IN THE SUPERIOR COURT OF THE STATE OF CALIFORNIA

IN AND FOR THE COUNTY OF LOS ANGELES

CITY OF PASADENA, a municipal corporation,
Plaintiff,

vs.

CITY OF ALHAMBRA, a municipal corporation, et al.
Defendants,

No. Pasadena C-1323

REPORT OF REFEREE

DIVISION OF WATER RESOURCES

DEPARTMENT OF PUBLIC WORKS

STATE OF CALIFORNIA, REFEREE

TABLE 34

ESTIMATED UNDERFLOW FROM SUBDIVISIONS OF RAYMOND BASIN AREA

UNDER NATURAL CONDITIONS

Mean for Twenty-nine Year Period, 1904-05 to 1932-33, inclusive

Acre Feet

	Monk Hill Basin	Pasadena Sub-area	Santa Anita Sub-area (Eastern Unit)	Entire Area
Water available				
Precipitation (Table 6)	12100	29600	4450	46150
Inflow from mountains (Table 7)	9600	4560	7140	21300
Inflow from hills (Table 8)	291	153	0	444
Storm inflow from Monk Hill Basin	--	4750[a]	--	--
Rising water inflow from Monk Hill Basin	--	2170	--	--
Underflow from Monk Hill Basin	--	5080	--	--
1. Total	21990	46310	11590	67890
Disposal				
Consumptive use (Table 30)	9840	28650	3620	42110
Storm outflow (Table 12)	4900	6670	3960	10780[b]
Rising water flowing out	2170	7730	0	7730
2. Total accounted for	16910	43050	7580	60620
Underflow (Item 1 minus Item 2)	5080[c]	3260[d]	4010	7270[e]

a Storm outflow from Monk Hill Basin excluding Verdugo Drainage (Table 98).
b Includes only Verdugo Drainage from Monk Hill Basin.
c The large variation from the corresponding value in Table 33 may be due in part to error resulting from subtracting one relatively large estimated quantity from another. With the more continuous high water table in Monk Hill Basin, however, considerable underflow may have occurred north of Monk Hill. There is some indication in the graphs of wells 10 and 16, on Plate 31, that the water table south of Monk Hill responds more pronouncedly to changes to the north when the water table in Monk Hill Basin is high. From this it may be deduced that the underflow is materially greater when the water table in Monk Hill Basin is high.
d Underflow from Pasadena Sub-area is the same as from the Western Unit.
e Sum of that from Pasadena and Santa Anita Sub-areas only. Underflow from Monk Hill Basin goes into Pasadena Sub-area.

SAFE YIELD AND OVERDRAFT

43. General Discussion

The safe yield from a body of ground water under any given set of conditions may be defined as the amount of water which can be continuously extracted from it for useful purposes over an unlimited period of time. Under different sets of conditions it may vary widely. Since water cannot come out of storage indefinitely, the safe yield cannot be greater than the difference between the supply which reaches the ground water and the amount of water which flows out from it or is consumed by types of water-loving natural vegetation which extract and use water from below the water table.

The supply reaching the ground water varies considerably from year to year and from period to period, while the outflow and extractions are more uniform. The result is that water alternately goes into and comes out of storage with a corresponding rise and fall of the water

table. The supply which determines the safe yield is not that of any one year or short series of years but is the average for a longer period which includes both wet and dry years. Where usable storage capacity is unlimited, the supply is the long time mean. Where, however, the usable storage capacity is limited either by shallow depth between water table and ground surface or by excessive cost of pumping from a lowered water table the insufficient capacity does not provide complete regulation, and safe yield is limited by this lack of regulating storage.

The supply which reaches the ground water underlying a particular area consists of underflow from adjoining areas and direct deep percolation from precipitation, from mountain streams, from water applied on the surface for irrigation and from cesspools. While the total of precipitation and stream flow remains the same, in Raymond Basin Area the deep percolation from them is different for different stages of cultural development because the amount of water artificially applied and the consequent deep percolation from areas so watered changes and the return from use within buildings depends upon what part enters cesspools and what part is carried away in sewers.

The amount of outflow and wasteful consumption from the ground water depends upon the elevation of the water table. It has been shown that extraction by pumping results in a lowering of the water table and a reduction in the outflow and wasteful consumption. Conversely, the safe yield depends upon the average elevation of the water table chosen as the condition which should be maintained. If it is desired to maintain a high water table, the outflow and waste will be greater and the safe yield will be less. If practical considerations permit that the average elevation of the water table be lower, the safe yield will be greater.

In the following paragraphs, estimates of safe yield for three stages of development, (1) that of the present, (2) that under natural conditions, and (3) that which will ultimately be reached, are made. As is justified by the depth of the ground water above bedrock in Raymond Basin Area and the large expense which can be borne for the urban and other uses of water in the Area, the results of all three estimates are predicated on an underground storage capacity sufficient to regulate the mean supply. The capacity required for this approximates 200,000 acre feet as shown by Table 52 while the storage capacity between bedrock and present water table is about 800,000 acre feet. The estimates are further predicated on the continuance of the present average water table elevation just above the boundaries where outflow underground occurs so that the average underflow will be the same as that which actually occurred during the 11 year period 1927-28 to 1937-38.

44. Safe Yield with Present Development

If it were possible to find a historic period in which development was as at present, in which the supply reaching the ground water was equal to the long time mean under that development, and in which the water table elevation and the resulting outflow and wasteful consumption from the ground water were the average of that for the 11 year period, the decrease in amount in

storage during such a period would directly measure the amount by which the actual extractions during the period exceeded the safe yield. This excess would be the overdraft.

In the absence of such a period it is necessary to estimate the overdraft from the change in storage which occurred in any base period for which the supply reaching the ground water, the outflow and wasteful consumption from it and the useful extractions can be evaluated from observations. Since the overdraft is the amount which must have come from storage under the conditions of the preceding paragraph, the change in storage during the base period must be adjusted for the differences between the long time mean and base period values of these items.

It is necessary that the base period should be one in which the change in storage can be estimated with reasonable accuracy and desirable that it be one in which as many as possible of the elements which make up the recharge and natural extractions may be assumed equal to their long time mean values under present development without significant error. Such elements need not be evaluated in estimating the overdraft since they play no part in the required adjustment.

The 11 year period 1927-28 to 1937-38, inclusive, reasonably satisfies these requirements. During that period, changes in water table elevation upon which the estimate of storage change below the water table is based, are fairly well defined. With two wet years preceding both the beginning and end of the period, the amount of water in transit from the surface to the water table is deemed to be the same at the beginning and the end of the 11 year period and thus only the storage change beneath the water table need be considered. The change in elevation has been recorded and by methods previously discussed the change in storage of water can be evaluated. Since the condition has been imposed that the long time mean and 11 year average water table elevation should be the same, it follows that the natural escapes must also be about equal since these are a function of water table elevation. It may also be assumed without significant error that the 11 year average and long time mean values under present development are the same for consumptive use and for underflow from one part of the Area to another. All of these are difficult to evaluate accurately and the fact that they can here be eliminated from consideration is advantageous.

Other than underflow into the basin and water injected directly through wells, the recharge to the ground water consists solely of percolation from water applied on the surface either naturally or artificially. The simplest way to evaluate this percolation is to subtract the sum of the consumptive use and surface outflow from the total entering the Area on the surface. Since 11 year average and long time mean consumptive use are assumed equal, only the supply reaching the surface of the area overlying the basin and the outflow need be evaluated here.

While the substitution of water pumped locally for imported water would increase the overdraft, and either increased importation or decreased exportation would decrease it, neither would in any way change the safe yield unless development on the Area were changed, so neither importation nor exportation for use need be considered in the adjustment. Sewage outflow, however, reduces the amount of deep percolation and the sewage outflow has been continuously in-

creasing. Because of this, the difference between its 1937-38 value and the average for the 11 year period is considered.

In Table 37, the required adjustment is evaluated, and the safe yield estimated by subtracting the resulting overdraft under present development and with importations and exportations for use equal to their 11 year averages, from the average extractions by pumping during that period.

In the same table, the overdrafts which would have resulted had local pumping been substituted for importations from San Gabriel River, and had pumping been substituted for all importations, are estimated. Water has been imported from San Gabriel River since 1933-34 (Table 114) and while it is probable that very little of it actually entered Monk Hill Basin, it is assumed for reasons given immediately following that more water would have been pumped there for use in Pasadena Sub-area, had there been no importation. Consequently, both Pasadena Sub-area and Monk Hill Basin have been affected by the importation. During the six year period 1927-28 to 1932-33 inclusive, 30 per cent of the total pumped by Pasadena in the two areas (Table 61) came from Monk Hill Basin. During the period 1933-34 to 1937-38 inclusive, the average sum of pumped water and that imported for use was 11,600 acre feet. Had it been necessary to pump all of this and had 30 per cent of it been from Monk Hill Basin, an average of 3480 acre feet would have come from that source. Actually, 2800 acre feet per year was pumped from that Basin, the average annual difference for the five years being 680 acre feet. Thus, during the 11 year period, 1927-28 to 1937-38 inclusive, the average annual increase in extraction from Monk Hill Basin, had no San Gabriel River water been imported, would have been five-elevenths of this value or 310 acre feet. Had pumping been substituted for the 165 acre feet imported from other sources (Table 114), the average increase would have been 475 acre feet. An 11 year average of 27 acre feet was imported to Pasadena Sub-area from other sources and the corresponding increases there would have been 2460 and 2490 acre feet excluding imported water spread down well No. 15. These values are used in Table 37 instead of the actual importations, a larger part of which was to Pasadena Sub-area.

TABLE 35

SUMMARY

PRESENT DEVELOPMENT

(See Table 37)

Acre Feet

	11 year average			OVERDRAFT	
	Extractions	Change in ground water storage	SAFE YIELD	With present importations for use	Without importations from San Gabriel River
Monk Hill Basin	6380	+ 122	6060	321	631
Pasadena Sub-area	17570	-5930	11910	5660	8120
Total Western Unit	23950	-5808	17970	5980	8750
Santa Anita Sub-area (Eastern Unit)	3380	+ 11	3870	- 491[a]	- 491[a]
Total for Area	27330	-5800	21840	5490	8260

a Surplus.

It will be noted that the serious overdraft is in the Pasadena Sub-area and that the average annual decrease in ground water storage in that subdivision during the 11 year period is 5,930 acre feet or practically the same as the overdraft which is 5660 acre feet for the long time period. Thus the other quantity, 271 acre feet, which enters into the calculation of overdraft, is negligible. The overdraft subtracted from the amount pumped gives the safe yield. The reliability of the estimate of overdraft therefore is dependent almost entirely on the accuracy of the estimate of the amount of water stored between two elevations of the water table and this is from well logs, laboratory experiments and judgment. Thus there is no direct check which can be applied.

There is, however, an indirect check by which the reasonebleness of the calculated change in storage and overdraft may be tested. This test rests upon the values of pertinent items during the 11 year period. These are tabulated in Table 36.

TABLE 36

CHANGES IN WATER TABLE ELEVATION, PRODUCTION AND PRECIPITATION INDICES

FOR PASADENA SUB-AREA

11 year period

	Change in water table elevation,* feet (Table C)	Gross production from wells, acre feet (Table 3)	Water spread down wells, acre feet (Table Q)	Net production acre feet	Precipitation index (Table 65)
1927-28	- 9.52	21046	0	21046	68
28-29	- 9.55	22646	0	22646	76
29-30	- 5.51	22880	0	22880	76
30-31	- 8.15	22987	0	22987	79
31-32	- 8.07	19155	0	19155	108
32-33	- 6.97	18725	0	18725	79
33-34	- 0.77	16565	29	16536	102
34-35	+ 1.20	10791	32	10759	122
35-36	- 7.22	17616	63	17553	82
36-37	+ 5.75	10825	100	10725	141
37-38	+ 6.57	9996	1026	8970	153

		Average Annual		
Period	Inclusive	Change in water table elevation, feet	Net production, acre feet	Precipitation index
A	1932-33 to 1937-38	- 0.24	13900	113
B	1933-34 to 1937-38	+ 1.11	12900	120
C	1933-34 to 1934-35	+ 0.22	13600	111
D	1935-36 to 1936-37	- 0.74	14100	111

* Determined by averaging annual changes at typical wells throughout the Sub-area.

The item in this table on which change in underground storage is based is found in the column headed "Change in water table elevation". The other items are from direct measurements. As it is desired to check the estimate of change in ground water storage the periods of consecutive years in which the change in water table elevation was the least should be selected in approaching the matter in order to as far as possible eliminate this quantity from the equation. All the periods complying with this criterion are shown as groups A, B, etc. In all, precipitation was above average and in all except Period C there probably was an excess of water in transit from the surface to the water table which introduces an element of uncertainty. As heretofore stated, if a period in which surface culture was as at present, had normal rainfall and runoff and if no change in water table elevation occurred in it and if it covered a sufficient period of years, the production from the ground water would be the safe yield of the subdivision. . In all of the periods cited in Table 36 the water table changes were very small but the precipitation was above normal. The general conclusion can be made from this study that the safe yield of Pasadena Sub-area is considerably less than the net average production of 14,000 acre feet in periods A and D during which the water table fell and that it is also less than the net production of 12,900 acre feet and 13,600 acre feet respectively in Periods B and C since in both of these latter periods, although the water table rose slightly, the above average precipitation would appear to be sufficient to more than account for the rise.

It therefore may be concluded that the average annual change in storage in Pasadena Sub-area during the 11 year period which, subtracted from the average annual extraction during the same period and slightly adjusted for long time mean conditions gives the safe yield as 11,910 acre feet in Tables 35 and 37, is as reliably evaluated as is possible with present information. As the safe yield in that evaluation depends primarily on the change in ground water storage and takes into consideration all modifying factors which is impossible under the direct method discussed in the preceding paragraph, it is also concluded that the safe yield and overdraft in Pasadena Sub-area are reliably evaluated.

The values of safe yield derived in Table 37 are based on the assumption that there is sufficient usable storage capacity to regulate the 29 year mean supply. The fluctuation of the water table required to accomplish this is discussed in a later section of the report headed "Fluctuations of Water Table with Extractions from Ground Water Limited to Safe Yield". On the basis of values derived in Table 53, fluctuations in both Monk Hill Basin and Santa Anita Subarea may be materially greater than any which have occurred, but in neither case, nor in the case of Pasadena Sub-area are they great enough to preclude the use of the required storage capacity if the well owner is willing to meet the cost of pumping from the greater depth. As pointed out in that discussion, however, it is possible that the slope of the water table toward the east into Santa Anita Sub-area may at times be steep and this might result in a material flow in that direction from Pasadena Sub-area. At such times the water table in Santa Anita Sub-area would be low and a reduction of the pumping in that subdivision to some value less than the safe yield would not result in a material increase in the outflow across Raymond Fault.

SAFE YIELD AND OVERDRAFT WITH PRESENT DEVELOPMENT*

Acre Feet

TABLE 37

SAFE YIELD AND OVERDRAFT WITH PRESENT DEVELOPMENT*

Acre Feet

Items for which 11 year average and 29 year mean values differ.	Monk Hill Basin			Pasadena Sub-area		
	29 year mean	11 year avg.	Difference equals excess of 29 year mean over 11 year avg.	29 year mean	11 year avg.	Difference equals excess of 29 year mean over 11 year avg.
1. Water entering Subdivision						
a. Precipitation (a)	12100	11640	460	29600	29280	320
b. Inflow from mountains (b)	9600	7680	1920	4560	3570	990
c. Inflow from hills (c)	291	228	63	153	119	34
d. Storm inflow from Monk Hill Basin (d)	--	--	--	5220	2370	2850
e. Sewage inflow from Monk Hill Basin (e)	--	--	--	139*	123	16
f. Imported water sunk in wells	0	0	0	0	114	- 114
	21991	19548	2443	39672	35576	4096
2. Water leaving Subdivision						
a. Storm outflow (f)	5430	2560	2870	10980	7940	3040
b. Sewage outflow (e)	139*	123	16	5915*	5130	785
	5569	2683	2886	16895	13070	3825
3. Water retained in Subdivision (Item 1 minus Item 2) The difference between the two sums is the difference which would occur in increment to ground water storage.	16422	16865	- 443	22777	22506	+ 271
4. From Item 3		- 443			+ 271	
5. Change in ground water storage (11 year average) (g)		+ 122[h]			- 5930	
6. OVERDRAFT with present importation and use (Item 4 plus Item 5 with sign changed)		321			5660	
7. Average pumped during 11 year period (i)		6380			17570	
8. SAFE YIELD (Item 7 minus Item 6)		6060			11910	
9. Importation for use from San Gabriel River (j)		310			2460[k]	
10. OVERDRAFT with pumping substituted for Item 9 (Item 6 plus Item 9)		631			8120	
11. Importations from other sources (L)		165			27	
12. OVERDRAFT with pumping substituted for Item 11 (Item 10 plus Item 11)		796			8150	

* Development as of 1937-38.
a See Table 6.
b See Table 7.
c See Table 8.
d Storm outflow from Monk Hill Basin excluding Verdugo Drainage. See Tables 88 and 91.
e See Tables 21, 23 and 27.
f See Table 10.
g See Table 32.
h Water table rose during 11 year period.
i See Table 133.
j See paragrapns preceding this table.
k Excludes 114 acre feet spread down well No. 15.
L See Table 27.

Western Unit			Eastern Unit, Santa Anita Sub-area			Area as a whole		
29 year mean	11 year avg.	Difference equals excess of 29 year mean over 11 year avg.	29 year mean	11 year avg.	Difference equals excess of 29 year mean over 11 year avg.	29 year mean	11 year avg.	Difference equals excess of 29 year mean over 11 year avg.
41700	40920	780	4450	4350	100	46150	45270	880
14160	11250	2910	7140	5860	1280	21300	17110	4190
444	347	97	0	0	0	444	347	97
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--
0	114	- 114	0	0	0	0	114	- 114
56304	52631	3673	11590	10210	1380	67894	62841	5053
11190	8130	3060	4140	3240	900	15330	11370	3960
5915*	5130	785	0	0	0	5915*	5130	785
17105	13260	3845	4140	3240	900	21245	16500	4745
39199	39371	- 172	7450	6970	+ 480	46649	46341	+ 308

- 172	+ 480	+ 308
-5808	+ 11[h]	-5800
5980	- 491	5490
23950	3380	27330
17970	3870	21840
2770[k]	0	2770
8750	- 491	8260
192	0	192
8940	- 491	8450

45. Safe Yield under Natural Conditions

If all the natural conditions including wasteful consumption from below the water table and underflow out of Raymond Basin Area were maintained, it would not be possible to extract any water for useful purposes; in other words, there would be no safe yield. Assuming, however, the water table to have been lowered so that the underflow is reduced, rising water is eliminated and the only consumptive use on the Area is that by vegetation which derives its supply directly from precipitation or surface water in streams emerging from the mountains, an amount of water equal to the reduction in outflow and water consumed resulting from the lowering, can be extracted for useful purposes without lowering the water table below some particular average elevation. For the purposes of this discussion, this average elevation is taken as that which would result in an outflow underground equal to the average of that which occurred during the 11 year period. Under this condition, there would be no swamp area north of Raymond Fault and no rising water.

Elimination of the original swamp area results in a decrease in consumptive use and in storm outflow. On the assumption that grass and brush consuming an average of 1.58* acre feet per acre would replace the water loving vegetation which consumed 4.00 acre feet per acre, the reduction in wasteful consumption on the 1000 acres of former swamp, would amount to 2420 acre feet per year. Of the approximately 1700 acre feet of precipitation which falls annually on the 1000 acres it may be assumed that 100 per cent and 5 per cent would run off from swamp and from grass and brush respectively. This decrease due to lowering the water table would be about 1600 acre feet.

Table 38 presents an estimate of the safe yield with culture as it was prior to any development but with a lowered water table. Since the assumption is that only natural culture occupies the Area, all water extracted would have to be exported.

46. Safe Yield with Ultimate Development

Assuming again that the water table elevation is such that the outflow from the ground water is the same as during the 11 year period, which it should be if overdraft is eliminated, the safe yield is equal to the deep percolation from all sources plus the inflow underground minus the outflow underground. In Article 48, deep percolation is discussed and in Table 43 its value under ultimate cultural development in each subdivision of Raymond Basin Area is estimated. Using those values and the 11 year average underflow values derived in Table 33, the estimated safe yield is as presented in Table 39.

* Average of unit values for brush and grass and weeds, Table 30.

TABLE 38

SAFE YIELD UNDER NATURAL CONDITIONS OF CULTURE

BUT WITH LOWERED WATER TABLE

Acre Feet

	Monk Hill Basin	Pasadena Sub-area	Total Western Unit	Eastern Unit Santa Anita Sub-area	Area es a whole
Underflow in					
Natural (a)	0	5080	0	0	0
Eleven year period (b)	0	2220	0	0	0
Decrease	0	2860	0	0	0
Decrease in rising water inflow (a)	0	2170	0	0	0
Total decrease	0	5030	0	0	0
Underflow out					
Natural (a)	5080	3260	3260	4010	7270
Eleven year period (b)	2220	2860	2860	620	3480
Decrease	2860	400	400	3390	3790
Decrease in rising water outflow (a)	2170	7730	7730	0	7730
Decrease in storm outflow	0	1600	1600	0	1600
Decrease in consumptive use	0	2420	2420	0	2420
Total decreese	5030	12150	12150	3390	15540
Safe yield	5030	7120	12150	3390	15540

See Table 34.
See Table 33.

TABLE 39

ESTIMATED SAFE YIELD WITH ULTIMATE DEVELOPMENT

Acre Feet

	Monk Hill Basin	Pasadena Sub-area	Total Western Unit	Eastern Unit Santa Anita Sub-area	Entire Raymond Basin Area
1. Deep percolation	7430	11390	18820	4300	23120
2. Inflow underground	0	2220	0	0	0
3. Outflow underground	2220	2860	2860	620	3480
Safe Yield	5210	10750	15960	3680	19640