ATTACHMENT 1

Over the next 20 years, PWP will replace aging infrastructure, increase substation and distribution capacity, and increase system efficiency. A combination of additional engineering and operating personnel, technology to improve the management of work, and selective outsourcing to leverage the capabilities of PWP staff are the key strategies to ensuring a sustainable safe, reliable, and cost-effective distribution system.

EXECUTIVE SUMMARY

In the coming two decades, Pasadena Water and Power must address a nexus of challenges to ensure a sustainable safe, reliable, and cost effective electric distribution system. Most of the City's electric distribution infrastructure is at or beyond its useful economic life and requires replacement. Many of the oldest substations and distribution circuits are at or beyond their reliable capacity limits and will be replaced or upgraded. The total electric demand in the system will continue increasing at a long-term rate of approximately two percent per year, initially at the rate of over three percent per year. To serve this increasing demand for electricity, the City needs additional substation and distribution capacity. To address these challenges, PWP requires:

- A long-term vision of the future
- A detailed strategy for achieving that vision
- Additional personnel with the right expertise to increase its ability to implement the strategy
- The advantage of technology solutions to manage information, assets, and work
- Strategic reliance on temporary or contracted resources to manage the workload throughout the power delivery enterprise

It is the combination of these solutions taken together that will lead to PWP's long-term success. The most important, though, are a long-term vision to guide the utility, a specific but flexible plan, and the resources to implement the plan.

In anticipation of these growing challenges, PWP has been methodically positioning itself for the future. Over the past two

years, much energy has been devoted to organizational review and efficiency gains through process improvement, team building, and technology development initiatives. Today, PWP is at the point where the gains from these efforts have been maximized and it is now the time to begin implementing its strategies, which along with the development of a Geographic Information System and a Work Management System, include the preparation of this Master Plan.

This Electric System Master Plan provides a long-term vision for the distribution system, offers specific recommendations to achieve that vision, and identifies and justifies the resources that PWP requires to be a sustainable, reliable, safe, and cost-effective utility.

The Long-Term Vision

In the development of this Master Plan, stakeholders from across the City provided expectations, insight, and review at the beginning and throughout the development of the plan. The visions of this diverse set of stakeholders converge around a few key points:

- PWP's electric distribution system must safely and reliably serve the City as it continues to grow and redevelop in accordance with a carefully crafted general plan that focuses on preserving Pasadena's history, culture, and community while embracing technology, diversity, and environmental conservation.
- As the ways in which residential, commercial, and industrial customers use electricity become increasingly complex, PWP must provide electric service that meets acceptable levels of quality and reliability.
- To nurture a healthy, vibrant, and sustainable economy, the price of electricity must be maintained at levels that stimulate rather than stifle the prosperity of local business and industries while providing for the operational needs of the utility.
- PWP must be flexible and adaptable to adjust to the challenges of an energy industry that is increasingly uncertain and complex.
- The City will install its new distribution lines underground and existing overhead distribution lines will be converted under the Utility Underground District process.

The Specific Challenges

The specific challenges that PWP's power delivery operation face fall into three broad categories: 1) the replacement of aging infrastructure, 2) the need for additional reliable power distribution capacity, and 3) the lack of organizational preparedness to address the next 20 years of providing safe, reliable, and cost-effective electric service to the City of Pasadena. Each set of challenges requires a careful analysis of solutions and, overall, a plan the combines the solutions into a logical and progressive guide for making decisions about how to address the challenges over the next two decades.

Infrastructure Replacement

Pasadena's electric distribution system was initially established in the early 1900s. As the City expanded, so did the electric distribution system. As technologies for power generation, transmission, and distribution evolved, PWP embraced and implemented those technologies that most benefited the City's electric customers. As power plants and distribution equipment came to the end of its useful life, PWP replaced it. As the City's population grew and the developed areas expanded, the distribution system grew with the addition of substations and distribution feeders. There are two predominant waves of aging infrastructure that will affect PWP over the next 20 years. One is occurring today as infrastructure installed the 1950s and 1960s requires replacement, and another will occur in 10 years as equipment installed in the 1970s and 1980s requires replacement. Much of the oldest distribution infrastructure that requires replacement is now at or beyond its useful economic life of 40 years. The manifestation of this aging presents as increased operating cost due to electrical inefficiency, increased maintenance costs as aging equipment requires more frequent and more expensive repairs, decreased system reliability as the aging equipment fails more frequently, and reduced safety as the older equipment becomes hazardous to operate. Without replacement, the oldest equipment will continue failing, but at an increasing rate, system reliability will degrade to the point where it is markedly noticeable by PWP's customers, and the public and PWP operating personnel will be exposed to increasingly unsafe conditions.

PWP's infrastructure replacement challenges include:

- Replacement of deteriorated underground equipment vaults
- Replacement of oil-filled electrical switches and circuit breakers
- Replacement of distribution cables (4-kV and 17-kV)
- Replacement of subtransmission cables (34-kV)
- Replacement of distribution unit substations (4-kV)
- Replacement of 34-kV system protection and control equipment

Reliable Capacity

To serve customer demands for electricity, the City installs electrical equipment of a certain size and capability. To provide a measure of reliability for that service, the capability of the installed equipment must be greater than the requirements of customer demand. This allows equipment to be out of service for maintenance or to allow for an outage due to some unforeseen event without causing customers to go without power. However, as that margin between the capability of the equipment and the demands of the customer narrows, so does the level of reliability. In looking at the current reliability of service to Pasadena's customers, as measured by the time and frequency that customers go without power, the City maintains an acceptable, but declining, level of reliability. However, as measured by that margin between equipment capability and customer

demand, the margins have never been lower and the City needs to provide additional equipment capacity immediately. To sustain an acceptable level of reliability going forward, the City must invest more resources toward regular periodic analysis and planning of the distribution system. The significant capacity challenges that the City faces include:

- The need for additional distribution substation transformer capacity at Glenarm and Hastings Substations now, and most other substations in the future
- The need for additional capacitor banks at Santa Anita now, and Glenarm and Santa Anita in the future
- The need for a second point of interconnection with the CAISO/SCE transmission grid to ensure sustainable system reliability in the event of a catastrophic event at the current single point of interconnection

Organizational Preparedness

Since the onset of electric utility deregulation pressures, PWP has operated as a "lean and mean" organization focusing on the management of immediate customer needs and addressing maintenance and planning functions when time and availability of resources permitted. The result of this approach has been in many ways very successful and has in some ways left room for improvement. Pasadena's electric rates have remained competitive, its service reliability acceptable, and its operating costs low. While these are tremendously good achievements in their own right, the realities of a mature workforce and aging infrastructure need to be addressed to ensure that the success enjoyed so far is sustained into the future. The specific organizational and preparedness issues facing PWP's power delivery operation include:

- Insufficient engineering and operating resources to accomplish all of the work that needs to be completed, especially infrastructure replacement and maintenance.
- Little or no remaining improvement to gain through additional process improvement efforts without additional staff and management technologies.
- Insufficient depth of staff to address the loss of institutional knowledge and management succession needs resulting from retirements expected in the next five years.
- Insufficient staff levels and capabilities to implement the infrastructure replacement and reliable capacity improvements required over the next 10 years.

Implementation Strategies

The Master Plan provides for a range of solutions to address each of the challenges identified during the development of the plan. These recommendations address a range of implementation objectives. The Gold Standard offers a set of solutions that strive to achieve the level infrastructure that Pasadena has historically strived toward—highly redundant, highly reliable equipment that when properly maintained provides a very high level of reliability for the longest

possible useful life. The Silver Plan solution represents a compromise from the Gold Plan by relying on technology and innovation to provide a level of reliability approaching the Gold Plan but with greater emphasis on cost effectiveness and higher tolerance for risk and uncertainty. The Bronze Plan represents the minimum acceptable level of service at the least initial cost without concern for long-term implications of safety cost and reliability. The Gold Plan solutions have the highest up-front costs, the lowest long-term operating costs, the highest levels of reliability, and the greatest margins for addressing future uncertainties. The Silver Standard costs less initially, costs more in the long run, and provides less reliability than the Gold Plan but is also less expensive than the Gold Plan. The Bronze Plan represents the least initial cost without regard for reliability or service capability.

The following tables summarize the characteristics of the three plans in the major categories of cost elements.

Table ES-1 Vault Replacement Plan Strategies

	Gold (Most Replacements)	Silver (Less Replacements)	Bronze (Least Replacements)
Major Replacements (Highest Cost)	172	62	29
Major Repairs (Expected Cost)	220	220	143
Minor Repairs (Least Cost)	110	220	330
Five Year Program Cost Estimate	$4.1 MM	$3.1 MM	$2.2 MM
20 Year Program Cost Estimate	$29.3 MM	$19.4 MM	$13.4 MM
Impact on Risk of Property Damage	Least Risk	Higher Risk	Highest Risk
Impact on Risk of Injury	Least Risk	Higher Risk	Highest Risk
Reliability	Highest Reliability	Less Reliable	Least Reliability

Table ES-2 Cable Replacement Plan Strategies

Metric	Gold (Most Replacements)	Silver (Less Replacements)	Bronze (Least Replacements)
Total Cable Replaced over 20 yrs	700 Miles (50%)	462 Miles (33%)	350 Miles (25 %)
Highest Cost Replacement	$400,000 / mile	$400,000 / mile	$400,000 / mile
Expected Cost Replacement	$165,000 / mile	$165,000 / mile	$165,000 / mile
Least Cost Replacement	$50,000 / mile	$50,000 / mile	$50,000 / mile
Five Year Program Cost Estimate	$19 MM	$15 MM	$8 MM
Cable Replacement over 5 years	98 miles	78 miles	40 miles
20 Year Program Cost Estimate	$132 MM	$87 MM	$66 MM
Impact on Risk of Property Damage	Least Risk	Higher Risk	Highest Risk
Impact on Risk of Injury	Least Risk	Higher Risk	Highest Risk
Reliability	Highest Reliability	Less Reliable	Least Reliability

Table ES-3 Switch Replacement Plan Strategies

Metric	Gold (Most Replacements)	Silver (Less Replacements)	Bronze (Least Replacements)
Total Switches Replaced over 20 yrs	830 (100%)	415 (50%)	277 (33%)
Highest Cost Replacement	$50,000 / 20%	$50,000 / 20%	$50,000 / 20%
Expected Cost Replacement	$40,000 / 60%	$40,000 / 60%	$40,000 / 60%
Least Cost Replacement	$22,000 / 20%	$22,000 / 20%	$22,000 / 20%
Five Year Program Cost Estimate	$11 MM	$6 MM	$4 MM
Switches Replaced over 5 years	290 switches	145 switches	96 switches
20 Year Program Cost Estimate	$32 MM	$16 MM	$11 MM
Impact on Risk of Property Damage	Least Risk	Higher Risk	Highest Risk
Impact on Risk of Injury	Least Risk	Higher Risk	Highest Risk
Reliability	Highest Reliability	Less Reliable	Least Reliability

Table ES-4 Circuit Breaker Replacement Plan Strategies

Metric	Gold (Most Replacements)	Silver (Less Replacements)	Bronze (Least Replacements)
Total Breakers Replaced over 20 yrs	270 (100%)	135 (50%)	90 (33%)
Highest Cost Replacement	$125,000 / 20%	$125,000 / 20%	$125,000 / 20%
Expected Cost Replacement	$90,000 / 60%	$90,000 / 60%	$90,000 / 60%
Least Cost Replacement	$25,000 / 20%	$25,000 / 20%	$25,000 / 20%
Five Year Program Cost Estimate	$7 MM	$3 MM	$2 MM
Breakers Replaced over 5 years	80 breakers (30%)	38 breakers (14%)	11 breakers (4%)
20 Year Program Cost Estimate	$23 MM	$11 MM	$8 MM
Impact on Risk of Property Damage	Least Risk	Higher Risk	Highest Risk
Impact on Risk of Injury	Least Risk	Higher Risk	Highest Risk
Reliability	Highest Reliability	Less Reliable	Least Reliability

Table ES-5 Substation Oil Containment Strategies

	Gold Plan		Silver Plan		Bronze Plan	
Year	Substation	Cost	Substation	Cost	Substation	Cost
2006	TM Goodrich	$578,000	TM Goodrich	$578,000	TM Goodrich	$578,000
2007	Santa Anita	$340,000		$0		$0
2008	Receiving Station	$280,000	Santa Anita	$340,000		$0
2009	Hastings	$122,000		$0	Santa Anita	$340,000
2010	Oak Knoll	$95,000	Receiving Station	$280,000		$0
2011	Chester	$95,000		$0		$0
2012	Del Mar	$95,000	Hastings	$122,000	Receiving Station	$280,000
2013	Villa	$95,000		$0		$0
2014	Fair Oaks	$95,000	Oak Knoll	$95,000		$0
2015	Brookside	$95,000		$0	Hastings	$122,000
2016	Eastern	$95,000	Chester	$95,000		$0
2017	0	$0		$0		$0
2018	0	$0	Del Mar	$95,000	Oak Knoll	$95,000
2019	0	$0		$0		$0
2020	0	$0	Villa	$95,000		$0
2021	0	$0		$0	Chester	$95,000
2022	0	$0	Fair Oaks	$95,000		$0
2023	0	$0		$0		$0
2024	0	$0	Brookside	$95,000	Del Mar	$95,000
2025	0	$0		$0		$0
2026	0	$0	Eastern	$95,000		$0
Total		$1,985,000		$1,985,000		$1,605,000

Implementation Strategies

To demonstrate the cost impacts of the three strategies, Table ES-6 compares the initial capital cost of the three plans over the first five years of implementation. The Gold Plan provides the highest level of safety, reliability, and operating cost efficiency while the Silver Plan represents a compromise between initial costs, reliability, and safety and the Bronze Plan strictly minimizes initial capital costs without meeting reliability criteria and while accepting substantial risks of injury and property damage.

Table ES-6 Comparison of Five-Year Capital Improvement Programs

Implementation Plan	2006	2007	2008	2009	2010
			(costs in thousands)		
Gold - Most Reliable, Highest Cost	$26,617	$29,353	$33,017	$43,028	$72,260
Silver - Less Reliable, Less Cost	$12,825	$9,444	$14,561	$14,100	$20,487
Bronze - Least Reliable, Least Cost	$4,466	$7,381	$4,624	$4,730	$8,337

Note: All costs are in constant 2004 dollars.

There is no right or wrong answer as to which plan is the best for PWP. Factors to consider in selecting the right plan include:

- Decisions should look to take elements of the Gold Plan in some cases, such as providing adequate substation capacity, and of the Bronze Plan in others, such as circuit breaker replacement.
- Knowing which plan element to chose, when to implement it, and at what rate to implement it will depend a great deal on what is learned from improved asset management, especially the ability to assess remaining useful life and predict failures. For example, it may turn out that cable replacements never become a significant portion of the capital budget because the cable lasts much longer than expected.
- The City's tolerance for future risk when weighed against immediate priorities will always be a challenging struggle, especially when considering a major expense such as the second point of interconnection—while it would be a real discomfort to experience a major outage at Goodrich Receiving Station, the probability of this occurring is very low. Anaheim and Riverside, roughly twice Pasadena's size, are only just now facing this difficult decision—both are several years away from realizing their second points of interconnection and neither has as much internal generation available to serve their own loads.
- The three plans contain an infinite amount of variability and choices that can reduce and/or defer costs. The three plans presented here demonstrate the extremes of this variability.
- Regardless of which type of plan, Gold, Silver, or Bronze, suits Pasadena, the steps that need to be take in the coming months are crucial to any of the plans—these include additional full-time staff in engineering, operations, and construction; the implementation of an enterprise asset and work management system, and the use, on a temporary as-needed basis, of contract support to manage peak work loads.

Financial Requirements in the First Five Years – The Gold Plan

The Gold Plan strives to continue PWP's long-lived development of the distribution system with an emphasis on reliability, safety, and operating cost efficiency. The Gold Plan has the highest initial capital investment of the three plans. Elements of the Gold Plan include:

- Aggressive vault replacement program designed to replace 502 of the expected 1,100 Type-H vaults over the next 20 years with nearly half of the vaults being replaced and the others repaired.
- A cable replacement program designed to replace half of the existing cable in the system over 20 years without regard for failure history.
- A switch replacement program designed to replace all of the oil-filled switches in the system over 20 years.
- A circuit breaker replacement program that replaces all circuit breakers over 20 years.
- An oil containment program intended to bring all facilities into EPA compliance as soon as possible at the rate of one substation per year beginning with the three receiving stations.
- Reactive power supply additions to provide adequate reactive power supplies at the rate of one new 34-kV capacitor bank per year through 2010.
- Substation capacity additions designed to provide sufficient substation transformer capacity to comply with the reliability criteria while eliminating 4-kV unit substations at the rate of one new 17-kV unit substation per year.
- Development of a 230-kV second point of interconnection at Goodrich and a 230-kV transmission line between Goodrich and Glenarm Receiving Stations by 2010.
- Elimination of the 4-kV distribution system and conversion to underground 17-kV at the rate of 5.65 miles per year, which would eliminate the 4-kV system over 20 years.

Table ES-7 illustrates the estimated costs of the Gold Plan over the first five years of the Master Plan.

Table ES-7 Five-Year Capital Improvement Program -- Gold

Item	2006	2007	2008	2009	2010
			(costs in thousands)		
Vault Replacements	$470	$620	$770	$940	$1,340
Cable Replacement	$1,512	$2,268	$3,402	$4,536	$6,804
Switch Replacements	$1,536	$1,920	$2,304	$2,688	$2,688
Circuit Breaker Replacements	$840	$1,176	$1,344	$1,680	$1,680
Oil Containment	$578	$340	$280	$122	$95
Reactive Power Supply Additions	$161	$161	$161	$161	$161
Substation Capacity Additions	$3,440	$3,440	$3,440	$3,440	$3,440
Second Interconnection	$0	$1,348	$3,236	$11,381	$37,972
4-kV to 17-kV Conversions	$18,080	$18,080	$18,080	$18,080	$18,080
Total Master Plan Projects	**$26,617**	**$29,353**	**$33,017**	**$43,028**	**$72,260**

Note: All costs are in constant 2004 dollars.

Financial Requirements in the First Five Years – The Silver Plan

The Silver Plan is intended to be a compromise between initial capital cost, timing of projects, and the level of reliability of the design. Elements of the Silver Plan include:

- Vault replacement program designed to replace approximately 500 of the expected 1,100 Type-H vaults over the next 20 years with fewer vaults requiring replacement and more vaults being repaired than in the Gold Plan.
- A cable replacement program designed to replace half of the existing cable in the system over 20 years with testing and expected failure rates dictating the rate of replacement such that less cable is replaced in the first five years than the Gold Plan.
- A switch replacement program designed to replace half of the oil-filled switches in the system over 20 years at a slower rate than in the Gold Plan.
- A circuit breaker replacement program that replaces half of the circuit breakers over 20 years and at a slower initial rate than in the Gold Plan.
- An oil containment program intended to bring all facilities into EPA compliance at the rate of one substation every other year beginning with the three receiving stations.
- Reactive power supply additions to provide adequate reactive power supplies at the rate of one new 34-kV capacitor bank every other year through 2010.
- Substation capacity additions designed to provide sufficient substation transformer capacity to comply with the reliability criteria while eliminating 4-kV unit substations at the rate of one new 17-kV unit substation every other year.

- Development of a 230-kV second point of interconnection at Goodrich and a 230-kV transmission line between Goodrich and Glenarm Receiving Stations by 2012 instead of 2010 as in the Gold Plan.
- Elimination of the 4-kV distribution system and conversion to underground 17-kV at the rate of 2.82 miles per year, which would eliminate half of the 4-kV system over 20 years.

Table ES-8 illustrates the estimated costs of the Silver Plan over the first five years of the Master Plan.

Table ES-8 Five-Year Capital Improvement Program -- Silver

Item	2006	2007	2008	2009	2010
		(costs in thousands)			
Vault Replacements	$380	$440	$500	$760	$1,000
Cable Replacement	$1,512	$1,890	$2,646	$4,158	$4,536
Switch Replacements	$768	$960	$1,152	$1,344	$1,344
Circuit Breaker Replacements	$336	$504	$672	$840	$840
Oil Containment	$578	$0	$340	$0	$280
Reactive Power Supply Additions	$161	$0	$161	$0	$161
Substation Capacity Additions	$3,440		$3,440		$3,440
Second Interconnection	$0	$0	$0	$1,348	$3,236
4-kV to 17-kV Conversions	$5,650	$5,650	$5,650	$5,650	$5,650
Total Master Plan Projects	**$12,825**	**$9,444**	**$14,561**	**$14,100**	**$20,487**

Note: All costs are in constant 2004 dollars.

Financial Requirements in the First Five Years – The Bronze Plan

The Bronze Plan represents the least initial capital cost of the three plans. Characteristics of the Bronze Plan include:

- Vault replacement program designed to replace approximately 500 of the expected 1,100 Type-H vaults over the next 20 years with only six percent of the vaults requiring replacement and the rest of the vaults being repaired instead of replaced.
- A cable replacement program designed to replace one third of the existing cable in the system over 20 years with testing and primarily expected failure rates dictating the rate of replacement such that least amount of cable is replaced in the first five years as compared to the other plans.

- A switch replacement program designed to replace one third of the oil-filled switches in the system over 20 years at the slowest rate of the three plans.
- A circuit breaker replacement program that replaces one third of the circuit breakers over 20 years and at the slowest rate of the three plans
- An oil containment program intended to bring facilities into EPA compliance at the rate of one substation every three years beginning with the three receiving stations.
- Reactive power supply additions to provide additional, but probably not adequate, reactive power supplies at the rate of one new 34-kV capacitor bank every third year through 2010.
- Substation capacity additions designed to provide additional, but probably not sufficient, substation transformer capacity while eliminating 4-kV unit substations at the rate of one new 17-kV unit substation every third year.
- Development of a 230-kV second point of interconnection at Goodrich and a 230-kV transmission line between Goodrich and Glenarm Receiving Stations by 2014 instead of 2010 as in the Gold Plan.
- Elimination of the 4-kV distribution system and conversion to underground 17-kV at the rate of 1.4 miles per year, which would eliminate one quarter of the 4-kV system over 20 years.

Table ES-9 illustrates estimated costs of the Bronze Plan over the first five years of the Master Plan.

Table ES-9 Five-Year Capital Improvement Program – Bronze Plan

Item	2006	2007	2008	2009	2010
			(costs in thousands)		
Vault Replacements	$250	$310	$370	$540	$700
Cable Replacement	$1,512	$1,512	$1,512	$1,512	$1,512
Switch Replacements	$499	$653	$768	$883	$883
Circuit Breaker Replacements	$336	$336	$504	$504	$672
Oil Containment	$578	$0	$340	$0	$0
Reactive Power Supply Additions	$161	$0	$0	$161	$0
Substation Capacity Additions	$0	$3,440		$0	$3,440
Second Interconnection	$0	$0	$0	$0	$0
4-kV to 17-kV Conversions	$1,130	$1,130	$1,130	$1,130	$1,130
Total Master Plan Projects	**$4,466**	**$7,381**	**$4,624**	**$4,730**	**$8,337**

Note: All costs are in constant 2004 dollars.

Conclusions and Recommendations

Embedded within the Master Plan are hundreds of specific recommendations regarding what PWP can do to ensure its ability to provide safe, reliable, and cost-effective electric service over the next 20 years. However, this Master Plan does not answer every possible question, nor does it surface every potential issue or address every potential outcome. The Master Plan is a decision making guide intended to capture the boundaries and extremes of the decisions that PWP needs to begin making now.

Taking a thorough look at how the near-term future appears to be unfolding and how well the utility is performing over recent history is the best way to be prepared to respond the range of possible outcomes regarding aging infrastructure, load growth, and sustained reliability. This planning must become a formalized, continual process within the organization at every level such that the entire organization is always looking ahead at where it is going while at the same time analyzing how it is performing along the way. To set this in motion, each year, the General Manager should require the staff of the utility to report on the "state of the system," the expected near-term future, and the details of how the utility is progressing through its implementation.

In addition to driving home the point that PWP needs to plan regularly, three crucial first steps will ultimately decide how well the utility fares in coming months and years:

- The utility needs additional permanent staff to increase its ability to manage and perform more work and prepare for the loss of expertise and institutional knowledge that will come with a significant number of expected retirements over the next three to five years.
- A enterprise asset and work management system is needed immediately to take advantage of and put into use all of the hard work that has gone into process and efficiency improvement within the Power Delivery Business Unit over the past two years.
- The fastest way to close the growing gap between the amount of work that needs to be done and the amount of work that is getting done is to increase the use, on a temporary as-needed basis, of contract resources in engineering, management, and construction to provide support to permanent staff during peak workload periods

None of these individual actions taken alone will provide the beneficial effect of all three taken together over the next year.