REPORT

To the Honorable Mayor and City Council
From the City Manager

February 27, 2006

Subject
Street Tree Failure Data Analysis (Informational Only)

Background
Companion Report to Tree Program and Sidewalk Repair Program project acceptance staff report.

Gordon Mann
Public Works Superintendent

Peter Ingram
Public Works Services Director

Ed Everett
City Manager

Attachments:
"Street Tree Failure Data Analysis"

PUBLIC WORKS SERVICES DEPARTMENT
M E M O R A N D U M

Date: February 27, 2006

To: Honorable Mayor and City Council Members

Through: Peter Ingram, Public Works Services Director

From: Gordon Mann, Public Works Superintendent

SUBJECT: STREET TREE FAILURE DATA ANALYSIS

This report is in response to inquiries about recent failures of street trees that have been root pruned. Public Works Services (PWS) staff has investigated several recent failure incidents and has researched methods to test standing trees to determine if a likelihood of failure can be accurately predicted. The report will cover the following areas:

Brief summary of findings
The history of the sidewalk project
The history of Redwood City tree failures
Conclusion

Brief Summary of Findings

Approximately 4,790 trees have been root pruned over the history of the sidewalk repair program. The root pruning work around these trees has been directed by City staff during annual sidewalk replacement project construction.

Staff findings are:

- Four Ash trees located on Bristol Way, Maddux Drive, Pecan Court, and Massachusetts Avenue were root pruned. One tree failed in late September (Bristol). One was determined to be unstable and removed prior to failure in late December (Maddux). Two failed during a storm December 31st (Pecan and Massachusetts). The Bristol tree was root pruned during the most recent project. The Maddux and Massachusetts trees were root pruned approximately two years ago. The Pecan tree was root pruned approximately five years ago.
- All four trees failed as a result of a very high wind or significant outside force (hit by debris box truck) combined with saturated soil conditions at the root crown.
- Approximately 1.4% or 67 of the 4,790 root pruned trees have failed over the course of the program since 1985.
- Some branch and twig dieback occurs in most trees following root pruning.
- Supplemental irrigation does have a beneficial affect on an individual tree's response to and recovery from root pruning.
- Significant dieback has occurred in approximately 5% of the trees following root pruning, resulting in follow-up pruning. If individual trees continue to decline over

time, tree removal is necessary.

- Roots must be pruned to some degree in almost all cases in order to remove and replace concrete sidewalks (City Standard) adjacent to large, existing trees. Temporary asphalt sidewalks are not an approved City standard.
- Staff has both increased the distance from the tree and reduced the depth that root pruning has been performed over the course of the program. The Tree Policy Task Force recommendations in 1999 supported the modification of the public right-of-way to provide the largest space possible for trees, and supported more assertive easement solicitation by staff.
- Root pruning of trees does increase the risk of tree failure and dieback in trees. Redwood City's climate provides reduced risk following root pruning due to the drier climate, lack of summer storms when the leaves are in full canopy, and lack of snow or ice loads.
- The introduction of rubber sidewalk panels (in lieu of concrete) greatly reduces the need to root prune and allows for acceptable walking surfaces adjacent to trees. The City Engineer has accepted the rubber material for alternative use Public Works Services staff will monitor the performance of the material.

History of Sidewalk Project

The City's sidewalk repair program was initiated in 1984. The stated policy objective was to repair sidewalks without removing all of the trees along a street. The program goals were developed by staff to retain 80% or more of the existing large trees during the sidewalk repair process. The first root pruning began with the first Sidewalk Repair and Tree Program project in 1985. Prior to this program any root cutting performed may have been randomly performed during utility and sidewalk repairs.

In 1998, the first public review of the Sidewalk Repair and Tree Program was initiated by the City Council. In November 1999, five policy changes were recommended by the Community Tree Policy Task Force and accepted by Council:

1. Modify planting sites to provide the largest tree growing and planting area feasible; avoid planting small scale trees.
2. Plant trees in vacant planting sites.
3. Better notify the public of work scheduled in their neighborhood.
4. Trees will be planted at the discretion of the City and be watered by the City for the first two years if necessary.
5. Phase necessary tree removals over time and interplant to lessen the impact on neighborhoods where many trees must be removed.

Additional changes implemented as a result of the task force recommendations:

- The title of the program was changed from Sidewalk Repair and Tree Program to Tree Preservation and Sidewalk Repair Program.
- An additional goal was added to avoid removing more than two trees in a row while keeping within the 80% retention goal along a street.
- The City pursued sidewalk maintenance easements more vigorously in order to re-construct the sidewalk farther away from the tree to root prune farther from the tree.

The Tree Preservation and Sidewalk Repair Program (100% Project) has completed sidewalk repairs following a block by block format through the City, by geographic areas, on a scheduled basis. Root pruning has been performed on 138 to 354 trees per project year, depending on the scope of work. The Cost Shared Sidewalk Repair Project (50/50 Project) was introduced in response to property owner requests for sidewalk repairs outside of the block by block area. Root pruning has been performed on 21 to 68 trees per project year, depending on the scope of work. The 100% Project has completed 17 construction contracts over the 20 years of the program. The 50/50 Project has completed 14 construction contracts. An average of 250 trees were root pruned per year on the 100 % project and an average of 41 trees were root pruned per year on the 50/50 project for a historic total root pruning of approximately 4,790 trees, which is 27% of a total population of 18,000 existing trees.

History of Tree Failures

Most arborists can agree on one thing: Any tree will fail given enough time. Inspection and observations are often focused on how to quantify the likely timing of failure so trees can be removed prior to failure, but not too prematurely.

In Redwood City, there have been tree failures due to many factors. The failures can be separated into two types – branch or limb failures and whole tree failures.

Branch or limb failures occur when:

- The wood structure of the crotch or attachment point is weakened due to decay or abnormal growth.
- The weight of foliage on the limb or pruning performed results in foliage growth that exceeds the strength of the attachment.
- Summer branch drop – an "unpredictable" limb failure that occurs under normal weather conditions with no apparent decay or other obvious causal factor.

Whole tree failure occurs when the root system can no longer support the tree. This can be the result of:

- Outside forces – a storm or high wind exceed the holding capacity of the tree's root system.
- Root decay that reduces the root system necessary to support the tree.
- Excessive soil moisture that reduces the ability of the roots to hold onto the soil.
- Excessive mechanical damage or severance of roots

PWS staff monitors the tree failures that occur on City-owned trees and some private trees as observed through the Tree Preservation Ordinance permit process. This approach provides continued learning about external signs and symptoms of internal or underground degradation.

Staff also participates in the University of California Cooperative Extension California Tree Failure Reporting Program (in the process of shifting to an international database). Annually, staff attends the Cooperative Extension tree failure update meetings which provide information about tree failure and information to improve prevention.

The monitoring of failures can be difficult during a storm. Response crews are focused on the safe and timely removal of fallen trees and debris. Some work is performed by contract crews called directly by dispatch so initial reporting may not be complete. The actual cause of each tree failure may not always be recorded fully or accurately. However, staff has tried to be diligent in monitoring the root pruned tree failures to learn about the amount of roots lost due to root pruning and if there is a correlation to failure.

Staff attributes 67 tree failures to root pruning (1.4% of root pruned trees) over the history of the sidewalk repair program. The majority of these failures occurred during significant storms when other trees failed that were not root pruned.

There are two tree species – Evergreen Chinese Elm (Ulmus parviflora) and Deodar Cedar (Cedrus deodara) – that have failed due to root pruning without storm events. Two other species also showed very shallow root systems – California Pepper (Schinus molle) and Tulip Tree (Liriodendron tulipifera) – that are regarded as highly prone to failure following root pruning. Staff's practice is to avoid root pruning these four species.

The most significant tree failure event was in November 2003. During a severe storm 14 large whole tree failures occurred, of which nine trees had been root pruned, and five had not. Additionally, over 400 other calls for service for large broken limbs, torn branches, and private tree failures were recorded.

During the recent December 31, 2005 storm, 63 service calls were received citywide for failed limbs and whole tree failures. Some of the 63 calls had multiple occurrences at an address. Eleven trees on private property failed, 8 large and 3 small. Four large City-owned trees failed. Two Ash trees located in the Woodside Plaza neighborhood had been root pruned, one approximately five years ago and the other approximately two years ago. The other two failures were Acacia trees located east of the railroad tracks, one along Chew Street and one along Blomquist. Fourteen small City-owned trees were destroyed at different locations throughout the City. No storm-induced failures occurred on trees that were root pruned during the current project.

One Ash tree, root pruned during the current project, was observed to be leaning in late December 2005. Staff inspected, found the stability compromised, and removed the tree. One Ash tree located along Bristol Way, root pruned during the current project, failed during September 2005. After investigation, staff concluded the tree was hit by a debris box truck and also had over-saturated soil at the root crown.

The root systems of the four root pruned trees (in the previous paragraph) were carefully excavated and the roots washed off. Staff found that the root pruning that occurred ranged from a distance of 36 inches from the trunk (target distance) to 28 inches from the trunk. The root pruning distances were directed by staff based on the available space present in order to perform the necessary sidewalk repairs. It was concluded that in these situations, the Contractor performed the root pruning as directed by the City. Decay was present in the base

of the tree root pruned five years ago. It could not be determined that the decay was the result of the root pruning as the decay extended well into the trunk of the tree. If basal decay was observed to be present at the time of construction, root pruning would not have been performed. On all four trees, staff found large lateral roots that had been left intact and were either torn or pulled from the soil as the tree failed.

Conclusion

Root pruning has served as an alternative to tree removal during the 19 year progression of the sidewalk repair program. As the program has evolved, there are many streets where the trees continue to thrive and provide the canopy desired in the neighborhoods. On some streets, no trees were removed and the neighborhood has retained the original character with more space between the sidewalks and trees. On some streets, as follow-up tree removal has been required, the impact has been spread out over several years, creating a transition to a more mixed-aged tree population which is the most sustainable tree canopy for a City.

There is a variable balance between tree removal and root pruning. If the goal is to have no trees fail, in order to achieve that goal with no risk, the project would require removal of all the trees that are in conflict with sidewalks. Staff's goal has been to practice root pruning to emulate a "normal" failure rate – failures that would randomly occur under normal to exceptional circumstances.

There is some risk associated with root pruning. A portion of the root system of the tree will be removed or compromised. Staff has designed the project specifications to minimize the risk of tree failure, with the following steps:

- Include Certified Arborists in the project plans, tree decisions, and inspections.
- Evaluate the tree condition first to validate the tree should be retained.
- The target distance from the tree trunk that the root pruning is performed to was increased from 18 to 24 inches in the early project years to 30 inches in the mid 1990's. The target distance was increased to 36 inches following the 1999 Task Force recommendations.
- The target depth to which root pruning is performed was decreased from 18 inches in the early project years to twelve inches in the mid 1990's. Following the 1999 Task Force recommendations, the target depth was reduced to eight inches – the minimum depth needed for concrete construction.
- Relocate curbs to avoid root pruning.
- Develop species profiles to avoid root pruning less stable species.
- Prune trees to reduce the canopy "sail" when too dense.
- Test trees suspected of instability to determine if the tree should be removed.

There are some other impacts to trees following root pruning. Some branch and twig dieback occurs in most trees following root pruning. Supplemental irrigation does have a beneficial affect on an individual tree's response to root pruning. The adjacent resident's care can provide a beneficial or detrimental effect. The City has provided deep watering to root pruned trees during exceptional circumstances such as during the drought.

Significant dieback has occurred in approximately 5% of the trees following root pruning, resulting in follow-up pruning and in some cases tree removal. The trees may decline over time, or they may recover and provide a greater canopy than a newly planted tree. These trees could have been removed at the time of the initial sidewalk repair, or the location could have been skipped and a temporary repair made. The practice – based on the original policy objective – of root pruning and retaining trees, even if in some doubt as to the long-term viability, has resulted in many more recovered trees and a reasonable level of failures.

The data shows that the project is completing the sidewalk removal and replacement process in a manner that meets the goal of low risk. Approximately 1.4% of the root pruned trees have failed. The majority of these failures have occurred during significant weather events which have also caused damage to trees not receiving the root pruning treatment.

The alternative to root pruning is to remove more trees to complete sidewalk re-construction. This intensity of tree removal was not in the Council's program vision or direction to staff. Root pruning provides an alternative to the tree removal approach. A new alternative - rubber sidewalk panels - is allowing sidewalk construction with very minimal root pruning. Staff now has an option to construct more sidewalks to engineering standards while avoiding root pruning adjacent to sidewalks. Some root pruning may still be required in order to construct driveway approaches and curb and gutter. This root pruning will be more selective in most cases.

There will continue to be situations where trees have outgrown their available growing space, there is no room to design street and driveway access around the tree, and tree removal will be the only option. However, most sidewalk situations, with easements, rubber sidewalks, and relocating the sidewalk further from the tree should allow the construction of sidewalks to City standards.

Information on the Public Works Services tree stability testing procedure is attached to this report.

Attachment:
Tree Stability Testing

Tree Stability Testing

Approximately ten years ago, staff developed a tree pulling test to determine the relative stability of trees growing along streets and in parks. The test was designed to apply a force to the tree from one direction and add to the force with pulsating increases causing the tree canopy to move similar to wind loads during storms. The force applied is not an attempt to pull the tree over or break major limbs from the tree. The force is applied to observe ground movement at the root plate.

Staff evaluates the stability of the tree by observing and feeling the root plate movement. If a tree has been root pruned, staff observes the edge of the root plate adjacent to the severed root area for movement. Trees not previously root pruned are observed for any cracks in the soil or root plate movement. A secondary evaluation is made by staff standing on the soil plate and feeling for any movement. The root plate evaluations have provided observational data to make decisions to either remove some trees where movement was detected or retain trees where movement was not detected. There is no measurable data associated with this test process, only observations and staff experience to support the test findings. Trees left standing after this test have a 100% survival rate. Trees have been removed after the test determined instability.

There is current research looking at different forces on trees and tree stability being conducted in Europe, Canada, and Australia. The quantitative data is still being evaluated and is specific for each test situation. Staff has contacted three different researchers in order to develop protocols to measure the pull force and any movement quantitatively. This would provide data for making a better decision about a tree with questionable stability, whether a result of root pruning or other factors.

The different researchers are measuring both trunk strength and root strength. The measuring devices for the pull forces are similar. However, the measuring devices for the tree movement are different. The strength of the root plate is the primary concern in Redwood City soils, so the need to include any incremental movement at the base of the tree or root plate is key. Instruments which measure stretch or bend along the trunk or limbs do not provide root plate strength data.

Staff contacted researchers to determine if a more quantitative measure of root plate stability can be obtained. Advice was received and a root pruned tree scheduled for removal was selected to apply measuring devices to capture data. In December 2005, staff obtained recommended measuring equipment for force pull and directional movement to initiate the testing process. The process combined the previous testing procedure with the new measuring devices. Rope and a vehicle were used for pulling. The measuring device for incremental

movement was attached to the trunk of the tree about eighteen inches off the ground. The test results were inconclusive. The pull force was measured and recorded. There was no recorded incremental movement from the inclinometer (incremental movement) instrument.

Staff discovered the problems that occurred with the data measurement process design. The use of synthetic rope used for the previous pull test creates stretch in the rope. While this causes the tree canopy to move similar to a storm wind loading for the previous observations, it didn't work well for the pull measuring device. The use of a vehicle to generate the pull does not allow for controlled incremental changes in pull force. The results were that as different pull forces were applied, the rope stretched and the force measured initially decreased. Staff concluded that there is measurable data that can be derived by further improving the test procedures.

At the same time, staff observed the base of the tree following the previous pull testing observations. Some minor movement was noticed as previously, which was the basis for the reason to remove the tree, but it may not have been significant along the trunk where the instrument was attached. Staff will experiment with placement of the incremental movement measuring instrument to find the most advantageous location.

Next Steps

The next tree stability testing will utilize a web sling choker around the tree to minimize both stretch and damage to the tree. A steel cable will be connected to the sling and used to pull from an anchored vehicle. Tension will be increased using a Tirfor winching device – which provides incremental tightening and loosening for adjusting the pulling forces with control versus moving the vehicle to apply tension.

The placement of the incremental movement measuring instrument will be tested in different positions to find the most advantageous location.

The next tree stability pull testing is scheduled for mid to late February, 2006. A consultant from Ontario, Canada is going to be in California on other business. Staff has scheduled a field testing with his participation. Trees have been identified that are good candidates for the pull testing and could provide staff with useful data about tree species we are interested in further testing.

The desired outcome is to create a more useful process staff can use over time to collect better data on tree stability in order to make better tree management decisions.