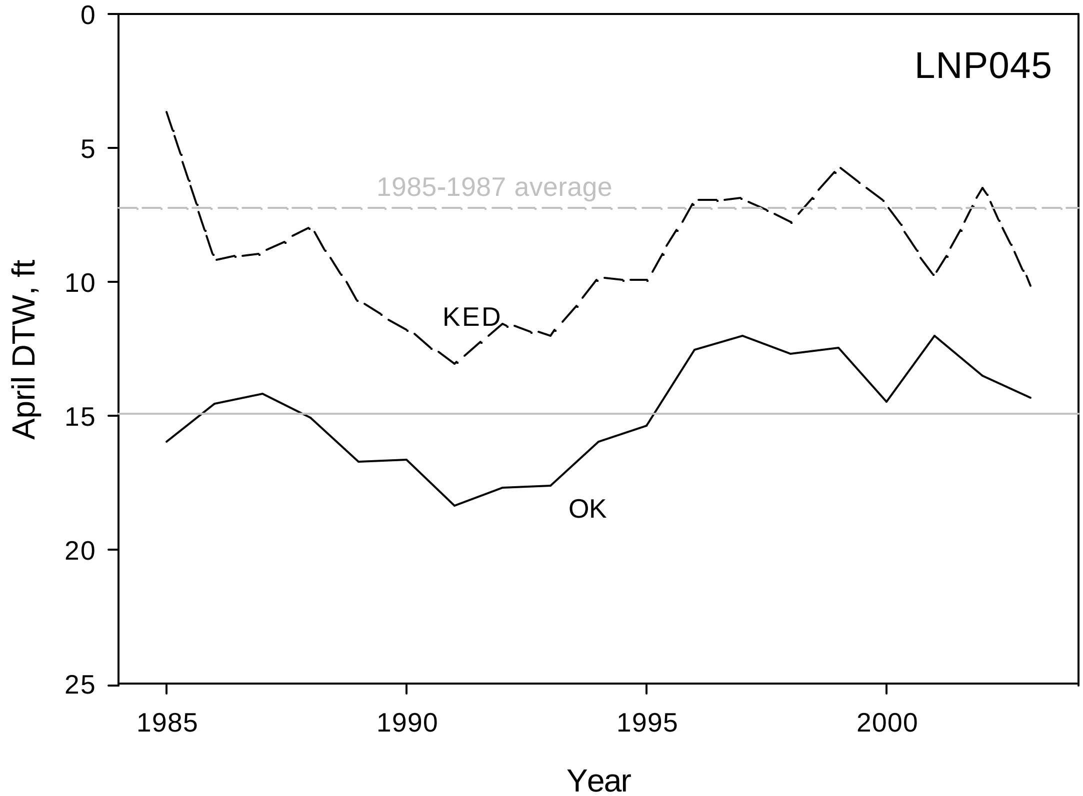
LAW187. KED and OK are parallel with KED 1-3 ft shallower. The kriged water table is too deep for this river-influenced parcel, as demonstrated by the sharp rise in 2002 due to the addition of 837T to the data. 837T is on the other side of the Owen River from LAW187, so it is not clear that this well is representative of the parcel. DTW probably varies within the parcel as the parcel slopes north to the Owen River. The kriging in this area may benefit from inclusion of surface water data. Baseline, relative recovery, and 2002 DTW are unreliable.



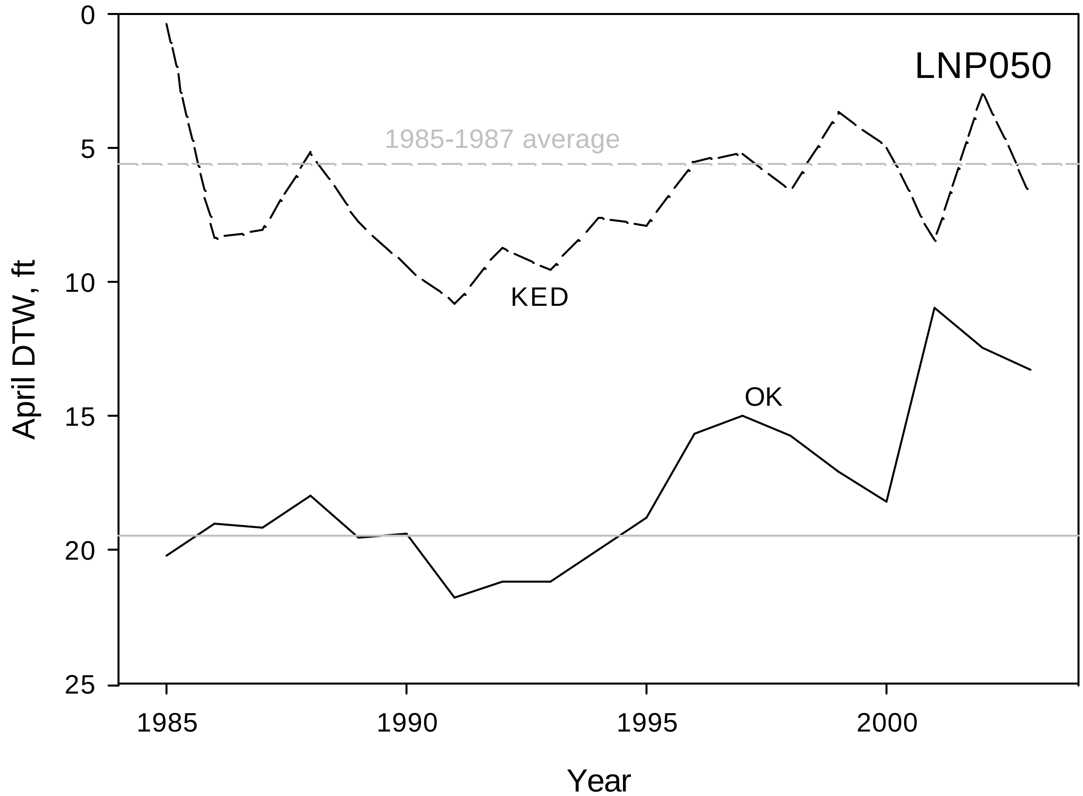
LNP018. KED and OK are both erratic and inconsistent with 564T, 592T, and 593T. Baseline, relative recovery, and DTW are unreliable.



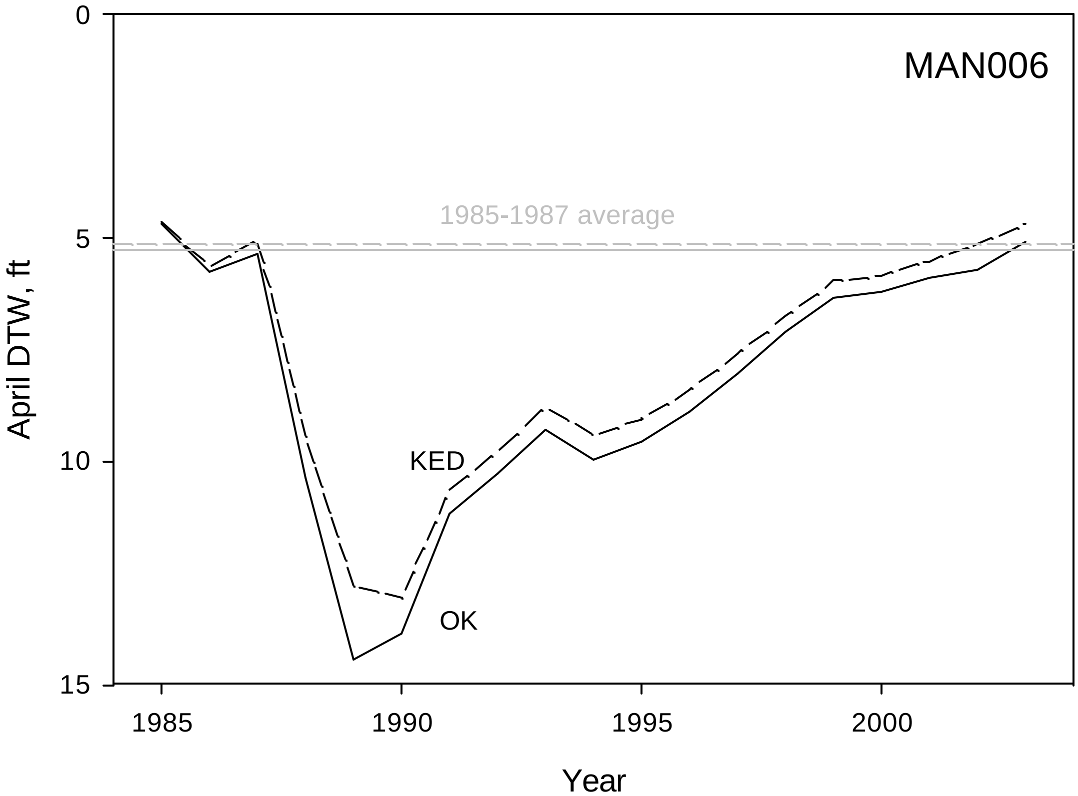
LNP019. Same comments as LNP018.



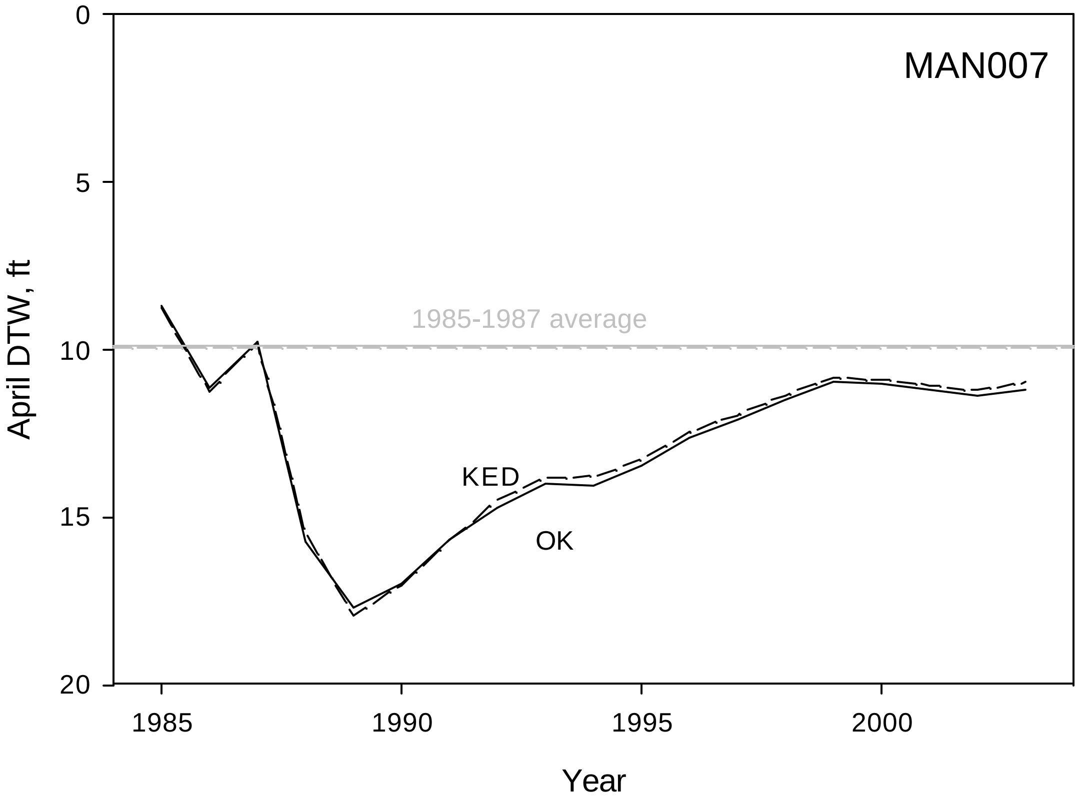
LNP045. KED and OK are different with KED being the more consistent with 588T. Baseline and relative recovery questionable. DTW probably lies between the two estimates.



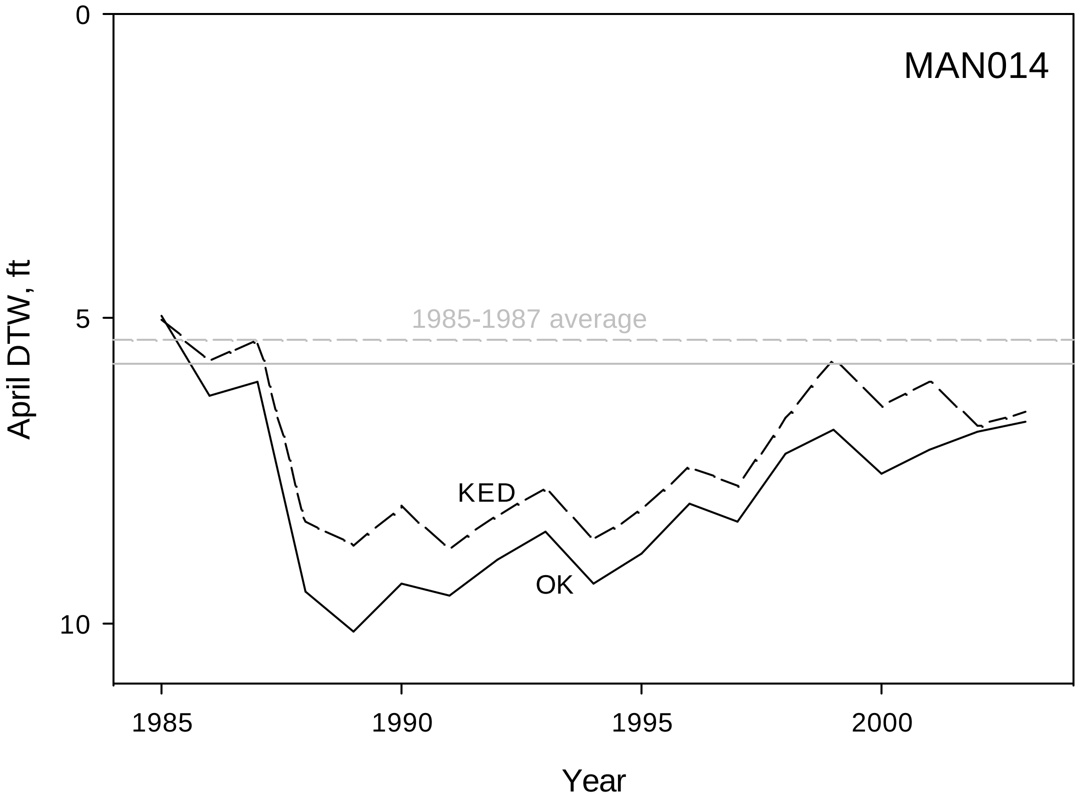
LNP050. Baseline, relative recovery, and DTW unreliable.



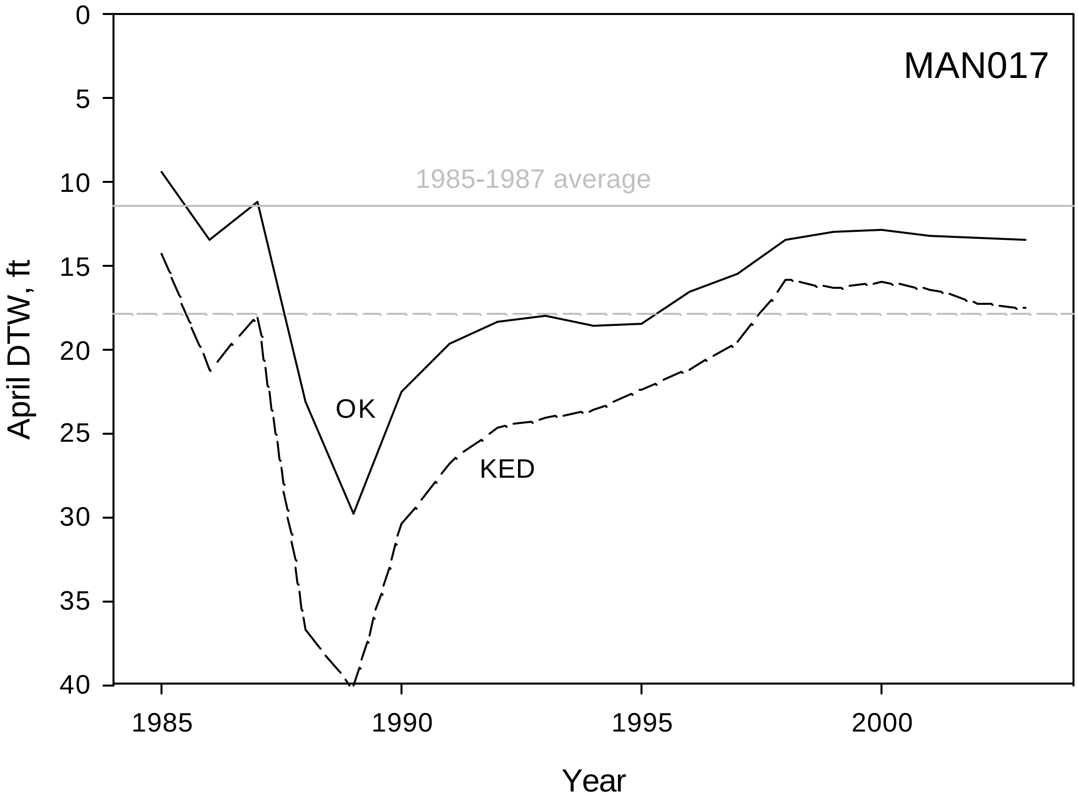
MAN006. KED and OK are parallel with KED 0-0.5 ft shallower and are consistent with 403T, 404T, and 562T. The parcel estimate relies primarily on 403T. There is a DTW gradient across the parcel as it slopes east to the LAA. Baseline, relative recovery, and DTW are reliable.



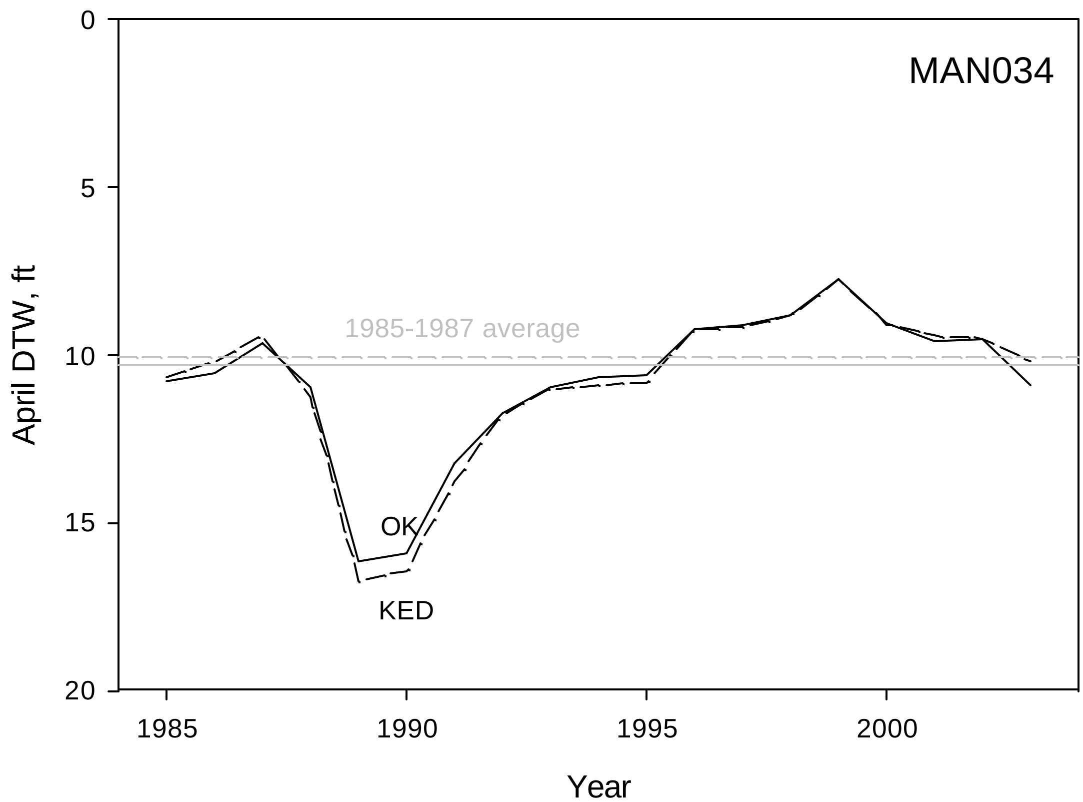
MAN007. KED and OK are congruent and consistent with 402T, 403T, 404T, and 510T. DTW varies across this large parcel as it slopes eastward to the aqueduct. The well network is dense, and has undergone changes during the modeling period: 622T was added in 1988 and 811T was added in 1990. Despite these changes, baseline, relative recovery, and DTW appear reliable.



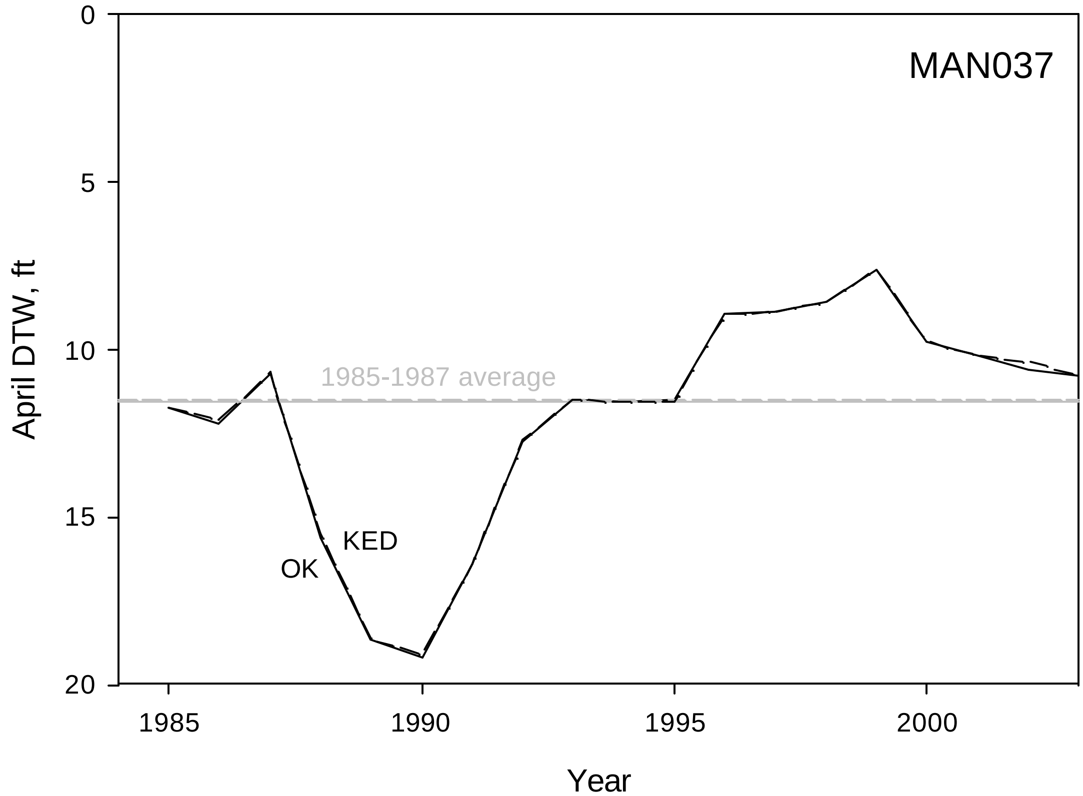
MAN014. KED and OK are parallel with KED ~1 ft shallower than OK. Well coverage around this parcel is poor. The decline in KED in 2002 is due to the entry of 855T into the data set. Due to the sparse well coverage baseline, relative recovery, and DTW are questionable.



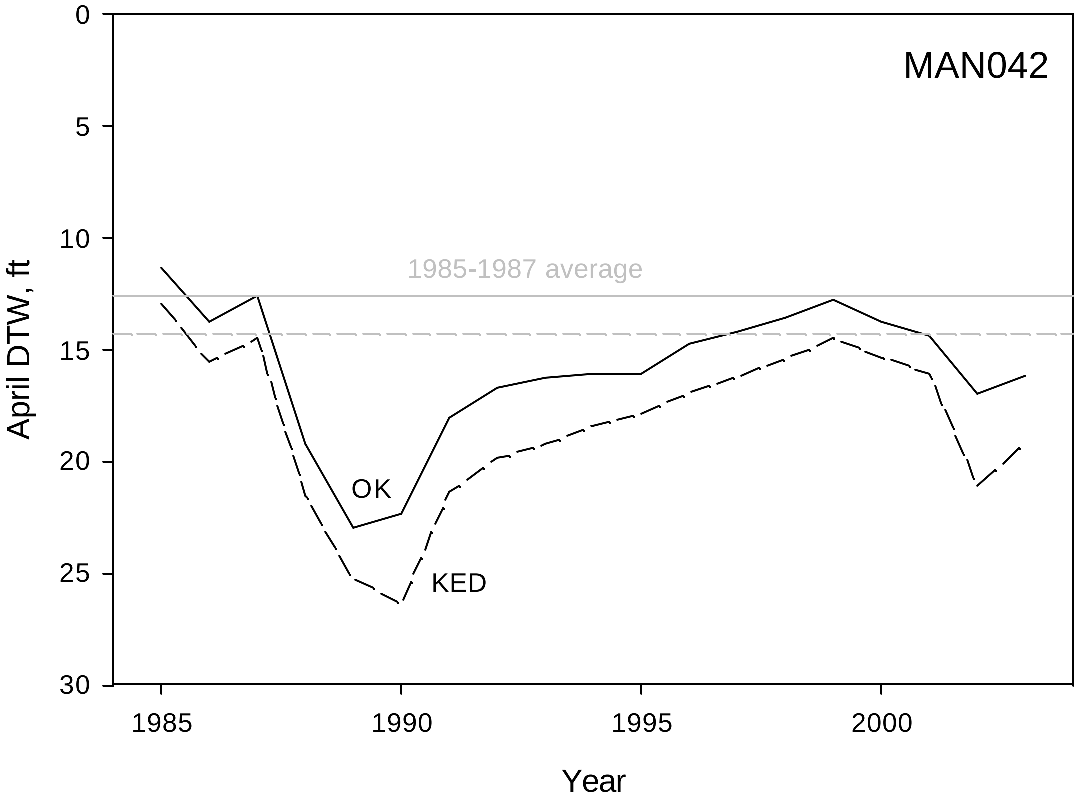
MAN017. KED and OK are parallel with OK 3-10 ft shallower than KED. 784T enters the record in 1989; it is hard to assess whether this resulted in a step-change in the hydrograph because DTW was undergoing rapid decline at that time. The incomplete recovery of OK is consistent with 401T, V070, and V169, but the deeper water table of KED is more representative of the up-slope southwest portion of the parcel. Relative recovery of OK is probably reliable, but baseline and DTW are questionable.



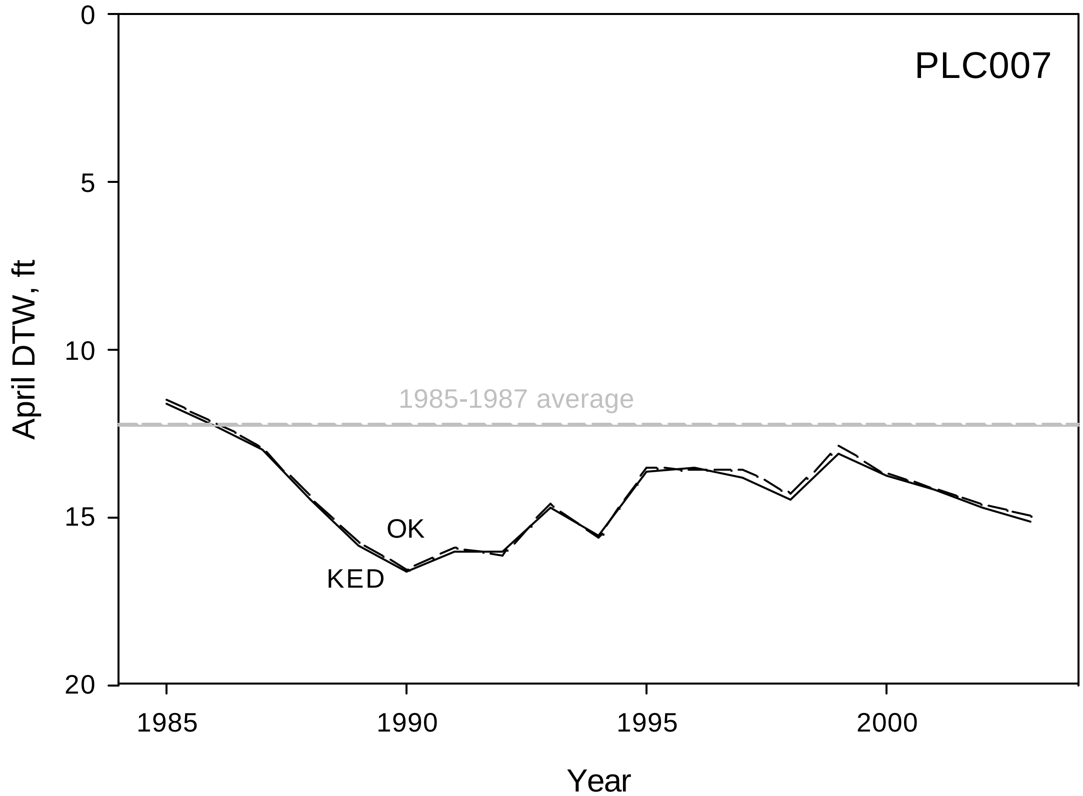
MAN034. KED and OK are congruent. The well network configuration changed with the addition of 812T in 1990 and the loss of 812T in 2002 due to fire. These changes caused no obvious anomaly; however the modeled relative recovery is inconsistent with 598T, 599T, V086, and V097. Baseline and relative recovery are questionable due to changes in well network configuration; DTW is questionable because the water table is probably shallower in the vicinity of the LAA compared to 812T and 598T.



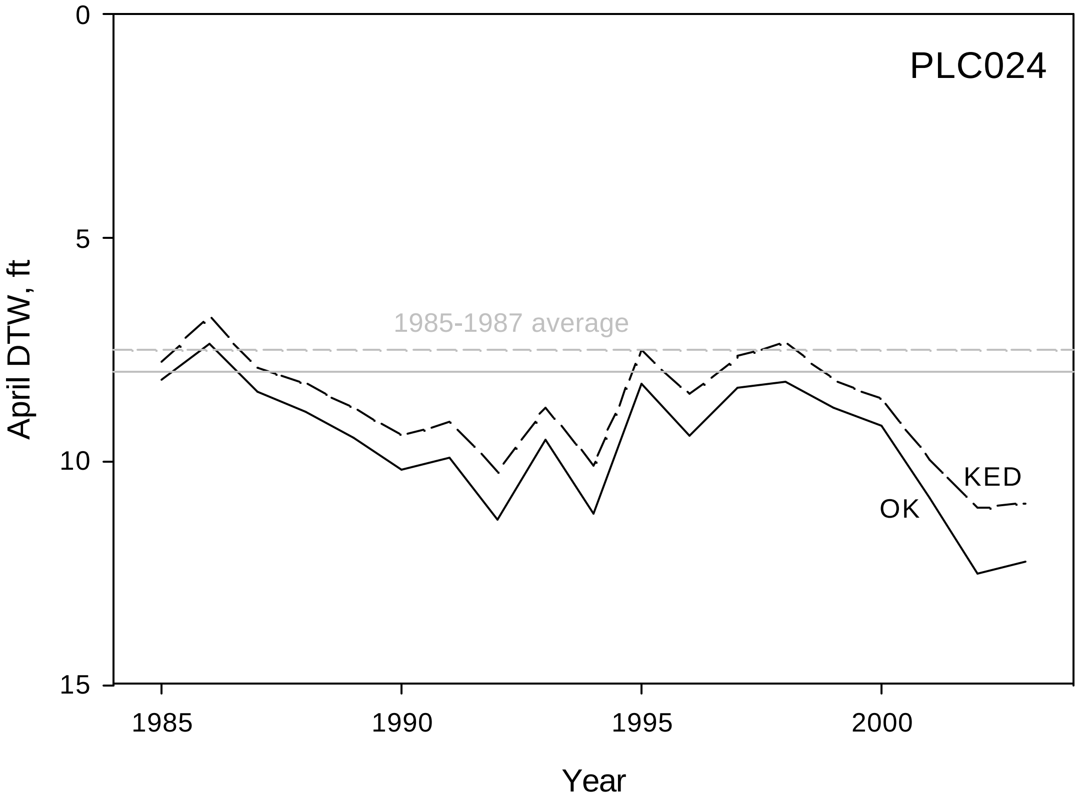
MAN037. KED and OK are congruent. The well network configuration changed with the addition of 812T in 1990 and the loss of 812T in 2002 due to fire. Baseline and relative recovery is consistent with the April measurements from 598T, however the high stand of 598T was in November 1986 and it had declined ~8 ft by April 1987. V097 (a deep well not used for kriging) suggests that the shallow well network in this area may not have captured the water level maximum in 1985. Baseline and relative recovery are questionable, but recent DTW is reliable.



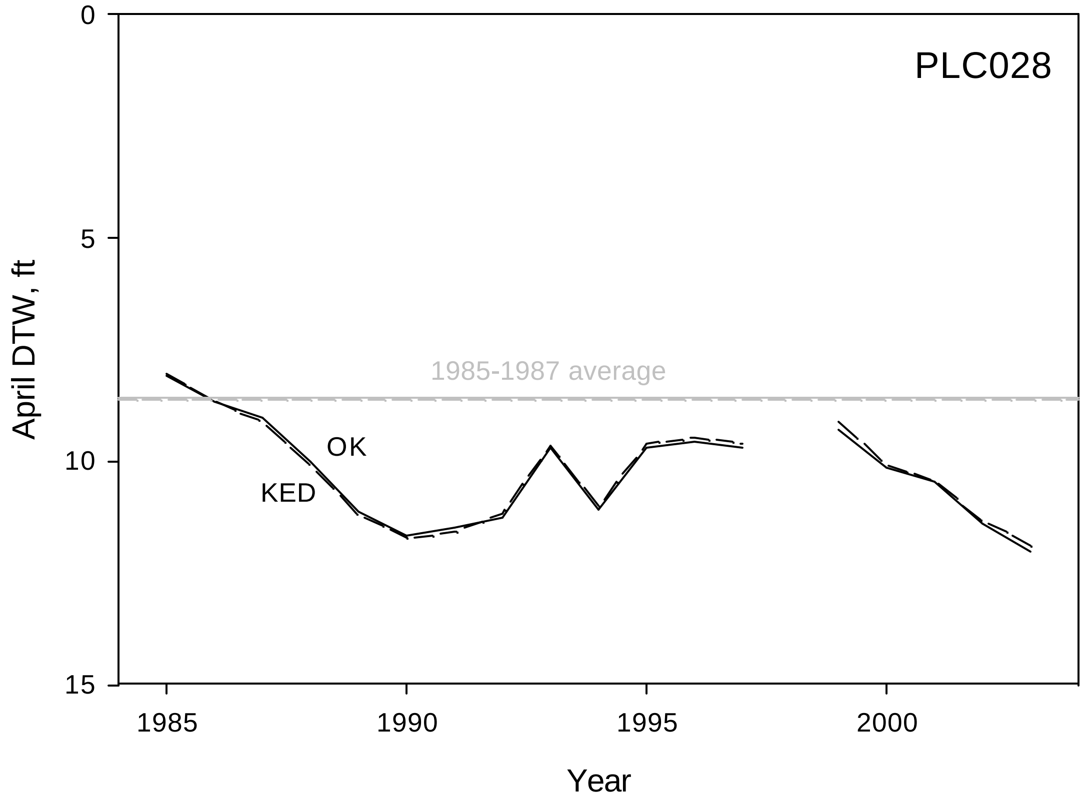
MAN0042. KED and OK are parallel with OK 2-3 ft shallower. The well network is sparse in this area. The sharp drop in 2002 is due to the loss of 812T from the data set. Estimated DTW is consistent with 788T, that is, the head in the shallow aquifer is less than the head at 100 ft. Due to the poor well coverage, baseline, relative recovery, and DTW are questionable.



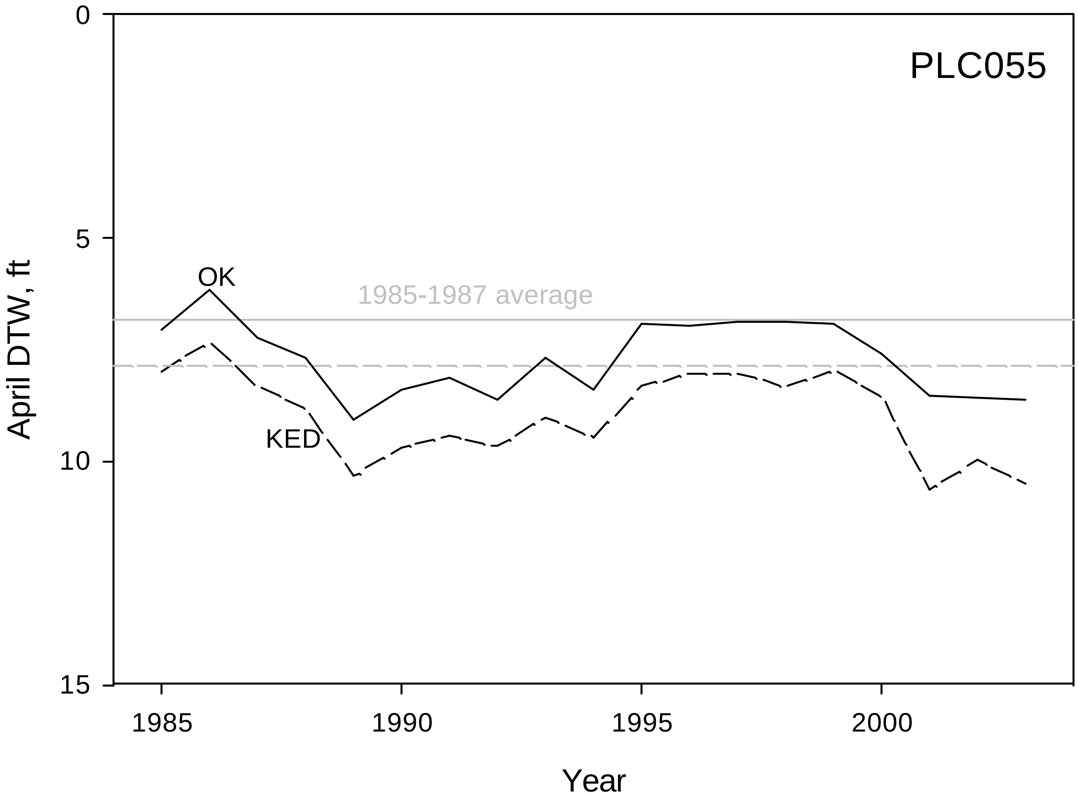
PLC007. KED and OK are congruent and consistent with the DTW gradient between 499T and 501T. Well network configuration stays the same during the modeling period. Baseline, relative recovery, and DTW are reliable.



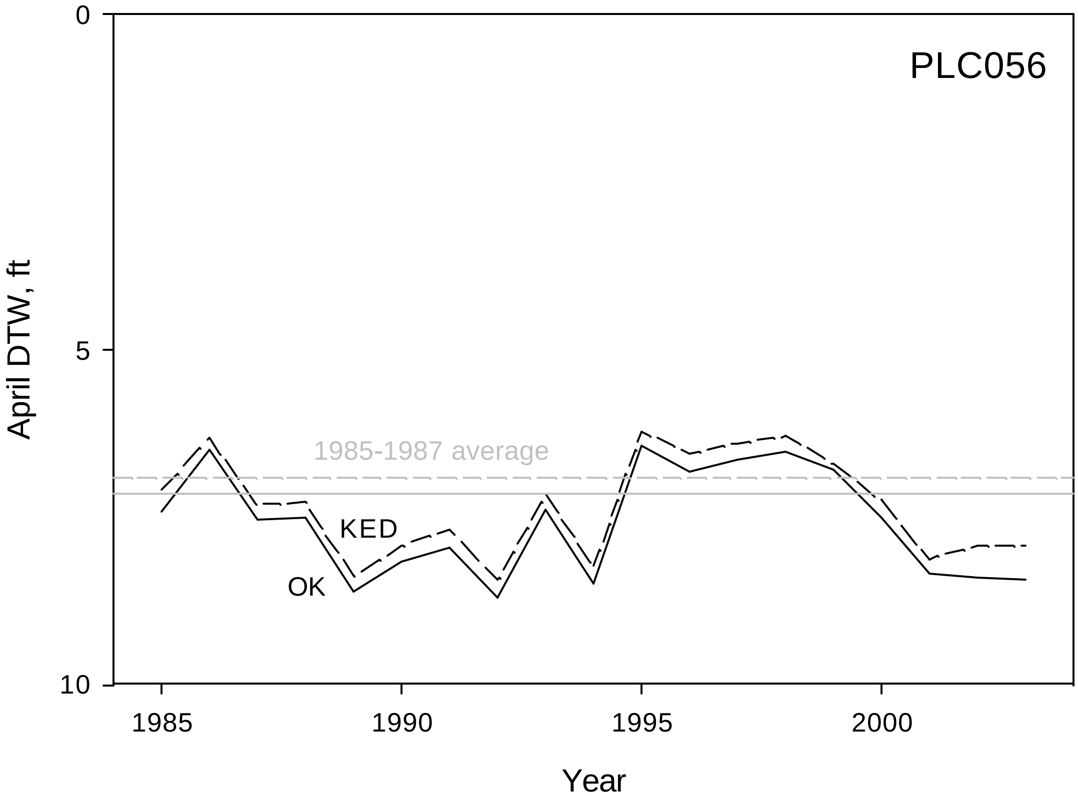
PLC024. KED and OK are parallel with KED ~0.5 ft shallower. A decline occurs in 2002 due to 323AT absence of in the kriging data set. DTW varies in this parcel as it slopes northeastward to Owens River. Baseline is reliable; relative recovery and DTW are reliable except for 2002 and 2003.



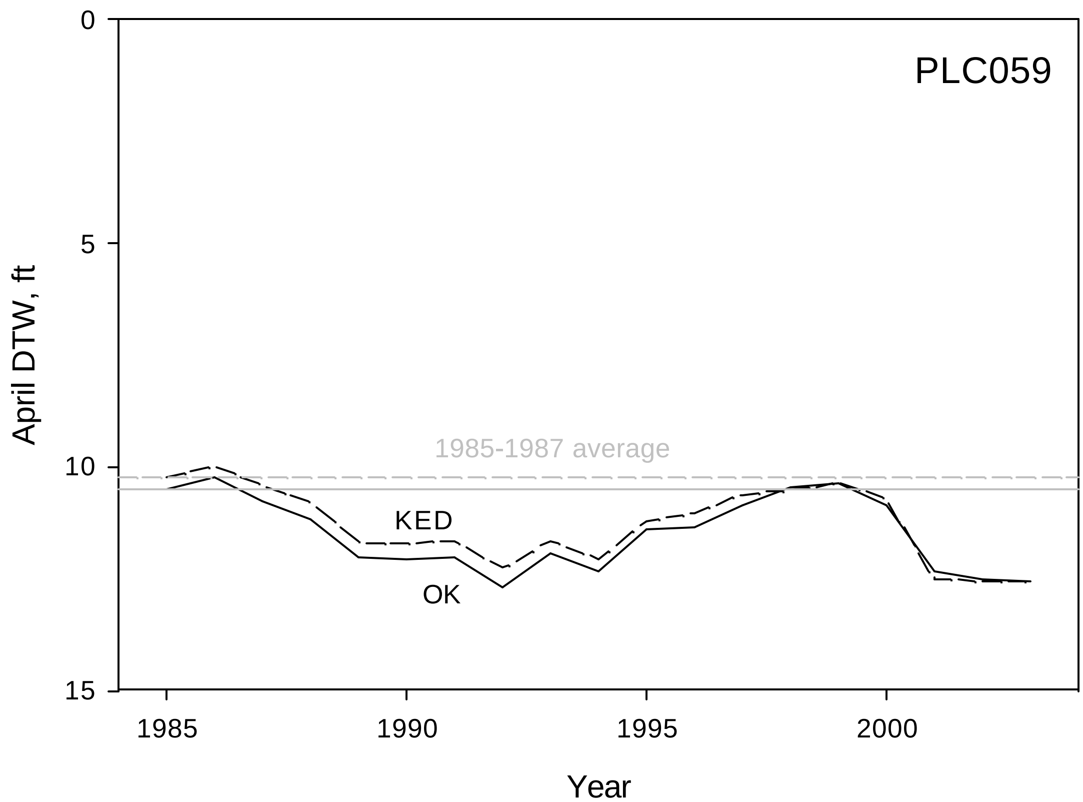
PLC028. KED and OK are congruent and parallel to 499T. An anomaly in 1998 is due to the absence of data from 499T for that year was removed. Baseline and relative recovery are reliable; DTW is reliable except for 1998.



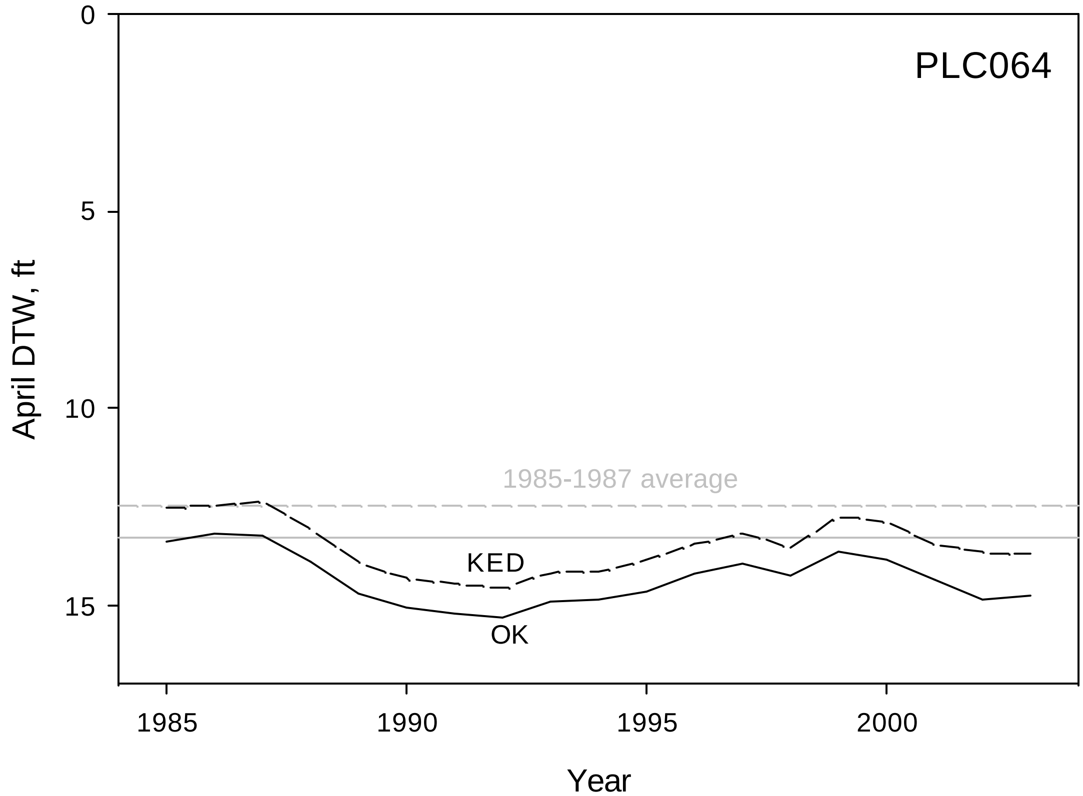
PLC055. KED and OK are parallel with OK ~1 ft shallower and consistent with 320AT. Well network configuration stays the same throughout the modeling period. This parcel is situated on a river terrace west of the Owen River, and the nearest monitoring well, 320AT is situated in the river flood plain at lower elevation, suggesting that the water table beneath the parcel is likely deeper than at any of the closest wells. Alternatively, Buckley Ponds may maintain a relatively shallow water table beneath the parcel despite the parcel's terrace location. Relative recovery is reliable, but baseline and 2002 DTW are uncertain.



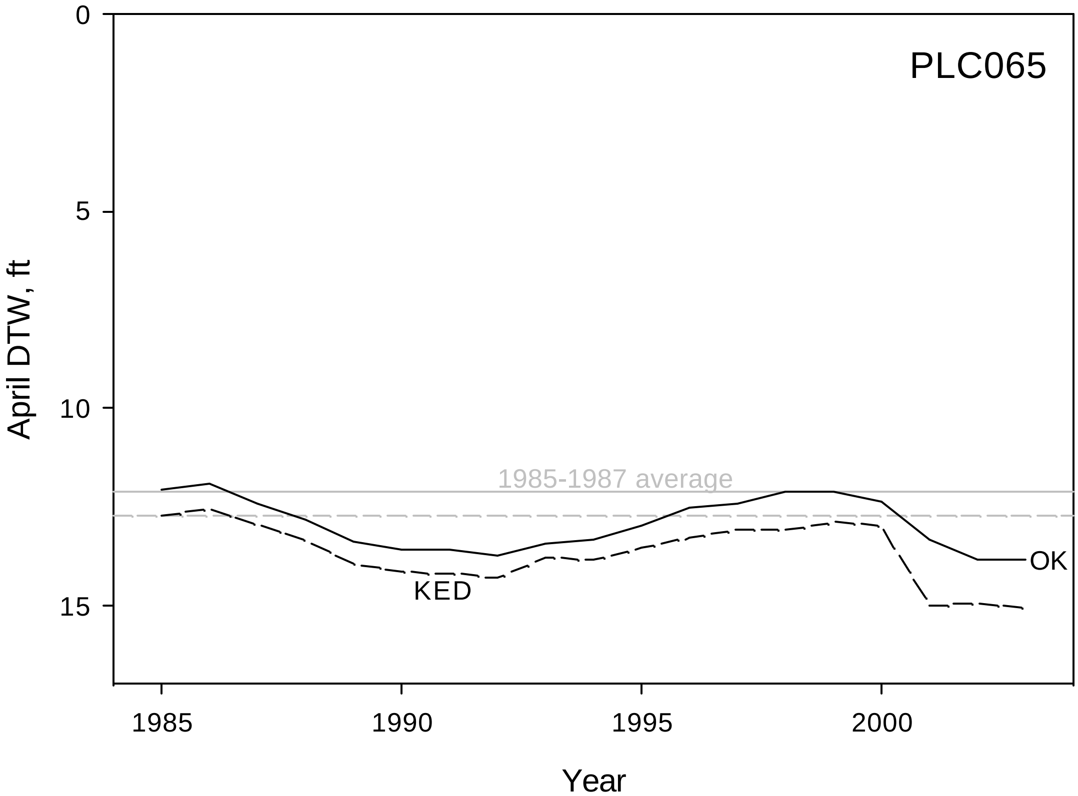
PLC056. KED and OK are parallel with KED a few inches shallower and consistent with 318AT and 320AT. Relative recovery is reliable, but, similar to PLC055, the parcel is located on a terrace above the Owens River flood plain, and the nearest monitoring DTW data comes from wells situated on the flood plain. Relative recovery is reliable, but baseline and DTW are uncertain.



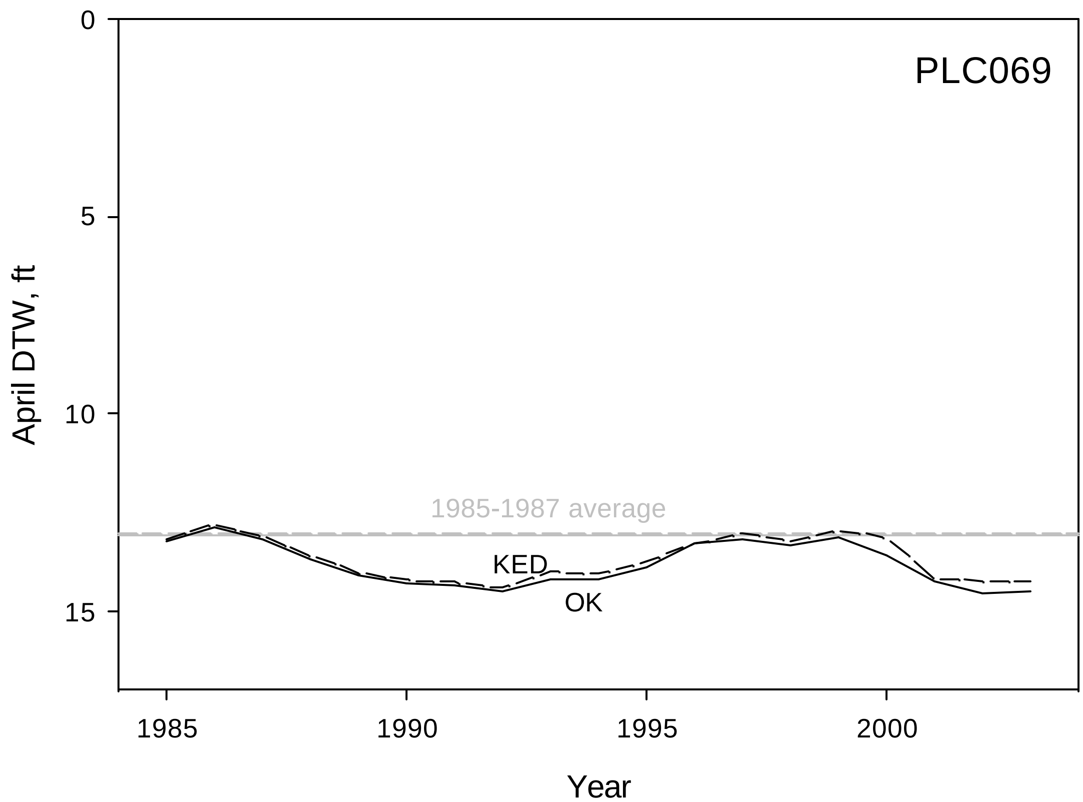
PLC059. KED and OK are nearly congruent and consistent with 481T, 485T, and 318AT. Though the well network is sparse in this area, a favorable configuration of wells around the parcel indicates that baseline, relative recovery, and DTW are reliable.



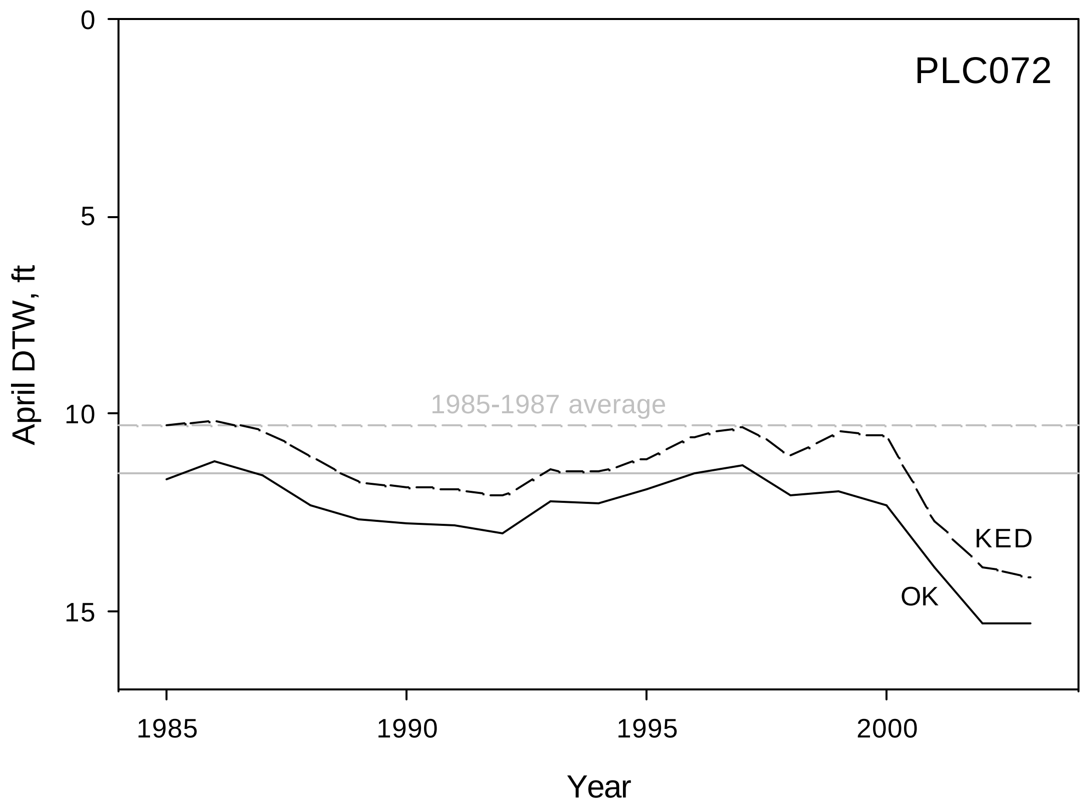
PLC064. KED and OK are parallel with KED ~1 ft shallower and consistent with 485T. Baseline, relative recovery, and DTW are reliable.



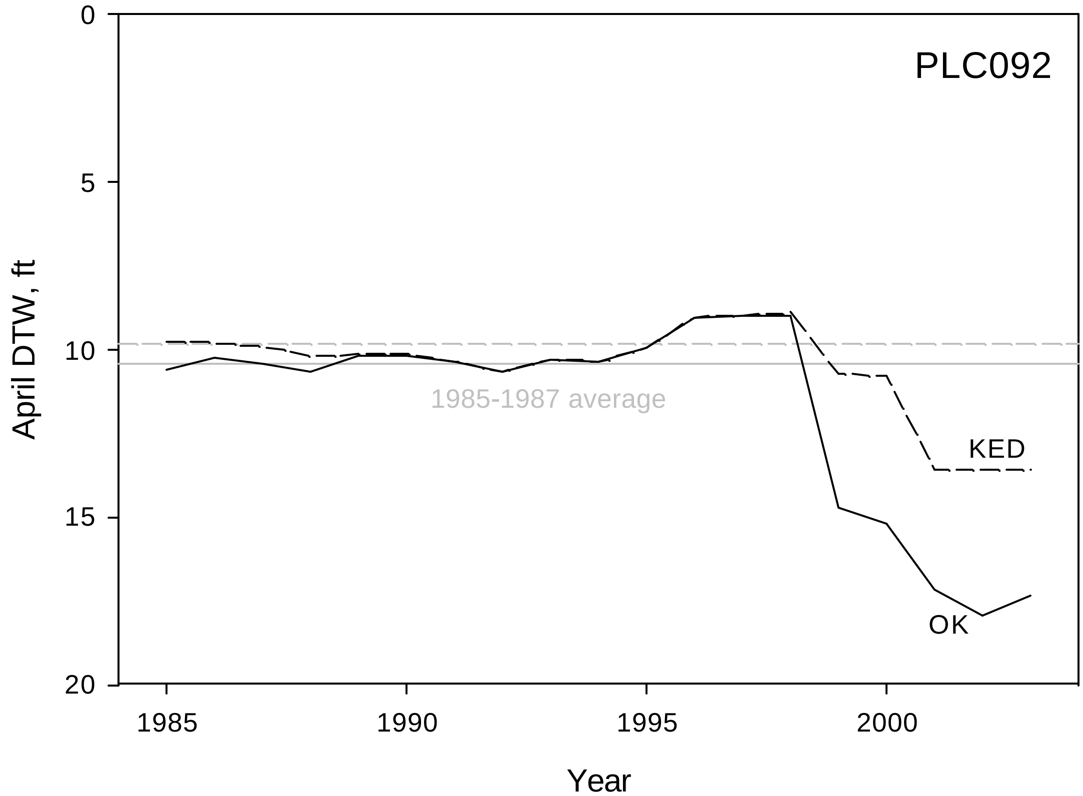
PLC065. KED and OK are parallel with OK ~0.5 ft shallower until 2000, when KED drops sharply. OK is consistent with 485T. OK baseline, relative recovery, and DTW are reliable.



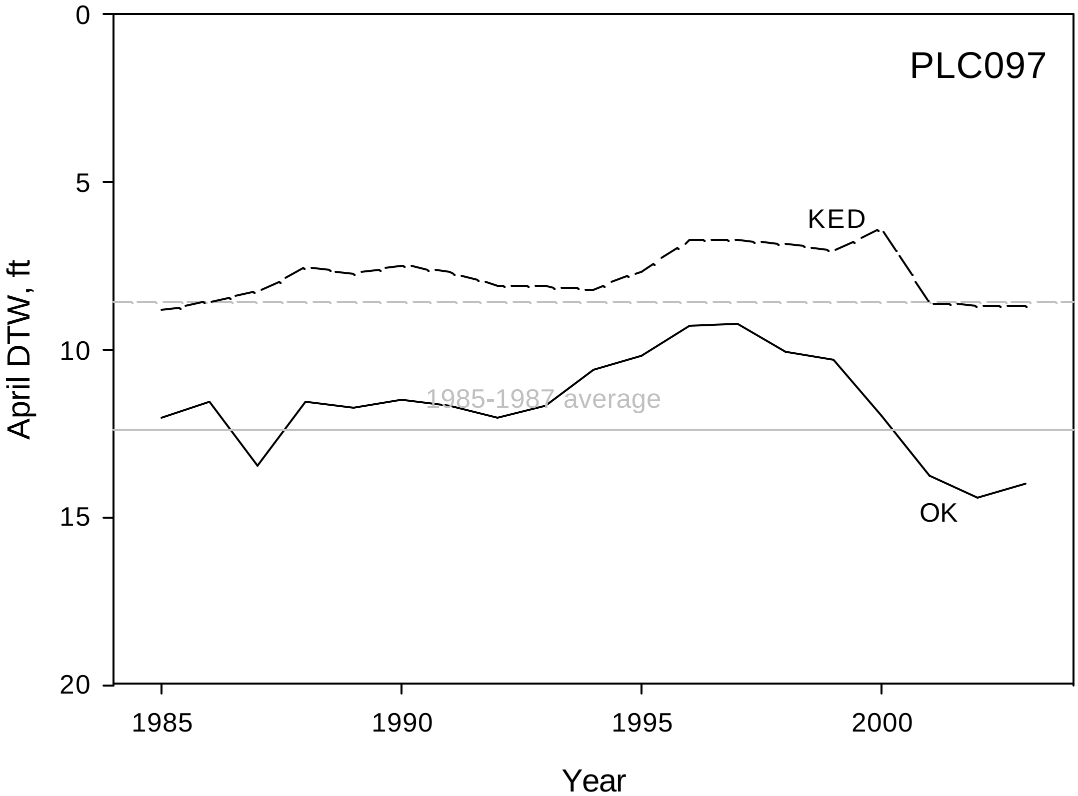
PLC069. KED and OK are congruent and consistent with 481T and 485T. Though the well network is sparse in this area, the similarity of KED and OK and the consistency with the nearest wells indicates that baseline, relative recovery, and DTW are reliable.



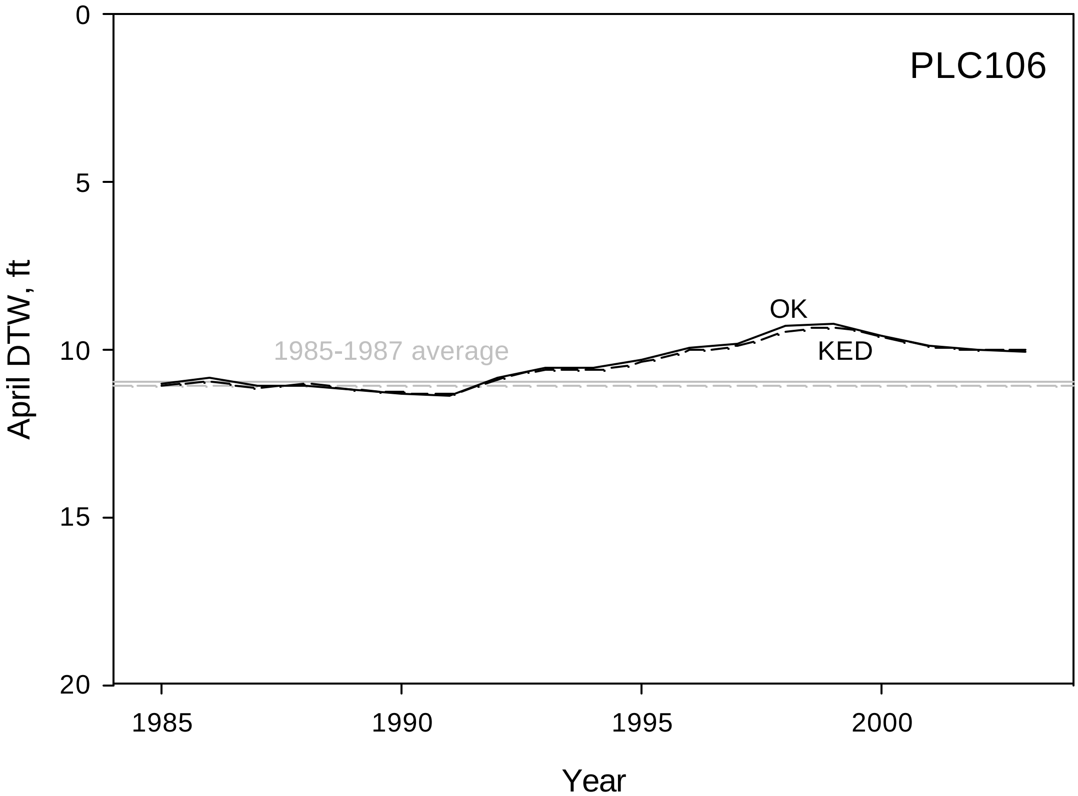
PLC072. KED and OK are parallel with KED ~1 ft shallower and are consistent with 484T until 2000. The sharp decline in 2000 is due to the loss of 484T, which was apparently destroyed. The hydrographs for this parcel could be made more precise by including well reads from the nearby USGS site. Baseline, relative recovery, and DTW are reliable up to 2000.



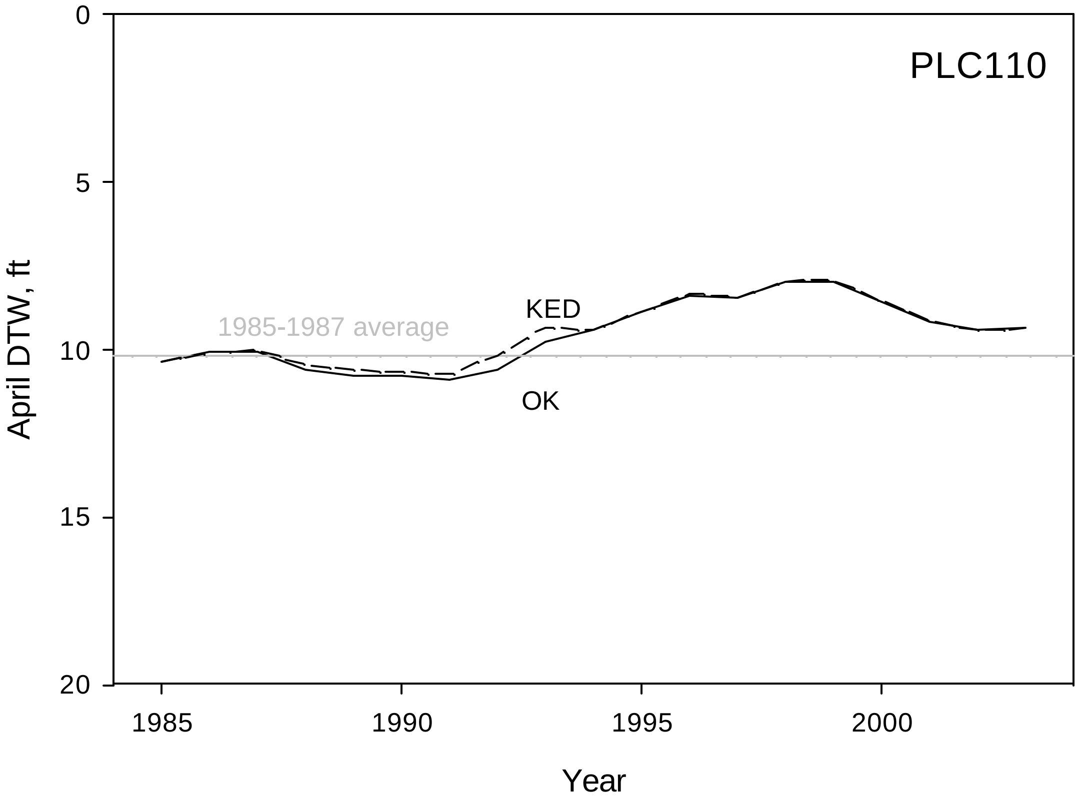
PLC092. KED and OK are similar up until 1998, after which the hydrographs become erratic due to the loss of 335T. Hydrographer's notes indicate it was "filled with rocks." Baseline is reliable, but relative recovery and recent DTW are questionable.



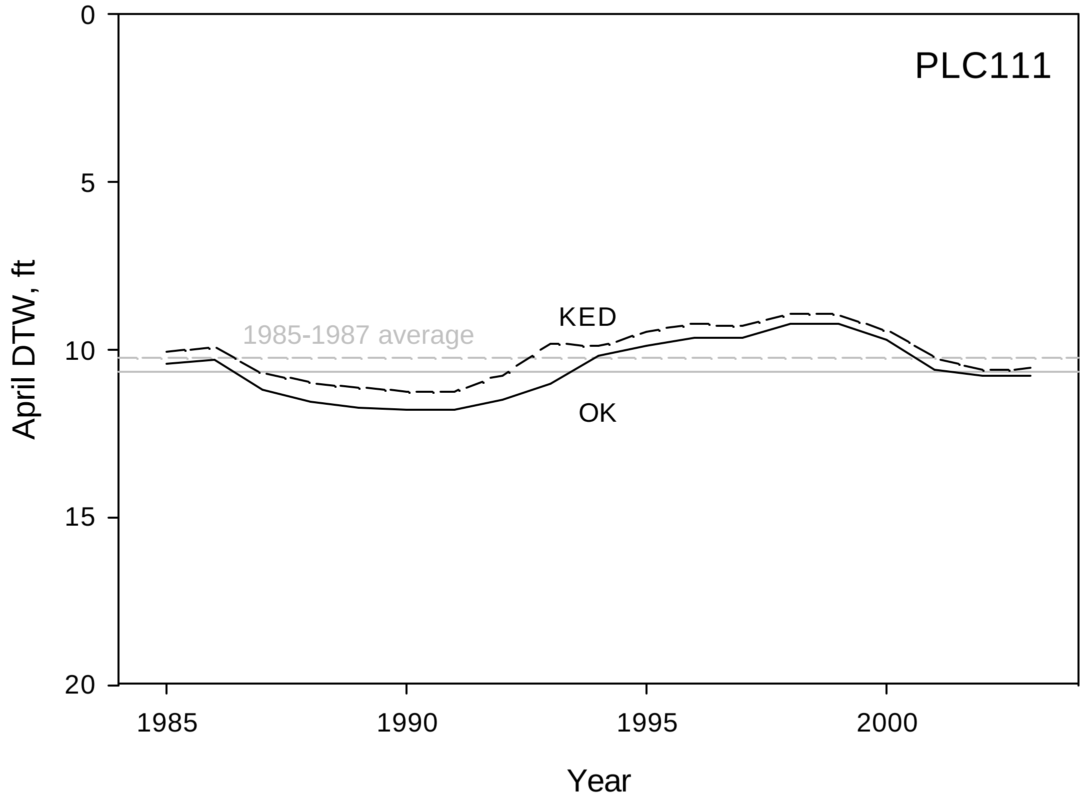
PLC097. Similar problems to PLC092, except that baseline is not reliable because of sparse well coverage.



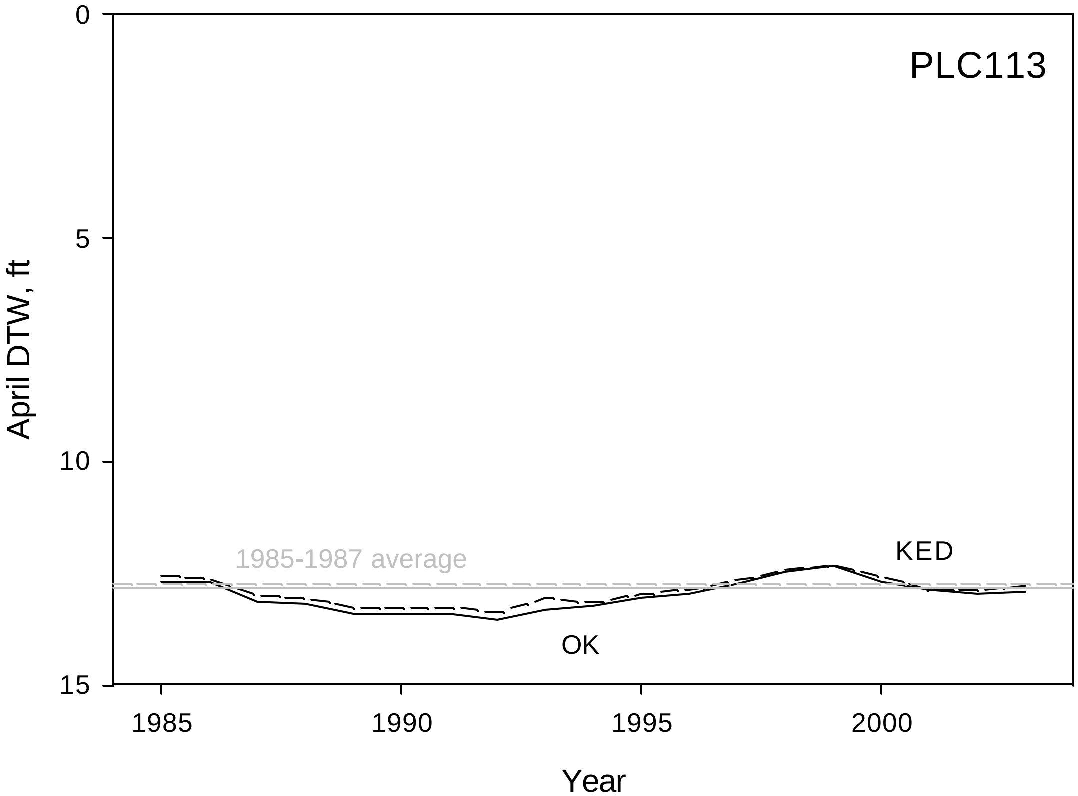
PLC106. KED and OK are congruent and consistent with 480T and T02AI. Baseline, relative recovery, and DTW are reliable.



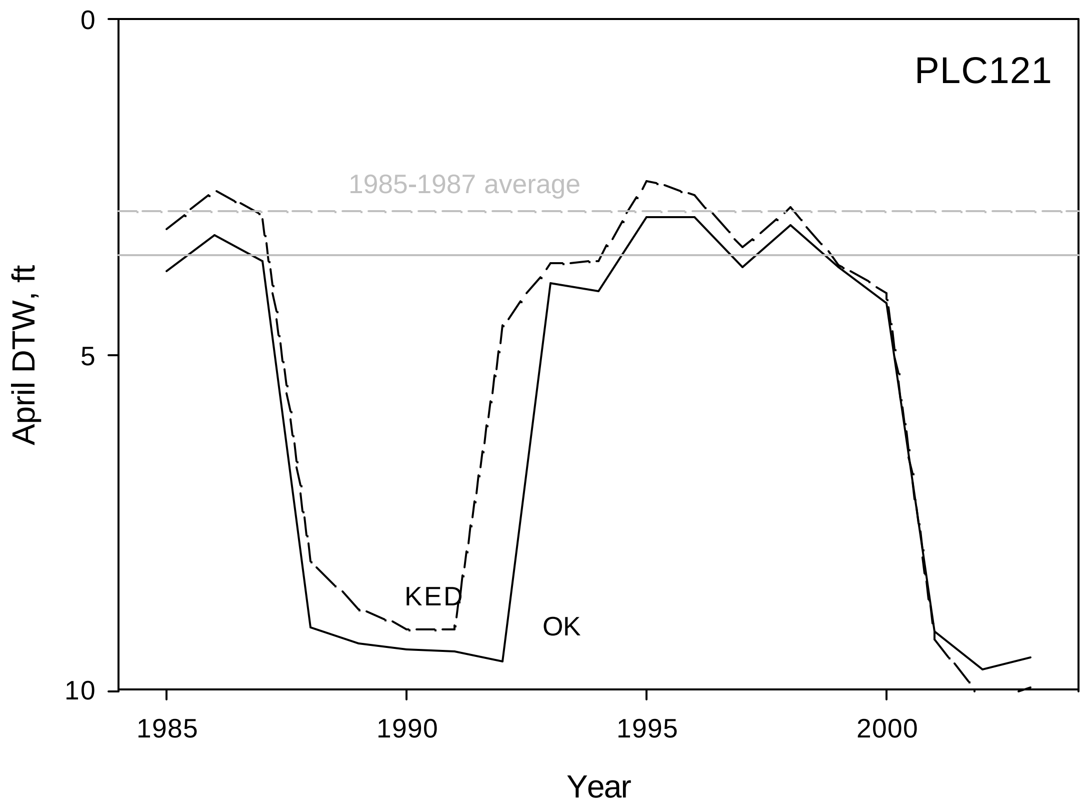
PLC110. Similar comments as PLC106.



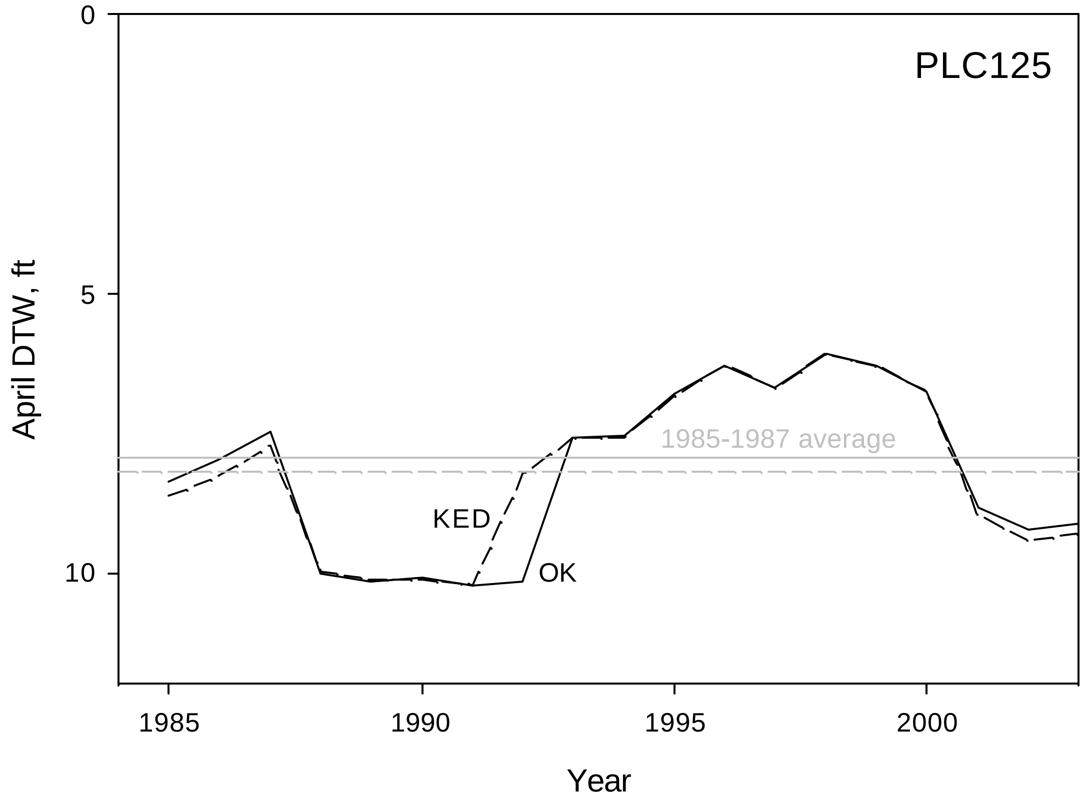
PLC111. KED and OK are parallel with KED ~0.5 ft shallower and consistent with 480T and 481T. Baseline, relative recovery, and DTW are reliable.



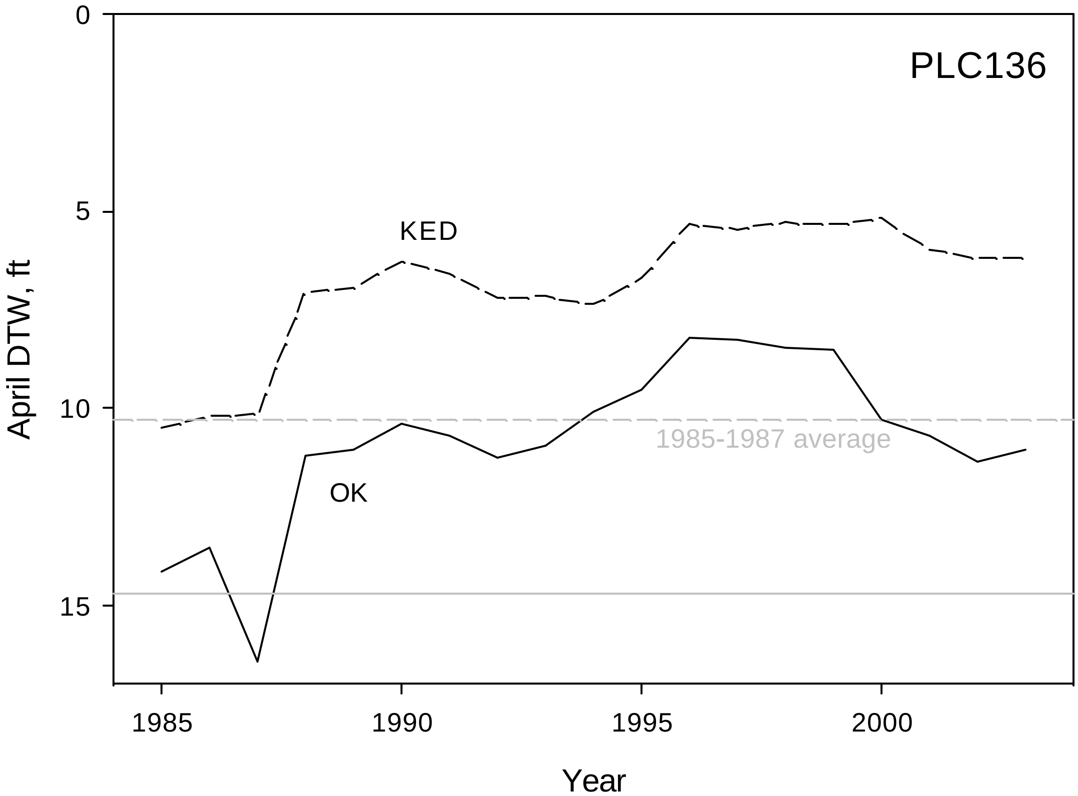
PLC113. KED and OK are congruent and consistent with 481T, which is located within the parcel. Baseline, relative recovery, and DTW are reliable.



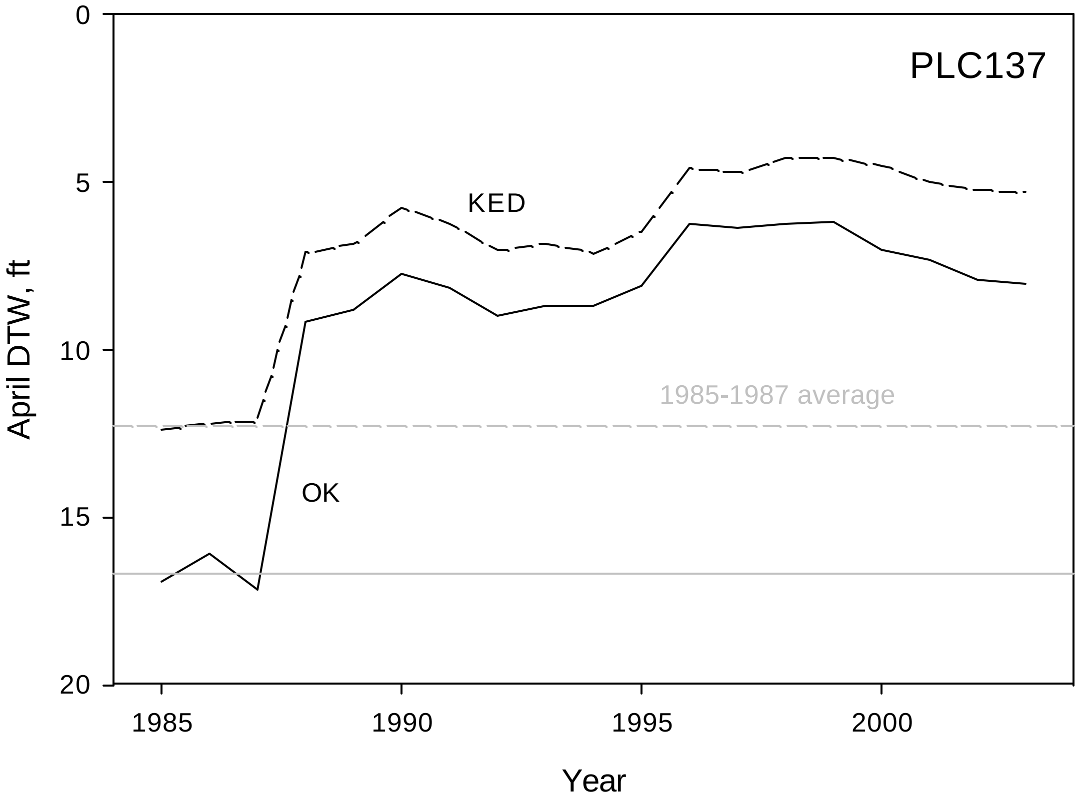
PLC121. KED and OK are both erratic due to intermittent presence of 314T in the data. Hydrographs are unreliable.



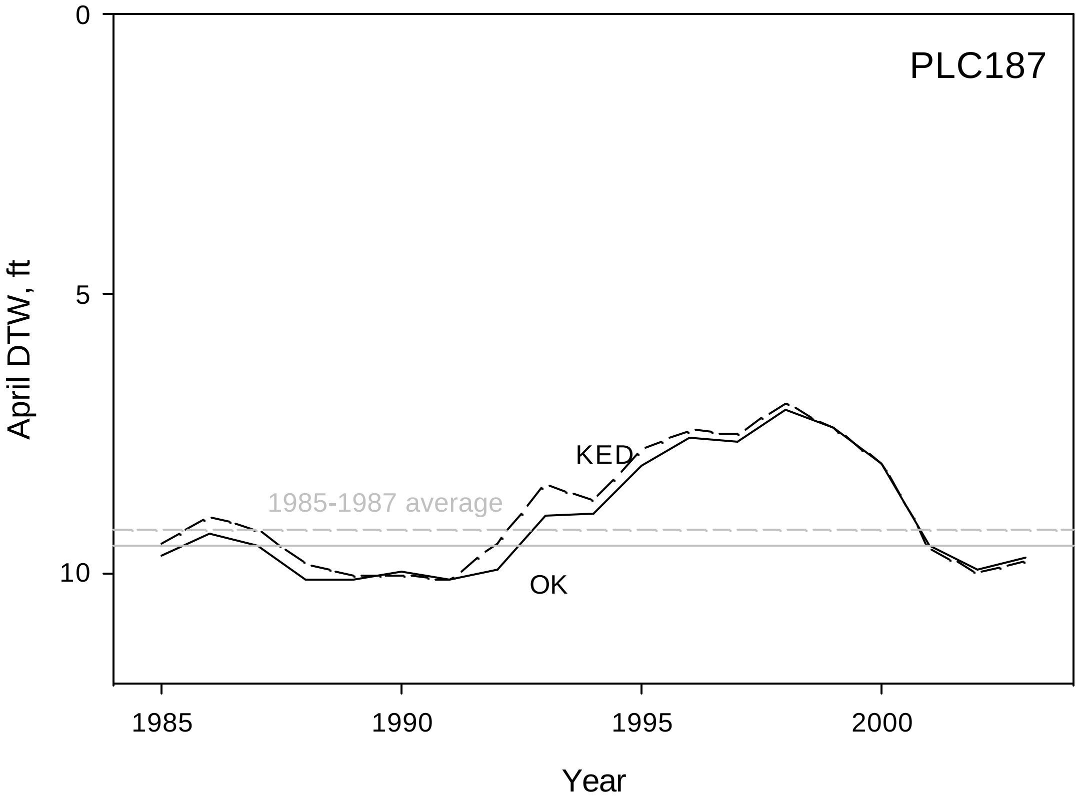
PLC125. Similar to PLC121.



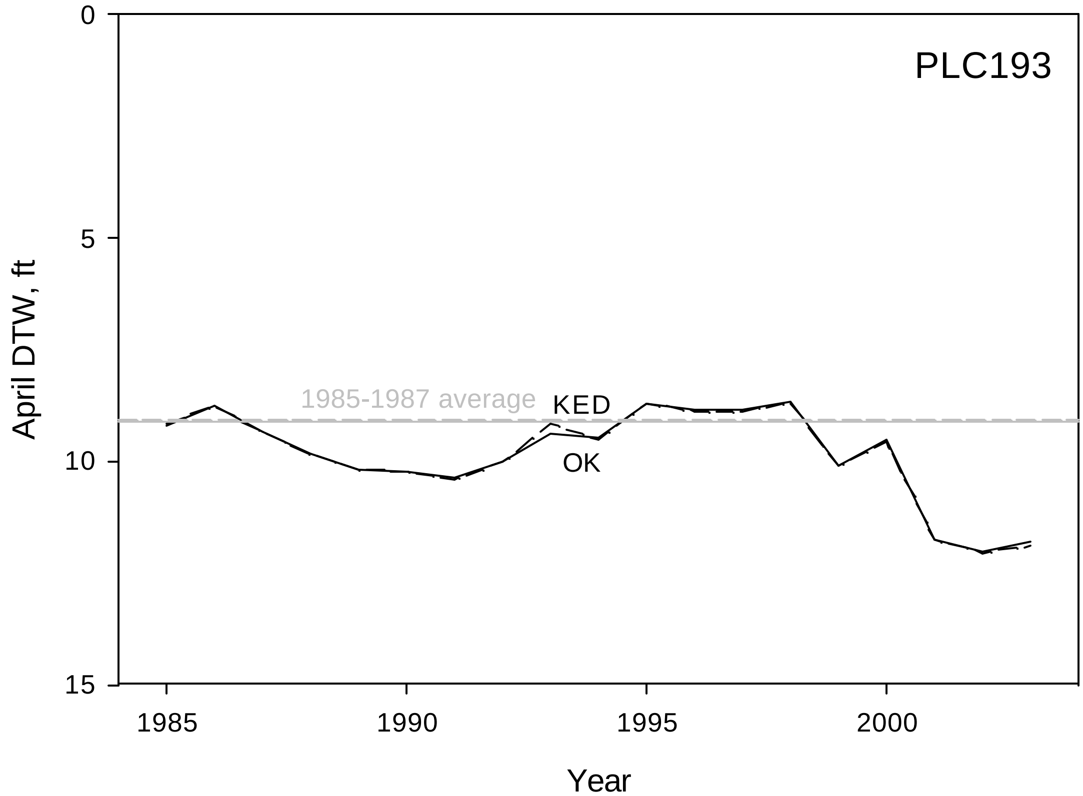
PLC136. Baseline is unreliable for both methods due to the absence of 797T until 1990. The wide spread between KED and OK indicates that DTW is unreliable.



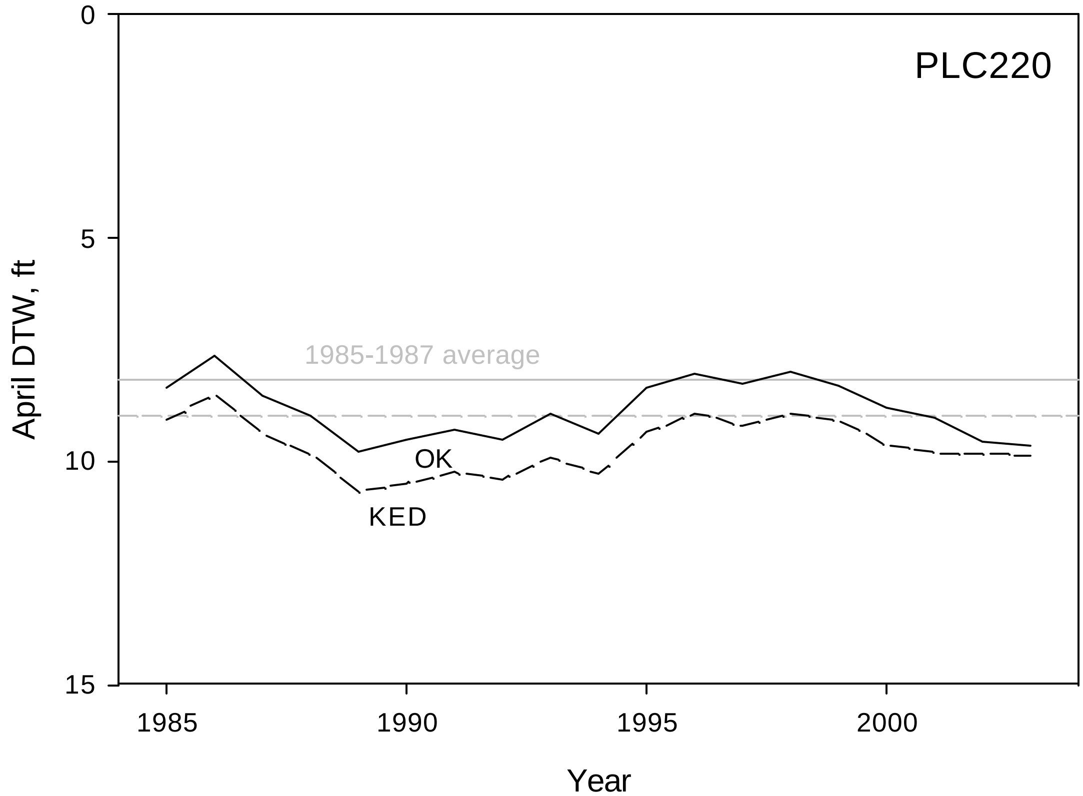
PLC137. Similar problems to PLC136.



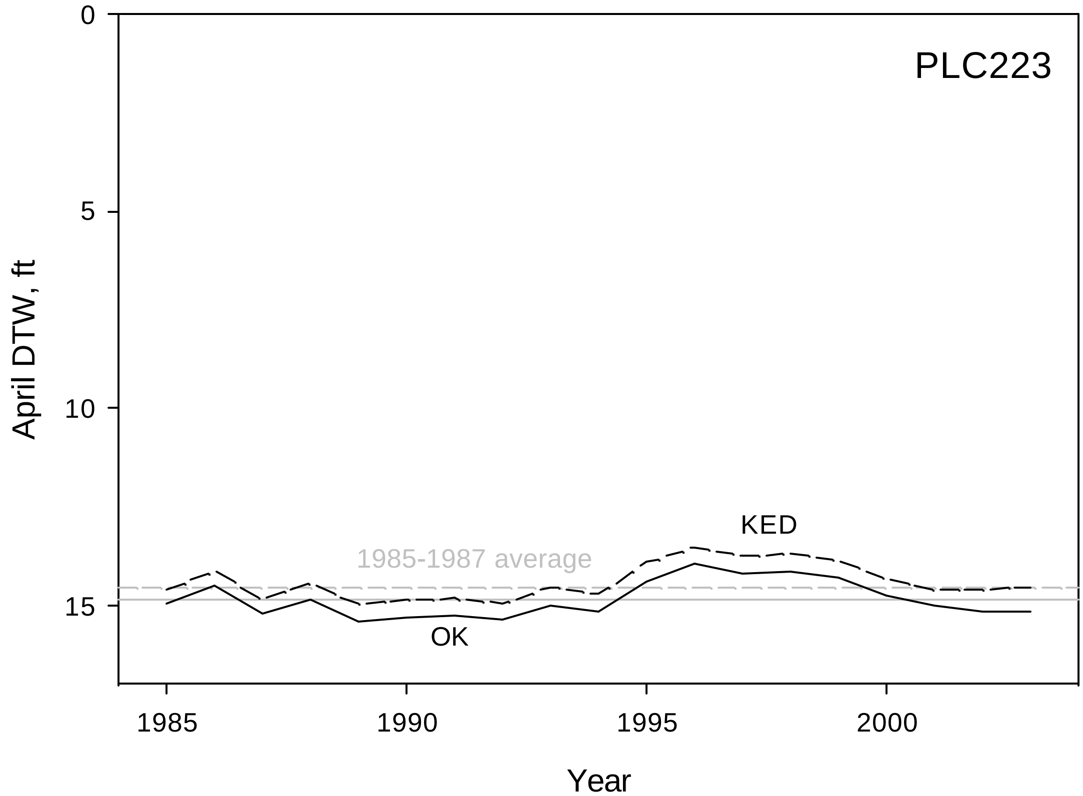
PLC187. KED and OK are nearly congruent. Well coverage in this area is poor. The decline in 2001 is inconsistent with 480T, and is apparently due to the entry of 842T into the data. Relative recovery is probably reliable, but baseline and DTW are unreliable.



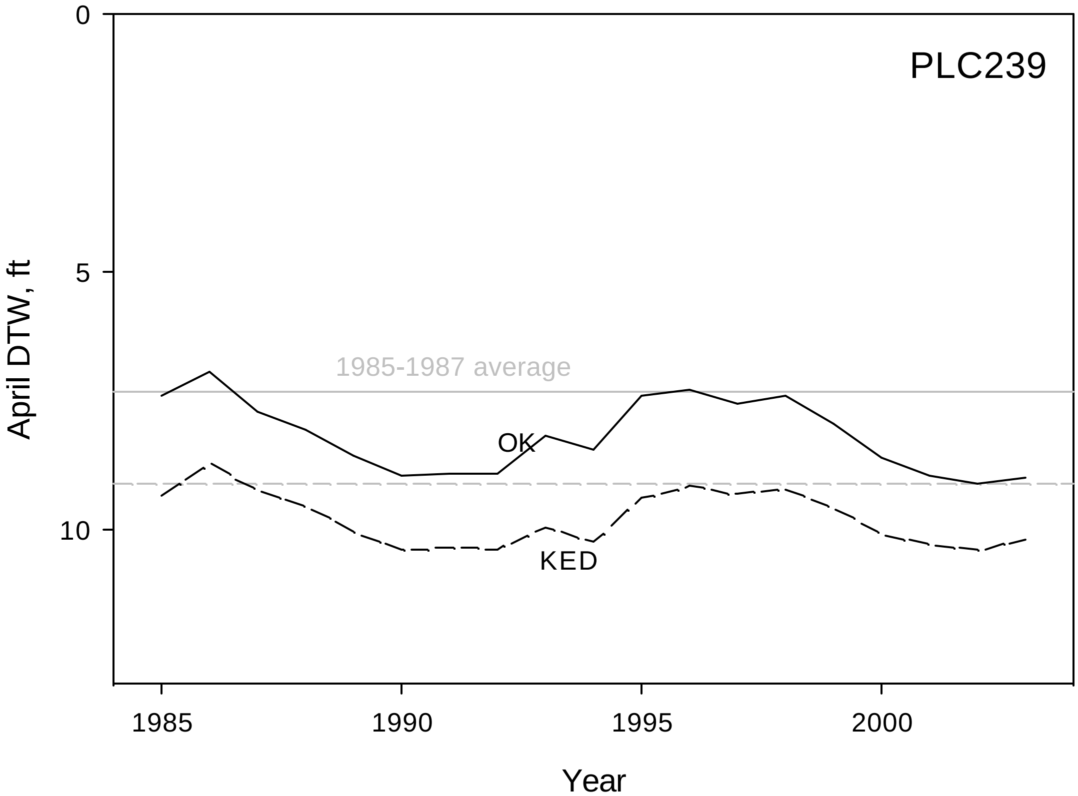
PLC193. KED and OK are congruent. DTW is variable in this large parcel (cf. 842T and 479T). The sharp decline in 2001 is due to the entry of 842T into the data. Relative recovery is reliable up until the late-1990's, and unreliable thereafter. DTW for 2001 through 2003 are reliable.



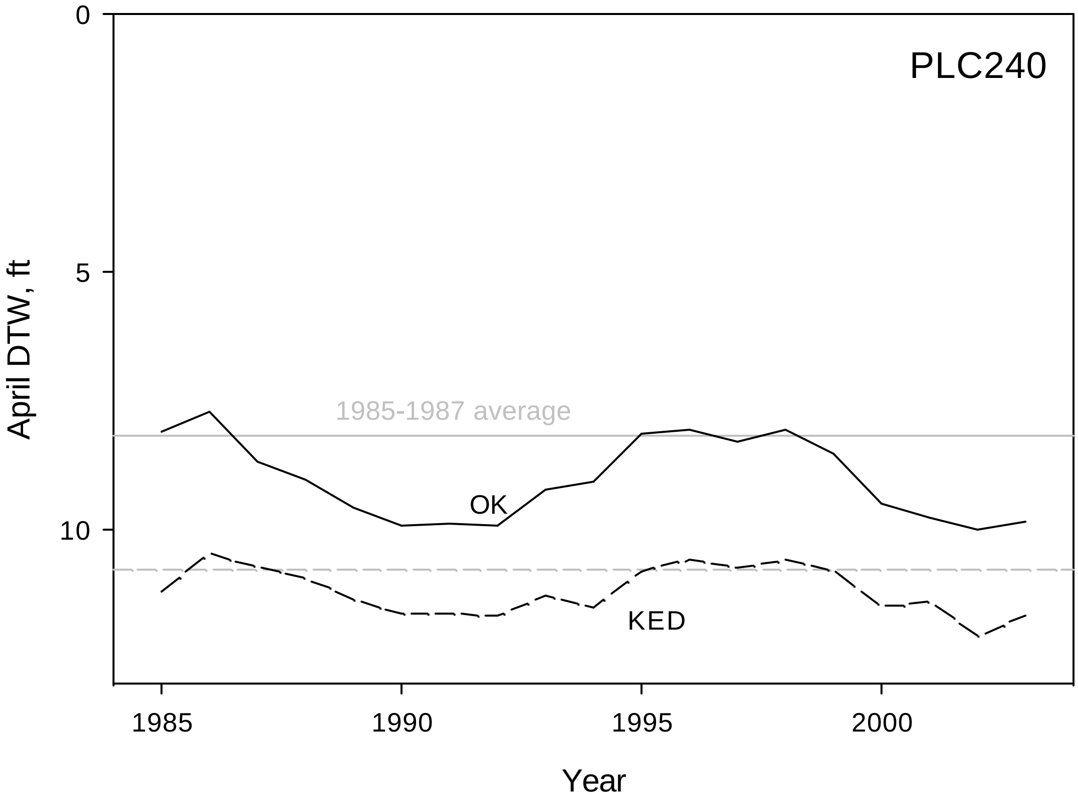
PLC220. KED and OK are parallel with OK ~1 ft shallower and consistent with 320AT and 321AT. Baseline, relative recovery, and DTW are reliable.



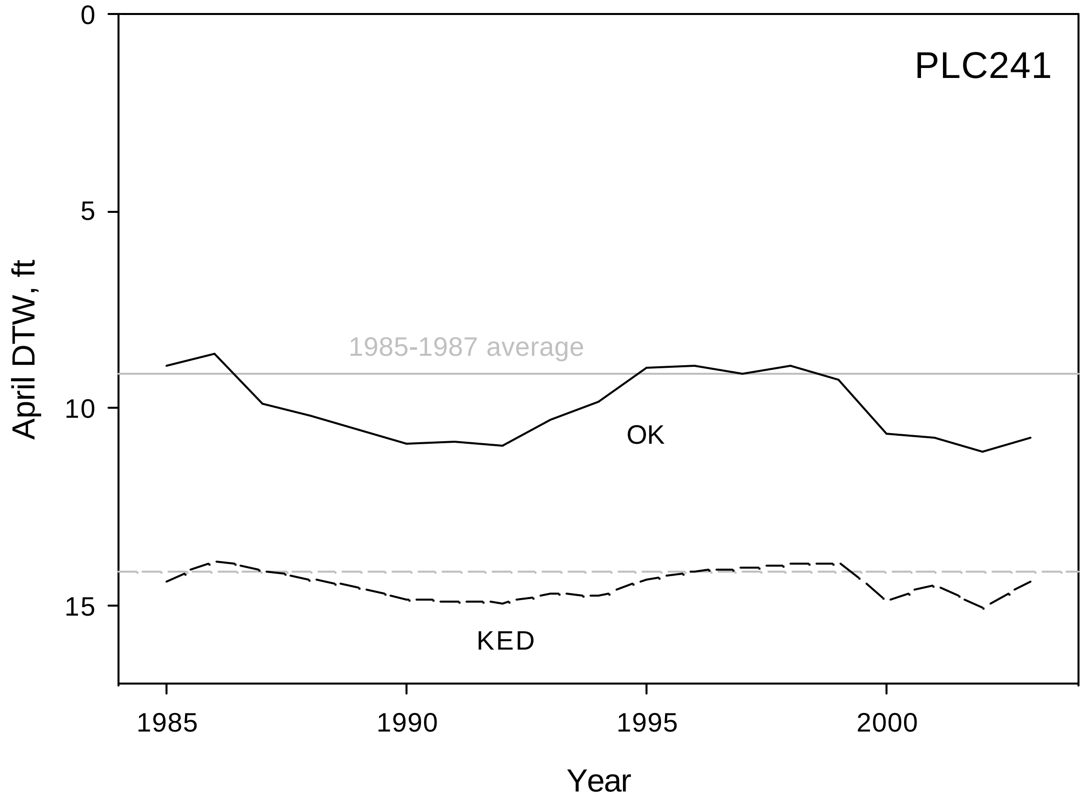
PLC223. KED and OK are parallel with KED ~0.5 ft shallower. Relative recovery is exaggerated by the entry of 796T into the data set in 1990. 2003 DTW is reliable.



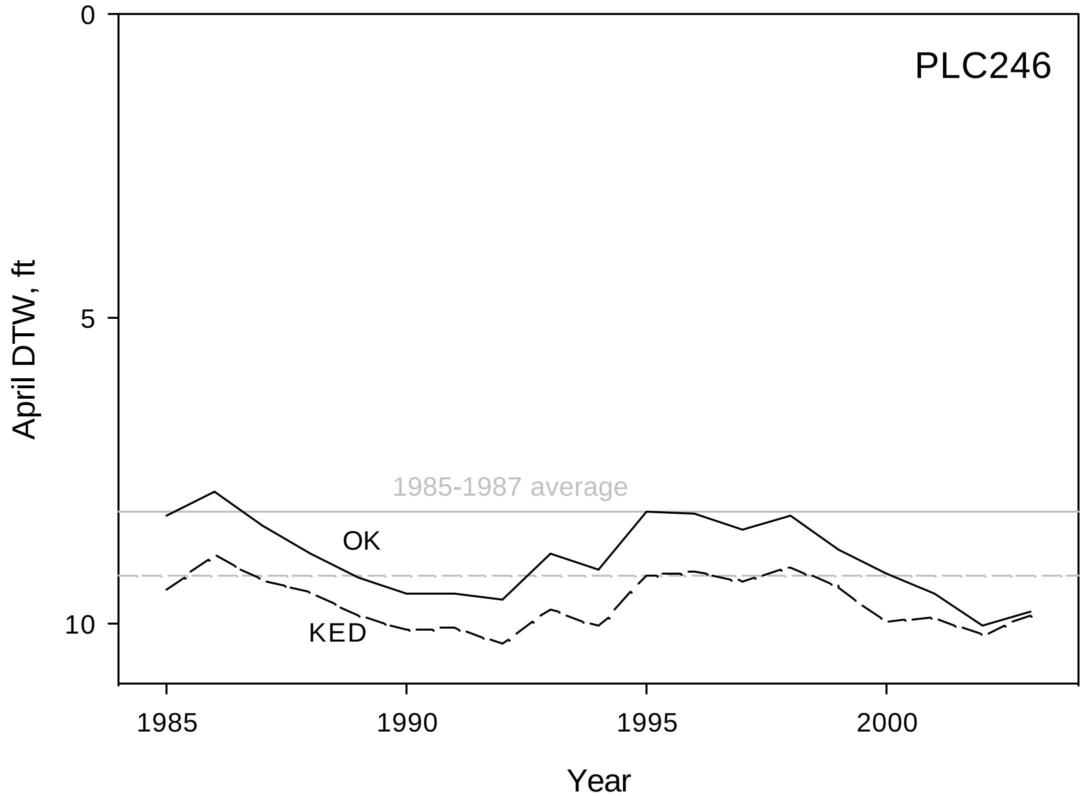
PLC239. KED and OK are parallel with OK ~2 ft shallower and are consistent with 315AT and 487T. KED is probably more reliable based on the up-slope location of the parcel relative to the nearest wells. KED baseline, relative recovery, and DTW are reliable.



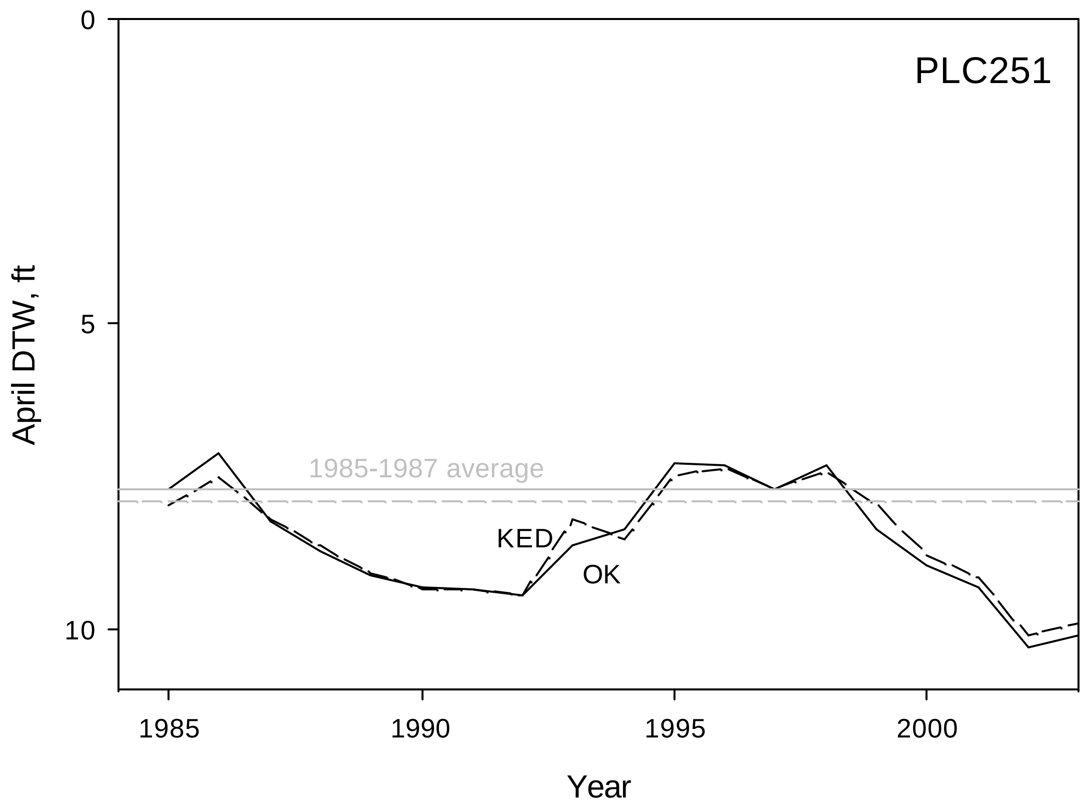
PLC240. Similar comments to PLC239.



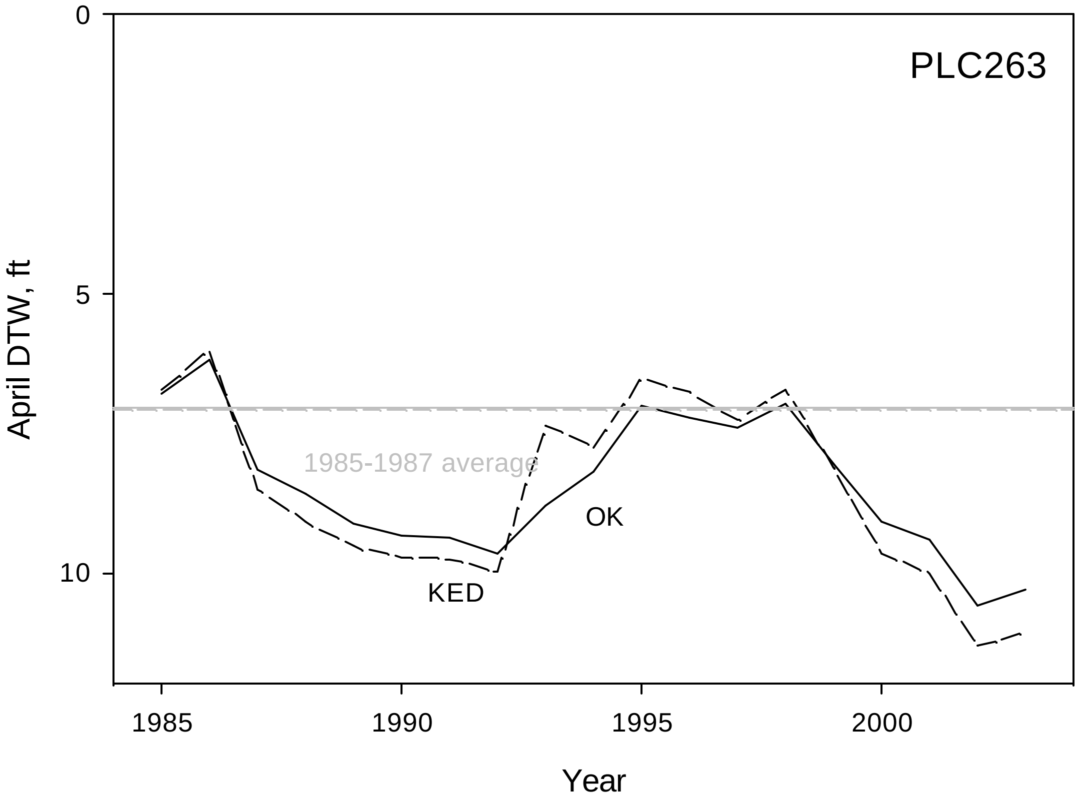
PLC241. Similar comments to PLC239.



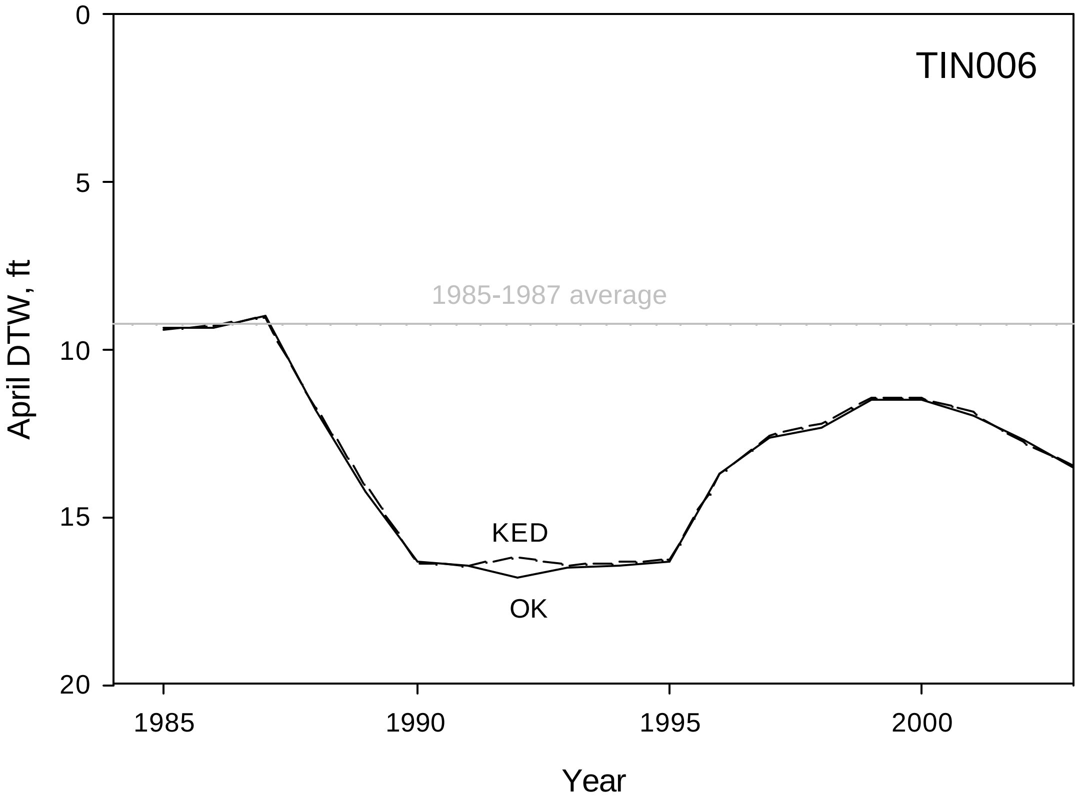
PLC246. KED and OK are parallel, with OK ~1 ft shallower, and are consistent with 486T and 487T. Similar comments as PLC239, except DTW is more uncertain due to poor well coverage.



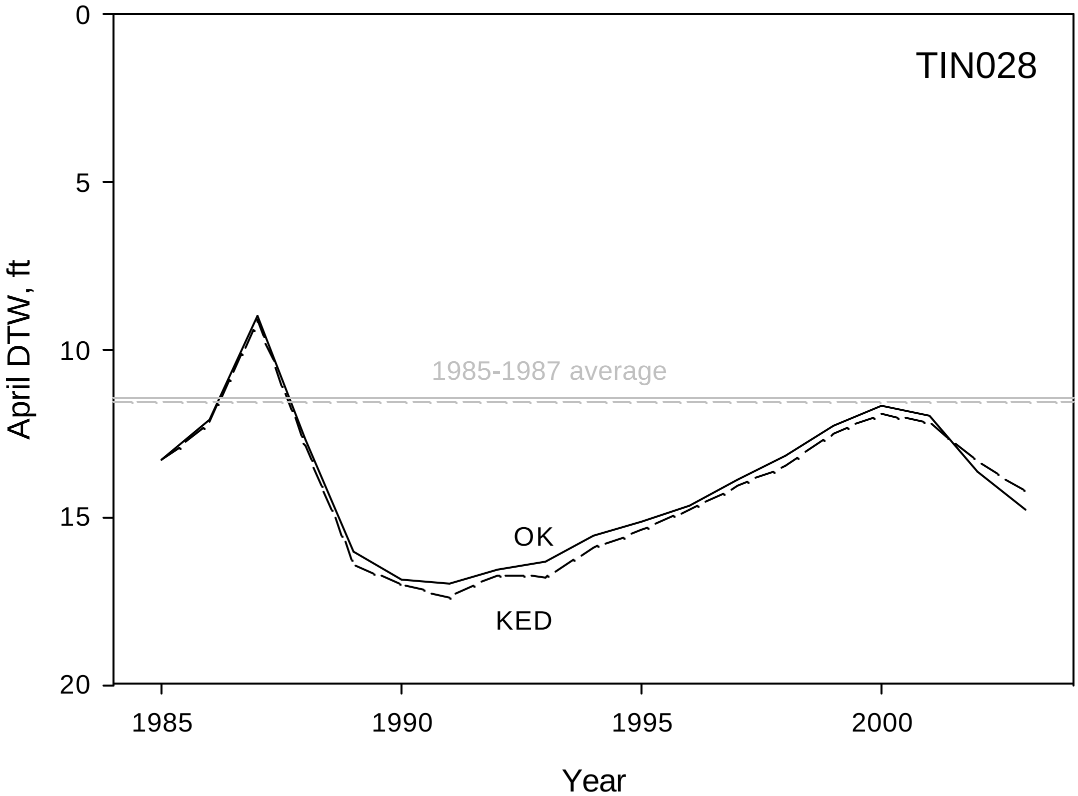
PLC251. KED and OK are nearly congruent. Hydrographs are consistent with 486T, except the addition of 824T to the data in 2001 causes DTW to decline more than is evident in 486T's hydrograph. Baseline, relative recovery, and recent DTW are reliable, but due to poor well coverage, this hydrograph has a large uncertainty relative to other parcels.



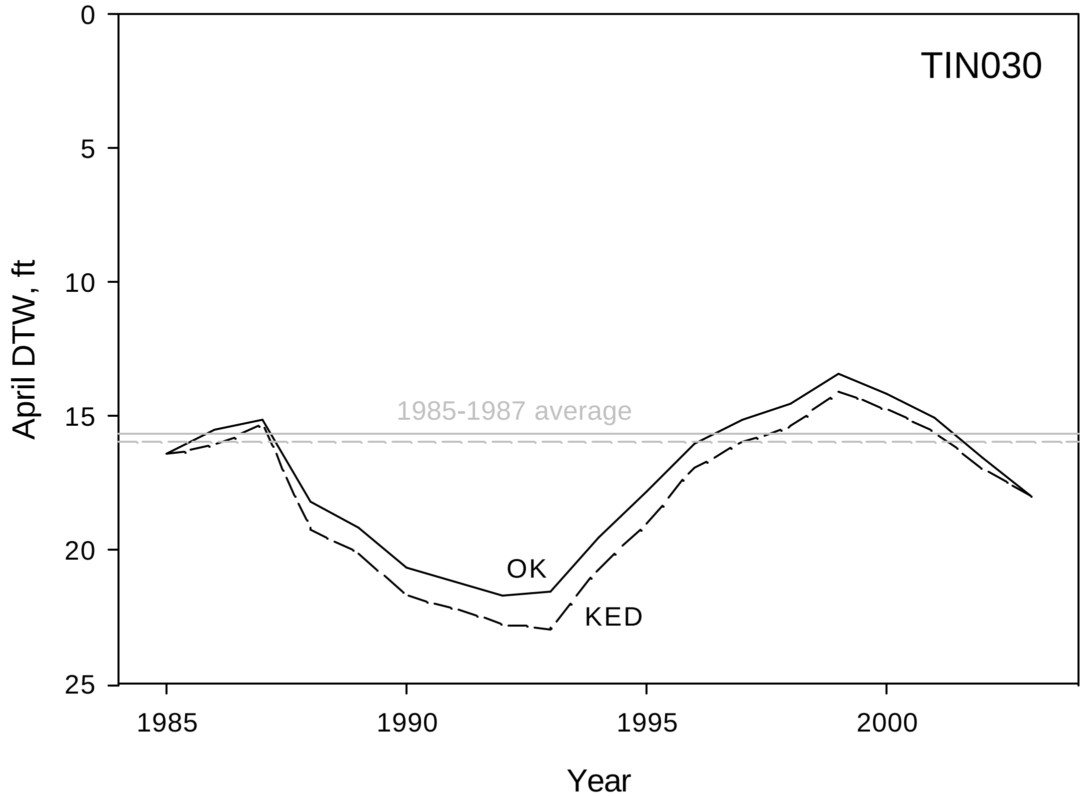
PLC263. Poor well coverage makes these estimates unreliable.



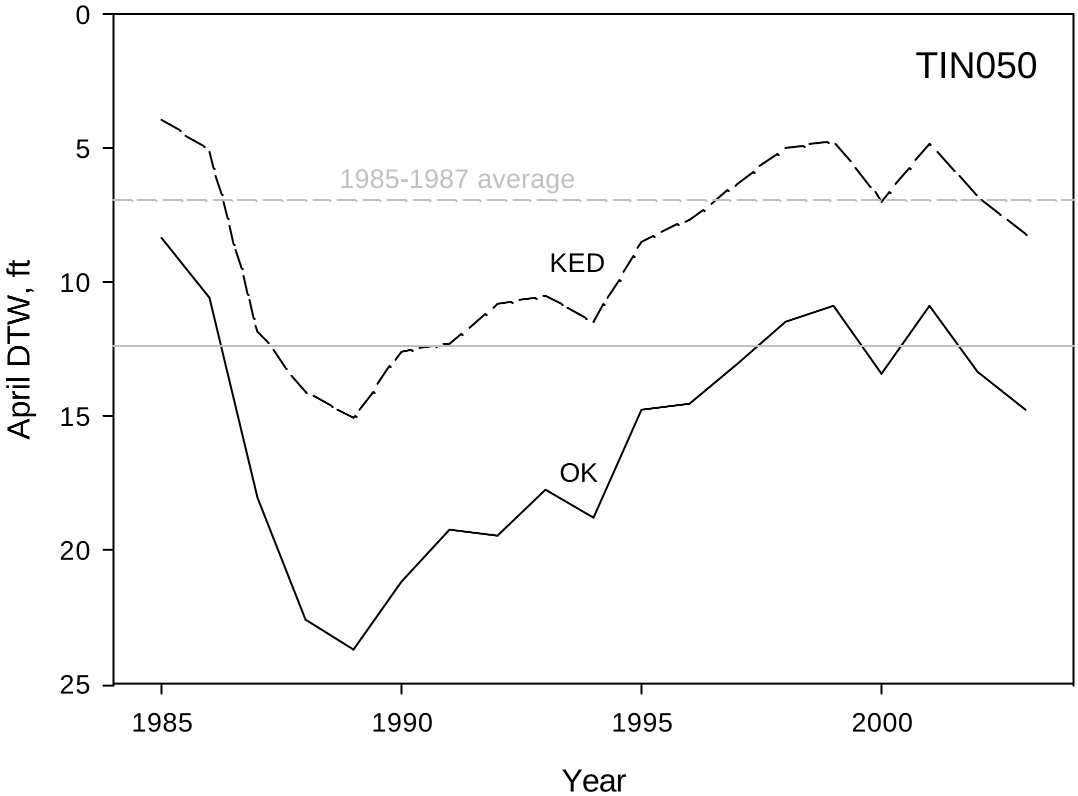
TIN006. KED and OK are congruent, and consistent with 426T and V005G, which are both located within the parcel. Baseline, relative recovery, and DTW are accurate.



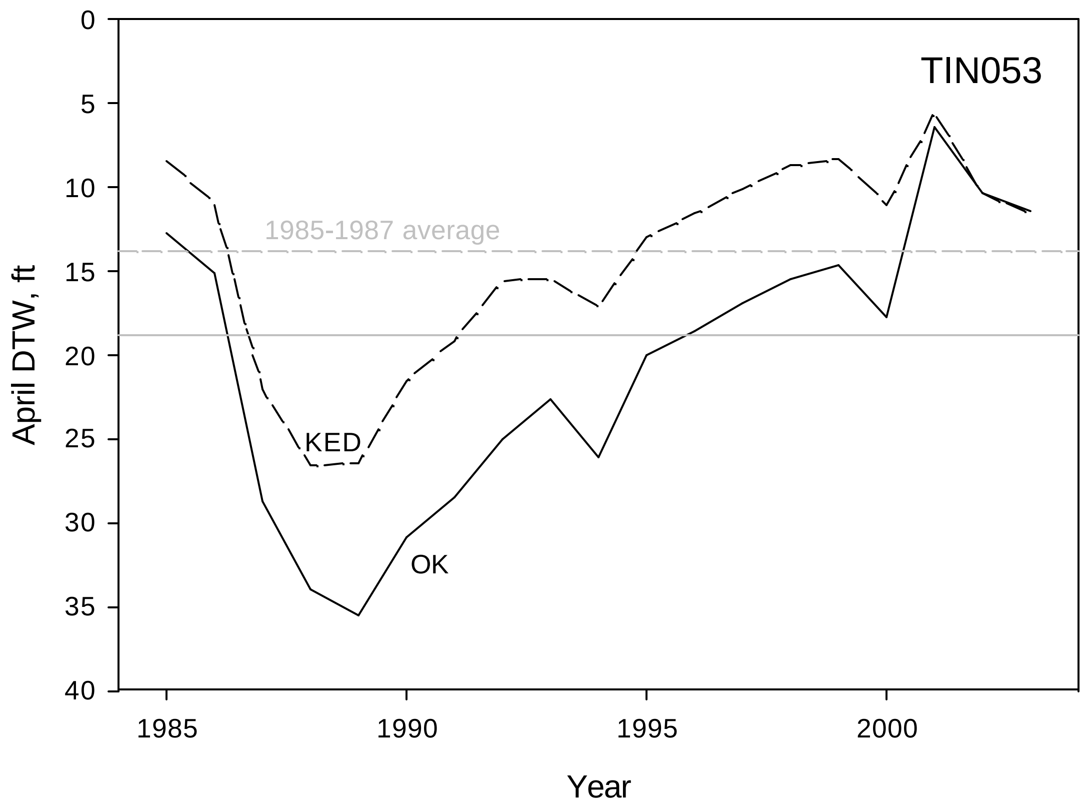
TIN028. KED and OK are congruent, and consistent with 566T and V017GC. DTW varies with distance from the Fish Springs Hatchery return ditch. Baseline and relative recovery are unreliable, because the records for 800T, 566T, and V017GC do not completely span the baseline period; recent DTW is reliable.



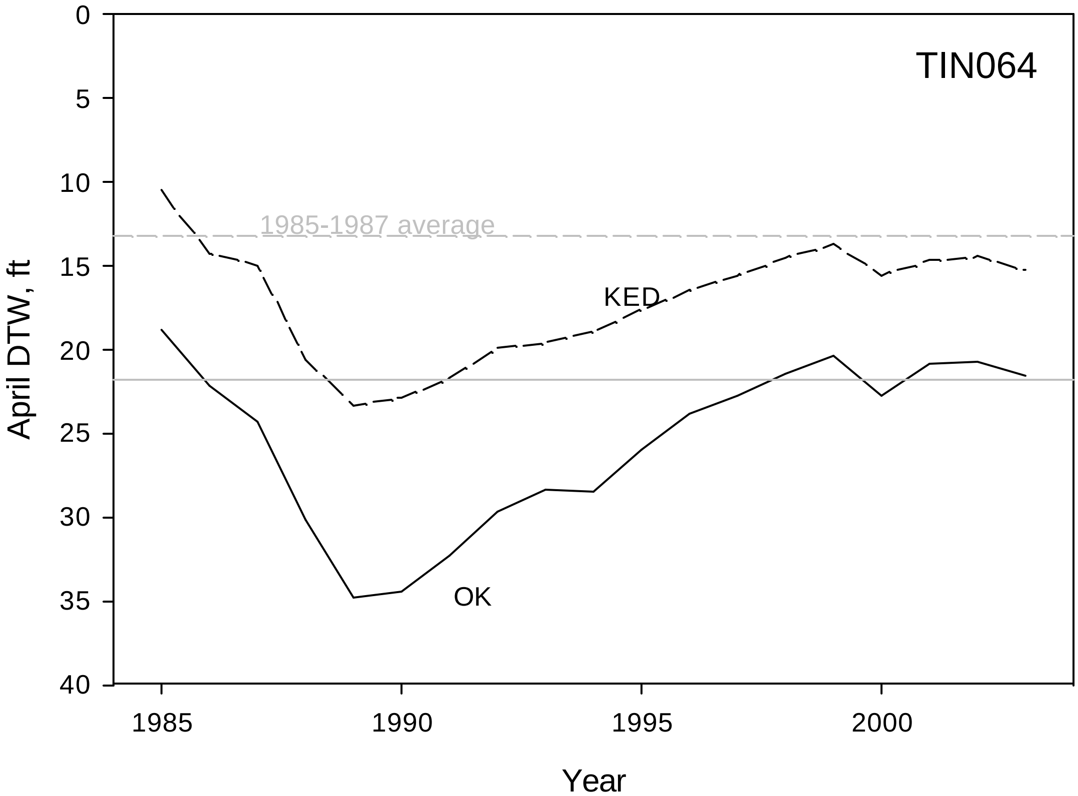
TIN030. KED and OK are parallel with OK ~1 ft shallower than KED, and are consistent with 565T and V017GC. Neither 565T or V017GC have records for April 1985. DTW varies with distance from hatchery return ditch and Birch Creek. This parcel also appears to receive some tail water from irrigation to the west. Baseline and relative recovery are questionable due to poor well coverage during baseline; recent DTW is reliable.



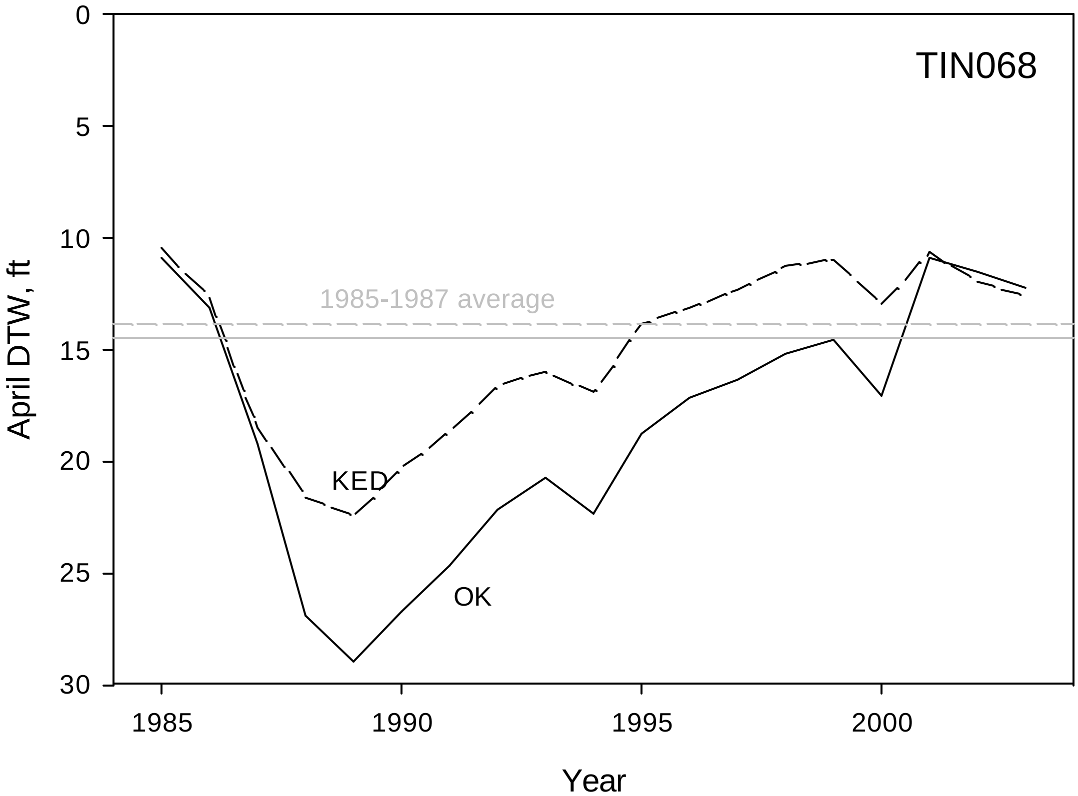
TIN050. KED and OK are parallel with KED 5-10 ft shallower. These hydrographs rely mainly on 502T and are consistent with it, except that relative recovery in the late-1990's is greater than observed in 502T. KED is probably more reliable than OK due to the up-slope position of 502T relative to the parcel. DTW in 846T is ~2 ft shallower than 502T, supporting this hypothesis. OK baseline, relative recovery, and DTW are unreliable. KED DTW is reliable, but baseline and relative recovery are uncertain.



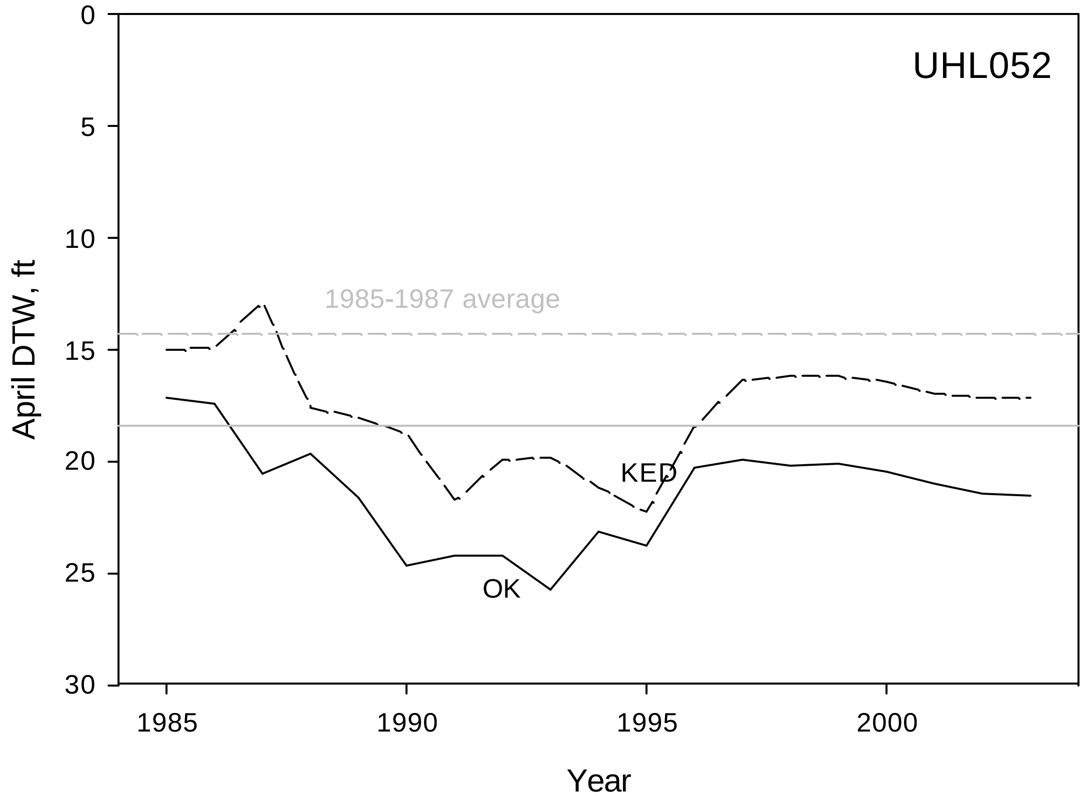
TIN053. KED and OK are parallel with KED ~5 ft shallower until 2001 when the hydrographs converge due to the entry of 846T into the data. The relative effect of 846T on KED and OK suggests that KED was the more accurate throughout the modeling period. Relative recovery of both KED and OK is inconsistent with 502T, which shows less recovery, indicating that baseline and relative recovery are questionable, but recent DTW is accurate due to the addition of 846T.



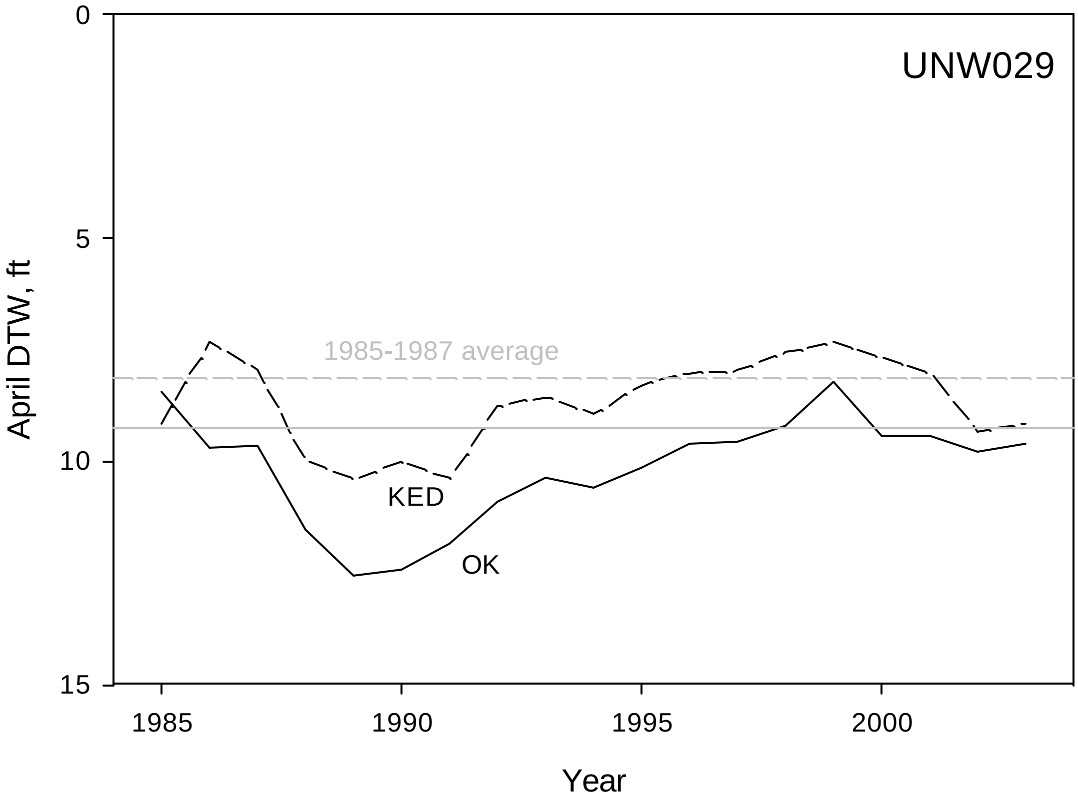
TIN064. KED and OK are parallel with KED 4-8 ft shallower. Despite changes in the well network over time, relative recovery of KED and OK is consistent with 421T. DTW is variable in this area due to variable topography and the proximity of the Owens River and production well 349W (cf. 420T and 421T). KED probably provides a more accurate recent DTW than OK, but both are questionable. KED relative recovery is probably reliable.



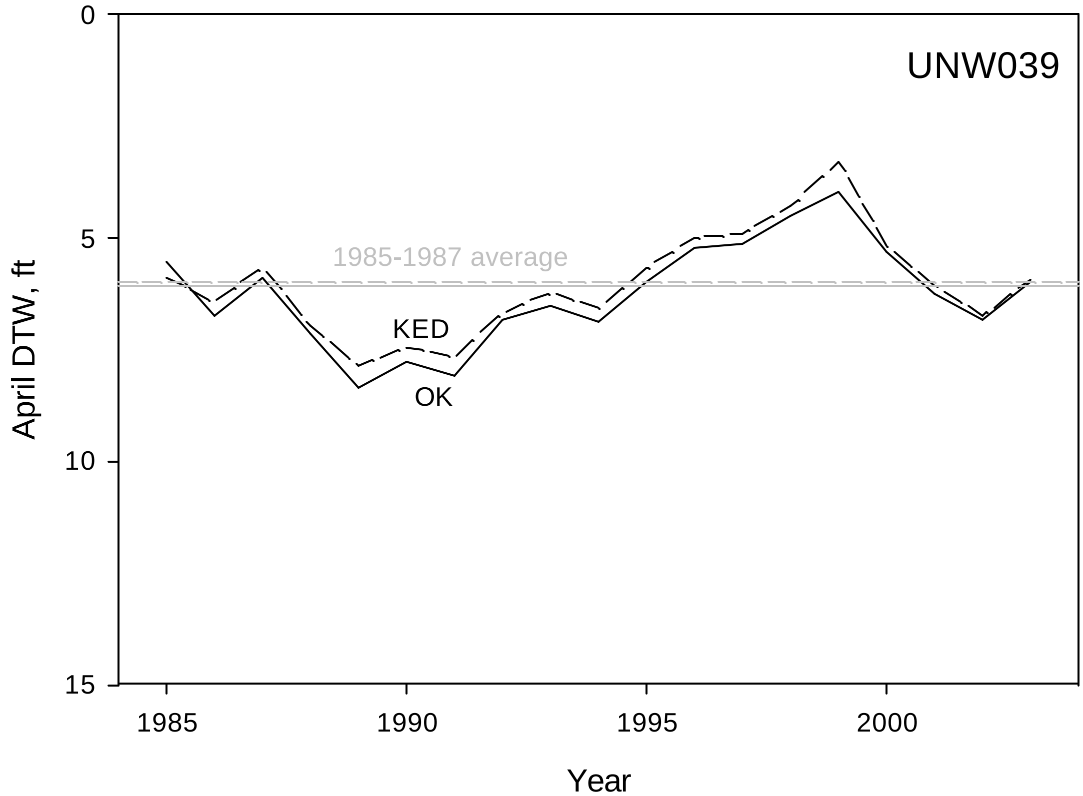
TIN068. KED and OK coincide during and shortly after baseline, are parallel up to 2001 when the hydrographs reconverge due to the entry of 846T into the data. Judging from the relative effects of 846T on KED and OK, KED provides more accurate DTW throughout the modeling period. Relative recovery in both KED and OK is greater than observed in 420T and 421T. Recent DTW is reliable, but baseline and relative recovery are questionable.



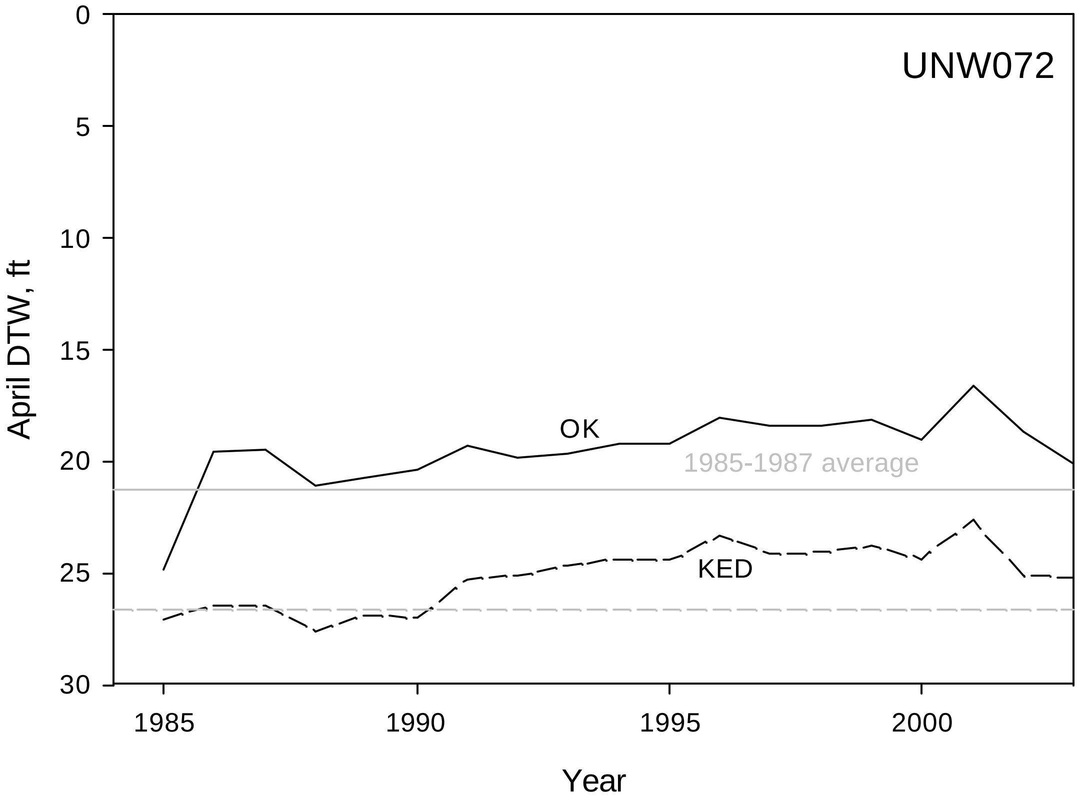
UHL052. KED and OK are roughly parallel with KED 2-5 ft shallower. Relative recovery is consistent with V006GB, but baseline and DTW are questionable due to the sparse well coverage.



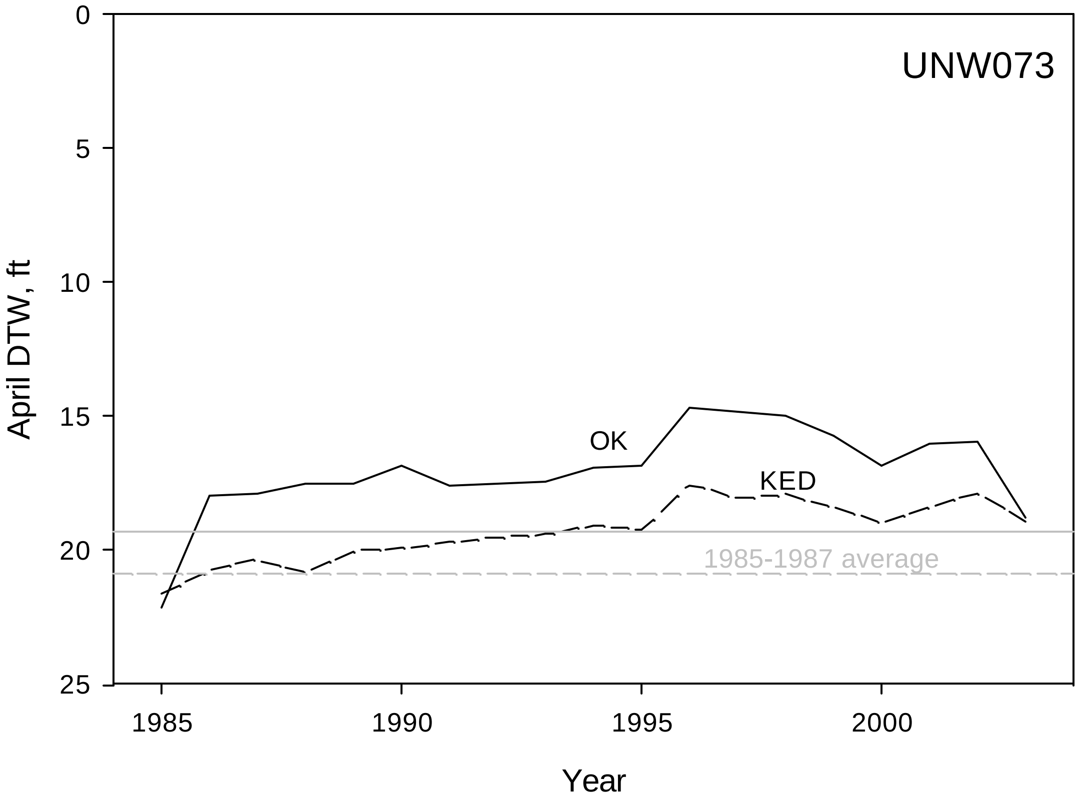
UNW029. KED and OK are roughly parallel except during baseline. Well coverage is sparse. Relative recovery is consistent with 400T. 442T has a spreading-affected hydrograph similar to IND064 and IND066. Relative recovery appears reliable, but baseline and recent DTW are unreliable.



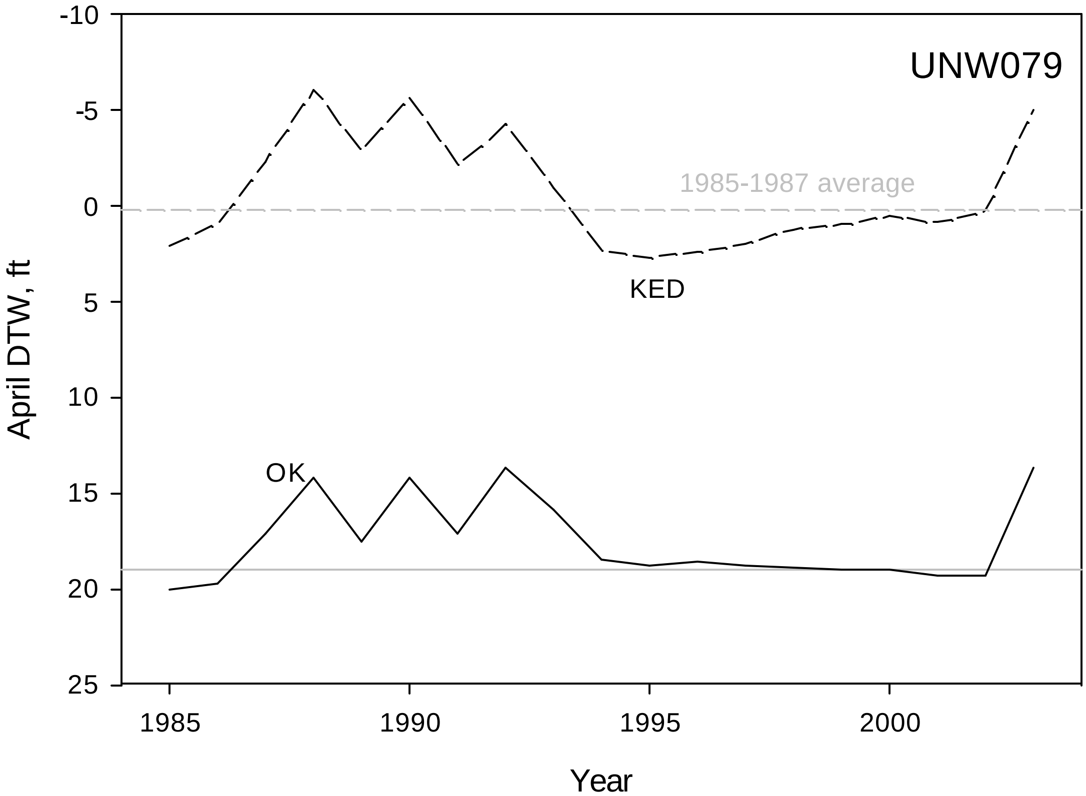
UNW039. KED and OK are nearly congruent, but are inconsistent with 400T, 444T, 597T, and 856T. This large parcel is traversed by the Owens Valley fault. Down-slope wells have greater DTW, possibly due to up-slope position of LAA. Baseline, relative recovery, and DTW are unreliable.



UNW072. KED and OK are parallel except for during baseline, with OK ~6 ft shallower than KED. This parcel lies in a narrow strip of alluvium between the Owens Valley Fault and the Alabama Hills The gradual rise in the water table is consistent with 563T, 593T, and 594T; the sharp drop in 2002 is anomalous and related to the entry of 860T into the data. Due to the poor well coverage and locally complicated hydrogeology, kriging results for this parcel are unreliable.



UNW073. Similar comments to UNW072.



UNW079. Sparse well coverage and complicated hydrogeology render the kriging results extremely unreliable in this area.

Appendix II. Evaluation of parcel hydrographs.

Based on the narrative assessments given in Appendix I of each hydrograph's accuracy and reliability, the following table designates each hydrograph as being either useful for not useful for estimating baseline DTW, relative recovery to baseline following the drought of the late-1980's through early-1990's, and 2003 DTW. Useful estimates are indicated with shading. Also given is the parcel DTW standard error estimated for year 2002 using OK.

Method:	OK				KED		
Parcel	Baseline	Relative recovery	Current DTW	2002 SE (feet)	Baseline	Relative recovery	Current DTW
BGP013				8.54			
BGP031				7.07			
BGP047				6.78			
BGP086				7.14			
BGP088				6.93			
BGP154				7.00			
BGP157				5.20			
BGP162				11.05			
BGP204				8.78			
BGP205				9.90			
BIS019							
BIS055				4.36			
BIS068				8.19			
BIS085				15.97			
BLK002				16.58			
BLK006				3.32			
BLK009				6.16			
BLK011				8.72			
BLK016				7.21			
BLK021				4.00			
BLK024				6.48			
BLK029				19.82			
BLK033				6.08			
BLK039				8.12			
BLK040				7.21			
BLK044				4.69			
BLK069				3.87			
BLK074				2.83			
BLK075				3.00			
BLK077				4.24			
BLK094				8.37			
BLK095				7.21			
BLK099				7.21			

Method:	OK				KED		
Parcel	Baseline	Relative recovery	Current DTW	2002 SE (feet)	Baseline	Relative recovery	Current DTW
BLK115				10.82			
BLK142				3.32			
BLK143				2.45			
FSL051				2.65			
FSL065				5.39			
FSL116				8.78			
FSL118				8.72			
FSL122				3.00			
FSL123				1.73			
FSL133				8.72			
FSL179				11.27			
FSL187				5.66			
FSP004				7.48			
FSP006				6.00			
IND011				3.32			
IND019				6.25			
IND021				3.74			
IND029				9.33			
IND035				2.45			
IND064				3.32			
IND066				3.61			
IND067				7.81			
IND087				2.65			
IND096				2.00			
IND099				2.00			
IND106				7.94			
IND111				8.25			
IND119				7.75			
IND122				7.94			
IND132				7.68			
IND133				9.38			
IND139				6.08			
IND151				3.74			
IND156				3.87			
IND163				6.00			
IND205				6.25			
IND231				9.64			
LAW030				11.92			
LAW040				11.23			
LAW052				8.49			
LAW062				8.06			
LAW063				8.00			

Method:	OK				KED		
Parcel	Baseline	Relative recovery	Current DTW	2002 SE (feet)	Baseline	Relative recovery	Current DTW
LAW065				9.75			
LAW076				5.48			
LAW078				5.10			
LAW082				8.49			
LAW085				7.14			
LAW104				7.94			
LAW107				2.65			
LAW109				3.32			
LAW110				3.16			
LAW112				5.10			
LAW120				5.48			
LAW122				6.32			
LAW137				9.27			
LAW154				6.08			
LAW167				6.56			
LAW187				3.32			
LNP018				4.12			
LNP019				4.12			
LNP045				7.07			
LNP050				6.48			
LNP095				6.56			
MAN006				3.00			
MAN007				6.56			
MAN014				5.48			
MAN017				7.94			
MAN034				7.07			
MAN037				5.48			
MAN042				11.27			
MAN060				10.10			
PLC007				10.72			
PLC024				6.71			
PLC028				8.72			
PLC055				13.56			
PLC056				5.48			
PLC059				13.56			
PLC064				8.94			
PLC065				13.42			
PLC069				10.34			
PLC072				17.52			
PLC092				14.97			
PLC097				7.14			
PLC106				14.97			

Method:	OK				KED		
Parcel	Baseline	Relative recovery	Current DTW	2002 SE (feet)	Baseline	Relative recovery	Current DTW
PLC110				9.33			
PLC111				12.21			
PLC113				6.00			
PLC121				18.36			
PLC125				10.68			
PLC136				6.63			
PLC137				4.36			
PLC187				12.57			
PLC193				6.08			
PLC220				5.92			
PLC223				6.08			
PLC239				5.29			
PLC240				8.37			
PLC241				10.30			
PLC246				12.12			
PLC251				9.06			
PLC263				12.33			
TIN006				4.12			
TIN028				7.35			
TIN030				8.43			
TIN050				6.78			
TIN053				5.48			
TIN064				8.54			
TIN068				5.66			
UHL052				11.14			
UNW029				9.27			
UNW039				7.48			
UNW072				12.12			
UNW073				13.38			
UNW079				9.43			