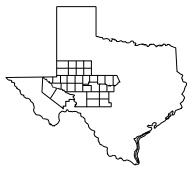
Appendix 4D
Approach to Subordination Modeling



Region F
Water Planning Group

Freese and Nichols, Inc.
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TECHNICAL MEMORANDUM

To: File

From: Andres Salazar Ph.D., P.E – Freese and Nichols, Inc.
Jon S. Albright - Freese and Nichols, Inc.

Re: Approach to Subordination Modeling

Date: May 18, 2005

Modeling Approach

At the time of this analysis the Water Rights Analysis Package (WRAP) did not have a method to directly model subordination of water rights. The model does not track water passed downstream by individual water rights to other senior water rights, only the total amount of water passed downstream. (WRAP is the model used for the Colorado WAM. A beta version of WRAP that includes some subordination options was made available at the time of completion of this analysis. This version of the model has not been evaluated at this time.) Because the model does not track the needed data, much of the calculation involved with the strategy was done outside of the model.

The modeling approach used a three-step process, with each step using a different model setup, referred to as a 'run'. These runs are:

- A Base Run of the basin operating in perfect priority order (similar to the Colorado WAM);
- A 'MiniWAM' of the upper basin water rights; and
- An Impact Run to assess the changes in water availability in Region K due to subordination.

Each step of the process is described in detail below.

These models were used to evaluate four different scenarios:

1. Year 2000 conditions with no return flows
2. Year 2000 conditions with current City of Austin return flows
3. Year 2060 conditions with no return flows
4. Year 2060 conditions with expected 2060 return flows from the City of Austin

City of Austin return flows were provided by Region K. Region F return flows were not included in the analysis because very little of the wastewater in the region is currently discharged into streams. The existing wastewater discharges will most likely be targeted for direct reuse at some point in the planning process.

Base Runs of the Full Colorado WAM

Different base runs were developed for each scenario. The base runs are modified versions of the TCEQ Colorado WAM Run 3 (November 12, 2004 version). The modifications include:

1. Original area-capacity relationships were replaced with either year 2000 conditions or 2060 conditions. Reservoirs in Region F used sedimentation rates developed by Freese and Nichols for the 2001 Region F Plan. Region K provided their own year 2000 and 2060 sediment conditions for the reservoirs in their region. Other reservoirs were based on WAM Run 8 data (the TCEQ current conditions run).

2. The subordination modeling of the Highland Lakes to Ivie Reservoir was removed. This prevented upstream reservoirs from passing water to satisfy Ivie Reservoir depletions.

3. The yield of the Highland Lakes system was increased to account for the removal of the subordination to Ivie Reservoir.

4. Pairs of dummy water rights with zero diversion were added to track the water passed by the junior water rights in the upper basin to the downstream senior water rights included in this subordination strategy. Table 1 includes a list of the junior water rights and Table 2 is a list of the senior water rights that were tracked with the dummy water rights. The first set of dummy water rights had a priority date

one day senior and the second set of water rights had a priority date one day junior to the downstream senior water rights as specified in Tables 1 and 2, respectively. The difference in available water for these water rights represents the flow passed downstream.

Table 1
Junior Upstream Water Rights Used to Track Releases for Downstream Senior Water Rights

Junior Upstream Rights	Priority Date (mm/dd/yyyy)	Subordinated Senior Right Group*
Lake Thomas	5/08/1946	LCRA, Corpus and Austin Rights
Champion Creek Reservoir	4/08/1957	LCRA, Corpus and Austin Rights
Lake Colorado City	11/22/1948	LCRA, Corpus and Austin Rights
Spence Reservoir	8/17/1964	LCRA, Corpus and Austin Rights
Oak Creek Reservoir	4/27/1949	LCRA, Corpus and Austin Rights
Ballinger	10/04/1946	LCRA, Corpus and Austin Rights
Lake Winters	12/18/1944	LCRA, Corpus and Austin Rights
Fisher Reservoir	5/27/1949	LCRA, Corpus and Austin Rights
Twin Buttes Reservoir	5/06/1959	LCRA, Corpus and Austin Rights
Lake Nasworthy	3/11/1929	LCRA, Corpus and Austin Rights
Ivie Reservoir	2/21/1978	LCRA, Corpus and Austin Rights
Hords Creek Lake	3/23/1946	LCRA, Corpus and Austin Rights, and BCWID
Lake Coleman	8/25/1958	LCRA, Corpus and Austin Rights, and BCWID
Lake Clyde	2/02/1965	LCRA, Corpus and Austin Rights, and BCWID
Lake Brownwood	9/29/1925	LCRA irrigation, Corpus and Austin rights
Brady Creek Reservoir	9/02/1959	LCRA, Corpus and Austin Rights
Run-of-the river right City of Junction	11/23/1964	LCRA, Corpus and Austin Rights

* Subordination of Ivie Reservoir is described in step 2 above. Subordination of Lake Nasworthy is described in step 5 of the section *Hydrology for the MiniWAM*.

Table 2
Senior Water Rights Tracked for Releases by Junior Water Rights*

Senior Water Right Group	Water Right Number	Priority Date (mm/dd/yyyy)	Total Diversion (Ac-Ft/Yr)
LCRA	5434	11/1/1900	168,000
	5476	12/1/1900	228,570
	5475	1/4/1901	52,500
		9/2/1907	55,000
	5477	9/1/1907	55,000
		3/27/1926	Target & critical flows
	5478	3/29/1926	Refill Lake Buchanan
		12/31/1929	532
		3/7/1938	560,000
	5480	3/29/1926	Refill LBJ
	5479	3/29/1926	Refill Inks Lake
	5482	03/07/1938	178,300
City of Austin	5471	6/30/1913	250,000
		6/30/1913	150
		6/27/1914	21,403
		6/27/1914	24,000
		12/31/1928	Refill Barton Springs
BCWID	2454	9/29/1925	15,996
		9/29/1925	5,004
		9/29/1925	8,712

* Subordination of Ivie Reservoir is described in step 2 above. Subordination of Lake Nasworthy is described under Hydrology for the MiniWAM step 5.

5. Several of the senior water rights have multiple priority dates. Only the portions of water rights with priority dates of 1938 or earlier will be considered for subordination.

6. For the return flow scenarios, City of Austin wastewater return flows were added at the appropriate locations as constant monthly inflows (CI cards).

MiniWAM Runs of the Upper Basin Water Rights

The upper basin water rights (water rights in Region F and Brazos G) are assumed not to make calls on each other. To facilitate the modeling of this situation, a simplified 'MiniWAM' was developed which contains only the upper basin water rights. The

MiniWAM uses artificial hydrology based on depletions by the water rights, flows passed downstream and unappropriated flow. The results of the MiniWAM became the basis for the Impact Model.

Figure 1 shows the primary control points in the MiniWAM. These control points are associated with the upstream water rights in Table 1. The hydrology for each primary control point is the sum of the water passed to the downstream senior water rights in Table 6, the depletions made by the junior water rights in the respective base run, and the unappropriated flow at each junior water right location. Flows at the secondary control points were calculated as the sum of flows from upstream control points. Equivalent channel losses were incorporated in the MiniWAMs as needed.

Each scenario has its own version of the MiniWAM with hydrology based on the corresponding base run. Hydrology for the MiniWAMs was developed as follows:

1. Using the output of the base runs, the water passed by a reservoir to a senior right was computed as the difference in the available flow at the junior water right's control point before and after allocating for the senior water rights. For example, the following formulas was applied for subordination of the Highland Lakes:

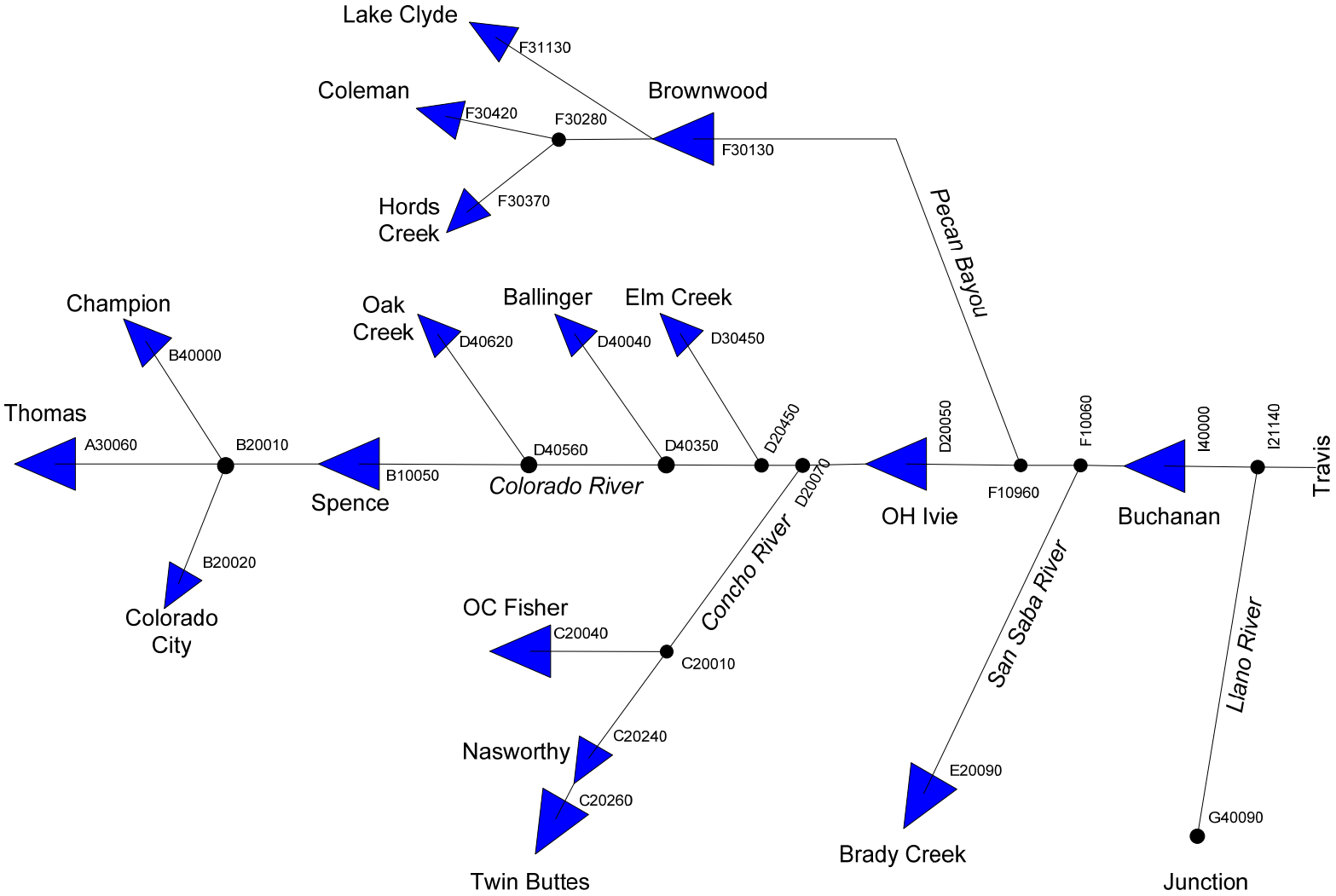
   Water passed to Highland Lakes for first refill (Priority 3/29/1926) = available at 3/28/1926 - available at 3/30/1926

   Water passed to Highland Lakes for second refill (Priority 3/08/1938) = available at 3/07/1938 - available at 3/09/1938

   The total water passed for senior water rights is the sum of the amounts passed for each individual senior water right.

2. Unappropriated flows at each junior water right control point were extracted from the WRAP output file for each base run. These unappropriated flows were added to the water passed by senior water rights from step 1 to develop flows for the MiniWAMs. These flows were input using IN cards, taking the place of the naturalized flows in the full Colorado WAM.

Figure 1
Schematic of MiniWAM



3. Depletions made by each junior water right under each base run were entered into the MiniWAM as flow adjustments (FA cards). Using FA cards eliminates the need to manually add the depletions at each downstream control point. The WRAP model adds these flows to the flows entered on the IN cards at each downstream control point, calculating the total flow at each control point adjusted for channel losses.

4. Lake Nasworthy was assumed to be subordinate to Twin Buttes Reservoir. Because of the relatively senior priority date of Lake Nasworthy, these two water rights were treated somewhat differently than other water rights in Table 5. In the base runs, the water passed by Twin Buttes was included in the depletions by Lake Nasworthy. To implement subordination, the flows passed by Twin Buttes to Lake Nasworthy were added to the Twin Buttes unappropriated flows. Equal amounts were subtracted at Lake Nasworthy, after adjusting for channel losses if needed.

5. Evaporation and area capacity relationships in the MiniWAM were identical to those used in the equivalent base run of the full Colorado WAM.

The MiniWAMs were used to calculate the safe yield of the upper basin reservoirs in natural order. Natural order makes depletions for water rights in upstream to downstream order, ignoring the priority of the water right. This is identical to assuming that all major upper basin water rights will not make priority calls on each other. Yields of the reservoirs were limited to the permitted diversion of the reservoir.

Most reservoirs in Region F are operated on a safe yield basis, which is a more conservative definition of yield than firm yield. Firm yield fully uses the storage in the reservoir, leaving no reserve content at the lowest point in the simulation period. Safe yield reserves one year of supply in the reservoir at the lowest point in the simulation period. Safe yield allows for the occurrence of more severe droughts than have occurred in the simulation period. Because most of Region F experienced critical drought conditions since 1998 which are not included in the Colorado WAM (the Colorado WAM

ends in 1998), it is prudent to use safe yield rather than firm yield as the basis for water availability in the Region.

Using safe yield as the definition of reliable supply also has less impact on water rights in Region K than if firm yields were used. Because safe yields are less than firm yields, not as much water is depleted to meet demands and there is less empty storage in the reservoirs to fill when water is available.

Water availability for the City of Junction is defined by the minimum annual diversion from the river.

The specific steps in determining yields of the reservoirs using the MiniWAM were as follows:

Safe yields were calculated in natural order, starting with Lake Thomas. The computations for a reservoir assume that upstream reservoirs operate at their safe yield. Safe yield was limited to the permitted diversion.

Impact Runs

The Impact Runs replace the water rights in the MiniWAM with depletions made by the water rights in the MiniWAM. The depletions of the MiniWAM represent the water that is available for the reservoirs in Region F after subordination. Monthly depletions are entered for each MiniWAM water right using the WRAP model's TS records. Each month has a unique value. Each region may then use this output to determine the impact of subordination on the water availability within their region.

The proposed approach was developed to have minimal impact on water rights not included in the subordination analysis. However, the interaction of water rights in the WAMs is complex, and some differences between the Base Runs and the Impact Runs is to be expected. The approach used in this analysis has reduced the impacts on other water rights not included in the subordination analysis. However, future modeling efforts with an improved version of WRAP with subordination options may develop approaches with fewer impacts on other water rights.

The water rights that have access to water released from storage in the Highland Lakes as defined in the LCRA Water Management Plan may experience some impacts from subordination even if the water right is not directly included in the subordination analysis. Water rights that depend on interruptible supplies may be impacted significantly. These impacts will be determined by Region K.

The specific steps used to develop the Impact Runs were as follows:

1. The total available flow in the upstream basin after subordination was computed from the MiniWAM. This computation is performed for each reservoir in Region F.
2. The additional flow obtained as a direct result of subordination was calculated as the difference between the depletions of the MiniWAM and the depletions under the Base Run. This computation was performed for each reservoir in Region F.
3. The total additional flow in Region F obtained as a result of subordination was calculated as the sum of the gains at each reservoir, adjusting for channel losses between each reservoir and Lake Buchanan. The total additional flow in Region F was equal to the reduction of flow coming into Region K, and represents the flow that would have been passed for Region K in the absence of subordination.
4. The total water available for senior rights in Region K after subordination was computed as the total depletion from the base run minus the reduction of flow calculated in step 3.
5. The approximate physical regulated flow at diversion points in Region K was computed as the naturalized flow at each point minus the reduction of flow computed in step 3.
6. The total amount available for Region K was distributed among the water rights in priority order. The allocation started with the most senior water right. The allocation was limited to the physical regulated flow computed in step 5. If the total available for Region K was not used by the first right, the next water right in priority was allocated. The allocation stops once the total amount available for

Region K was reached. Water rights to be allocated after the limit was reached did not get any water.

7. The allocation of water rights of step 6 produced the water available for each senior water right. These amounts were written in TS Cards for each right.

8. The impact run replaced Region F Reservoirs with TS Cards from step 1 with the most senior water right. It also limited the depletions of Region K water rights to the allocation of step 6.