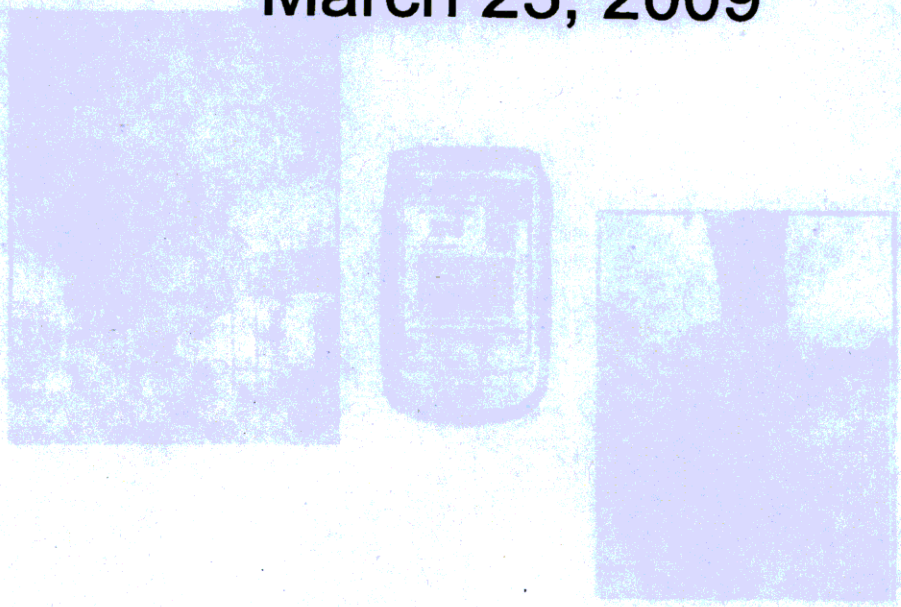
Exhibit F
STRATUM Report
March 23, 2009



City of Pasadena, California STRATUM Analysis, Playhouse District Development

February 2009

DAVEY RESOURCE GROUP

A Division of The Davey Tree Expert Company

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Section 1: Introduction

Davey Resource Group (DRG) was contracted by the City of Pasadena (the City) to conduct a short term STRATUM analysis for proposed street tree inventory changes related to the new construction of the Pasadena Playhouse. Existing tree inventory data was furnished by the City to DRG for use in analyzing current tree statistics. Proposed changes to the inventory were also provided. Size projections for growth of the proposed inventory, including removals and plantings, were conducted using methods for UFORE analysis of urban forest populations. Growth projections for 5 years and 15 years of the new inventory were analyzed through STRATUM to give projected annual benefits for the City based on the updated tree population.

STRATUM and UFORE

STRATUM and UFORE are part of the i-Tree urban forest analysis tools. STRATUM (Street Tree Resource Analysis Tool for Urban Forest Managers) was the principle tools used in this analysis. STRATUM uses peer-reviewed modeling techniques to quantify the value of annual environmental and aesthetic benefits provided by the urban forest. When used in conjunction with more complete street data and municipal budget data, STRATUM can also analyze management needs, and costs of the trees.

UFORE (Urban Forest Effects Model) utilizes data from randomly selected plots throughout a community to quantify urban forest structure and environmental effects. In this analysis, UFORE was only referenced to estimate annual DBH[1] growth increases of the evaluated project tree species.

[1] DBH – Diameter at breast height; tree trunk diameter measured 54 inches above ground level.

Section 2: Methodology

Inventory Data

Existing street tree inventory data was furnished by the City to DRG for the STRATUM analysis. When compared to the proposed changes to the inventory, it was determined that the street tree inventory was inaccurate in regards to tree locations. Maps of the proposed construction and changes were requested and furnished by the City which gave more accurate tree location and DBH information which was used for the STRATUM analysis. Because of the inaccuracies observed in the inventory DBH and location data, it was determined that relying on the inventory for tree health and sidewalk damage would not be accurate either. For this analysis, it is assumed that the trees are in relatively good health and there is no significant sidewalk damage. Since sidewalks would be expected to be repaired/replaced during construction, and it is assumed only healthy trees would be retained, the projected benefits of the proposed inventory should remain reliable. However, it is recommended that an updated inventory be conducted in the City before performing further in-depth tree cost/benefit analysis.

For the newly planted trees, DBH is assumed to be consistent with a 36 inch box tree for the species. Heights of the proposed Mexican fan palm plantings were furnished and the DBH was extrapolated from that information.

STRATUM Analyses

Three separate STRATUM analyses were conducted for each phase of construction as well as the combined tree population of both phases.

1. Current inventory before removal and planting
2. Proposed inventory 5yrs after removal/replacement/planting
3. Proposed inventory 15yrs after removal/replacement/planting

The data analysis will look at each phase separately.

Five annual benefits are assessed in STRATUM. Each benefit is quantified in terms or resource units and a dollar value is assigned to the resource unit. The benefits categories are.

1. Energy – the sum of energy savings due to reduced natural gas in winter in reduced air-conditioning in the summer. These savings come from the shading provided by trees, transpiration resulting in cooling the air, and wind-speed reduction which also reduces conductive heat loss. (Maco *et al* 2005)
2. Carbon Dioxide (CO_2) – the sum of the decreased atmospheric carbon dioxide due to sequestering by trees and the reduced carbon emissions from power plants due to energy savings. This model accounts for carbon released by trees due to decomposition when they die and from pruning activities.

3. Air Quality – The sum of air pollutants deposited on trees and taken out of the atmosphere and reduced emissions from power plants. This model accounts for potential negative effects from BVOC (Biogenic Volatile Organic Compounds) released by trees into the environment. In some cases these BVOC's cause an overall negative impact on air quality by trees.
4. Stormwater – measures reduced annual storm water runoff due to trees through interception or absorption through roots.
5. Aesthetic – a measure of the tangible and intangible benefits of trees reflected in increases in property values due to trees. (itree)

DBH Projections

STRATUM uses DBH as one of the main factors when analyzing annual benefits. For species where data was available to predict DBH growth by species was used (Maco *et al* 2003). Where it was not available annual DBH growth was projected using data from UFORE giving an annual projected DBH growth ranging from 0.1 to 0.5in per year, with the exception of the Mexican fan palms which once established at the height the city is planning, put on very little DBH growth in relation to height (UFORE).

Although many studies relating to DBH growth have been conducted, models are very specific to tree, site, and region given the variety of factors that can affect tree growth. Planting site (tree box, park, etc), pruning activities, climate, and irrigation are only a few examples of the factors that affect tree growth rates. The projected rates of growth of DBH should be considered as a predicted average of how the trees will perform. Although the projected DBH values are consistent with what is expected of trees of each species, many factors could influence how the individual trees of Pasadena actually grow. Accuracy could be improved if the DBH of trees of the same species with known ages and similar site characteristics in the City could be inventoried, and that data substituted into the projected DBH growth rates for the proposed tree populations in the Playhouse District.

Section 3: Analysis

Phase 1D

Species Composition

The tree species percentages in the Phase 1D inventory changed significantly between the current state and the proposed inventory. Figure 1 shows the current species distribution. The inventory is comprised primarily of Gingko with the next most common species being Carrotwood. There are a total of five different species in the current inventory. Figure 2 shows the changes in species distribution by the proposed inventory following removals and planting. In the proposed inventory the number of species is reduced from five to three. Gingko is still the primary species, however its relative importance increases by 16%.

Figure 1. Phase 1D Current Species Distribution

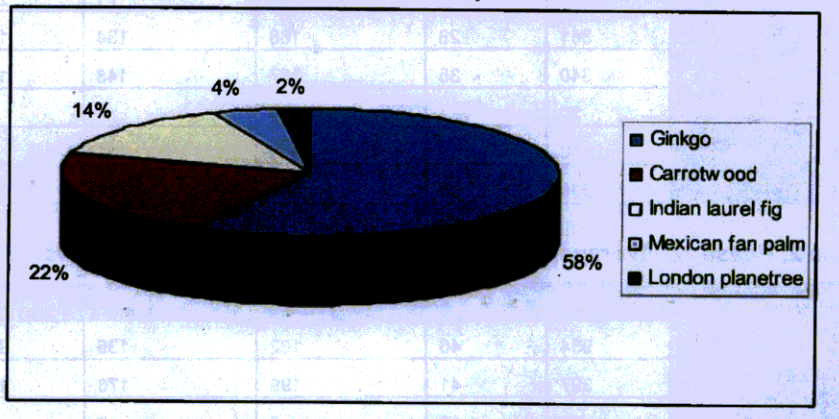
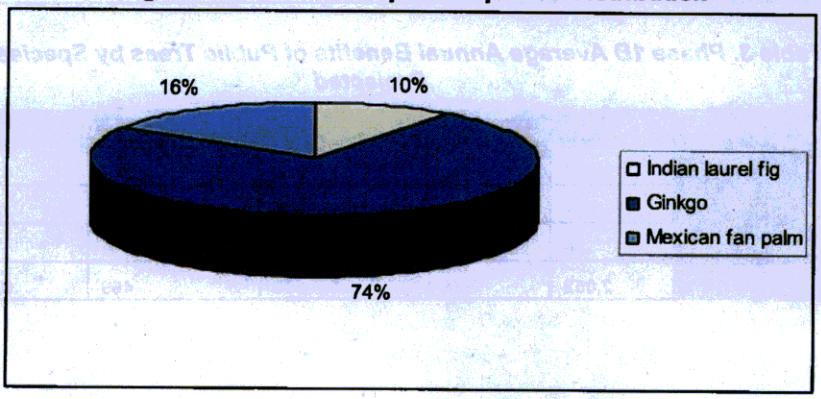


Figure 2. Phase 1D Proposed Species Distribution



Annual Benefits

Tables 1-3 show the summary of net annual benefits provided by trees in the five categories analyzed by STRATUM. The different tables show the current inventory, five year projected inventory, and 15 year projected inventory respectively. Characteristic of the species and owing to the revised tree count total, Gingko trees increase in importance in terms of benefits as time goes on.

Figures 3-5 (next page) show the relative importance of each species in terms of environmental benefits. These figures correlate with the data showing the Gingko trees providing an increased percentage of benefits

Table 1. Phase 1D Average Annual Benefits of Public Trees by Species – Current Inventory

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	468	24	69	71	2,250	2,883
Carrotwood	361	28	166	134	1,456	2,145
Indian laurel fig	340	35	157	148	1,089	1,769
Mexican fan palm	20	1	4	4	79	109
London planetree	50	4	0	14	194	262
Citywide total	**1,239**	**93**	**396**	**371**	**5,069**	**7,168**

Table 2. Phase 1D Average Annual Benefits of Public Trees by Species – 5yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	954	46	102	139	3,966	5,208
Indian laurel fig	397	41	199	176	1,223	2,036
Mexican fan palm	59	6	6	12	372	455
Citywide total	**1,411**	**93**	**308**	**326**	**5,561**	**7,699**

Table 3. Phase 1D Average Annual Benefits of Public Trees by Species – 15yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	1,523	82	246	247	4,455	6,553
Indian laurel fig	453	47	248	205	1,350	2,302
Mexican fan palm	76	6	12	17	415	526
Citywide total	**2,052**	**134**	**505**	**469**	**6,220**	**9,380**

Figure 3. Phase 1D Relative Percentage of Annual Benefits by Species – Current Inventory

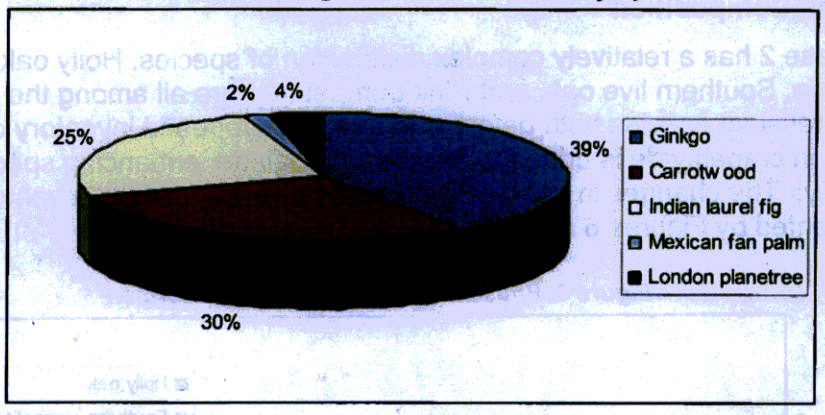


Figure 4. Phase 1D Relative Percentage of Annual Benefits by Species – 5yr Projected

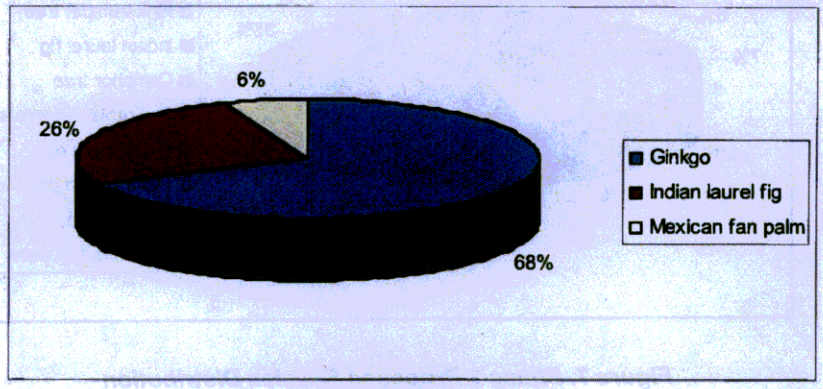
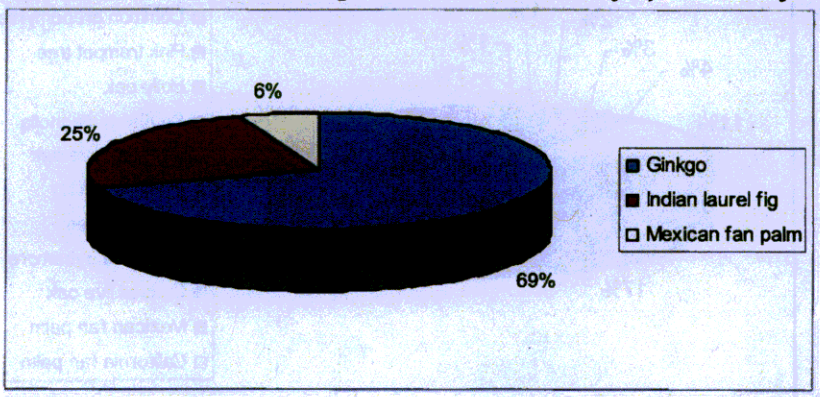


Figure 5. Phase 1D Relative Percentage of Annual Benefits by Species – 15yr Projected



Phase 2

Species Composition

Phase 2 has a relatively complex distribution of species. Holly oak, Southern Magnolia, Southern live oak, and Pink trumpet tree are all among the top five most prevalent species both before and after the proposed inventory changes. Common crapemyrtle is added to the planting palette, enhancing species diversity. The changes in species distribution by the proposed inventory are represented by Figures 6 and 7.

Figure 6. Phase 2 Current Species Distribution

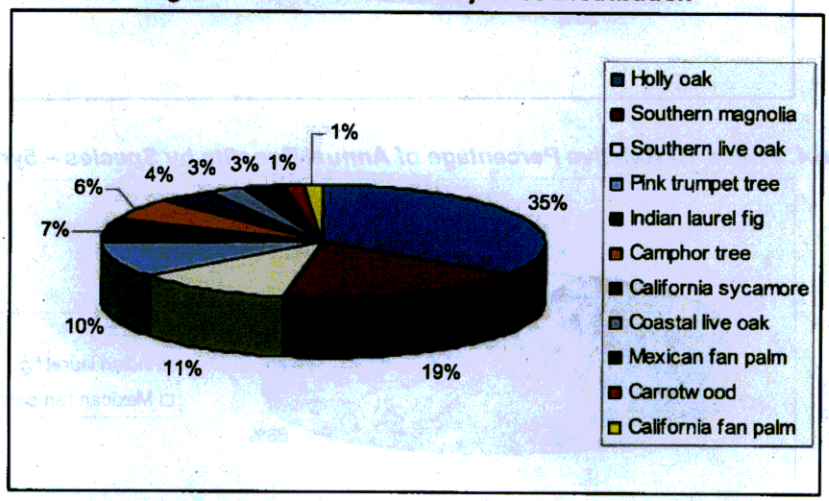
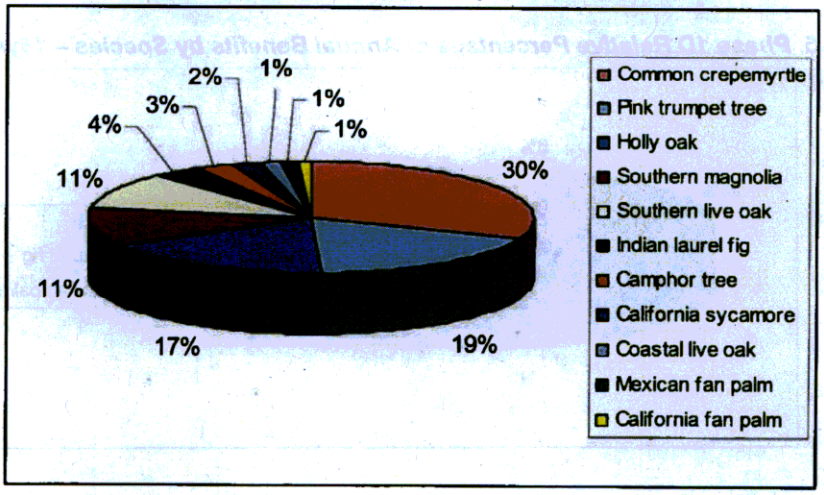


Figure 7. Phase 2 Proposed Species Distribution



Annual Benefits

Tables 4-6 show the current and projected summary of net annual benefits provided by trees in the five STRATUM categories for Phase 2.

The proposed plan for Phase 2 shows immediate increases in benefits across all but the air quality categories. Due to the BVOC emissions from Holly oak, Southern magnolia, and coast and southern live oak there is a continued net reduction in air quality from the current inventory through the 15yr projected inventory. In all other categories, energy, carbon dioxide, storm water and aesthetics, the proposed changes to the inventory are positive and continue to provide additional benefits as time goes on. The BVOC emissions by the four species are outweighed by their increased contributions to savings in the other categories especially in energy savings, most likely due to their large stature and shade canopy.

Figures 8-10 (page 10) demonstrate the relative importance of the total trees in each species in terms of environmental benefits. Despite the BVOC emissions, the Holly oak is relatively the most valuable species in the proposed projected inventory. Although they contribute to species diversity, the Mexican and Californian fan palms, and Coast live oak are relatively less important species. This is due to the combined factors of not being represented as well in the overall inventory and their lower net environmental benefits on average.

Table 4. Phase 2 Average Annual Benefits of Public Trees by Species – Current Inventory

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Holly oak	606	74	-538	218	2,631	2,991
Southern magnolia	198	17	-15	74	819	1,093
Southern live oak	214	25	-185	70	899	1,023
Pink trumpet tree	29	2	3	7	397	438
Indian laurel fig	147	15	80	66	441	749
Camphor tree	111	12	52	49	355	579
California sycamore	112	14	43	32	649	850
Coast live oak	30	4	-26	9	211	228
Mexican fan palm	10	1	2	2	40	54
Carrotwood	18	1	9	7	73	108
California fan palm	7	0	2	1	13	24
Citywide total	1,483	164	-572	537	6,527	8,139

Table 5. Phase 2 Average Annual Benefits of Public Trees by Species – 5yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Common crapemyrtle	169	18	24	31	1,520	1,761
Pink trumpet tree	151	9	16	40	1,483	1,699
Holly oak	636	77	-562	227	2,662	3,040
Southern magnolia	215	18	-17	80	934	1,229
Southern live oak	317	37	-267	96	1,693	1,876
Indian laurel fig	151	15	81	68	454	769
Camphor tree	111	12	52	49	355	579
California sycamore	112	14	43	32	649	850
Coast live oak	40	5	-33	11	227	250
Mexican fan palm	10	1	2	2	40	54
California fan palm	7	0	2	1	13	24
Citywide total	**1,918**	**206**	**-660**	**637**	**10,030**	**12,131**

Table 6. Phase 2 Average Annual Benefits of Public Trees by Species – 15yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Common crapemyrtle	169	18	24	31	1,520	1,761
Pink trumpet tree	173	11	24	48	1,497	1,753
Holly oak	773	100	-701	330	2,570	3,072
Southern magnolia	286	23	-26	104	1,156	1,544
Southern live oak	435	53	-385	160	1,656	1,919
Indian laurel fig	186	19	115	88	544	952
Camphor tree	146	15	80	65	427	732
California sycamore	112	14	43	32	649	850
Coast live oak	57	7	-50	20	223	256
Mexican fan palm	10	1	2	2	40	54
California fan palm	7	0	2	1	13	24
Citywide total	**2,352**	**261**	**-873**	**882**	**10,296**	**12,918**

Due to the slight increase in size of Crapemyrtle from 4 inches DBH to 6 inches from 5 to 15 years, annual benefits were not affected.

Figure 8. Phase 2 Relative Percentage of Annual Benefits by Species – Current Inventory

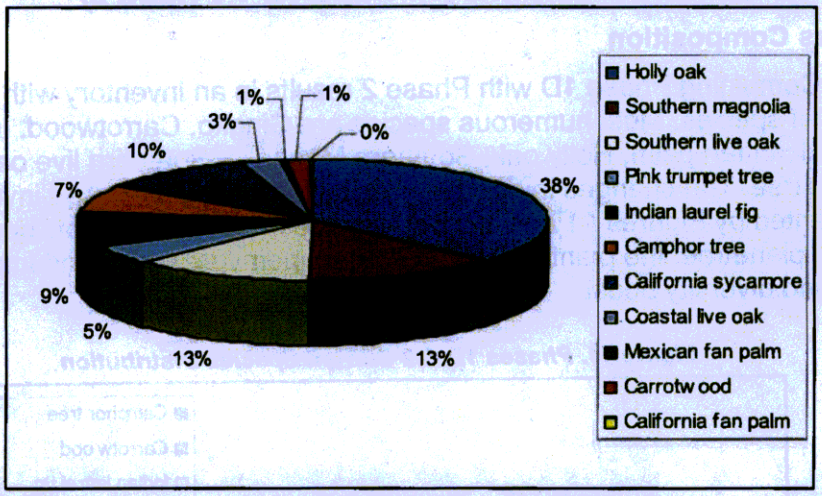


Figure 9. Phase 2 Relative Percentage of Annual Benefits by Species – 5yr Projected

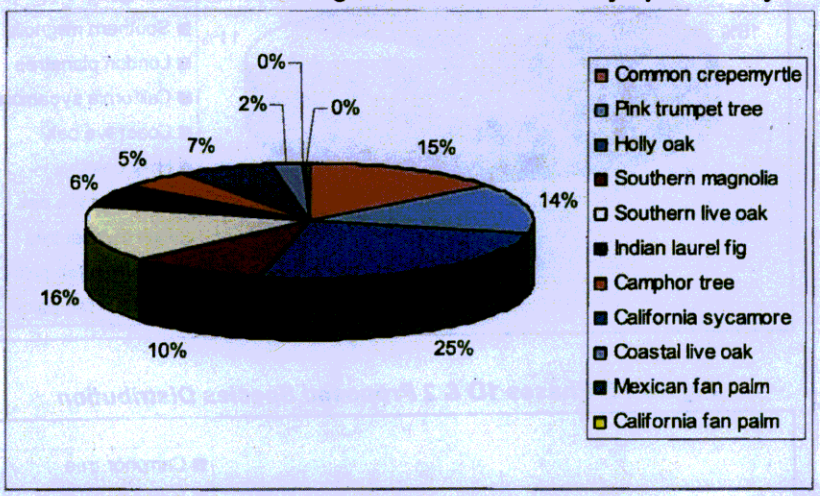
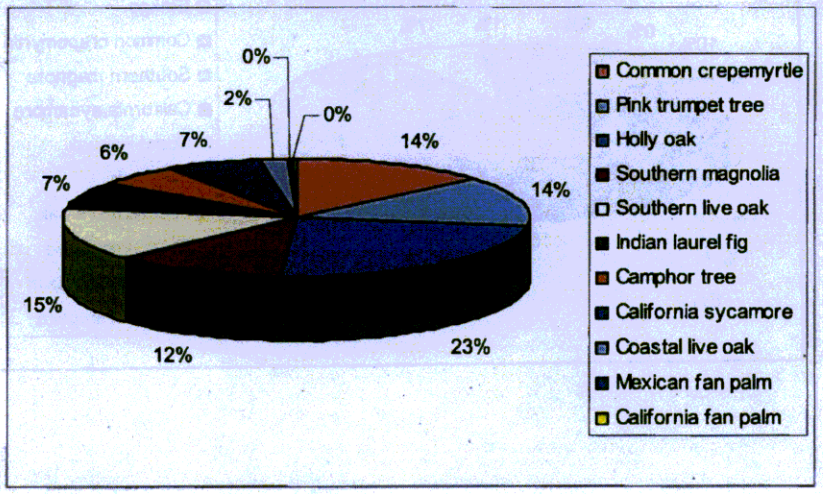


Figure 10. Phase 2 Relative Percentage of Annual Benefits by Species – 15yr Projected



Playhouse District Summary (Phase 1D + Phase 2)

Species Composition

Combining Phase 1D with Phase 2 results in an inventory with a great variety of species. Most numerous species are Gingko, Carrotwood, Indian laurel fig, Mexican fan palm, Holly oak, Southern Magnolia, Southern live oak, and Pink trumpet tree. The changes in species distribution by the proposed inventory are represented by Figures 11 and 12. Besides the removal of Carrotwood and London planetree, the planting of Common crapemyrtle yields and instant tree count and diversity boost.

Figure 11. Phases 1D & 2 Current Species Distribution

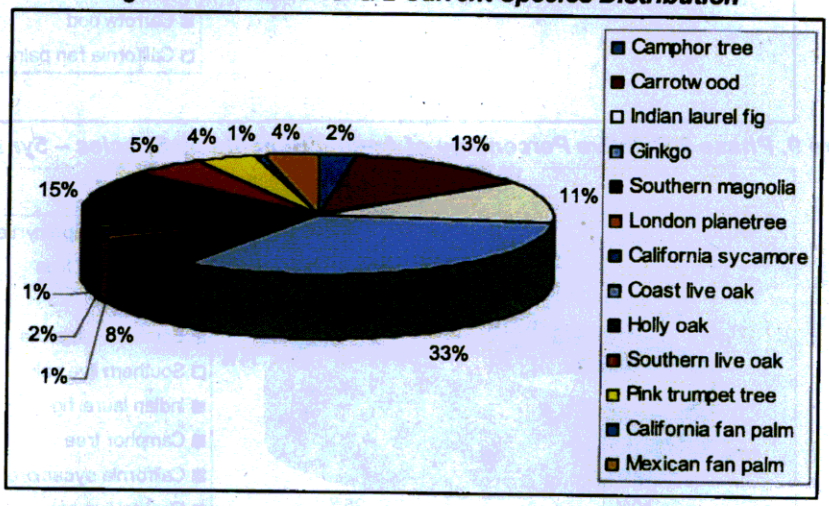
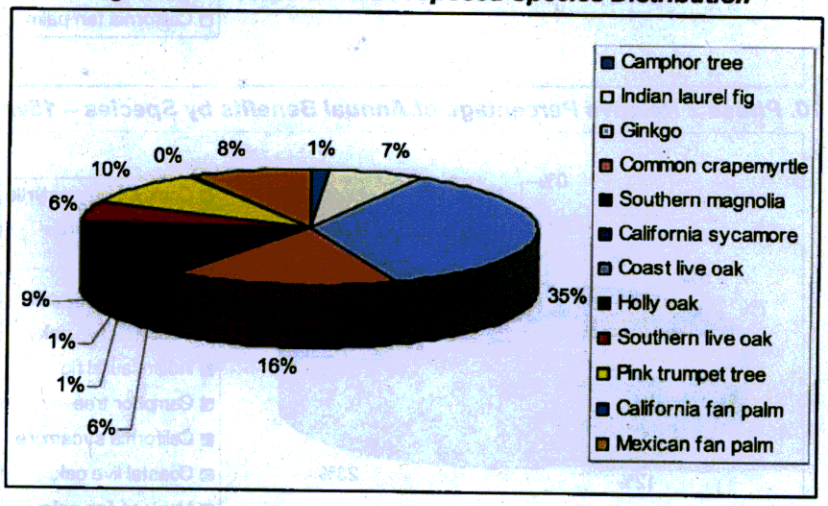


Figure 12. Phases 1D & 2 Proposed Species Distribution



Annual Benefits

Tables 7-9 show the current and projected summary of net annual benefits provided by trees in the five STRATUM categories for the combined tree population for Phases 1D and 2.

The proposed plan for the Playhouse District shows immediate increases in benefits across all but the air quality categories. Due to the BVOC emissions from Holly oak, Southern magnolia, and coast and southern live oak there is a continued net reduction in air quality from the current inventory for the first projected five years. Projecting through to 15 years, net air quality benefits, though still negative, increase due mostly to the overwhelming positive contribution of Ginkgo species. Throughout the future, all other benefits, energy, carbon dioxide, storm water and aesthetics continue to increase.

Figures 13-15 (pages 14 and 15) demonstrate the relative importance of the total trees in each species in terms of environmental benefits. Ginkgo proves to be the most valuable species in the proposed projected inventory. The contribution of Californian fan palms and coast live oak are almost negligible, primarily due to their low representation in the combined tree population of the Playhouse District.

Table 7. Phases 1D & 2 Average Annual Benefits of Public Trees by Species – Current Inventory

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	468	25	69	71	2,250	2,883
Holly oak	606	74	-538	218	2,631	2,991
Carrotwood	379	29	175	141	1,529	2,254
Indian laurel fig	487	50	237	214	1,530	2,518
Southern magnolia	198	17	-15	74	819	1,093
Southern live oak	214	25	-185	70	899	1,023
Pink trumpet tree	29	2	3	7	397	438
Mexican fan palm	30	2	6	6	119	163
Camphor tree	111	12	52	49	355	579
California sycamore	112	14	43	32	649	850
London planetree	50	4	0	14	194	262
Coast live oak	30	4	-26	9	211	228
Other species	7	0	2	1	13	24
Citywide total	2,722	257	-176	908	11,596	15,307

Table 8. Phases 1D & 2 Average Annual Benefits of Public Trees by Species – 5yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	954	46	102	139	3,966	5,208
Common crapemyrtle	169	18	24	31	1,520	1,761
Pink trumpet tree	151	9	16	40	1,483	1,699
Holly oak	636	77	-562	227	2,662	3,040
Mexican fan palm	70	6	8	14	411	510
Indian laurel fig	548	56	280	243	1,678	2,805
Southern magnolia	215	18	-17	80	934	1,229
Southern live oak	317	37	-267	86	1,693	1.876
Camphor tree	111	12	52	49	355	579
California sycamore	112	14	43	32	649	850
Other species	47	5	-31	13	240	274
Citywide total	**3,328**	**299**	**-352**	**963**	**15,591**	**19,830**

Table 9. Phases 1D & 2 Average Annual Benefits of Public Trees by Species – 15yr Projected

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total ($)
Ginkgo	1,523	82	246	247	4,455	6,553
Common crapemyrtle	169	18	24	31	1,520	1,761
Pink trumpet tree	173	11	24	48	1,497	1,753
Holly oak	773	100	-701	330	2,570	3,072
Mexican fan palm	87	7	13	19	454	580
Indian laurel fig	639	66	363	293	1,894	3,254
Southern magnolia	286	23	-26	104	1,156	1,544
Southern live oak	435	53	-385	160	1,656	1,919
Camphor tree	146	15	80	65	427	732
California sycamore	112	14	42	32	649	850
Other species	63	7	-48	21	236	280
Citywide total	**4,405**	**396**	**-369**	**1,352**	**16,516**	**22,298**

Due to the slight increase in size of Crapemyrtle from 4 inches DBH to 6 inches from 5 to 15 years, annual benefits were not affected.

Figure 13. Phases 1D & 2 Relative Percentage of Annual Benefits by Species – Current Inventory

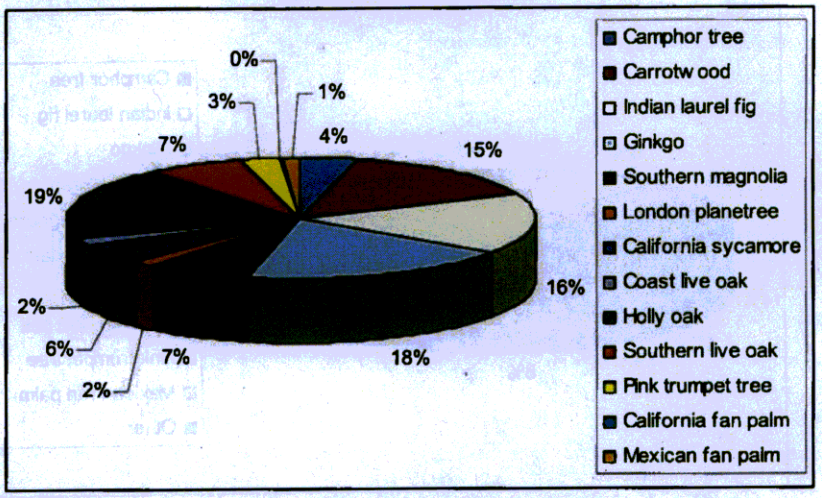
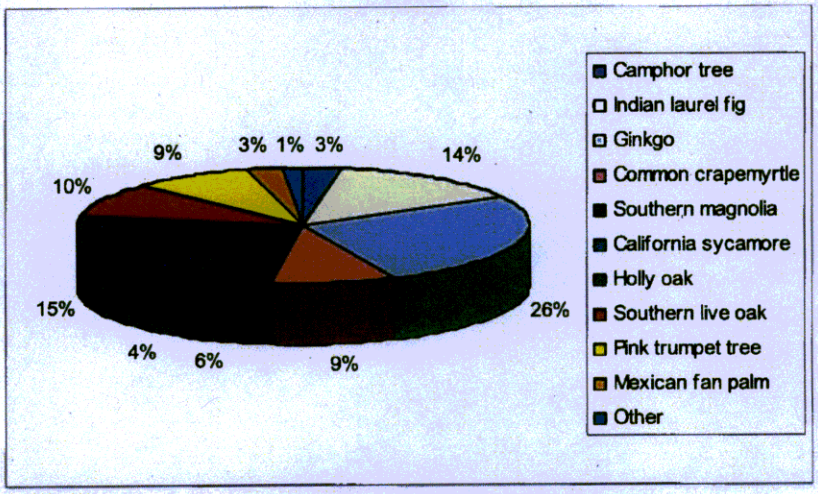
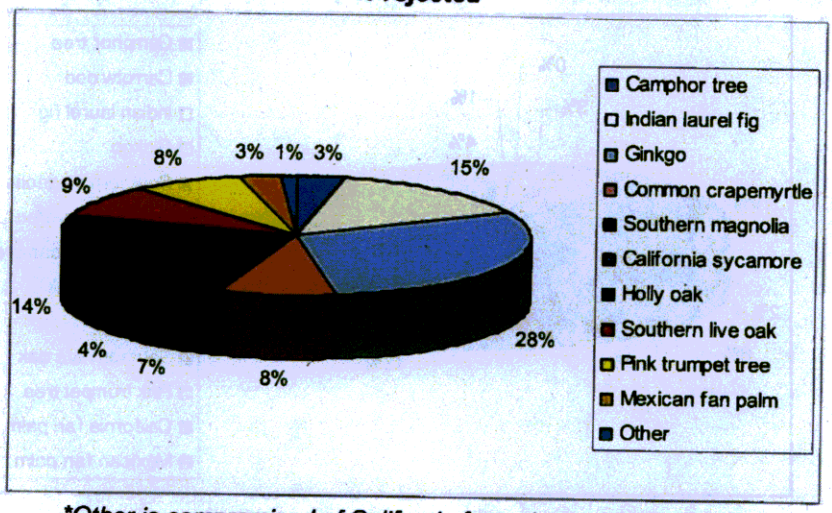


Figure 14. Phases 1D & 2 Relative Percentage of Annual Benefits by Species – 5yr Projected



**Other is compromised of California fan palm and Coast live oak*

Figure 15. Phases 1D & 2 Relative Percentage of Annual Benefits by Species – 15yr Projected



**Other is compromised of California fan palm and Coast live oak*

Section 4: Species Benefit Summary

The tables and figures in the previous section demonstrate the benefits provided by each tree species as they are represented in the proposed inventories comprehensively and for each Phase. Table 10 and Figure 16 below represent the performance of a single tree's benefits for each individual species. A hypothetical tree inventory was created with one tree from each species with a DBH of 7 inches (offered as a reasonable five year old tree size). This includes the two species, Carrotwood and London planetree, planned for removal in the proposed inventories. The new tree data set assumes that no maintenance or priority work is required on the trees.

The analysis table helps to demonstrate the relative performance of each tree species featured in Pasadena in terms of net benefits. The species benefit data can be used to help determine if the current proposed inventory utilizes trees that provide the most return on investment in term of environmental benefits.

From a dollar standpoint, the most significant benefit of all the trees is their aesthetic value. Equally as important, though less monetary value per tree, are the environmental benefits for energy conservation, CO_2 absorption, air quality improvement and stormwater interception. Figure 16 graphically represents the same data as Figure 16, however in order to better recognize the values of the trees on the environment, aesthetic value has been eliminated. By summarizing these values by species, this analysis will help the urban forest managers and planners determine if the proposed inventories utilize the correct trees to gain the most return in environmental benefits.

Table 10. Average Annual Benefits per Single 7" DBH Tree by Species ($/tree)

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic	Total
Ginkgo	14.66	0.83	1.99	2.34	50.38	70.20
Common crapemyrtle	8.93	1.18	1.92	1.61	38.83	52.47
Pink trumpet tree	11.21	0.77	2.62	3.68	60.65	78.93
Holly oak	14.72	1.68	-11.78	3.69	113.52	121.83
Mexican fan palm	2.31	0.27	0.15	0.44	17.20	20.37
California fan palm	2.31	0.27	0.15	0.44	17.20	20.37
Indian laurel fig	5.32	0.52	1.07	2.23	27.46	36.60
Southern magnolia	10.25	0.70	-1.70	3.33	58.23	70.81
Southern live oak	14.72	1.68	-11.78	3.69	113.52	121.83
Camphor tree	5.32	0.52	1.07	2.23	27.46	36.60
California sycamore	6.67	0.85	2.02	2.64	70.80	82.99
London planetree	15.58	1.25	-1.12	3.56	117.20	136.45
Coast live oak	14.72	1.68	-11.78	3.69	113.52	121.83
Carrotwood	11.21	0.77	2.62	3.68	60.65	78.93

Figure 16. Average Annual Benefits per Single 7" DBH Tree by Species ($/tree)

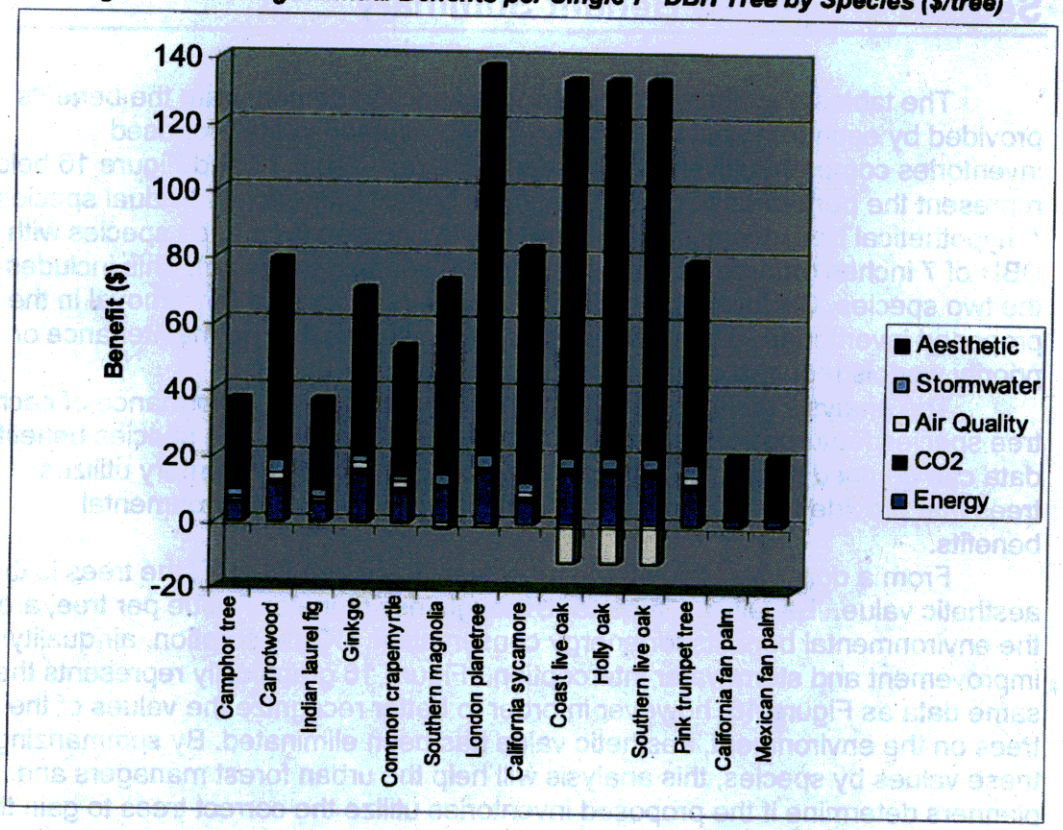
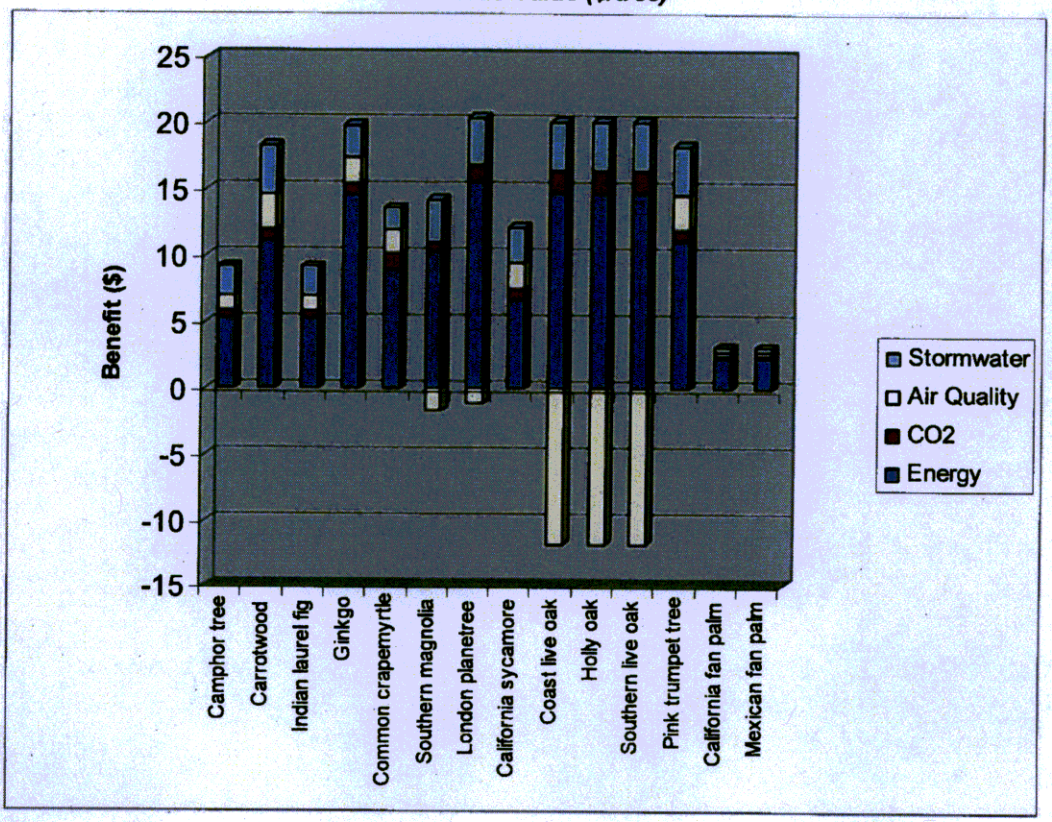


Figure 17. Average Annual Benefits per Single 7" DBH Tree by Species Excluding Aesthetic Value ($/tree)



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