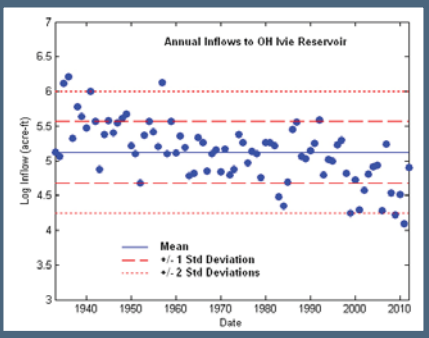
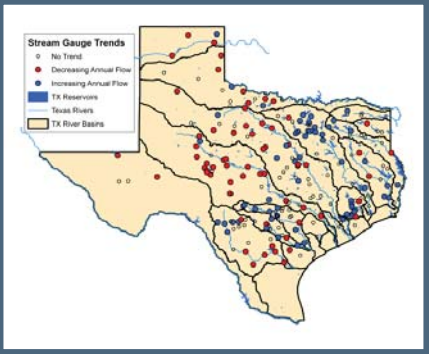
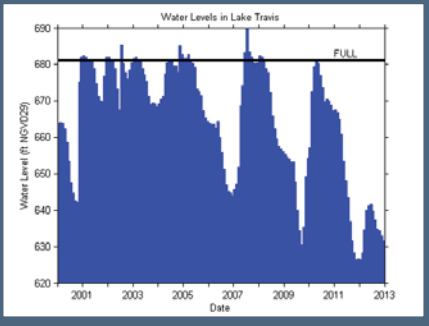
Evidence for the Need to Change the Approach to Water Planning in the Lower Colorado Basin







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EXECUTIVE SUMMARY

The State of Texas and the Lower Colorado River Authority (LCRA) base their water planning and management on historical flow records. Inflows to the Highland Lakes have been significantly lower in recent years, causing many to wonder if the use of historical hydrology is justified for decision-making. The Central Texas Water Coalition (CTWC) commissioned a rigorous study of historical Highland Lake inflows to determine if past hydrology is a good surrogate for future hydrology in the Lower Colorado River Basin.

Findings of the study demonstrate that the average annual naturalized inflow to the Highland Lakes in recent years is, statistically, significantly lower than the average annual naturalized inflow in historical records, indicating that there has been a downward shift in the natural flow regime. Furthermore, the firm yield of the Highland Lakes, which is the starting point for water availability studies and the Lower Colorado River Basin Water Management Plan (WMP), is likely lower than the number currently being used. This is corroborated by the fact that if dry conditions persist for just a few more months, the Lower Colorado Basin will be experiencing a new drought of record. These findings lead us to conclude that past hydrology is not a good proxy for future hydrology. As such, the recently submitted WMP, while a step in the right direction from the previous plan, is not appropriate for planning and allocation of flows in the basin and must be revised as soon as possible. The following sections describe the various analyses that lead to CTWC's assertions.

1.0 STREAMGAGE RECORDS SUGGEST A DRYING TREND

Recent low lake levels in Texas have caused many to speculate that we are experiencing a measurable trend in decreasing flows, not only into the Highland Lakes, but in many other parts of the state. Scientists often use the Mann-Kendall test to determine if there is a statistically significant trend in discrete hydrologic data. An analysis of active streamgages across the entire state with period of record greater than 50 years indicates that there is in fact a trend in decreasing flows across much of central, north and west Texas (see Figure 1). Furthermore, there may be a progression of these drier conditions from the northwest to the southeast of the state, as evidenced by lake levels across the region. For example in Lake Meredith, north of Amarillo, contents have been diminishing since 2000 and it no longer has any usable water. Other lakes closer to Central Texas have been shrinking since 2008. The areas in Figure 1 showing clusters of blue dots are expanding urban areas where impermeable surfaces can increase the amount of runoff and where wastewater discharge and water imported from other basins may result in more water for local streams and rivers.

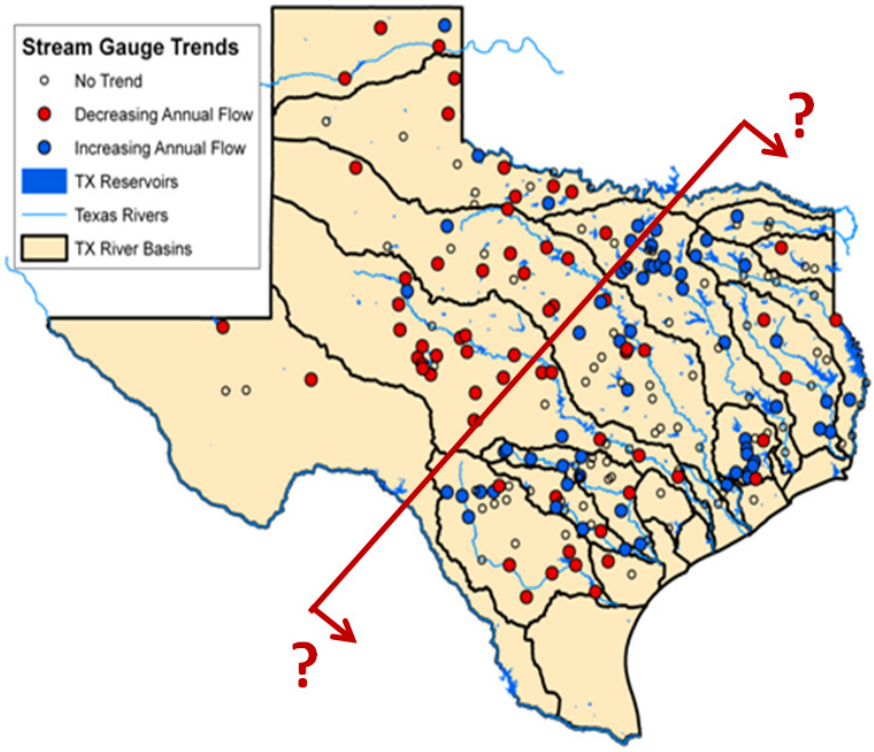


Figure 1. Trend in measured flow from active streamgages with period of record greater than 50 years

2.0 NATURALIZED FLOW DATA DEMONSTRATE A SHIFT IN HYDROLOGY

The fact that measured flows have been decreasing in some parts of the state is to be expected as reservoirs have been built and water diversions have steadily increased in the basin. For example, construction of Lake O.H. Ivie on the Colorado River above the Highland Lakes was completed in 1990, resulting in a reduction in the inflows to Lake Buchanan. To demonstrate that the hydrology has changed beyond what one would expect through increased use of water in the basin, naturalized flows (flows with anthropogenic impacts artificially removed) should be used and in fact these flows form the basis for water planning and water availability modeling in the state.

A time series of naturalized flows from 1940 through 1998 was developed for the TCEQ Water Availability Model (WAM). LCRA extended these naturalized flows through 2009 for the WMP and these data were obtained. Developing naturalized flows is a lengthy and tedious process and has been simplified here. For the purposes of this report, naturalized inflows to the Highland Lakes for the period 2010 through 2012 were estimated based on the largest ratio between measured and naturalized Highland Lake annual inflows from past records. This is a very conservative approach for the point we're making as it results in naturalized flows that are likely higher (wetter) than reality. The results (Figure 2) show that three of the past seven years (2006, 2008 and 2011) have been below the 5th percentile (two standard deviations below the mean). Furthermore, the naturalized inflows for 2011 were far below any other year in the hydrologic record and in fact the 5th percentile for low flows was not exceeded prior to 2006 – not even during the drought of record (1947 through 1956) or in 1963, which was the driest year on record until 2006.

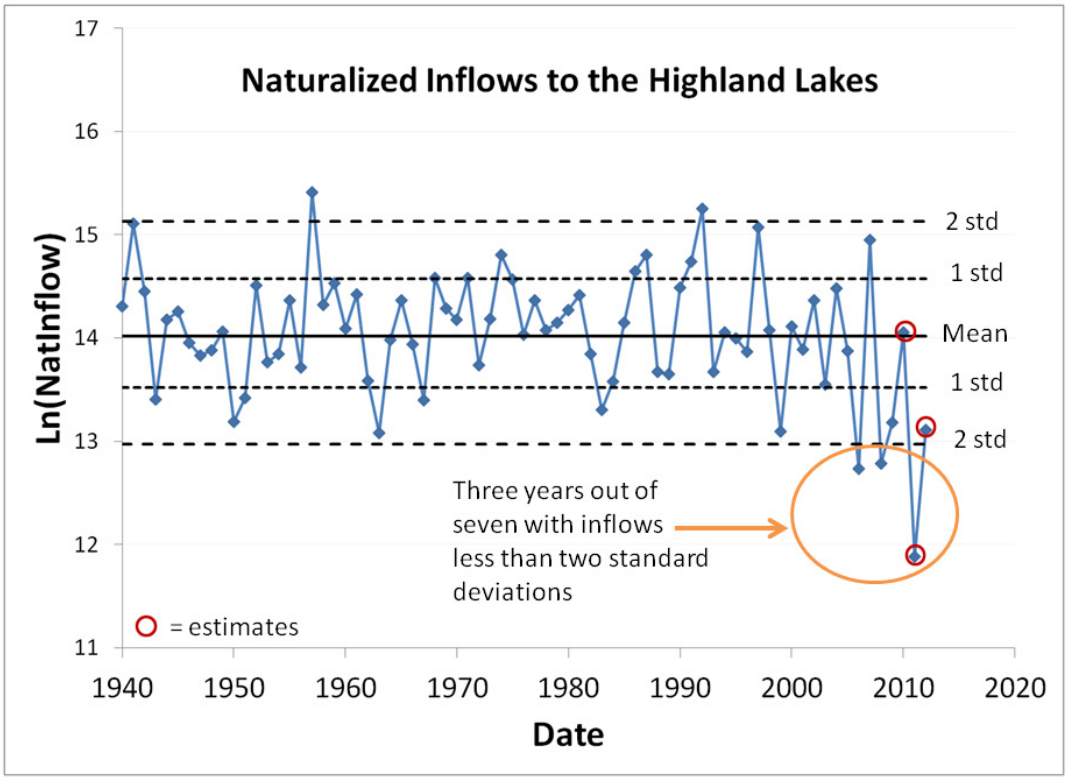


Figure 2 – Demonstration of the fact that naturalized inflows to the Highland Lakes have changed.

This analysis strongly suggests that we are in a hydrologic regime with naturalized flows for which the mean has shifted significantly lower than what we have seen historically (i.e., beyond natural variability). The statistics tell us that the hydrologic regime has changed, rather than the magnitude of that change. However, this past decade (2003 – 2012) has seen naturalized inflows that are on average more than 30 percent lower than the average for the period of record prior to that (1940 – 2002). The past five years (2008 – 2012) have seen average annual naturalized inflows more than 55 percent lower than the average for the period of record prior (1940 – 2007). Unfortunately there is nothing in the literature that suggests this dry weather will break anytime soon.

A persistence of these lower inflows would be crippling to our economy and place a real threat on water providers' ability to continue supplying water to their customers, even with strict water conservation measures in place. Preparation for that eventuality requires careful planning and a move away from a reliance on historical hydrologic data to a more realistic assessment of flows likely to occur over the next several years. We can no longer assume that the future will be like the past.

Possible reasons for this shift in hydrology include, but are not limited to:

- An increase in illegal diversions in the basin;
- An increase in withdrawals of water from the river alluvium that is not accounted for in the naturalization process;
- Changes in the vegetation of the watershed and riparian areas, such as the proliferation of Salt Cedar and Ashe Juniper;
- The construction of stock tanks, amenity ponds and flood control structures in the watershed; and
- Climate variability.

While a better understanding of the reason(s) that the Lower Colorado basin is experiencing a shift in hydrology is desirable, answering that question would require a lot of research and the point of this document is to highlight the fact that the hydrology *has* changed, not why it has changed. Therefore the approach used for long-range water supply planning must change as well.

3.0 THE STOCHASTIC METHODS FOR SHORT-TERM FORECASTING NEED TO BE IMPROVED

The LCRA has been applying stochastic methods to water supply planning and operations for over twenty years. A stochastic process is one whose predictive behavior is not completely known and is determined both by the process' predictable and random factors. Following the drought of 2006, LCRA developed short range forecast model that incorporates stochastically generated inflows. Based on email communications with Mr. Ron Anderson of the LCRA, the short range stochastic forecast model utilizes the following concept:

- Gaged records of the Highland Lakes for the period of 1940 to 2011 are analyzed and computed for the month to month persistence of streamflows for conditions of El Niño, La Niña, neutral, or unspecified (ENSO conditions);
- Monthly streamflows are grouped into lower quartile, inner quartile range, and upper quartile bins for dry, normal, and wet conditions respectively;
- The model calculates 'transitional probabilities', representing the probability of one month going from its current state (dry, normal, wet) to another (dry, normal, wet) for different ENSO conditions;
- Once the system state for a given month is predicted (based on the transitional probability) streamflows are picked randomly from the historic record corresponding to the predicted classification (dry, normal, wet) under the various ENSO conditions. Thus, future forecasts are entirely based on past records; and
- The streamflows are then used to predict lake levels for future conditions.

There are two drawbacks to this approach, which may be addressed as follows:

1) This methodology bins everything into three discrete categories (dry, normal, wet). It has been shown that such a 'block adjustment' approach does not capture the period to period persistence adequately, especially for persistent extreme conditions such as extended drought periods. There are statistical techniques available that could be used to improve the modeling of this persistence by taking into account the continuum of historical flow conditions.
2) The model assumes that past lake levels and flows are adequate representations of future states. In times worse than the drought of record or under changed hydrologic conditions, which have demonstrated to have occurred, the historical streamflow would not be able to capture the extreme low flows that would be expected under such conditions. This problem may be addressed (to a degree) using techniques (Kalman filters) that correct future forecasts based on estimates of errors in past predictions. Any systematic errors in lake levels (due to, for example, being in conditions drier than the drought of record) would then be reduced iteratively as the methodology corrects for bias seen in past months.

In short, the existing approach is not suitable for use during extreme drought conditions, or in a non-stationary environment, both of which are currently occurring based on the statistics of the naturalized flow time series.

4.0 A NEW DROUGHT OF RECORD IS IMMINENT AND THE FIRM YIELD OF THE HIGHLAND LAKES NEEDS TO BE REASSESSED

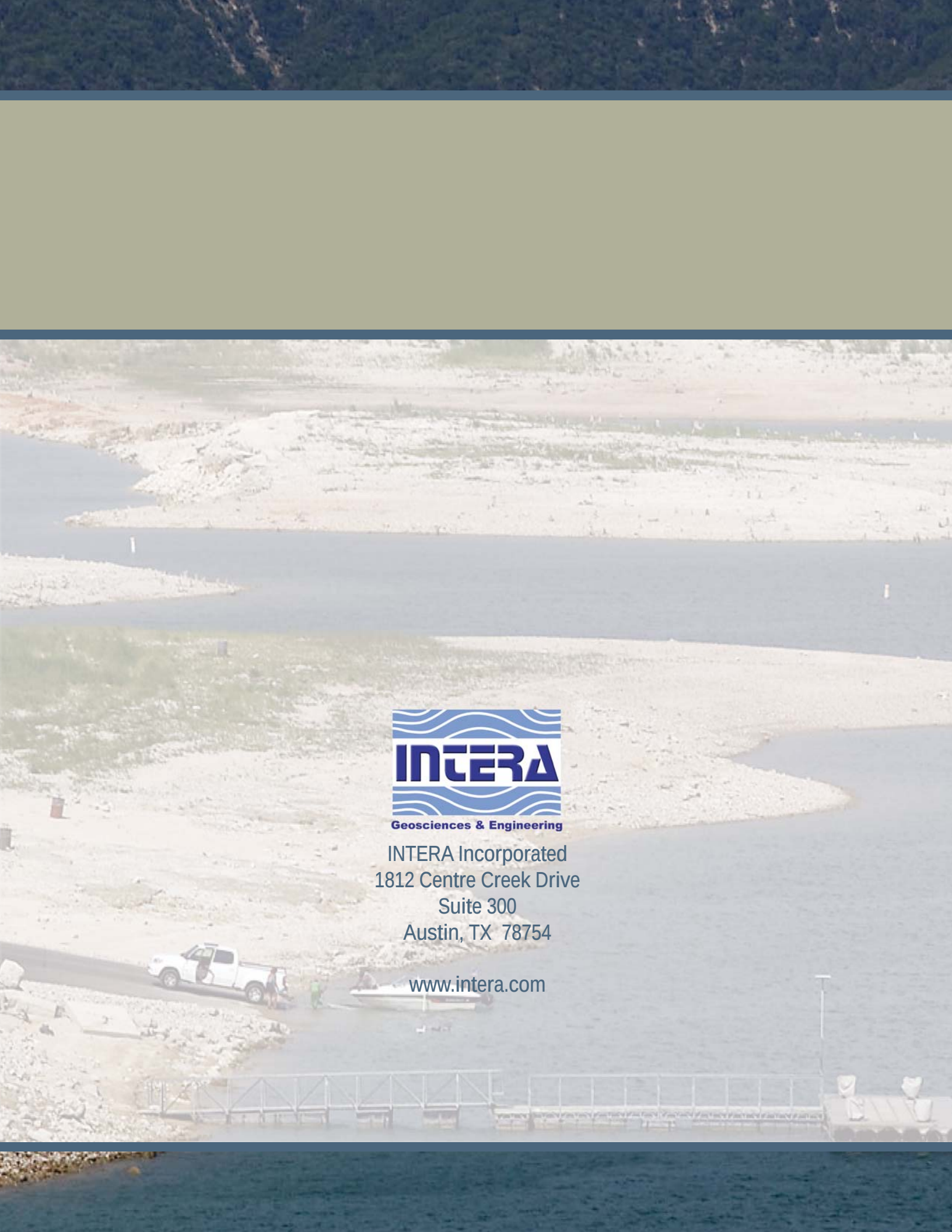
In a previous section we made the case that there is a high probability that we have experienced a shift in the naturalized flows entering the Highland Lakes. This is more than an anomaly or serious drought - we have a new normal and this new normal flow condition is significantly lower than it used to be. The question we need to answer is does this new condition signify that we have a new drought of record, thus requiring a reassessment of the firm yield of the Highland Lakes and an update to the WMP? The firm yield is the amount of water that is available out of a water supply source, such as a reservoir or system of reservoirs, every year through a repeat of the drought of record and is an important planning tool in Texas and elsewhere. In fact most water availability studies use the firm yield as a starting point for permitting and planning. A new drought of record would lead to the need to reassess the firm yield of the Highland Lakes and would also raise serious questions about the WMP. LCRA uses a customized methodology for determining "Drought Worse than Drought of Record" conditions. The drought of record for the Lower Colorado River is currently the period from May 1947 through to June 1956.

Water Availability Models (WAMs) were developed to address this question, and were based on LCRA's Firm Yield WAM developed during the creation of the WMP using two sets of modified naturalized flow data. The first modified dataset consisted of reduced flows for the period 1940-1998 such that the reduced mean flow for that period matched the mean flow for the period 1999-2012. Model results indicated that under the reduced-flow conditions, the combined storage of the Highland Lakes drops to zero several times during the 73 year simulation period, confirming a lower firm yield. The second modified dataset was identical to the naturalized flow dataset discussed above and shown in Figure 2, yet was extended to include simulated years 2013-2016 by twice repeating the naturalized flows from 2006 and 2008. This modified naturalized flow dataset therefore assumes that recent low flows will persist into the near future. The interesting conclusion from this WAM analysis is that with the continued dry weather, simulated lake contents will hit zero by middle to late summer (2013), again indicating that the firm yield will need to be revised downwards and that we have a new drought of record. We won't know the magnitude of the new drought of record or the extent to which it affects the firm yield until lake levels fully recover, or we have a sufficiently long period of record to quantify the new normal.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The stochastic model used for short term prediction of lake levels needs to be revisited and is not appropriate for forecasting during extremely dry or shifted hydrologic conditions. Recommendations for improvements to the model have been provided in this report.

Despite the fact that LCRA has extended the TCEQ-published naturalized flow series for the 2010 WMP, the use of naturalized flows for 1940 to 2009 is not a good basis for determining future water availability in the Lower Colorado Basin. The naturalized flow dataset needs to be officially extended through to the end of 2012 and serious consideration needs to be given to the evidence presented in this report that the hydrology of the basin has shifted significantly downwards. Reducing the full naturalized flow dataset by 30 percent for recalculation of the firm yield and reassessment of water availability is a possible and reasonable approach in the short term. However, we will not know how bad the current drought is or by how much the firm yield should be reduced until the drought has broken or we have a good understanding of the new hydrology of the basin. Until that time, policy-makers should take a conservative approach to water management to ensure that there remains sufficient water in the basin to meet the needs of firm customers under uncertain future conditions. In very short order, we need to revisit the data, models, techniques, triggers and rule curves for management of the Highland Lakes in order properly to deal with this changed hydrologic condition.



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