Go to # 2803-05, 07  #2
Kunia Army Wells

file #2 starts WUP transfer request (WUP586)
dated 26 Dec. 2008. Land ownership questions
to be resolved.

FM
2/11/2009
6. **Hawaii Drought Plan Briefing by the Commission Staff**

Mr. Neal Fujii, State Drought Coordinator, did a powerpoint presentation of the Hawaii Drought Plan.

In answer to Commissioner Nishida’s question on the Agricultural Water Use and Development Plan (AWUDP), Mr. Dean Nakano stated that no funds from this past legislature were appropriated. Because drought directly affects the agriculture industry, funding support for the plan is being pursued at both the federal and state level.

7. **Waiahole-Waikane Community Association, Hakipu’u Ohana, Ka Lahui Hawaii, Kahalu’u Neighborhood Board No. 29, and Makawai Stream Restoration Alliance,**

**PETITION FOR DECLARATORY ORDER**

**DENYING BISHOP ESTATE’S WATER USE PERMIT APPLICATION FOR FAILING TO COMPLY WITH THE COMMISSION ON WATER RESOURCE MANAGEMENT’S FINAL DECISION AND ORDER IN THE WAIHAOLE DITCH COMBINED CONTESTED CASE HEARING (DEC-OA00-G6)**

Kamehama Schools APPLICATION FOR A WATER USE PERMIT, Waiau Development Tunnel (Well No. 2657-05), TMK 9-6-05:003, Existing/New (Irrigation and Dust Control) Use for 4.2 mgd., Koolaupoko, Kahana, and Waipahu-Waiau Ground Water Management Areas, Oahu

**PRESENTATION OF SUBMITTAL:** Mr. Ed Sakoda

**RECOMMENDATIONS:**

Staff recommends that the Commission approve an additional 60-day extension of time, for a total of ninety days from the date KS provided the report to Earthjustice (May 30, 2001). Earthjustice shall amend their petition for declaratory order by August 28, 2001.

Commissioner Nishida recused himself from Item 7.

**MOTION:** (GIRALD/RICHARDS)

To approve the submittal.

**UNANIMOUSLY APPROVED.**

8. **Del Monte Fresh Produce (Hawaii) Inc., REVOCATION/MODIFICATION OF WATER USE PERMIT, Del Monte Wells 3 & 4 (Well Nos. 2003-05-5160), From WUP No. 116 (4.32 mgd) to WUP No. 589 (3.96 mgd), Wahiawa Ground Water Management Area, Oahu**

**MODIFICATION OF A WATER USE PERMIT, Kunia Well & Basal Well (Well No. 3002-005-2000), TMK 9-2-005:002, Future (Agricultural) Use From WUP No. 113 (0.154 mgd) to WUP No. 507 (1.000 mgd), Ewa-Kunia Ground Water Management Area, Oahu**
PRESENTATION OF SUBMITTAL: Ms. Lenore Nakama

AMENDED RECOMMENDATIONS:

Staff recommends that the Commission:

1. Approve the issuance of water use permit no. 507 to Del Monte Fresh Produce (Hawaii) Inc. for the reasonable and beneficial use of 1.075 million gallons per day of fresh, nonpotable water for agricultural use from the Kunia Well & Basal Well (Well Nos. 2703-01 & 02), subject to the standard water use permit conditions listed in Attachment B and the following special conditions:
   
   a. Should an alternate permanent source of water be found for this use, then the Commission reserves the right to revoke this permit, after a hearing.
   
   b. In the event that the tax map key at the location of the water use is changed, the permittee shall notify the Commission in writing of the tax map key change within thirty (30) days after the permittee receives notice of the tax map key change.
   
   c. This water use permit, WUP No. 507, shall supersede WUP No. 113.
   
   d. WUP No. 113 is revoked.

2. Approve the issuance of water use permit no. 589 to Del Monte Fresh Produce (Hawaii) Inc. for the reasonable and beneficial use of 3.96 million gallons per day of fresh, nonpotable water for agricultural use from the Del Monte Wells (Well Nos. 2803-05 & 07), subject to the standard water use permit conditions listed in Attachment B and the following special conditions:
   
   a. Should an alternate permanent source of water be found for this use, then the Commission reserves the right to revoke this permit, after a hearing.
   
   b. In the event that the tax map key at the location of the water use is changed, the permittee shall notify the Commission in writing of the tax map key change within thirty (30) days after the permittee receives notice of the tax map key change.
   
   c. This water use permit, WUP No. 589, shall supersede WUP No. 116.
   
   d. WUP No. 116 is revoked.
   
   e. The permittee shall obtain approvals from the Department of Health and the U.S. Environmental Protection Agency prior to use of the water.

Commissioner Nishida recused himself from Item 8.
Del Monte Fresh Produce (Hawaii) Inc.
REVOCATION/MODIFICATION OF WATER USE PERMIT
Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07)
From WUP No. 116 (4.32 mgd) to WUP No. 589 (3.96 mgd)
Wahiawa Ground Water Management Area, Oahu

MODIFICATION OF A WATER USE PERMIT
Kunia Well & Basal Well (Well No. 2703-01 & 02), TMK 9-2-005:002
Future (Agricultural) Use
From WUP No. 113 (0.154 mgd) to WUP No. 507 (1.000 mgd)
Ewa-Kunia Ground Water Management Area, Oahu

APPLICANT:
Del Monte Fresh Produce (Hawaii) Inc.
94-1000 Kunia Road
Kunia, HI 96759

LANDOWNER:
The Estate of James Campbell
1001 Kamokila Blvd.
Kapolei, HI 96707

LOCATION MAP: See Exhibit 1

BACKGROUND:
On February 13, 2001, a completed water use permit application was received from Del Monte Fresh Produce (Hawaii) Inc. by the Commission on Water Resource Management (Commission). The application is to modify the water use permit for Well No. 2703-01 (WUP No. 113) from 0.154 mgd to 1.0 mgd and to add an existing source, Well No. 2703-02, on the permit. The water will be used to supply 2,480 acres of pineapple agriculture. Our records show these wells have not been used since 1994. Well No. 2703-01 was the site of a pesticide spill and has been undergoing cleanup efforts coordinated by the Environmental Protection Agency and the Department of Health.
On March 1, 2001, the staff met with Del Monte to discuss issues related to the water use permit application, as described in our letter dated March 6, 2001 (Exhibit 2).

In letters dated April 5, 2001 and May 30, 2001, Del Monte provided additional justification to support their application (Exhibits 3 and 4).

Additional information regarding the sources, use, notification, objections, and field investigation(s) is provided in Attachment A.

ANALYSIS/ISSUES:

Section 174C-49(a) of the State Water Code establishes seven (7) criteria that must be met to obtain a water use permit. An analysis of the proposed permit in relation to these criteria follows:

(1) **Water availability**

Through the Hawaii Water Plan, the Commission has adopted 16 mgd as the sustainable yield for the Ewa-Kunia Aquifer System. Individual existing water use permits in this aquifer system are shown in Exhibit 5. A summary of the current ground water conditions in the aquifer is provided in Table 1:

<table>
<thead>
<tr>
<th>Sustainable Yield</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less: Other Existing Water Use Permits (shown in Exhibit 5)</td>
<td>14.492</td>
</tr>
<tr>
<td>Subtotal (Current Available Allocation)</td>
<td>1.508</td>
</tr>
<tr>
<td>Less: Pending Completed Applications (shown in Exhibit 6)</td>
<td>4.076</td>
</tr>
<tr>
<td>Subtotal (Potential Allocation Deficit)</td>
<td>-2.568</td>
</tr>
</tbody>
</table>

Table 1 shows that satisfaction of all pending requests would result in an allocation deficit of 2.568 mgd. However, WUPA Nos. 430 and 493 (see Exhibit 6) have been deferred since 1996 and 1998, respectively, pending the re-evaluation and possible adjustment of the sustainable yield in the Ewa-Kunia Aquifer. Although the new sustainable yield estimate of 16 mgd was adopted in March, 2000, final action on these two applications for industrial and irrigation uses over the non-potable Ewa Caprock Aquifer has not been scheduled to encourage the applicants to work toward the use of reclaimed water to meet their proposed non-potable needs. We understand that negotiations with the Honolulu Board of Water Supply, the new purveyor of reclaimed water from the Honoluluui...
Wastewater Reclamation Plant, are ongoing. Del Monte’s request is for use over the potable Ewa-Kunia Aquifer. The current available allocation in Ewa-Kunia, 1.508 mgd, is adequate to fully satisfy Del Monte’s request for a 0.846 mgd increase in permitted use.

(2) **Reasonable-beneficial**

Section 174C-3 HRS defines "reasonable-beneficial use" is

"...the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is both reasonable and consistent with the state and county land use plans and the public interest".

An issue is the proposed agricultural duty of 2,000 gpd/acre. This computes to a projected daily irrigation requirement for 4.960 mgd.

In 1995, the Commission granted Del Monte an increase in permitted use for Well Nos. 2803-05 & 07, which also supply these same Kunia fields, using a duty of 2,000 gpd/ac based on a study by Dr. Paul Eckern (August 16, 1995 Staff Submittal). Dr. Eckern’s study showed that the conversion from overhead to drip irrigation can double the irrigation water requirement, as the pineapple is less stressed and therefore able to consume a greater quantity of water. This relationship between conversion to drip and greater water consumption was observed on Lanai. Also, following the conversion to the drip method, pineapple will experience about a 10% faster growth rate if roughly twice as much water is applied. If irrigation water is not adjusted, a faster growth rate will not ensue. The relationship between growth rate and economic yield has not been established. Based on Eckern’s study, the Commission increased the allocation for Well Nos. 2803-05 & 07 to 4.32 mgd. These sources are also a public water system monitored by the Department of Health supplying domestic water to Del Monte workplaces and 150 residences at the Village of Kunia. Assuming the domestic needs are about 0.075 mgd (150 units * 500 gpd/unit), the remaining 4.245 mgd can be used for irrigation. However, the current twelve-month moving average withdrawal for Well Nos. 2803-05 & 07 is only 2.725 mgd (as of 3/31/00). Del Monte has explained that the conversion of Kunia Section fields to the new drip method has not yet been completed (Exhibit 3). In addition, there was a lightning strike on Well No. 2803-05 in January 2000, and 7-month down time to repair bowls in the pump for Well No. 2803-07. According to Del Monte, all these infrastructure constraints have resulted in less than optimal water use.

To further justify the proposed 2,000 gpd/acre irrigation requirement for their Kunia fields, Del Monte has suggested that the Commission review actual water use for their Waiahole fields (Fields 161, 171 & 172), which were converted to the drip irrigation system in May, 1998 and which are planted in the same variety of pineapple (Hawaii Gold). The Waiahole fields are immediately makai of the Kunia fields. Exhibit 7 shows the graph of actual water use for the converted fields receiving irrigation water from the Waiahole Ditch. For about the past year and a half, the twelve-month moving average withdrawal has been below 0.250 mgd, which for 160 acres, computes to a daily irrigation requirement of about 1,560 gpd/ac. Del Monte has explained that infrastructure and management constraints have resulted in less than optimal water use in their Waiahole fields at the present time. However, Del Monte cites actual average use in 2000 in
both the Kunia and Honouliuli converted fields is about 2000 gpd/ac (Exhibit 4), which shows that the projected duty is reflective of actual need.

Existing allocation and demand information are summarized below:

Existing Allocations:
- 2803-05 & 07: 4.320 mgd
- 2703-01 & 02: 0.154 mgd
- 4.474 mgd

Projected Demand:

<table>
<thead>
<tr>
<th>Estimated Duty</th>
<th>Projected Demand</th>
<th>Total Projected Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>acres</td>
<td>units¹</td>
<td></td>
</tr>
<tr>
<td>2480</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Requested Duty, gpd</td>
<td>2000</td>
<td>500</td>
</tr>
<tr>
<td>Subtotal, mgd</td>
<td>4.496</td>
<td>0.075</td>
</tr>
<tr>
<td>Guideline Duty, gpd</td>
<td>1000</td>
<td>500</td>
</tr>
<tr>
<td>Subtotal, mgd</td>
<td>2.480</td>
<td>0.075</td>
</tr>
<tr>
<td>Actual Duty, gpd²</td>
<td>1321</td>
<td>500</td>
</tr>
<tr>
<td>Subtotal, mgd</td>
<td>3.276</td>
<td>0.075</td>
</tr>
<tr>
<td>Actual Duty, gpd³</td>
<td>2010</td>
<td>500</td>
</tr>
<tr>
<td>Subtotal, mgd</td>
<td>4.985</td>
<td>0.075</td>
</tr>
</tbody>
</table>

¹ Estimated domestic demand based on number of residential service connections.
² Current 12-MAV for Waiahole Fields 161, 171, & 172 (Exhibit 7)
³ 2000 12-MAV for Kunia Fields 5 & 62 (Exhibit 4)

Del Monte is still in the process of converting their Kunia fields in terms of both pineapple variety and irrigation method. Del Monte claims that this conversion will increase yields, produce a superior variety of pineapple, preserve and create jobs, and keep Del Monte competitive in the global pineapple market. To date, infrastructure constraints and ineffective irrigation management have resulted in less water use than would be necessary to maximize crop yields. Del Monte claims it is committed to resolution of these problem areas and is requesting that the Commission provide them with time and water as they undergo this transition.

Del Monte has offered Dr. Eckern’s study and actual field experience in converted fields in Honouliuli and Kunia sections to justify their request for a duty of 2,000 gpd/ac for pineapple agriculture. Using this figure, the total allocation for wells supplying 2,480 acres of Kunia pineapple fields and 150 existing residences would compute to 5.035 mgd. Any unused allocation would be subject to revocation after four continuous years of nonuse pursuant to §174C-58 Haw. Rev. Stat.
Our records indicate that the maximum pumping capacity for Well Nos. 2803-05 & 07 is only 3.96 mgd, although the wells have an allocation for 4.32 mgd (WUP No. 116). Del Monte has agreed to reduce the allocation for Well Nos. 2803-05 & 07 to 3.96 mgd. The remainder of the projected 5.035 total allocation, 1.075 mgd, should be assigned to Well Nos. 2703-01 & 02. (Del Monte has also submitted applications to install 1050 gpm pumps in Well Nos. 2703-01 & 02. These applications have been deferred pending action on the water use permit modification application. Should the Commission approve an increase in the allocation for Well Nos. 2703-01 & 02, the staff will administratively approve the pump installation permit applications.)

(3) Interference with other existing legal uses

Honolulu Board of Water Supply (BWS) has expressed concern with the impact on water quality for down gradient wells resulting from increased pumpage at Well Nos. 2703-01 & 02. BWS has recommended ground-water modeling to evaluate the potential impact on BWS’s Honouliuli Wells, which already exhibit elevated chloride concentrations. BWS also recommends that any permit granted be conditioned to promote the possible future application of reclaimed water, should its application over potable aquifers be found to be safe. (Beginning in about 1995, the staff recommendations for non-potable use permits have routinely included a special condition to allow for the future conversion to alternative sources as they become available).

To address the issue of potential well interference, Del Monte provided two technical memorandums, one prepared by Golder Associates in 1998 (Exhibit 8) and the other by John Mink in 2001 (Exhibit 9), to address potential well impacts. Mink used a U.S. Geological Survey numerical model prepared for the Navy (Souza and Meyer, 1995) to estimate the impacts of increased pumpage (at Barbers Pt. Shaft) in Ewa-Kunia.

Commission staff assessed potential impacts to Honouliuli Wells (Well Nos. 2303-01 to 06) by analyzing pump testing results from Well Nos. 2703-01 & 02 using a Theis drawdown calculation (Exhibits 10 and 11). In our analyses, staff used hydraulic conductivity values from the recovery test, 2309 ft/day, which appear reasonable for Koolau flank flows. Exhibit 10 uses an aquifer thickness of 230 ft (1.6 * bottom of well, or 1.6 * -143 ft = 230 ft). Exhibit 11 assumed an aquifer thickness of 500 ft used in Mink’s diagram. Honouliuli Wells are 22,000 ft downgradient from Well Nos. 2703-01 & 02. The results of the Theis analysis using an aquifer thickness of 230 ft shows a steady state drawdown of 1.8 inches or a rise in the mid-point interface of 6.24 ft. Using an aquifer thickness of 500 ft, the steady state drawdown is 0.9 inches or a rise of 2.88 ft in the mid-point interface. These results indicate that effects on Honouliuli Wells will be negligible.

(4) Public interest

The use of water for agricultural purposes, where existing correlative uses, established water rights, and the public trust resources are protected, is deemed to be in the public interest. There are no streams in the vicinity of the wells.

The Office of Hawaiian Affairs has expressed concerns regarding the limited sustainable yield available for allocation from the Ewa-Kunia Aquifer System and the adequacy of long-range planning for water use (Exhibit 12). The staff’s response is shown in Exhibit 13.
(5) **State & county general plans and land use designations**

These proposed uses are consistent with the state and county general plans and land use designations.

(6) **County land use plans and policies**

These proposed uses are consistent with county land use plans and policies.

(7) **Interference with Hawaiian home lands rights**

All permits are subject to the prior rights of Hawaiian home lands. The Department of Hawaiian Home Lands (DHHL) has reviewed this application and has no comments.

**RECOMMENDATION:**

Staff recommends that the Commission:

1. Approve the issuance of water use permit no. 507 to Del Monte Fresh Produce (Hawaii) Inc. for the reasonable and beneficial use of 1.075 million gallons per day of fresh, nonpotable water for agricultural use from the Kunia Well & Basal Well (Well Nos. 2703-01 & 02), subject to the standard water use permit conditions listed in Attachment B and the following special conditions:
   a. Should an alternate permanent source of water be found for this use, then the Commission reserves the right to revoke this permit, after a hearing.
   b. In the event that the tax map key at the location of the water use is changed, the permittee shall notify the Commission in writing of the tax map key change within thirty (30) days after the permittee receives notice of the tax map key change.
   c. This water use permit, WUP No. 507, shall supersede WUP No. 113.
   d. WUP No. 113 is revoked.

2. Approve the issuance of water use permit no. 589 to Del Monte Fresh Produce (Hawaii) Inc. for the reasonable and beneficial use of 3.96 million gallons per day of fresh, nonpotable water for agricultural use from the Del Monte Wells (Well Nos. 2803-05 & 07), subject to the standard water use permit conditions listed in Attachment B and the following special conditions:
   a. Should an alternate permanent source of water be found for this use, then the Commission reserves the right to revoke this permit, after a hearing.
Staff Submittal
June 20, 2001

b. In the event that the tax map key at the location of the water use is changed, the permittee shall notify the Commission in writing of the tax map key change within thirty (30) days after the permittee receives notice of the tax map key change.

c. This water use permit, WUP No. 589, shall supersede WUP No. 116.

d. WUP No. 116 is revoked.

Respectfully submitted,

LINNEL T. NISHIOKA
Deputy Director

Attachment(s):
A (Water Use Permit Detailed Information)
B (Water Use Permit Standard Conditions)

Exhibit(s):
1 (Location Map)
2 (March 6, 2001 Letter from Linnel T. Nishioka to Calvin Oda)
3 (April 5, 2001 Letter from Calvin H. Oda to Linnel T. Nishioka)
4 (May 30, 2001 Letter from Calvin H. Oda to Lenore Nakama)
5 (Existing Water Use Permits and 12-Month Moving Average Withdrawal)
6 (Pending Water Use Permit Applications)
7 (Graph of Pumpage for Waiahole Fields 161, 171, & 172)
8 (1998 Technical Memorandum, Golder Associates)
9 (2001 Technical Memorandum, Mink & Yues, Inc.)
10 (Theis Drawdown Calculation 1)
11 (Theis Drawdown Calculation 2)
12 (April 2, 2001 Letter from Colin C. Kippen, Jr. to Gilbert S. Coloma-Agaran)
13 (May 4, 2001 Letter from Linnel T. Nishioka to Colin C. Kippen, Jr.)
14 (Physical Well Information)
WATER USE PERMIT DETAILED INFORMATION

Source Information

AQUIFER:
Sustainable Yield: Ewa-Kunia System, Pearl Harbor Sector, Oahu
Existing Water Use Permits: 16 mgd
Available Allocation: 14.492 mgd
Total of pending allocations: 1.508 mgd

WELL:
(See Exhibit 14)

Kunia Well & Basal Well (Well No. 2703-01 & 02)

Use Information

Quantity Requested: 1.000 gallons per day.
Future Type of Water Use: Agricultural
Place of Water Use: TMK: 9-4-12:por 2,3; 9-2-5:por 1,2; 9-2-4:por 1,3,5,6

Reported Water Usage: NA gpd

Ewa-Kunia Aquifer System
Current 12-Month Moving Average Withdrawal (See Exhibit 5): 11.479 mgd

ATTACHMENT A
Nearby Surrounding Wells and Other Registered Ground Water Use

There are only a couple of other wells within a mile of the wells (see Exhibit 1). Well Nos. 2803-01 & 02 are Navy wells that are currently unused.

Public Notice

In accordance with HAR §13-171-17, a public notice was published in the Honolulu Advertiser on March 12, 2001 and March 19, 2001 and a copy of the notice was sent to the Mayor's office. Copies of the completed application were sent to the Department/Board of Water Supply, Planning Department, Department of Land Utilization (Oahu only), Department of Health, Department of Hawaiian Home Lands, Office of Hawaiian Affairs, the various divisions within the Department of Land and Natural Resources, and other interested parties for comments. Written comments and objections to the proposed permit were to be submitted to the Commission by April 3, 2001.

Objections

The public notice specifies that an objector meet the following requirements: (1) state property or other interest in the matter; (2) set forth questions of procedure, fact, law, or policy, to which objections are taken; (3) state all grounds for objections to the proposed permits, (4) provide a copy of the objection letter(s) to the applicant, and (5) submit objections meeting the previous requirements to the Commission by April 3, 2001.

To the best of staff's knowledge there are no objectors who have property interest within the Ewa-Kunia Aquifer System or who will be directly and immediately affected by the proposed water use.

Briefs in Support

Responses to objections, or briefs in support, regarding the application are required to be filed with the Commission ten (10) days after an objection is filed and, presumably, copies are served to the applicant. No briefs in support were filed with the Commission.

Field Investigation

Well No. 2703-01 was investigated on July 16, 1981. The investigation verified the source and proposed domestic and agricultural use of the well. No investigation has been conducted for Well No. 2703-02.
STANDARD WATER USE PERMIT CONDITIONS

1. The water described in this water use permit may only be taken from the location described and used for the reasonable beneficial use described at the location described above. Reasonable beneficial uses means "the use of water in such a quantity as is necessary for economic and efficient utilization which is both reasonable and consistent with State and County land use plans and the public interest." (HRS § 174C-3)

2. The right to use ground water is a shared use right.

3. The water use must at all times meet the requirements set forth in HRS § 174C-49(a), which means that it:
   a. Can be accommodated with the available water source;
   b. Is a reasonable-beneficial use as defined in HRS § 174C-3;
   c. Will not interfere with any existing legal use of water;
   d. Is consistent with the public interest;
   e. Is consistent with State and County general plans and land use designations;
   f. Is consistent with County land use plans and policies; and
   g. Will not interfere with the rights of the Department of Hawaiian Home Lands as provided in section 221 of the Hawaiian Homes Commission Act and HRS § 174C-101(a).

4. The ground-water use here must not interfere with surface or other ground-water rights or reservations.

5. The ground-water use here must not interfere with interim or permanent instream flow standards. If it does, then:
   a. A separate water use permit for surface water must be obtained in the case an area is also designated as a surface water management area;
   b. The interim or permanent instream flow standard, as applicable, must be amended.

6. The water use authorized here is subject to the requirements of the Hawaiian Homes Commission Act, as amended, if applicable.

7. The water use permit application and submittal, as amended, approved by the Commission at its June 20, 2001 meeting are incorporated into this permit by reference.

8. Any modification of the permit terms, conditions, or uses may only be made with the express written consent of the Commission.

9. This permit may be modified by the Commission and the amount of water initially granted to the permittee may be reduced if the Commission determines it is necessary to:

ATTACHMENT B
a. protect the water sources (quantity or quality);
b. meet other legal obligations including other correlative rights;
c. insure adequate conservation measures;
d. require efficiency of water uses;
e. reserve water for future uses, provided that all legal existing uses of water as of June, 1987 shall be protected;
f. meet legal obligations to the Department of Hawaiian Home Lands, if applicable; or
g. carry out such other necessary and proper exercise of the State's and the Commission's police powers under law as may be required.

Prior to any reduction, the Commission shall give notice of its proposed action to the permittee and provide the permittee an opportunity to be heard.

10. An approved flowmeter(s) must be installed to measure monthly withdrawals and a monthly record of withdrawals, salinity, temperature, and pumping times must be kept and reported to the Commission on Water Resource Management on forms provided by the Commission on a monthly basis (attached).

11. This permit shall be subject to the Commission's periodic review of the Ewa-Kunia Aquifer System's sustainable yield. The amount of water authorized by this permit may be reduced by the Commission if the sustainable yield of the Ewa-Kunia Aquifer System, or relevant modified aquifer(s), is reduced.

12. A permit may be transferred, in whole or in part, from the permittee to another, if:

   a. The conditions of use of the permit, including, but not limited to, place, quantity, and purpose of the use, remain the same; and
   b. The Commission is informed of the transfer within ninety days.

Failure to inform the department of the transfer invalidates the transfer and constitutes a ground for revocation of the permit. A transfer which involves a change in any condition of the permit, including a change in use covered in HRS § 174C-57, is also invalid and constitutes a ground for revocation.

13. The use(s) authorized by law and by this permit do not constitute ownership rights.

14. The permittee shall request modification of the permit as necessary to comply with all applicable laws, rules, and ordinances which will affect the permittee's water use.

15. The permittee understands that under HRS § 174C-58(4), that partial or total nonuse, for reasons other than conservation, of the water allowed by this permit for a period of four (4) continuous years or more may result in a permanent revocation as to the amount of water not in use. The Commission and the permittee may enter into a written agreement that, for reasons satisfactory to the Commission, any period of nonuse may not apply towards the four-year period. Any period of nonuse which is caused by a declaration of water shortage pursuant to section HRS § 174C-62 shall not apply towards the four-year period of forfeiture.

ATTACHMENT B
16. The permittee shall prepare and submit a water shortage plan within 30 days of the issuance of this permit as required by HAR § 13-171-42(c). The permittee's water shortage plan shall identify what the permittee is willing to do should the Commission declare a water shortage in the Ewa-Kunia Ground-Water Management Area.

17. The water use permit shall be subject to the Commission's establishment of instream standards and policies relating to the Stream Protection and Management (SPAM) program, as well as legislative mandates to protect stream resources.

18. Special conditions in the attached cover transmittal letter are incorporated herein by reference.

19. The permittee understands that any willful violation of any of the above conditions or any provisions of HRS § 174C or HAR § 13-171 may result in the suspension or revocation of this permit.
Mr. Calvin Oda  
Del Monte Fresh Produce (Hawaii) Inc.  
P.O. Box 200  
Kunia, HI 96759

Dear Mr. Oda:

Thank you for meeting with us on March 1, 2001 to discuss your pending water use permit application for Well Nos. 2703-01 & 02.

As we discussed, the following information would be helpful to support your requested allocation:

- Your 5-year plan/schedule to convert your Kunia fields from overhead to drip irrigation. We understand that this plan will show that none of the Kunia fields have been converted as yet, and will explain why your current pumpage is lower than the total irrigation allocation (4.32 mgd for Well Nos. 2803-05 & 07) for these fields.

- A brief explanation for the delay in converting the fields and pump operational problems. The planned conversion to drip irrigation, and the associated increase in irrigation demand, was used to justify an increase in allocation for Well Nos. 2803-05 to 07 in 1996. The Commission may question why the current water allocation has not been used in the last six years.

- An analysis of actual use data showing that the projected 2,000 gpd/ac duty is substantiated. We understand that some of your Waiahole fields have been converted to drip and that the actual irrigation requirement for these converted fields is 2,000 gpd/ac.

We would also recommend that you review your plans for Well Nos. 2803-05 & 07, which currently have an allocation for 4.32 mgd, but only have the capacity to pump up to 3.96 mgd. Unless you have plans to install larger pumps, you may want to relinquish some of the 4.32 mgd allocation and apply it to Well Nos. 2703-01 & 02 instead. If you wish to proceed in this manner, please indicate so in your response to this letter and we will schedule the necessary Commission action. If you decide that you may want to install larger pumps in Well Nos. 2803-05 & 07 at some future date, please do not forget to apply for the appropriate permits.

Also, you mentioned that the proposed Superfund Study with source control issues may require up to 6 new wells. If permanent, these wells will require Well Construction Permit and Pump Installation Permit Applications.

If you have any questions, please contact Lenore Nakama at 587-0218.

Sincerely,

[Signature]

LINNEL T. NISHIOKA  
Deputy Director

LN:ky

EXHIBIT 2

March 6, 2001
April 5, 2001

Ms. Linnel T. Nishioka
Deputy Director
State of Hawaii
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nishioka,

Thank you again for meeting with Dr. John Mink and I on March 1, 2001 regarding the pending water use permit application for the Kunia Well battery (State Well No. 2703-01 and 2703-02). The current water allocation in the Wahiawa High Level Aquifer System and the increased allocation for the Kunia Well located in the Ewa-Kunia Aquifer System will greatly support the expansion of Del Monte Hawaii Gold thus preserving existing jobs and creating new agricultural jobs.

Pursuant to your letter dated March 6, 2001, is the following information to support the requested water allocation.

5-Year Drip Irrigation System Installation Plan

As we discussed, Del Monte is happy to report that Del Monte Hawaii Gold, a new, extra sweet golden variety with about four times the Vitamin C than traditional pineapples is being expanded on Del Monte's Oahu Plantation. Del Monte Hawaii Gold grows faster and requires more water to maintain uniform, growth and development than traditional Smooth Cayenne varieties that are currently produced.

Based on commercial production practices from other growing areas, the requirement for Del Monte Hawaii Gold is significantly higher than the current allocation of 2,000 gallons per acre per day. Rather than add more confusion, Del Monte will provide justification for a greater water allocation after the drip conversion and Hawaii Gold expansion is implemented.

An integral part of the expansion is to increase irrigation supply line capacity and install drip irrigation systems in all of the Kunia Section fields. Under current conditions, approximately 1,643 acres of the 2,594.7 acres located in the Kunia Section are irrigated with drip.
irrigation systems. If approved by executive management, the entire Kunia Section or remaining 951.1 acres will be converted to drip irrigation culture. The business confidential proposed drip irrigation system conversion schedule is shown in Table 1. Please note that the acres may vary slightly from Mr. Robert Pang's recent testimony due to the need to be consistent with the current water allocation permit application.

As stated in our meeting, the current pumpage from the Navy Well (State Well No. 2803-05) and Del Monte Well No. 4 (State Well No. 2803-07) is lower than the total water allocation of 4.32 mgd due to several reasons. In Kunia, there is inadequate supply line capacity to operate irrigation systems efficiently. Use of irrigation water is also hindered by low irrigation efficiency in overhead irrigated fields (only 45 percent of total water requirement applied in year 2000). In January 2000, there was a lightning strike on well 2803-05. In addition, Del Monte experienced a 7 month downtime to repair bowls in the pump for well 2803-07.

Justification for Current Water Allocation

Assuming a watering rate of 2000 gpd, the 2,594 acres in Kunia can use approximately 5.188 mgd. For Del Monte Hawaii Gold irrigation practices in Costa Rica applies about 4,000 gallons of water per acre per day. Del Monte feels strongly that the Hawaii Gold crop grown in the Kunia Section will require more than 2,000 gpd, however, we want to demonstrate our ability to utilize the current allocation prior to requesting any additional assistance.

Del Monte recognizes that our irrigation management has not been effective within the last six years. Del Monte Well No. 4 (State Well No. 2803-07) is operated with a diesel powered turbine pump. We have struggled with operation and maintenance of this system and have replaced or repaired the pump twice in the last six years at great business costs.

As previously stated, the Kunia Section does not have adequate irrigation supply lines to deliver the water as efficiently as desired. We are currently planning to install three new 10 to 12 inch diameter irrigation supply lines to minimize this deficiency.

Starting from 1993, Del Monte began planting pineapples on former sugarcane lands located in Honouliuli. The relatively high capital investment to refurbish previous sugarcane drip irrigation systems consumed available irrigation funds. The current phased approach to drip irrigation system conversion started with the agronomic success of Del Monte Hawaii Gold production on the former
sugarcane lands. The recent marketing success of Hawaii Gold has made it economically feasible to consider conversion of all of the Kunia Section fields to drip irrigation culture.

Use Data

The pineapple crop requires a minimum of 2,000 gpd to maintain uniform and rapid growth and to attain crop yield targets and fruit delivery schedules.

As you know, the water usage for the pineapple fields irrigated with Waiahole Ditch water has been erratic ranging from 1,300 to 2,800 gpd. We have taken steps to improve on irrigation system management to apply consistent amounts of water. The water usage from the fields irrigated by the Waiahole Ditch system are available upon request.

It is acceptable to reduce the allocation for Well Numbers 2803-05 and 2803-07 from 4.32 mgd to 3.96 mgd. Although the existing pumps operated at 100 percent efficiency can attain the 4.32 mgd amount, standard operating procedures requires some down time each day to service the groundwater supply wells limiting actual pumping rates.

On behalf of all of the people at Del Monte, please allow me to thank you for your support and patience in considering the increased water allocation for the Kunia Well battery. Proper irrigation of the Del Monte Hawaii Gold production in the Kunia Section will establish the framework for the future of Hawaiian Agriculture.

Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

xc: R. Pang
Dr. John Mink
Business Confidential Information

Table 1. Proposed Drip Irrigation Installation Schedule
May 30, 2001

Ms. Lenore Nakama
State of Hawaii
Commission on Water Resources Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nakama,

Following up on our telephone conversation regarding providing documentation on water use in pineapples and the percentage of agricultural lands that may be in fallow in a given year is the following written response.

Water Use In Pineapples

In my previous letter to the State Commission on Water Resource Management dated April 5, 2001, Del Monte reported that we are in the process of expanding production of Del Monte Hawaii Gold. Del Monte Hawaii Gold grows faster and requires more water to maintain uniform, growth and development than traditional Smooth Cayenne varieties that are currently being produced.

The current irrigation regime requires application of 2,000 gallons per acre per day (see Table 1). In some cases, more water is already applied to the pineapple crop grown in the Kunia Section of the Oahu Plantation. As previously stated, irrigation practices from Costa Rica applies about 4,000 gallons of water per acre per day to the hybrid pineapple crop. A conservative water requirement for the Hawaii Gold is 2,500 gallons per acre per day.

Percentage of Lands in Fallow

In a given year, approximately 25 percent of the total acreage enters into some stage of fallow. Roughly one-half of the fallow acres are replanted to pineapple within the same year. Therefore, approximately 12.5 percent of the total acres may be in fallow in a given year.

The current crop management program for the Kunia and Honouliuli Sections of the Oahu Plantation uses a 4 to 6 month fallow period between crop cycles. Therefore, most of the fields are returned back to pineapple production within a given year.
Justification for Current Water Allocation

Assuming a watering rate of 2,500 gallons per acre per day, the 2,269.75 producing acres (2,594 less 0.125 percent of net acres) in the Kunia Section can use approximately 5.674 million gallons per day.

Starting from 1993, Del Monte began planting pineapples on former sugarcane lands located in the Honouliuli. The Honouliuli fields encompass approximately 829 net acres of pineapples. The combined acreage in the Kunia and Honouliuli Sections of the Oahu Plantation is approximately 3,423 acres.

Assuming a watering of 2,500 gallons per acre per day, the 2,995.13 producing acres (3,423 net acres less 0.125 percent of net acres) in the Kunia and Honouliuli Sections of the Oahu Plantation can use approximately 7.487 million gallons per day.

We trust that the information provided about will provide additional justification in maintaining current water allocations and increasing the water allocation from the Kunia Well and the Basal Well on June 20, 2001.

If there are any questions, please call me at (808) 621-1205.

Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

xc: R. Pang
Dr. John Mink
Table 1. Kunia Section-12 Month Average

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Table 2. Honouliuli Section-12 Month Average

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EXHIBIT 4
### Aquifer System Water Use Permit Index

#### ISLAND OF OAHU

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Summary for 'SYSTEM' = EWA-KUNIA (32 detail records)

Totaling 14.492

Thursday, May 24, 2001

Page 1 of 1

EXHIBIT 5
### Pending Water Use Applications

**Aquifer System:** EWA-KUNIA  
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__Thursday, May 24, 2001__  
__Page 1 of 1__

**EXHIBIT 6**
Del Monte Pineapple Irrigation
Fields 161,171,172 Combined

![Graph showing monthly use and 12-MAV of Del Monte Pineapple Irrigation Fields 161,171,172 Combined. The graph plots use (mgd) on the y-axis and date (latest data 4/01) on the x-axis. The graph includes two lines: a dashed line representing monthly use and a solid line representing 12-MAV.]
E-1. BASAL WELL DRILLING AND WELL CONSTRUCTION

The Basal Well (USGS #27032) was drilled between September 11 and October 6, 1997 to a total depth of 993.5 feet below ground surface (ft BGS). The well installation was completed on October 16, 1997. Drilling and well installation were completed by Roscoe Moss, Hawaii Inc. Pertinent details for the borehole and well installation are summarized in Tables E-1 to E-3. The location of the Basal Well, and the boring log/well construction diagram are shown in Figures 2-2 and 3-20, respectively, of the main text.

E-1.1 Drilling

Prior to drilling, piezometer P-1 was abandoned and the soil in vicinity of the new Basal Well was excavated. A 20 inch O.D. conductor casing was then installed in the pre-existing excavation to a depth of 10.2 ft BGS. A bag of powdered bentonite was placed around the outside of the casing to act as a seal. The excavation was backfilled around the conductor casing to a depth of approximately 4 to 5 ft BGS; cement was then used to create a working pad for the drill rig to the surface.

Drilling was performed with a top drive air rotary rig using a 900 SCFM compressor. The circulation medium was “AMPLI-FLOW” foam. The foam was circulated down through the drill pipe and out through the drill bit, and then upwards in the annular space between the hole and drill pipe to the surface, carrying the cuttings in suspension. At the surface, the foam was washed to remove cuttings. The cuttings were logged by a Golder geologist and archived, typically in 5 foot intervals. No loss circulation zones were encountered while drilling. The drilling penetration rate is shown in Figure E-1. The boring log for the well is shown in Figure 2-15 of the main text of this report.

Drilling started at 10.2 ft BGS with a 17.5 inch tricone bit and continued to 202.8 ft BGS, some 12.8 ft below the top of the unweathered basalt. The drilling was interrupted to install 14 inch O.D. surface casing. The annular space between the casing and the borehole walls was sealed with neat cement containing 3-5% bentonite. The seal was placed with a tremie pipe.

The drilling resumed at 202.8 ft BGS with a 12.25 inch tricone bit and continued to the total depth of 993.5 ft BGS. Deviations surveys were performed with a TOTCO model 26-26A every approximately 30 ft. If the deviation measurements were greater the 30 minutes, the interval was “reamed” by running the drill bit up and down the interval until the deviation was corrected. In addition, Baker Hughes INTEQ performed a gyroscopic multi-shot survey to measure the deviation in three coordinates after installation of screen and casing. The results show a total deviation of 2.66 ft in the horizontal direction of S 41.70 E, well within state regulations. The survey also shows that water level measurements made in the well need to be subtracted by 0.01 ft to obtain the true vertical distance from the ground surface.

After the total depth of the borehole was reached, the tools were removed to the surface and preparations were made for well casing and screen installation. First, a 13 inch diameter “cage” was constructed and lowered to the bottom of the hole on a wireline.
the cage reached the bottom of the hole, the open borehole was confirmed to be at least 13 in. and sufficiently large to accommodate both the 8.625 inch O.D. casing and 1.5 inch tremie pipe. The larger hole in relation to the 12.25 inch bit size can be attributed to reaming. Secondly, 60 ft of 8 inch casing was welded together and lowered to the bottom of the borehole on a wireline. By reaching the bottom of the hole, no significant deviations were confirmed and the casing therefore would not encounter restrictions during well installation.

E-1.2 Well Construction

The well screen consists of Roscoe Moss 8 5/8-inch OD Type 304 stainless steel "Ful-Flo" louvered screen with 0.25 inch wall thickness (ASTM A-409). The casing was Corten 8 5/8-inch OD steel blank casing with 0.312 inch wall thickness (ASTM A-606-75 Type 4). The louvered screen openings are 3/16 inch diameter and provide 29 in.² of open area per linear ft. A stainless steel louvered screen was chosen for its greater strength over the more commonly used continuous slot type.

The 8-inch screen and casing were installed by welding approximately 20 ft sections with stainless steel welds. The top of the 150.5 ft length of screen with end cap was placed at 820.6 ft BGS, some 5.4 ft above the top of the water table. The seasonal fluctuations in the potentiometric surface are expected to be less than 5 feet; therefore the top of the screen will normally be above the water table.

Annular material was placed around the screen and casing to enhance specific capacity and seal off perched water bodies to prevent vertical migration along the borehole. Several measures were taken to ensure that the annular material was placed at the correct depth and to assure that material did not bridge resulting in air gaps: 1) the theoretical annular volume was calculated, 2) volume of material placed in the hole was accurately measured, 3) the depth to the top of the annular material was frequently taken with a sounding rod, and 4) a tremie pipe was used.

All material placed in the annulus below the water table was washed. Chemical analyses were provided to ensure the lack of significant amount of carbonate material, and sieve analysis was conducted by the supplier to ensure compatibility with the size of the screen openings. Basalt chips (3/8 inch) were placed in the open hole below the bottom of the screen. All the gravel (3/8 inch) present on site was used to fill the annular space adjacent to the screen to 841.9 ft. The locally supplied basalt chips were then used to fill the annular space to 810.2 ft, some 10.4 ft above the top of the screen. A 13.5 ft seal of fine sand and bentonite chips was placed above the basalt to prevent the downward vertical migration of the overlying grout seal.

The mixture for the grout seal above the sand pack consisted of 7 gallons of water per 94 pound bag of Portland Type I-II cement with 3 to 5 % powdered bentonite. This mixture was used to fill the annular space between to 600.1 ft BGS. Above this point, sand was
added at equal parts to cement to prevent loss of grout into the formation. In general, the used annular material was greater than a factor of 2 compared to the theoretical annular space volume.

E-1.3 Well Development and Pump Installation

Well development is required to grade the sand pack to optimize production and remove foam that entered the aquifer while drilling. The well was developed with air on October 17, 1997 for 4 hours at a discharge rate of 20 gpm. During this time, the appearance of the water changed from murky to clear. After the 7.5 hp electric sampling pump was installed on October 20, 1997, the well was further developed by pumping at 20 gpm for over 50 hours. The pump intake is located at 885.0 ft BGS and contains a 2 inch I.D. discharge pipe.

E-1.4 Water Notes While Drilling

Table E-4 provides a summary of the water notes while drilling. Two potential perched water bodies were detected while drilling:

1. Prior to installation of the surface casing, perched water was measured in the open borehole at 38.3 ft BGS. The measurements were taken after the borehole was idle for more than 12 hours. The bottom of the perched water zone is uncertain but does not extend below 202.8 ft BGS as no water was encountered in the hole after drilling resumed with the surface casing sealed.

2. The driller noted water in the hole between 658 and 705 ft BGS based on the wetness of the foam that was being circulated out of the borehole while drilling through this interval. At 658 ft BGS, a reddish brown basalt was encountered and the drilling penetration rate increased.

The depth to the water table in the basal aquifer was measured at 826.00 ft BGS on October 17, 1997.

E-2. BASAL WELL AND PERCHED AQUIFER TESTING

E-2.1 Introduction

The objectives of the testing program were to derive hydraulic parameters that may be used in both help determining the lateral and vertical extent of contamination in the groundwater system, and to evaluate and select remedial alternatives, if deemed to be necessary. Both the shallow perched water in the saprolite and the basal aquifer in the basalt were investigated. Slug tests were performed in the perched water to determine local hydraulic properties. A constant rate withdrawal and recovery test was conducted in the basal aquifer to derive more areal scale properties and qualitative information for the geometry of the flow system.
E-2.2 Software

Two software packages were used to analyze the test data. Golder's in house program FLOWDIM, version 3.14, was used to interpret slug test data with the deconvolution method (Chakrabarty and Enachescu, 1997). The deconvolution method and conversion of slug test data to equivalent constant rate allows for significantly improved recognition of the flow model resulting in improved reliability of derived parameters. This technique incorporates both the pressure change and the derivative of pressure change to reduce ambiguity in the analyses.

The basal aquifer constant rate pump test data was analyzed with INTERPRET2 (INT2) of SCIENTIFIC SOFTWARE INTERCOMP, Windows version 1.6. INT2 contains full superposition to interpret both the pumping period and recovery phase. In addition, the program contains a variety of near wellbore, formation and outer boundary models that can be used with a linear regression matching routine to derive an optimized set of hydraulic parameters.

E-2.3 Equipment

The response of the aquifer to induced disturbances and barometric changes was measured with Geokon Vibrating Wire Transducers, Model 4500L. The specifications for the transducers used in the investigation are provided in the Table E-5.

The gauges measure changes in both water levels and atmospheric pressure. Atmospheric pressure changes were monitored on site manually with a Weens and Plath Barometer. In regards to test data, the resolution is the most important specification as hydraulic parameters are derived from absolute pressure changes. The 50 psi gauge is able to detect pressure changes of 0.0125 psi (0.35 in. of hydraulic head) or greater. For the 10 psi gauge, pressure changes of 0.0025 psi (0.07 in. of hydraulic head) or greater can be recognized above gauge noise.

Prior to the start of the pumping test, the gauges were lowered in the well below the water table and function checked by moving the gauges a specified distance and recording the corresponding pressure change. The results, provided in Table E-6, confirms that the gauges were recording within the manufactures specifications.

An existing inline flow meter was used to measure the discharge from the Kunia Well during the pump test. As no calibration records exist, the meter was checked at the operating rate of 325 gallons per minute using a 915 gallon tank and a stop watch. The measured rate was 323 gallons per minute and considered within the accuracy of the method of measurement. Hence, the flowmeter rate of 325 gallons per minute was confirmed to be an accurate representation of the actual flow rate.
E-2.4 Shallow Perched Water

Slug tests were performed in 2 inch diameter monitoring wells MW-1, MW-2, MW-3S, MW-3, MW-5, MW-6 and in 1 inch diameter piezometers P-3, P-4 and P-6. It was not possible to perform tests in P-7 and P-8 as silt had filled the bottom of the boreholes to near the water table.

E-2.4.1 Test Design

The slug test procedure is detailed below:

1. Measure static water level with an electric tape and place transducers in well below the water table;
2. Monitor static conditions prior to start of test to evaluate barometric effects or significant interference effects;
3. Perform at least 1 withdrawal and 1 injection test utilizing either 1 gallon of deionized water injected at the surface or a solid PVC rod;
4. Repeat test if results are anomalous;
5. Continue test until at least 90% recovery is obtained.

Due to restrictions from the small diameter of the piezometers, the slug tests were limited to the injection type and water level changes were monitored with a stop watch and electric tape. All tests in the monitoring wells were performed with pressure transducers with the exception of MW-6. This borehole was drilled after the transducers were returned to the manufacturer and therefore, an injection test was carried out with an electric tape and stop watch.

No significant barometric or interference effects were detected with the exception of tests performed in MW-5. These tests show anomalous responses in mid to late time data and recovery to non-static conditions. The test was repeated several times with the same atypical response. Hence, the analysis approach was to analyze the early time data, prior to the non-formation responses, to derive the appropriate hydraulic parameters.

E-2.4.2 Slug Test Analyses

The slug analyses procedure was as follows:

1. Identification of the flow model by evaluation of the derivative data on the log-log diagnostic plot;
2. Match the data to the appropriate type curves;
3. Examine the match on Ramey A, B, and C with each plot emphasizing different parts of the data set;
4. Iterate between plots until the quality of fit is optimized.
The Ramey A analyses, equivalent to the Cooper technique, was typically selected to show the match between the data and type curves. The data was matched with two models: homogenous and composite. The composite model is recognized as two stabilization's or leveling off of the derivative data on the log-log deconvolution plot. Each stabilization represents a radial cylindrical region about the well with different transmissivities. The outer zone transmissivity is considered to be more representative of the formation response as the inner zone parameters may be influence by the disturbed zone adjacent to the well.

The derived storativity is less well constrained compared to transmissivity due to its correlation to skin. In most cases the skin was assumed to be zero due to the lack of "clean" early time data to select the appropriate type curve. Hence, if the actual skin is 2, the storativity will be underestimated by approximately 2 orders of magnitude.

E-2.4.3 Slug Test Results

The results for the slug test analyses are summarized in Table E-7. Transmissivity was derived from the analyses and hydraulic conductivity was computed by assuming that the contributing flow was evenly distributed over the saturated portion of the screened interval. The 9 test intervals in the saprolite perched water body shows a range of less than 2 orders of magnitude, 3.24E-06 cm/s to 2.11E-04 cm/s. In intervals with results derived from both injection and withdrawals test types, there is good consistency with the difference less than one half an order of magnitude. It is interesting to note that the lowest permeability was measured in monitoring wells MW3 and MW3S which show the highest concentration of EDB/DBCP.

E-2.5 Basal Aquifer

E-2.5.1 Background Monitoring in Kunia Well

Remedial Investigation Technical Memorandum 97-3 required monitoring of static conditions in the Kunia Well for at least a two week period prior to the pumping test. The purpose of this monitoring was to evaluate the influence of atmospheric pressure changes on transducer measurements. This background monitoring was deemed necessary as the expected drawdown in the observation well, located approximately 156 ft from the pumping well, was 2 to 4 in. This response may be of the same order of magnitude as atmospheric pressure changes. As mentioned above, the transducers measure absolute changes in pressure above static conditions. Hence, if atmospheric pressure increases, the water level will be depressed for a confined aquifer. In this case, the transducer will record an increase in pressure as the total pressure, water and air, has increased above static conditions.

The static conditions were monitored for some 24 days with a pressure transducer starting on September 17, 1997. The acquisition rate was initially 120 seconds and was later increased to 500 seconds to reduce the size of the data file. Simultaneously, manual
atmospheric pressure readings were taken, typically several times a day, from an onsite barometer. Both the transducer readings in psi and barometers readings in mbar were converted to in. of water head to allow for comparison between the two measurements.

A comparison between the absolute atmospheric pressure changes and absolute transducer pressure changes generally shows a direct relation with some periodic differences of 0.5 in. of water head. The total pressure change was approximately 1.5 in. of water head for the transducer and 2 in. of equivalent water head for atmospheric changes. Noisy transducer data on October 4 (Day 17.5) and October 6 (Day 18.5) may be attributed to interference effects from activities in the Basal Well, as drilling was below the water table at this time.

E-2.5.2 Test Design

A constant rate test and recovery test was specified using the Kunia Well as the pumping well and the new Basal Well as the observation zone at an approximate distance of 156 feet. The recovery period will provide confirmation of the parameters derived in the production phase. As the test proceeds information is obtained about the system farther from the observation zone. The test duration was to be determined by real time analyses recognizing two important aspects:

1. As the test proceeds, the pressure changes will become smaller and the formation response will be masked by barometric changes;

2. The cone of depression expands logarithmically with time and it generally takes an additional log cycle of data to confirm a boundary or formation response.

The rate was limited to approximately 325 gpm as the maximum capacity of the filtration system. The source zone was to be monitored with a 50 psi transducer to allow for flexibility in the pumping well and a 10 psi transducer was installed in the Basal Well to optimize the resolution for the relatively small expected drawdowns in the observation zone.

E-2.5.3 Measured Pressure Response

A total drawdown of 1.65 psi (3.81 feet of water head) was recorded in the pumping well (Kunia Well) during the 46.23 hours of production at a rate of 325 gpm. The aquifer response shows a relatively rapid pressure change and then a steady monotonic variation in both the pumping and recovery phase. The rapid decline at the start of each phase can be attributed to linear and non-linear head losses near the well referred to as positive skin effects in the petroleum industry. The relatively steady decline after early time data suggests that the production rate was relatively constant during the pumping period. Barometric effects are not considered to significantly influence the measured data except in the late time when the aquifer response is small and in the same magnitude as atmospheric pressure changes.

A total drawdown of 0.0905 psi (2.51 in. of water head) was recorded in the observation well (Basal Well) during the production phase compared to an atmospheric pressure
November 6, 1998

E-2.5.4 Test Analyses

The input parameters used in the analyses are summarized in Table E-8.

Both the pumping and recovery phases were analyzed in the source and observation zones using INT2. The interpretation strategy was as follows:

1. Identify the flow model by evaluation of the derivative data in the log-log diagnostic plot;
2. Match the test data with the appropriate type curves using a non-linear regression algorithm to provide an optimized set of parameters, emphasizing the early and mid time data as the late time noisy derivative data is likely influenced by atmospheric changes;
3. Simulate the entire test sequence in Cartesian coordinates; this final step is used to check the consistency of the model to the entire data set.

E-2.5.5 Results

The results of the analyses of the pumping test data are provided in Table E-9.

E-2.5.5.1 Source Zone [Kunia Well]

The source and recovery phases show consistent responses and were analyzed with the following model:

<table>
<thead>
<tr>
<th>Inner Boundary:</th>
<th>Wellbore Storage and Skin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation:</td>
<td>Homogeneous</td>
</tr>
<tr>
<td>Outer Boundary:</td>
<td>Infinite Lateral Extent</td>
</tr>
</tbody>
</table>

The pumping phase log-log plot is annotated to show which part of the data is used to derive the corresponding parameters: the wellbore storage and skin is derived from the early time data and the transmissivity is taken from the assumed radial flow stabilization, leveling off, of the derivative data. The relatively large separation of the pressure and pressure derivative data indicates a restriction in flow close to the wellbore resulting in a high matched positive skin. As there is no clear stabilization in the derivative data due to noise resulting from small fluctuations in the rate, the approach was to assume the stabilization in the middle of the data to derive a best estimate for transmissivity. In addition, sensitivity analyses were performed for transmissivity by assuming radial flow stabilizations near the top and bottom of the mid time derivative data to derive upper...
and lower limits. The late time derivative data after 10 hours shows an undulating response that is signature for barometric effects and therefore not emphasized. The results are summarized in Table E-10.

The simulation match shows a reasonable match to entire data set with discrepancies partially attributed to atmospheric pressure changes during the test.

E-2.5.5.2 Observation Zone [Basal Well]

The log-log analyses of pumping (annotated) and recovery phases show consistent responses and were analyzed with the following model:

<table>
<thead>
<tr>
<th>Inner Boundary:</th>
<th>Line Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation:</td>
<td>Homogeneous</td>
</tr>
<tr>
<td>Outer Boundary:</td>
<td>Channel Boundaries, Both No Flow</td>
</tr>
</tbody>
</table>

The derivative data use to diagnose the formation model is less noisy compared to the source zone as the response is significantly less influenced from small fluctuations in the pumping rate. The match between the data and type curves is poor in the early time; the data shows wellbore storage and skin effects while the observation model is limited to a line source. The poor match to the early time data results in significant uncertainty in parameters derived from the time match including storativity and distance to boundaries.

After the wellbore storage effects, the derivative data shows a brief period of leveling off which was used to derive transmissivity. In late time, the derivative data shows an increasing trend indicating a restriction in flow away from the borehole. In this case, the restriction was assumed to be 2 no flow boundaries. The increasing derivative data may also be attributed to a less well connected fracture system away from the borehole. In late time, like the source zone, the derivative data shows an undulating character signifying that barometric effects are beginning to mask the formation response.

The parameters derived from the analysis of the observation data is summarized in Table E-11.

The entire simulation match shows a good match to the start of the phase that is being analyzed and a relatively poor match to the remainder of the data set. The good match to start of the phase indicates that the early time and mid time data are responding to pumping events in the source zone and the late time is being influenced by atmospheric pressure changes.

E-2.5.5.3 Discussion

The computed hydraulic conductivity from all the analyses shows a range of approximately half an order of magnitude, 1041 to 6651 ft/day. The difference in flow models between the source and observation zone may be attributed to noise masking the true formation response in the pumping well. Because of the noisy derivative data in the
source zone, a homogeneous formation model was selected to simplify the analysis. The observation derivative data shows an easily recognized restriction in flow away from the borehole that may be attributed to 2 no flow boundaries (channel boundaries) or a less well connected fracture system away from the borehole. The derived storativity in the observation data is poorly constrained but the order of magnitude indicates a confined aquifer response. As the distance to boundaries is also computed with the derived storativity, these values should also be viewed with caution.
### TABLE E-1

Basal Well Borehole Diameters

<table>
<thead>
<tr>
<th>Interval [ft BGS]</th>
<th>Borehole Diameter [in.]</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10.2</td>
<td>20.0</td>
<td>Backfilled excavation around casing</td>
</tr>
<tr>
<td>10.2 to 202.8</td>
<td>17.5</td>
<td>Drilled with a 17.5 inch tricone bit</td>
</tr>
<tr>
<td>202.8 to 993.5</td>
<td>13.0</td>
<td>Drilled with a 12.25 inch tricone bit but survey showed borehole diameter at least 13&quot;</td>
</tr>
</tbody>
</table>
### TABLE E-2

Basal Well Casing and Screen Details

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor Casing</td>
<td>0 - 10.2</td>
<td>19.000</td>
<td>20.000</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>Surface Casing</td>
<td>0 - 202.8</td>
<td>13.250</td>
<td>14.000</td>
<td>Welded Carbon Steel</td>
</tr>
<tr>
<td>Well Casing</td>
<td>0 - 820.6</td>
<td>8.000</td>
<td>8.625</td>
<td>ASTM-606-75 Type 4 Corten Steel Casing w/ stainless steel welds</td>
</tr>
<tr>
<td>Screen</td>
<td>820.6 - 971.1</td>
<td>8.375</td>
<td>8.625</td>
<td>Stainless Steel Type 304 with 3/16&quot; openings and 29.2 in² of openings per linear foot with stainless steel welds</td>
</tr>
</tbody>
</table>
TABLE E-3
Basal Well Summary of Annular Material

<table>
<thead>
<tr>
<th>Type</th>
<th>Interval [ft BGS]</th>
<th>Outer Wall</th>
<th>Inner Wall [gallons]</th>
<th>Quantity [gallons]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powdered Bentonite</td>
<td>9.2 to 10.2</td>
<td>21&quot; borehole</td>
<td>20&quot; casing</td>
<td>5</td>
</tr>
<tr>
<td>Neat Cement w/3-5 % Bentonite</td>
<td>0 to 202.8</td>
<td>0-10.2 ft - 20&quot; casing; 10.2 - 202.8 - 17.5&quot; borehole</td>
<td>14&quot; casing</td>
<td>2900</td>
</tr>
<tr>
<td>1:1 Cement to Sand Grout</td>
<td>0 to 600.1</td>
<td>0 - 202.8 - 13.25&quot; casing; 202.8 - 600.1 - 13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>4850</td>
</tr>
<tr>
<td>Neat Cement w/3-5 % Bentonite</td>
<td>600.1 to 796.7</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>2600</td>
</tr>
<tr>
<td>Bentonite Chips</td>
<td>796.7 to 806.7</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>150</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>806.7 to 810.2</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>40</td>
</tr>
<tr>
<td>3/8&quot; Basalt Chips</td>
<td>810.2 to 841.9</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>600</td>
</tr>
<tr>
<td>3/8&quot; Gravel</td>
<td>841.9 to 971.1</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>1120</td>
</tr>
<tr>
<td>3/8&quot; Basalt Chips</td>
<td>971.1 to 993.5</td>
<td>13&quot; borehole</td>
<td>N/A</td>
<td>200</td>
</tr>
</tbody>
</table>

EXHIBIT 8
Golder Associates
TABLE E-8

Input Parameters Used In the Analyses

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kunia Well (source zone)</th>
<th>Basal Well (observation well)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole Radius</td>
<td>17.5 in.</td>
<td>13 in.</td>
</tr>
<tr>
<td>Top of Interval</td>
<td>824.0 ft BGS</td>
<td>826.0 ft BGS</td>
</tr>
<tr>
<td>Bottom of Interval</td>
<td>967.0 ft BGS</td>
<td>972.0 ft BGS</td>
</tr>
<tr>
<td>Interval Thickness</td>
<td>143.0 ft</td>
<td>146.0 ft</td>
</tr>
<tr>
<td>Storativity</td>
<td>3.10E-05 -¹</td>
<td>Derived In Analysis</td>
</tr>
<tr>
<td>Distance to Source Zone</td>
<td>N/A</td>
<td>156 ft</td>
</tr>
</tbody>
</table>

¹) The assumed storativity is strongly correlated to skin.
TABLE E-9

Summary of Results for Analysis of Pump Test Data

<table>
<thead>
<tr>
<th>ZONE</th>
<th>PHASE</th>
<th>INNER BOUNDAR</th>
<th>FORMATION</th>
<th>UPPER BOUNDAR</th>
<th>T [m²/s]</th>
<th>K [m/s]</th>
<th>K [ft/day]</th>
<th>S [-]</th>
<th>s</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Pumping</td>
<td>WBS &amp; Skin</td>
<td>Homogeneous</td>
<td>Infinite</td>
<td>3.33E-01</td>
<td>7.63E-03</td>
<td>2159</td>
<td>3.10E-05</td>
<td>102</td>
<td>2.14E-02</td>
</tr>
<tr>
<td>Source</td>
<td>Recovery</td>
<td>WBS &amp; Skin</td>
<td>Homogeneous</td>
<td>Infinite</td>
<td>3.56E-01</td>
<td>8.16E-03</td>
<td>2309</td>
<td>3.10E-05</td>
<td>109</td>
<td>4.35E-02</td>
</tr>
<tr>
<td>Sensitivity Analyses of Pumping Phase for Source Zone - Lower Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.68E-01</td>
<td>3.68E-03</td>
<td>1041</td>
<td>3.10E-05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity Analyses of Pumping Phase for Source Zone Upper Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.40E-01</td>
<td>1.70E-02</td>
<td>4811</td>
<td>3.10E-05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>Pumping</td>
<td>Line Source</td>
<td>Homogeneous</td>
<td>Channel Boundaries</td>
<td>1.05E+00</td>
<td>2.35E-02</td>
<td>6651</td>
<td>3.16E-05</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Observation</td>
<td>Recovery</td>
<td>Line Source</td>
<td>Homogeneous</td>
<td>Channel Boundaries</td>
<td>9.98E-01</td>
<td>2.24E-02</td>
<td>6339</td>
<td>3.16E-05</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Storativity is an assumed parameter in the source zone analysis and matched parameter in the observation zone analysis. The storativity derived in the observation zone analysis is poorly constrained due to poor early time match to the model.
### TABLE E-11

Summary of Results from Analysis of Observation Zone Data

<table>
<thead>
<tr>
<th>Phase</th>
<th>S [-]</th>
<th>T [m²/s]</th>
<th>K [m/s]</th>
<th>K [ft/day]</th>
<th>D1 [m]</th>
<th>D3 [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>3.16E-05</td>
<td>1.05E+00</td>
<td>2.35E-02</td>
<td>6651</td>
<td>4952 1)</td>
<td>13045 1)</td>
</tr>
<tr>
<td>Recovery</td>
<td>3.16E-05</td>
<td>9.98E-01</td>
<td>2.24E-02</td>
<td>6339</td>
<td>5952 1)</td>
<td>20048 1)</td>
</tr>
</tbody>
</table>

1) Parameters are poorly constrained due to poor early time match between data and model.
Date: May 3, 2001
To: Calvin Oda, Del Monte Fresh Fruit Hawaii
From: John F. Mink, Mink and Yuen, Inc.
Re: Proposed allocation for Del Monte Wells 2703-01 and 02; potential effects on the Board of Water Supply Honouliuli Wells.

The Board of Water Supply (BWS) has suggested that CWRM conduct groundwater modeling to determine whether increase in pumpage at 2703-01 and 02 by 0.846 mgd to total 1 mgd will have an effect on salinity of the BWS Honouliuli Wells 2303-03, 04, 05, and 06. No model in use today would be able to unequivocally make such a determination.

A numerical model to evaluate the impact of increasing pumping in the Ewa-Kunia Aquifer System by 2 mgd is discussed in the USGS report by W.R. Souza and W. Meyer (1995, Numerical Solution of Regional Changes in Groundwater Levels and in the Fresh Water – Salt Water Interface Induced by Increased Pumpage at Barbers Point Shaft, Oahu, Hawaii: U.S. Geological Survey Water Resources Investigation 95-246). That model, prepared for the US Navy, attempted to define the consequences of increasing the Barbers Point Shaft production by 2 mgd over the contemporary rate of about 2 mgd. At that time the authors reported total allocation for the Aquifer System as 16 mgd and, based on their model, recommended that the allocation for Barbers Point Shaft could be increased by 2 mgd to bring the Aquifer System average to 18 mgd without creating problems at other stations exploiting the aquifer.

The authors concluded that at an Aquifer System pumpage of 18 mgd the rise of the transition zone, the source of salinity in pumping wells, would be 30 feet at the Barbers Point Shaft and 15 feet at 2703-01. At BWS Honouliuli the extrapolated rise would be about 20 feet. The attached graph from the report illustrates the changes.

Assuming that the model calculations could be linearly transposed to pumpage of 1 mgd at 2703-01, the rise in the transition zone at the Honouliuli wells would be about 7.5 feet. As in all models, these are coarse approximations, but they probably are of the correct magnitude.
The deepest of the Honouliuli Wells (2303-04) reaches to 134 feet below sea level (BSL). The Souza-Meyer estimate of the thickness of the transition zone above the Ghyben-Herzberg sharp interface in the vicinity of Barbers Point Shaft - Honouliuli is 300 feet. Head at Honouliuli is 15 to 16 feet, say 15.5 feet, and thus the theoretical depth to the midpoint of the transition zone is 620 feet (40 x 15.5). This means that the top of the transition zone lies 320 feet BSL (620 - 300). The vertical distance between the bottom of the deepest well and the calculated top of the transition zone is 186 feet. A rise of 7.5 feet in the transition zone resulting from pumping 1 mgd at 2703-01 would reduce the distance to 179 feet, about 96% of the putative distance at Aquifer System pumpage of 16 mgd. This small a rise is unlikely to affect salinity in the BWS Honouliuli Wells.

The above conclusions are extrapolated from the Souza - Meyer model and consequently are far from being accurate, but they nevertheless indicate the improbability that pumping 1 mgd at 2703-01 will measurably influence salinity at the BWS wells. Another numerical model would not appreciably improve on the Souza - Meyer effort. Numerical models are not casually created nor do they generate acceptable results without a great deal of contention among investigators.
Figure 2.4: Hydrologic section through Waianae aquifer showing estimated freshwater-saltwater interface and depth of screened intervals of selected wells. Line of section A-A' shown in Figure 2.2; well locations are shown in Figure 7.
Théis Drawdown Calculation

by Glenn Bauer & Roy Hardy with numerical approximations by Huntoon (1980)

FILE NAME = Del Monte Well 2703-01.02
TEST NAME = K value from an aquifer test (recovery) performed by Golder Associates
DATE = October 1997

INPUT PARAMETERS GREEN VALUES

| Transmissivity | T = 531,070 ft.²/day |
| Storage Coeff. | S = 0.200 dimensionless |
| Time | t = 200,000 days |
| Pumping Rate | Q = 134,759.36 cubic ft./day |

Aquifer thickness | b = 230 ft. |
Hydraulic Conductivity | K = 2,309.0 ft./day |
Pumping rate | Q = 700 gpm |
| | 1.008 mgd |
| | 1.560 cfs |

Radial distance from well r ft.

| Drawdown s | u | W(u) ft. |
| 1 | 0.000000 | 27.807 |
| 10 | 0.000000 | 21.572 |
| 50 | 0.000000 | 18.353 |
| 100 | 0.000000 | 16.968 |
| 250 | 0.000000 | 15.134 |
| 500 | 0.000000 | 13.748 |
| 1000 | 0.000000 | 12.361 |
| 1500 | 0.000001 | 11.550 |
| 2000 | 0.000002 | 10.975 |
| 2500 | 0.000003 | 10.529 |
| 3000 | 0.000004 | 10.164 |
| 5000 | 0.000012 | 9.142 |
| 22000 | 0.000228 | 7.756 |

OBSERVATION WELL

Radial distance r from pumping well = 22000 ft.

| Drawdown s | u | W(u) ft. |
| 1 | 0.000000 | 0.000 |
| 10 | 0.000000 | 45.568381 |
| 50 | 0.000000 | 22.784190 |
| 100 | 0.000000 | 15.189460 |
| 250 | 0.000000 | 11.392095 |
| 500 | 0.000001 | 9.113676 |
| 1000 | 0.000002 | 7.594730 |
| 2000 | 0.000003 | 6.509769 |
| 3000 | 0.000004 | 5.696048 |
| 5000 | 0.000012 | 4.556838 |
| 22000 | 0.000228 | 3.227 |

Theoretical drawdown a mile (5,280 ft) from the pumping well when u =< 0.01

T = 531,070 ft²/day
Sp. yield = 0.2
| Drawdown s | u | W(u) ft. |
| 1 | 0.000000 | 0.000 |
| 10 | 0.000000 | 45.568381 |
| 50 | 0.000000 | 22.784190 |
| 100 | 0.000000 | 15.189460 |
| 250 | 0.000000 | 11.392095 |
| 500 | 0.000001 | 9.113676 |
| 1000 | 0.000002 | 7.594730 |
| 2000 | 0.000003 | 6.509769 |
| 3000 | 0.000004 | 5.696048 |
| 5000 | 0.000012 | 4.556838 |
| 10,000 | 0.000046 | 3.227 |

EXHIBIT 10
INPUT PARAMETERS GREEN VALUES

Transmissivity T = 1,154,500 ft^2/day
Storage Coeff. S = 0.200 dimensionless
Time t = 200,000 days
Pumping Rate Q = 134,759.36 cubic ft/day

Radial distance from well r ft.

<table>
<thead>
<tr>
<th>r (ft)</th>
<th>u</th>
<th>W(u)</th>
<th>Drawdown s</th>
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Aquifer thickness b = 500 ft.
Hydraulic Conductivity K = 2,309.0 ft/day
Pumping rate Q = 700 gpm

Theoretical drawdown a mile (5,280 ft) from the pumping well when u<= 0.01

T = 1154500 ft^2/day
Sp. yield = 0.2
t = 365 days
s = 0.048 ft.

EXHIBIT 11
April 2, 2001

Gilbert S. Coloma-Agaran, Chairperson
Department of Land and Natural Resources
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Subject: Water Use Permit Application for Del Monte Fresh Produce (Hawaii) Inc.
Ewa-Kunia Ground Water Management Area, Oahu

Dear Mr. Coloma-Agaran:

Thank you for the opportunity to comment on the above-referenced water use permit application.

The Office of Hawaiian Affairs is aware that the Commission on Water Resource Management recently revised the sustainable yield from 20 mgd. to 16 mgd. for the Ewa-Kunia Water Management Area. At present, there is an available balance of 1,508 mgd. We are concerned that if the Commission grants the permit application for Del Monte Fresh Produce (Hawaii) Inc. for Well Nos. 2703-01 & 02, the Ewa-Kunia Water Management Area will reach its sustainable yield. We hope that adequate long range plans have been done to properly inform decision-making on this permit that will push water use in this area to its maximum limit.

If you have any questions, please contact Sharla Manley, assistant policy analyst, at 594-1944 or e-mail her at sharlam@oha.org.

Sincerely,

Colin C. Kippen, Jr.
Deputy Administrator

cc: Board of Trustees
    Randall K. Ogata, Administrator

EXHIBIT 12
Ref:2703-1b.let

May 4, 2001

Colin C. Kippen, Jr.
Deputy Administrator
State of Hawaii
Office of Hawaiian Affairs
711 Kapiolani Blvd., Ste. 500
Honolulu, HI 96813

Dear Mr. Kippen:

Water Use Permit Application
Del Monte Fresh Produce (Hawaii) Inc.
Kunia Well and Basal Well (Well Nos. 2703-01 & 02)
Ewa-Kunia Ground Water Management Area, Oahu

This is in response to your review comments on the above-referenced application. You are correct in that there is only 1.508 mgd of available sustainable yield in the Ewa-Kunia Aquifer System.

Because of the uncertainties regarding the Ewa-Kunia sustainable yield estimate, the Commission has adopted a milestone approach to management. We have attached a copy of the submittal to the Commission that outlines our strategy. Exhibit 5 of the submittal shows the milestone actions and their triggers. Current actions to ensure the continued viability of the aquifer include the development of a deep well monitoring plan and an aquifer-wide water shortage plan.

The Commission has also adopted a framework for updating the Hawaii Water Plan (attached) to enable the development of alternative strategies that can address future uncertainties. We hope that future updates to the counties' water use and development plans adequately account for all water needs and identify alternative sources of water that can be used to meet those needs.

If you have any questions, please contact Lenore Nakama at 587-0218.

Sincerely,

[Signature]

LINNEL T. NISHIOKA
Deputy Director

LN:k/ky
Attachments

EXHIBIT 13
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<th>Drilled Latitude</th>
<th>Drilled Longitude</th>
<th>Drilled Type</th>
<th>Drilled Dia. (in.)</th>
<th>Total Depth (ft)</th>
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<th>Bottom Perf Casing</th>
<th>Bottom Hole Elevation</th>
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</table>
May 4, 2001

Ms. Lenore Nakama
State of Hawaii
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nakama,

Following up on our telephone conversation regarding the Honolulu Board of Water Supply's request to conduct modeling to estimate the potential impacts of increased pumping of the Kunia Well (State Well No. 2703-01) on the Honouliuli II Wells (State Well No(s). 2303-03, 2303-04, 2303-05, and 2303-06) are the following enclosures.

1. Technical Memorandum prepared by Golder Associates, Inc. dated November 6, 1998 on the basal aquifer testing using the Kunia Well at the pumping well and the Basal Well (2703-02) as the observation well.

2. Technical Memorandum prepared by Dr. John Mink on behalf of Del Monte Fresh Produce (Hawaii) Inc. dated May 3, 2001 providing qualitative evidence that pumping of the Kunia Well at a higher rate will not have an influence on salinity of the Honouliuli II wells.

Hopefully, this information will be sufficient to address the BOWS's request for the evaluation of the potential impacts of the increased allocation for the Kunia Well.

Thank you for changing the date for the hearing on Del Monte's request for the increased allocation for the Kunia Well from May 18 to June 20, 2001.

If there are any questions, please do not hesitate to call me at (808) 621-1205. Thank you for your support and assistance in this matter.
Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda.
Director, Pineapple Research

xc:  R. Pang
     Dr. J. Mink
Date: May 3, 2001  
To: Calvin Oda, Del Monte Fresh Fruit Hawaii  
From: John F. Mink, Mink and Yuen, Inc.  
Re: Proposed allocation for Del Monte Wells 2703-01 and 02; potential effects on the Board of Water Supply Honouliuli Wells.

The Board of Water Supply (BWS) has suggested that CWRM conduct groundwater modeling to determine whether increase in pumpage at 2703-01 and 02 by 0.846 mgd to total 1 mgd will have an effect on salinity of the BWS Honouliuli Wells 2303-03, 04, 05, and 06. No model in use today would be able to unequivocally make such a determination.

A numerical model to evaluate the impact of increasing pumping in the Ewa-Kunia Aquifer System by 2 mgd is discussed in the USGS report by W.R. Souza and W. Meyer (1995, Numerical Solution of Regional Changes in Groundwater Levels and in the Fresh Water – Salt Water Interface Induced by Increased Pumpage at Barbers Point Shaft, Oahu, Hawaii: U.S. Geological Survey Water Resources Investigation 95-246). That model, prepared for the US Navy, attempted to define the consequences of increasing the Barbers Point Shaft production by 2 mgd over the contemporary rate of about 2 mgd. At that time the authors reported total allocation for the Aquifer System as 16 mgd and, based on their model, recommended that the allocation for Barbers Point Shaft could be increased by 2 mgd to bring the Aquifer System average to 18 mgd without creating problems at other stations exploiting the aquifer.

The authors concluded that at an Aquifer System pumpage of 18 mgd the rise of the transition zone, the source of salinity in pumping wells, would be 30 feet at the Barbers Point Shaft and 15 feet at 2703-01. At BWS Honouliuli the extrapolated rise would be about 20 feet. The attached graph from the report illustrates the changes.

Assuming that the model calculations could be linearly transposed to pumpage of 1 mgd at 2703-01, the rise in the transition zone at the Honouliuli wells would be about 7.5 feet. As in all models, these are coarse approximations, but they probably are of the correct magnitude.
The deepest of the Honouliuli Wells (2303-04) reaches to 134 feet below sea level (BSL). The Souza-Meyer estimate of the thickness of the transition zone above the Ghyben-Herzberg sharp interface in the vicinity of Barbers Point Shaft - Honouliuli is 300 feet. Head at Honouliuli is 15 to 16 feet, say 15.5 feet, and thus the theoretical depth to the midpoint of the transition zone is 620 feet (40 x 15.5). This means that the top of the transition zone lies 320 feet BSL (620 - 300). The vertical distance between the bottom of the deepest well and the calculated top of the transition zone is 186 feet. A rise of 7.5 feet in the transition zone resulting from pumping 1 mgd at 2703-01 would reduce the distance to 179 feet, about 96% of the putative distance at Aquifer System pumpage of 16 mgd. This small a rise is unlikely to affect salinity in the BWS Honouliuli Wells.

The above conclusions are extrapolated from the Souza - Meyer model and consequently are far from being accurate, but they nevertheless indicate the improbability that pumping 1 mgd at 2703-01 will measurably influence salinity at the BWS wells. Another numerical model would not appreciably improve on the Souza - Meyer effort. Numerical models are not casually created nor do they generate acceptable results without a great deal of contention among investigators.
Figure 24. Hydrologic section through Waianae aquifer showing estimated freshwater-saltwater interface and depth of screened intervals of selected wells. Line of section A-A' shown in figure 23; well locations are shown in figure 7.
E-1. BASAL WELL DRILLING AND WELL CONSTRUCTION

The Basal Well (USGS #27032) was drilled between September 11 and October 6, 1997 to a total depth of 993.5 feet below ground surface (ft BGS). The well installation was completed on October 16, 1997. Drilling and well installation were completed by Roscoe Moss, Hawaii Inc. Pertinent details for the borehole and well installation are summarized in Tables E-1 to E-3. The location of the Basal Well, and the boring log/well construction diagram are shown in Figures 2-2 and 3-20, respectively, of the main text.

E-1.1 Drilling

Prior to drilling, piezometer P-1 was abandoned and the soil in vicinity of the new Basal Well was excavated. A 20 inch O.D. conductor casing was then installed in the pre-existing excavation to a depth of 10.2 ft BGS. A bag of powdered bentonite was placed around the outside of the casing to act as a seal. The excavation was backfilled around the conductor casing to a depth of approximately 4 to 5 ft BGS; cement was then used to create a working pad for the drill rig to the surface.

Drilling was performed with a top drive air rotary rig using a 900 SCFM compressor. The circulation medium was “AMPLI-FLOW” foam. The foam was circulated down through the drill pipe and out through the drill bit, and then upwards in the annular space between the hole and drill pipe to the surface, carrying the cuttings in suspension. At the surface, the foam was washed to remove cuttings. The cuttings were logged by a Golder geologist and archived, typically in 5 foot intervals. No loss circulation zones were encountered while drilling. The drilling penetration rate is shown in Figure E-1. The boring log for the well is shown in Figure 2-15 of the main text of this report.

Drilling started at 10.2 ft BGS with a 17.5 inch tricone bit and continued to 202.8 ft BGS, some 12.8 ft below the top of the unweathered basalt. The drilling was interrupted to install 14 inch O.D. surface casing. The annular space between the casing and the borehole walls was sealed with neat cement containing 3-5% bentonite. The seal was placed with a tremie pipe.

The drilling resumed at 202.8 ft BGS with a 12.25 inch tricone bit and continued to the total depth of 993.5 ft BGS. Deviations surveys were performed with a TOTCO model 26-26A every approximately 30 ft. If the deviation measurements were greater than the 30 minutes, the interval was “reamed” by running the drill bit up and down the interval until the deviation was corrected. In addition, Baker Hughes INTEQ performed a gyroscopic multi-shot survey to measure the deviation in three coordinates after installation of screen and casing. The results show a total deviation of 2.66 ft in the horizontal direction of S 41.70 E, well within state regulations. The survey also shows that water level measurements made in the well need to be subtracted by 0.01 ft to obtain the true vertical distance from the ground surface.

After the total depth of the borehole was reached, the tools were removed to the surface and preparations were made for well casing and screen installation. First, a 13 inch diameter “cage” was constructed and lowered to the bottom of the hole on a wireline. As
the cage reached the bottom of the hole, the open borehole was confirmed to be at least 13 in. and sufficiently large to accommodate both the 8.625 inch O.D. casing and 1.5 inch tremie pipe. The larger hole in relation to the 12.25 inch bit size can be attributed to reaming. Secondly, 60 ft of 8 inch casing was welded together and lowered to the bottom of the borehole on a wireline. By reaching the bottom of the hole, no significant deviations were confirmed and the casing therefore would not encounter restrictions during well installation.

E-1.2 Well Construction

The well screen consists of Roscoe Moss 8 5/8-inch OD Type 304 stainless steel “Ful-Flo” louvered screen with 0.25 inch wall thickness (ASTM A-409). The casing was Corten 8 5/8-inch OD steel blank casing with 0.312 inch wall thickness (ASTM A-606-75 Type 4). The louvered screen openings are 3/16 inch diameter and provide 29 in.² of open area per linear ft. A stainless steel louvered screen was chosen for its greater strength over the more commonly used continuous slot type.

The 8-inch screen and casing were installed by welding approximately 20 ft sections with stainless steel welds. The top of the 150.5 ft length of screen with end cap was placed at 820.6 ft BGS, some 5.4 ft above the top of the water table. The seasonal fluctuations in the potentiometric surface are expected to be less than 5 feet; therefore the top of the screen will normally be above the water table.

Annular material was placed around the screen and casing to enhance specific capacity and seal off perched water bodies to prevent vertical migration along the borehole. Several measures were taken to ensure that the annular material was placed at the correct depth and to assure that material did not bridge resulting in air gaps: 1) the theoretical annular volume was calculated, 2) volume of material placed in the hole was accurately measured, 3) the depth to the top of the annular material was frequently taken with a sounding rod, and 4) a tremie pipe was used.

All material placed in the annulus below the water table was washed. Chemical analyses were provided to ensure the lack of significant amount of carbonate material, and sieve analysis was conducted by the supplier to ensure compatibility with the size of the screen openings. Basalt chips (3/8 inch) were placed in the open hole below the bottom of the screen. All the gravel (3/8 inch) present on site was used to fill the annular space adjacent to the screen to 841.9 ft. The locally supplied basalt chips were then used to fill the annular space to 810.2 ft, some 10.4 ft above the top of the screen. A 13.5 ft seal of fine sand and bentonite chips was placed above the basalt to prevent the downward vertical migration of the overlying grout seal.

The mixture for the grout seal above the sand pack consisted of 7 gallons of water per 94 pound bag of Portland Type1-II cement with 3 to 5 % powdered bentonite. This mixture was used to fill the annular space between to 600.1 ft BGS. Above this point, sand was

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added at equal parts to cement to prevent loss of grout into the formation. In general, the used annular material was greater then a factor of 2 compared to the theoretical annular space volume.

E-1.3 Well Development and Pump Installation

Well development is required to grade the sand pack to optimize production and remove foam that entered the aquifer while drilling. The well was developed with air on October 17, 1997 for 4 hours at a discharge rate of 20 gpm. During this time, the appearance of the water changed from murky to clear. After the 7.5 hp electric sampling pump was installed on October 20, 1997, the well was further developed by pumping at 20 gpm for over 50 hours. The pump intake is located at 885.0 ft BGS and contains a 2 inch I.D. discharge pipe.

E-1.4 Water Notes While Drilling

Table E-4 provides a summary of the water notes while drilling. Two potential perched water bodies were detected while drilling:

1. Prior to installation of the surface casing, perched water was measured in the open borehole at 38.3 ft BGS. The measurements were taken after the borehole was idle for more then 12 hours. The bottom of the perched water zone is uncertain but does not extend below 202.8 ft BGS as no water was encountered in the hole after drilling resumed with the surface casing sealed.

2. The driller noted water in the hole between 658 and 705 ft BGS based on the wetness of the foam that was being circulated out of the borehole while drilling through this interval. At 658 ft BGS, a reddish brown basalt was encountered and the drilling penetration rate increased.

The depth to the water table in the basal aquifer was measured at 826.00 ft BGS on October 17, 1997.

E-2. BASAL WELL AND PERCHED AQUIFER TESTING

E-2.1 Introduction

The objectives of the testing program were to derive hydraulic parameters that may be used in both help determining the lateral and vertical extent of contamination in the groundwater system, and to evaluate and select remedial alternatives, if deemed to be necessary. Both the shallow perched water in the saprolite and the basal aquifer in the basalt were investigated. Slug tests were performed in the perched water to determine local hydraulic properties. A constant rate withdrawal and recovery test was conducted in the basal aquifer to derive more areal scale properties and qualitative information for the geometry of the flow system.
E-2.2 Software

Two software packages were used to analyze the test data. Golder's in house program FLOWDIM, version 3.14, was used to interpret slug test data with the deconvolution method (Chakrabarty and Enachescu, 1997). The deconvolution method and conversion of slug test data to equivalent constant rate allows for significantly improved recognition of the flow model resulting in improved reliability of derived parameters. This technique incorporates both the pressure change and the derivative of pressure change to reduce ambiguity in the analyses.

The basal aquifer constant rate pump test data was analyzed with INTERPRET/2 (INT2) of SCIENTIFIC SOFTWARE INTERCOMP, Windows version 1.6. INT2 contains full superposition to interpret both the pumping period and recovery phase. In addition, the program contains a variety of near wellbore, formation and outer boundary models that can be used with a linear regression matching routine to derive an optimized set of hydraulic parameters.

E-2.3 Equipment

The response of the aquifer to induced disturbances and barometric changes was measured with Geokon Vibrating Wire Transducers, Model 4500L. The specifications for the transducers used in the investigation are provided in the Table E-5.

The gauges measure changes in both water levels and atmospheric pressure. Atmospheric pressure changes were monitored on site manually with a Weens and Plath Barometer. In regards to test data, the resolution is the most important specification as hydraulic parameters are derived from absolute pressure changes. The 50 psi gauge is able to detect pressure changes of 0.0125 psi (0.35 in. of hydraulic head) or greater. For the 10 psi gauge, pressure changes of 0.0025 psi (0.07 in. of hydraulic head) or greater can be recognized above gauge noise.

Prior to the start of the pumping test, the gauges were lowered in the well below the water table and function checked by moving the gauges a specified distance and recording the corresponding pressure change. The results, provided in Table E-6, confirms that the gauges were recording within the manufactures specifications.

An existing inline flow meter was used to measure the discharge from the Kunia Well during the pump test. As no calibration records exist, the meter was checked at the operating rate of 325 gallons per minute using a 915 gallon tank and a stop watch. The measured rate was 323 gallons per minute and considered within the accuracy of the method of measurement. Hence, the flowmeter rate of 325 gallons per minute was confirmed to be an accurate representation of the actual flow rate.
E-2.4 Shallow Perched Water

Slug tests were performed in 2 inch diameter monitoring wells MW-1, MW-2, MW-3S, MW-3, MW-5, MW-6 and in 1 inch diameter piezometers P-3, P-4 and P-6. It was not possible to perform tests in P-7 and P-8 as silt had filled the bottom of the boreholes to near the water table.

E-2.4.1 Test Design

The slug test procedure is detailed below:

1. Measure static water level with an electric tape and place transducers in well below the water table;
2. Monitor static conditions prior to start of test to evaluate barometric effects or significant interference effects;
3. Perform at least 1 withdrawal and 1 injection test utilizing either 1 gallon of deionized water injected at the surface or a solid PVC rod;
4. Repeat test if results are anomalous;
5. Continue test until at least 90% recovery is obtained.

Due to restrictions from the small diameter of the piezometers, the slug tests were limited to the injection type and water level changes were monitored with a stop watch and electric tape. All tests in the monitoring wells were performed with pressure transducers with the exception of MW-6. This borehole was drilled after the transducers were returned to the manufacturer and therefore, an injection test was carried out with an electric tape and stop watch.

No significant barometric or interference effects were detected with the exception of tests performed in MW-5. These tests show anomalous responses in mid to late time data and recovery to non-static conditions. The test was repeated several times with the same atypical response. Hence, the analysis approach was to analyze the early time data, prior to the non-formation responses, to derive the appropriate hydraulic parameters.

E-2.4.2 Slug Test Analyses

The slug analyses procedure was as follows:

1. Identification of the flow model by evaluation of the derivative data on the log-log diagnostic plot;
2. Match the data to the appropriate type curves;
3. Examine the match on Ramey A, B, and C with each plot emphasizing different parts of the data set;
4. Iterate between plots until the quality of fit is optimized.

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The Ramey A analyses, equivalent to the Cooper technique, was typically selected to show the match between the data and type curves. The data was matched with two models: homogenous and composite. The composite model is recognized as two stabilization's or leveling off of the derivative data on the log-log deconvolution plot. Each stabilization represents a radial cylindrical region about the well with different transmissivities. The outer zone transmissivity is considered to be more representative of the formation response as the inner zone parameters may be influence by the disturbed zone adjacent to the well.

The derived storativity is less well constrained compared to transmissivity due to its correlation to skin. In most cases the skin was assumed to be zero due to the lack of “clean” early time data to select the appropriate type curve. Hence, if the actual skin is 2, the storativity will be underestimated by approximately 2 orders of magnitude.

E-2.4.3 Slug Test Results

The results for the slug test analyses are summarized in Table E-7. Transmissivity was derived from the analyses and hydraulic conductivity was computed by assuming that the contributing flow was evenly distributed over the saturated portion of the screened interval. The 9 test intervals in the saprolite perched water body shows a range of less than 2 orders of magnitude, 3.24E-06 cm/s to 2.11E-04 cm/s. In intervals with results derived from both injection and withdrawals test types, there is good consistency with the difference less than one half an order of magnitude. It is interesting to note that the lowest permeability was measured in monitoring wells MW3 and MW3S which show the highest concentration of EDB/DBC.

E-2.5 Basal Aquifer

E-2.5.1 Background Monitoring in Kunia Well

Remedial Investigation Technical Memorandum 97-3 required monitoring of static conditions in the Kunia Well for at least a two week period prior to the pumping test. The purpose of this monitoring was to evaluate the influence of atmospheric pressure changes on transducer measurements. This background monitoring was deemed necessary as the expected drawdown in the observation well, located approximately 156 ft from the pumping well, was 2 to 4 in. This response may be of the same order of magnitude as atmospheric pressure changes. As mentioned above, the transducers measure absolute changes in pressure above the transducer. Hence, if atmospheric pressure increases, the water level will be depressed for a confined aquifer. In this case, the transducer will record an increase in pressure as the total pressure, water and air, has increased above static conditions.

The static conditions were monitored for some 24 days with a pressure transducer starting on September 17, 1997. The acquisition rate was initially 120 seconds and was later increased to 500 seconds to reduce the size of the data file. Simultaneously, manual
atmospheric pressure readings were taken, typically several times a day, from an onsite barometer. Both the transducer readings in psi and barometers readings in mbar were converted to in. of water head to allow for comparison between the two measurements.

A comparison between the absolute atmospheric pressure changes and absolute transducer pressure changes generally shows a direct relation with some periodic differences of 0.5 in. of water head. The total pressure change was approximately 1.5 in. of water head for the transducer and 2 in. of equivalent water head for atmospheric changes. Noisy transducer data on October 4 (Day 17.5) and October 6 (Day 18.5) may be attributed to interference effects from activities in the Basal Well, as drilling was below the water table at this time.

E-2.5.2 Test Design

A constant rate test and recovery test was specified using the Kunia Well as the pumping well and the new Basal Well as the observation zone at an approximate distance of 156 feet. The recovery period will provide confirmation of the parameters derived in the production phase. As the test proceeds information is obtained about the system farther from the observation zone. The test duration was to be determined by real time analyses recognizing two important aspects:

1. As the test proceeds, the pressure changes will become smaller and the formation response will be masked by barometric changes;
2. The cone of depression expands logarithmically with time and it generally takes an additional log cycle of data to confirm a boundary or formation response.

The rate was limited to approximately 325 gpm as the maximum capacity of the filtration system. The source zone was to be monitored with a 50 psi transducer to allow for flexibility in the pumping well and a 10 psi transducer was installed in the Basal Well to optimize the resolution for the relatively small expected drawdowns in the observation zone.

E-2.5.3 Measured Pressure Response

A total drawdown of 1.65 psi (3.81 feet of water head) was recorded in the pumping well (Kunia Well) during the 46.23 hours of production at a rate of 325 gpm. The aquifer response shows a relatively rapid pressure change and then a steady monotonic variation in both the pumping and recovery phase. The rapid decline at the start of each phase can be attributed to linear and non-linear head losses near the well referred to as positive skin effects in the petroleum industry. The relatively steady decline after early time data suggests that the production rate was relatively constant during the pumping period. Barometric effects are not considered to significantly influence the measured data except in the late time when the aquifer response is small and in the same magnitude as atmospheric pressure changes.

A total drawdown of 0.0905 psi (2.51 in. of water head) was recorded in the observation well (Basal Well) during the production phase compared to an atmospheric pressure
decline of 0.038 psi (1.05 in. of water head) over the same period. The start of both the production and recovery phase show monotonic changes in pressure that can be attributed to the formation response. In late time data as the formation pressure changes become relatively small, the data shows unusual undulating responses that can be ascribed to significant influence from atmospheric pressure changes.

E-2.5.4 Test Analyses

The input parameters used in the analyses are summarized in Table E-8.

Both the pumping and recovery phases were analyzed in the source and observation zones using INT2. The interpretation strategy was as follows:

1. Identify the flow model by evaluation of the derivative data in the log-log diagnostic plot;
2. Match the test data with the appropriate type curves using a non-linear regression algorithm to provide an optimized set of parameters, emphasizing the early and mid time data as the late time noisy derivative data is likely influenced by atmospheric changes;
3. Simulate the entire test sequence in Cartesian coordinates; this final step is used to check the consistency of the model to the entire data set.

E-2.5.5 Results

The results of the analyses of the pumping test data are provided in Table E-9.

E-2.5.5.1 Source Zone [Kunia Well]

The source and recovery phases show consistent responses and were analyzed with the following model:

- **Inner Boundary:** Wellbore Storage and Skin
- **Formation:** Homogeneous
- **Outer Boundary:** Infinite Lateral Extent

The pumping phase log-log plot is annotated to show which part of the data is use to derive the corresponding parameters: the wellbore storage and skin is derived from the early time data and the transmissivity is taken from the assumed radial flow stabilization, leveling off, of the derivative data. The relatively large separation of the pressure and pressure derivative data indicates a restriction in flow close to the wellbore resulting in a high matched positive skin. As there is no clear stabilization in the derivative data due to noise resulting from small fluctuations in the rate, the approach was to assume the stabilization in the middle of the data to derive a best estimate for transmissivity. In addition, sensitivity analyses were performed for transmissivity by assuming radial flow stabilizations near the top and bottom of the mid time derivative data to derive upper
and lower limits. The late time derivative data after 10 hours shows an undulating response that is signature for barometric effects and therefore not emphasized. The results are summarized in Table E-10.

The simulation match shows a reasonable match to entire data set with discrepancies partially attributed to atmospheric pressure changes during the test.

E-2.5.5.2 Observation Zone [Basal Well]

The log-log analyses of pumping (annotated) and recovery phases show consistent responses and were analyzed with the following model:

- Inner Boundary: Line Source
- Formation: Homogeneous
- Outer Boundary: Channel Boundaries, Both No Flow

The derivative data use to diagnose the formation model is less noisy compared to the source zone as the response is significantly less influenced from small fluctuations in the pumping rate. The match between the data and type curves is poor in the early time; the data shows wellbore storage and skin effects while the observation model is limited to a line source. The poor match to the early time data results in significant uncertainty in parameters derived from the time match including storativity and distance to boundaries.

After the wellbore storage effects, the derivative data shows a brief period of leveling off which was used to derive transmissivity. In late time, the derivative data shows an increasing trend indicating a restriction in flow away from the borehole. In this case, the restriction was assumed to be 2 no flow boundaries. The increasing derivative data may also be attributed to a less well connected fracture system away from the borehole. In late time, like the source zone, the derivative data shows an undulating character signifying that barometric effects are beginning to mask the formation response.

The parameters derived from the analysis of the observation data is summarized in Table E-11.

The entire simulation match shows a good match to the start of the phase that is being analyzed and a relatively poor match to the remainder of the data set. The good match to start of the phase indicates that the early time and mid time data are responding to pumping events in the source zone and the late time is being influenced by atmospheric pressure changes.

E-2.5.5.3 Discussion

The computed hydraulic conductivity from all the analyses shows a range of approximately half an order of magnitude, $10^{4.1}$ to $6651$ ft/day. The difference in flow models between the source and observation zone may be attributed to noise masking the true formation response in the pumping well. Because of the noisy derivative data in the
source zone, a homogeneous formation model was selected to simplify the analysis. The observation derivative data shows an easily recognized restriction in flow away from the borehole that may be attributed to two no flow boundaries (channel boundaries) or a less well connected fracture system away from the borehole. The derived storativity in the observation data is poorly constrained but the order of magnitude indicates a confined aquifer response. As the distance to boundaries is also computed with the derived storativity, these values should also be viewed with caution.
### TABLE E-1

Basal Well Borehole Diameters

<table>
<thead>
<tr>
<th>Interval [ft BGS]</th>
<th>Borehole Diameter [in.]</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 10.2</td>
<td>20.0</td>
<td>Backfilled excavation around casing</td>
</tr>
<tr>
<td>10.2 to 202.8</td>
<td>17.5</td>
<td>Drilled with a 17.5 inch tricone bit</td>
</tr>
<tr>
<td>202.8 to 993.5</td>
<td>13.0</td>
<td>Drilled with a 12.25 inch tricone bit but survey showed borehole diameter at least 13 in.</td>
</tr>
</tbody>
</table>
**TABLE E-2**

Basal Well Casing and Screen Details

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor Casing</td>
<td>0 - 10.2</td>
<td>19.000</td>
<td>20.000</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>Surface Casing</td>
<td>0 - 202.8</td>
<td>13.250</td>
<td>14.000</td>
<td>Welded Carbon Steel</td>
</tr>
<tr>
<td>Well Casing</td>
<td>0 - 820.6</td>
<td>8.000</td>
<td>8.625</td>
<td>ASTM-606-75 Type 4 Corten Steel Casing w/ stainless steel welds</td>
</tr>
<tr>
<td>Screen</td>
<td>820.6 - 971.1</td>
<td>8.375</td>
<td>8.625</td>
<td>Stainless Steel Type 304 with 3/16&quot; openings and 29.2 in² of openings per linear foot with stainless steel welds</td>
</tr>
</tbody>
</table>

Golder Associates
<table>
<thead>
<tr>
<th>Type</th>
<th>Interval [ft BGS]</th>
<th>Outer Wall</th>
<th>Inner Wall</th>
<th>Quantity [gallons]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powdered Bentonite</td>
<td>9.2 to 10.2</td>
<td>21&quot; borehole</td>
<td>20&quot; casing</td>
<td>5</td>
</tr>
<tr>
<td>Neat Cement w/3-5% Bentonite</td>
<td>0 to 202.8</td>
<td>0-10.2 ft - 20&quot; casing; 10.2-20.8 - 17.5&quot; borehole</td>
<td>14&quot; casing</td>
<td>2900</td>
</tr>
<tr>
<td>1:1 Cement to Sand Grout</td>
<td>0 to 600.1</td>
<td>0 - 202.8 - 13.25&quot; casing; 202.8 - 600.1 - 13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>4850</td>
</tr>
<tr>
<td>Neat Cement w/3-5% Bentonite</td>
<td>600.1 to 796.7</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>2600</td>
</tr>
<tr>
<td>Bentonite Chips</td>
<td>796.7 to 806.7</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>150</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>806.7 to 810.2</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>40</td>
</tr>
<tr>
<td>3/8&quot; Basalt Chips</td>
<td>810.2 to 841.9</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>600</td>
</tr>
<tr>
<td>3/8&quot; Gravel</td>
<td>841.9 to 971.1</td>
<td>13&quot; borehole</td>
<td>8.6&quot; casing</td>
<td>1120</td>
</tr>
<tr>
<td>3/8&quot; Basalt Chips</td>
<td>971.1 to 993.5</td>
<td>13&quot; borehole</td>
<td>N/A</td>
<td>200</td>
</tr>
</tbody>
</table>


**TABLE E-8**

Input Parameters Used In the Analyses

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Kunia Well (source zone)</th>
<th>Basal Well (observation well)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borehole Radius</td>
<td>17.5 in.</td>
<td>13 in.</td>
</tr>
<tr>
<td>Top of Interval</td>
<td>824.0 ft BGS</td>
<td>826.0 ft BGS</td>
</tr>
<tr>
<td>Bottom of Interval</td>
<td>967.0 ft BGS</td>
<td>972.0 ft BGS</td>
</tr>
<tr>
<td>Interval Thickness</td>
<td>143.0 ft</td>
<td>146.0 ft</td>
</tr>
<tr>
<td>Storativity</td>
<td>3.10E-05 -¹</td>
<td>Derived In Analysis</td>
</tr>
<tr>
<td>Distance to Source Zone</td>
<td>N/A</td>
<td>156 ft</td>
</tr>
</tbody>
</table>

¹) The assumed storativity is strongly correlated to skin.
### TABLE E-9

Summary of Results for Analysis of Pump Test Data

<table>
<thead>
<tr>
<th>ZONE</th>
<th>PHASE</th>
<th>INNER BOUNDAR</th>
<th>FORMATION</th>
<th>OUTER BOUNDAR</th>
<th>T [m/s]</th>
<th>K [m/s]</th>
<th>K [ft/day]</th>
<th>S [-]</th>
<th>s</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>Pumping</td>
<td>WBS &amp; Skin</td>
<td>Homogeneous</td>
<td>Infinite</td>
<td>3.33E-01</td>
<td>7.63E-03</td>
<td>2159</td>
<td>3.10E-05</td>
<td>102</td>
<td>2.14E-02</td>
</tr>
<tr>
<td>Source</td>
<td>Recovery</td>
<td>WBS &amp; Skin</td>
<td>Homogeneous</td>
<td>Infinite</td>
<td>3.56E-01</td>
<td>8.16E-03</td>
<td>2309</td>
<td>3.10E-05</td>
<td>109</td>
<td>4.35E-02</td>
</tr>
<tr>
<td>Sensitivity Analyses of Pumping Phase for Source Zone - Lower Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensitivity Analyses of Pumping Phase for Source Zone Upper Limit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observation</td>
<td>Pumping</td>
<td>Line Source</td>
<td>Homogeneous</td>
<td>Channel Boundaries</td>
<td>1.05E+00</td>
<td>2.35E-02</td>
<td>6651</td>
<td>3.16E-05</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Observation</td>
<td>Recovery</td>
<td>Line Source</td>
<td>Homogeneous</td>
<td>Channel Boundaries</td>
<td>9.98E-01</td>
<td>2.24E-02</td>
<td>6339</td>
<td>3.16E-05</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Note: Storativity is an assumed parameter in the source zone analysis and matched parameter in the observation zone analysis. The storativity derived in the observation zone analysis is poorly constrained due to poor early time match to the model.
### TABLE E-11

Summary of Results from Analysis of Observation Zone Data

<table>
<thead>
<tr>
<th>Phase</th>
<th>S [-]</th>
<th>T [m²/s]</th>
<th>K [m/s]</th>
<th>K [ft/day]</th>
<th>D1 [m]</th>
<th>D3 [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>3.16E-05</td>
<td>1.05E+00</td>
<td>2.35E-02</td>
<td>6651</td>
<td>4952</td>
<td>13045</td>
</tr>
<tr>
<td>Recovery</td>
<td>3.16E-05</td>
<td>9.98E-01</td>
<td>2.24E-02</td>
<td>6339</td>
<td>5952</td>
<td>20048</td>
</tr>
</tbody>
</table>

1) Parameters are poorly constrained due to poor early time match between data and model.
April 5, 2001

Ms. Linnel T. Nishioka
Deputy Director
State of Hawaii
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nishioka,

Thank you again for meeting with Dr. John Mink and I on March 1, 2001 regarding the pending water use permit application for the Kunia Well battery (State Well No. 2703-01 and 2703-02). The current water allocation in the Wahiawa High Level Aquifer System and the increased allocation for the Kunia Well located in the Ewa-Kunia Aquifer System will greatly support the expansion of Del Monte Hawaii Gold thus preserving existing jobs and creating new agricultural jobs.

Pursuant to your letter dated March 6, 2001, is the following information to support the requested water allocation.

5-Year Drip Irrigation System Installation Plan

As we discussed, Del Monte is happy to report that Del Monte Hawaii Gold, a new, extra sweet golden variety with about four times the Vitamin C than traditional pineapples is being expanded on Del Monte's Oahu Plantation. Del Monte Hawaii Gold grows faster and requires more water to maintain uniform, growth and development than traditional Smooth Cayenne varieties that are currently produced.

Based on commercial production practices from other growing areas, the requirement for Del Monte Hawaii Gold is significantly higher than the current allocation of 2,000 gallons per acre per day. Rather than add more confusion, Del Monte will provide justification for a greater water allocation after the drip conversion and Hawaii Gold expansion is implemented.

An integral part of the expansion is to increase irrigation supply line capacity and install drip irrigation systems in all of the Kunia Section fields. Under current conditions, approximately 1,643 acres of the 2,594.7 acres located in the Kunia Section are irrigated with drip.
irrigation systems. If approved by executive management, the entire Kunia Section or remaining 951.1 acres will be converted to drip irrigation culture. The business confidential proposed drip irrigation system conversion schedule is shown in Table 1. Please note that the acres may vary slightly from Mr. Robert Pang's recent testimony due to the need to be consistent with the current water allocation permit application.

As stated in our meeting, the current pumpage from the Navy Well (State Well No. 2803-05) and Del Monte Well No. 4 (State Well No. 2803-07) is lower than the total water allocation of 4.32 mgd due to several reasons. In Kunia, there is inadequate supply line capacity to operate irrigation systems efficiently. Use of irrigation water is also hindered by low irrigation efficiency in overhead irrigated fields (only 45 percent of total water requirement applied in year 2000). In January 2000, there was a lightning strike on well 2803-05. In addition, Del Monte experienced a 7 month downtime to repair bowls in the pump for well 2803-07.

Justification for Current Water Allocation

Assuming a watering rate of 2000 gpd, the 2,594 acres in Kunia can use approximately 5.188 mgd. For Del Monte Hawaii Gold irrigation practices in Costa Rica applies about 4,000 gallons of water per acre per day. Del Monte feels strongly that the Hawaii Gold crop grown in the Kunia Section will require more than 2,000 gpd, however, we want to demonstrate our ability to utilize the current allocation prior to requesting any additional assistance.

Del Monte recognizes that our irrigation management has not been effective within the last six years. Del Monte Well No. 4 (State Well No. 2803-07) is operated with a diesel powered turbine pump. We have struggled with operation and maintenance of this system and have replaced or repaired the pump twice in the last six years at great business costs.

As previously stated, the Kunia Section does not have adequate irrigation supply lines to deliver the water as efficiently as desired. We are currently planning to install three new 10 to 12 inch diameter irrigation supply lines to minimize this deficiency.

Starting from 1993, Del Monte began planting pineapples on former sugarcane lands located in Honouliuli. The relatively high capital investment to refurbish previous sugarcane drip irrigation systems consumed available irrigation funds. The current phased approach to drip irrigation system conversion started with the agronomic success of Del Monte Hawaii Gold production on the former
sugarcane lands. The recent marketing success of Hawaii Gold has made it economically feasible to consider conversion of all of the Kunia Section fields to drip irrigation culture.

Use Data

The pineapple crop requires a minimum of 2,000 gpd to maintain uniform and rapid growth and to attain crop yield targets and fruit delivery schedules.

As you know, the water usage for the pineapple fields irrigated with Waiahole Ditch water has been erratic ranging from 1,300 to 2,800 gpd. We have taken steps to improve on irrigation system management to apply consistent amounts of water. The water usage from the fields irrigated by the Waiahole Ditch system are available upon request.

It is acceptable to reduce the allocation for Well Numbers 2803-05 and 2803-07 from 4.32 mgd to 3.96 mgd. Although the existing pumps operated at 100 percent efficiency can attain the 4.32 mgd amount, standard operating procedures requires some down time each day to service the groundwater supply wells limiting actual pumping rates.

On behalf of all of the people at Del Monte, please allow me to thank you for your support and patience in considering the increased water allocation for the Kunia Well battery. Proper irrigation of the Del Monte Hawaii Gold production in the Kunia Section will establish the framework for the future of Hawaiian Agriculture.

Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

xc: R. Pang
Dr. John Mink
<table>
<thead>
<tr>
<th>Year</th>
<th>Field</th>
<th>Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Field 95</td>
<td>153.0 acres</td>
</tr>
<tr>
<td>2002</td>
<td>Field 31</td>
<td>183.8 acres</td>
</tr>
<tr>
<td></td>
<td>Field 32</td>
<td>125.9 acres</td>
</tr>
<tr>
<td>2003</td>
<td>Field 13</td>
<td>124.7 acres</td>
</tr>
<tr>
<td></td>
<td>Field 60</td>
<td>36.8 acres</td>
</tr>
<tr>
<td></td>
<td>Field 68</td>
<td>64.3 acres</td>
</tr>
<tr>
<td>2004</td>
<td>Field 4</td>
<td>53.1 acres</td>
</tr>
<tr>
<td></td>
<td>Field 66</td>
<td>93.5 acres</td>
</tr>
<tr>
<td></td>
<td>Field 67</td>
<td>86.3 acres</td>
</tr>
<tr>
<td></td>
<td>Field 71</td>
<td>29.7 acres</td>
</tr>
<tr>
<td></td>
<td><strong>Total Acres:</strong></td>
<td><strong>951.1 acres</strong></td>
</tr>
</tbody>
</table>
November 17, 2009

Ms. Linnel Nishioka
Deputy Director
State of Hawaii
Commission on Water Resources Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nishioka,

Pursuant to your letter dated October 10, 2000, regarding the Water Use Permit and Pump Installation for the Kunia Well (State Well No. 2703-01) and the Basal Well (State Well No. 2703-02) are the following enclosures.

1. Fifteen copies of the revised Water Use and Pump Installation Application for the Kunia Well and Basal Well (Attachment 1).

2. USGS and TMK map showing the location of the sources and the proposed use locations (Attachment 2).

3. The $25.00 filing fees for the water use permit and pump installation applications have already been payed.

4. The previous memorandum related to water uses in the Kunia Section of the Oahu Plantation is provided for your convenience in Attachment 3.

The modifications to the water use permit and pump installation applications include:

- The previously submitted water use application was revised to list the correct aquifer system source designation. The Kunia Well and Basal Well at the KVA are hydrogeologically located within the Ewa-Kunia Aquifer System.

- The pump installation application was revised to list the correct incremental pumping rate for the Kunia Well and the Basal Well.

Responses to questions posed in the September 24, 1998 letter from Mr. Timothy Johns are provided below. More detailed information is available upon request.
Phase Source Control at the Kunia Village Area

The remedial alternatives for basal groundwater to meet remedial action objectives are described in the Final Draft FS for the NPL Site. In early 2001, the selected remedy will be documented in a Proposed Plan and Record of Decision. A summary of the source control component of the most likely basal alternative that will be required by EPA and the State is described below.

The NPL Site can be geographically defined as the perched aquifer (and deep soils) at the Kunia Village Area (KVA) and the downgradient travel distances of ethylene dibromide (EDB) and 1,2 dibromo-3-chloropropane (DBCP) at MCLs in the Ewa-Kunia Aquifer System near the Kunia Well site.

The modeled worst case downgradient travel distance of DBCP is about a mile to the south-south-westerly direction. An extensive basal groundwater monitoring network will be installed as part of the remedy to provide additional data on groundwater flow direction, estimate the boundaries of the downgradient plume, evaluate performance of source control, and monitor degradation of chemicals that may be migrating from the Kunia Village Area.

The objective of phased source control at the KVA is to contain basal groundwater containing chemicals to the vicinity of the Kunia Well site. After the source is contained, the impacted basal groundwater in the Ewa-Kunia Aquifer System should be restored to concentrations below MCLs within a relatively short period of time. Source control at the KVA will continue to protect and preserve basal groundwater quality until the sources within the perched aquifer at the KVA are removed and treated.

The United States Environmental Protection Agency will require implementation of phased source control at the Kunia Village Area. Phased source control will consist of increasing the pumping capacity of the Kunia Well from 350 gpm to 750 gpm. The Basal Well will be used to evaluate the effectiveness of source control at the KVA.

If source control is not attained at the pumping rate of 750 gpm, it will be necessary to increase pumping capacity in the Basal Well from 20 to 300 gpm pump. If source control is not attained at a pumping rate of 1050 gpm, it may be necessary to activate additional wells for source control that will be installed as part of the remedy for the NPL Site.
Proposed Use of the Treated Water

As part of a Basal Alternative, Del Monte will treat the basal groundwater extracted for source control using air stripping and/or carbon adsorption to meet State MCLs. If the water use permit is approved by the State, the treated water will be used to irrigate pineapple crops in the Kunia Section of the Oahu Plantation.

Based on established water requirements for the 2,595 acres of pineapples, the Kunia Section can efficiently consume more than 5 million gallons of water per day. The water use permit application describes in detail the estimated water use to irrigate the pineapple crop in Kunia Section of the Oahu Plantation. As part of the remedy, additional irrigation infrastructure (pipelines, drip irrigation systems) will be installed in the Kunia Section to consistently use the 5 million gallons of water per day, if the additional water allocation is approved.

Relationship to WUP No. 116

As you know, Water Use Permit No. 116 allows Del Monte Fresh to withdraw 4.32 million gallons of water per day from the Wahiawa High Level Aquifer System for irrigation of the pineapple crops grown in the Kunia Section of the Oahu Plantation.

The current water allocation for Well Nos. 2803-05 and 2803-07 while greatly appreciated is not adequate to meet the water requirements for the pineapple crop grown in the Kunia Section.

If the increased water allocation for the Kunia Well and Basal Well is approved, the use of the treated water for irrigation of pineapples in the Kunia Section will support the attainment of crop yield targets helping to preserve critical agricultural jobs on Oahu. During the current drought, areas that could not be adequately watered are or will experience crop yield reductions of 13 to 26 percent.

If there are any questions, please do not hesitate to call me at (808) 621-1205. Thank you for your support in this matter.
Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

cc: J. Mink
J. Rosati (EPA Region IX)
W. Wong (SDWB)
A. Playdon (HEER)
APPLICATION FOR WATER USE PERMIT

PERMITTEE INFORMATION

1. (a) APPLICANT
   Firm/Name: Del Monte Fresh Produce (Hawaii)
   Contact Person: Mr. Calvin H. Oda
   Address: 94-1000 Kunia Road
   Phone: (808)621-1205

(b) LANDOWNER OF SOURCE
   Firm/Name: The Estate of James Campbell
   Contact Person: Ms. Donna Goth
   Address: 1001 Kamokila Blvd.
   Phone: (808)674-6674

SOURCE INFORMATION

2. WATER MANAGEMENT AREA: Ewa-Kunia Aquifer System
   ISLAND: Oahu

3. (a) EXISTING WELL/DIVERSION NAME AND STATE NUMBER: Kunia Well (State No. 2703-01) / Basa Well (State No. 2703-02)
   (b) PROPOSED (NEW) WELL/DIVERSION NAME:

(c) LOCATION: Address 94-1000 Kunia Road, Kunia, HI 96759
   Tax Map Key: 9 - 2-005-002
   (Attach a USGS map, scale 1"=2000', and a property tax map showing source location referenced to established proper boundaries.)

4. SOURCE TYPE (check one): Stream  □ Basal  □ Dike-confined  □ Perched  □ Caprock
   LOCATION: Address 94-1000 Kunia Road, Kunia, HI 96759
   Tax Map Key: 9 - 2-005-002
   (Attach a USGS map, scale 1"=2000', and a property tax map showing source location referenced to established proper boundaries.)

5. METHOD OF TAKING WATER: Artesian  □ Well & Pump  □ Diverted Surface  □ Other (explain)

USE INFORMATION

6. LOCATION OF PROPOSED WATER USE: (If possible, show on same maps as source location. Otherwise, attach similar maps)
   (a) PUC-Regulated System  □ Intended Dedication to Dept./Board of Water Supply  □ Non-PUC-Regulated Private System
   (b) Proposed use of water is: □ Existing  □ New  □ Both existing & new uses
   (c) Tax Map Key: ____________________________
   (d) Address: ________________________________

   (e) Current State Land Use District(s):
       □ Urban  □ Agriculture  □ Conservation  □ Rural
   (f) Current County Zoning District(s):

   (additional)
   gallons per day (averaged over 1 year)

7. QUANTITY OF WATER REQUESTED: 1.0 mgd 0.846 mgd

8. METHOD OF MEASUREMENT: □ Flowmeter  □ Open-pipe  □ Weir  □ Office  □ Other (explain)

9. QUALITY OF WATER REQUESTED: □ Fresh  □ Brackish  □ Salt  □ Potable  □ Non-Potable

10. PROPOSED USE: □ Municipal (including hotels, stores, etc.)
       □ Industrial
       □ Individual Domestic  □ Irrigation
       □ Military  □ Other (explain)

   For questions 11 & 12: If multiple TMKs are involved where water is to be used, please complete Table 1 on back of application.

11. TOTAL NUMBER OF RESIDENCES TO BE SERVED: NONE

12. TOTAL ACRES TO BE IRRIGATED AND TYPE OF CROP: 2,585 acres

13. PROPOSED TIME OF WATER WITHDRAWAL OR DIVERSION: 6:00am to 6:00am (24 hours)
    (Daytime hours of operation, ex. 7 a.m. to 2 p.m.)

14. APPLICANT MUST ESTABLISH THAT THE PROPOSED USE OF WATER:
   (a) Can be accommodated with the available water source. YES
   (b) Is a reasonable-beneficial use as defined in section 13-171-2, HAR. (see backside of this application) YES
   (c) Will not interfere with any existing legal use. NO
   (d) Is consistent with the public interest. YES
   (e) Is consistent with state and county general plans and land use designations. YES
   (f) Is consistent with county land use plans and general policies. YES

15. REMARKS, EXPLANATIONS: (see backside of this application)

NOTE: Signing below indicates that the signatories understand and swear that: 1) the information provided on this application is accurate and true to the best of the their knowledge; 2) item 14 is the responsibility of the applicant prior to Commission approval; 3) if necessary, further information may be required before the application is considered complete; 4) if a water use permit is granted by the Commission, this permit is subject to prior existing permitted uses, changes in sustainable yields and between floor standards, reserved uses as defined by the Commission, and Hawaiian Home Lands future uses; and 5) Upon permit approval, a water shortage plan must be submitted by the applicant should the Commission require one.

Applicant (print)  Mr. Calvin H. Oda
Signature  ____________________________
Date  7/17/98

Landowner (print)  Ms. Donna Goth
Signature  ____________________________
Date  7/23/98

THE ESTATE OF JAMES CAMPBELL

WUPAFORM(12695)
"Reasonable-beneficial use" means the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is not wasteful and is both reasonable and consistent with the state and county land use plans and the public interest.

15. REMARKS, EXPLANATIONS (cont'd):


### TABLE 1. MULTIPLE TMKs TO USE REQUESTED WATER

<table>
<thead>
<tr>
<th>PROJECT NAME</th>
<th>CATEGORY</th>
<th>NON-USE</th>
<th>NON-TABLED</th>
<th>WM</th>
<th>COUNTY ZONING CODE</th>
<th>NET ACRES</th>
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<th>YEAR 4</th>
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TABLE 1. MULTIPLE TMKs TO USE REQUESTED WATER

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Del Monte Fresh Produce (Hawaii) Inc.
Oahu Plantation General View

Scale: Approximately 1" = 40,000'

May 1980 - Revised 4/80

Schofield Barracks Army Garrison

Wheeler Army Air Field

To Honolulu
Kam Highway

Whitmore Village

NCTAMS Navy Base

Wheel_Anay
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n-Nortla
DelMonte
.Fresh Produce
(Bawaii
Inc.

Oahu Plantation General View

Scale: Approximately 1" = 40,000'

May 1980 - Revised 4/80

Schofield Barracks Army Garrison

Wheeler Army Air Field

To Honolulu
Kam Highway

Whitmore Village

NCTAMS Navy Base
APPLICATION FOR PERMIT

☐ Well Construction or ☐ Pump Installation

1. APPLICANT: (circle primary contact b, c, or) Primary Fax: (808) 621-1296
   (a) WELL OWNER
   Firm Name: Del Monte Fresh Produce (Hawaii) Inc.
   Contact Person: Calvin H. Oda
   Address: 94-1000 Kunia Road
   Kunia, Hawaii 96759

   (b) LANDOWNER
   Firm Name: The Estate of James Campbell
   Contact Person: Ms. Donna Goo
   Address: 1001 Kamokila Blvd.
   Kapolei, Hawaii 96707

   (c) CONTRACTOR
   Firm Name: Roscoe Moss Hawaii, Inc.
   Contact Person: Tracy Runnett
   Address: 95-250A Olai St.
   Kapolei, HI 96707

2. WELL LOCATION/NAME: Kunia Well (2703-01)/Bagal Well (2703-02) Island: Oahu
   Address: 94-1000 Kunia Road, Kunia, Hawaii 96759
   Tax Map Key: 9-2-5-2

3. (a) PROPOSED WORK: ☐ Drill New Well    ☐ Deepen    ☐ Install New Pump
   ☐ Modifying Existing Well    ☐ Redrill    ☐ Modify Pump
   ☐ Abandon/Seal    ☐ Re-drill    ☐ Replace Pump
   * Be sure to complete and submit well abandonment report upon completion of work.

   (b) WELL TYPE: ☐ Dog    ☐ Bored    ☐ Driven    ☐ Drilled    ☐ Radial
   Is this well a part of a battery of wells? ☐ Yes    ☐ No
   (Briefly describe and fill in the diagram on the back of this form.)

4. PROPOSED PUMP INFORMATION: Rated Pump Capacity: 1050 gallons per minute
   Pump Type: (see attached remarks)
   ☐ Deep Well Turbine    ☐ Rotary    ☐ Propeller
   ☐ Submersible    ☐ Rotary-Displacement    ☐ Reciprocating
   ☐ Centrifugal    ☐ Rotary-Gear    ☐ Impulse
   Motor: ☐ Diesel
   ☐ Electric, rated horsepower:
   Gallons per minute

5. PROPOSED USE: ☐ Municipal (Including hotels, stores, etc.)
   ☐ Domestic (including noncommercial water uses)
   ☐ Irrigation (crop)
   ☐ pineapple
   ☐ Other:
   # Dwelling Units
   # Acres

6. (a) PROPOSED AMOUNT OF WITHDRAWAL: 1.0 million gallons per day
   (b) METHOD OF FLOW MEASUREMENT: ☐ Flow-meter    ☐ Open-pipe
   ☐ Office Plate    ☐ Weir

7. PENDING ACTIONS: ☐ CDUA    ☐ SMA    ☐ IOS    ☐ EA
   Completion Date: 7/2/98
   ☐ NONE    ☐ Other (explain)

8. REMARKS, EXPLANATIONS: (see attachment)

   (If more space is needed, continue on back)

Understand that approval of this application attaches the following standard conditions: 1) the proposed work is to be completed within two (2) years of approval date; 2) the contractor shall submit to the Commission a well completion/abandonment report within 30 days after the completion date of the permit work; 3) monthly water use data shall be submitted to the Commission; 4) such approval shall not constitute a determination of correlative water rights and shall not constitute a determination of pumping capacity or future use up to the permitted pump capacity.

Owner: Calvin H. Oda
Signature: 7/2/98

Landowner: Donna Goo
Signature: 7/2/98

Contractor: Roscoe Moss Hawaii, Inc.
Signature: 7/2/98

For Official Use Only: Longitude (  ) Aquifer System Name
Date:
Field Checked By:
Date:
State Well No.

10/10/97 WCPF
9. PROPOSED WELL SECTION

Elevation at top of casing

--- ft., msl.
(surveyed to nearest 0.01 ft)

Cement Grout: _____ ft.
(70% distance surface to water)

Rock Packing: _____ ft.

Hole Diameter: _____ in.
(allow 3" annular space)

Ground Elevation: _____ ft., msl

Solid Casing:
(see well standards)
Material
Length
(90% distance surface to water)

Diameter
Wall thickness

Casing:
☐ Perforated
☐ Screen
(see well standards)
Material
Length
Diameter
Wall thickness
Openings sq. in./L.F.

Open Hole:
Length
Diameter

Total Depth
(± 10 x head)

Approximate elevation at time of filing application. Ground elevation above mean sea level (msl) by a surveyor licensed by the State must be submitted at start of construction. Final elevations of well components shall be submitted in the well completion/well abandonment reports.
8. Remarks, Explanations

If the application for Water Use Permit for an increase in water allocation of 0.846 mgd for the Kunia Well battery, is approved by the State Commission on Water Resource Management, two new pumps will be installed in the Kunia Well (State Well No. 2703-01) and the Basal Well (State Well No. 2703-02).

The existing pump capacities of the Kunia Well and Basal Well are 350 and 20 gallons per minute, respectively. The proposed new pump capacities for the Kunia Well and the Basal Well are 700 and 350 gpm, respectively.

The proposed specifications for the new pump for Kunia Well are 700 gpm, electric motor driven, vertical lineshaft turbine pump. The proposed specifications for the new pump for the Basal Well are 350 gpm electric motor driven, submersible pump.

After completion of the proposed work, the total pumping capacity for the Kunia Well battery will be 1050 gpm. The proposed water use would allow for an average of 1.0 mgd to be withdrawn from the Ewa-Kunia Aquifer System.

For additional information, please refer to the accompanying Application for Water Use Permit.
ATTACHMENT 2
April 5, 2001

Ms. Linnel T. Nishioka
Deputy Director
State of Hawaii
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Nishioka,

Thank you again for meeting with Dr. John Mink and I on March 1, 2001 regarding the pending water use permit application for the Kunia Well battery (State Well No. 2703-01 and 2703-02). The current water allocation in the Wahiawa High Level Aquifer System and the increased allocation for the Kunia Well located in the Ewa-Kunia Aquifer System will greatly support the expansion of Del Monte Hawaii Gold thus preserving existing jobs and creating new agricultural jobs.

Pursuant to your letter dated March 6, 2001, is the following information to support the requested water allocation.

5-Year Drip Irrigation System Installation Plan

As we discussed, Del Monte is happy to report that Del Monte Hawaii Gold, a new, extra sweet golden variety with about four times the Vitamin C than traditional pineapples is being expanded on Del Monte's Oahu Plantation. Del Monte Hawaii Gold grows faster and requires more water to maintain uniform, growth and development than traditional Smooth Cayenne varieties that are currently produced.

Based on commercial production practices from other growing areas, the requirement for Del Monte Hawaii Gold is significantly higher than the current allocation of 2,000 gallons per acre per day. Rather than add more confusion, Del Monte will provide justification for a greater water allocation after the drip conversion and Hawaii Gold expansion is implemented.

An integral part of the expansion is to increase irrigation supply line capacity and install drip irrigation systems in all of the Kunia Section fields. Under current conditions, approximately 1,643 acres of the 2,594.7 acres located in the Kunia Section are irrigated with drip
irrigation systems. If approved by executive management, the entire Kunia Section or remaining 951.1 acres will be converted to drip irrigation culture. The business confidential proposed drip irrigation system conversion schedule is shown in Table 1. Please note that the acres may vary slightly from Mr. Robert Pang's recent testimony due to the need to be consistent with the current water allocation permit application.

As stated in our meeting, the current pumpage from the Navy Well (State Well No. 2803-05) and Del Monte Well No. 4 (State Well No. 2803-07) is lower than the total water allocation of 4.32 mgd due to several reasons. In Kunia, there is inadequate supply line capacity to operate irrigation systems efficiently. Use of irrigation water is also hindered by low irrigation efficiency in overhead irrigated fields (only 45 percent of total water requirement applied in year 2000). In January 2000, there was a lightning strike on well 2803-05. In addition, Del Monte experienced a 7 month downtime to repair bowls in the pump for well 2803-07.

Justification for Current Water Allocation

Assuming a watering rate of 2000 gpd, the 2,594 acres in Kunia can use approximately 5.188 mgd. For Del Monte Hawaii Gold irrigation practices in Costa Rica applies about 4,000 gallons of water per acre per day. Del Monte feels strongly that the Hawaii Gold crop grown in the Kunia Section will require more than 2,000 gpd, however, we want to demonstrate our ability to utilize the current allocation prior to requesting any additional assistance.

Del Monte recognizes that our irrigation management has not been effective within the last six years. Del Monte Well No. 4 (State Well No. 2803-07) is operated with a diesel powered turbine pump. We have struggled with operation and maintenance of this system and have replaced or repaired the pump twice in the last six years at great business costs.

As previously stated, the Kunia Section does not have adequate irrigation supply lines to deliver the water as efficiently as desired. We are currently planning to install three new 10 to 12 inch diameter irrigation supply lines to minimize this deficiency.

Starting from 1993, Del Monte began planting pineapples on former sugarcane lands located in Honolulu. The relatively high capital investment to refurbish previous sugarcane drip irrigation systems consumed available irrigation funds. The current phased approach to drip irrigation system conversion started with the agronomic success of Del Monte Hawaii Gold production on the former
sugarcane lands. The recent marketing success of Hawaii Gold has made it economically feasible to consider conversion of all of the Kunia Section fields to drip irrigation culture.

Use Data

The pineapple crop requires a minimum of 2,000 gpd to maintain uniform and rapid growth and to attain crop yield targets and fruit delivery schedules.

As you know, the water usage for the pineapple fields irrigated with Waiahole Ditch water has been erratic ranging from 1,300 to 2,800 gpd. We have taken steps to improve on irrigation system management to apply consistent amounts of water. The water usage from the fields irrigated by the Waiahole Ditch system are available upon request.

It is acceptable to reduce the allocation for Well Numbers 2803-05 and 2803-07 from 4.32 mgd to 3.96 mgd. Although the existing pumps operated at 100 percent efficiency can attain the 4.32 mgd amount, standard operating procedures requires some down time each day to service the groundwater supply wells limiting actual pumping rates.

On behalf of all of the people at Del Monte, please allow me to thank you for your support and patience in considering the increased water allocation for the Kunia Well battery. Proper irrigation of the Del Monte Hawaii Gold production in the Kunia Section will establish the framework for the future of Hawaiian Agriculture.

Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

xc: R. Pang
Dr. John Mink
Business Confidential Information

Table 1. Proposed Drip Irrigation Installation Schedule

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Del Monte Fresh Produce (Hawaii) Inc.

July 21, 1994

Ms. Rae Loui
Deputy Director
State of Hawaii
Department of Land and Natural Resources
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Ms. Loui,

Subject: Del Monte Fresh Produce (Hawaii) Inc’s Request to Increase Permitted Uses for Del Monte Wells 3 and 4 (Well Nos. 2803-05 and 2803-07) in the Wahiawa Groundwater Management Area, Oahu

Following up on my previous submittal letter to you dated July 17, 1995, providing supporting documentation for Del Monte’s applications for water use permits to modify the allocated use of Wells 3 and 4 to allow for more irrigation water for existing pineapple crops grown in Kunia.

As stated in my previous submittal, previous guidelines for water consumption in pineapple of 1,000 gallons per day are outdated. Based on conservative water consumption rates for current fresh pineapple production operations, a minimum of 1,940 gallons water per acre per day or 0.5 acre inch per week is required to maintain uniform plant growth, maximize crop yields, and optimize saleable product recovery per acre.

After a detailed analysis based on the best available information (Appendix1), Dr. Paul C. Ekern, Professor Emeritus of the University of Hawaii concluded that fresh pineapple crop water requirements is 0.5 acre inch per week. Dr. Ekern strongly supports Del Monte’s water use permit application to allow for increased allocation of water from existing groundwater supply wells for pineapple grown in Kunia (P. Ekern, personal communication).

The pineapple crop in Kunia is suffering due to water stress. In
1995, a 10,000 ton or 9.3 percent decrease in crop yields are expected. Reductions in crop yields due to water stress will result in severe economic losses and the need for extended workforce reductions.

On behalf of all of the people associated with Del Monte Fresh Produce (Hawaii) Inc., we respectfully request that the Commission on Water Resource Management grant the increased water allocation for Wells 3 and 4 for irrigation of existing pineapple crops in Kunia during the next water hearing.

If there are any questions relating to the information provided, please don’t hesitate to call me at (808) 621-1205.

Sincerely,

Calvin Oda
Director, Pineapple Research
Del Monte Fresh Produce (Hawaii) Inc.

xc: B. Nishida
    R. McCloskey
    G. Anderson
Calvin Oda  
19 July, 1995

The effect of mulch and drip irrigation on pineapple irrigation.

General considerations:
1. Pineapple is non-transpiring. Water loss can occur directly from water in leaf axils or droplets of rainfall or dew on the leaf.
2. Plastic mulch forms a vapor barrier over the soil but again water on the mulch can evaporate.
3. Water loss occurs by evaporation from the bare soil walkspace but the immediate soil surface dries rapidly and evaporation is sharply reduced since heat transfer down thru the dry surface slows & evaporation does not have sufficient heat to continue.

Ekern 1965 paper PRI TP 308: Table I shows how pineapple water use was 0.23 that from a pan for all soil moisture stages in fall 1961. Table II shows when soil water was high (0.06 bar stress) pineapple use was 0.19/0.61 = 0.31 pan evaporation. When moisture stress increased to 0.85 bar, pineapple use was 0.11/0.69 = 0.16 pan. Drip irrigation keeps the soil at the higher moisture contents and may well be twice that of pineapple under drier conditions.

Ekern 1967 PRI TP 316, fig 1 and 2 shows that paper and plastic mulch actually increased the rate above that for the unmulched bare soil case when the soil dried to the 0.8 bar stress point. The mechanism is detailed in p 275 para 2, a consequence of the increased soil temperature under the mulch.

Ekern 1966 PRI TP 312 in fig I shows the rapid reduction in bare soil evaporation as the soil dries.

One other factor may play a role as seen in the papers of Randi Schneider et al, Pesticide Sci 1990 and Nematology 1992 since drip irrigation at 13 mm (about ½")/week appears to allow enuf water percolate to affect the distribution of the nematocide. Any percolate will perch on the tillage pan and move from under the mulch to help keep the soil in the walkspace moist and speed evaporative loss.

My WRRC TR 156, Oct. 1983 - Measured evaporation in high rainfall areas, Leeward Koolau range, O'ahu, Hawai'i. has a summary of evaporation rates in the Wahiawa-Waipio area. Again, my report WRRC Special Report 10.16.89. Evaporation along a transect across southern O'ahu, Hawai'i. recaps some of the central O'ahu data. See also my 1965 paper PRI TP 305 on pan evaporation.

The Ekern & Chang DL&NR Report R74 sums pan evaporation for central Oahu as about 72"/year about 1½"/week and 0.3 pan would be about ½"/week for pineapple requirements.

Paul C Ekern

Remember ratoons may depend heavily on aerial roots. Our. ananas ananassoides and bracteatus are doing quite well.
Evapotranspiration of Pineapple in Hawaii

Paul C. Ekern

Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii

The plants of the cerrado and caatinga ecological provinces of Brazil, the suggested original home of pineapple (3), have many and varied mechanisms whereby they have adapted to the frequent development of moisture stress. The pineapple plant presents a peculiarly interesting combination of those traits that have been proposed for xerophytic and scrophylous plants (10, 15). Preferential collapse of the water storage tissue of the leaf in time of moisture stress is further evidence of the intriguing adaptation of the pineapple plant to water deficit (15, 19).

Reduction in the daytime rate of vapor exchange from the pineapple leaf (14) could well be accomplished by the highly cutinized upper epidermis and the deeply entrenched stomatal pores with an overlying mat of trichomes on the undersurface. The very low rate of but 0.3 to 0.5 mg of water lost per cm² of leaf surface in an hour contrasts sharply with the 26 mg from a corn leaf, and the 43 mg from a cocklebur leaf (23). Such restricted daytime gas exchange through the leaf requires some compensatory mechanism for a CO₂ supply for photosynthesis. The acid metabolism of crassulacean plants has been shown to provide such a mechanism, and it has been reported specifically for pineapple (21, 22).

Materials and Methods

Continuous record was made of evaporation from a class A pan (5). Bermuda grass sod, Cynodon dactylon L. Pers., and smooth cayenne pineapple, Ananas comosus L. Merr., were planted in Wahiawa Low Humic Latosol (26) on hydraulic lysimeters (5, 12) at the Pineapple Research Institute field station, Wahiawa (index 820.2, 21° 28' N, 217 m elev.) (24). The lysimeters were 1.525 m square and 0.5 m deep. Continuous record of moisture consumption was made with a float recorder on the hydraulic scale of the lysimeter. Sunlight was recorded by an Eppley pyrheliometer calibrated on the Smithsonian scale (2). Each lysimeter has a self-borer-planting 5 m in width.

Correlative studies of the leaf area indices of pineapple plants were made by tracing onto cardboard or photographic paper the outline of leaves stripped from field plants. Leaf area was interpolated from the accumulated weight of the cardboard. In several instances the leaf area was also calculated from the leaf dimensions based upon a trapezoidal shape. Pineapple crowns newly rooted in water culture at the Honolulu glasshouse of the Pineapple Research Institute were used for the collection of the gas evolved from the roots of the sunlit plants.

Results

The fraction of the day's evaporation that occurred at night (20:00 to 08:00) was measured for the pan. Bermuda grass sod, Latosol, and pineapple plantings in the spring of 1959. Year-old potted pineapple plants had been transplanted onto a lysimeter in October 1958, and were in the red-bud stage of flowering at the time of these measurements. The 0.38 fraction of the water use that occurred at night for the pineapple was in distinct contrast to the 0.17 fraction from the pan, the 0.13 from the sod, and the 0.19 from the Latosol. The pattern of loss for 2-hour intervals clearly demonstrated the suppression of daytime transpiration by the pineapple plants.

In August 1959 the diurnal pattern of the water use of the several surfaces again had the same relative aspect. Sixteen potted pineapple plants about a year old were set on one of the lysimeters to exaggerate the effect of the pineapple cover, since a normal field would have but 9 plants in this area. The Bermuda sod had been clipped short on August 7 after a 10-cm rain had thoroughly wetted the lysimeter. The pattern of water loss from the pan and the sod closely followed sunlight, whereas the pattern for pineapple indicated daytime suppression of transpiration. On days when the leaf axils of the pineapple were filled with water from rainfall, some increase in the daytime consumptive use was found. More precise determination of the moisture use pattern of pineapple was obtained in the fall of 1959 from the lysimeter on which 16 pineapple plants grew through a complete cover of 0.038 mm black polyethylene. Bermuda grass sod and moist Latosol had nearly identical use rates with a strong midday maximum which corresponded closely to the pattern of sunlight. The pineapple had greatly restricted daytime transpiration. The pineapple plants had more nearly complete cover on this lysimeter in April 1960 than in the fall of 1959, and the sharp contrast between the use pattern of pineapple and of
sod persisted. As soil moisture stress beneath the sod increased, the use pattern of the wilted sod gradually approach that of pineapple, with a much reduced rate of loss that was nearly constant day and night.

The effect of pineapple growth and the increased canopy coverage which accompanied that growth was dramatically demonstrated by a series of measurements which were begun in October 1960, when a lysimeter was planted with 9 slips (table I). The plantings were through black polyethylene mulch 0.038 mm thick and 1 m wide. A 50% reduction in the daily rate of consumptive use of water occurred by the time of 60% canopy closure, in August 1961. This reduction took place despite a 2-fold increase in the potential evaporation, as indexed by the rate of pan evaporation.

Comparison of the relative use rates of Bermuda grass sod, pineapple plants 8 months old, and pineapple plants 24 months old demonstrated the increase in suppression of daytime water use as the nontranspiring pineapple canopy increased (fig 1). The moisture use of pineapple after the canopy closed in the fall of 1961 averaged 0.15 of the energy of the incident sunlight.

Measurement of the water use by the 1960 planting was continued into 1962 as the fruit matured, and records for weekly periods (table II) gave what

Table I. Fraction of Sunlight Used to Evaporate Water by a Class A Pan and by Pineapple Planted in October 1960

<table>
<thead>
<tr>
<th>Date</th>
<th>Sunlight, ly/day</th>
<th>Pan</th>
<th>Pineapple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>346</td>
<td>0.77</td>
<td>0.32</td>
</tr>
<tr>
<td>Feb</td>
<td>444</td>
<td>0.56</td>
<td>0.28</td>
</tr>
<tr>
<td>Mar</td>
<td>422</td>
<td>0.58</td>
<td>0.24</td>
</tr>
<tr>
<td>Apr</td>
<td>440</td>
<td>0.65</td>
<td>0.20</td>
</tr>
<tr>
<td>May</td>
<td>546</td>
<td>0.70</td>
<td>0.15</td>
</tr>
<tr>
<td>June</td>
<td>533</td>
<td>0.62</td>
<td>0.13</td>
</tr>
<tr>
<td>July</td>
<td>560</td>
<td>0.67</td>
<td>0.16</td>
</tr>
<tr>
<td>Aug</td>
<td>506</td>
<td>0.63</td>
<td>0.13</td>
</tr>
<tr>
<td>Sept</td>
<td>511</td>
<td>0.68</td>
<td>0.14</td>
</tr>
<tr>
<td>Oct</td>
<td>538</td>
<td>0.69</td>
<td>0.22</td>
</tr>
<tr>
<td>Nov</td>
<td>305</td>
<td>0.62</td>
<td>...</td>
</tr>
<tr>
<td>Dec</td>
<td>363</td>
<td>0.44</td>
<td>0.15</td>
</tr>
<tr>
<td>1962</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jan</td>
<td>349</td>
<td>0.49</td>
<td>...</td>
</tr>
<tr>
<td>Feb</td>
<td>421</td>
<td>0.49</td>
<td>0.19</td>
</tr>
<tr>
<td>Mar</td>
<td>453</td>
<td>0.58</td>
<td>0.20</td>
</tr>
<tr>
<td>Apr</td>
<td>513</td>
<td>0.59</td>
<td>...</td>
</tr>
<tr>
<td>May</td>
<td>599</td>
<td>0.58</td>
<td>0.19</td>
</tr>
<tr>
<td>Jun</td>
<td>568</td>
<td>0.67</td>
<td>0.15</td>
</tr>
<tr>
<td>July</td>
<td>500</td>
<td>0.72</td>
<td>0.09</td>
</tr>
<tr>
<td>Aug</td>
<td>536</td>
<td>0.72</td>
<td>0.09</td>
</tr>
<tr>
<td>Sept</td>
<td>500</td>
<td>0.77</td>
<td>0.08</td>
</tr>
<tr>
<td>Oct</td>
<td>441</td>
<td>0.67</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Table II. Fraction of Sunlight Used to Evaporate Water by a Class A Pan and by Pineapple 18 Months after Planting During a Period of Increasing Soil Moisture Stress

<table>
<thead>
<tr>
<th>1962</th>
<th>Sunlight, ly/day</th>
<th>Pan</th>
<th>Pineapple</th>
<th>Tensiometer, bars</th>
<th>Rainfall, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-4</td>
<td>437</td>
<td>0.61</td>
<td>0.19</td>
<td>0.06</td>
<td>0</td>
</tr>
<tr>
<td>4-8</td>
<td>594</td>
<td>0.66</td>
<td>0.15</td>
<td>0.15</td>
<td>2.38</td>
</tr>
<tr>
<td>8-12</td>
<td>595</td>
<td>0.67</td>
<td>0.15</td>
<td>0.12</td>
<td>0</td>
</tr>
<tr>
<td>12-18</td>
<td>612</td>
<td>0.69</td>
<td>0.12</td>
<td>0.22</td>
<td>1.52</td>
</tr>
<tr>
<td>18-25</td>
<td>560</td>
<td>0.73</td>
<td>0.14</td>
<td>0.50</td>
<td>1.78</td>
</tr>
<tr>
<td>25-2</td>
<td>565</td>
<td>0.72</td>
<td>0.16</td>
<td>0.80</td>
<td>5.35</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-9</td>
<td>576</td>
<td>0.63</td>
<td>0.09</td>
<td>0.85</td>
<td>12.70</td>
</tr>
<tr>
<td>9-16</td>
<td>610</td>
<td>0.69</td>
<td>0.11</td>
<td>...</td>
<td>8.13</td>
</tr>
<tr>
<td>16-23</td>
<td>624</td>
<td>0.73</td>
<td>0.09</td>
<td>...</td>
<td>3.81</td>
</tr>
<tr>
<td>23-30</td>
<td>653</td>
<td>0.79</td>
<td>0.08</td>
<td>...</td>
<td>0.76</td>
</tr>
</tbody>
</table>

* Soil moisture beneath plastic: July 13, 0.33 cc/cc = one-third bar stress; July 27, 0.27 cc/cc = 8 bar stress.
get of the plant. Though there may be potential extension of the root system through a large soil depth, the actual development of the roots in the Latosol is confined to the tilled area (4, 13). Evidence of the shallow depth of rooting was found from the measurements of water withdrawal made with Boyoucos resistance blocks at Wahiawa in 1955. No moisture withdrawal by the pineapple roots was indicated from depths greater than the surface 30 cm of 1.5-m deep percolate lysimeters, whereas moist­

Summary

Full pineapple plant canopy effectively suspended water vapor exchange by midday. This restriction of the water loss rate was accomplished despite a leaf area index of nearly 6. The control of transpiration was a direct physiological function of the pineapple leaf, which is excellently designed for the control of gaseous exchange.

Literature Cited

9. EKERN, P. C. 1965. The disposition of net radia­
14. KRAUSS, B. H. 1930. The transpiration of pine­
might be evidence of some decrease in consumptive use as the soil moisture approached the 15-bar wilting point.

Peculiar evidence for the effective closure of the leaf to gas exchange by day was found in the production of gas from the root tips of pineapple plants growing in water culture. Abel (1) had shown that on bright days with active photosynthesis, this gas, collected from intact root tips, contained 30 to 40% O₂ and was free from CO₂. Gas volumes of 13.7 cc accumulated in a day. The same phenomenon was noted again in 1961, and samples of gas which evolved from broken roots of slips in water culture accumulated as much as 5 cc in an hour at midday. Analysis by gas chromatography indicated the samples to be 78% O₂. The evolution of this gas was closely keyed to sunlight since evolution stopped within a few minutes after a plant became shaded. Excised pineapple leaves also produced the gas, which could be seen escaping from the air channels of the leaf when sunlight struck the leaf. In these leaves, too, evolution ceased shortly after the leaf became shaded.

Lest it be thought that the conservative use of moisture by pineapple planting indicates transpiration from a limited amount of leaf area, measurement was made of the leaf area index (27) (Table III). Leaf area index does not equal total leaf surface but rather only the area of 1 side of the leaf. The leaf area of 13,000 cm² for a pineapple plant gave a comparatively high leaf area index of 5.8 for a conventional planting of 4.3 plants per square meter.

**Discussion**

The initial evaporation rate of the lysimeter with the surface one-half black polyethylene and one-half bare Latosol, newly planted to pineapple, was one-third the rate of pan evaporation and bore out the self-mulching action of the Low Humic Latosol (9). The reduction to rates one-fifth that of pan evaporation or one-sixth of the energy in the sunlight, as the pineapple plant grew to give full vegetative cover, was a remarkable departure. The Bermuda grass sod used water that was equivalent to six-tenths of the energy of the sunlight, a rate reported to be typical for conventional vegetation (25).

The design of the pineapple leaf (15) is ideal for the suppression of water vapor exchange since the stomates are entrenched on the undersurface and are covered with a mass of trichomes (direct observation of the status of stomatal openings is thus precluded). In addition, the heart-shaped array of the erect leaves and the 5/13 and N + 1 phyllotaxy of the leaves concentrates dew and light showers into the axils where the water can be efficiently conserved (16).

The diurnal cycle of the leaf thickness suggests that the plant is most turgid in the afternoon and least turgid early in the morning. (Linford, N. B. 1934. Private publications of the Pineapple Research Institute.) Such a pattern is in accord with the restricted water vapor escape from the leaf by day. A similar reversal of the water balance has been reported for opuntia and other succulent plants where the rate of water uptake from the soil by day has exceeded transpiration (17, 20).

The design of the leaf array and the persistent, small, zenith angles of the noon sun in the subtropics make the net radiation burden on the pineapple very great (7, 8). The thick succulent pineapple leaf was reported (18) to develop temperatures 5° above air temperature. This 5° elevation of the leaf temperature is in close accord with that forecast by Gates (11) for a nontranspiring leaf cooled by convection forced by a 650 cm per second wind under a 1.1 ly per minute radiation load when the ambient air temperature is 30°. This elevated leaf temperature and a total leaf mass some 10-fold that of conventional crops makes the assumption of negligible heat storage in the plant canopy a matter of questionable validity when an attempt is made to strike a heat balance for the pineapple crop.

The restricted development of the pineapple root system is yet another phase of the unusual water bud-
Soil Moisture and Soil Temperature Changes with the Use of Black Vapor-Barr Mulch and Their Influence on Pineapple (Ananas comosus (L.) Merr.) Growth in Hawaii

Paul C. Eckert

ABSTRACT

As the mulching practice in pineapple culture in Hawaii has developed over the last 50 years, a number of functions have been assigned to the action of the mulch. This study gives primary consideration to the effect of soil moisture and soil temperature changes upon pineapple growth. Soil moisture changes were determined from field samplings and lysimeter studies at Wahiawa, Oahu. Changes in the soil moisture budget with the mulch were so slight that the variability of field sampling preceded assessment without excessive replication. Coefficients of variability for samples taken at the plant butt were 3 to 5% of a moisture constant (e.g., 15-bar point) for a soil series or within a single field. Moisture use, measured by semicontained hydraulic lysimeters, was reduced by the mulch when the soil was very wet but changed little when the soil moisture ranged from field capacity (0.15-bar) to the 15-bar point.

The mulch raised the average soil temperature about 1.6°C during the winter. The measured one-third increase in the plant growth was nearly identical with the increase calculated from the growth-response of pineapple to temperature.

The agronomic practice of mulching with paper or plastic has been a unique Hawaiian contribution as indicated by the patents which have been granted for the procedure. (W. J. Hartung. 1928. The function of paper mulch in pineapple culture. Private publication issued by Hawaiian Pineapple Co., Ltd. (Dole Corp.) to its sub-licensees under the Eckart patents in Hawaii.)

The first of these patents, filed in 1914 and obtained in 1916, claimed weed control in sugarcane culture as the prime intent (12). Another patent, obtained in 1917, protected a claim that a higher soil moisture was produced by the black color of the paper mulch. A third patent, obtained in June 1921, claimed that the mulch enhanced growth by promoting the rise in soil temperature, weed control, prevention of evaporation by the waterproof paper, and by channeling the entry of runoff waters from the impervious section onto the perforated section of the mulch.

Stewart et al. (14) reiterated the effect of temperature and moisture changes upon growth and introduced changes in the available plant nutrient status beneath the mulch as an additional factor responsible in part for the increased growth of the pineapple plant. The introduction of soil fumigation as the standard practice in pineapple culture in the 1930's brought yet another role for the mulch into being (3).

Among the functions currently assigned to the mulch are, (i) fumigant retention, (ii) guidance for plant spacing, (iii) accumulation of the heat and moisture budgets of the plant root zone, (iv) change in the budgets of several gases within the soil, (v) weed control by shading and mechanical suppression, and (vi) channeling of runoff and infiltration; hence, change in the pattern of rewetting, leaching, and erosion.

Primary consideration was given in this study to the effect of two general features on plant growth: soil moisture changes and soil temperature changes of Wahiawa Low Humic Latsol with paper or plastic mulched pineapple plantings. Soil moisture changes were determined by field samplings, lysimeter studies, and tensiometer readings. The soil temperature changes were measured with Fries, Palmer, and thermistor instruments. In order to characterize the soil moisture cycle, evaporation was measured by estimation of the plant weight (a highly developed art in pineapple logging) and weighing the largest mature leaf (13).

In accord with the current field practice, about 60% of the soil surface was covered by the mulch. A 0.8-m wide strip of mulch was laid on 1.525-m bed centers with a layer of soil along each edge of the mulch to anchor it to the ground. The pineapple slips were inserted through the mulch approximately 15 cm from each edge.

PROCEDURE AND RESULTS

Field Samplings

Gravimetric determination of soil moisture was made on samples of the 0- to 15-cm soil layer. Detailed moisture measurements were made to ascertain the coefficient of variability of fields composed of single soil series and to establish the effect of the sampling site position relative to the plant.

Minor differences when the soil is mulched with different materials (Table 1) are typical of the extensive field moisture samplings over nearly 50 years. Note particularly that the paper mulch applied in the fall did not preclude the drying of the soil to the 15-bar point by the next spring (Table 1). In this instance, the lowest soil moisture content measured in the unmulched soil (24.8%) was only 3.4% less than the minimum content beneath the black plastic mulch. This is equivalent to 10.2 mm of water in the surface 30 cm of soil and represents a single day of pan evaporation in midsummer (5).

Neither the paper, nor the plastic mulch prevented soil from drying to the 15-bar point when the mulches were applied in the spring (Table 1). On a Molokai site the nearly impervious plastic mulch imposed a lower limit to the soil moisture content measured. The vapor content of the soil air beneath the plastic remained near saturation and the soil moisture content even for the 2.5-cm depth remained near the 15-bar level, 19% for this soil (Holomus Low Humic Lатsols). This was in distinct contrast to extreme drying of the surface layers in the unmulched, bare soil where the moisture content approached the reported air-dry content of 4.67% for a typical Low Humic Latsol in equilibrium with 70% relative humidity at 26.7°C. (C.A. Farden. 1929. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.)

A major limitation to estimates of water-use by sequential gravimetric samples lies in the error from field variability. The soil moisture release curves of the Low Humic Latsol are remarkably uniform within the same soil series. For example, the coefficient of variability of 533 sampling sites on the island of...
### Table 1—Soil moisture content of the 0 to 10 cm layer sampled at the plant butt beneath various mulches at specified periods in 1954

<table>
<thead>
<tr>
<th>Mulch Treatment</th>
<th>Planted in November 1953</th>
<th>Soil water content, % (v/v)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feb. 17</td>
<td>Mar. 19</td>
</tr>
<tr>
<td>Unmulched</td>
<td>20.7</td>
<td>21.2</td>
</tr>
<tr>
<td>Chilled kraft paper (55 lb)</td>
<td>20.6</td>
<td>22.4</td>
</tr>
<tr>
<td>Chilled kraft paper (65 lb)</td>
<td>29.8</td>
<td>25.0</td>
</tr>
<tr>
<td>Ashphalt-saturated felt paper</td>
<td>25.7</td>
<td>23.4</td>
</tr>
<tr>
<td>Black 1.5 mil polyethylene</td>
<td>31.0</td>
<td>32.2</td>
</tr>
<tr>
<td>Clear 1.5 mil polyethylene</td>
<td>31.0</td>
<td>32.0</td>
</tr>
<tr>
<td>Gray 1.0 mil Saran</td>
<td>31.0</td>
<td>32.0</td>
</tr>
<tr>
<td>Clear 1.0 mil polyethylenechloride</td>
<td>31.0</td>
<td>32.0</td>
</tr>
</tbody>
</table>

### Table 2—Evaporation rates from a pan, and from unmulched, paper mulched, and polyethylene mulched Low Humic Latozol measured with hydraulic lysimeters at Wahiawa, Oahu

<table>
<thead>
<tr>
<th>Mulch Treatment</th>
<th>1960</th>
<th>1961</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dec</td>
<td>Jan</td>
<td>Feb</td>
</tr>
<tr>
<td>Water loss rate, mm/day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pan</td>
<td>2.30</td>
<td>4.40</td>
<td>4.00</td>
</tr>
<tr>
<td>Unmulched</td>
<td>2.20</td>
<td>4.40</td>
<td>4.00</td>
</tr>
<tr>
<td>Paper mulched</td>
<td>2.09</td>
<td>2.07</td>
<td>1.97</td>
</tr>
<tr>
<td>Polyethylene mulched</td>
<td>1.91</td>
<td>2.28</td>
<td>1.83</td>
</tr>
</tbody>
</table>

Lanai for the Molokai series had a value of 3.54% of the moisture equivalent (33.8%), 4.51% of the 4-bar content (26.03%), and 4.5% of the 15-bar moisture content (23.4%).

Though small, these variations do introduce error into the determination of the average moisture content for a specific field, though the coefficients of variability for these moisture values within a single field (50 ha), for eight samples of a Wahiawa series soil on Oahu, were only 2.2% of the 4-bar (26.0%) and 2.9% of the 15-bar (23.6%) moisture contents. When a Student's t value of 3 and a coefficient of variability of 5% are assumed for a small sample number at 19:1 odds, with the intent to distinguish a 1% difference in soil moisture content near the 15-bar suction, a minimum of 20 samples is required. This sample number is all too often not used in the assessment of field moisture content.

Soil moisture measurements were made for this same 80 ha field in the summer of 1957 for pineapple planted in July 1956. On six separate occasions, seven samples were taken, each composed of sub-samples from the butt of 20 different plants. The coefficients of variability ranged from 3.46% of an average June moisture content of 19.4% to 6.5% of an average August moisture content of 23.8% and had an average value of 4.44% for the mean moisture content of 30.8% for the six occasions. The 4.44% coefficient of variability of this study in Wahiawa is nearly identical with the 4.4% value reported for a 92.9 m² plot of very fine sandy loam in Nebraska (1).

In another study on Oahu, the coefficient of variability was 7% of a 27.6% moisture content at the plant butt, whereas it was 33.8% of a 24.6% moisture content in the plant line between plants for 10 samples taken 48 hours after root irrigation of a 0.2-ha plot. The sampling site at the plant butt has the least coefficient of variability for it is more uniformly revetted by showers or irrigation; hence, it has been the preferred site for sampling for gravimetric moisture determinations.

### lysimeter Studies

The hydraulic, semicontained lysimeters (8, 10) were 1.525 m³ in area and held a 0.356-m depth of Wahiawa Low Humic Latozol. Each lysimeter had a 7.625-m self-planted buffer zone. The strip of mulch crossed the central part of each lysimeter and formed a direct continuation of the bed pattern of the surroundings. The beds were oriented at right angles to the prevailing east-north-east (70°) trade winds at the Pineapple Research Institute Field Station, Wahiawa, latitude 21°28' N, 121 m elevation. The area immediately upwind from the lysimeters had a 6.437-km fetch over pineapple plantings. Oil saturated, black, creped, 14 mil kraft paper mulch was used on two lysimeters and black 1.5 mil polyethylene was used on three lysimeters. One other lysimeter was mulched only while the fumigant was applied to eliminate the effect of unequal fumigation on the growth response, and the mulch was removed five days later. Each of the lysimeters was planted with nine slips in October 1960. This is equivalent to a planting density of 4.3 plants per square meter. The slips required nearly 12 months to develop a complete canopy cover. During the last months of 1960 and the spring of 1961, water loss from the lysimeter was dominated by the action of the mulch since the pineapple plants were quite small. The unconventional pineapple plants, even if full-grown, will not transpire; hence direct evaporation is always in the ascendancy (6).

During selected periods from December 1960 through March 1961, the unmulched Latozol had evaporation rates that were about one-half that of a Class A pan (Table 2) Shower were frequent and the soil moisture was often returned to 0.43 volumetric fraction (0.05-bar suction) (7). The minimum soil moisture was a 0.33 volumetric fraction, equivalent to 0.33 bar suction.

While the soil remained quite wet, the paper mulch caused a 15.8% reduction and the plastic mulch a 21% reduction in evaporation compared to the rate from the unmulched Latozol. This effect of the mulching materials was compatible with their relative water vapor permeabilities since the rate of evaporation through paper mulch was 15% and through polyethylene mulch only 0.5% that from a free water surface in laboratory tests. (P. C. Ekern, and A. Fo, 1955. *Private publication of the Pineapple Research Institute, Honolulu, Hawaii."

During a period with increasing values of soil water suction in June 1961 (Fig. 1), mulching generally failed to conserve moisture, and the mulched lysimeters frequently evaporated more water than the unmulched one. The water loss from the unmulched lysimeter was now only about one-fifth that from a Class A pan. The paper mulch caused an increase of 8.5% and the plastic mulch an increase of 3% above the rate of evaporation from the unmulched lysimeter. Soil moisture content in the lysimeters at the start was approximately equal to a 0.34-volumetric water content (0.25-bar suction) and had decreased to a 0.30-volumetric water fraction (0.5-bar suction) by the end of the period.

The diurnal pattern of water loss from the several mulching practices had a direct relationship to soil moisture. When the soil was wet (0.05-bar suction), the paper and polyethylene mulches...
each reduced the evaporation, and the diurnal pattern of evaporation from all lysimeters was similar (Fig. 2, July 4-6). When the soil was near field capacity (0.15-bar suction), the amount of evaporation was nearly identical, but the diurnal pattern of the mulched and unmulched lysimeters was different (Fig. 2, May 10-12). The plastic mulch retarded the moisture loss by day but speeded the water loss by night so that the net loss was nearly identical with the unmulched lysimeter. When the soil dried so that the suction was 0.7-bar or more, the unmulched Latosol had the least evaporation (Fig. 2, June 21-23).

Fig. 1—Pan evaporation and the ratio between evaporation from a mulched lysimeter and the pan during a period of increasing soil moisture suction from April through June 1961 at Wahiawa, Oahu.

Fig. 2—The water loss pattern from an unmulched and a black polyethylene mulched lysimeter for periods of increasing soil moisture suction at Wahiawa, Oahu.
Tensiometer Readings and Plant Growth

Tensiometers (30 cm Irrometers), placed with the 15- to 22.5-cm soil zone compassing the porous tip, were installed in the hydraulic lysimeters at the plant butts in the lee and windward lines and through the mulch in the bed center.

The effect of both the presence of the mulch and the bed orientation upon the rewetting pattern of the lysimeter is shown in Fig. 3. Tensiometric readings were reduced as the soil on the windward side was rewetted by late June rains, whereas they remained high and the soil dry beneath the plastic mulch and also beneath the pineapple plants on the lee side of the bed.

Throughout most of the period from the planting in October 1960 until summer 1961, the soil moisture suction measured by tensiometers was approximately 0.05 bars. It had a maximum value of 0.8 bars in late June. Despite the absence of any prolonged period of high soil moisture suction, marked difference in plant growth occurred. By mid-August, plants in the polyethylene mulched lysimeters were one-third larger than those in the unmulched lysimeter. The unmulched canopy covered an estimated 35% of the surface, the larger plants in the paper mulched lysimeter covered 50%, and the still larger plants in the plastic mulched lysimeter covered 60% of the soil surface.

This growth rate gain is typically found for field observations of plant response to mulching in Hawaii.

The roofing action of the mulch is shown in a field situation by Fig. 4, where the bed center beneath the plastic mulch was wetted sufficiently to reduce the suction below the 15-bar point for only a brief interval in March. This is not unlike the features reported for plastic covered ridges by Willis et al. (16). Despite the generally less favorable moisture status of the soil with the plastic mulch (Fig. 4), plant growth by January was 8% greater than the unmulched case and remained greater throughout the summer. Again, the plastic mulch did not prevent the development of 15-bar soil suction though it delayed the attainment of this critical level by one week.

Soil Temperature Studies

Friez recording soil thermographs, Palmer maximum-minimum soil thermometers, and continuously recorded bead thermistors were used to measure soil temperatures. The thermal units of the Friez and Palmer instruments were placed horizontally with the central axes at a nominal 7.5 cm depth.

The average monthly soil temperature measured with a Palmer soil thermograph at Wahiawa beneath unmulched soil ranged from 21.3°C in January to 29.4°C in August for the years 1962 to 1966. The January value for the soil temperature was only 0.5°C warmer than the Wahiawa air temperature at shelter height, but the August value was nearly 5.0°C warmer than the air temperature. The average soil and air temperature were derived from the daily maximum and minimum values. If the daily values were calculated from the average hourly values derived from Friez thermographs, the daily mean would be reduced 0.1°C since the diurnal wave was not truly sinusoidal. The large thermal unit of the Palmer instrument reduced the diurnal range in the soil temperature nearly 5.5°C when compared to the thermistor measurements, but the daily average temperature was nearly identical for measurements taken in August and September 1962. This gives greater credence to the average soil temperatures recorded by the very large elements of the Friez or Palmer Instruments.

Soil temperatures measured by Friez units installed beneath

---

Fig. 3—Tensiometric measurements at the 15- to 22.5-cm depth in several different positions relative to the plant in polyethylene-mulched pineapple planted in October 1960 on lysimeters at Wahiawa, Oahu.

Fig. 4—Gravimetric soil moisture samples of the 0- to 15-cm depth for unmulched and polyethylene mulched pineapple planted in October 1959 at Wahiawa, Oahu.
Table 3—Soil temperatures recorded at a nominal 7.5 cm depth in the plant line at Wahiawa, Oahu. Pineapple planted in November 1953 and growth status assessed in April and May 1954

| Mulch treatment         | Average temperature, °C | Comparative leaf weight |  |  |
|-------------------------|-------------------------|-------------------------|  |  |
|                         | Dec. 1953 to Mar. 1954 (incl.) | Dec. 1953 to April 1954 (incl.) | 7 April | 21 May |
| Unmulched               | 20.6                    | 21.6                    | 1.00       | 1.00       |
| Oiled kraft paper       | 20.7                    | 21.1                    | 1.21       | 1.17       |
| Asphalt-saturated felt paper | 21.6            | 22.1                    | 1.33       | 1.21       |
| Black 1.3 mil polyethylene | 22.4            | 23.1                    | 1.35       | 1.20       |
| Clear 1.5 mil polyethylene | 22.9            | 23.4                    | 1.45       | 1.43       |

Average air temperature 20.5

Table 4—Soil temperatures at a nominal 7.5 cm depth in the plant line for sunny as opposed to cloudy periods at Wahiawa, Oahu beneath pineapple planted in November 1953

<table>
<thead>
<tr>
<th>Mulch treatment</th>
<th>Sunny, warming period 1954</th>
<th>Cloudy, rainy period 1954</th>
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<tr>
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<td>Jan. 17</td>
</tr>
<tr>
<td>Unmulched</td>
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</tr>
<tr>
<td>Oiled kraft paper</td>
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<tr>
<td>Asphalt-saturated felt paper</td>
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<td>21.4</td>
</tr>
<tr>
<td>Black 1.3mil polyethylene</td>
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</tr>
<tr>
<td>Clear 1.5 mil polyethylene</td>
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Average daily temperature, °C

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<tr>
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Air temperature °C

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Sunlight/day

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Rainfall, mm

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<tr>
<td>1.8</td>
<td>1.8</td>
</tr>
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</table>

several different mulching materials at Wahiawa in November 1953 exemplified the mulch-induced increases in the winter (Table 3). Mean monthly soil temperatures beneath the black mulches were as much as 1.6°C warmer than those beneath unmulched soil. This monthly mean was a compound of the rainy days, when no difference was found, and the sunny days when nearly 2°C increases in the average soil temperature were found in January (Table 4).

The growth response of pineapple to the mulching practices was indexed by the measured leaf weights. The expected gain in plant growth from the increase in soil temperature was calculated from the growth response curve of pineapple (13). The exponential portion of this curve with an optimum at 20.4°C was fitted to the relationship:

\[
\log (w/w_o) = 0.0735T - 2.2
\]

where \( w \) = weight at temperature \( T \) °C, and \( w_o \) = weight at optimum temperature. The leaf weights calculated by this relationship from the average soil temperature beneath the several mulches corresponded closely to the measured leaf weights (Table 3). The major portion of the observed growth increase could indeed arise from the extra soil warmth.

DISCUSSION AND CONCLUSIONS

Field variability in soil moisture contents has made difficult, if not impossible, large-scale demonstrations of a reduction in the rate of water loss with paper or plastic mulches in pineapple culture. More precise determination of water loss from lysimeters covered with different mulches has revealed little, if any, reduction in the rate of use of soil moisture from field capacity to the 15-bar point for Latosols in Hawaii. When the soil was frequently wetted by showers, and remained wet (above field capacity, the paper or plastic mulches caused a 20% reduction in the rate of water loss. When the soil was at moisture contents between field capacity and wilting point, the mulch may have even slightly increased the rate of water loss: A most intriguing effect was a greater rate of water loss during the night when the mulch was present.

The plastic mulch is a much better vapor-barrier than the paper mulch, yet neither was an absolute barrier when it covered no more than 60% of the soil surface, a feature not entirely unpredicted (9, 15). Moreover, the Low Humic Latosol forms a very effective self-mulch as it dries, for when the soil moisture reaches field capacity, the rate of water loss falls to but 1/3 that of a pan (7). This low rate from the bare Latosol is nearly identical with the rate of water loss from a pan through a complete cover of the paper mulch, especially after the paper has been exposed for a time to weathering in the field. The excellent vapor-barrier action of the polyethylene persists throughout the life of the mulch. It makes an important reduction in further water loss when extreme drying occurs and soil moisture content nears the 15-bar point. The 15-bar point is critical for root growth just as it forms a critical point for pineapple leaves. (C.P. Sideris and B.K. Krauss 1928. Private publication of the Pineapple Research Institute Honolulu, Hawaii.) Root elongation ceases and root tips suberize when the soil moisture approaches the 15-bar point (M. B. Linsford. 1934. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.) Regrowth by bursting the suberized cap will occur upon rewetting the soil. Prolonged exposure to greater soil moisture stress results in death of the
root and necessitates regrowth from the plant butt upon rewetting of the soil. (B. K. Krauss. 1959. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.)

Increases of 20 to 30% in the rate of vegetative growth of the mulched pineapple have occurred during the winter though soil moisture has been optimum for growth in either case. This accelerated growth of the plant speeds the day when canopy closure occurs and a thick, nontranspiring, insulating mulch of pineapple plant is formed over the soil to reduce the rate of water loss. When a mulch prevents growth of conventional weeds which do transpire, a large contribution can be made toward water savings in pineapple culture.

The change in soil temperature does not stem from the effect of the black mulch net radiation since the reflectance of the Latosol is low and nearly identical with that of the mulch (4). Rather, the vapor-barrier formed by the mulch enhances the apparent thermal conductivity of the Latosol, increases the thermal contact coefficient of the soil in comparison with that of air, and causes more of the net radiation to be stored in the soil by day (2, 11). This more effective entry of heat into the soil beneath the plastic mulch raised the average winter soil temperature at Wahiawa about 1.6°C above that for unmulched soil.

The measured leaf weights recorded in table 3 correspond remarkably well with the calculated values. The 50% increase in plant growth resulting from a 2.75°C rise in soil temperature in winter keynotes the success of the mulching practice in pineapple culture in Hawaii.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the skillful assistance rendered by A. Fo, formerly Junior Soil Scientist, Pineapple Research Institute, for soil samplings and moisture analyses, and J. Fo, Physiologist, Pineapple Research Institute, for plant logs.

LITERATURE CITED

Evaporation from Bare Low Humic Latosol in Hawaii

PAUL C. EKERN

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(Manuscript received 24 September 1964, in revised form 23 November 1965)

ABSTRACT

Despite the high potential evaporation, actual evaporation from Wahiawa Low Humic Latosol measured by hydraulic lysimeters is very low under field conditions. The evaporation from Latosol at field moisture content is only one-third the rate from a pan. The heavy clay soil is so strongly aggregated that the water release for low values of soil moisture suction is determined by the aggregate rather than by the mechanical composition of the soil. The unsaturated hydraulic conductivities determined for the Latosol decrease rapidly as the soil dries, a feature in accord with the self-mulching action of the soil. Moreover, the mineralogic and aggregate composition of the soil make the material an excellent thermal insulator and the consequent restriction of heat flow also reduces the rate of evaporation since much of the water movement within the unsaturated Latosol is in the vapor phase along temperature gradients. The transfer of latent heat within the soil contributes appreciably to the heat storage in the soil.

1. Introduction

The average evaporation rate of 0.75 cm per July day from a class A pan recorded for many areas in Hawaii is evidence of the high potential evaporation rate under Hawaiian conditions (Ekern, 1965b). This high rate of evaporation is in accord with the particularly large fraction of solar and sky radiation which has been reported to be converted into net radiation in Hawaii over several different surfaces (Ekern, 1965a). Specifically over Low Humic Latosol, the high clay and iron oxide contents (Tamura et al., 1953; Uehara et al., 1962) produce a low value of 0.08 for the reflectance which in turn ensures retention of a high fraction of the incident energy as net radiation. Moreover, consideration of other physical properties reported for the Low Humic Latosol (Sherman and Alexander, 1959; Kawano and Holmes, 1958; Trouse and Humbert, 1961; Thorne, 1950; Cornelison, 1954) suggests that the portion of net radiation used by evaporation from bare Latosol might differ sharply from the portion reported as used by evaporation from more conventional mineral soils of the temperate latitudes (Tanner and Lemon, 1962; Wiegand, 1962; Lemon, 1956; Businger and Beuttner, 1961; Hanks et al., 1961). This paper reports measured rates of evaporation from a Low Humic Latosol and determinations of several physical properties of the Latosol pertinent to these evaporation rates. Among these determinations are the moisture content as a function of soil moisture suction, the unsaturated hydraulic conductivities and diffusivities calculated from the outflow characteristics in response to that suction, the thermal diffusivity calculated from temperature profile measurements and the rate of vapor transfer along temperature gradients anticipated within the Latosol.

2. Measured rates of evaporation from Latosol

Evaporation from a Low Humic Latosol (Wahiawa silty clay, Cline et al., 1955) was measured under field conditions by recording hydraulic lysimeters (Ekern, 1965c; Glover and Forsgate, 1962) at the Pineapple Research Institute Wahiawa field station, Oahu (21°31'N, 216 m MSL). The lysimeters were 1.5 m square and contained a 0.35 m depth of Latosol. Continuous measurement of the hydraulic scale was made by a float recorder on an open-end manometer.

There was a very rapid onset of the falling rate portion of the drying curve (McCormick, 1962). This is more clearly shown when the day to day variations in the evaporational stress are smoothed by the transformation of the water loss into the equivalent fraction of the total radiant energy which reached the soil surface (Fig. 1). When the drying rate is represented as a log-log plot of change in volumetric water content of the soil layer with time, the slope ranged from −0.066 to −0.08 even for the very early periods of evaporation. This slope is quite different from the −1.09 to −0.166 values reported for Hidalgo sandy clay loam (Wiegand, 1962), or the −0.25 value reported for Pachappa sandy loam (Richards et al., 1956). This drying rate for the Latosol in Hawaii, while very low compared to the rates for temperate latitude soils, resembles the slow
The relationships for low soil water suctions were determined by pressure plate methods (Fig. 2). The desorption curve of water content (I) for the Wahiawa silty clay loam shows an initial portion of the curve resembling the gravimetric moisture fractions of an Ewa Latosol (Wadsworth, 1944). Moisture equivalent determinations were presumed to represent 0.33 bar of suction and the field capacity approximately 48 hours after thorough flooding of the soil to be a soil water suction of 0.15 bar.

The water release curve for the Wahiawa soil has three major segments. Since the bulk density of the tilled soil is very close to 1.0, the volumetric and gravimetric moisture fractions are essentially identical. The initial portion of the desorption curve depends upon the withdrawal of water from among the soil aggregates. Wet-sieve analyses of this Wahiawa soil showed 80.4 per cent of the particles aggregated into units larger than fine sand (0.25 mm diameter) and 43.7 per cent aggregated into units larger than coarse sand (1 mm diameter). This initial portion of the curve resembles the moisture relationship for selected Davidson soil aggregates reported by Baver (1942). Drainage of the large pores among the aggregates begins with the least amount of soil moisture suction and is nearly completed by 0.3 bar of suction. The gradual nature of the slope of this section indicates a wide array of effective pore sizes and infer a relatively uniform distribution of aggregate sizes. The flexure of the moisture release curve for the Molokai soil more nearly resembles the release curve from well sorted sands and aggregates with little water removal initially and then an abrupt flexure with very rapid removal of the water as suction increases (Fig. 2). The Molokai soil, though a Low Humic Latosol, has much less well developed structure than the Wahiawa (Cagauan and Uehara, 1965) and the moisture release curve gives evidence of this difference. However, the slope of the curves for each of the Latosols is nearly identical beyond the 0.1-bar soil moisture suction.

4. Unsaturated hydraulic conductivities and diffusivities calculated for transient outflow from the Latosol

Since the falling rate phase in the drying of porous materials has been held to be dependent on the failure of liquid water to move to the surface and a consequent retard of the plane of vaporization within the media (McCormick, 1962; Gardner and Hillel, 1962), the unsaturated hydraulic conductivity and diffusivity of the soil are critically related to the nature of evaporation from the Latosol. The hydraulic conductivities of two Low Humic Latosols (Wahiawa silty clay and Molokai silty clay) were calculated from transient outflow of water from tension plate devices (Fig. 3). Samples were taken from both the topsoil (0-15 cm)
Disposition of Net Radiation by a Free Water Surface in Hawaii

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Hawaii Institute of Geophysics, University of Hawaii, Honolulu

Abstract. Temperate latitudinal expressions such as the Dalton and Penman formulations predict class A pan evaporation though certain of the constants seemed unique for the tropics. Air temperature alone was not a sensitive index of evaporation. The winter rate of pan evaporation supports the contention that a large fraction of sunlight is converted to net radiation. The seasonal shift in the fraction of sunlight used for pan evaporation responded to the seasonal shift in net radiation, but also included was the effect of strong positive advection of heat from the surroundings, particularly in the summer. Pineapple planted upwind from the pan served as a dry fetch. Evaporation measured by atmometer followed conventional patterns, with the black Bellani plate as the best index of sunlight and pan evaporation.

Introduction. The fraction of sunlight represented by evaporation from a class A pan at Wahiawa was quite large. This evidence supports the contention that a large fraction of sunlight is converted into net radiation in the tropics (Table 1). The pans had a 25-ft border of Bermuda grass sod but were located immediately downwind from extensive plantings of pineapple. The peculiar moisture use habit of the nontranspiring pineapple would be expected to make even a well-watered pineapple planting act as a dry fetch [Ekern, 1965].

The evaporation from a constant-level, recording class A pan [Campbell et al., 1959] averaged 0.94 times the evaporation from a standard class A pan for a period of 339 days from April 1958 through June 1959 at the Wahiawa experiment station (index 820.2, 710-ft elev., 21°28'N lat.) [Taliaferro, 1961]. The average annual pan evaporation of 73 inches at Wahiawa for the period 1957 through 1962 was in reasonable agreement with other long-term observations on the Wahiawa plain. The annual pan evaporation at Waipahu Sugar Company, field 42 (index 826, 700-ft elev.), was reported as 68.55 inches for the period 1927 through 1951 and at Upper Hoaeae (index 813, 750-ft elev.) as 63.4 inches for the period 1920 through 1938 [Hawaii, 1961].

Dalton representation. Where information was available, pan evaporation could be fitted to a Dalton-type representation [Rohwer, 1931; Kohler et al., 1955] (Figure 1):

\[
\text{Pan evaporation} = (\text{vapor deficit}) \times (a + b \text{ wind})
\]

where \(a\) and \(b\) were constants and the vapor deficit was computed as the difference between saturation at pan water temperature and the actual moisture content of the air at shelter height (4.5 ft). The value of 0.004 for the constant \(b\) from the Wahiawa results resembled other published values for the slope of the wind relationship in miles per day [Kohler et al., 1955; McIlroy, 1957; Reidhead, 1960; Webb, 1960; Robinson and Johnson, 1961; Nordenson and Baker, 1962]. The Wahiawa value for the constant \(a\) seemed unique; it depended on the method for estimation of the average vapor deficit and on the height of the wind measurement as well as on the use of the correction factor recommended for the standard three-cup anemometer at these velocities [Middleton, 1942]. The value of 0.5 for \(a\) with corrected pan-level wind became 0.4 with the corrected wind at 6 ft. Short-term (hourly) intervals allowed a more accurate estimate of the vapor deficit and made the value of \(a\) more nearly 0.4 for the uncorrected pan-level wind and 0.2 for the uncorrected 6-ft-level wind. Limited numbers of hourly observations and the general failure of the Dalton relationship for short-term intervals was apparent in the scatter of the data.

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1 Pineapple Research Institute Technical Paper 305, and Hawaii Institute of Geophysics Contribution 78.
2 Formerly at the Pineapple Research Institute; now at the Hawaii Institute of Geophysics and the Department of Agronomy and Soil Science, University of Hawaii.
TABLE 1. Average Monthly Class A Pan Evaporation and the Fraction of Sunlight Represented by That Evaporation for Pineapple Research Institute Field Station, Wahiawa, for the Period 1957 through 1962

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Pan/ in./ day</td>
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<td>Jan.</td>
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<td>0.58</td>
<td>0.153</td>
<td>0.58</td>
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<td>0.63</td>
<td>0.294</td>
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<td>0.270</td>
<td>0.67</td>
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<td>0.62</td>
<td>0.279</td>
<td>0.71</td>
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<td>0.208</td>
<td>0.68</td>
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* 1 inch of evaporation = 1490 langleys.

The more refined Penman approach [Penman, 1956] to the factors responsible for pan evaporation yielded results which for the daily values clustered about the 1:1 line (Figure 2). Sunlight, wind velocity, temperature, and vapor pressure deficit are combined into a single expression. However, the fraction of sunlight retained as net radiation must be estimated for tropical Hawaiian conditions, and the pan constants recommended for the high-latitude English conditions must be modified. The net radiation over the pan was calculated on the basis of 0.08 short-wave reflectance [Wartena and Borghorst, 1960] and a net long-wave radiation equivalent to 0.08 inches of evaporation per day [Ekern, 1965a]. A psychrometric constant of 0.025 (OF, inches of Hg) was used, but it was not much better than the usual constant of 0.011 [Kohler et al., 1955]. The values for the a and b constants used to calculate

![Fig. 1. Dalton relationship for pan evaporation, Pineapple Research Institute field station, Wahiawa (index 820.2). Daily values, May 1956 to May 1958.](image-url)
the estimate with sufficient rapidity as higher temperatures occurred. Since high summer temperatures bring high evaporation rates at a time critical for plant growth, failure to properly estimate the water use in these periods is a major deficiency of such temperature-based formulas. In continental areas, where air temperature more nearly responds to sunlight, these methods have more merit, though even at best they are of minor value for the establishment of rates for short periods.

Wind effects. Sutton [1955] suggested that evaporation might be a function of the 0.78 power of the wind velocity. In most empirical relationships which have been developed for evaporation the first power has been used, since the limited range of velocities encountered makes this power fit equally as well as the 0.78. Daily pan evaporation at Wahiawa from May 1956 to May 1958, when plotted versus wind on a log-log basis, gave a straight line for a range of wind from 30 to 200 miles per day. The 0.8 power of the wind at 6 ft gave a reasonable relationship between wind and the daily evaporation per unit vapor deficit. Wind less than 3 mph (72 mi/day, corrected value) at pan level sharply restricted the fraction of sunlight used for

Several of the empirical relationships between evaporation and temperature [Tabor, 1931; Thornthwaite, 1948; Criddle, 1953; Bauer, 1954; Holdridge, 1959] have been found to fit reasonably well for temperatures up to 63°F [Pelton et al., 1960], but only the higher power functions of temperature increased the value of the pan evaporation in Figures 2 and 3 are those derived from Wahiawa. The calculated (after Penman) and measured pan evaporation for Maalaea, Maui (index 310), were in general agreement, though a good deal of scatter was present about the 1:1 line (Figure 3).

Temperature-based representation. The extreme simplification wherein evaporation was indexed by air temperature alone formed at best only a rough guide to evaporation, particularly since the day-to-day average temperatures have such small differences under Hawaiian conditions (Figure 4). Adjustment to a standard day-length from 10 hours 50 minutes for winter to 13 hours 17 minutes for summer was not sufficient to eliminate the seasonal loop in the plot of monthly pan evaporation rates and air temperature for Wahiawa that gave a markedly greater rate of summer evaporation over winter evaporation at the same temperature (Figure 5).

Several of the empirical relationships between evaporation and temperature [Tabor, 1931; Thornthwaite, 1948; Criddle, 1953; Bauer, 1954; Holdridge, 1959] have been found to fit reasonably well for temperatures up to 63°F [Pelton et al., 1960], but only the higher power functions of temperature increased the value of the estimate with sufficient rapidity as higher temperatures occurred. Since high summer temperatures bring high evaporation rates at a time critical for plant growth, failure to properly estimate the water use in these periods is a major deficiency of such temperature-based formulas. In continental areas, where air temperature more nearly responds to sunlight, these methods have more merit, though even at best they are of minor value for the establishment of rates for short periods.

Wind effects. Sutton [1955] suggested that evaporation might be a function of the 0.78 power of the wind velocity. In most empirical relationships which have been developed for evaporation the first power has been used, since the limited range of velocities encountered makes this power fit equally as well as the 0.78. Daily pan evaporation at Wahiawa from May 1956 to May 1958, when plotted versus wind on a log-log basis, gave a straight line for a range of wind from 30 to 200 miles per day. The 0.8 power of the wind at 6 ft gave a reasonable relationship between wind and the daily evaporation per unit vapor deficit. Wind less than 3 mph (72 mi/day, corrected value) at pan level sharply restricted the fraction of sunlight used for
evaporation, yet still indicated a value of 0.5 inches of evaporation per inch vapor deficit per day for calm conditions.

Sunlight-based representation. Statistical analysis of the pan evaporation at Wahiawa of days with less than 0.01 inch rainfall for the period May 1958 through May 1959 had the relationship

\[
\text{Pan evaporation} = 0.78 \times \text{sunlight} - 0.043 \text{ in./day}
\]

\[r^2 = 0.69, n = 168\]

Sunlight was converted to equivalent evaporation based on latent heat of 1490 langleys per inch depth of water.

The measured fraction of sunlight represented by class A pan evaporation for Wahiawa had a seasonal swing from 0.55 in February to 0.72 in September, with an annual average value of 0.65 for the period 1957 through 1962 (Table 1).

The monthly averages of pan evaporation displayed a relationship that is comparable to full net radiation when used for evaporation. Even for the rainy months with a moist fetch the expected 0.85 fraction of net radiation used for evaporation seemed too small to be representative [Tanner and Lemon, 1962]. Strong positive advection of heat to the pan must have occurred in the summer months, and in the dry winter periods as well, for evaporation was well in excess of the net radiation.

Monthly averages for selected days with rainfall less than 0.01 in./day still gave a marked seasonal loop with evidence for strong positive advection to the pan through the summer months, though the winter months approached the expected 0.85 net radiation (Figure 6). Several days of peak use in each month, selected...
in an effort to find clear-day cases, again clustered about the full net radiation relationship rather than a fraction thereof.

Evapotranspiration with positive advection of heat from a dry fetch (area upwind) has been reported as equivalent to as much as 1.1 times the net radiation, in contrast to the evapotranspiration with a moist fetch, equivalent to 0.85 of the net radiation [Pruitt and Angus, 1961; Fritschen and van Bavel, 1962; Tannen and Lemon, 1962]. Values of pan evaporation at Wahiawa of 1.1 to 1.2 times the net radiation in periods of strong positive advection would agree with these reports. The consistently high fraction of net radiation used by pan evaporation in the lee of pineapple fields suggests that the pineapple plantings acted as a dry upwind fetch much of the time.

Atmometer evaporation. Sunlight and pan evaporation relationships to several types of atmometers appeared to affirm the contentions held by other workers [Halkias et al., 1955; Holmes and Robertson, 1955; Carder, 1960; Heeney et al., 1961; Noffsinger, 1961; Wilcos, 1962]. A battery composed of triplicates of each of several types of atmometers was exposed immediately adjacent to the pan evaporation site at a uniform height of 3 feet above the ground from May 1958 through May 1959. The relationship to the single-valued black Bellani plate seemed to bear the most useful potential correlation with sunlight and pan evaporation among the following:

\[
\text{Sunlight} = \frac{(282 + 226 \text{ (black-white Livingston in.)})}{1490} = \text{equiv. inches/day}
\]

\[
r^2 = 0.28, n = 169
\]

\[
\text{Sunlight} = \frac{(177 + 91.3 \text{ (black Bellani in.)})}{1490} = \text{equiv. inches/day}
\]

\[
r^2 = 0.546, n = 169
\]

\[
\text{Sunlight} = \frac{(100 + 80.5 \text{ (black Livingston in.)} + 84.5 \text{ (black-white Livingston in.)})}{1490} = \text{equiv. inches/day}
\]

\[
r^2 = 0.596, n = 169
\]

\[
\text{Pan} = \frac{(120.3 + 96.5 \text{ (black-white Livingston in.)})}{1490} = \text{inches/day}
\]

\[
r^2 = 0.15, n = 168
\]

\[
\text{Pan} = \frac{93 \text{ (black Bellani in.)}}{1490} = \text{inches/day}
\]

\[
r^2 = 0.735, n = 168
\]

REFERENCES


Middleton, W. E. K., Meteorological Instruments, University of Toronto Press, 1942.

(Manuscript received August 7, 1964; revised October 30, 1964.)
The reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira) has been a serious pest of pineapple in Hawaii for several decades. The perennial nature of pineapple, with three fruit crops produced from a single planting, requires nematode control over a 4- to 5-year period. Recent changes in commercial pineapple culture in Hawaii include increased use of drip irrigation and a transition from canny operations to fresh fruit production. The most prevalent chemical control strategy is preplant fumigation (1,3-dichloropropene [1,3-D] or methyl bromide) followed by postplant systemic nematicides, usually fenamiphos (ethyl 3-methyl-4-(methylthio)phenyl (1-methylethyl)phosphoramidate) by drip irrigation. A fallow cycle of 6 to 12 months is now used on some plantations to augment chemical control of nematodes. Preplant fumigation is usually sufficient to produce a successful plant crop. This research was part of an integrated effort to evaluate nematicide efficacy by characterizing plant and root development, nematode population dynamics, and fenamiphos concentrations in the soil. We used a combination of nematicides, preplant 1,3-D fumigation, and postplant fenamiphos application, and compared the effect of weekly and restricted irrigation on fenamiphos movement and efficacy.

**Materials and Methods**

**Experimental site:** The experimental plot (0.2 ha) was located near Kunia, Oahu, Hawaii, within a commercial field. Wahiawa silty clay (Tropeptic Eutrustox; sand 7%, silt 40%, clay 53%), is a well-aggregated oxisol that is representative of much of the pineapple acreage on the island of Oahu. Four treatments were replicated three times in a completely random-
Field Movement and Persistence of Fenamiphos in Drip-Irrigated Pineapple Soils

Randi C. Schneider,* Richard E. Green,* Walter J. Apt, b Duane P. Bartholomew* & Edward P. Caswell b

*Department of Agronomy and Soil Science, *Department of Plant Pathology, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822, USA

(Revised manuscript received 19 March 1990; accepted 18 April 1990)

ABSTRACT

The persistence and mobility of fenamiphos and its toxic oxidation products in soil with pineapple cropping were studied in three field experiments on the islands of Oahu and Lanai, and by sampling three commercial fields on Oahu. Fenamiphos was applied by drip irrigation after planting, following pre-plant application of 1,3-dichloropropene (1,3-D) in most treatments. The Oahu experiments, conducted on highly weathered Oxisol and Ultisol soils, evaluated the impact of restricted irrigation to reduce leaching and also the effect of 1,3-D on fenamiphos behavior. Total toxic residue (TTR) concentrations of 1000 µg kg⁻¹ or greater were maintained in the root-zone with fenamiphos applications of 3.4 kg ha⁻¹ tri-monthly on the Oxisol (Kunia site) and bi-monthly on the Ultisol (Whitmore site). The relatively high applications, along with weekly irrigations and unseasonably high rainfall, resulted in leaching of fenamiphos TTR out of the root-zone with concentrations between 10 and 100 µg kg⁻¹ at 3 m depth. Reduced leaching with restricted irrigation was evident in the early months of both Oahu experiments. The potential to minimize leaching of fenamiphos by reduced application rates and limited irrigation during rainy periods was evident from nematicide concentration profiles measured on three commercial pineapple fields on Oahu; little fenamiphos TTR was detectable below 1 m.

1 INTRODUCTION

A long-term field study was conducted to assess the behavior of fenamiphos, an organophosphate nematicide, applied by drip irrigation to several pineapple soils in Hawaii.
Mr. Calvin H. Oda  
Del Monte Fresh Produce (Hawaii) Inc.  
P.O. Box 200  
Kunia, HI 96759

Dear Mr. Oda:

This is in response to your May 4, 2000 letter, requesting preservation of the water allocation for the Kunia Well (Well No. 2703-01).

In setting a new sustainable yield for the Ewa-Kunia Aquifer System, which is the aquifer system tapped by Well No. 2703-01, the Commission on Water Resource Management (Commission) established pumpage and allocation milestones and required actions related to the milestones as part of the resource management strategy (Exhibit 1).

One of the required actions was to execute water use permit revocations within one (1) year of the adoption of the new sustainable yield. The list of proposed revocations, which includes Well No. 2703-01, is attached as Exhibit 2.

The staff does not have the authority to modify the milestone requirements that were approved by the Commission. Therefore, we are planning to submit the water use permits to the Commission for a possible revocation action by March, 2001. The existing water use permit for the source is for 0.154 mgd for irrigation use (landscape and pineapple). With regard to the potential use of the well for remedial actions, this would constitute a new use of the well, and an application to modify the permit should be made pursuant to Administrative Rule 13-171-23.

We will send you a copy of the staff submittal at least six (6) days in advance of the Commission meeting. We will incorporate any new information that you may have provided to us. You may also submit either oral or written testimony to the Commission at the public meeting.

If you have any questions, please contact Lenore Nakama at 587-0218.

Sincerely,

[Signature]

LINNEL T. NISHIOKA
Deputy Director

LN:ss
Attachments
APPLICATION FOR WATER USE PERMIT

NAME: Del Monte Fresh Produce (Hawaii)

CONTACT PERSON: Mr. Calvin H. Oda

ADDRESS: 24-1000 Kunia Road, Kunia, Hawaii 96759

PHONE: (808)621-1205 Fax (808)621-1226

LANDOWNER OF SOURCE

NAME: The Estate of James Campbell

CONTACT PERSON: Ms. Donna Goth

ADDRESS: 1001 Kamokila Blvd., Kapolei, Hawaii 96707

PHONE: (808)674-6674 Fax (808)674-3111

SOURCES INFORMATION

1. WATER MANAGEMENT AREA: Waipahu-Waipawa Aquifer System

2. EXISTING WELL/DIVERSION NAME AND STATE NUMBER: Kunia Well (State No. 2703-01) / Basal Well (State No. 2703-02)

3. LOCATION: Address 94-1000 Kunia Road, Kunia, HI 96759

4. SOURCE TYPE (check one): Stream / Basal / Dike-confined / Perched / Caprock

5. METHOD OF TAKING WATER (check one): Artesian / Well & Pump / Diverted Surface / Other (explain)

USE INFORMATION

6. LOCATION OF PROPOSED WATER USE: (If possible, show on same maps as source location. Otherwise, attach similar maps)

(a) PUC-Regulated System / Intended Dedication to Dept. Board of Water Supply / Non-PUC-Regulated Private System

(b) Proposed use of water: Existing / New / Both existing & new uses

(c) Tax Map Key: If (location of use is over multiple TMKs, please complete Table 1 on back of application)

(d) Address:

(e) Current State Land Use District(s):

(f) Current County Zoning District(s):

7. QUANTITY OF WATER REQUESTED: 1.0 mgd 0.225 mgd (additional)

8. METHOD OF MEASUREMENT: Flowmeter / Open-pipe / Weir / Orifice / Other (explain)

9. QUALITY OF WATER REQUESTED: Fresh / Brackish / Salt / Potable / Non-Potable

10. PROPOSED USE: Municipal (including hotels, stores, etc.) / Industrial / Irrigation / Military / Other (explain)

11. TOTAL NUMBER OF RESIDENCES TO BE SERVED: NONE

12. TOTAL ACRES TO BE IRRIGATED AND TYPE OF CROP: 2,595 acres

13. PROPOSED TIME OF WATER WITHDRAWAL OR DIVERSION: 6:00am to 6:00am (24 hours)

14. APPLICANT MUST ESTABLISH THAT THE PROPOSED USE OF WATER:

(a) Can be accommodated with the available water source. YES

(b) Is a reasonable-beneficial use as defined in section 13-171-2, HAR. (see backside of this application) YES

(c) Will not interfere with any existing legal use. NO

(d) Is consistent with the public interest. YES

(e) Is consistent with state and county general plans and land use designations. YES

(f) Is consistent with county land use plans and general policies. YES

15. REMARKS, EXPLANATIONS: (see backside of this application)

NOTE: Signing below indicates that the signatories understand and swear that: 1) the information provided on this application is accurate and true to the best of their knowledge; 2) Item 14 is the responsibility of the applicant prior to Commission approval; 3) If necessary, further information may be required before the application is considered complete; 4) If a water use permit is granted by the Commission, this permit is subject to prior existing permitted uses, changes in sustainable yields and stream flow standards, reserved uses as defined by the Commission, and Hawaiian Home Lands future uses; and 5) Upon permit approval, a water shortage plan must be submitted by the applicant should the Commission require one.

Applicant (print) Calvin H. Oda

Signature 11/17/98

Landowner (print) The Estate of James Campbell

Signature 11/17/98

Date 1/12/1998

WUPAFORM (12/96)
“Reasonable-beneficial use” means the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is not wasteful and is both reasonable and consistent with the state and county land use plans and the public interest.

16. REMARKS, EXPLANATIONS (cont’d):


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TOTAL GDP
### TABLE 1. MULTIPLE TMKs TO USE REQUESTED WATER

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**TOTAL** 2594.7
June 22, 1998

Ms. Lenore Nakama
State of Hawaii
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Subject: Application for Water Use Permit to Increase Water Allocation for the Kunia Well and a new Basal Groundwater Supply Well from 0.228 MGD to 1.0 MGD.

Dear Ms. Nakama,

The purpose of this memorandum is to provide the objectives, rationale, justification, and the benefits of approval of this Application for Water Use Permit for increased water allocation of 0.772 MGD from the Kunia Well (State Well No. 2703-01) and a new basal groundwater supply well (State Well No. 2703-02) operated as a well battery for hydraulic containment and irrigation purposes.

1. Background Information

Del Monte Fresh Produce (Hawaii) Inc. is the largest agricultural employer on the island of Oahu. Each year, Del Monte produces approximately 110,000 to 116,000 tons of pineapple representing more than 30 percent of the State's total pineapple production. Agricultural operations, fresh fruit packing, and processing facilities employ more than 700 people.

Since 1993, Del Monte has expanded the pineapple growing areas significantly by returning abandoned sugarcane lands to productive agriculture. Today, the Oahu Plantation is located on approximately 10,400 acres of land at 400 to 1200 foot elevation on the western side of the Central Oahu plain on the island of Oahu in the State of Hawaii. The Oahu Plantation can be divided into three distinct sections: Kunia, Poamoho, and Honouliuli.
Due to the uneven distribution of rainfall and the basic agricultural need to sustain uniform plant growth, it is critical to routinely irrigate the pineapple crop to maximize crop yields and saleable product per acre; maintain optimal plant growth to reduce pest pressure and attain consistent, good quality fruit; and prevent delays in harvests that result in disruptions in fruit deliveries.

In the Kunia and Poamoho sections, the sole source of irrigation water for the pineapple crop are groundwater supply wells. In Honouliuli, Del Monte is dependent on the Waiahole Ditch system to provide irrigation water for the pineapple crop. Each Section has separate water distribution and irrigation infrastructure that are not physically connected due to geographical locations and the need to distribute irrigation water economically.

The Kunia section is the largest contiguous body of the farm encompassing approximately 5,300 acres. Average annual rainfall in Kunia is 41 inches, with most of it falling between November and March in winter storms. Normal orographic rainfall occurring chiefly from April through November is less voluminous and falls in light showers. January is the month of highest annual rainfall (6 inches), June the lowest (1 inch). Due to the uneven distribution of rainfall on the Oahu Plantation, irrigation of the pineapple crop occurs on some or all of the Oahu Plantation yearround.

The facility is composed primarily of agricultural areas dedicated to pineapple production, but also contains five groundwater supply wells used for drinking water and/or irrigation purposes. The three active groundwater supply wells include the Navy Well (State Well No. 2803-05), Del Monte Well No. 4 (State Well No. 2803-07), and Del Monte Well No. 5 (State Well No. 3103-01). The Kunia Well (State Well No. 2703-01) and the new basal well (State Well No. 2703-02) are pumped periodically for water quality sampling purposes for the Remedial Investigation/Feasibility Study for the NPL Site. As part of the Remedy, after approval by EPA and the State, the Kunia Well battery will be pumped routinely for hydraulic containment purposes.

For the purposes of this Application, the water uses from the Navy Well and Del Monte Well No. 4 are relevant to evaluation and decision-making of the merits of the proposed water use. The Navy Well and Del Monte Well No. 4 are operated as a well battery under the a Water Use Permit that allows pumpage of 4.16 million gallons of water per day to provide drinking water for Kunia Village and irrigation water for the
Kunia section of the Oahu Plantation. The Navy Well and Del Monte Well No. 4 are located in the Wahiawa High-Level Aquifer.

As discussed in greater detail in the following sections, the pineapple crop in the Kunia Section can consume more than 5.0 million gallons of water per day. By allowing pumpage of 1.0 mgd or an increase in allocation of 0.772 mgd from the Kunia Well battery (State Well No.(s) 2703-01 and 2703-02) located in the Ewa-Kunia Aquifer System, Del Monte will be able to greatly improve our ability to consistently meet crop water requirements.

Del Monte Well No. 5 located in the Wahiawa High-Level Aquifer is used for irrigation purposes for pineapple grown in the Poamoho section of the Oahu Plantation. The previous sugarcane lands in the Honouliuli section of Oahu Plantation are irrigated with water from the Waiahole Ditch system.

2. Rationale and Justification

As supported by commercial experience and Dr. Paul Ekern's water use calculations (see Appendix A), the pineapple crop requires a minimum of 0.5 acre inch water per week (or 2,000 gallons per day) to sustain plant growth and to attain maximum economic crop yields. Assuming use of 2,000 gallons per day on approximately 2,600 acres of pineapple, the average irrigation water requirement for the Kunia Section is 5.042 million gallons per day (mgd).

In 1995, in recognition of the need to adequately irrigate the pineapple crop, the State of Hawaii approved an increased allocation for the Navy Well and Del Monte Well No. 4 for irrigation of the existing pineapple crop in the Kunia section. Del Monte is appreciative of the State's support and assistance in preserving agriculture on Oahu by allowing use of our valuable groundwater resource. However, due to equipment and manpower limitations of the water pumping and distribution system, Del Monte routinely attains only 60 to 70 percent irrigation coverage on the current acreage. In 1998, the inability to properly irrigate the pineapple crop in Kunia has resulted in a 9 percent reduction in crop yields, delays in fruit harvests, and disruptions in market supply.

The irrigation water distribution system in the Kunia section is centered around an earthen, HDPE lined irrigation basin located above field 9. Allowing pumpage from other existing wells, specifically the Kunia
Well and the new basal well will provide a practical means of improving on water distribution capacities through more effective filling of the irrigation basin.

Assuming typical flow rates of 2,940 gallons per minute when operating two drip irrigation systems and one overhead irrigation system and a realistic average pumping capacity of 2,280 gallons per minute (at 80 percent pumping efficiency), it is difficult to fill the 2.4 million gallon irrigation basin to provide a buffer for normal operations. The pumping of the Kunia Well will allow for more consistent filling of the irrigation basin greatly increasing irrigation operating efficiencies by more evenly matching pumpage rates with desired flow rates.

If approved, to achieve an average pumpage of 1.0 mgd, a 700 gpm pump and 350 gpm pump will be installed in the Kunia Well and the basal well, respectively. The total installed pumping capacity of 1.5 mgd for the Kunia Well battery will allow for an average draft of 1.0 mgd. The pump installation permit application for both wells is shown in Appendix C.

The Kunia Well and the basal well located 156 feet south of the Kunia Well contains low concentrations of volatile organic chemicals at or above their respective Maximum Contaminant Levels (MCLs). For many years, Del Monte has been trying to address basal groundwater contamination in the vicinity of the Kunia Well. More recently, a Remedial Investigation under CERCLA guidance was completed. Pump and irrigation for hydraulic containment will be evaluated as one of the remedial alternatives of the Groundwater Operable Unit in the Feasibility Study for the NPL Site.

The preliminary capture zone analysis described in the draft RI Report indicates that routine pumping of the Kunia Well (and the downgradient basal well) will be effective for hydraulic containment of chemicals in the basal aquifer at the Kunia Village Area (see Appendix B). Based on the preliminary capture zone analysis, pumping of the Kunia Well battery at approximately 700 gallons per minute will effectively capture the plume before it moves downgradient. Pumping of the Kunia Well battery at approximately 1050 gallons per minute will completely capture the plume in the basal aquifer at the Kunia Village Area before it moves downgradient. Therefore, even during low irrigation water demand periods, pumping of the Kunia Well will provide for the hydraulic containment of chemicals in the basal aquifer.
For many years, the Kunia Well was pumped routinely for hydraulic containment purposes. The State Department of Health supports the reinstatement of pumping of the Kunia Well battery. EPA is currently considering reinstatement of pumping using a phased and integrated approach. Although the current situation does not appear to present an imminent hazard to human health and the environment, it will be beneficial to pump the Kunia Well battery to minimize any potential future environmental impacts.

The rationale and justification for the proposed water use which will serve two major purposes includes: 1) attainment of optimal irrigation of the pineapple crop in the Kunia section of the Oahu Plantation by providing practical resources to increase crop yields and predictability of fruit harvests, and 2) pumping of the Kunia Well battery for hydraulic containment of chemicals before migration downgradient to minimize potential environmental risks.

3. Description of Benefits to the State of Hawaii and Water User

If approved, the increased allocation of 0.772 mgd will increase total cumulative pumpage to 1.0 mgd from the Kunia Well (State Well No. 2703-01) and a new basal groundwater supply well (State Well No. 2703-02) to be operated as a battery. The increased allocation will provide several benefits to the State of Hawaii and the water user.

First, the current water use permit does not allow for adequate irrigation water from current sources in the Kunia section of the Oahu Plantation. As previously stated, during peak crop consumption demands, the pineapple crop in Kunia section can efficiently use more than 5.0 million gallons of water per day. The increased allocation from the Kunia well and the new basal well will provide for the most cost effective, practical means to better utilize the current irrigation system infrastructure. The optimal utilization of the existing irrigation water distribution system will allow more effective irrigation management thus permitting Del Monte to attain expected crop yields and saleable product recovery per acre.

Secondly, the basal groundwater in the vicinity of the Kunia Well contains traces of ethylene dibromide (EDB), 1,2 dibromo-3-chloropropane (DBCP), and 1,2,3 trichloropropane (TCP) at concentrations at or above Maximum Contaminant Levels. Fate and transport modeling indicates infiltration of perched groundwater to the basal groundwater may be impacting basal groundwater quality near the Kunia Well. The estimated
source area in the basal aquifer is 300 feet by 300 feet with a depth of 1 to 10 feet deep. The preliminary capture zone analysis completed as part of the Remedial Investigation indicates that periodic pumping of the Kunia Well and the downgradient well can effectively capture chemicals in the basal groundwater before they migrate downgradient. The pumping of the Kunia Well battery will meet EPA, State, and Del Monte mutual goals to protect and preserve invaluable groundwater resources. Restricting the movement of the chemicals in the basal aquifer to the vicinity of the Kunia Well will protect human health and the environment by minimizing any potential future impacts on downgradient receptors.

Lastly, due to increased foreign competition, Del Monte must continue to make farm improvements to remain competitive in today's global market. The reduction in physical constraints to irrigate the crop using existing assets will vastly increase Del Monte's ability to meet required yield and revenue expectations thus preserving critical agricultural jobs.

If there are any questions regarding the information provided, please do not hesitate to call me at (808) 621-1205. Thank you for your support in this matter.

Sincerely,

Del Monte Fresh Produce (Hawaii) Inc.

Calvin H. Oda
Director, Pineapple Research

cc: B. Nishida
    B. Hataoka/A. Playdon (HDOA)
    J. Rosati (EPA Region IX)
    R. Pang
    G. Anderson
The effect of mulch and drip irrigation on pineapple irrigation. General considerations:
1. Pineapple is non-transpiring. Water loss can occur directly from water in leaf axils or droplets of rainfall or dew on the leaf.
2. Plastic mulch forms a vapor barrier over the soil but again water on the mulch can evaporate.
3. Water loss occurs by evaporation from the bare soil walkspace but the immediate soil surface dries rapidly and evaporation is sharply reduced since heat transfer down thru the dry surface slows & evaporation does not have sufficient heat to continue.

Ekern 1965 paper PRI TP 308: Table I shows how pineapple water use was 0.23 that from a pan for all soil moisture stages in fall 1961. Table II shows when soil water was high (0.06 bar stress) pineapple use was 0.19/0.61 = 0.31 pan evaporation. When moisture stress increased to 0.85 bar, pineapple use was 0.11/0.69 = 0.16 pan. Drip irrigation keeps the soil at the higher moisture contents and may well be twice that of pineapple under drier conditions. Ekern 1967 PRI TP 316, fig 1 and 2 shows that paper and plastic mulch actually increased the rate above that for the unmulched bare soil case when the soil dried to the 0.8 bar stress point. The mechanism is detailed in p 275 para 2, a consequence of the increased soil temperature under the mulch.

Ekern 1966 PRI TP 312 in fig I shows the rapid reduction in bare soil evaporation as the soil dries.

One other factor may play a role as seen in the papers of Randi Schneider et al, Pesticide Sci 1990 and Nematology 1992 since drip irrigation at 13 mm (about ½")/week appears to allow enuf water percolate to affect the distribution of the nematocide. Any percolate will perch on the tillage pan and move from under the mulch to help keep the soil in the walkspace moist and speed evaporative loss.

My WRRC TR 156, Oct. 1983 - Measured evaporation in high rainfall areas, Leeward Koolau range, O'ahu, Hawai'i, has a summary of evaporation rates in the Wahiawa-Waipio area. Again, my report WRRC Special Report 10.16.89. Evaporation along a transect across southern O'ahu, Hawai'i, recaps some of the central O'ahu data. See also my 1965 paper PRI TP 305 on pan evaporation. (1985)

The Ekern & Chang DL&NR Report R74 sums pan evaporation for central Oahu as about 72"/year about 1½"/week and 0.3 pan would be about ½"/week for pineapple requirements.

Paul C. Ekern

Remember ratoons may depend heavily on aerial roots. Our ananas ananassoides and bracteatus are doing quite well.
Evapotranspiration of Pineapple in Hawaii

Paul C. Ekern
Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii

The plants of the cerrado and caatinga, ecological provinces of Brazil, the suggested original home of pineapple (3), have many and varied mechanisms whereby they have adapted to the frequent development of moisture stress. The pineapple plant presents a peculiarly interesting combination of those traits that have been proposed for xerophytic and scro­pellous plants (10, 15). Preferential collapse of the water storage tissue of the leaf in time of moisture stress is further evidence of the intriguing adaptation of the pineapple plant to water deficit (15, 19). Reduction in the daytime rate of vapor exchange from the pineapple leaf (14) could well be accomplished by the highly cutinized upper epidermis and the deeply entrenched stomatal pores with an overlaying mat of trichomes on the undersurface. The very low rate of but 0.3 to 0.5 mg of water lost per cm² of leaf surface in an hour contrasts sharply with the 26 mg from a corn leaf, and the 43 mg from a cocklebur leaf (23). Such restricted daytime gas exchange through the leaf requires some compensatory mechanism for a CO₂ supply for photosynthesis. The acid metabolism of crassulacean plants has been shown to provide such a mechanism, and it has been reported specifically for pineapple (21, 22).

Materials and Methods

Continuous record was made of evaporation from a class A pan (5). Bermuda grass sod, Cynodon dactylon L. Pers., and smooth cayenne pineapple, Ananas comosus L. Merr., were planted in Wahiawa Low Humic Latosol (26) on hydraulic lysimeters (C. 12) at the Pineapple Research Institute field station, Wahiawa (index 820.2, 21° 28' N, 127° 21' W) (24). The lysimeters were 1.525 m square and 0.5 m deep. Continuous record of moisture consumption was made with a float recorder on the hydraulic scale of the lysimeter. Sunlight was recorded by an Eppley pyrheliometer calibrated on the Smithsonian scale (2). Each lysimeter has a self-border-planting 5 m in width.

Correlative studies of the leaf area indices of pineapple plants were made by tracing onto cardboard or photographic paper the outline of leaves stripped from field plants. Leaf area was interpolated from the accumulated weight of the cardboard. In several instances the leaf area was also calculated from the leaf dimensions based upon a trapezoidal shape. Pineapple crowns newly rooted in water culture at the Honolulu glasshouse of the Pineapple Research Institute were used for the collection of the gas evolved from the roots of the sunlit plants.

Results

The fraction of the day's evaporation that occurred at night (20:00 to 08:00) was measured for the pan, Bermudagrass sod, Latosol, and pineapple plantings in the spring of 1959. Year-old potted pineapple plants had been transplanted onto a lysimeter in October 1958, and were in the red-bud stage of flowering at the time of these measurements. The 0.38 fraction of the water use that occurred at night for the pineapple was in distinct contrast to the 0.17 fraction from the pan, the 0.13 from the sod, and the 0.19 from the Latosol. The pattern of loss for 2-hour intervals clearly demonstrated the suppression of daytime transpiration by the pineapple plants.

In August 1959 the diurnal pattern of the water use of the several surfaces again had the same relative aspect. Sixteen potted pineapple plants about a year old were set on one of the lysimeters to exaggerate the effect of the pineapple cover, since a normal field would have but 9 plants in this area. The Bermuda sod had been clipped short on August 7 after a 10-cm rain had thoroughly wetted the lysimeter. The pattern of water loss from the pan and the sod closely followed sunlight, whereas the pattern for pineapple indicated daytime suppression of transpiration. On days when the leaf axes of the pineapple were filled with water from rainfall, some increase in the daytime consumptive use was found. More precise determination of the moisture use pattern of pineapple was obtained in the fall of 1959 from the lysimeter on which 16 pineapple plants grew through a complete cover of 0.038 mm black polyethylene. Bermuda grass sod and moist Latosol had nearly identical use rates with a strong midday maximum which corresponded closely to the pattern of sunlight. The pineapple had greatly restricted daytime transpiration. The pineapple plants had more nearly complete cover on this lysimeter in April 1960 than in the fall of 1959, and the sharp contrast between the use pattern of pineapple and of...
sod persisted. As soil moisture stress beneath the sod increased, the use pattern of the wilted sod gradually approached that of pineapple, with a much reduced rate of loss that was nearly constant day and night.

The effect of pineapple growth and the increased canopy coverage which accompanied that growth was dramatically demonstrated by a series of measurements which were begun in October 1960, when a lysimeter was planted with 9 slips (table I). The plantings were through black polyethylene mulch 0.038 mm thick and 1 m wide. A 50% reduction in the daily rate of consumptive use of water occurred by the time of 60% canopy closure, in August 1961. This reduction took place despite a 2-fold increase in the potential evaporation, as indexed by the rate of pan evaporation.

Comparison of the relative use rates of Bermuda grass sod, pineapple plants 8 months old, and pineapple plants 24 months old demonstrated the increase in suppression of daytime water use as the nontranspiring pineapple canopy increased (fig 1). The moisture use of pineapple after the canopy closed in the fall of 1961 averaged 0.15 of the energy of the incident sunlight.

Measurement of the water use by the 1960 planting was continued into 1962 as the fruit matured, and records for weekly periods (table II) gave what

### Table I. Fraction of Sunlight Used to Evaporate Water by a Class A Pan and by Pineapple Planted in October 1960

<table>
<thead>
<tr>
<th>Date</th>
<th>Sunlight, ly/day</th>
<th>Fraction used by Pan</th>
<th>Fraction used by Pineapple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>346</td>
<td>0.77</td>
<td>0.32</td>
</tr>
<tr>
<td>Feb</td>
<td>444</td>
<td>0.56</td>
<td>0.28</td>
</tr>
<tr>
<td>Mar</td>
<td>422</td>
<td>0.58</td>
<td>0.24</td>
</tr>
<tr>
<td>Apr</td>
<td>440</td>
<td>0.65</td>
<td>0.20</td>
</tr>
<tr>
<td>May</td>
<td>546</td>
<td>0.70</td>
<td>0.15</td>
</tr>
<tr>
<td>June</td>
<td>533</td>
<td>0.62</td>
<td>0.13</td>
</tr>
<tr>
<td>July</td>
<td>604</td>
<td>0.67</td>
<td>0.16</td>
</tr>
<tr>
<td>Aug</td>
<td>606</td>
<td>0.65</td>
<td>0.13</td>
</tr>
<tr>
<td>Sept</td>
<td>511</td>
<td>0.68</td>
<td>0.14</td>
</tr>
<tr>
<td>Oct</td>
<td>358</td>
<td>0.69</td>
<td>0.22</td>
</tr>
<tr>
<td>Nov</td>
<td>306</td>
<td>0.62</td>
<td>...</td>
</tr>
<tr>
<td>Dec</td>
<td>363</td>
<td>0.34</td>
<td>0.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Sunlight, ly/day</th>
<th>Fraction used by Pan</th>
<th>Fraction used by Pineapple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>349</td>
<td>0.49</td>
<td>...</td>
</tr>
<tr>
<td>Feb</td>
<td>421</td>
<td>0.49</td>
<td>0.19</td>
</tr>
<tr>
<td>Mar</td>
<td>453</td>
<td>0.58</td>
<td>0.20</td>
</tr>
<tr>
<td>Apr</td>
<td>513</td>
<td>0.59</td>
<td>...</td>
</tr>
<tr>
<td>May</td>
<td>499</td>
<td>0.58</td>
<td>0.19</td>
</tr>
<tr>
<td>Jun</td>
<td>508</td>
<td>0.67</td>
<td>0.15</td>
</tr>
<tr>
<td>July</td>
<td>507</td>
<td>0.72</td>
<td>0.09</td>
</tr>
<tr>
<td>Aug</td>
<td>536</td>
<td>0.72</td>
<td>0.09</td>
</tr>
<tr>
<td>Sept</td>
<td>500</td>
<td>0.77</td>
<td>0.08</td>
</tr>
<tr>
<td>Oct</td>
<td>441</td>
<td>0.67</td>
<td>0.10</td>
</tr>
</tbody>
</table>

### Table II. Fraction of Sunlight Used to Evaporate Water by a Class A Pan and by Pineapple 18 Months after Planting During a Period of Increasing Soil Moisture Stress

<table>
<thead>
<tr>
<th>Date</th>
<th>Sunlight, ly/day</th>
<th>Fraction used for evaporation Pan</th>
<th>Fraction used for evaporation Pineapple</th>
<th>Tensiometer, bars</th>
<th>Rainfall, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-4</td>
<td>437</td>
<td>0.61</td>
<td>0.19</td>
<td>0.06</td>
<td>0</td>
</tr>
<tr>
<td>4-8</td>
<td>594</td>
<td>0.66</td>
<td>0.15</td>
<td>...</td>
<td>2.38</td>
</tr>
<tr>
<td>8-12</td>
<td>595</td>
<td>0.67</td>
<td>0.15</td>
<td>0.12</td>
<td>0</td>
</tr>
<tr>
<td>12-18</td>
<td>612</td>
<td>0.69</td>
<td>0.12</td>
<td>0.22</td>
<td>1.52</td>
</tr>
<tr>
<td>18-25</td>
<td>560</td>
<td>0.73</td>
<td>0.14</td>
<td>0.50</td>
<td>1.78</td>
</tr>
<tr>
<td>25-2</td>
<td>565</td>
<td>0.72</td>
<td>0.16</td>
<td>0.80</td>
<td>5.35</td>
</tr>
<tr>
<td>July</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-9</td>
<td>576</td>
<td>0.63</td>
<td>0.09</td>
<td>0.85</td>
<td>12.70</td>
</tr>
<tr>
<td>9-16</td>
<td>610</td>
<td>0.69</td>
<td>0.11</td>
<td>...</td>
<td>8.13</td>
</tr>
<tr>
<td>16-23</td>
<td>624</td>
<td>0.73</td>
<td>0.09</td>
<td>...</td>
<td>3.81</td>
</tr>
<tr>
<td>23-30</td>
<td>653</td>
<td>0.79</td>
<td>0.08</td>
<td>...</td>
<td>0.76</td>
</tr>
</tbody>
</table>

* Soil moisture beneath plastic: July 13, 0.33 cc/cc = one-third bar stress; July 27, 0.27 cc/cc = 8 bar stress.
EXERN—EVAPOTRANSPIRATION OF PINEAPPLE IN HAWAII 739

gert of the plant. Though there may be potential extension of the root system through a large soil depth, the actual development of the roots in the Latosol is confined to the tilled area (4, 13). Evidence of the shallow depth of rooting was found from the measurements of water withdrawal made with Boyoucos resistance blocks at Wahiawa in 1955. No moisture withdrawal by the pineapple roots was indicated from depths greater than the surface 30 cm of 1.5-m deep percolate lysimeters, whereas moisture withdrawal was indicated for the entire 1.5-m deep profile beneath Bermuda grass sod in a similar lysimeter. This restricted root zone of the pineapple plant makes only a small soil water reservoir available to the plant, a feature that would make most conventional plants extremely susceptible to drought.

Summary

Full pineapple plant canopy effectively suspended water vapor exchange by midday. This restriction of the water loss rate was accomplished despite a leaf area index of nearly 6. The control of transpiration was a direct physiological function of the pineapple leaf, which is excellently designed for the control of gaseous exchange.

Literature Cited

might be evidence of some decrease in consumptive use as the soil moisture approached the 15-bar wilting point.

Peculiar evidence for the effective closure of the leaf to gas exchange by day was found in the production of gas from the root tips of pineapple plants growing in water culture. Abel (1) had shown that on bright days with active photosynthesis, this gas, collected from intact root tips, contained 30 to 40% O₂ and was free from CO₂. Gas volumes of 13.7 cc accumulated in a day. The same phenomenon was noted again in 1961, and samples of gas which evolved from broken roots of slips in water culture accumulated as much as 5 cc in an hour at midday. Analysis by gas chromatography indicated the samples to be 78% O₂. The evolution of this gas was closely keyed to sunlight since evolution stopped within a few minutes after a plant became shaded. Excised pineapple leaves also produced the gas, which could be seen escaping from the air channels of the leaf when sunlight struck the leaf. In these leaves, too, evolution ceased shortly after the leaf became shaded.

Lest it be thought that the conservative use of moisture by pineapple planting indicates transpiration was made from a limited amount of leaf area, measurement was made of the leaf area index (27) (table III). Leaf area index does not equal total leaf surface but rather only the area of 1 side of the leaf. The leaf area of 13,000 cm² for a pineapple plant gave a comparatively high leaf area index of 5.8 for a conventional planting of 4.3 plants per square meter.

**Discussion**

The initial evaporation rate of the lysimeter with the surface one-half black polyethylene and one-half bare Latosol, newly planted to pineapple, was one-third the rate of pan evaporation and bore out the self-mulching action of the Low Humic Latosol (9). The reduction to rates one-fifth that of pan evaporation or one-sixth of the energy in the sunlight, as the pineapple plant grew to give full vegetative cover, was a remarkable departure. The Bermuda grass sod used water that was equivalent to six-tenths of the energy of the sunlight, a rate reported to be typical for conventional vegetation (25).

The design of the pineapple leaf (15) is ideal for the suppression of water vapor exchange since the stomates are entrenched on the undersurface and are covered with a mass of trichomes (direct observation of the status of stomatal openings is thus precluded). In addition, the heart-shaped array of the erect leaves and the 5/13 and N + 1 phyllotaxy of the leaves concentrates dew and light showers into the axils where the water can be efficiently conserved (16).

The diurnal cycle of the leaf thickness suggests that the plant is most turgid in the afternoon and least turgid early in the morning. (Linford, M. B. 1934. Private publications of the Pineapple Research Institute.) Such a pattern is in accord with the restricted water vapor escape from the leaf by day. A similar reversal of the water balance has been reported for opuntia and other succulent plants where the rate of water uptake from the soil by day has exceeded transpiration (17, 20).

The design of the leaf array and the persistent, small, zenith angles of the noon sun in the subtropics make the net radiation burden on the pineapple very great (7, 8). The thick succulent pineapple leaf was reported (18) to develop temperatues 5° above air temperature. This 5° elevation of the leaf temperature is in close accord with that forecast by Gates (11) for a nontranspiring leaf cooled by convection forced by a 650 cm per second wind under a 1.1 ly per minute radiation load when the ambient air temperature is 30°. This elevated leaf temperature and a total leaf mass some 10-fold that of conventional crops makes the assumption of negligible heat storage in the plant canopy a matter of questionable validity when an attempt is made to strike a heat balance for the pineapple crop.

The restricted development of the pineapple root system is yet another phase of the unusual water bud-
ABSTRACT

As the mulching practice in pineapple culture in Hawaii has developed over the last 50 years, a number of functions has been assigned to the action of the mulch. This study gives primary consideration to the effects of soil moisture and soil temperature changes upon pineapple growth. Soil moisture changes were determined from field samplings and lysimeter studies at Wahiawa, Oahu. Changes in the soil moisture budget with the mulch were so slight that the variability of field sampling precluded assessment without excessive replication. Coefficients of variability for samples taken at the plant butt were 3 to 5% of a moisture constant (e.g., 15-bar point) for a soil series or within a single field. Moisture use, measured by semicontained hydraulic lysimeters, was reduced by the mulch when the soil was very wet but changed little when the soil moisture ranged from field capacity (0.15-bar) to the 15-bar point.

The mulch raised the average soil temperature about 1.6°C during the winter. The measured one-third increase in the plant growth was nearly identical with the increase calculated from the growth-response of pineapple to temperature.

The agronomic practice of mulching with paper or plastic has been a unique Hawaiian contribution as indicated by the patents which have been granted for the procedure. (W.J. Hartung, 1926. The function of paper mulch in pineapple culture. Private publication issued by Hawaiian Pineapple Co., Ltd. (Dole Corp.) to its sub-licensees under the Eckart patents in Hawaii.)

The first of these patents, filed in 1914 and obtained in 1916, claimed weed control in sugarcane culture as the prime intent (12). Another patent, obtained in 1917, protected a claim that a higher soil temperature was produced by the black color of the paper mulch. A third patent, obtained in June 1921, claimed that the mulch enhanced growth by promoting the rise in soil temperature, weed control, prevention of evaporation by the waterproof paper, and by channeling the entry of runoff waters from the impervious section onto the perforated section of the mulch.

Stewart et al. (14) reiterated the effect of temperature and moisture changes upon growth and introduced changes in the available plant nutrient status beneath the mulch as an additional factor responsible in part for the increased growth of the pineapple plant. The introduction of soil fumigation as the standard practice in pineapple culture in the 1930's brought yet another role for the mulch into being (3).

Among the functions currently assigned to the mulch are, (i) fumigant retention, (ii) guidance for plant spacing, (iii) utilization of the heat and moisture budgets of the plant root zone, (iv) change in the budgets of several gases within the soil, (v) weed control by shading and mechanical suppression, and (vi) channeling of runoff and infiltration; hence, change in the pattern of rewetting, leaching, and erosion.

Primary consideration was given in this study to the effect of two general features on plant growth: soil moisture changes and soil temperature changes of Wahiawa Low Humic Latosol with paper or plastic mulched pineapple plantings. Soil moisture changes were determined by field samplings, lysimeter studies, and tensiometer readings. The soil temperature changes were measured with Fritz, Palmer, and thermistor instruments. In order to characterize the soil moisture cycle, evaporation was measured with a Class A pan (5). Plant growth was assessed by estimation of the plant weight (a highly developed art in pineapple logging) and weighing the largest mature leaf (13).

In accord with the current field practice, about 60% of the soil surface was covered by the mulch. A 0.9-m wide strip of mulch was laid on 1.525-m bed centers with a layer of soil along each edge of the mulch to anchor it to the ground. The pineapple slips were inserted through the mulch approximately 15 cm from each edge.

PROCEDURE AND RESULTS

Field Samplings

Gravimetric determination of soil moisture was made on samples of the 0- to 15-cm soil layer. Detailed moisture measurements were made to ascertain the coefficient of variability of fields composed of single soil series and to establish the effect of the sampling site position relative to the plant.

Minor differences when the soil is mulched with different materials (Table 1) are typical of the extensive field moisture samplings over nearly 50 years. Note particularly that the paper mulch applied in the fall did not preclude the drying of the soil to the 15-bar point by the next spring (Table 1). In this instance, the largest soil moisture content measured in the unmulched soil (24.8%) was only 3.4% less than the minimum content beneath the black plastic mulch. This is equivalent to 10.2 mm of water in the surface 30 cm of soil and represents a single day of pan evaporation in midsummer (5).

Neither the paper, nor the plastic mulch prevented the soil from drying to the 15-bar point when the mulches were applied in the spring (Table 1). On a Molokai site the nearly impervious plastic mulch imposed a lower limit to the soil moisture content measured. The vapor content of the soil air beneath the plastic remained near saturation and the soil moisture content even for the 2.5-cm depth remained near the 15-bar level, 19% for this soil (Holomuu Low Humic Latosol). This was in distinct contrast to extreme drying of the surface layers in the unmulched, bare soil where the moisture content approached the 10% content at 20°C. (C.A. Farden, 1929. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.)

A major limitation to estimates of water-use by sequential gravimetric samples lies in the error from field variability. The soil moisture release curves of the Low Humic Latosol are remarkably uniform within the same soil series. For example, the coefficient of variability of 533 sampling sites on the island of...
Lanai for the Molokai series had a value of 3.54% of the moisture equivalent (33.8%), 4.51% of the 4-bar content (26.0%), and 4.5% of the 15-bar moisture content (24.4%).

Though small, these variations do introduce error into the determination of the average moisture content for a specific field, though the coefficients of variability for these moisture values within single field (50 ha), for eight samples of a Wahiwah series soil on Oahu, were only 2.2% of the 4-bar (26.0%) and 2.9% of the 15-bar (23.6%) moisture contents. When a Student’s t value of 3 and a coefficient of variability of 5% are assumed for a small sample number at 19:1 odds, with the intent to distinguish a 1% difference in soil moisture content near the 15-bar suction, a minimum of 20 samples is required. This sample number is too often not used in the assessment of field moisture content.

Soil moisture measurements were made for this same 80 ha field in the summer of 1957 for pineapple planted in July 1956. On six separate occasions, seven samples were taken, each composed of sub-samples from the butt of 20 different plants. The coefficients of variability ranged from 3.46% of an average June moisture content of 19.4% to 6.5% of an average August moisture content of 20.8% and had an average value of 4.44% for the mean moisture content of 30.8% for the six occasions. The 4.44% coefficient of variability of this study in Wahiwah is nearly identical with the 4.4% value reported for a 92.2 m² plot of very fine sandy loam soil in Nebraska (1).

In another study, on Oahu, the coefficient of variability was 73% of a 27.6% moisture content at the plant butt, whereas it was 33.8% of a 21.6% moisture content in the plant line between plants for 10 samples taken 48 hours after boom irrigation of a 0.2 ha plot. The sampling site at the plant butt has the least coefficient of variability for it is more uniformly wetted by showers or irrigation; hence, it has been the preferred site for sampling for gravimetric moisture determinations.

Lysimeter Studies

The hydraulic, semicontained lysimeters (8, 10) were 1.525 m³ in area and held a 0.356 m depth of Wahiwah Low Humic Latosol. Each lysimeter had a 7.623 m self-planted buffer zone. The strip of mulch crossed the central part of each lysimeter and formed a direct continuation of the bed pattern of the surroundings. The beds were oriented at right angles to the prevailing east-north-east (70°) trade winds at the John Forbush Research Institute field station, Wahiwah, latitude 21°28' N, 216 m elevation. The area immediately upwind from the lysimeters had a 6.437-km fetch over pineapple plantings. Oil saturated, black, creped, 14 mil kraft paper mulch was used on two lysimeters and black 1.5 mil polyethylene was used on three lysimeters. One other lysimeter was mulched only while the fumigant was applied to eliminate the effect of unequal fumigation of the growth response, and the mulch was removed five days later. Each of the lysimeters was planted with nine slips in October 1960. This is equivalent to a planting density of 4.3 plants per square meter. The slips required nearly 12 months to develop a complete canopy cover. During the last months of 1960 and the spring of 1961, water loss from the lysimeter was dominated by the action of the mulches in the pineapples were quite small. The unconventional pineapple plants, even if full-grown, will not transpire; hence direct evaporation is always in the ascendency (6).

During selected periods from December 1960 through March 1961, the unmulched Latosol had evaporation rates that were about one-half that of a Class A pan (Table 2). Showers were frequent and the soil moisture was often restored to 0.45 volumetric fraction (0.05-bar suction) (7). The minimum soil moisture was a 0.33 volumetric fraction, equivalent to 0.33 bar suction.

While the soil remained quite wet, the paper mulch caused a 15.5% reduction and the plastic mulch a 21% reduction in evaporation when compared to the rate from the unmulched Latosol. This effect of the mulching materials was compatible with their relative water vapor permeabilities since the rate of evaporation through paper mulch was 15% and through polyethylene mulch only 0.5% that from a free water surface in laboratory tests. (P. C. Ekern, and A. Fo, 1955. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.)

During a period with increasing values of soil water suction in June 1961 (Fig. 1), mulching generally failed to conserve moisture, and the mulched lysimeter frequently evaporated more water than the unmulched one. The water loss from the unmulched lysimeter was now only about one-fifth that from a Class A pan. The paper mulch caused an increase of 8.5% and the plastic mulch an increase of 4% above the rate of evaporation from the unmulched lysimeter. Soil moisture content in the lysimeters at the start was approximately equal to a 0.34-volumetric water content (0.25-bar suction) and had decreased to a 0.36-volumetric water fraction (0.5-bar suction) by the end of the period.

The diurnal pattern of water loss from the several mulching practices had a direct relationship to soil moisture. When the soil was wet (0.05-bar suction), the paper and polyethylene mulches

| Table 1—Soil moisture content of the 0 to 15 cm layer sampled at the plant butt beneath various mulches at specified periods in 1954* |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Mulch treatment | Planted in November 1953 | | | | | | | | |
|                 | Feb. 17 | Mar. 19 | Apr. 6 | Apr. 22 | May 11 | June 17 | July 16 | Aug. 3 | Sept. 7 | Oct. 5 | Nov. 23 |
| Unmulched       | 20.7    | 27.2    | 24.3   | 25.9   | 27.0   | 23.9   | 27.1   | 25.4   | 22.8   | 23.1   | 23.9   |
| Oiled kraft paper (65 lb) | 22.6    | 27.4    | 25.6   | 27.4   | 27.0   | 24.2   | 25.1   | 21.6   | 24.2   | 24.8   |
| Oiled kraft paper (45 lb) | 20.3    | 27.0    | 25.9   | 27.4   | 26.8   | 24.2   | 25.1   | 21.6   | 24.2   | 24.8   |
| Asphalt-saturated felt paper | 29.1    | 27.4    | 28.2   | 27.8   | 28.0   | 25.7   | 25.3   | 24.3   | 24.8   |
| Black 1.5 mil polyethylene | 21.0    | 27.0    | 27.6   | 28.0   | 28.1   | 25.2   | 25.3   | 24.3   | 24.8   |
| Clear 1.0 mil polyethylene | 31.4    | 27.9    | 27.5   | 30.4   | 30.3   | 25.2   | 25.0   | 24.6   | 24.8   |
| Gray 1.0 mil polyethylene | 26.0    | 31.5    | 29.2   | 30.4   | 30.3   | 27.0   | 27.2   | 26.7   | 26.2   |
| Clear 1.0 mil polyethylene | 26.8    | 31.5    | 29.2   | 30.4   | 30.3   | 27.0   | 27.2   | 26.7   | 26.2   |

Average monthly rainfall (mm) |
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<tbody>
<tr>
<td>Feb. 17</td>
<td>Mar. 19</td>
<td>Apr. 6</td>
<td>Apr. 22</td>
<td>May 11</td>
<td>June 17</td>
<td>July 16</td>
<td>Aug. 3</td>
<td>Sept. 7</td>
<td>Oct. 5</td>
<td>Nov. 23</td>
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<tr>
<td>121.4</td>
<td>173.9</td>
<td>120.0</td>
<td>120.0</td>
<td>22.6</td>
<td>27.1</td>
<td>25.4</td>
<td>22.8</td>
<td>23.1</td>
<td>23.9</td>
<td>23.9</td>
<td></td>
</tr>
</tbody>
</table>

*Experiments conducted at the Pineapple Research Institute Experiment Station, Wahiwah. f Wahiwah Low Humic Latosol: 15-bar = 30%, 4-bar = 25%, 0.33-bar = 20%.%}

Table 2—Evaporation rates from a pan, and from unmulched, paper mulched, and polyethylene mulched Low Humic Latosol measured with hydraulic lysimeters at Wahiwah, Oahu

<table>
<thead>
<tr>
<th>Mulch Treatment</th>
<th>1960</th>
<th>1961</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pan</td>
<td>3.20</td>
<td>4.40</td>
</tr>
<tr>
<td>Unmulched</td>
<td>3.76</td>
<td>4.75</td>
</tr>
<tr>
<td>Paper mulched</td>
<td>3.97</td>
<td>5.17</td>
</tr>
<tr>
<td>Polyelethench</td>
<td>3.62</td>
<td>4.87</td>
</tr>
<tr>
<td>Water loss rate, mm/day</td>
<td></td>
<td></td>
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<tr>
<td>-----------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Average</td>
<td>3.38</td>
<td>5.15</td>
</tr>
</tbody>
</table>
each reduced the evaporation, and the diurnal pattern of evaporation from all lysimeters was similar (Fig. 2, July 4–6). When the soil was near field capacity (0.15-bar suction), the amount of evaporation was nearly identical, but the diurnal pattern of the mulched and unmulched lysimeters was different (Fig. 2, May 10–12). The plastic mulch retarded the moisture loss by day but speeded the water loss by night so that the net loss was nearly identical with the unmulched lysimeter. When the soil dried so that the suction was 0.7-bar or more, the unmulched Latosol had the least evaporation (Fig. 2, June 21–23).

Fig. 1—Pan evaporation and the ratio between evaporation from a mulched lysimeter and the pan during a period of increasing soil moisture suction from April through June 1961 at Wahiawa, Oahu.

Fig. 2—The water loss pattern from an unmulched and a black polyethylene mulched lysimeter for periods of increasing soil moisture suction at Wahiawa, Oahu.
Tensiometer Readings and Plant Growth

Tensiometers (30 cm thermometers), placed with the 15- to 22.5-cm soil zone comprising the porous top, were installed in the hydraulic lysimeters at the plant butts in the lee and windward lines and through the mulch in the bed center.

The effect of both the presence of the mulch and the bed orientation upon the rewetting pattern of the lysimeter is shown in Fig. 3. Tensiometric readings were reduced as the soil on the windward side was rewetted by late June rains, whereas they remained high and the soil dry beneath the plastic mulch and also beneath the pineapple plants on the lee side of the bed.

Throughout most of the period from the planting in October 1960 until summer 1961, the soil moisture suction measured by tensiometers was approximately 0.05 bars. It had a maximum value of 0.8 bars in late June. Despite the absence of any prolonged period of high soil moisture suction, marked difference in plant growth occurred. By mid-August, plants in the polyethylene mulched lysimeters were one-third larger than those in the unmulched lysimeter. The unmulched surface covered an estimated 35% of the surface, the larger plants in the paper mulched lysimeter covered 50%, and the still larger plants in the plastic mulched lysimeter covered 60% of the soil surface.

This growth rate gain is typically found for field observations of plant response to mulching in Hawaii.

The roofing action of the mulch is also in a field situation by Fig. 4, where the bed center beneath the plastic mulch was wetted sufficiently to reduce the suction below the 15-bar point for only a brief interval in March. This is not unlike the features reported for plastic covered ridges by Willis et al. (16). Despite the generally less favorable moisture status of the soil with the plastic mulch (Fig. 4), plant growth by January was 8% greater than the unmulched case and remained greater throughout the summer. Again, the plastic mulch did not prevent the development of 15-bar soil suction though it delayed the attainment of this critical level by one week.

Soil Temperature Studies

Friez recording soil thermographs, Palmer maximum-minimum soil thermometers, and continuously recorded bead thermistors were used to measure soil temperatures. The thermal units of the Friez and Palmer instruments were placed horizontally with the central axis at a nominal 7.5 cm depth.

The average monthly soil temperatures measured with a Palmer soil thermograph at Wahiawa beneath unmulched soil ranged from 21.8°C in January to 29.4°C in August for the years 1962 to 1965. The January value for the soil temperature was only 0.5°C warmer than the Wahiawa air temperature at shelter height, but the August value was nearly 5.0°C warmer than the air temperature. The average soil and air temperatures were derived from the daily maximum and minimum values. If the daily values were calculated from the average hourly values derived from Friez thermographs, the daily mean would be reduced 0.1°C since the diurnal wave was not truly sinusoidal. The large thermal unit of the Palmer instrument reduced the diurnal range in the soil temperature nearly 5.5°C when compared to the thermistor measurements, but the daily average temperature was nearly identical for measurements taken in August and September 1962. This gives greater credence to the average soil temperatures recorded by the very large elements of the Friez or Palmer instruments.

Soil temperatures measured by Friez units installed beneath
Table 2—Soil temperatures recorded at a nominal 7.5 cm depth in the plant line at Wahia, Oahu. Pineapple planted in November 1953 and growth status assessed in April and May 1954

<table>
<thead>
<tr>
<th>Mulch treatment</th>
<th>Average temperature, °C</th>
<th>Comparative leaf weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dec. 1953 to Mar. 1954 (incl.)</td>
<td>Dec. 1953 to April 1954 (incl.)</td>
</tr>
<tr>
<td></td>
<td>Measured</td>
<td>Calculated</td>
</tr>
<tr>
<td>Unmulched</td>
<td>20.8</td>
<td>21.4</td>
</tr>
<tr>
<td>Oiled Kraft paper</td>
<td>21.8</td>
<td>23.0</td>
</tr>
<tr>
<td>Asphalt saturated felt paper</td>
<td>21.8</td>
<td>22.5</td>
</tr>
<tr>
<td>Black 1.5 mil polyethylene</td>
<td>22.4</td>
<td>23.3</td>
</tr>
<tr>
<td>Clear 1.5 mil polyethylene</td>
<td>22.9</td>
<td>23.4</td>
</tr>
</tbody>
</table>

Average air temperature: 20.8

Table 4—Soil temperatures at a nominal 7.5 cm depth in the plant line for sunny as opposed to cloudy periods at Wahia, Oahu beneath pineapple planted in November 1953

<table>
<thead>
<tr>
<th>Mulch treatment</th>
<th>Sunny, warming period 1954</th>
<th>Cloudy, rainy period 1954</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average daily temperature, °C</td>
<td>Air temperature °C</td>
</tr>
<tr>
<td>Unmulched</td>
<td>20.0</td>
<td>20.6</td>
</tr>
<tr>
<td>Oiled Kraft paper</td>
<td>21.6</td>
<td>21.4</td>
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<tr>
<td>Asphalt saturated felt paper</td>
<td>21.1</td>
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<tr>
<td>Black 1.5 mil polyethylene</td>
<td>22.7</td>
<td>22.6</td>
</tr>
<tr>
<td>Clear 1.5 mil polyethylene</td>
<td>22.8</td>
<td>23.0</td>
</tr>
</tbody>
</table>

Average daily temperature, °C

Air temperature °C 20.3 19.4 22.2 18.9 20.0 19.4

Sunlight, hr/day 403 308 301 58 99 100 (est.)

Rainfall, mm 0.0 0.0 0.8 31.8 15.5 29.1

several different mulching materials at Wahia in November 1953 exemplified the mulch-induced increases in the winter (Table 3). Mean monthly soil temperatures beneath the black mulches were as much as 1.6°C warmer than those beneath unmulched soil. This monthly mean was a compound of the rainy days, when no difference was found, and the sunny days when nearly 2°C increases in the average soil temperature were found in January (Table 4).

The growth-response of pineapple to the mulching practices was indexed by the measured leaf weights. The expected gain in plant growth from the increase in soil temperature was calculated from the growth-response curve of pineapple (13). The exponential portion of this curve with an optimum at 29.4°C was fitted to the relationship:

\[ \log (w/w_0) = 0.075T - 2.2 \]

where \( w \) = weight at temperature \( T \) °C, and \( w_0 \) = weight at optimum temperature. The leaf weights calculated by this relationship from the average soil temperature beneath the several mulches corresponded closely to the measured leaf weights (Table 3). The major portion of the observed growth increase could indeed arise from the extra soil warmth.

**DISCUSSION AND CONCLUSIONS**

Field variability in soil moisture contents has made difficult, if not impossible, large-scale demonstration of a reduction in the rate of water loss with paper or plastic mulches in pineapple culture. More precise determination of water loss from lysimeters covered with the different mulches has revealed little, if any, reduction in the rate of use of soil moisture from field capacity to the 15-bar point for Latosols in Hawaii. When the soil was frequently wetted by showers, and remained wet (above field capacity, the paper or plastic mulches caused a 20% reduction in the rate of water loss. When the soil was at moisture contents between field capacity and wilting point, the mulch may have even slightly increased the rate of water loss. A most intriguing effect was a greater rate of water loss during the night when the mulch was present.

The plastic mulch is a much better vapor-barrier than the paper mulch, yet neither was an absolute barrier when it covered no more than 60% of the soil surface, a feature not entirely unpredicted (9, 15). Moreover, the Low Humic Latosol forms a very effective self-mulch as it dries, for when the soil moisture reaches field capacity, the rate of water loss falls to but 1/3 that of a pan (7). This low rate from the bare Latosol is nearly identical with the rate of water loss from a pan through a complete cover of the paper mulch, especially after the paper has been exposed for a time to weathering in the field. The excellent vapor-barrier action of the polyethylene persists throughout the life of the mulch. It makes an important reduction in further water loss when extreme drying occurs and soil moisture content nears the 15-bar point. The 15-bar point is critical for root growth just as it forms a critical point for pineapple leaves. (C.P. Sideris and B.K. Krauss 1928. Private publication of the Pineapple Research Institute Honolulu, Hawaii.) Root elongation ceases and root tips suberize when the soil moisture approaches the 15-bar point (M. B. Linford. 1934. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.) Regrowth by bursting the suberized cap will occur upon rewetting the soil. Prolonged exposure to greater soil moisture stress results in death of the
root and necessitates regrowth from the plant butt upon rewetting of the soil. (B. K. Krauss. 1959. Private publication of the Pineapple Research Institute, Honolulu, Hawaii.)

Increases of 20 to 30% in the rate of vegetative growth of the mulched pineapple have occurred during the winter though soil moisture has been optimum for growth in either case. This accelerated growth of the plant speeds the day when canopy closure occurs and a thick, nontranspiring, insulating mulch of pineapple plant is formed over the soil to reduce the rate of water loss. When a mulch prevents growth of conventional weeds which do transpire, a large contribution can be made toward water savings in pineapple culture.

The change in soil temperature does not stem from the effect of the black mulch on net radiation since the reflectance of the Latosol is low and nearly identical with that of the mulch (4). Rather, the vapor-barrier formed by the mulch enhances the apparent thermal conductivity of the Latosol, increases the thermal contact coefficient of the soil in comparison with that of air, and causes more of the net radiation to be stored in the soil by day (2, 11). This more effective entry of heat into the soil beneath the plastic mulch raised the average winter soil temperature at Waiau about 1.6°C above that for unmulched soil.

The measured leaf weights recorded in table 3 correspond remarkably well with the calculated values. The 50% increase in plant growth resulting from a 2.75°C rise in soil temperature in winter keynotes the success of the mulching practice in pineapple culture in Hawaii.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the skillful assistance rendered by A. Fo, formerly Junior Soil Scientist, Pineapple Research Institute, for soil samplings and moisture analyses, and J. Fo, Physiologist, Pineapple Research Institute, for plant logs.

LITERATURE CITED

Evaporation from Bare Low Humic Latosol in Hawaii

PAUL C. EKERN

Water Resources Research Center, University of Hawaii, Honolulu

(Manuscript received 24 September 1964, in revised form 23 November 1965)

ABSTRACT

Despite the high potential evaporation, actual evaporation from Wahiawa Low Humic Latosol measured by hydraulic lysimeters is very low under field conditions. The evaporation from Latosol at field moisture content is only one-third the rate from a pan. The heavy clay soil is so strongly aggregated that the water release for low values of soil moisture suction is determined by the aggregate rather than by the mechanical composition of the soil. The unsaturated hydraulic conductivities determined for the Latosol decrease rapidly as the soil dries, a feature in accord with the self-mulching action of the soil. Moreover, the mineralogic and aggregate composition of the soil make the material an excellent thermal insulator and the consequent restriction of heat flow also reduces the rate of evaporation since much of the water movement within the unsaturated Latosol is in the vapor phase along temperature gradients. The transfer of latent heat within the soil contributes appreciably to the heat storage in the soil.

1. Introduction

The average evaporation rate of 0.75 cm per July day from a class A pan recorded for many areas in Hawaii is evidence of the high potential evaporation rate under Hawaiian conditions (Ekern, 1965b). This high rate of evaporation is in accord with the particularly large fraction of solar and sky radiation which has been reported to be converted into net radiation in Hawaii over several different surfaces (Ekern, 1965a). Specifically over Low Humic Latosol, the high clay and iron oxide contents (Tamura et al., 1953; Uehara et al., 1962) produce a low value of 0.08 for the reflectance which in turn ensures retention of a high fraction of the incident energy as net radiation. Moreover, consideration of other physical properties reported for the Low Humic Latosol (Sherman and Alexander, 1959; Kawano and Holmes, 1958; Trouse and Humbert, 1961; Thorne, 1950; Cornelison, 1954) suggests that the portion of net radiation used by evaporation from bare Latosol might differ sharply from the portion reported as used by evaporation from more conventional mineral soils of the temperate latitudes (Tanner and Lemon, 1962; Wiegand, 1962; Lemon, 1956; Businger and Beuttnner, 1961; Hanks et al., 1961). This paper reports measured rates of evaporation from a Low Humic Latosol and determinations of several physical properties of the Latosol pertinent to these evaporation rates. Among these determinations are the moisture content as a function of soil moisture suction, the unsaturated hydraulic conductivities and diffusivities calculated from the outflow characteristics in response to that suction, the thermal diffusivity calculated from temperature profile measurements and the rate of vapor transfer along temperature gradients anticipated within the Latosol.

2. Measured rates of evaporation from Latosol

Evaporation from a Low Humic Latosol (Wahiawa silty clay, Cline et al., 1955) was measured under field conditions by recording hydraulic lysimeters (Ekern, 1965c; Glover and Forsgate, 1962) at the Pineapple Research Institute Wahiawa field station, Oahu (21°31'N, 216 m MSL). The lysimeters were 1.5 m square and contained a 0.35 m depth of Latosol. Continuous measurement of the hydraulic scale was made by a float recorder on an open-end manometer.

There was a very rapid onset of the falling rate portion of the drying curve (McCormick, 1962). This is more clearly shown when the day to day variations in the evaporational stress are smoothed by the transformation of the water loss into the equivalent fraction of the total radiant energy which reached the soil surface (Fig. 1). When the drying rate is represented as a log-log plot of change in volumetric water content of the soil layer with time, the slope ranged from -0.066 to -0.08 even for the very early periods of evaporation. This slope is quite different from the -1.09 to -0.166 values reported for Hidalgo sandy clay loam (Wiegand, 1962), or the -0.25 value reported for Pachappa sandy loam (Richards et al., 1956). This drying rate for the Latosol in Hawaii, while very low compared to the rates for temperate latitude soils, resembles the slow
The relationships for low soil water suction were determined by pressure plate methods (Fig. 2).

3. Measured water content and soil moisture suction for the Latosol

The desorption curve of water content as a function of soil water suction for the Wahiawa silty clay loam was determined by pressure plate methods (Fig. 2). The relationships for low soil water suction were extended by gravimetric sampling of the moisture content of a 20-cm layer of Latosol which contained a tensiometer embedded in the lower 6 cm of the layer. The relationships for very high soil moisture suction were extended from the values reported for equilibrium of an Ewa Latosol with several relative humidities at 25.6°C (Wadsworth, 1944). Moisture equivalent determinations were presumed to represent 0.33 bar of suction and the field capacity approximately 48 hours after thorough flooding of the soil to be a soil water suction of 0.15 bar.

The water release curve for the Wahiawa soil has three major segments. Since the bulk density of the tilled soil is very close to 1.0, the volumetric and gravimetric moisture fractions are essentially identical. The initial portion of the desorption curve depends upon the withdrawal of water from among the soil aggregates. Wet-sieve analyses of this Wahiawa soil showed 80.4 per cent of the particles aggregated into units larger than fine sand (0.25 mm diameter) and 43.7 per cent aggregated into units larger than coarse sand (1 mm diameter). This initial portion of the curve resembles the moisture relationship for selected Davidson soil aggregates reported by Baver (1942). Drainage of the large pores among the aggregates begins with the least amount of soil moisture suction and is nearly completed by 0.3 bar of suction. The gradual nature of the slope of this section indicates a wide array of effective pore sizes and infers a relatively uniform distribution of aggregate sizes. The flexure of the moisture release curve for the Molokai soil more nearly resembles the release curve from well sorted sands and aggregates with little water removal initially and then an abrupt flexure with very rapid removal of the water as suction increases (Fig. 2). The Molokai soil, though a Low Humic Latosol, has much less well developed structure than the Wahiawa (Cagauan and Ueham, 1965) and the moisture release curve gives evidence of this difference. However, the slope of the curves for each of the Latosols is nearly identical beyond the 0.1-bar soil moisture suction.

4. Unsaturated hydraulic conductivities and diffusivities calculated for transient outflow from the Latosol

Since the falling rate phase in the drying of porous materials has been held to be dependent on the failure of liquid water to move to the surface and a consequent retreat of the plane of vaporization within the media (McCormick, 1962; Gardner and Hillel, 1962), the unsaturated hydraulic conductivity and diffusivity of the soil are critically related to the nature of evaporation from the Latosol. The hydraulic conductivities of two Low Humic Latosols (Wahiawa silty clay and Molokai silty clay) were calculated from transient outflow of water from tension plate devices (Fig. 3). Samples were taken from both the topsoil (0-15 cm)
Disposition of Net Radiation by a Free Water Surface in Hawaii

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Abstract. Temperate latitudinal expressions such as the Dalton and Penman formulations predict class A pan evaporation though certain of the constants seemed unique for the tropics. Air temperature alone was not a sensitive index of evaporation. The winter rate of pan evaporation supports the contention that a large fraction of sunlight is converted to net radiation. The seasonal shift in the fraction of sunlight used for pan evaporation responded to the seasonal shift in net radiation, but also included was the effect of strong positive advection of heat from the surroundings, particularly in the summer. Pineapple planted upwind from the pan served as a dry fetch. Evaporation measured by atmometer followed conventional patterns, with the black Bellani plate as the best index of sunlight and pan evaporation.

Introduction. The fraction of sunlight represented by evaporation from a class A pan at Wahiawa was quite large. This evidence supports the contention that a large fraction of sunlight is converted into net radiation in the tropics (Table 1). The pans had a 25-ft border of Bermuda grass sod but were located immediately downwind from extensive plantings of pineapple. The peculiar moisture use habit of the nontranspiring pineapple would be expected to make even a well-watered pineapple planting act as a dry fetch [Ekern, 1965].

The evaporation from a constant-level, recording class A pan [Campbell et al., 1959] averaged 0.94 times the evaporation from a standard class A pan for a period of 339 days from April 1958 through June 1959 at the Wahiawa experiment station (index 8202, 710-ft elev., 21°28'N lat.) [Taliaferro, 1961]. The average annual pan evaporation of 73 inches at Wahiawa for the period 1957 through 1958 was in reasonable agreement with other long-term observations on the Wahiawa plain. The annual pan evaporation at Waipahu Sugar Company, field 42 (index 826, 700-ft elev.), was reported as 68.55 inches for the period 1927 through 1951 and at Upper Honeae (index 813, 750-ft elev.) as 63.4 inches for the period 1920 through 1938 [Hawaii, 1961].

Dalton representation. Where information was available, pan evaporation could be fitted to a Dalton-type representation [Rohwer, 1931; Kohler et al., 1955] (Figure 1):

\[
\text{Pan evaporation} = (\text{vapor deficit}) (a + b \text{ wind})
\]

where \(a\) and \(b\) were constants and the vapor deficit was computed as the difference between saturation at pan water temperature and the actual moisture content of the air at shelter height (4.5 ft). The value of 0.004 for the constant \(b\) from the Wahiawa results resembled other published values for the slope of the wind relationship in miles per day [Kohler et al., 1955; McIlroy, 1957; Reidhead, 1960; Webb, 1960; Robinson and Johnson, 1961; Nordenson and Baker, 1962]. The Wahiawa value for the constant \(a\) seemed unique; it depended on the method for estimation of the average vapor deficit and on the height of the wind measurement as well as on the use of the correction factor recommended for the standard three-cup anemometer at these velocities [Middleton, 1942]. The value of 0.5 for \(a\) with corrected pan-level wind became 0.4 with the corrected wind at 6 ft. Short-term (hourly) intervals allowed a more accurate estimate of the vapor deficit and made the value of \(a\) more nearly 0.4 for the uncorrected pan-level wind and 0.2 for the uncorrected 6-ft-level wind. Limited numbers of hourly observations and the general failure of the Dalton relationship for short-term intervals was apparent in the scatter of the data.

1 Pineapple Research Institute Technical Paper 305, and Hawaii Institute of Geophysics Contribution 78.

2 Formerly at the Pineapple Research Institute; now at the Hawaii Institute of Geophysics and the Department of Agronomy and Soil Science, University of Hawaii.
TABLE 1. Average Monthly Class A Pan Evaporation and the Fraction of Sunlight Represented by That Evaporation for Pineapple Research Institute Field Station, Wahiawa, for the Period 1957 through 1962

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<tbody>
<tr>
<td></td>
<td>Pan/ in./ day</td>
<td>Pan/ in./ day</td>
<td>Pan/ in./ day</td>
<td>Pan/ in./ day</td>
<td>Pan/ in./ day</td>
<td>Pan/ in./ day</td>
<td>Sunlight, in./ day*</td>
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<td>0.214 0.69</td>
<td>0.196 0.64</td>
<td>0.200 0.64</td>
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</table>

*1 inch of evaporation = 1400 langleya.

Penman representation. The more refined Penman approach [Penman, 1956] to the factors responsible for pan evaporation yielded results which for the daily values clustered about the 1:1 line (Figure 2). Sunlight, wind velocity, temperature, and vapor pressure deficit are combined into a single expression. However, the fraction of sunlight retained as net radiation must be estimated for tropical Hawaiian conditions, and the pan constants recommended for the high-latitude English conditions must be modified. The net radiation over the pan was calculated on the basis of 0.08 short-wave reflectance [Wartena and Borghorst, 1960] and a net long-wave radiation equivalent to 0.08 inches of evaporation per day [Ekern, 1965a]. A psychrometric constant of 0.025 (°F, inches of Hg) was used, but it was not much better than the usual constant of 0.011 [Kohler et al., 1955]. The values for the a and b constants used to calculate
the estimate with sufficient rapidity as higher temperatures occurred. Since high summer temperatures bring high evaporation rates at a time critical for plant growth, failure to properly estimate the water use in these periods is a major deficiency of such temperature-based formulas. In continental areas, where air temperature more nearly responds to sunlight, these methods have more merit, though even at best they are of minor value for the establishment of rates for short periods.

Wind effects. Sutton [1955] suggested that evaporation might be a function of the 0.78 power of the wind velocity. In most empirical relationships which have been developed for evaporation the first power has been used, since the limited range of velocities encountered makes this power fit equally as well as the 0.78. Daily pan evaporation at Wahiawa from May 1956 to May 1958, when plotted versus wind on a log-log basis, gave a straight line for a range of wind from 30 to 200 miles per day; the 0.8 power of the wind at 6 ft gave a reasonable relationship between wind and the daily evaporation per unit vapor deficit. Wind less than 3 mph (72 mi/day, corrected value) at pan level sharply restricted the fraction of sunlight used for

![Image of Figure 2](image2.png)

**Fig. 2.** Measured and calculated pan evaporation after Penman [1956] modified for tropical, latitudes, Pineapple Research Institute field station, Wahiawa (index 820.2), March 1956 through March 1957. Daily values, wind at 6-ft level.

the pan evaporation in Figures 2 and 3 are those derived from Wahiawa. The calculated (after Penman) and measured pan evaporation for Maalaea, Maui (index 310), were in general agreement, though a good deal of scatter was present about the 1:1 line (Figure 3).

Temperature-based representation. The extreme simplification wherein evaporation was indexed by air temperature alone formed at best only a rough guide to evaporation, particularly since the day-to-day average temperatures have such small differences under Hawaiian conditions (Figure 4). Adjustment to a standard day-length from 10 hours 50 minutes for winter to 13 hours 17 minutes for summer was not sufficient to eliminate the seasonal loop in the plot of monthly pan evaporation rates and air temperature for Wahiawa that gave a markedly greater rate of summer evaporation over winter evaporation at the same temperature (Figure 5).

Several of the empirical relationships between evaporation and temperature [Tabor, 1931; Thornthwaite, 1948; Criddle, 1953; Baver, 1954; Holdridge, 1959] have been found to fit reasonably well for temperatures up to 68°F [Pelton et al., 1960], but only the higher power functions of temperature increased the value of

![Image of Figure 3](image3.png)

**Fig. 3.** Measured pan evaporation compared with values calculated after Penman [1956] with modification for tropical latitudes, Maalaea, Maui (index 310), June to December, 1955. Weekly values, wind at pan level.
evaporation, yet still indicated a value of 0.5 inches of evaporation per inch vapor deficit per day for calm conditions.

Sunlight-based representation. Statistical analysis of the pan evaporation at Wahiawa of days with less than 0.01 inch rainfall for the period May 1958 through May 1959 had the relationship

\[
\text{Pan evaporation} = 0.78 \text{ sunlight} - 0.043 \frac{\text{in.}}{\text{day}}
\]

\[
\hat{r}^2 = 0.69, \ n = 168
\]

Sunlight was converted to equivalent evaporation based on latent heat of 1490 langley per inch depth of water.

The measured fraction of sunlight represented by class A pan evaporation for Wahiawa had a seasonal swing from 0.55 in February to 0.72 in September, with an annual average value of 0.65 for the period 1957 through 1962 (Table 1).

The monthly averages of pan evaporation displayed a relationship that is comparable to full net radiation when used for evaporation. Even for the rainy months with a moist fetch the expected 0.85 fraction of net radiation used for evaporation seemed too small to be representative [Tanner and Lemon, 1962]. Strong positive advection of heat to the pan must have occurred in the summer months, and in the dry winter periods as well, for evaporation was well in excess of the net radiation.

Monthly averages for selected days with rainfall less than 0.01 in./day still gave a marked seasonal loop with evidence for strong positive advection to the pan through the summer months, though the winter months approached the expected 0.85 net radiation (Figure 6).

Several days of peak use in each month, selected...
in an effort to find clear-day cases, again clustered about the full net radiation relationship rather than a fraction thereof.

Evapotranspiration with positive advection of heat from a dry fetch (area upwind) has been reported as equivalent to as much as 1.1 times the net radiation, in contrast to the evapotranspiration with a moist fetch, equivalent to 0.85 of the net radiation [Pruitt and Angue, 1961; Fritschen and van Bavel, 1962; Tanner and Lemon, 1962]. Values of pan evaporation at Wahiawa of 1.1 to 1.2 times the net radiation have been reported, again clustered in an effort to find clear-day cases, and would agree with these reports. The consistently high fraction of net radiation used by pan evaporation in the lee of pineapple fields suggests that the pineapple plantings acted as a dry upwind fetch much of the time.

Atmometer evaporation. Sunlight and pan evaporation relationships to several types of atmometers appeared to confirm the contentions held by other workers [Halkias et al., 1955; Holmes and Robertson, 1958; Carder, 1960; Heeney et al., 1961; Noffsinger, 1961; Wilcox, 1962]. A battery composed of triplicates of each of several types of atmometers was exposed immediately adjacent to the pan evaporation site at a uniform height of 3 feet above the ground from May 1958 through May 1959. The relationship to the single-valued black Bellani plate seemed to bear the most useful potential correlation with sunlight and pan evaporation among the following:

\[
\text{Sunlight} = \frac{[282 + 226 \text{ (black-white Livingston in.})]}{1490} = \text{equiv. inches/day} \\
\rho_r = 0.28, n = 169
\]

\[
\text{Sunlight} = \frac{[177 + 91.3 \text{ (black Bellani in.})]}{1490} = \text{equiv. inches/day} \\
\rho_r = 0.546, n = 169
\]

\[
\text{Sunlight} = \frac{[100 + 80.5 \text{ (black Livingston in.}) + 84.5 \text{ (black-white Livingston in.})]}{1490} = \text{equiv. inches/day} \\
\rho_r = 0.596, n = 169
\]

\[
\text{Pan} = \frac{[120.3 + 96.5 \text{ (black-white Livingston in.})]}{1490} = \text{inches/day} \\
\rho_r = 0.15, n = 168
\]

\[
\text{Pan} = \frac{[93 \text{ (black Bellani in.})]}{1490} = \text{inches/day} \\
\rho_r = 0.735, n = 168
\]

REFERENCES


Middleton, W. E. K., Meteorological Instruments, University of Toronto Press, 1942.

(Manuscript received August 7, 1964; revised October 30, 1964.)
Nematicide Efficacy, Root Growth, and Fruit Yield in Drip-irrigated Pineapple Parasitized by *Rotylenchulus reniformis*¹

R. C. Schneider,² J. Zhang,² M. M. Anders,² D. P. Bartholomew,² and E. P. Caswell-Chen³

Abstract: A 3-year field trial near Kunia, Oahu, Hawaii, was conducted to evaluate four nematicide treatments for efficacy against *Rotylenchulus reniformis* in drip-irrigated pineapple (*Ananas comosus* L. (Merr.)). The treatments were (A) preplant fumigation with 1,3-dichloropropene (1,3-D) (336 liter/ha) and postplant drip application of fenamiphos (3.4 kg/ha) with restricted irrigation, (B) preplant 1,3-D only, weekly irrigation, (C) 1,3-D fenamiphos, weekly irrigation, and (D) postplant fenamiphos only, weekly irrigation. Fenamiphos was applied at 3-month intervals for 1 year after planting in three treatments. Although nematode populations increased in all treatments 1 year after planting, no differences in fruit yield were detected among treatments in the first (plant crop) harvest 19 months after planting. In the second (ratoon) crop (33 months after planting) significant yield differences, larger fruit size, and greater root biomass were obtained in the dual nematicide treatments. Root biomass increased continuously throughout the crop cycle, was greatest near the drip line, and showed a shallow depth distribution (30-40 cm). *Rotylenchulus reniformis* populations and fenamiphos concentrations were negatively correlated in soil profiles taken 13 months after planting. In the absence of postplant fenamiphos applications, nematode numbers were positively correlated with root biomass.

Key words: *Ananas comosus*, 1,3-dichloropropene, drip irrigation, fenamiphos, nematicide, nematode, pineapple, reniform nematode, root development, *Rotylenchulus reniformis*.

The reniform nematode (*Rotylenchulus reniformis* Linford & Oliveira) has been a serious pest of pineapple in Hawaii for several decades (2,6,7,18,19). The perennial nature of pineapple, with three fruit crops produced from a single planting, requires nematode control over a 4- to 5-year period. Recent changes in commercial pineapple culture in Hawaii include increased use of drip irrigation and a transition from cannery operations to fresh fruit production. The most prevalent chemical control strategy is preplant fumigation (1,3-dichloropropene [1,3-D] or methyl bromide) followed by postplant systemic nematicides, usually fenamiphos (ethyl 3-methyl-4-(methylthio)phenyl (1-methylethyl)phosphoridate) by drip irrigation. A fallow cycle of 6 to 12 months is now used on some plantations to augment chemical control of nematodes. Preplant fumigation is usually sufficient to produce a successful plant crop (2,19).

This research was part of an integrated effort to evaluate nematicide efficacy by characterizing plant and root development, nematode population dynamics, and fenamiphos concentrations in the soil. We used a combination of nematicides, preplant 1,3-D fumigation, and postplant fenamiphos application, and compared the effect of weekly and restricted irrigation on fenamiphos movement and efficacy.

Materials and Methods

Experimental site: The experimental plot (0.2 ha) was located near Kunia, Oahu, Hawaii, within a commercial field. Wahiawa silty clay (Troleptic Eutrude, sand 7%, silt 40%, clay 53%), is a well-aggregated oxisol that is representative of much of the pineapple acreage on the island of Oahu. Four treatments were replicated three times in a completely random-
Field Movement and Persistence of Fenamiphos in Drip-Irrigated Pineapple Soils

Randi C. Schneider,* Richard E. Green,* Walter J. Apt, b Duane P. Bartholomew a & Edward P. Caswell a

*Department of Agronomy and Soil Science, bDepartment of Plant Pathology, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa, Honolulu, Hawaii 96822, USA

(Revised manuscript received 19 March 1990; accepted 18 April 1990)

ABSTRACT

The persistence and mobility of fenamiphos and its toxic oxidation products in soil with pineapple cropping were studied in three field experiments on the islands of Oahu and Lanai, and by sampling three commercial fields on Oahu. Fenamiphos was applied by drip irrigation after planting, following pre-plant application of 1,3-dichloropropene (1,3-D) in most treatments. The Oahu experiments, conducted on highly weathered Oxisol and Ultisol soils, evaluated the impact of restricted irrigation to reduce leaching and also the effect of 1,3-D on fenamiphos behavior. Total toxic residue (TTR) concentrations of 1000 µg kg⁻¹ or greater were maintained in the root-zone with fenamiphos applications of 3·4 kg ha⁻¹ tri-monthly on the Oxisol (Kunia site) and bi-monthly on the Ultisol (Whitmore site). The relatively high applications, along with weekly irrigations and unseasonably high rainfall, resulted in leaching of fenamiphos TTR out of the root-zone with concentrations between 10 and 100 µg kg⁻¹ at 3 m depth. Reduced leaching with restricted irrigation was evident in the early months of both Oahu experiments. The potential to minimize leaching of fenamiphos by reduced application rates and limited irrigation during rainy periods was evident from nematicide concentration profiles measured on three commercial pineapple fields on Oahu; little fenamiphos TTR was detectable below 1 m.

1 INTRODUCTION

A long-term field study was conducted to assess the behavior of fenamiphos, an organophosphate nematicide, applied by drip irrigation to several pineapple soils in Hawaii.
STAFF RECOMMENDATION:

Staff recommended that the Commission accept the evaluation of the Attorney General that projects sponsored by the U.S. Army Corps of Engineers on private and County lands affecting the bed or banks of streams are subject to stream channel alteration permits pursuant to Section 13-169-50, Hawaii Administrative Rules.

Further, that the Commission:

a. Find the County of Hawaii, Department of Public Works and the U.S. Army Corps of Engineers, the project sponsor, in violation of Section 13-169-50, Hawaii Administrative Rules, for altering the bed and banks of Alenaio Stream without a stream channel alteration permit.

b. Fine the County of Hawaii, Department of Public Works and the U.S. Army Corps of Engineers a total of $1000 for the above violation.

c. Send the County of Hawaii, Department of Public Works, a warning letter indicating future after-the-fact permits from the Department of Public Works may be considered "willful" violations.

d. Issue a warning letter to the U.S. Army Corps of Engineers indicating future after-the-fact stream channel alteration permits from Corps sponsored projects may be considered "willful" violations.

UNANIMOUSLY APPROVED. (NOBRIGA/MIEKE)

ITEM 7

DEL MONTE FRESH PRODUCE (HAWAII) INC. APPLICATIONS FOR WATER USE PERMITS: REQUESTS TO INCREASE PERMITTED USES FOR DEL MONTE WELLS 3 & 4 (WELL NOS. 2803-05 & 07) AND KUNIA WELL (WELL NO. 2703-01), TMK 9-2-005:002, WAHIWA AND WAIPAHU-WAIWA GROUNDWATER MANAGEMENT AREAS, OAHU

PRESENTATION OF SUBMITTAL: Lenore Nakama
STAFF RECOMMENDATION:

Staff recommended that the Commission:

1. Defer action on the applications for Del Monte Wells 3 & 4 and Kunia Well for a period of thirty (30) days from the date of this submittal to provide additional time for Del Monte to submit evidence in support of the requested water quantities.
   
   a. In the event that such supporting documents are provided in a timely manner, then the staff will schedule these applications for the next Commission meeting on Oahu.
   
   b. In the event that supporting documents are not provided within the specified deferral period, then these applications shall be deemed to be denied without prejudice as of the date of this submittal.

AMENDMENT: Staff requested that the recommended action be amended to defer action to the next meeting on Oahu, to provide additional time for staff to review the documents that were submitted by Del Monte on July 17, 1995.

TESTIMONIES:

Brian Nishida and Calvin Oda of Del Monte Fresh Produce (Hawaii) Inc. presented oral testimony requesting approval of the water use permits.

UNANIMOUSLY APPROVED STAFF’S RECOMMENDATION TO DEFER ACTION. (NOBRIGA/GIRALD)

ITEM 8

CITY & COUNTY OF HONOLULU, BOARD OF WATER SUPPLY APPLICATION FOR A STREAM CHANNEL ALTERATION PERMIT, CONSTRUCTION OF A CULVERT CROSSING AT HANAIMOA GULCH, HAUULA, OAHU (TMK 5-4-5:01)

PRESENTATION OF SUBMITTAL: Mr. David Higa
for the meeting of the
COMMISSION ON WATER RESOURCE MANAGEMENT

August 16, 1995
Honolulu, Hawaii

RESUBMITTAL

Del Monte Fresh Produce (Hawaii) Inc.
APPLICATIONS FOR WATER USE PERMITS
Requests to Increase Permitted Uses for
Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07) and
Kunia Well (Well No. 2703-01), TMK 9-2-005:002
Wahiawa and Waipahu-Waiawa Groundwater Management Areas, Oahu

Applicant: Del Monte Fresh Produce (Hawaii) Inc. 94-1000 Kunia Road Kunia, HI 96759
Landowner: Same

BACKGROUND:

On February 14, 1995, Del Monte Fresh Produce (Hawaii) Inc. (Del Monte) submitted two (2) completed applications for water use permits to modify the permitted use quantities for Kunia Well (Well No. 2703-01) and Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07). The applications are for allocation increases of 0.278 million gallons per day (mgd) for Kunia Well and 2.2 mgd for Wells 3 & 4.

Kunia Well is located in the Waipahu-Waiawa Aquifer System (Exhibit 1) and has an existing water use permit for 0.154 mgd. The application is for a total allocation of 0.432 mgd. The groundwater developed in Kunia Well will be used for remedial actions in the immediate vicinity of the well site to bring contaminant levels in the soil, saprolite, and

AGENDA 1
Item 3
groundwater, at approximately 40 feet below ground surface, to or below State maximum contaminant levels. The contamination occurred as a result of accidental releases of pesticides from fumigant storage and mixing areas and the direct application of DBCP on pineapple fields.

The present total allocation to Wells 3 & 4, which are interconnected, is 2.121 mgd. Approval of Del Monte's request would bring the total permitted use of these sources to 4.32 mgd. The wells develop high-level groundwater in the Wahiawa Aquifer System (Exhibit 2) and are the sole irrigation source for the 2,500 acres of pineapple grown in the Kunia area. This source also supplies domestic water to Del Monte workplaces and 150 residences at the Village of Kunia. The privately owned Del Monte water system (system no. 303) is monitored by the Department of Health.

In a letter dated April 5, 1995, the Commission staff recommended that Del Monte provide any reports or studies in support of the projected increase in pineapple water requirements. Such documents would provide a basis by which the Commission may evaluate reasonable beneficial water use.

On July 17, Del Monte submitted two reports relating to pineapple agriculture. On July 19, 1995, the Commission deferred action on Del Monte's applications because additional time was needed for the staff to review the reports.

Additional background information on the sources, uses, notification, and field investigation is provided in Attachment A.

ANALYSIS & ISSUES:

Section 174C-49(a) of the State Water Code establishes seven (7) criteria that must be met to obtain a water use permit. An analysis of the proposed permits in relation to these criteria follows:

(1) Water availability

Wells 3 & 4 - The sustainable yield of the Wahiawa Aquifer System is 23 mgd. Current water allocations total 18.547 mgd. A listing of permitted uses in the aquifers is shown in Exhibit 3. There is 4.453 mgd of groundwater available for allocation from the Wahiawa Aquifer System. This quantity is sufficient to meet the applicant's full request for 2.2 mgd for Wells 3 & 4. This would leave 2.253 mgd of groundwater available for allocation to other new users. At present, there are no other pending applications in the aquifer at this time. This information is summarized in the following Table 1.
Table 1. Wahiawa Aquifer System

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<tr>
<td>(shown in Exhibit 3)</td>
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<tr>
<td>Current Available Allocation</td>
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<td>Less: Pending Applications</td>
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<tr>
<td>Available Allocation if approved</td>
<td>2.253</td>
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Kunia Well - The sustainable yield of the Waipahu-Waiawa Aquifer System is 119 mgd. Current water allocations total 114.753 mgd. An additional 1.581 mgd of Waipahu-Waiawa groundwater has been reserved for future uses on lands administered by the Department of Hawaiian Home Lands (DHHL). The total of reserved and permitted use quantities is 116.334 mgd (shown in Exhibit 4). This leaves 2.666 mgd available for allocation.

At present, there is one other completed application for the Waipahu-Waiawa Aquifer System that is pending Commission action. This application is for the Department of Housing and Community Development (DHCD) for a future use of 3.5 mgd of groundwater for irrigation and other nonpotable uses at the City's Ewa Villages and West Loch developments. DHCD completed their application on June 30, 1995 with the submittal of required source information.

The applicability of Chapter 343 is unclear with respect to water use permits for new sources that are constructed with government funds. Staff is seeking a determination from the Office of Environmental Quality Control (OEQC) to clarify this issue with DHCD's water use permit application. In the event that OEQC determines that completion of the EA/EIS process is not required for water use, then DHCD's application may be in competition with Del Monte's application for Kunia Well, as there is insufficient water to accommodate both requests. This is shown in Table 2 below.
We are requesting additional irrigation water (2.2 mgd) from Wells 3 & 4 to allow for improvements in plant growth and attain maximum economic yields. Staff recommended that Del Monte provide documents to support their requested increase since there has been no expansion of the use area, which has been in pineapple for many years, and Del Monte's pumpage reports indicate that the present permitted use quantity, which is based on a 12-month moving average withdrawal, has not been exceeded in recent years (Exhibit 4). Furthermore, the Oahu Water Management Plan provides a guideline of 1,000 gallons per acre per day for pineapple agriculture. This figure is consistent with Del Monte's present permitted use quantities.

Staff reviewed the two reports that were submitted by Del Monte. The reports are rather lengthy and do not readily yield information pertinent to this submittal. However, staff has ascertained that the projected increase in pineapple irrigation may be attributed to the conversion from overhead to drip irrigation and increased planting densities. Dr. Paul Eckem, who provided the 1,000 gpd/acre estimate for pineapple agriculture that is shown in Table 4-4 of the Oahu Water Management Plan, has indicated to staff that he supports Del Monte's request. Dr. Eckem's
studies show that the conversion from overhead to drip irrigation can double the irrigation water requirement, as the pineapple is less stressed and therefore able to consume a greater quantity of water. This relationship between conversion to drip and greater water consumption was observed on Lanai. Also, following the conversion to the drip method, pineapple will experience about a 10% faster growth rate if roughly twice as much water is applied. If irrigation water is not adjusted, a faster growth rate will not ensue. The relationship between growth rate and economic yield has not been established.

As there is no competition for the available water, and Del Monte's agricultural operations are in the interests of the public, it is reasonable and beneficial to allocate an additional 2.2 mgd to Wells 3 & 4.

Domestic use accounts for about 0.304 mgd of the developed in Well Nos. 2803-05 & 07 (based on average use for the four-year period, 1990 to 1994). No increase in domestic use has been requested.

Kunia Well - In their application, Del Monte states that "[u]se of the allocation will be dependent on the outcome of negotiations with the United States Environmental Protection Agency on appropriate remedial actions at the site. As the specifics of the remedial work have yet to be defined, it is not possible at this time to evaluate the reasonableness of the requested 0.278 mgd increase in water use. As such, it would be premature to allocate additional water to Kunia Well since the quantity needed for remedial actions has not been determined. Based on the latest 12-month moving average of reported monthly water use for Kunia Well, Del Monte has been using only about one-half of their 0.154 mgd allocation since 1989 (Exhibit 5).

(3) **Interference with other existing legal uses** - No objections or concerns have been raised in this regard. All water use permits are subject to reduction should interference with other legal uses be established.

(4) **Public interest** - Agricultural water use is consistent with the public interest, and it is a policy of the State of Hawaii that agriculture be supported.

(5) **State & county general plans and land use designations** - This proposed use has been shown to be consistent with the state and county general plans and land use designations. No objections to this application were raised following review of this application by other divisions of the State Dept. of Land and Natural Resources and the County Dept. of Planning, Board of Water Supply, and Office of the Mayor.

(6) **County land use plans and policies** - This proposed use has been shown to be consistent with county land use plans and policies.
(7) Interference with Hawaiian home lands rights - All permits are subject to the prior rights of Hawaiian home lands. The Department of Hawaiian Home Lands (DHHL) and the Office of Hawaiian Affairs have reviewed this application. No comments or objections have been raised.

No specific objections to this application have been submitted to the Commission.

RECOMMENDATION:

Staff recommends that the Commission:

1. Approve the issuance of an interim water use permit to Del Monte Fresh Produce (Hawaii), Inc. for use of 4.32 mgd of fresh groundwater for Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07) for agriculture use on 2,500 acres at Kunia, Oahu, subject to the standard water use permit conditions in Attachment B.

2. Deny without prejudice Del Monte’s application for a water use permit for Kunia Well (Well No. 2703-01). The applicant may resubmit a new application when negotiations on remedial actions have been finalized.

Respectfully submitted,

[Signature]

RAE M. LOUI
Deputy Director

Attachments

APPROVED FOR SUBMITTAL:
WATER USE PERMIT DETAILED INFORMATION

Source Information

**AQUIFER:**

- **Sustainable Yield:** Wahiawa System, Central Sector, Oahu 23 mgd
- **Existing Water Use Permits:** 22.687 mgd
- **Available Allocation:** 0.313 mgd
- **Total of other pending allocations:** 0 mgd

**WELL:**

**Location:** Del Monte Well 3 (Well No. 2803-05) Kunia, Oahu, TMK:9-2-5:2

- **Year Drilled:** 1959
- **Casing Diameter:** 16 in.

**Elevations** (msl = 0 ft.)

- **Water Level:** 277.4 ft.
- **Ground:** 857 ft.
- **Bottom of Solid Casing:** 196 ft.
- **Bottom of Perforated:** -30 ft.
- **Bottom of Open Hole:** -163 ft.

**Total Depth:** 1020 ft.

**Pump Capacity:** 1350 gpm

**WELL:**

**Location:** Del Monte Well 4 (Well No. 2803-07) Kunia, Oahu, TMK:9-2-5:2

- **Year Drilled:** 1979
- **Casing Diameter:** 16 in.

**Elevations** (msl = 0 ft.)

- **Water Level:** 201 ft.
- **Ground:** 872 ft.
- **Bottom of Solid Casing:** 42 ft.
- **Bottom of Perforated:** -30 ft.
- **Bottom of Open Hole:** -118 ft.

**Total Depth:** 990 ft.

**Pump Capacity:** 1500 gpm

ATTACHMENT A
Use Information

Quantity Requested: 4.32 mgd, Wells 3 & 4; 0.432 mgd (Kunia Well)
Proposed Type of Water Use: Agriculture
Place of Water Use: 94-1000 Kunia Rd., Oahu

Reported Water Usage: Wells 3 & 4
Kunia Well

1.454 mgd
0.062 mgd

Wahiawa Aquifer System
Current 12-Month Moving Average Withdrawal:
9.794 mgd

Waipahu-Waiawa Aquifer System
May 1994 12-Month Moving Average Withdrawal:
90.765 mgd
(76% of SY)

Public Notice

In accordance with HAR §13-171-17, a public notice was published in the Star-Bulletin on April 5, 1995 and April 10, 1995 and copies of the notice were sent to the Mayor's office and the Board of Water Supply. Additional notice copies were sent to the County Council and Department of Water Supply. Copies of the completed application were sent to the Department of Health, Department of Hawaiian Home Lands, Office of Hawaiian Affairs, Aquatic Resources & Historic Preservation Divisions of the Department of Land and Natural Resources, and other interested parties for comments. Written comments and objections to the proposed permit were to be submitted to the Commission by April 25, 1995.
Objections

The public notice specifies that an objector meet the following requirements: (1) state property or other interest in the matter; (2) set forth questions of procedure, fact, law, or policy, to which objections are taken; (3) state all grounds for objections to the proposed permits, (4) provide a copy of the objection letter(s) to the applicant, and (5) submit objections meeting the previous requirements to the Commission by April 25, 1995.

To the best of staff's knowledge there are no objectors who have property interest within the affected Aquifer Systems or who will be directly and immediately affected by the proposed water use.

Field Investigation

A field investigation on November 6, 1991 verified Kunia Well (Well No. 2703-01) is used for irrigating about five (5) acres of landscape and grass around the Del Monte business offices. This investigation also verified agriculture use (roughly 2,100 acres of pineapple) and domestic use for Wells 3 & 4 (Well Nos. 2803-05 & 07).
STANDARD WATER USE PERMIT CONDITIONS

1. The groundwater described in the water use permit may only be taken from the location described, used for the reasonable-beneficial use described, and at the location described above and in the attachments. Reasonable-beneficial use means "the use of water in such a quantity as is necessary for economic and efficient utilization, for a purpose, and in a manner which is not wasteful and is both reasonable and consistent with the state and county land use plans and the public interest." (HAR §13-171-2).

2. The right to use groundwater is a shared use right.

3. The water use must at all times meet the requirements set forth in HAR §13-171-13 which means that it:
   a. Can be accommodated with the available water source;
   b. Is a reasonable-beneficial use as defined in section §13-171-2;
   c. Will not interfere with any existing legal use of water;
   d. Is consistent with the public interest;
   e. Is consistent with state and county general plans and land use designations;
   f. Is consistent with county land use plans and policies; and
   g. Will not interfere with the rights of the Department of Hawaiian Home Lands as provided in section 221 of the Hawaiian Homes Commission Act and 174C-101(a), HRS.

4. The groundwater use approved must not interfere with surface or groundwater rights or reservations.

5. The groundwater use approved must not interfere with interim or permanent instream flow standards or policies as determined by the Commission. If it does, then:
   a. A separate water use permit for surface water must be obtained in the case an area is also designated as a surface water management area;
   b. The interim or permanent instream flow standard, as applicable, must be amended.

6. The water use permit is subject to the requirements of the Hawaiian Homes Commission Act, as amended, if applicable.

ATTACHMENT B
7. The water use permit application and staff submittal approved by the Commission at its August 16, 1995 meeting are incorporated into the permit by reference.

8. Any modification of the permit terms, conditions, or uses can only be made with the express written consent of the Commission on Water Resource Management.

9. The water use permit may be modified by the Commission and the amount of water initially granted to the permittee may be reduced if the Commission determines it is necessary to:

a. Protect water sources in quantity, quality, or both;
b. Meet other legal obligations including other correlative rights;
c. Insure adequate conservation measures;
d. Require efficiency of water uses;
e. Reserve water for future uses, provided that all legal existing uses of water as of June 1987, shall be protected;
f. Meet legal obligations to the Department of Hawaiian Homes, if applicable; or
g. Carry out such other necessary and proper exercise of the State’s and the Commission’s police powers under law as may be required.

Prior to any reduction, the Commission shall give notice of its proposed action to the permittee and provide the permittee an opportunity to be heard.

10. If the groundwater source does not presently exist, the new well shall be completed, i.e. able to withdraw water for the proposed use on a regular basis, within twenty-four (24) months from the date the water use permit is approved.

11. An approved flowmeter(s) must be installed to measure withdrawals and a monthly record of withdrawals, water-levels, salinity, and temperature must be kept and reported to the Commission on a monthly basis in accordance the Commission’s September 16, 1992 action on reporting requirements;

12. The water use permit shall be subject to the Commission’s periodic review of the applicable aquifer’s sustainable yield. The amount of groundwater use authorized by the permit may be reduced by the Commission if the sustainable yield of the Wahiawa Aquifer System, or relevant modified aquifer, is reduced;

13. The water use permit may not be transferred or the use rights granted by this permit sold or in any other way alienated. Pursuant to HAR §13-171-25 and the requirements of Chapter 174C, the Commission has the authority to allow the transfer of the permit and the use rights granted by the permit in a manner consistent with HAR §13-171-25. Any such transfer shall only occur with the

ATTACHMENT B
Commission's prior express written approval. Any sale, assignment, lease, alienation, or other transfer of any interest in this permit shall be void.

14. The use(s) authorized by law and by the water use permit do not constitute ownership rights.

15. The permittee shall comply with all applicable laws, rules, ordinances, and other agencies' permits and conditions pertaining to water use or the water resource.

16. The permittee shall prepare and submit a water shortage plan within 30 days of issuance of the permit to assist the Commission in fulfilling HAR § 13-171-42(c). The permittee's water shortage plan shall identify what the permittee is willing to do should the Commission declare a water shortage in the Wahiawa Groundwater Management Area.

17. The water use permit granted shall be an interim water use permit, pursuant to HAR §13-171-21. The final determination of the water use quantity shall be made within five years of the filing of the application to continue the existing use.

18. The water use permit shall be subject to the Commission's establishment of instream standards and policies to Stream Protection and Management (SPAM), as well as legislative mandates to protect stream resources.

ATTACHMENT B
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154 Permits Totaling 116.334

154 Permits Totaling 116.334
DEL MONTE FRESH PRODUCE COMB. PUMPAGE
WELL #3 & #4 (2803-05,07)

EXHIBIT 5

MONTHLY VALUES

12-MAV

REQUESTED AMOUNT

DATE (Latest Data 1-95)
DELMONTE FRESH PRODUCE PUMPAGE
WELL #1 (2703-01)

MONTHLY VALUES
12-MAV
REQUESTED AMOUNT

EXHIBIT 6
AGENDA 1

I. OLD BUSINESS/ANNOUNCEMENTS

Deputy Director Rae Loui announced that the time on Agenda 2 should be 1:00 p.m. instead of 1:00 a.m.

II. CITY AND COUNTY OF HONOLULU DEPARTMENT OF PUBLIC WORKS, EXTENSION REQUEST FOR A STREAM CHANNEL ALTERATION PERMIT, KAHALUU MULTI-PURPOSE LAGOON, KANEHOE, OAHU

PRESENTATION OF SUBMITTAL: Mr. David Higa

STAFF RECOMMENDATION:

Staff recommended that the Commission approve the two year extension request, subject to the same conditions on the previous stream channel alteration permit issued on October 27, 1993 and new standard conditions as listed in the staff submittal.

PRESENTATION BY APPLICANT: Mr. Tyler Sugihara of the Department of Public Works was present and available to answer questions.

MOTION: (NOBRIGA/GIRALD)

To approve staff's recommendation.

UNANIMOUSLY APPROVED.

III. DEL MONTE FRESH PRODUCE (HAWAII) INC. - APPLICATIONS FOR WATER USE PERMITS, REQUESTS TO INCREASE PERMITTED USES FOR DEL MONTE WELLS 3 & 4 (WELL NOS. 2803-05 & 07) AND KUNIA WELL (WELL NO. 2703-01), TMK 9-2-005:002, WAHIAWA AND WAIPAHU-WAIWA GROUNDWATER MANAGEMENT AREAS, OAHU

PRESENTATION OF SUBMITTAL: Ms. Lenore Nakama

STAFF RECOMMENDATION:

Staff recommended that the Commission:

1. Approve the issuance of an interim water use permit for Del Monte Wells 3 & 4 to the applicant, subject to the standard water use permit conditions listed in Attachment B of the staff submittal.
2. Deny without prejudice, Del Monte’s application for a water use permit for Kunia Well.

PRESENTATION BY APPLICANT: Mr. Rodger McCloskey of Del Monte Fresh Produce (Hawaii) Inc. was available for questions and stated he was satisfied with staff’s recommendation.

TESTIMONIES:

Ms. Toni Bissen of the Native Hawaiian Advisory Council presented an oral & written testimony stating that should the Commission approve Del Monte’s water use permit application for Wells 3 and 4 (Well Nos. 2803-05 and 07), there is no need for water from the Waiahole Ditch system for these lands and therefore Campbell and DLNR should withdraw its water request from the Waiahole proceedings.

Mr. Rodger McCloskey of Del Monte Fresh Produce (Hawaii) Inc. responded that the water out of wells 3 and 4 are separate from the Waiahole Ditch water.

AMENDMENT:

Staff requested to amend the recommendation in the submittal as follows:

Under recommendation #1, add a special condition "a":

a. In the event that Del Monte should secure an alternate source of irrigation water for their pineapple lands in Kunia, this permit will be subject to revocation.

MOTION: (NOBRIGA/GIRALD)

To approve staff’s recommendation as amended.

UNANIMOUSLY APPROVED AS AMENDED.

(Item V was heard next, due to a request to move the item up.)

V. WATER USE PERMIT APPLICATIONS - Koolauea Groundwater Management Area, Oahu

HAWAII RESERVES INC. (HRI), (FORMERLY ZION’S SECURITY CORP.) (WELL NOS. 3554-01 & 02, 3654-03, 3755-04 & 06, 3855-04, 3856-04 & 07, 3956-05)

LAIE WATER CO. (LWC) (WELL NOS. 3855-06 TO 08, 3956-03)

POLYNESIAN CULTURAL CENTER (WELL NO. 3855-09)
Del Monte Fresh Produce (Hawaii) Inc.  
APPLICATIONS FOR WATER USE PERMITS  
Requests to Increase Permitted Uses for  
Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07) and  
Kunia Well (Well No. 2703-01), TMK 9-2-005:002  
Wahiawa and Waipahu-Waiawa Groundwater Management Areas, Oahu  

Applicant: Del Monte Fresh Produce (Hawaii) Inc.  
Landowner: Same  

94-1000 Kunia Road  
Kunia, HI 96759  

BACKGROUND:  

On February 14, 1995, Del Monte Fresh Produce (Hawaii) Inc. (Del Monte) submitted two (2) completed applications for water use permits to modify the permitted use quantities for Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07) and its Kunia Well (Well No. 2703-01). Del Monte is requesting allocation increases of 2.2 million gallons per day (mgd) for Wells 3 & 4 and 0.278 mgd for Kunia Well to meet increased irrigation needs for 2,500 acres of existing pineapple lands in Kunia (See Exhibit 3 with WUPA in Wahiawa and Waipahu-Waiawa Aquifer System). The present allocation to Wells 3 & 4, which are interconnected, is 2.121 mgd. Approval of Del Monte’s full request would bring the total permitted use to 4.32 mgd. This source develops high-level groundwater in the Wahiawa Aquifer System (Exhibit 1) and also supplies domestic water to Del Monte workplaces and 150 residences at the Village of Kunia. The privately owned Del Monte water system (system no. 303) is monitored by the Department of Health.
Kunia Well has an existing water use permit for 0.154 mgd of groundwater from the Waipahu-Waiawa Aquifer System (Exhibit 2). The proposed permit requests a total allocation of 0.432 mgd. In addition to pineapple agriculture, the pumped groundwater will be used for remedial actions in the immediate vicinity of the well site to bring contaminant levels in the soil, saprolite, and groundwater at approximately 40 feet below ground surface at or below State maximum contaminant levels. The contamination occurred as a result of accidental releases in fumigant storage and mixing areas and direct application of DBCP in pineapple culture.

Additional information regarding the sources, uses, notification, objections, and field investigation(s) is provided in Attachment A.

ANALYSIS & ISSUES:

Section 174C-49(a) of the State Water Code establishes seven (7) criteria that must be met to obtain a water use permit. An analysis of the proposed permits in relation to these criteria follows:

(1) **Water availability** - The sustainable yield of the Wahiawa Aquifer System is 23 mgd. Current water allocations total 22.687 mgd. A listing of permitted uses in the aquifers is provided in Exhibit 3. There are no other pending applications for the aquifer at this time.

In a separate item on this agenda, Commission action is requested to accept voluntary reductions in Waialua Sugar Company's existing permitted uses. Approval of the staff recommendation on this item would result in an additional 4.14 mgd of groundwater becoming available for allocation. This quantity is sufficient to meet the applicant's full requests. In the event that this revocation action does not proceed, only 0.313 mgd of groundwater is available for allocation.

(2) **Reasonable-beneficial** - Del Monte is requesting additional irrigation water (2.2 mgd from Wells 3 & 4 and 0.278 mgd from Kunia Wells) to allow for improvements in plant growth and attain maximum economic yields. There has been no expansion of the use area, which has been in pineapple for many years. Actual pumpage data indicate that Del Monte's present permitted use quantities, which are based on a 12-month moving average withdrawal, have not been exceeded in recent years (Exhibits 4 and 5). The Oahu Water Management Plan provides a guideline of 1,000 gallons per acre per day for pineapple agriculture. This figure is more in line with Del Monte's present permitted use quantities. In light of the above, a firm basis should be provided for Del Monte's demand projections.
In a letter dated April 5, 1995, the Commission staff recommended that Del Monte provide any reports or studies in support of their applications. Such documents would allow a means for evaluating reasonable beneficial water use. Del Monte has not provided any supporting documents to the Commission as yet, but they have indicated that such studies would be made available.

Some quantity of water from Kunia Well may be used for future remedial actions. However, Del Monte has stated that this usage will be dependent on the outcome of negotiations with the U.S. Environmental Protection Agency. As such, it would be premature to allocate additional water to Kunia Well at this time since the quantity needed for remedial actions has not been determined as yet or if this remedial action is acceptable to the EPA. Based on the latest 12-month moving average of reported monthly water use for Kunia Well, Del Monte has been using only about one-half of their 0.154 mgd allocation since 1989.

Domestic use accounts for about 0.304 mgd of the developed in Well Nos. 2803-05 & 07 (based on average use for the four-year period, 1990 to 1994). No increase in domestic use has been requested.

(3) Interference with other existing legal uses - No objections or concerns have been raised in this regard. All water use permits are subject to reduction should interference with other legal uses be established.

(4) Public interest - Agricultural water use is consistent with the public interest, and is a policy of the State of Hawaii that agriculture be supported.

(5) State & county general plans and land use designations - This proposed use has been shown to be consistent with the state and county general plans and land use designations. No objections to this application were raised following review of this application by other divisions of the State Dept. of Land and Natural Resources and the County Dept. of Planning, Board of Water Supply, and Office of the Mayor.

(6) County land use plans and policies - This proposed use has been shown to be consistent with county land use plans and policies.

(7) Interference with Hawaiian home lands rights - All permits are subject to the prior rights of Hawaiian home lands. The Department of Hawaiian Home Lands (DHHL) and the Office of Hawaiian Affairs have reviewed this application. No comments or objections have been raised. Water has been reserved from this aquifer for use on Hawaiian Homestead areas.

No specific objections to this application have been submitted to the Commission.
RECOMMENDATION:

Staff recommends that the Commission:

1. Defer action on the applications for Del Monte Wells 3 & 4 and Kunia Well for a period of thirty (30) days from the date of this submittal to provide additional time for Del Monte to submit evidence in support of the requested water quantities.

   a. In the event that such supporting documents are provided in a timely manner, then the staff will schedule these applications for the next Commission meeting on Oahu.

   b. In the event that supporting documents are not provided within the specified deferral period, then these applications shall be deemed to be denied without prejudice as of the date of this submittal.

Respectfully submitted,

RAE M. LOUI
Deputy Director

Attachments

APPROVED FOR SUBMITTAL:

MICHAEL D. WILSON, Chairperson

- converted in mid-1980's to fresh fruit.
- Dr. Eckern supports.

~10% reduction in yields, work force, economics

Brian Nishida - weather & heat during last few months

Calvin Oda
WATER USE PERMIT DETAILED INFORMATION

Source Information

AQUIFER: Wahiawa System, Central Sector, Oahu
Sustainable Yield: 23 mgd
Existing Water Use Permits: 22.687 mgd
Available Allocation: 0.313 mgd
Total of other pending allocations: 0 mgd

WELL: Del Monte Well 3 (Well No. 2803-05)
Location: Kunia, Oahu, TMK:9-2-5:2
Year Drilled: 1959
Casing Diameter: 16 in.
Elevations (msl= 0 ft.)
  Water Level: 277.4 ft.
  Ground: 857 ft.
  Bottom of Solid Casing: 196 ft.
  Bottom of Perforated: -30 ft.
  Bottom of Open Hole: -163 ft.
Total Depth: 1020 ft.
Pump Capacity: 1350 gpm

WELL: Del Monte Well 4 (Well No. 2803-07)
Location: Kunia, Oahu, TMK:9-2-5:2
Year Drilled: 1979
Casing Diameter: 16 in.
Elevations (msl= 0 ft.)
  Water Level: 201 ft.
  Ground: 872 ft.
  Bottom of Solid Casing: 42 ft.
  Bottom of Perforated: -30 ft.
  Bottom of Open Hole: -118 ft.
Total Depth: 990 ft.
Pump Capacity: 1500 gpm
Use Information

Quantity
Requested: 4.32 mgd, Wells 3 & 4; 0.432 mgd (Kunia Well)
Proposed Type of Water Use: Agriculture
Place of Water Use: 94-1000 Kunia Rd., Oahu

Reported Water Usage: Wells 3 & 4
Kunia Well
1.454 mgd
0.062 mgd

Wahiawa Aquifer System
Current 12-Month Moving Average Withdrawal:
9.794 mgd

Waipahu-Waiawa Aquifer System
May 1994 12-Month Moving Average Withdrawal:
90.765 mgd
(76% of SY)

Public Notice

In accordance with HAR §13-171-17, a public notice was published in the Star-Bulletin on April 5, 1995 and April 10, 1995 and copies of the notice were sent to the Mayor's office and the Board of Water Supply. Additional notice copies were sent to the County Council and Department of Water Supply. Copies of the completed application were sent to the Department of Health, Department of Hawaiian Home Lands, Office of Hawaiian Affairs, Aquatic Resources & Historic Preservation Divisions of the Department of Land and Natural Resources, and other interested parties for comments. Written comments and objections to the proposed permit were to be submitted to the Commission by April 25, 1995.

ATTACHMENT A
Objections

The public notice specifies that an objector meet the following requirements: (1) state property or other interest in the matter; (2) set forth questions of procedure, fact, law, or policy, to which objections are taken; (3) state all grounds for objections to the proposed permits, (4) provide a copy of the objection letter(s) to the applicant, and (5) submit objections meeting the previous requirements to the Commission by April 25, 1995.

To the best of staff's knowledge there are no objectors who have property interest within the affected Aquifer Systems or who will be directly and immediately affected by the proposed water use.
Well No. 2803-05, 07

EXHIBIT 1
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### EXHIBIT 3
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## ISLAND OF OAHU

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**ISLAND OF OAHU**

**Aquifer System: WAHIAWA**

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DEL MONTE FRESH PRODUCE COMB. PUMPAGE
WELL #3 & #4 (2803-05,07)

EXHIBIT 4
DEL MONTE FRESH PRODUCE PUMPAGE
WELL #1 (2703-01)
April 25, 1995

Ms. Lenore Nakama
Commission on Water Resource Management
P.O. Box 621
Honolulu, HI 96809

Dear Ms. Nakama:

This letter is to request an extended review period for the following water use permit applications:

- Del Monte Fresh Produce for Wells 2703-05 & 07 2803-05
- Caprock Wells Nos. 1905-05, 07, & 09, Ewa, Oahu
- Ewa Plain Water Develop. Corp. for Wells 2303-08 to 10

Please contact me or Luis Manrique at 594-1935 should you have any question on this matter.

Sincerely yours,

Linda K. Delaney
INR Officer
April 17, 1995

MEMORANDUM

TO: Rae M. Loui, Deputy Director
Commission on Water Resource Management

FROM: Don Hibbard, Administrator
Historic Preservation Division

SUBJECT: Application for Water Use Permit, Ground Water Management Areas, O'ahu Del Monte Fresh Produce (Hawaii) for Well Nos. 2703-01 and 2803-05 & 07
Honouliuli, Kunia, 'Ewa, O'ahu
TMK: 9-2-005:002

Thank you for the opportunity to review this project. The applicant proposes to use water from existing sources. Since an approved permit will not authorize any ground disturbing activities we believe that there will be "no effect" on historic sites.

EJ: amk
Mr. Calvin H. Oda  
Del Monte Fresh Produce (Hawaii)  
94-1000 Kunia Road  
Kunia, HI 96759

Dear Mr. Oda:

We acknowledge receipt, on February 14, 1995, of your applications to modify the water use permits for Well Nos. 2703-01 and Well Nos. 2803-05 & 07.

Your application for Well Nos. 2803-05 & 07 is unclear with respect to the quantity of water that will be used for non-agricultural uses at the Village of Kunia. Table 1, on the back of the application form, indicates that the proposed agricultural use is 4.32 mgd. Please provide your estimate of the domestic demand for the 150 existing residential units that are served by the wells and describe how this will be accommodated by the 4.32-mgd allocation request.

A tentative date for Commission action on your applications is May 3, 1995. As such, we recommend that you submit this information no later than April 15, 1995 so that it may be incorporated in the staff's submittal to the Commission. It is further recommended that you provide any reports or studies that support your request for an increased irrigation supply in order to maximize economic yields.

Enclosed is a copy of the public notice for your water use permit applications that will be published in the Honolulu Star Bulletin issues of April 5, 1995 and April 10, 1995.

Please be aware that there may be objections to your applications. If objections are made, the objector is required to file such objections with the Commission and is also required to send you a copy of the objections.

You, or any other party, may respond to objections by filing a brief in support of your applications with the Commission within ten (10) days of the filing of an objection. You, or the other party, must also send a copy of the response to the objector.

If you have any questions, please contact Lenore Nakama at 587-0218.

Sincerely,

RAE M. LOUI  
Deputy Director

LN:ss  
Encl.
TO: Aquatic Resources
Forestry and Wildlife/Natural Area Reserve System
Historic Preservation
Land Management
Office of Conservation and Environmental Affairs
State Parks
Water and Land Development

FROM: Rae M. Loui, Deputy Director

SUBJECT: Request for Comments
Water Use Permit Applications
Groundwater Management Areas, Oahu

Transmitted for your review and comment are copies of water use permit applications for Del Monte Fresh Produce (Hawaii) for Well Nos. 2703-01 and 2803-05 & 07. Notice of these applications will be published in the Honolulu Star Bulletin issues of April 5, 1995 and April 10, 1995.

We would appreciate your review of the attached applications for any conflicts or inconsistencies with the programs, plans, and objectives specific to your division only. Please return this cover memo form by April 25, 1995.

If you have any questions regarding these applications, please contact Lenore Nakama at 587-0218.

LN:ss
Attachment(s)

Response:

( ) We have no comments
( ) We have no objections
( ) Comments attached
( ) Additional information requested
( ) Extended review period requested

Contact person: Phone:

Signed: Date:
TO: Other Interested Parties  
FROM: Rae M. Loui, Deputy Director, Commission on Water Resource Management  
SUBJECT: Request for Comments  
Water Use Permit Applications  
Groundwater Management Areas, Oahu

Transmitted for your review and comment are copies of water use permit applications for Del Monte Fresh Produce (Hawaii) for Well Nos. 2703-01 and 2803-05 & 07. Notice of these applications will be published in the Honolulu Star Bulletin issues of April 5, 1995 and April 10, 1995.

We would appreciate your review of the attached applications for any conflicts or interferences with the programs, plans, and objectives of the organization or agency that you represent. Written objections should be made in accordance with Section 13-171-18 of our Administrative Rules and must be filed by the April 25, 1995 deadline.

If you have any questions regarding these applications, please contact Lenore Nakama at 587-0218.

LN: ss  
Attachment(s)  
Response:  

( ) We have no comments  
( ) We have no objections  
( ) Comments attached  
( ) Additional information requested  
( ) Extended review period requested  

Contact person: ____________________________ Phone: ________________  
Signed: ____________________________ Date: ________________
TO: Mr. Kali Watson, Chairperson
Department of Hawaiian Home Lands
Dr. Lawrence Miike, Director
Department of Health
Mr. Clayton H. W. Hee, Chairperson
Office of Hawaiian Affairs
Ms. Esther Ueda, Executive Officer
Land Use Commission
Mr. Raymond Sato, Manager & Chief Engineer
Honolulu Board of Water Supply
Mr. Patrick Onishi, Director
Department of Land Utilization
Mrs. Cheryl D. Soon, Chief Planning Officer
Planning Department

FROM: Michael D. Wilson, Chairperson
Commission on Water Resource Management

SUBJECT: Water Use Permit Applications
Groundwater Management Areas, Oahu

Transmitted for your review and comment are copies of the water use permit applications for Del Monte Fresh Produce (Hawaii) for Well Nos. 2703-01 and 2803-05 & 07. Notice of these applications will be published in the Honolulu Star Bulletin issues of April 5, 1995 and April 10, 1995.

We would appreciate your review of the attached applications for any conflicts or inconsistencies with the programs, plans, or objectives specific to your organization or department only. Please return this cover memo form by April 21, 1995.

If you have any questions regarding these applications, please contact Lenore Nakama at 587-0218.

Attachment(s)

Response:

() We have no comments
() We have no objections
() Comments attached
() Additional information requested
() Extended review period requested

Contact person: ___________________________________ Phone: _______________________
Signed: ________________________________________ Date: ______________________
Honorable Jeremy Harris, Mayor  
City & County of Honolulu  
City Hall  
Honolulu, HI 96813

Dear Mayor Harris:

Notice of Applications for Water Use Permits  
Groundwater Management Areas, Oahu

In accordance with the Department of Land and Natural Resources Administrative Rules, Section 13-171-17(a), we are sending you a copy of the public notice for the water use permit applications for Del Monte Fresh Produce (Hawaii) for Well Nos. 2703-01 and 2803-05 & 07, which will be published in the Honolulu Star Bulletin.

In addition, Section 13-171-13(b), of our Administrative Rules, states:

"Within sixty days after receipt of notice of a permit application, the county shall inform the commission if the proposed use is inconsistent with the county land use plans and policies."

We have attached a copy of the applications for your review and would appreciate receiving your comments, within the next sixty (60) days, on whether the proposed water use is consistent with county plans and policies.

Aloha,

MICHAEL D. WILSON

Enclosures
PUBLIC NOTICE

Application for Water Use Permit
Groundwater Management Areas, Oahu

The following applications for water use permits have been received and are hereby made public in accordance with Department of Land and Natural Resources Administrative Rules 13-171, "Designation and Regulation of Water Management Areas."

Honouliuli Wells 7, 8, & 9 (Well Nos. 2303-08 to 10)
Applicant: Ewa Plain Water Development Corp.
1001 Kamokila Blvd.
Kapolei, HI 96707
Date Completed Application Received: December 29, 1994
Aquifer: Ewa-Kunia System, Pearl Harbor Sector, Oahu
Water Source: Honouliuli 7, 8, & 9 (Well Nos. 2303-08 to 10) at Honouliuli, Ewa, Oahu, Tax Map Key 9-2-1:1
Quantity Requested: 7,068,689 gallons per day.
New Water Use: Municipal for Ewa by Gentry, Ko Olina Resort, Ewa Marina, and James Campbell Industrial Park developments
Place of Water Use: Ewa Plain, Oahu

Kunia Well (Well No. 2703-01)
Applicant: Del Monte Fresh Produce (Hawaii)
94-1000 Kunia Road
Kunia, HI 96759
Date Completed Application Received: February 14, 1995
Aquifer: Waipahu-Waiawa System, Pearl Harbor Sector, Oahu
Water Source: Kunia Well (Well No. 2703-01) at 94-1000 Kunia Rd., Oahu, Tax Map Key 9-2-5:2
Quantity Requested: 432,000 gallons per day.
Existing and New Water Use: Agricultural use for 2,500 acres of pineapple (application is to modify existing water use permit to increase the current allocation by 278,000 gpd for a total allocation of 432,000 gpd)
Place of Water Use: 94-1000 Kunia Road, Oahu

Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07)
Applicant: Del Monte Fresh Produce (Hawaii)
94-1000 Kunia Road
Kunia, HI 96759
Date Completed Application Received: February 14, 1995
Aquifer: Wahiawa System, Central Sector, Oahu
Water Source: Del Monte Wells 3 & 4 (Well Nos. 2803-05 & 07) at 94-1000 Kunia Rd., Oahu, Tax Map Key 9-2-5:2
Quantity Requested: 4,320,000 gallons per day.
Existing and New Water Use: Agricultural use for 2,500 acres of pineapple (application is to modify existing water use permit to increase the current allocation by 2,200,000 gpd for a total allocation of 4,320,000 gpd)

Place of Water Use: 94-1000 Kunia Road, Oahu

Caprock Wells 1, 2, & 3 (Well Nos. 1905-05, 07, & 09)

Applicant: State Dept. of Land and Natural Resources, Division of Water and Land Development
1151 Punchbowl St., Rm. 227
Honolulu, HI 96813

Date Completed Application Received: February 3, 1995

Aquifer: Ewa Caprock System, Oahu

Water Source: Caprock Wells 1, 2, & 3 (Well Nos. 1905-05, 07, & 09) at Campbell Industrial Park, Oahu, Tax Map Key 9-1-15:12

Quantity Requested: 1,000,000 gallons per day.

Existing and New Water Use: Demonstration Desalting Plant (application is to modify existing water use permit for 1905-05 to include 1905-07 & 09 and to increase the current allocation by 500,000 gpd for a total allocation of 1,000,000 gpd for the battery)

Place of Water Use: Campbell Industrial Park (Demonstration Desalting Plant)

Written objections or comments on the above applications may be filed by any person who has property interest in any land within the hydrologic unit of the source of water supply, any person who will be directly and immediately affected by the proposed water use, or any other interested person. Written objections shall: (1) state property or other interest in the matter (provide TMK information); (2) set forth questions of procedure, fact, law, or policy, to which objections are taken; and (3) state all grounds for objections to the proposed permit.

Written objections must be received by April 25, 1995. Objections must be sent to 1) the Commission on Water Resource Management, P.O. Box 621, Honolulu, Hawaii 96809 and 2) the applicant at the above address.

COMMISSION ON WATER RESOURCE MANAGEMENT

EDWIN T. SAKOYA for

for: MICHAEL D. WILSON
Chairperson

Dated: MAR 31 1995

Mr. Calvin H. Oda
Del Monte Fresh Produce (HI) Inc.
94-1000 Kunia Road
Kunia, HI 96759

Dear Mr. Oda,

Applications for Water Use Permits
Well Nos. 2803-05, 2803-07, and 2703-01
Wahiawa Groundwater Management Area, Oahu

Pursuant to your discussion on January 4, 1995 with Lenore Nakama of my staff, we are returning your applications for water use permit and your check for $75.00 for the filing fee.

Please find enclosed an updated application form. At your option, you may submit new applications using the enclosed form, or complete the highlighted areas to supplement the information that has been provided in your original applications. If you choose the latter, please resubmit the original applications also.

As was further discussed, only one application is needed for Well Nos. 2803-05 and 2803-07, which operate as a battery. To further clarify your intent for the public review process, we suggest that you indicate on your application that you are seeking approval for a modification of the existing water use permit for an increase of 2.2 mgd in the allocation specified therein.

Please contact Lenore Nakama at 587-0218 if you have any questions.

Sincerely,

RAE M. LOUI
Deputy Director

LN:ss
Encl.
November 7, 1994

Division of Water Resource Management
Department of Land and Natural Resources
P. O. Box 373
Honolulu, Hawaii  96809

Subject: Applications For Water Use Permits

Del Monte Fresh Produce (Hawaii) Inc. is an agricultural operation that produces more than 110 thousand tons of pineapple per year that provides employment for approximately 700 people.

Del Monte Fresh Produce (Hawaii) Inc. farms 2,500 acres of pineapple in the Kunia area on the island of Oahu in the State of Hawaii. The pineapple crop requires a minimum of 0.5 acre inch water per week (or 2,000 gallons per day) to sustain plant growth and to attain maximum economic yields. Irrigation water is supplied by deep wells (State numbers 2803-05 and 2803-07) owned and operated by Del Monte Fresh Produce (Hawaii) Inc. located in the Pearl Harbor Aquifer. After government approval, a third deep well (State number 2703-01) may be used for irrigating pineapple fields.

Current water use permits do not allow for adequate water for irrigation purposes from existing sources. During peak demands, the pineapple crop in the Kunia area can efficiently use 5.0 million gallons of water per day (or 2,000 gallons per acre per day).

Economic pineapple production by Del Monte Fresh Produce (Hawaii) Inc. is based on agricultural operations' ability to supply fresh fruit packing and marketing operations with controlled quantities of fruit of proper fruit size distribution during specified periods determined in planning processes three years prior to actual harvests.

In the current production system, yield losses, shifts in fruit size distribution, and delays in fruit deliveries caused by the inability to properly irrigate the pineapple crop can result in severe economic losses. In recent years, increasing foreign competition and rising production
costs has made maximizing yields of marketable fruit sizes and proper scheduling of fruit deliveries increasingly more critical for economic pineapple production. Del Monte Fresh Produce (Hawaii) Inc. respectfully requests approval of the enclosed permit applications for water permits for existing Del Monte wells to allow for continued economic production of the pineapple crop in the Kunia, Hawaii.

If there are any questions relating to the enclosed water use permit applications, please don't hesitate to call me at (808) 621-1205. Thank you for your support of the pineapple industry in Hawaii.

Sincerely,

Calvin H. Oda
Director, Pineapple Research
Del Monte Fresh Produce (Hawaii) Inc.

xc: D. Wilson
    B. Nishida
    R. McCloskey
    file
Ms. Lenore Nakama  
State of Hawaii  
Department of Land and Natural Resources  
Commission on Water Resource Management  
P. O. Box 621  
Honolulu, HI  96809

Dear Ms. Nakama,

Enclosed are the revised applications for a modification of existing water use permits for Del Monte Wells 3 and 4 (State No. 2803-05 and 2803-07) and the Kunia Well (State No. 2703-01).

The intent of the water use permit application for Del Monte Wells 3 and 4 which is operated as a battery is for an increased allocation of 2.2 million gallons of water per day.

As stated in the background information in the water use application for the Kunia Well, an increase in the allocation of 278 thousand gallons per day has been requested for irrigation of the existing pineapple crop in the Kunia area and to increase the efficiency of the remedial programs at the site. Use of the allocation will be dependent on the outcome of negotiations with the United States Environmental Protection Agency on appropriate remedial actions at the site.

If there are any questions, please call me at (808) 621-1205. Thank you for your assistance in this matter.

Sincerely,

Calvin H. Oda
Director, Pineapple Research
Del Monte Fresh Produce (Hawaii) Inc.
APPLICATION FOR WATER USE PERMIT

3-Ground Water or □ Surface Water

PERMIT INFORMATION

1. (a) APPLICANT
   Firm/Name: Del Monte Fresh Produce (Hawaii) Inc.
   Contact Person: Calvin H. Oda
   Address: 94-1000 Kunia Road, Kunia, Hawaii 96759

(b) LANDOWNER OF SOURCE
   Firm/Name: same
   Contact Person: Ph:
   Address: same

SOURCE INFORMATION

2. WATER MANAGEMENT AREA: Pearl Harbor Aquifer (Waipahu Low Level)
   ISLAND: Oahu

3. (a) EXISTING WELL/DIVERSION NAME AND STATE NUMBER: Kunia Well (State No. 2703-01)
   (b) PROPOSED (NEW) WELL/DIVERSION NAME: Not Applicable
   (c) LOCATION: Address 94-1000 Kunia Road, Kunia, Hawaii 96759

   (Attach a USGS map, scale 1"=2000', and a property tax map showing source location referenced to established property boundaries.)

4. SOURCE TYPE (check one): □ Stream □ Well □ Perched □ Dike-confined □ Open-pipe □ Artesian □ Well & Pump □ Diverted Surface □ Other (explain)

5. METHOD OF TAKING WATER (check one): □ South Stream □ Dike-confined □ Perched □ Artesian □ Well & Pump □ Diverted Surface □ Other (explain)

USE INFORMATION

6. LOCATION OF PROPOSED WATER USE: (if possible, show on same maps as source location. Otherwise, attach similar maps)
   (a) Proposed use of water in: □ Existing □ New □ Both existing & new use
   (b) Tax Map Key: 9-2-002
   (c) Address: 94-1000 Kunia Road, Kunia, Hawaii 96759
   (d) Current Land Use District: □ Urban □ Agriculture □ Conservation □ Rural
   (e) Current County Zoning Code: □ __________

7. QUANTITY OF WATER REQUESTED: 432,000 gallons per day (averaged over 1 year)

8. METHOD OF MEASUREMENT: □ Flowmeter □ Open-pipe □ Well □ Office □ Other (explain)

9. QUALITY OF WATER REQUESTED: □ Fresh □ Brackish □ Salt □ Potable □ Non-Potable

10. PROPOSED USE: □ Municipal (including hotels, stores, etc.) □ Individual Domestic □ Irrigation □ Industrial □ Military □ Other (explain)

   For questions 12 & 13: If multiple TMKs are involved, please complete Table 1 on back of application.

11. TOTAL NUMBER OF RESIDENCES TO BE SERVED: none

12. TOTAL ACRES TO BE IRRIGATED AND TYPE OF CROP: 2,595 acres pineapple

13. PROPOSED TIME OF WATER WITHDRAWAL OR DIVERSION: 6:00AM to 6:00AM (24 hrs.)

14. APPLICANT MUST BRIEFLY DESCRIBE FOLLOWING POTENTIAL RESTRICTIONS ON WATER USE:
   (a) Impact on Sustainable yield (7?): none anticipated
   (b) Instream Flow Standards affected (7?): not applicable
   (c) Hawaiian Home Lands use affected (7?): not applicable
   (d) Other existing legal uses affected (7?): not applicable
   (e) Other (permitting, EIS, etc.) (7?): compliance with CERCLA Consent Agreement

15. REMARKS, EXPLANATIONS: see attached

If more space is needed, continue on back side)

NOTE: Signing below indicates that the applicant understands that, if a water use permit is granted by the Commission on Water Resource Management, a permit is subject to prior existing permitted uses, changes in sustainable yields and instream flow standards, reserved uses as defined by the Commission, and Hawaiian Home Lands future uses. In addition, applicant understands that, upon permit approval, a water shortage plan must be submitted should the Commission require one.

Applicant (print): Calvin H. Oda
Signature: ____________________________
Date: January 24, 1995

Applicant (print): same
Signature: ____________________________
Date: January 24, 1995

For Official Use Only:
Date Received: _____________________ Hydrologic Unit No.: _____________________ Diversion Works No.: _____________________ State Well No.: _____________________
Date Approved: ____________________

5/19/93 WUPA Form
15. Oahu Plantation is a pineapple agricultural operation owned and operated by Del Monte Fresh Produce (Hawaii) Inc. The street address for the facility is 94-1000 Kunia Road, P. O. Box 200, Kunia, Hawaii, 96759.

Oahu Plantation is located on 7,500 acres of land at 720 to 1200 foot elevation on the western side of the Central Oahu plain on the island of Oahu in the State of Hawaii. The facility is composed primarily of agricultural areas dedicated to pineapple production, but also contains four (4) well sites, two company operated housing complexes, equipment maintenance areas, warehouses, administrative buildings, and fresh pineapple packing operations.

In 1994, Del Monte Fresh Produce (Hawaii) Inc. produced 110,000 tons of pineapple representing approximately 30 percent of the State’s production. Agricultural operations and packing facilities employ approximately 700 people.

The proposed water use is for irrigation of the existing pineapple crop grown in the Kunia section of Oahu Plantation. The use area consists of approximately 2,500 acres of arable lands on the slopes of the Waianae mountain range.

The pineapple crop requires a minimum of 0.5 acre inch water per week (or 2,000 gallons per day) to sustain plant growth and attain maximum economic yields.

Current water use permits do not allow for adequate water for irrigation purposes from these existing sources. During peak demands, the pineapple crop in the Kunia area can efficiently utilize 5.0 million gallons of water per day.

Del Monte Fresh Produce (Hawaii) Inc. respectfully requests approval of this permit application to allow use of up to 432 thousand gallons of water per day or an increase of 228 thousand gallons of water per day from the Del Monte Kunia Well (State Well No. 2703-01). This will allow for improvements in plant growth and the continuation of production of pineapple crops in the Kunia area.
Other Benefits - Remedial Action

Ethylene dibromide (EDB) and 1, 2 dibromo - 3 - chloropropane (DBCP) are preplant soil fumigants previously registered under the Federal Fungicide, Insecticide, and Rodenticide Act for control of parasitic nematodes in pineapple culture. As a result of accidental releases in fumigant storage and mixing areas located near the Kunia Well (State No. 2703-01) and the legal application of DBCP, both EDB and DBCP have contaminated soil, saprolite, perched groundwater at approximately 40 feet below ground surface, and groundwater in the basal aquifer in the immediate vicinity of the Kunia Well located on Del Monte Fresh Produce (Hawaii) Inc.'s Oahu Plantation.

Voluntary site investigations and remedial actions started in 1980 immediately after the discovery of the contamination have been successful in significantly reducing contaminant levels in the soil, saprolite, perched groundwater, and groundwater in the basal aquifer in the vicinity of the Kunia Well. Current mean 1994 contaminant levels in the basal aquifer are 0.15 parts per billion (ppb) and 0.63 ppb representing declines in contaminant levels of 94.3 (DBCP) to 99.8 (EDB) when compared to the 1980 Hawaii Department of Health laboratory results.

Despite the significant voluntary effort on December 6, 1994, the United States Environmental Protection Agency listed Del Monte's Oahu Plantation on the National Priorities List of the Comprehensive Environmental Liability and Response Act.

In good faith, Del Monte Fresh Produce (Hawaii) Inc. will continue to voluntarily participate in remedial investigations and clean-up actions at the Kunia Well site under a Consent Agreement until contaminant levels are at or below State maximum contaminant levels. One of the most practical remedial actions is to pump the Kunia Well on a routine basis and after dilution use the non-potable, non-hazardous water for irrigation on the pineapple crop.

Approved by EPA, Del Monte Fresh Produce (Hawaii) Inc. will also use the increase of 278,000 gallons of water per day from the Kunia Well to allow for improved removal efficiency of contaminants in the basal aquifer in the vicinity of the well site.
If there are any questions relating to this permit application or if more information is required, please call Calvin H. Oda at (808) 621-1205.
TABLE 1. MULTIPLE TMKs TO USE REQUESTED WATER

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TOTAL 2594.7
APPLICATION FOR WATER USE PERMIT

1. (a) APPLICANT
   Firm/Name: Del Monte Fresh Produce (Hawaii) Inc.
   Contact Person: Calvin H. Oda
   Ph.: (808) 621-1200
   Address: 94-1000 Kunia Road
   Kunia, Hawaii 96759

(b) LANDOWNER OF SOURCE
   Name: same
   Address: 

2. WATER MANAGEMENT AREA: Pearl Harbor Aquifer (Wahiawa High Island: Oahu)
3. (a) EXISTING WELL/DIVERSION NAME AND STATE NUMBER:
   (b) PROPOSED (NEW) WELL/DIVERSION NAME: not applicable
   (c) LOCATION: Address: 94-1000 Kunia Road, Kunia, Hawaii 96759

4. SOURCE TYPE (check one): Stream □, Beal □, Dike-confined □, Perched □, Caprock □
5. METHOD OF TAKING WATER (check one): Artsen □, Well & Pump □, Diverted Surface □, Other (explain) □

6. LOCATION OF PROPOSED WATER USE: If possible, show on same map as source location. Otherwise, attach similar map
   (a) Proposed use of water is: □ Existing □ New □ Both existing & new uses
   (b) Tax Map Key: 4-2-005:002 (If location of use is over multiple TMKs, please complete Table 1 on back of application)
   (c) Address: 94-1000 Kunia Road, Kunia, Hawaii 96759
   (d) Current Land Use District: □ Urban □ Agriculture □ Conservation □ Rural
   (e) Current County Zoning Code: □ Agriculture □

7. QUANTITY OF WATER REQUESTED: 4.32 million gallons per day (averaged over 1 year)

8. METHOD OF MEASUREMENT: □ Flowmeter □ Open-pipe □ Weir □ Office □ Other (explain)

9. QUALITY OF WATER REQUESTED: □ Fresh □ Brackish □ Salt □ Potable □ Non-Potable

10. PROPOSED USE: □ Municipal (including hotels, stores, etc.) □ Individual Domestic □ Irrigation □ Industrial □ Military □ Other (explain)

11. TOTAL NUMBER OF RESIDENCES TO BE SERVED: 150 residential

12. TOTAL ACRES TO BE IRRIGATED AND TYPE OF CROP: 2,595 acres pineapple

13. PROPOSED TIME OF WATER WITHDRAWAL OR DIVERSION: 6:00AM to 6:00AM (24 hrs.)

14. APPLICANT MUST BRIEFLY DESCRIBE FOLLOWING POTENTIAL RESTRICTIONS ON WATER USE:
   (a) Impact on Sustainable yield (?): Increase represents only approximately 1.1% of total sustainable yield.
   (b) Instream Flow Standards affected (?): not applicable
   (c) Hawaiian Home Lands use affected (?): not applicable
   (d) Other existing legal uses affected (?): not applicable
   (e) Other (pending permits, EIS, etc.,?): not applicable

15. REMARKS, EXPLANATIONS: see attached

(If more space is needed, continue on back side)

NOTE: Signing below indicates that the applicant understands that, if a water use permit is granted by the Commission on Water Resources Management, a permit is subject to prior existing permitted uses, changes in sustainable yields and instream flow standards, reserved uses as defined by the Commission, and Hawaiian Home Lands hours uses. In addition, applicant understands that, upon permit approval, a water shortage plan must be submitted should the Commission require one.

Applicant (print): Calvin H. Oda
Signature: ______________________ Date: January 24, 1995

Landowner (print): ______________________
Signature: ______________________ Date: 

For Official Use Only: 
Date Received: ______________________ Hydrologic Unit No. ______________________ Diversion Wells No. ______________________ State Well No. ______________________
15. Oahu Plantation is a pineapple agricultural operation owned and operated by Del Monte Fresh Produce (Hawaii) Inc.. The street address for the facility is 94-1000 Kunia Road, P.O. Box 200, Kunia, Hawaii, 96759.

Oahu Plantation is located on 7,500 acres of land at 720 to 1200 foot elevation on the western side of the Central Oahu plain on the island of Oahu in the State of Hawaii. The facility is composed primarily of agricultural areas dedicated to pineapple production, but also contains four (4) well sites, two company operated housing complexes, equipment maintenance areas, warehouses, administrative buildings, and fresh pineapple packing operations.

In 1994, Del Monte Fresh Produce (Hawaii) Inc. produced 110,000 tons of pineapple representing approximately 30 percent of the State's production. Agricultural operations and packing facilities employ approximately 7000 people.

The proposed water use is for irrigation of the existing pineapple crop grown in the Kunia section of Oahu Plantation. The use area consists of 2,500 acres of arable lands on the slopes of the Waianae mountain range. A portion of the water would be used to provide potable water for the Village of Kunia and workplaces.

The pineapple crop requires a minimum of 0.5 acre inch water per week (or 2,000 gallons per day) to sustain plant growth and attain maximum economic yields.

Current water use permits for Del Monte Wells 3 (State No. 2803-05) and 4 (State No. 2803-07) do not allow for adequate water for irrigation purposes from these existing sources. During peak demands, the pineapple crop in the Kunia area can efficiently utilize 5.0 million gallons of water per day.

Del Monte Fresh Produce (Hawaii) Inc. respectfully requests approval of this permit application to allow use of up to 4.32 million gallons of water per day or an increase of 2.2 million gallons of water per day from Del Monte Wells 3 and 4 operated as a battery. This will allow for improvements in plant growth and the continuation of production of pineapple crops in the Kunia area.
If there are any questions relating to this permit application or if more information is required, please don't hesitate to call Calvin Oda at (808) 621-1205.
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TOTAL | 2594.7
Mr. William W. Paty  
Chairperson  
Board of Land and Natural Resources  
State of Hawaii  
P.O. Box 621  
Honolulu, Hawaii 96809

Dear Mr. Paty:

Enclosed is your fully executed Supplemental Agreement No. 1 to Department of the Army License, Contract No. DACA84-3-83-2, extending the term of the license to September 30, 1991.

Sincerely,

Lyle E. Toepke  
Chief, Real Estate Division

Enclosure
SUPPLEMENTAL AGREEMENT NO. 1
TO
LICENSE, CONTRACT NO. DAC84-3-83-2
U.S. ARMY FIELD STATION, KUNIA

THIS SUPPLEMENTAL AGREEMENT NO. 1, made between the
Secretary of the Army (hereinafter Secretary) or duly
authorized representative, and the Department of Land and
Natural Resources, State of Hawaii (hereinafter licensee),
WITNESSETH:

WHEREAS, by License, Contract No. DAC84-3-83-2, the
Secretary authorized the licensee, for a term ending
September 30, 1986, use of Deep Water Well No. 3 together with
its water pump and for the installation, operation and
maintenance of a bypass system at U.S. Army Field Station,
Kunia, Honolulu, Ewa, Oahu, Hawaii, to provide irrigation
water service to the licensee and its authorized permittees;
and

WHEREAS, the licensee, having complied with the
requirements of the State of Hawaii Department of Health Safe
Drinking Water Act, desires use of the well water for drinking
purposes in addition to providing irrigation water service;
and

WHEREAS, it is mutually desired to substitute a State of
Hawaii well identification number in place of the existing
Department of the Army number; and

WHEREAS, it is mutually desired to extend the term of said
license as hereinafter set forth.

NOW, THEREFORE, the parties hereto do mutually agree as
follows:

1. That the licensee is authorized use of the well water
for drinking purposes in addition to providing irrigation
water service to its authorized permittees insofar as the
licensee complies with the State of Hawaii Department of
Health Safe Drinking Water Act and any other applicable law or
ordinance that may be promulgated relative to safe and clean
drinking water.
2. That Well Identification Number 2803-05 is hereby substituted in place of the existing "Well No. 3".

3. That said License, Contract No. DACA84-3-83-2, is hereby extended for a term of five (5) years beginning October 1, 1986 and ending September 30, 1991, but revocable at will by the Secretary or duly authorized representative.

4. That except as hereinabove expressly provided, all of the conditions of said license shall be and remain the same.

5. This supplemental agreement is not subject to Title 10, United States Code, Section 2662.

IN WITNESS WHEREOF, I have hereunto set my hand by authority of the Secretary of the Army as of the 1st day of October 1986.

LYLE E. TOEPKE
Chief, Real Estate Division
U.S. Army Engineer Division,
Pacific Ocean
Corps of Engineers

The above instrument, together with all the conditions thereof, is hereby accepted as of the 1st day of October 1986.

STATE OF HAWAII
DEPARTMENT OF LAND AND
NATURAL RESOURCES

APPROVED AS TO FORM

Deputy Attorney General, State of Hawaii

APPROVED BY THE BOARD OF
LAND AND NATURAL RESOURCES
APR 10 1987

Page 2 of 2 Pages
S.A. #1 to Lic, DACA84-3-83-2
U.S. Army Kuni Wells 2803-03-06

GROUND WATER CONTROL AREA CHECKLIST

Sept. 18, 1984

Receive Application for Water Use Permit

Dec. 18, 1984

Prepare Board Submittal (water must be put to beneficial use within 24 months from the date of issuance of the permit).

Ten-day public notice for Board meeting on Dec. 28, 1984.

Mar. 17, 1985

180-day expiration date, Board action due.

Board approved at 12/28/84 meeting.

Jan. 12, 1985

Issue Water Use Permit.

Receive Well Drilling Permit.

Issue Well Drilling Permit.
PEARL HARBOR GROUND WATER CONTROL AREA

WATER WITHDRAWAL and USE PERMIT

for

KUNIA Wells 2803-03 and 2803-06
Kunia, Oahu

TO: Colonel Ronald A. Borrello
Directorate of Facilities
Engineering, USASCH
Fort Shafter, Hawaii 96858

Permission is hereby granted to the United States Army to withdraw and use water from Kunia Wells 2803-03 and 2803-06 located in Kunia, Oahu, subject to all requirements of Chapter 177, HRS, DLNR Chapter 166 of Title 13, and the following conditions:

1. The term of this permit shall be fifteen years from the date of issuance of the permit with a review every five years by the Board to determine compliance with the provisions of the permit.

2. The water withdrawn shall be 0.25 million gallons per day (mgd) total maximum daily.

3. The use authorized by the permit must not interfere substantially and materially with existing individual household uses and existing preserved uses.

4. The use of this well shall be subject to the shortage and emergency powers of the Board of Land and Natural Resources (BLNR).

5. This permit may be suspended or revoked, in accordance with Chapter 166.

6. The permit holder may be required to relinquish this permit to BLNR, in accordance with Chapter 166.

7. The combined average daily water withdrawal from the Kunia Wells (2803-03 and 2803-06) and the Schofield Battery (2901-02 to 2901-04, 2901-10) will be no greater than 5.455 mgd.

8. Approved flowmeters shall be installed to measure water withdrawals.
9. The withdrawals shall be recorded and reported to DLNR on a monthly basis.

The Board of Land and Natural Resources may declare this permit null and void, if it determines that the foregoing conditions 7 through 9 have not been met within 36 months after its date of issuance.

SUSUMU ONO, Chairperson of the Board

1/12/85
Date of issuance

cc: USGS
Dept. of Health
Chairperson and Members  
Board of Land and Natural Resources  
State of Hawaii  
Honolulu, Hawaii  

Gentlemen:

U.S. Army Water Use Permit Application for  
Kunia Wells No. 2803-03 and 2803-06  
Pearl Harbor Ground Water Control Area

The Department of the Army has submitted a Water Use Permit Application for Kunia Wells No. 2803-03 and 2803-06 located in the Pearl Harbor Ground Water Control Area. The proposed use of these existing wells for drinking water is part of an effort to establish an emergency source of potable water for the U.S. Army Field State (USAFS) Kunia. These wells are located near USAFS Kunia and the wells will only be utilized in the event that the primary water supply from the Schofield Battery (State Well Nos. 2901-02 to 2901-04, 2901-10) is interrupted. The Schofield Battery is the Army's certified source of potable water with a preserved use of 5.455 mgd average daily withdrawal. The combined average daily water withdrawal for the Kunia Wells and the Schofield Battery will be no greater than 5.455 mgd.

Permitting the use of wells 2803-03 and 2803-06 as alternate sources during an emergency will not increase pumpage from the Pearl Harbor Ground Water Control Area. It will provide the Department of the Army with potable water for the USAFS Kunia during emergency situations when the normal source of water from Schofield is disrupted.

RECOMMENDATION:

That the Board approve the issuance of a Water Use Permit to the Department of the Army to utilize Kunia Wells No. 2803-03 and 2803-06 as alternate sources of potable water in the event of an emergency situation in which the primary water supply from the Schofield Battery (State Well Nos. 2901-02 to 2901-04, 2901-10) is interrupted. The combined average daily water withdrawal from the Kunia Wells and the Schofield Battery will be no greater than 5.455 mgd. The duration of the permit shall be 15 years with a review every five years by the Board to determine compliance with provisions of the permit. The application shall be subject to any special conditions and applicable laws, rules and regulations.

Respectfully submitted,

ROBERT T. CHUCK  
Manager-Chief Engineer

APPROVED FOR SUBMITTAL:  
SUSUMU ONO, Chairperson
Mr. Robert Chuck  
Manager-Chief Engineer  
Division of Water and Land Development  
Department of Land and Natural Resources  
P.O. Box 373  
Honolulu, Hawaii 96809  

Dear Mr. Chuck:  

Enclosed for your review is an application for a permit to supply water to the United States Army Field Station Kunia during an emergency and a supporting engineering report.  

If you have any questions regarding the application or report, please contact Mr. Clifton K. Takenaka, Environmental Engineer, at 655-0694.  

Sincerely,  

[Signature]  
Ronald A. Borrello  
Colonel, Corps of Engineers  
Director of Facilities Engineering  

Enclosures
Mr. Robert Chuck  
Manager-Chief Engineer  
Division of Water and Land Development  
Department of Land and Natural Resources  
P.O. Box 373  
Honolulu, Hawaii 96809

Dear Mr. Chuck:

Enclosed for your review is an application for a permit to supply water to the United States Army Field Station Kunia during an emergency and a supporting engineering report.

If you have any questions regarding the application or report, please contact Mr. Clifton K. Takenaka, Environmental Engineer, at 655-0694.

Sincerely,

Ronald A. Borrello  
Colonel, Corps of Engineers  
Director of Facilities Engineering

Enclosures
APPLICATION FOR: (check one)
☐ PERMIT TO WITHDRAW WATER FOR BENEFICIAL USE
☒ PERMIT TO SUPPLY WATER FOR BENEFICIAL USE

Instructions: Fill out, sign, and send application with pertinent attachments to Dept. of Land & Natural Resources, P.O. Box 373, Honolulu, Hawaii 96809. A non-refundable filing fee of $100 is required, excepting military, federal, state, and local government agencies.

1. NAME OF APPLICANT: COLONEL RONALD A. BORRELLO
   Address: Shafter, HI 96858
   Phone: 655-483

2. REQUESTED BENEFICIAL USE OF WATER:
   ☑ Domestic ☐ Municipal ☐ Military ☐ Agricultural ☐ Industrial ☐ Other
   (specify)
   Appropriately describe nature and purpose of requested use: The wells in the past have been used as cooling water. Request a change in the use to include an alternate source of potable water during an emergency.
   Proposed commencement date of water use: August 1, 1984

3. REQUESTED AMOUNT OF WITHDRAWAL OR SUPPLY:
   Average Annual NA mgd; Maximum Month NA mgd; Maximum Day 0.25 mg
   Appropriately describe schedule or times of taking requested withdrawal: As needed in emergency. Wells will only be utilized for emergency purposes in the event that the primary water supply from Schofield is interrupted.

4. NATURE AND TERM OF REQUESTED PERMIT: ☐ Temporary ☐ Permanent
   Requested period of permit: 15 Years

5. PROPOSED SOURCE OF WATER SUPPLY:
   ☑ Existing source ☐ Modification of existing source ☒ New source
   Briefly describe existing or proposed source and any related facilities and submit map, plot plan, and plans or drawings of source of supply: Existing well numbers are as follows: 2803-03 and 2803-06. Location and site maps are contained within the attached study.

If construction work is proposed for new or modified existing source, give:
   Commencement Date July 1, 1984
   Completion Date August 1, 1984

6. ASSESSMENT OF REQUESTED WATER USE OR SUPPLY
   In a separate attachment to this application, applicant must provide a written assessment addressing the desirability of issuing the requested permit, including such considerations as the availability of water, the beneficial purpose of the proposed water use, and the impact, if any, of the proposed water use on existing permitted uses, preserved uses, and individual household uses.

   Signature: [Signature]
   Date: 29 Aug 84
   Water User or Supplier
   R.M. BUNE, Colonial, HI, Commander, USAFS Kunia

   Signature: [Signature]
   Date: 11 Sep 84
   Owner of Water Source
   NAWC, BOCIA, Colonial, Inf. Commander, USAASCH

In accordance with Department Regulation No. 9, every permit approved and issued by the Board of Land & Natural Resources shall be for a specified period of time, for a specified beneficial use, subject to suspension and revocation, and subject to the shortage and emergency powers of the Board. Consideration of applications for a permit shall include: availability of water, beneficial purpose of water use, non-impairment of the most beneficial use and development of the water resources in the designated area, and no substantial and material interference with existing uses of water.
Division of Water and Land Development

From: [Redacted]
Date: 9/18
File In: [Redacted]

To Initial

Check
Robert T. Chuck
Takeo Fujii
Manabu Tagomori
Harold Sakai

See Me

Take action by

Route to your branch
Review & comment

Draft reply by

For Information
Xerox distributed

Acknowledge receipt

File

Jane Sakai
Doris Hamada
Lorraine Nanbu
Jean Siarot
Elsie Yonamine
Kay Oshiro

[Redacted]

- Water Use Permit to US Army for emergency purposes only.
- Board Submittal
- Publish notice of Board Action
- 180 days to act
- Etc.
ENGINEERING REPORT
FOR
NEW POTABLE WATER SOURCE

UNITED STATES ARMY FIELD STATION KUNIA
KUNIA WELLS NO. 2803-03 and 2803-06

BY:
Mr. Clifton K. Takenaka
Environmental Engineer

DIRECTORATE OF FACILITIES ENGINEERING
US ARMY SUPPORT COMMAND, HAWAII
FORT SHAFTER, HAWAII 96858-5000

PREPARED FOR:
STATE OF HAWAII
DEPARTMENT OF HEALTH

JULY 1984
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<td>IV</td>
<td>Potential Sources of Contamination</td>
<td>22</td>
</tr>
<tr>
<td>V</td>
<td>Sources of Water Supply</td>
<td>36</td>
</tr>
<tr>
<td>VI</td>
<td>Proposed Treatment Works</td>
<td>38</td>
</tr>
<tr>
<td>VII</td>
<td>Pumping Facilities/Water Storage</td>
<td>40</td>
</tr>
<tr>
<td>VIII</td>
<td>Financing</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>43</td>
</tr>
</tbody>
</table>
PROFESSIONAL ENGINEER'S CERTIFICATION

The undersigned, being a registered professional engineer, certifies that:

1. The work was prepared by me or under my supervision and the information contained therein is true to the best of my information and belief; and

2. The water produced by Kunia Wells No. 2803-03 and 2803-06, the drinking water system identified in the attached report, will comply with the State primary drinking water regulations contained in Public Health Regulations Chapter 49, Potable Water Systems, and will comply with the Rules and Regulations of the Board of Water Supply, City and County of Honolulu, when said drinking water system is operated and maintained in accordance with the instructions and information contained in this report.

CHARLES C.H. YANG
Chief, Utilities Division
Directorate of Facilities Engineering
US Army Support Command, Hawaii
INSTALLATION MEDICAL AUTHORITY CERTIFICATION

The undersigned, being the installation medical authority, certifies that:

1. The information contained therein is true to the best of my information and belief; and

2. The water produced by Kunia Wells No. 2303-03 and 2303-06, the drinking water system identified in the attached report, will comply with Army Regulation (AR) 420-46, Water and Sewage, and Technical Bulletin Medical (TB MED) 576, Sanitary Control and Surveillance of Water Supplies at Fixed Installations and other applicable regulations, when said drinking water system is operated and maintained in accordance with the instructions and information contained in this report.

WILLIAM P. MORGAN, M.D.
Colonel, MC
Chief, Preventive Medicine Service
Directorate of Health Services
US Army Support Command, Hawaii
CHAPTER I - GENERAL INFORMATION

The proposed use of existing Wells No. 2803-03 and 2803-06 for drinking water is part of an effort to establish an emergency source of potable water for the US Army Field Station (USAFS) Kunia. These wells are located near USAFS Kunia (see Exhibits 1, 2, and 3) and are currently used to cool emergency generators and provide make up water for air conditioning systems. A liquid sodium hypochlorite injection system has been designed and will be installed to chlorinate water from both wells. Plans to modify the existing pipe network so that well waters may be diverted into the potable water distribution system have not yet been initiated at this time.
CHAPTER II - PHYSICAL AND HYDROLOGICAL CHARACTERISTICS OF AREA

USAFS Kunia is located in the Oahu Central Plains approximately 15 miles north of Pearl Harbor (see Exhibit 2) and adjacent to Wheeler Air Force Base and Schofield Barracks (Main Post).

The vicinity has an annual rainfall of about 44.1 inches and an annual median rainfall of about 43.7 inches. The wet season occurs between the months of November and March. The dry season occurs between the months of April and September. According to the "Storm Drainage Standard" of the City and County of Honolulu, the area can expect a rainfall intensity of one hour equal to 3.0 inches based on a 10 year storm while a 50 year storm would generate only four inches.

The average maximum temperature for the area ranges from 74°F to 85°F and the average annual minimum temperature ranges from about 60°F to 65°F. Temperatures in the 90's have been recorded with minimums near 50°F.

As seen on Exhibit 3, Well 2803-03 is located near antennas and an exhaust structure. The land slopes gently toward the east from 860 to 830 feet, a steep gulch is then encountered with a drop of 70 feet into a parking area. Well No. 2803-06 is located near the center of this parking area. The parking area is enclosed by an access road which extends about 400 feet to Kunia Road. To the east of the access road is another steep gulch which drops from
760 to 725 feet. Contained within the gulch are recreational facilities and a pond approximately 600 feet long and 200 feet wide.

According to the US Soil Conservation Soil Survey, USAFS Kunia lies within the ground soil classification of the Helemano - Wahiawa Association. These are deep, nearly level to moderately sloping, well drained soils that have fine textured subsoil occurring at elevations of 100 to 1200 feet. This association occurs over 18 percent of the island. Helemano soils make up approximately 40 percent of the association and Wahiawa soils 30 percent (reference 2). Descriptions of the soils found on the installation are presented in Table 1.

The USAFS Kunia area is classified by the Uniform Building Code to be in the seismic zone class one. Zone one is described as "Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the MM. Scale."

Groundwater hydrology in the vicinity is not well established. The Schofield High-Level Water Body is the major groundwater system. The groundwater table is believed to be about 200 to 300 feet above sea level. This is 500 to 600 feet below the USAFS Kunia area. The water body is part of a complex groundwater flow system which results from impoundment by groundwater dams. An estimated 127 million gallons of groundwater flows through this water body per day. About 90 percent of this flow is estimated to pass to the south to replenish the Pearl Harbor basal water body (Reference 3). The southern groundwater dam forms the southern boundary of
<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helemano Silty Clay, 30 to 90 percent slopes</td>
<td>Soil is on the sides of V shaped gulches. They developed in alluvium and colluvium derived from ingress rock. Permeability is moderately rapid, and erosion hazard is severe to very severe.</td>
<td>Sides of Waikele Gulch surrounding the parking area, at the tunnel entrance.</td>
</tr>
<tr>
<td>Fill land, mixed</td>
<td>Areas filled with material hauled from nearby sources.</td>
<td>Recreation area opposite stream bank from sewage pump station.</td>
</tr>
<tr>
<td>Kunia Silty Clay, 8 to 15 percent slopes</td>
<td>Soils developed in old alluvium, nearly level to moderately sloping. Occurs on narrow side slopes, mainly along drainage ways. Runoff is medium and erosion hazard is moderate.</td>
<td>Parking area, entrance road and land above the underground facility.</td>
</tr>
<tr>
<td>Kawaihapai clay loam 2 to 6 percent</td>
<td>Well drained soils in drainage ways and on alluvial fans. Formed in alluvium derived from basic igneous rocks in humid uplands, nearly level to moderately sloping. Runoff is slow and the erosion hazard is slight.</td>
<td>Waikele Gulch recreation area man made pond.</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Location</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Wahiawa Silty Clay, 0 to 3 percent slopes</td>
<td>Dusky red silty clay. Well drained soils developed in residium and old alluvium derived from basic igneous rock. Permeability is moderately rapid. Runoff is slow and erosion hazard is no more than slight.</td>
<td>Area between haul road and Kunia Highway.</td>
</tr>
<tr>
<td>Wahiawa Silty Clay, 3 to 8 percent slopes.</td>
<td>Runoff is slow, erosion hazard is slight.</td>
<td>Pocket in the pineapple fields just above the tunnel entrance.</td>
</tr>
</tbody>
</table>
the Schofield high-level water body. Based on water levels in nearby wells, an estimated 250 feet of head is dissipated as the water flows southward over and through the groundwater dam to the Pearl Harbor basal water body (Reference 3). Dike impounded water bodies underlie regional areas of maximum rainfall. The Koolau dike-impounded water body lies east of the Schofield high-water body and the Waianae dike-impounded water body lies to the west. Natural recharge to the groundwater occurs where the annual rainfall exceeds about 50-inches per year. The Koolau dike-impounded water body receives more recharge from the deep infiltration of rainfall than the Waianae dike-impounded water body due to a greater area that receives the required rainfall. In addition, the rock permeability in the Waianae Range is less than one-tenth that of the Koolau Range. Hence, the greatest portion of the Schofield high-water body inflow is derived from the Koolau dike-impounded water body (Reference 3).

Waiekele Stream originates on the north slope of the Waianae range approximately two or three miles upstream from USAFS Kunia and empties into Pearl Harbor. It enters the installation near the recreational area and exits through a concrete box culvert under Kunia Road. The stream is intermittent and only has flow during the rainy season.

The storm drainage system consists mainly of open ditches and culverts under roadways directing runoff water toward Waiekele Stream. The main ditch starts from the above-ground support area in the pineapple fields and runs past the helipad following the top of the gulch. It ends at a drop structure which conveys runoff down the side of the gulch, then into a 48-inch diameter
culvert beneath the tunnel access road. From the culvert another open ditch conveys the flow to the 36-inch diameter pipes located beneath Camp Road. From these pipes the ditch is divided into two branches. One branch is directed to the pond and the other continues along side the access road and eventually discharges to Waikele Stream. A 10 feet by 12 feet concrete box culvert conveys the flow beneath Kunia Road.

A secondary drainage system is located in the parking lot. A catch basin in the eastern part of the parking lot collects runoff and directs it to an open ditch via an 18-inch diameter concrete pipe.

Each well is located within an underground concrete lined chamber with access via a manhole. The well shaft is protected by a water tight seal between the concrete pavement and the annular space outside the well casing. A float activated sump pump is also located in each well chamber to prevent excessive flooding. The well shaft and pump are enclosed and at no time is the potable water exposed to the external environment.

The 1977 City and County General Plan represented broad objectives and policies which were used to draw up an islandwide set of development plans. The development plans divide the City and County of Honolulu into eight districts. The USAFS Kunia is within the Central Oahu District (Ordinance No. 83-7, dated 10 May 83). According to the development plan, the installation is divided between two land use designations, military and agriculture. The access road and surface parking areas are included in the military land use designation. The remaining portions, which include the underground facility,
are within the agriculture land use designation. This separation between the different land uses for the installation is delineated by the State Land Use boundary line (Exhibit 3A).

USAFS Kunia is located partly in the Clear Zone and partly in the Accident Potential Zone I for the active Class B runway (Runway 6-240), Wheeler Air Force Base. Information on airfield operations at Wheeler field indicates that a large percentage (over 80 percent) of aircraft takeoffs are towards the northeast away from USAFS Kunia. Also, there is no history of aircraft crashes in the area occupied by USAFS Kunia and the possibility thereof is minimal.
CHAPTER III - EXTENT OF WATERWORKS SYSTEM

USAFS Kunia obtains its domestic water from wells located on Schofield Barracks East Range. An eight inch transmission line from the Schofield Barracks system supplies USAFS Kunia and Wheeler Air Force Base via a connection at Wright Avenue and Kunia Road. The pipeline follows the Kunia Road alignment until the state right-of-way width change, turning at this point towards the underground facility entrance tunnel. Within the installation, there are branches leading to the recreational area and Buildings 42, 19 and 30. Three wells on USAFS Kunia supplied cooling water to the underground facility's air conditioning units and the electric generator motors; each well has a pump capacity of 1,600 gpm. In 1982 the air conditioners were switched from using the flow through cooling water to cooling tower condensers. Also, power started being obtained commercially from Hawaiian Electric Company and, as such, use of the wells has been greatly curtailed. Well production is presently limited to providing cooling water for the diesel electric-generators when operated for maintenance purposes (approximately one hour a week). Because of the reduction in water demand Well No. 2803-05 has been leased to Del Monte Corporation. Only Wells No. 2803-03 and 2803-06 supply cooling water for the diesel-generator motors.

USAFS Kunia is a self contained community providing a full range of services and facilities to support military personnel and their dependents. USAFS Kunia is supported by Schofield Barracks relative to housing, community facilities, maintenance, planning and supply services. The main activities
are always conducted in the three-story self-contained, underground primary facility. Currently support facilities on post include administrative, parking, storage and recreational areas, located outside the underground facility entrance.

USAFS Kunia hosts units of the US Army, Navy and Air Force. The current personnel strength at USAFS Kunia is 1,282 military and 84 civilians (February 1984). Of the military personnel, 802 are with the Army. Seven civilian personnel assigned to the Directorate of Facilities Engineering (DFE) and AAFES, work at USAFS Kunia, but are not reflected in the above figures.

The size of the service area is planned to increase by 6.89 acres to provide for the widening of Kunia Road, the inclusion of the heliport and the existing softball field fence and security fence with a cleared strip along the rim of Waikele Gulch (reference 6).

Two projects currently planned will impact on the future water requirements at USAFS Kunia. One of these projects is the construction of a warehouse located on the southeast corner of the parking lot. The overall building plan dimension is 114 feet by 151 feet 4 inches (17,200 SF). The other project is a Secured Compartment Information Facility (SCIF) which will consist of 50-60,000 GSF of floor area for administrative and operational type offices located on two-to-three floors.
The current and projected water supply requirements, other than for the recirculated air condition cooling water for the underground facility were computed with reference to TM-5-813-1 (Reference 7) and the results are summarized in Table 2.

Domestic water consumption was based on an allowance of 150 gpcd with peak flow requirements equal to 2-1/2 times the average. Since USAFS Kunia is operated on a 24-hour basis the maximum occupancy at any one time was estimated at approximately 60 percent of the reported current and long range population figures (no personnel reside permanently at USAFS Kunia).

Fire flow demand for the proposed warehouse and the Secured Compartment Information Facility (SCIF) building was taken at 1,750 gpm. This allows for a fire hose use of 500 gpm and a sprinkler use of 1,250 gpm or any combination thereof.

Requirements for irrigation purposes were not analyzed since pipe sizes were determined on the basis of domestic and fire flow requirements. The use of irrigation water is subject to control during periods of fire flow demand.

Domestic requirements for the peak use of the recreational area were deemed as offsetting other domestic requirements since such activities would involve most of the same personnel and would occur at off peak hours.

Water requirements for cooling air conditioning units was not considered on the assumption that if water is used for cooling the air conditioning
TABLE 2. Water Supply Requirements*

Current Requirements.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Design Population</th>
<th>Domestic Use</th>
<th>Fire Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg Gpm</td>
<td>Peak Gpm</td>
<td></td>
</tr>
<tr>
<td>Underground</td>
<td>870</td>
<td>90</td>
<td>227</td>
</tr>
</tbody>
</table>

Future Requirements.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Design Population</th>
<th>Domestic Use</th>
<th>Fire Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg Gpm</td>
<td>Peak Gpm</td>
<td></td>
</tr>
<tr>
<td>Warehouse</td>
<td>58</td>
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<td>16</td>
</tr>
<tr>
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<tr>
<td>Compartment</td>
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<td>Facility</td>
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<td>Underground</td>
<td>834</td>
<td>87</td>
<td>217</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,192</td>
<td>124</td>
<td>310</td>
</tr>
</tbody>
</table>

*Excluding requirements for irrigation and air condition cooling.

**Excludes sprinkler flow requirements which are supplied by water from an above ground 200,000 gallon storage tank.
equipment in the proposed warehouse and the SCIF building it would be recirculated as is that for the underground facility. The quantity required for make-up water was deemed to be minimal and included in the domestic per capita allowance of 150 gpd.

The results of a hydrant test to measure the flow and pressure at an existing hydrant in the vicinity of the proposed warehouse (Junction No. 2, Exhibit 4) was used to determine the head at the junction of the existing 8-inch main from Wheeler Field and a proposed 8-inch loop line. The existing 8-inch main was reported to be in good condition and this indicated that a Hazen-Williams coefficient of 100 could be used to analyze flows in the existing and proposed systems (Table 3).

It has been recommended that a new 8-inch water main be installed from a junction with the existing 8-inch water main in the vicinity of the old sewage treatment plant of the north access road to a connection with the existing 6-inch water main in the vicinity of the proposed warehouse (Reference 6).

The velocity of flow in the 8-inch main from Wheeler Field under fire flow conditions is somewhat high. However, this condition will exist only for periods of short duration and a new 8- or 10-inch water main from Schofield Barracks in the form of a loop would be expensive.

An alternate supply of potable water besides the use of water from Schofield or Wells No. 2803-03 and 2803-06 would be the City and County water supply. Use of the City and County water supply will require the installation
EXHIBIT 4
WATER SYSTEM JUNCTIONS
### TABLE 3*

**A. Existing System During Hydrant Test.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev Demand</th>
<th>HGL Ft</th>
<th>Pressure Psl</th>
<th>Dia In</th>
<th>Length Ft</th>
<th>Flow Gpm</th>
<th>Head Loss Ft</th>
<th>Veloc- city Ft/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>724</td>
<td>906.8</td>
<td>79.1</td>
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<td>752</td>
<td>761.0</td>
<td>10.9</td>
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<td>895.9</td>
<td>6</td>
<td>460</td>
<td>591.0</td>
<td>20.4</td>
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<td>3</td>
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<td>875.6</td>
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<td>981.0</td>
<td>14.2</td>
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<td>4</td>
<td>759</td>
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<td>591.0</td>
<td>9.3</td>
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<td>581</td>
<td>906.8</td>
<td>6</td>
<td>460</td>
<td>591.0</td>
<td>20.4</td>
<td>6.6</td>
</tr>
<tr>
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<td>724</td>
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<td>906.8</td>
<td>8</td>
<td>300</td>
<td>90.0</td>
<td>0.1</td>
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<tr>
<td>7</td>
<td>797</td>
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<td>895.8</td>
<td>8</td>
<td>300</td>
<td>90.0</td>
<td>0.1</td>
<td>0.6</td>
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</table>

**B. Planned System, Future Average Demand, W/O Fire Flow.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev Demand</th>
<th>HGL Ft</th>
<th>Pressure Psl</th>
<th>Dia In</th>
<th>Length Ft</th>
<th>Flow Gpm</th>
<th>Head Loss Ft</th>
<th>Veloc- city Ft/sec</th>
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<td>1</td>
<td>724</td>
<td>906.8</td>
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**C. Planned System, Future Peak Demand, W/O Fire Flow.**

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev Demand</th>
<th>HGL Ft</th>
<th>Pressure Psl</th>
<th>Dia In</th>
<th>Length Ft</th>
<th>Flow Gpm</th>
<th>Head Loss Ft</th>
<th>Veloc- city Ft/sec</th>
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<td>905.7</td>
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<td>217.0</td>
<td>0.5</td>
<td>1.4</td>
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</table>

* Obtained from Reference 6.
TABLE 3 (CONT'D)

D. Planned System, 1/2 Future Average Demand, W/Fire Flow at Warehouse.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev</th>
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<th>HQL</th>
<th>Pressure</th>
<th>Dia</th>
<th>Length</th>
<th>Flow</th>
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<tr>
<td></td>
<td>Ft</td>
<td>Gpm</td>
<td>Ft</td>
<td>Psi</td>
<td>In</td>
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<td>3</td>
<td>759</td>
<td>15</td>
<td>885.8</td>
<td>34.9</td>
<td>8</td>
<td>320</td>
<td>468.6</td>
<td>9.5</td>
<td>3.3</td>
</tr>
<tr>
<td>4</td>
<td>759</td>
<td>0</td>
<td>876.2</td>
<td>50.8</td>
<td>8</td>
<td>365</td>
<td>128.4</td>
<td>30.9</td>
<td>8.2</td>
</tr>
<tr>
<td>5</td>
<td>797</td>
<td>1750</td>
<td>875.9</td>
<td>50.6</td>
<td>8</td>
<td>300</td>
<td>49.0</td>
<td>0.0</td>
<td>0.3</td>
</tr>
</tbody>
</table>

E. Planned System, 1/2 Future Average Demand, W/Fire Flow at SCIF.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev</th>
<th>Demand</th>
<th>HQL</th>
<th>Pressure</th>
<th>Dia</th>
<th>Length</th>
<th>Flow</th>
<th>Head</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ft</td>
<td>Gpm</td>
<td>Ft</td>
<td>Psi</td>
<td>In</td>
<td>Ft</td>
<td>Gpm</td>
<td>Ft</td>
<td>Ft/sec</td>
</tr>
<tr>
<td>1</td>
<td>724</td>
<td>-1802</td>
<td>906.8</td>
<td>79.1</td>
<td>8</td>
<td>762</td>
<td>333.6</td>
<td>7.1</td>
<td>3.5</td>
</tr>
<tr>
<td>2</td>
<td>759</td>
<td>0</td>
<td>899.6</td>
<td>56.5</td>
<td>6</td>
<td>440</td>
<td>610.8</td>
<td>36.1</td>
<td>9.2</td>
</tr>
<tr>
<td>3</td>
<td>759</td>
<td>1750</td>
<td>853.9</td>
<td>40.9</td>
<td>6</td>
<td>320</td>
<td>939.2</td>
<td>34.5</td>
<td>10.7</td>
</tr>
<tr>
<td>4</td>
<td>759</td>
<td>0</td>
<td>888.0</td>
<td>55.8</td>
<td>8</td>
<td>300</td>
<td>939.2</td>
<td>1.3</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>759</td>
<td>3</td>
<td>887.3</td>
<td>56.4</td>
<td>8</td>
<td>655</td>
<td>942.2</td>
<td>17.5</td>
<td>6.0</td>
</tr>
</tbody>
</table>

* Junction Locations (See Fig. 8-2)

1. Northeast of old sewage treatment plant.
2. Existing Fire Hydrant near new warehouse site.
3. Northeast of planned warehouse site.
5. Northwest of planned SCIF building.
6. Junction of Camp Road and Tunnel Entrance Road.
7. Vicinity of Tunnel Entrance.

** Negative value indicates incoming flow.
of transmission lines and be more expensive than using the existing wells which will require only minor pipe modifications or water from Schofield.

Wells No. 2803-03 and 2803-06 were installed approximately 25 years ago and have caused no environmental impact. Well No. 2803-03 is located on agricultural land and near pineapple fields. Well No. 2803-06 is located in the parking lot on military land. No additional construction will be required on the external environment for use of these wells. Piping modifications to the existing network may be required within the underground facility to route well water into the potable water system.
CHAPTER IV - POTENTIAL SOURCES OF CONTAMINATION

Exhibit 3 contains a site and topographic map of the existing area surrounding the wells. Table 4 contains descriptive information regarding the existing Wells No. 2803-03 and 2803-06.

Results of chemical analyses indicate that the chemical water quality conforms with National Interim Primary Drinking Water and State of Hawaii Drinking Water Requirements (Table 5).

Microbiological results indicate that there is a moderate degree of bacteriological contamination of raw water from both wells. The organisms identified from a sample from Well No. 2803-03 on 29 May 1984 were predominantly Citrobacter freundii and the remainder were "non-coli forms" predominantly Aeromonas hydrophila. The organisms identified from a sample from Well No. 2803-06 on 29 May 1984 were predominantly non-gas producing Enterobacter cloacae and the remaining were predominantly from a Fluorescent Pseudomonas group. The groups of organisms identified indicate that the contamination is probably not fecal in nature but due to colonization of environmental bacteria in wells (Reference 8). Fecal coliform tests performed indicated concentrations of less than one colony/100 ml.
TABLE 4. Wells No. 2803-03 and 2803-06

<table>
<thead>
<tr>
<th></th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td>21°28'32&quot; N</td>
<td>21°28'44&quot; N</td>
</tr>
<tr>
<td>Longitude</td>
<td>158°03'33&quot; W</td>
<td>158°03'21&quot; W</td>
</tr>
<tr>
<td>Top Elevation of Well</td>
<td>863 ft</td>
<td>757 ft</td>
</tr>
<tr>
<td>Static Water Level Elevation</td>
<td>195 ft</td>
<td>195 ft</td>
</tr>
<tr>
<td>Pump Discharge</td>
<td>1800 gpm</td>
<td>1800 gpm</td>
</tr>
</tbody>
</table>

Note: Information from Table 4 was obtained from the US Geological Survey Well Files.

The results of chemical analyses performed on samples from Wells No. 2803-03 and 2803-06 are contained in Table 5.
TABLE 5. Chemical and Microbiological Results

INORGANIC CHEMICALS (Primary Contaminants)

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>*Maximum Contaminant Levels</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (mg/l)</td>
<td>0.05</td>
<td>- 0.01</td>
<td>- 0.01</td>
</tr>
<tr>
<td>Barium (mg/l)</td>
<td>1.0</td>
<td>- 0.3</td>
<td>- 0.3</td>
</tr>
<tr>
<td>Cadmium (mg/l)</td>
<td>0.01</td>
<td>- 0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Chromium (mg/l)</td>
<td>0.05</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
<tr>
<td>Lead (mg/l)</td>
<td>0.05</td>
<td>- 0.005</td>
<td>- 0.005</td>
</tr>
<tr>
<td>Mercury (mg/l)</td>
<td>0.002</td>
<td>- 0.0002</td>
<td>- 0.0002</td>
</tr>
<tr>
<td>Nitrate (mg/l as N)</td>
<td>10.0</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Selenium (mg/l)</td>
<td>0.01</td>
<td>- 0.005</td>
<td>- 0.005</td>
</tr>
<tr>
<td>Silver (mg/l)</td>
<td>0.05</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
</tbody>
</table>

*Chapter 20 of Title 11, Administrative Rules of the State of Hawaii.
- Indicates concentration of "less than."

OTHER INORGANIC CONTAMINANTS

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>**Maximum Contaminant Levels</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (mg/l)</td>
<td>1</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>0.3</td>
<td>- 0.10</td>
<td>- 0.10</td>
</tr>
<tr>
<td>Fluoride (mg/l)</td>
<td>0.20</td>
<td>- 0.03</td>
<td>- 0.03</td>
</tr>
<tr>
<td>Manganese (mg/l)</td>
<td>22.7</td>
<td>25.1</td>
<td>25.1</td>
</tr>
<tr>
<td>Sodium (mg/l)</td>
<td>5.0</td>
<td>0.017</td>
<td>0.027</td>
</tr>
<tr>
<td>Zinc (mg/l)</td>
<td>18</td>
<td>9.13</td>
<td>7.91</td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>250</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Magnesium (mg/l)</td>
<td>250</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Chloride (mg/l)</td>
<td>6.5-8.5</td>
<td>6.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Sulfate (mg/l)</td>
<td>63</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

- Indicates concentration of "less than."
## TABLE 5. Chemical and Microbiological Results (Contd)

### ORGANIC CHEMICALS

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>***Maximum Contaminant Levels</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endrin (mg/l)</td>
<td>0.0002</td>
<td>-0.00004</td>
<td>-0.00004</td>
</tr>
<tr>
<td>Lindane (mg/l)</td>
<td>0.004</td>
<td>-0.00008</td>
<td>-0.00008</td>
</tr>
<tr>
<td>Methoxychlor (mg/l)</td>
<td>0.1</td>
<td>-0.0016</td>
<td>-0.0016</td>
</tr>
<tr>
<td>Toxaphene (mg/l)</td>
<td>0.005</td>
<td>-0.0016</td>
<td>-0.0016</td>
</tr>
<tr>
<td>2,4-D (mg/l)</td>
<td>0.1</td>
<td>-0.0038</td>
<td>-0.0038</td>
</tr>
<tr>
<td>2,4,5 TP Silver (mg/l)</td>
<td>0.01</td>
<td>-0.0005</td>
<td>-0.0005</td>
</tr>
</tbody>
</table>

***Chapter 20 of Title 11, Administrative Rules of the State of Hawaii.***

- Indicates concentration of "less than."

**Note:** Samples were collected by Ms. Carolyn Matsuura, Environmental Laboratory Officer, Tripler Army Medical Center, on 28 February 1984. Analyses of samples were conducted by the US Army Environmental Hygiene Agency.

### MICROBIOLOGICAL RESULTS OF RAW WATER

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC</td>
<td>FC</td>
</tr>
<tr>
<td>10 June 1982</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>15 June 1982</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>22 June 1982</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td>29 June 1982</td>
<td>*</td>
<td>+</td>
</tr>
<tr>
<td>26 July 1982</td>
<td>49</td>
<td>+</td>
</tr>
<tr>
<td>9 August 1982</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>20 September 1982</td>
<td>-10</td>
<td>+</td>
</tr>
<tr>
<td>28 September 1982</td>
<td>-2</td>
<td>+</td>
</tr>
<tr>
<td>29 November 1982</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>29 May 1984</td>
<td>**</td>
<td>-1</td>
</tr>
</tbody>
</table>

**Note:**
1. All results are expressed as colonies/100 ml
2. TC indicates Total Coliforms
3. FC indicates Fecal Coliforms
4. SPC indicates Standard Plate Count
5. "*" indicates analysis not performed
6. "-" indicates less than
7. "**" indicates too numerous to count (TNTC) with Coliform and Non-Coliform colonies/100 ml.
8. "***" indicates non coliform colonies present
Before the wells are utilized for drinking water purposes they will be chlorinated to a concentration of 50 mg/l for a period of 24 hours in accordance with TB MED 576 (Reference 9). This should eliminate colonization of environmental bacteria within the wells. Also, a chlorination unit is currently being installed to disinfect water from each well.

Generally, the substrata profile of the well site is as follows:

<table>
<thead>
<tr>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 145</td>
<td>0 to 30</td>
</tr>
<tr>
<td>Decomposed lava and clay</td>
<td>Medium hard decomposed lava</td>
</tr>
<tr>
<td>145 to 415</td>
<td>20 to 302</td>
</tr>
<tr>
<td>Medium hard/hard rock</td>
<td>Medium soft/hard rock</td>
</tr>
<tr>
<td>415 to 494</td>
<td>302 to 312</td>
</tr>
<tr>
<td>Medium hard rock with ledges</td>
<td>Very hard rock</td>
</tr>
<tr>
<td>494 to 1020</td>
<td>312 to 405</td>
</tr>
<tr>
<td>Medium hard rock</td>
<td>405 to 422</td>
</tr>
<tr>
<td></td>
<td>422 to 501</td>
</tr>
<tr>
<td></td>
<td>501 to 593</td>
</tr>
<tr>
<td></td>
<td>593 to 646</td>
</tr>
<tr>
<td></td>
<td>Medium soft/hard rock</td>
</tr>
</tbody>
</table>

Note: The information above was obtained from the US Geological Survey Well Files.

The Koolau and Waianae dike impounded bodies both provide recharge to the Schofield high level groundwater body. The recharge from the Waianae dike-impounded water body is trivial compared to the Koolau dike-impounded
water body due to the low rock permeability of the Waianae Range. Recharge may also occur within the dike impounded Schofield high level water body as illustrated by Exhibits 5 and 6.

On 14 April 1980, Well No. 2703-01 exhibited concentrations of 11 parts per billion (ppb) dibromochloropropane (DBCP) and 92 ppb ethylene dibromide (EDB). The results were surprising because nowhere else in the deep basal aquifers of southern Oahu had any of the fumigants been detected. Further investigation revealed a spill of approximately 495 gallons of EDB had occurred on bare ground within 60 ft. of the well on 7 April 1977. Later, in the course of investigating the extent of contamination caused by the spill, another focus of contamination near the well was identified. On the slope of and in a small gully 50 to 150 feet north of the well, both DBCP and EDB had been stored on bare ground. Spillage at this site probably was intermittent over a span of years, and the total spillage of DBCP and EDB was probably greater than the well site (reference 4).

Well No. 2703-01 is located approximately 2 miles south of Wells No. 2803-03 and 2803-06. Well No. 2703-01 is not located within the Schofield High-Level Water Body but in a groundwater head gradient area towards the lower basal water areas (Exhibits 7 and 8). Contamination resulting from the spillage of EDB near Well No. 2703-01 would therefore not be expected in Wells No. 2803-03 and 2803-06 due to the direction of groundwater flow towards the lower basin from the Schofield High Level Water Body. Analyses of samples
Figure 1.6-6
GEOHYDROLOGIC MAP AND CROSS SECTIONS OF THE ISLAND OF OAHU (Page 1 of 2)
GEOHYDROLOGIC MAP AND CROSS SECTIONS OF THE ISLAND OF OAHU
EXPLANATION
-3102-01
Wells and Shafts
with Number

SCHOFIELD HIGH-LEVEL
WATER BODY

McKiea
Waiola

3203-01

Schofield Barracks

3102-01

2803-06

2801-01

2801-01,02

Waimea

Makaha

Kaneohe Bay

Kailua

PEARL HARBOR

HONOLULU
EXHIBIT 8
FRESHWATER-HEAD MAP
taken on 13 October 1983 and 24 and 30 May 1984 from Well No. 2803-06 indicate no detectable contamination of EDB and DBCP (Exhibit 9 and 10). No detectable trace of DBCP was found in the above samples from Well No. 2803-03. The presence of an unknown substance interfered with the analysis of EDB from samples taken from Well No. 2803-03. Concentrations of 1,2,3 trichloropropane (TCP) ranging from 83 to 90 ppt were found in Well No. 2803-06. The health significance of TCP is unknown at this time.

A gravity sewerage system was installed between 1943 and 1944 during construction of the underground facility. The system consists of 6-, 8-, and 10-inch sewer lines leading to a pump station located in the parking lot which transports the raw sewage through a 6-inch force main to the Schofield Barracks sewage treatment plant. The sewage pump station has a rated capacity of 100 gpm, and is served by duplex 100 gpm pumps. These pumps were recently installed, replacing older units of the same size that failed in 1983. The treatment plant at Schofield Barracks provides secondary treatment of wastewater from Schofield Barracks, Wheeler Air Force Base and USAFS Kunia. After treatment, the effluent is pumped to an irrigation ditch and mixed with water from Wahiawa Reservoir and used to irrigate sugar cane.

The Schofield Barracks Landfill is located approximately 3.5 miles north of USAFS Kunia. It covers almost 40 acres and since World War II had been utilized for the disposal of solid waste from Army installations. The landfill operation ceased on 1 January 1982 and construction of a protective seal cover was completed in December 1983.
MEMORANDUM

TO: Commander
Tripler Army Medical Center
Atten: HSHK-PV-L/C. Matsuura
Tripler AMC, Hawaii 96859

FROM: J. W. HyUn
Chairman

SUBJECT: Results of analysis of water samples for ethylene dibromide (EDB),
dibromochloropropane (DBCP) and 1,2,3 trichloropropane (TCP)

Water samples were received from your office on October 13, 1983 to be
analyzed for EDB, DBCP, and TCP residues.

Results:

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>ppt EDB</th>
<th>ppt DBCP</th>
<th>ppt TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dillingham RWO1 Well</td>
<td>N. D.*</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Kahuku Range RWO1 Well</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>2803-06 - Kunia Tunnel RWO1 Parking Lot</td>
<td>N. D.</td>
<td>N. D.</td>
<td>90</td>
</tr>
<tr>
<td>2803-03 - Kunia Tunnel RWO2 Upper Left</td>
<td>? **</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Kunia Tunnel RWO3 Upper Rt.</td>
<td>N. D.</td>
<td>N. D.</td>
<td>60</td>
</tr>
<tr>
<td>Schofield Bks RWO2 Well #2</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Bks RWO3 Well #3</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Bks RWO4 Well #4</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
</tbody>
</table>

* N. D. = None Detectable
** Presence of an unknown substance interferes with the analysis

Limit of Detectability: 
- EDB = 20 ppt (Dillingham & Kahuku Range)
  50 ppt (Schofield & Kunia RWO1 & RWO3)
- DBCP = 20 ppt
- TCP = 60 ppt

NOTE: Positive findings NOT confirmed by mass spectrometry.
MEMORANDUM

TO: Commander
Tripler Army Medical Center
Attn: H5IK-PV-L/C. Matsuura
Tripler AMC, Hawaii 96859

FROM: John W. Ilylin
Chairman

SUBJECT: Results of analysis of water samples for ethylene dibromide (EDB), dibromochloropropane (DBCP) and 1,2,3-trichloropropane (TCP) residues

Water samples were received from C. Matsuura on May 24 and 30, 1984 to be analyzed for EDB, DBCP, and TCP residues.

Results:

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>ppt EDB</th>
<th>ppt DBCP</th>
<th>ppt TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahuiku Range, 23 May 84</td>
<td>N. D.*</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Deepwell-Well #4, 23 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Deepwell-Well #2, 24 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Waialua Mill Res. -Waipio Ditch, 24 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
</tbody>
</table>
| 2803-06 - Kaniu Tunnel-Well #1 Parking Lot 29 May 84 | N. D. | N. D. | 83 ***
| 2803-03 - Kaniu Tunnel-Well #2 Upper Left 29 May 84 | ? **   | N. D.    | N. D.   |
| Ft. Shafter-Well #1, 30 May 84              | N. D.   | N. D.    | N. D.   |
| Ft. Shafter-Well #2, 30 May 84              | N. D.   | N. D.    | N. D.   |
| Tripler AMC-Well #1, 30 May 84              | N. D.   | N. D.    | N. D.   |
| Tripler AMC-Well #2, 30 May 84              | N. D.   | N. D.    | N. D.   |

* N. D. = None Detectable
** Presence of an unknown substance interferes with the analysis
*** TCP was NOT confirmed by mass spectrometry

Limit of Detectability: EDB = 20 ppt
                      50 ppt (Kaniu Well #1, Schofield Well #2 & 4)
                      DBCP = 20 ppt
                      TCP = 60 ppt

EXHIBIT 10
EDB, DBCP, AND TCP RESULTS
Schofield Barracks is located within the Schofield high-level water area. The groundwater table is believed to be about 200 to 300 feet above sea level, or 600 to 700 feet below Schofield Barracks. However, there is no conclusive evidence that the Schofield Barracks subsurface water body underlies the existing landfill. There has been no documented evidence of contamination due to the Schofield landfill thus far.
CHAPTER V - SOURCES OF WATER SUPPLY

USAFS Kunia is near a boundary between an alluvium and lower member of the Waianae Volcanic Series. Underlying the alluvium could be either the Koolau or Waianae Series and the depth of weathering could be as great as 200 feet. Below the weathered zone unaltered layered basalt occurs to depths beyond hydrologic interest.

The Ghyben-Herzberg equation states that the depth of the base of fresh water below sea level is 40 times the fresh water-head elevation above sea level. Two points of maximum fresh water head are in the Waianae and Koolau dike-impounded water bodies. The maximum head in the Waianae dike-impounded water body is 470 meters, which yields an interface position of 19,600 meters below sea level. The maximum head in the Koolau dike-impounded water body is 270 meters, which yields an interface position 10,800 meters below sea level. These calculations help serve to indicate that there is no salt water intrusion problem in either the Waianae or Koolau dike-impounded water bodies.

The Schofield high-level water body, with an average head of 85 meters, would have an interface at 3,400 meters below sea level. This body of water is probably terminated by impermeable rock, rather than extending to this depth. However, this calculation indicates that there is no possible salt water problem if the head is maintained at or near its present level (reference 3).
The Schofield high-level water body is contained in highly permeable rock and completely surrounded by low permeable rock. Thus, the head surface for this water body is nearly level. Pumpage from the Schofield high-level water body will reduce the head uniformly over the entire area of the water body. This will decrease the groundwater underflow along the full length of the dams toward lower gradient areas as well as increase the underflow along the contact between the Koolau and Schofield high-level water bodies. Thus, pumpage from the Schofield high-level water body will have a widespread, distributed effect. The pumping of more groundwater from the Schofield high-level water body will cause the fresh water head to decline and cause a reduction in groundwater flux to the adjacent basal-water bodies.

Water pumped from Wells No. 2803-03 and 2803-06 will be used for potable water purposes only in the event of an emergency such as when the normal source of water from Schofield is disrupted. At those times, the quantity of water pumped will not be more than what is currently needed.
CHAPTER VI - PROPOSED TREATMENT WORKS

Water pumped from the wells will be chlorinated in accordance with TM 5-813-3, Water Treatment. The extent of chlorination should be such that the chlorine residual in the active part of the potable water system is not less than 0.4 mg/l. The location of the chlorine injector point will be on the bottom floor of the underground facility where 3 water lines from each of the wells are combined (Exhibit 11). For safety purposes a liquid calcium hypochlorite system will be installed. A total of three liquid calcium hypochlorite feeders will be installed for each line from Wells No. 2803-03, 8203-06 and 2803-05 (Del Monte currently using). The design requirements are as follows:

Calcium hypochlorite solid = 70% Chlorine (dry weight)
Ratio of the weight of Water/Chlorine = 10%
Resultant 0.1/0.7 = 0.143
Flow = 1600 gpm
# Water/Day = 1600 gpm (8.34 #/gal) (60 min/hr) (24 hr/day) = 19.123 X 10^6
# Chlorine req = 19.123 (0.4) = 7.65
Wt Calcium hypochlorite solid = 7.65#/0.7 = 10.93#
Wt Water req = 10.93/0.143 = 76.50#
Vol Calcium Hypochlorite slurry req/day = 76.50#/8.34 = 9.1 gal/Day

Operation and maintenance requirements will consist of refilling the calcium hypochlorite storage tank and performing routine maintenance and replacement of pump diaphragms and injectors.
EXHIBIT 11
Location of Chlorination Station
CHAPTER VII - PUMPING FACILITIES

The existing pumps at Wells No. 2803-03 and 2803-06 are similar and have a maximum capacity 1600 gpm. Each pump is a turbine type with an electric motor rated as 3 phase, 60 cycle and 2200 volts. Power for the motor is supplied by the main underground facility which may obtain electricity from outside commercial sources or emergency generators located within the facility.

Water from the wells flows through the cooling network once and is disposed of into an irrigation ditch. At this time, no provisions have been made for water storage or for modifications of the existing piping network to connect the potable water system with the cooling system. Exhibit 12 contains the layout and sizes of existing mains.
CHAPTER VIII - FINANCING

The cost for the installation of chlorinators shall be paid by the US Army and is estimated at $5,000.
REFERENCES


8. Disposition Form (DF), APZV-HS-PV, dated 12 June 1984, subject: Results of DACP, EDB, TCP Pesticide Testing of Army Water Sources and Bacteriological Testing at Kunia Tunnel Wells.

Mr. Leslie S. Matsubara  
Director of Health  
Department of Health  
State of Hawaii  
P.O. Box 3378  
Honolulu, Hawaii 96801

Dear Mr. Matsubara:

United States Army Field Station Kunia  
Kunia Wells No. 2803-03 and 2803-06

Thank you for the opportunity to comment on the Engineering Report for the new potable source at the Kunia site.

The wells located in the Pearl Harbor Ground Water Control Area require a Water Withdrawal and Use Permit from the Board of Land and Natural Resources. An application for the withdrawal permit has been received by the Department. The staff is reviewing the application for action by the Board in the near future.

Very truly yours,

SUSUMU ONO
Chairperson of the Board
Mr. Susumu Ono  
Chairman of the Board  
Dept. of Land and Natural Resources  
1151 Punchbowl Street  
Honolulu, Hawaii 96813  

Dear Mr. Ono:

SUBJECT: UNITED STATES ARMY FIELD STATION KUNIA  
KUNIA WELLS NO.2803-03 AND 2803-06

Transmitted herewith for your review and comments is a copy of the preliminary engineering report for Kunia Wells No. 2803-03 and 2803-06. This report has been prepared pursuant to Section 11-20-29, Chapter 20, Title 11, Administrative Rules, Potable Water Systems.

Your review and comments are solicited as your concerns, knowledge and expertise in this area may assist us in determining potential impacts which may result by the proposed project.

Your early attention and reply to this matter will be greatly appreciated. Please respond by October 12, 1984.

Sincerely,

LESLEI S. MATSUBARA  
Director of Health

Enclosure
ENGINEERING REPORT
FOR
NEW POTABLE WATER SOURCE

UNITED STATES ARMY FIELD STATION KUNIA
KUNIA WELLS NO. 2803-03 and 2803-06

BY:
Mr. Clifton K. Takenaka
Environmental Engineer

DIRECTORATE OF FACILITIES ENGINEERING
US ARMY SUPPORT COMMAND, HAWAII
FORT SHAFTER, HAWAII  96858-5000

PREPARED FOR:
STATE OF HAWAII
DEPARTMENT OF HEALTH

JULY 1984
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<tr>
<td></td>
<td>References</td>
<td>43</td>
</tr>
</tbody>
</table>
PROFESSIONAL ENGINEER'S CERTIFICATION

The undersigned, being a registered professional engineer, certifies that:

1. The work was prepared by me or under my supervision and the information contained therein is true to the best of my information and belief; and

2. The water produced by Kunia Wells No. 2803-03 and 2803-06, the drinking water system identified in the attached report, will comply with the State primary drinking water regulations contained in Public Health Regulations Chapter 49, Potable Water Systems, and will comply with the Rules and Regulations of the Board of Water Supply, City and County of Honolulu, when said drinking water system is operated and maintained in accordance with the instructions and information contained in this report.

CHARLES C. H. YANG
Chief, Utilities Division
Directorate of Facilities Engineering
US Army Support Command, Hawaii
INSTALLATION MEDICAL AUTHORITY CERTIFICATION

The undersigned, being the installation medical authority, certifies that:

1. The information contained therein is true to the best of my information and belief; and

2. The water produced by Kunia Wells No. 2303-03 and 2303-06, the drinking water system identified in the attached report, will comply with Army Regulation (AR) 420-46, Water and Sewage, and Technical Bulletin Medical (TB MED) 576, Sanitary Control and Surveillance of Water Supplies at Fixed Installations and other applicable regulations, when said drinking water system is operated and maintained in accordance with the instructions and information contained in this report.

WILLIAM P. MORGAN, M.D.
Colonel, MC
Chief, Preventive Medicine Service
Directorate of Health Services
US Army Support Command, Hawaii
CHAPTER I - GENERAL INFORMATION

The proposed use of existing Wells No. 2803-03 and 2803-06 for drinking water is part of an effort to establish an emergency source of potable water for the US Army Field Station (USAFS) Kunia. These wells are located near USAFS Kunia (see Exhibits 1, 2, and 3) and are currently used to cool emergency generators and provide make up water for air conditioning systems. A liquid sodium hypochlorite injection system has been designed and will be installed to chlorinate water from both wells. Plans to modify the existing pipe network so that well waters may be diverted into the potable water distribution system have not yet been initiated at this time.
CHAPTER II - PHYSICAL AND HYDROLOGICAL CHARACTERISTICS OF AREA

USAFS Kunia is located in the Oahu Central Plains approximately 15 miles north of Pearl Harbor (see Exhibit 2) and adjacent to Wheeler Air Force Base and Schofield Barracks (Main Post).

The vicinity has an annual rainfall of about 44.1 inches and an annual median rainfall of about 43.7 inches. The wet season occurs between the months of November and March. The dry season occurs between the months of April and September. According to the "Storm Drainage Standard" of the City and County of Honolulu, the area can expect a rainfall intensity of one hour equal to 3.0 inches based on a 10 year storm while a 50 year storm would generate only four inches.

The average maximum temperature for the area ranges from 74°F to 85°F and the average annual minimum temperature ranges from about 60°F to 65°F. Temperatures in the 90's have been recorded with minimums near 50°F.

As seen on Exhibit 3, Well 2803-03 is located near antennas and an exhaust structure. The land slopes gently toward the east from 860 to 830 feet, a steep gulch is then encountered with a drop of 70 feet into a parking area. Well No. 2803-06 is located near the center of this parking area. The parking area is enclosed by an access road which extends about 400 feet to Kunia Road. To the east of the access road is another steep gulch which drops from
760 to 725 feet. Contained within the gulch are recreational facilities and a pond approximately 600 feet long and 200 feet wide.

According to the US Soil Conservation Soil Survey, USAFS Kunia lies within the ground soil classification of the Helemano - Wahiawa Association. These are deep, nearly level to moderately sloping, well drained soils that have fine textured subsoil occurring at elevations of 100 to 1200 feet. This association occurs over 18 percent of the island. Helemano soils make up approximately 40 percent of the association and Wahiawa soils 30 percent (reference 2). Descriptions of the soils found on the installation are presented in Table 1.

The USAFS Kunia area is classified by the Uniform Building Code to be in the seismic zone class one. Zone one is described as "Minor damage; distant earthquakes may cause damage to structures with fundamental periods greater than 1.0 second; corresponds to intensities V and VI of the MM. Scale."

Groundwater hydrology in the vicinity is not well established. The Schofield High-Level Water Body is the major groundwater system. The groundwater table is believed to be about 200 to 300 feet above sea level. This is 500 to 600 feet below the USAFS Kunia area. The water body is part of a complex groundwater flow system which results from impoundment by groundwater dams. An estimated 127 million gallons of groundwater flows through this water body per day. About 90 percent of this flow is estimated to pass to the south to replenish the Pearl Harbor basal water body (Reference 3). The southern groundwater dam forms the southern boundary of
### TABLE 1. Description of USAFS Kunia Soil

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helemano Silty Clay, 30 to 90 percent slopes</td>
<td>Soil is on the sides of V shaped gulches. They developed in alluvium and colluvium derived from ingress rock. Permeability is moderately rapid, and erosion hazard is severe to very severe.</td>
<td>Sides of Waieke Gulch surrounding the parking area, at the tunnel entrance.</td>
</tr>
<tr>
<td>Fill land, mixed</td>
<td>Areas filled with material hauled from nearby sources.</td>
<td>Recreation area opposite stream bank from sewage pump station.</td>
</tr>
<tr>
<td>Kauaihapa Clay, 8 to 15 percent slopes</td>
<td>Soils developed in old alluvium, nearly level to moderately sloping. Occurs on narrow side slopes, mainly along drainage ways. Runoff is medium and erosion hazard is moderate.</td>
<td>Parking area, entrance road and land above the underground facility.</td>
</tr>
<tr>
<td>Waikele Stream bed</td>
<td>Well drained soils in drainage ways and on alluvial fans. Formed in alluvium derived from basic igneous rocks in humid uplands, nearly level to moderately sloping. Runoff is slow and the erosion hazard is slight.</td>
<td>Waieke Gulch recreation area man made pond.</td>
</tr>
<tr>
<td>Name</td>
<td>Description</td>
<td>Location</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Wahiawa Silty Clay, 0 to 3 percent slopes</td>
<td>Dusky red silty clay. Well drained soils developed in residuum and old alluvium derived from basic igneous rock. Permeability is moderately rapid. Runoff is slow and erosion hazard is no more than slight.</td>
<td>Area between haul road and Kunia Highway.</td>
</tr>
<tr>
<td>Wahiawa Silty Clay, 3 to 8 percent slopes.</td>
<td>Runoff is slow, erosion hazard is slight.</td>
<td>Pocket in the pineapple fields just above the tunnel entrance.</td>
</tr>
</tbody>
</table>
the Schofield high-level water body. Based on water levels in nearby wells, an estimated 250 feet of head is dissipated as the water flows southward over and through the groundwater dam to the Pearl Harbor basal water body (Reference 3). Dike impounded water bodies underlie regional areas of maximum rainfall. The Koolau dike-impounded water body lies east of the Schofield high-water body and the Waianae dike-impounded water body lies to the west. Natural recharge to the groundwater occurs where the annual rainfall exceeds about 50-inches per year. The Koolau dike-impounded water body receives more recharge from the deep infiltration of rainfall than the Waianae dike-impounded water body due to a greater area that receives the required rainfall. In addition, the rock permeability in the Waianae Range is less than one-tenth that of the Koolau Range. Hence, the greatest portion of the Schofield high-water body inflow is derived from the Koolau dike-impounded water body (Reference 3).

Waikēle Stream originates on the north slope of the Waianae range approximately two or three miles upstream from USAFS Kunia and empties into Pearl Harbor. It enters the installation near the recreational area and exits through a concrete box culvert under Kunia Road. The stream is intermittent and only has flow during the rainy season.

The storm drainage system consists mainly of open ditches and culverts under roadways directing runoff water toward Waikēle Stream. The main ditch starts from the above-ground support area in the pineapple fields and runs past the helipad following the top of the gulch. It ends at a drop structure which conveys runoff down the side of the gulch, then into a 48-inch diameter
culvert beneath the tunnel access road. From the culvert another open ditch conveys the flow to the 36-inch diameter pipes located beneath Camp Road. From these pipes the ditch is divided into two branches. One branch is directed to the pond and the other continues along side the access road and eventually discharges to Waikele Stream. A 10 feet by 12 feet concrete box culvert conveys the flow beneath Kunia Road.

A secondary drainage system is located in the parking lot. A catch basin in the eastern part of the parking lot collects runoff and directs it to an open ditch via an 18-inch diameter concrete pipe.

Each well is located within an underground concrete lined chamber with access via a manhole. The well shaft is protected by a water tight seal between the concrete pavement and the annular space outside the well casing. A float activated sump pump is also located in each well chamber to prevent excessive flooding. The well shaft and pump are enclosed and at no time is the potable water exposed to the external environment.

The 1977 City and County General Plan represented broad objectives and policies which were used to draw up an islandwide set of development plans. The development plans divide the City and County of Honolulu into eight districts. The USAFS Kunia is within the Central Oahu District (Ordinance No. 83-7, dated 10 May 83). According to the development plan, the installation is divided between two land use designations, military and agriculture. The access road and surface parking areas are included in the military land use designation. The remaining portions, which include the underground facility,
are within the agriculture land use designation. This separation between the different land uses for the installation is delineated by the State Land Use boundary line (Exhibit 3A).

USAFS Kunia is located partly in the Clear Zone and partly in the Accident Potential Zone 1 for the active Class B runway (Runway 6-240), Wheeler Air Force Base. Information on airfield operations at Wheeler field indicates that a large percentage (over 80 percent) of aircraft takeoffs are towards the northeast away from USAFS Kunia. Also, there is no history of aircraft crashes in the area occupied by USAFS Kunia and the possibility thereof is minimal.
USAFS Kunia obtains its domestic water from wells located on Schofield Barracks East Range. An eight inch transmission line from the Schofield Barracks system supplies USAFS Kunia and Wheeler Air Force Base via a connection at Wright Avenue and Kunia Road. The pipeline follows the Kunia Road alignment until the state right-of-way width change, turning at this point towards the underground facility entrance tunnel. Within the installation, there are branches leading to the recreational area and Buildings 42, 19 and 30. Three wells on USAFS Kunia supplied cooling water to the underground facility's air conditioning units and the electric generator motors; each well has a pump capacity of 1,600 gpm. In 1982 the air conditioners were switched from using the flow through cooling water to cooling tower condensers. Also, power started being obtained commercially from Hawaiian Electric Company and, as such, use of the wells has been greatly curtailed. Well production is presently limited to providing cooling water for the diesel electric-generators when operated for maintenance purposes (approximately one hour a week). Because of the reduction in water demand Well No. 2803-05 has been leased to Del Monte Corporation. Only Wells No. 2803-03 and 2803-06 supply cooling water for the diesel-generator motors.

USAFS Kunia is a self contained community providing a full range of services and facilities to support military personnel and their dependents. USAFS Kunia is supported by Schofield Barracks relative to housing, community facilities, maintenance, planning and supply services. The main activities
are always conducted in the three-story self-contained, underground primary facility. Currently support facilities on post include administrative, parking, storage and recreational areas, located outside the underground facility entrance.

USAFS Kunia hosts units of the US Army, Navy and Air Force. The current personnel strength at USAFS Kunia is 1,282 military and 84 civilians (February 1984). Of the military personnel, 802 are with the Army. Seven civilian personnel assigned to the Directorate of Facilities Engineering (DFE) and AAFES, work at USAFS Kunia, but are not reflected in the above figures.

The size of the service area is planned to increase by 6.89 acres to provide for the widening of Kunia Road, the inclusion of the heliport and the existing softball field fence and security fence with a cleared strip along the rim of Waiekele Gulch (reference 6).

Two projects currently planned will impact on the future water requirements at USAFS Kunia. One of these projects is the construction of a warehouse located on the southeast corner of the parking lot. The overall building plan dimension is 114 feet by 151 feet 4 inches (17,200 SF). The other project is a Secured Compartment Information Facility (SCIF) which will consist of 50-60,000 GSF of floor area for administrative and operational type offices located on two-to-three floors.
The current and projected water supply requirements, other than for the recirculated air condition cooling water for the underground facility were computed with reference to TM-5-813-1 (Reference 7) and the results are summarized in Table 2.

Domestic water consumption was based on an allowance of 150 gpcd with peak flow requirements equal to 2-1/2 times the average. Since USAFS Kunia is operated on a 24-hour basis the maximum occupancy at any one time was estimated at approximately 60 percent of the reported current and long range population figures (no personnel reside permanently at USAFS Kunia).

Fire flow demand for the proposed warehouse and the Secured Compartment Information Facility (SCIF) building was taken at 1,750 gpm. This allows for a fire hose use of 500 gpm and a sprinkler use of 1,250 gpm or any combination thereof.

Requirements for irrigation purposes were not analyzed since pipe sizes were determined on the basis of domestic and fire flow requirements. The use of irrigation water is subject to control during periods of fire flow demand.

Domestic requirements for the peak use of the recreational area were deemed as offsetting other domestic requirements since such activities would involve most of the same personnel and would occur at off peak hours.

Water requirements for cooling air conditioning units was not considered on the assumption that if water is used for cooling the air conditioning
TABLE 2. Water Supply Requirements*

Current Requirements.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Design Population</th>
<th>Domestic Use</th>
<th>Fire Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Avg Gpm</td>
<td>Peak Gpm</td>
</tr>
<tr>
<td>Underground</td>
<td>870</td>
<td>90</td>
<td>227</td>
</tr>
</tbody>
</table>

Future Requirements.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Design Population</th>
<th>Domestic Use</th>
<th>Fire Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Avg Gpm</td>
<td>Peak Gpm</td>
</tr>
<tr>
<td>Warehouse</td>
<td>58</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Secured Compartment Information Facility</td>
<td>300</td>
<td>31</td>
<td>77</td>
</tr>
<tr>
<td>Underground</td>
<td>834</td>
<td>87</td>
<td>217</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,192</td>
<td>124</td>
<td>310</td>
</tr>
</tbody>
</table>

*Excluding requirements for irrigation and air condition cooling.
**Excludes sprinkler flow requirements which are supplied by water from an above ground 200,000 gallon storage tank.
equipment in the proposed warehouse and the SCIF building it would be recirculated as is that for the underground facility. The quantity required for make-up water was deemed to be minimal and included in the domestic per capita allowance of 150 gpd.

The results of a hydrant test to measure the flow and pressure at an existing hydrant in the vicinity of the proposed warehouse (Junction No. 2, Exhibit 4) was used to determine the head at the junction of the existing 8-inch main from Wheeler Field and a proposed 8-inch loop line. The existing 8-inch main was reported to be in good condition and this indicated that a Hazen-Williams coefficient of 100 could be used to analyze flows in the existing and proposed systems (Table 3).

It has been recommended that a new 8-inch water main be installed from a junction with the exiting 8-inch water main in the vicinity of the old sewage treatment plant of the north access road to a connection with the existing 6-inch water main in the vicinity of the proposed warehouse (Reference 6).

The velocity of flow in the 8-inch main from Wheeler Field under fire flow conditions is somewhat high. However, this condition will exist only for periods of short duration and a new 8- or 10-inch water main from Schofield Barracks in the form of a loop would be expensive.

An alternate supply of potable water besides the use of water from Schofield or Wells No. 2803-03 and 2803-06 would be the City and County water supply. Use of the City and County water supply will require the installation
### TABLE 3*

#### A. Existing System During Hydrant Test.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev</th>
<th>Demand</th>
<th>HGL</th>
<th>Pressure</th>
<th>Dia</th>
<th>Length</th>
<th>Flow</th>
<th>Head Loss</th>
<th>Veloc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ft</td>
<td>Gpm</td>
<td>Ft</td>
<td>Psi</td>
<td>Ft</td>
<td>In</td>
<td>Gpm</td>
<td>Ft</td>
<td>Ft/sec</td>
</tr>
<tr>
<td>1</td>
<td>724</td>
<td>-671**</td>
<td>906.8</td>
<td>79.1</td>
<td>8</td>
<td>762</td>
<td>671.0</td>
<td>10.9</td>
<td>4.3</td>
</tr>
<tr>
<td>6</td>
<td>759</td>
<td>0</td>
<td>895.9</td>
<td>59.3</td>
<td>6</td>
<td>460</td>
<td>581.0</td>
<td>20.4</td>
<td>6.6</td>
</tr>
<tr>
<td>5</td>
<td>759</td>
<td>0</td>
<td>879.6</td>
<td>50.5</td>
<td>6</td>
<td>320</td>
<td>581.0</td>
<td>14.2</td>
<td>6.6</td>
</tr>
<tr>
<td>4</td>
<td>759</td>
<td>0</td>
<td>861.4</td>
<td>44.3</td>
<td>6</td>
<td>120</td>
<td>581.0</td>
<td>5.3</td>
<td>6.6</td>
</tr>
<tr>
<td>2</td>
<td>797</td>
<td>381</td>
<td>906.3</td>
<td>82.0</td>
<td>8</td>
<td>300</td>
<td>90.0</td>
<td>0.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

#### B. Planned System, Future Average Demand, W/O Fire Flow.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev</th>
<th>Demand</th>
<th>HGL</th>
<th>Pressure</th>
<th>Dia</th>
<th>Length</th>
<th>Flow</th>
<th>Head Loss</th>
<th>Veloc.</th>
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<tr>
<td></td>
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<td>Gpm</td>
<td>Ft</td>
<td>Psi</td>
<td>Ft</td>
<td>In</td>
<td>Gpm</td>
<td>Ft</td>
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<tr>
<td>1</td>
<td>724</td>
<td>-671**</td>
<td>906.8</td>
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<td>8</td>
<td>762</td>
<td>671.0</td>
<td>10.9</td>
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<tr>
<td>6</td>
<td>759</td>
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<td>440</td>
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<td>759</td>
<td>0</td>
<td>879.6</td>
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<td>6</td>
<td>320</td>
<td>581.0</td>
<td>14.2</td>
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<tr>
<td>4</td>
<td>759</td>
<td>0</td>
<td>861.4</td>
<td>44.3</td>
<td>6</td>
<td>120</td>
<td>581.0</td>
<td>5.3</td>
<td>6.6</td>
</tr>
<tr>
<td>3</td>
<td>797</td>
<td>6</td>
<td>906.7</td>
<td>62.9</td>
<td>8</td>
<td>655</td>
<td>47.7</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>90.0</td>
<td>0.1</td>
<td>0.6</td>
</tr>
</tbody>
</table>

#### C. Planned System, Future Peak Demand, W/O Fire Flow.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elev</th>
<th>Demand</th>
<th>HGL</th>
<th>Pressure</th>
<th>Dia</th>
<th>Length</th>
<th>Flow</th>
<th>Head Loss</th>
<th>Veloc.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ft</td>
<td>Gpm</td>
<td>Ft</td>
<td>Psi</td>
<td>Ft</td>
<td>In</td>
<td>Gpm</td>
<td>Ft</td>
<td>Ft/sec</td>
</tr>
<tr>
<td>1</td>
<td>724</td>
<td>-310**</td>
<td>906.8</td>
<td>79.1</td>
<td>8</td>
<td>762</td>
<td>190.3</td>
<td>1.1</td>
<td>1.2</td>
</tr>
<tr>
<td>6</td>
<td>759</td>
<td>0</td>
<td>905.7</td>
<td>63.5</td>
<td>6</td>
<td>440</td>
<td>26.7</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>5</td>
<td>759</td>
<td>77</td>
<td>903.8</td>
<td>63.6</td>
<td>6</td>
<td>320</td>
<td>103.7</td>
<td>0.6</td>
<td>1.2</td>
</tr>
<tr>
<td>4</td>
<td>759</td>
<td>0</td>
<td>906.4</td>
<td>63.8</td>
<td>6</td>
<td>30</td>
<td>103.7</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>797</td>
<td>16</td>
<td>906.4</td>
<td>63.8</td>
<td>8</td>
<td>655</td>
<td>119.7</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>300</td>
<td>217.0</td>
<td>0.5</td>
<td>1.4</td>
</tr>
</tbody>
</table>

* Obtained from Reference 6.
TABLE 3 (CONT'D)

D. Planned System: 1/2 Future Average Demand, W/Fire Flow at Warehouse.

| No. | Elev | Demand | HGL | Pressure | Dia | Length | Flow | Head | Loss | Veloc- |
|-----|------|--------|-----|----------|-----|--------|------|------|------|city  |
|     | Ft   | Gpm    | Ft  | Psi      | In  | Ft     | Gpm  | Ft   | Ft/5ec |
| 1   | 724  | -1815  | 906.8 | 79.1     | 8   | 762    | 333.6 | 7.1  | 3.4   |
| 6   | 759  | 0      | 899.7 | 60.9     | 6   | 440    | 484.6 | 13.9 | 5.5   |
| 5   | 759  | 10     | 885.8 | 54.9     | 6   | 320    | 468.6 | 9.5  | 5.3   |
| 4   | 759  | 0      | 876.2 | 50.8     | 6   | 30     | 468.1 | 0.4  | 3.0   |
| 3   | 797  | 1750   | 875.9 | 50.6     | 8   | 655    | 128.4 | 30.9 | 8.2   |
| 7   | 797  | 90     | 899.7 | 44.4     | 8   | 300    | 49.0  | 0.0  | 0.3   |

E. Planned System: 1/2 Future Average Demand, W/Fire Flow at SCIF.

| No. | Elev | Demand | HGL | Pressure | Dia | Length | Flow | Head | Loss | Veloc- |
|-----|------|--------|-----|----------|-----|--------|------|------|------|city  |
|     | Ft   | Gpm    | Ft  | Psi      | In  | Ft     | Gpm  | Ft   | Ft/5ec |
| 1   | 724  | -1802  | 906.8 | 79.1     | 8   | 762    | 859.8 | 17.1 | 5.3   |
| 6   | 759  | 0      | 889.6 | 56.5     | 6   | 440    | 810.8 | 36.1 | 9.2   |
| 5   | 759  | 1750   | 853.3 | 40.9     | 6   | 320    | 939.2 | 34.5 | 10.7  |
| 4   | 759  | 0      | 888.0 | 55.8     | 6   | 50     | 939.2 | 1.3  | 6.0   |
| 3   | 797  | 3      | 889.3 | 56.4     | 8   | 655    | 942.2 | 17.3 | 6.0   |

* Junction Locations (See Fig. 2-2)
1. Northeast of old sewerage treatment plant.
2. Existing Fire Hydrant near new warehouse site.
3. Northeast of planned warehouse site.
5. Northwest of planned SCIF building.
6. Junction of Camp Road and Tunnel Entrance Road.
7. Vicinity of Tunnel Entrance.

** Negative value indicates incoming flow.
of transmission lines and be more expensive than using the existing wells which will require only minor pipe modifications or water from Schofield.

Wells No. 2803-03 and 2803-06 were installed approximately 25 years ago and have caused no environmental impact. Well No. 2803-03 is located on agricultural land and near pineapple fields. Well No. 2803-06 is located in the parking lot on military land. No additional construction will be required on the external environment for use of these wells. Piping modifications to the existing network may be required within the underground facility to route well water into the potable water system.
Chapter IV - Potential Sources of Contamination

Exhibit 3 contains a site and topographic map of the existing area surrounding the wells. Table 4 contains descriptive information regarding the existing Wells No. 2803-03 and 2803-06.

Results of chemical analyses indicate that the chemical water quality conforms with National Interim Primary Drinking Water and State of Hawaii Drinking Water Requirements (Table 5).

Microbiological results indicate that there is a moderate degree of bacteriological contamination of raw water from both wells. The organisms identified from a sample from Well No. 2803-03 on 29 May 1984 were predominantly *Citrobacter freundii* and the remainder were "non-coliforms" predominantly *Aeromonas hydrophila*. The organisms identified from a sample from Well No. 2803-06 on 29 May 1984 were predominantly non-gas producing *Enterobacter cloacae* and the remaining were predominantly from a Fluorescent *Pseudomonas* group. The groups of organisms identified indicate that the contamination is probably not fecal in nature but due to colonization of environmental bacteria in wells (Reference 8). Fecal coliform tests performed indicated concentrations of less than one colony/100 ml.
TABLE 4. Wells No. 2803-03 and 2803-06

<table>
<thead>
<tr>
<th>Coordinates</th>
<th>Well No.</th>
<th>Well No.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2803-03</td>
<td>2803-06</td>
</tr>
<tr>
<td>Latitude</td>
<td>21°28'32&quot; N</td>
<td>21°28'44&quot; N</td>
</tr>
<tr>
<td>Longitude</td>
<td>158°03'33&quot; W</td>
<td>158°03'21&quot; W</td>
</tr>
<tr>
<td>Top Elevation of Well</td>
<td>863 ft</td>
<td>757 ft</td>
</tr>
<tr>
<td>Static Water Level Elevation</td>
<td>195 ft</td>
<td>195 ft</td>
</tr>
<tr>
<td>Pump Discharge</td>
<td>1800 gpm</td>
<td>1800 gpm</td>
</tr>
</tbody>
</table>

Note: Information from Table 4 was obtained from the US Geological Survey Well Files.

The results of chemical analyses performed on samples from Wells No. 2803-03 and 2803-06 are contained in Table 5.
TABLE 5. Chemical and Microbiological Results

INORGANIC CHEMICALS (Primary Contaminants)

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>*Maximum Contaminant Levels</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic (mg/l)</td>
<td>0.05</td>
<td>- 0.01</td>
<td>- 0.01</td>
</tr>
<tr>
<td>Barium (mg/l)</td>
<td>1.0</td>
<td>- 0.3</td>
<td>- 0.3</td>
</tr>
<tr>
<td>Cadmium (mg/l)</td>
<td>0.01</td>
<td>- 0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>Chromium (mg/l)</td>
<td>0.05</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
<tr>
<td>Lead (mg/l)</td>
<td>0.05</td>
<td>- 0.005</td>
<td>- 0.005</td>
</tr>
<tr>
<td>Mercury (mg/l)</td>
<td>0.002</td>
<td>- 0.0002</td>
<td>- 0.0002</td>
</tr>
<tr>
<td>Nitrate (mg/l as N)</td>
<td>10.0</td>
<td>1.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Selenium (mg/l)</td>
<td>0.01</td>
<td>- 0.005</td>
<td>- 0.005</td>
</tr>
<tr>
<td>Silver (mg/l)</td>
<td>0.05</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
</tbody>
</table>

*Chapter 20 of Title 11, Administrative Rules of the State of Hawaii.
- Indicates concentration of "less than."

OTHER INORGANIC CONTAMINANTS

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>**Maximum Contaminant Levels</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper (mg/l)</td>
<td>1</td>
<td>- 0.025</td>
<td>- 0.025</td>
</tr>
<tr>
<td>Iron (mg/l)</td>
<td>0.3</td>
<td>- 0.10</td>
<td>- 0.10</td>
</tr>
<tr>
<td>Fluoride (mg/l)</td>
<td>0.05</td>
<td>- 0.03</td>
<td>- 0.03</td>
</tr>
<tr>
<td>Manganese (mg/l)</td>
<td>22.7</td>
<td>25.1</td>
<td></td>
</tr>
<tr>
<td>Sodium (mg/l)</td>
<td>5.0</td>
<td>0.017</td>
<td>0.027</td>
</tr>
<tr>
<td>Zinc (mg/l)</td>
<td>10.5</td>
<td>9.3</td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/l)</td>
<td>9.13</td>
<td>7.91</td>
<td></td>
</tr>
<tr>
<td>Magnesium (mg/l)</td>
<td>250</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Chloride (mg/l)</td>
<td>18</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>Sulfate (mg/l)</td>
<td>6.5-8.5</td>
<td>6.8</td>
<td>7.0</td>
</tr>
<tr>
<td>pH units</td>
<td>63</td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

- Indicates concentration of "less than."
TABLE 5. Chemical and Microbiological Results (Contd)

ORGANIC CHEMICALS

<table>
<thead>
<tr>
<th>Contaminant Name</th>
<th>***Maximum Contaminant Levels</th>
<th>Well No. 2B03-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endrin (mg/l)</td>
<td>0.0002</td>
<td>-0.00004</td>
<td>-0.00004</td>
</tr>
<tr>
<td>Lindane (mg/l)</td>
<td>0.004</td>
<td>-0.00008</td>
<td>-0.00008</td>
</tr>
<tr>
<td>Methoxychlor (mg/l)</td>
<td>0.1</td>
<td>-0.0016</td>
<td>-0.0016</td>
</tr>
<tr>
<td>Toxaphene (mg/l)</td>
<td>0.005</td>
<td>-0.0016</td>
<td>-0.0016</td>
</tr>
<tr>
<td>2,4-D (mg/l)</td>
<td>0.1</td>
<td>-0.0038</td>
<td>-0.0038</td>
</tr>
<tr>
<td>2,4,5 TP Silver (mg/l)</td>
<td>0.01</td>
<td>-0.0005</td>
<td>-0.0005</td>
</tr>
</tbody>
</table>

***Chapter 20 of Title 11, Administrative Rules of the State of Hawaii.

- Indicates concentration of "less than."

Note: Samples were collected by Ms. Carolyn Matsuura; Environmental Laboratory Officer, Tripler Army Medical Center, on 28 February 1984. Analyses of samples were conducted by the US Army Environmental Hygiene Agency.

MICROBIOLOGICAL RESULTS OF RAW WATER

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TC  FC  SPC</td>
<td>TC  FC  SPC</td>
</tr>
<tr>
<td>10 June 1982</td>
<td>+    +    +</td>
<td>34  +    +    +</td>
</tr>
<tr>
<td>15 June 1982</td>
<td>+    +    +</td>
<td>24  +    +    +</td>
</tr>
<tr>
<td>22 June 1982</td>
<td>1    +    -    1</td>
<td>*    +    +    +</td>
</tr>
<tr>
<td>29 June 1982</td>
<td>*    +    2300</td>
<td>34  +    450</td>
</tr>
<tr>
<td>26 July 1982</td>
<td>49   +    60</td>
<td>*    +    195</td>
</tr>
<tr>
<td>9 August 1982</td>
<td>+    +    +</td>
<td>216 +    2320</td>
</tr>
<tr>
<td>20 September 1982</td>
<td>-    10   +    34</td>
<td>44  +    2100</td>
</tr>
<tr>
<td>28 September 1982</td>
<td>-    2    +    42</td>
<td>+    +    +</td>
</tr>
<tr>
<td>29 November 1982</td>
<td>+    +    +</td>
<td>*    +    -    2</td>
</tr>
<tr>
<td>29 May 1984</td>
<td>**   -    1    136</td>
<td>*    -    1    178</td>
</tr>
</tbody>
</table>

Note: 1. All results are expressed as colonies/100 ml
2. TC indicates Total Coliforms
3. FC indicates Fecal Coliforms
4. SPC indicates Standard Plate Count
5. "+" indicates analysis not performed
6. "-" indicates less than
7. "**" indicates too numerous to count (TNTC) with Coliform and Non-Coliform colonies/100 ml.
8. "***" indicates non coliform colonies present
Before the wells are utilized for drinking water purposes they will be chlorinated to a concentration of 50 mg/l for a period of 24 hours in accordance with TB MED 576 (Reference 9). This should eliminate colonization of environmental bacteria within the wells. Also, a chlorination unit is currently being installed to disinfect water from each well.

Generally, the substrata profile of the well site is as follows:

<table>
<thead>
<tr>
<th>Well No. 2803-03</th>
<th>Well No. 2803-06</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 145 Decomposed lava and clay</td>
<td>0 to 30 Medium hard decomposed lava</td>
</tr>
<tr>
<td>145 to 415 Medium hard/hard rock</td>
<td>20 to 302 Medium soft/hard rock</td>
</tr>
<tr>
<td>415 to 494 Medium hard rock with ledges</td>
<td>302 to 312 Very hard rock</td>
</tr>
<tr>
<td>494 to 1020 Medium hard rock</td>
<td>312 to 405 Medium soft/hard rock</td>
</tr>
<tr>
<td></td>
<td>405 to 422 Very hard rock</td>
</tr>
<tr>
<td></td>
<td>422 to 501 Medium soft/hard rock</td>
</tr>
<tr>
<td></td>
<td>501 to 593 Medium with hard ledges</td>
</tr>
<tr>
<td></td>
<td>593 to 646 Medium soft/hard rock</td>
</tr>
</tbody>
</table>

Note: The information above was obtained from the US Geological Survey Well Files.

The Koolau and Waianae dike impounded bodies both provide recharge to the Schofield high level groundwater body. The recharge from the Waianae dike-impounded water body is trivial compared to the Koolau dike-impounded
water body due to the low rock permeability of the Waianae Range. Recharge may also occur within the dike impounded Schofield high level water body as illustrated by Exhibits 5 and 6.

On 14 April 1980, Well No. 2703-01 exhibited concentrations of 11 parts per billion (ppb) dibromochloropropane (DBCP) and 92 ppb ethylene dibromide (EDB). The results were surprising because nowhere else in the deep basal aquifers of southern Oahu had any of the fumigants been detected. Further investigation revealed a spill of approximately 495 gallons of EDB had occurred on bare ground within 60 ft. of the well on 7 April 1977. Later, in the course of investigating the extent of contamination caused by the spill, another focus of contamination near the well was identified. On the slope of and in a small gully 50 to 150 feet north of the well, both DBCP and EDB had been stored on bare ground. Spillage at this site probably was intermittent over a span of years, and the total spillage of DBCP and EDB was probably greater than the well site (reference 4).

Well No. 2703-01 is located approximately 2 miles south of Wells No. 2803-03 and 2803-06. Well No. 2703-01 is not located within the Schofield High-Level Water Body but in a groundwater head gradient area towards the lower basal water areas (Exhibits 7 and 8). Contamination resulting from the spillage of EDB near Well No. 2703-01 would therefore not be expected in Wells No. 2803-03 and 2803-06 due to the direction of groundwater flow towards the lower basin from the Schofield High Level Water Body. Analyses of samples
Figure 1.6-6
GEOHYDROLGIC MAP AND CROSS SECTIONS OF THE ISLAND OF OAHU (Page 1 of 2)
GEOHYDROLOGIC MAP AND CROSS SECTIONS OF THE ISLAND OF OAHU
EXHIBIT 8
FRESHWATER-HEAD MAP
taken on 13 October 1983 and 24 and 30 May 1984 from Well No. 2803-06 indicate no detectable contamination of EDB and DBCP (Exhibit 9 and 10). No detectable trace of DBCP was found in the above samples from Well No. 2803-03. The presence of an unknown substance interfered with the analysis of EDB from samples taken from Well No. 2803-03. Concentrations of 1,2,3 trichloropropane (TCP) ranging from 83 to 90 ppt were found in Well No. 2803-06. The health significance of TCP is unknown at this time.

A gravity sewerage system was installed between 1943 and 1944 during construction of the underground facility. The system consists of 6-, 8-, and 10-inch sewer lines leading to a pump station located in the parking lot which transports the raw sewage through a 6-inch force main to the Schofield Barracks sewage treatment plant. The sewage pump station has a rated capacity of 100 gpm, and is served by duplex 100 gpm pumps. These pumps were recently installed, replacing older units of the same size that failed in 1983. The treatment plant at Schofield Barracks provides secondary treatment of wastewater from Schofield Barracks, Wheeler Air Force Base and USAFS Kunia. After treatment, the effluent is pumped to an irrigation ditch and mixed with water from Wahiawa Reservoir and used to irrigate sugar cane.

The Schofield Barracks Landfill is located approximately 3.5 miles north of USAFS Kunia. It covers almost 40 acres and since World War II had been utilized for the disposal of solid waste from Army installations. The landfill operation ceased on 1 January 1982 and construction of a protective seal cover was completed in December 1983.
MEMORANDUM

TO: Commander
Tripler Army Medical Center
Atten: HSHK-PV-L/C. Matsuura
Tripler AMC, Hawaii 96859

FROM: J. W. Hylin
Chairman

SUBJECT: Results of analysis of water samples for ethylene dibromide (EDB), dibromochloropropane (DBCP) and 1,2,3 trichloropropane (TCP)

Water samples were received from your office on October 13, 1983 to be analyzed for EDB, DBCP, and TCP residues.

Results:

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>ppt EDB</th>
<th>ppt DBCP</th>
<th>ppt TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dillingham RWO1 Well</td>
<td>N. D.*</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Kahuku Range RWO1 Well</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>2803-06 - Kunia Tunnel RWO1 Parking Lot</td>
<td>N. D.</td>
<td>N. D.</td>
<td>90</td>
</tr>
<tr>
<td>2803-03 - Kunia Tunnel RWO2 Upper Left</td>
<td>? **</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Kunia Tunnel RWO3 Upper Rt.</td>
<td>N. D.</td>
<td>N. D.</td>
<td>60</td>
</tr>
<tr>
<td>Schofield Bks RWO2 Well #2</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Bks RWO3 Well #3</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Bks RWO4 Well #4</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
</tbody>
</table>

* N. D. = None Detectable

** Presence of an unknown substance interferes with the analysis

Limit of Detectability:

- EDB = 20 ppt (Dillingham & Kahuku Range)
- DBCP = 20 ppt
- TCP = 60 ppt

NOTE: Positive findings NOT confirmed by mass spectrometry.
University of Hawai'i at Manoa
College of Tropical Agriculture and Human Resources
Department of Agricultural Biochemistry
Honolulu, Hawai'i 96822
June 5, 1984

MEMORANDUM

TO: Commander
Tripler Army Medical Center

ATTN: HSHK-PV-L / C. Matsuura
Tripler AMC, Hawaii 96859

FROM: John W. Ilyin
Chairman

SUBJECT: Results of analysis of water samples for ethylene dibromide (EDB), dibromochloropropane (DBCP) and 1,2,3-trichloropropane (TCP) residues

Water samples were received from C. Matsuura on May 24 and 30, 1984 to be analyzed for EDB, DBCP, and TCP residues.

Results:

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>ppt EDB</th>
<th>ppt DBCP</th>
<th>ppt TCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kahuku Range 23 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Deepwell-Well #4 23 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Schofield Deepwell-Well #2 24 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Waiwai Mill Res. - Water hole Ditch 24 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Kunita Tunnel-Well #1 Parking Lot 29 May 84</td>
<td>N. D.</td>
<td>N. D.</td>
<td>83 ***</td>
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<td>Kunita Tunnel-Well #2 Upper Left 29 May 84</td>
<td>? **</td>
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<td>Ft. Shafter-Well #1 30 May 84</td>
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<td>N. D.</td>
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<td>N. D.</td>
<td>N. D.</td>
</tr>
<tr>
<td>Tripler AMC-Well #1 30 May 84</td>
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<tr>
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<td>N. D.</td>
<td>N. D.</td>
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</table>

* N. D. = None Detectable
** Presence of an unknown substance interferes with the analysis
*** TCP was NOT confirmed by mass spectrometry

Limit of Detectability: EDB = 20 ppt
50 ppt (Kunita Well #1, Schofield Well #2 & 4)
DBCP = 20 ppt
TCP = 60 ppt

EXHIBIT 10
EDB, DBCP, AND TCP RESULTS
Schofield Barracks is located within the Schofield high-level water area. The groundwater table is believed to be about 200 to 300 feet above sea level, or 600 to 700 feet below Schofield Barracks. However, there is no conclusive evidence that the Schofield Barracks subsurface water body underlies the existing landfill. There has been no documented evidence of contamination due to the Schofield landfill thus far.
CHAPTER V - SOURCES OF WATER SUPPLY

USAFS Kunia is near a boundary between an alluvium and lower member of the Waianae Volcanic Series. Underlying the alluvium could be either the Koolau or Waianae Series and the depth of weathering could be as great as 200 feet. Below the weathered zone unaltered layered basalt occurs to depths beyond hydrologic interest.

The Ghyben-Herzberg equation states that the depth of the base of fresh water below sea level is 40 times the fresh water-head elevation above sea level. Two points of maximum fresh water head are in the Waianae and Koolau dike-impounded water bodies. The maximum head in the Waianae dike-impounded water body is 470 meters, which yields an interface position of 19,600 meters below sea level. The maximum head in the Koolau dike-impounded water body is 270 meters, which yields an interface position 10,800 meters below sea level. These calculations help serve to indicate that there is no salt water intrusion problem in either the Waianae or Koolau dike-impounded water bodies.

The Schofield high-level water body, with an average head of 85 meters, would have an interface at 3,400 meters below sea level. This body of water is probably terminated by impermeable rock, rather than extending to this depth. However, this calculation indicates that there is no possible salt water problem if the head is maintained at or near its present level (reference 3).
The Schofield high-level water body is contained in highly permeable rock and completely surrounded by low permeable rock. Thus, the head surface for this water body is nearly level. Pumpage from the Schofield high-level water body will reduce the head uniformly over the entire area of the water body. This will decrease the groundwater underflow along the full length of the dams toward lower gradient areas as well as increase the underflow along the contact between the Koolau and Schofield high-level water bodies. Thus, pumpage from the Schofield high-level water body will have a widespread, distributed effect. The pumping of more groundwater from the Schofield high-level water body will cause the fresh water head to decline and cause a reduction in groundwater flux to the adjacent basal-water bodies.

Water pumped from Wells No. 2803-03 and 2803-06 will be used for potable water purposes only in the event of an emergency such as when the normal source of water from Schofield is disrupted. At those times, the quantity of water pumped will not be more than what is currently needed.
CHAPTER VI - PROPOSED TREATMENT WORKS

Water pumped from the wells will be chlorinated in accordance with TM 5-813-3, Water Treatment. The extent of chlorination should be such that the chlorine residual in the active part of the potable water system is not less than 0.4 mg/l. The location of the chlorine injector point will be on the bottom floor of the underground facility where 3 water lines from each of the wells are combined (Exhibit 11). For safety purposes a liquid calcium hypochlorite system will be installed. A total of three liquid calcium hypochlorite feeders will be installed for each line from Wells No. 2803-03, 8203-06 and 2803-05 (Del Monte currently using). The design requirements are as follows:

Calculated hypochlorite solid = 70% Chlorine (dry weight)

Ratio of the weight of Water/Chlorine = 10%

Resultant \[
\frac{0.1}{0.7} = 0.143
\]

Flow = 1600 gpm

# Water/Day = 1600 gpm (8.34 #/gal) (60 min/hr) (24 hr/day) = 19.123 \times 10^6

# Chlorine req = 19.123 (0.4) = 7.65

Wt Calcium hypochlorite solid = 7.65 #/0.7 = 10.93#

Wt Water req = 10.93/0.143 = 76.50#

Vol Calcium Hypochlorite slurry req/day = 76.50 #/8.34 = 9.1 gal/Day

Operation and maintenance requirements will consist of refilling the calcium hypochlorite storage tank and performing routine maintenance and replacement of pump diaphrams and injectors.
EXHIBIT 11
Location of Chlorination Station
CHAPTER VII - PUMPING FACILITIES

The existing pumps at Wells No. 2803-03 and 2803-06 are similar and have a maximum capacity 1600 gpm. Each pump is a turbine type with an electric motor rated as 3 phase, 60 cycle and 2200 volts. Power for the motor is supplied by the main underground facility which may obtain electricity from outside commercial sources or emergency generators located within the facility.

Water from the wells flows through the cooling network once and is disposed of into an irrigation ditch. At this time, no provisions have been made for water storage or for modifications of the existing piping network to connect the potable water system with the cooling system. Exhibit 12 contains the layout and sizes of existing mains.
CHAPTER VIII - FINANCING

The cost for the installation of chlorinators shall be paid by the US Army and is estimated at $5,000.
REFERENCES


8. Disposition Form (DF), APZV-HS-PV, dated 12 June 1984, subject: Results of DACP, EDB, TCP Pesticide Testing of Army Water Sources and Bacteriological Testing at Kunia Tunnel Wells.

Directorate of Public Works

Mr. Ernest Y.W. Lau
Deputy Director
Commission on Water Resource Management
P.O. Box 621
Honolulu, Hawaii 96809

Dear Mr. Lau:

There have been different well reference numbers used by the Department of Land and Natural Resources (DLNR), the Army and the Navy Operational Intelligence Center (NOIC) Hawaii to describe the wells at Field Station Kunia, see enclosure. The confusion with all the different well reference numbers has spurred the Army to reassess information relating to the DLNR wells numbered 2803-02, 2803-03, and 2803-04. After careful consideration the Army and Navy have agreed to utilize the well identification configuration used by the DLNR. No action by the DLNR is necessary; this correspondence is for informational purposes only.

<table>
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<tr>
<th>DLNR Well Numbers</th>
<th>Army Well Numbers</th>
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<tr>
<td>2803-02</td>
<td>Army Injection Well (sealed and closed)</td>
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<tr>
<td>2803-03</td>
<td>2803-01 (current reference)</td>
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<tr>
<td>2803-04</td>
<td>2803-06 (current reference)</td>
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<td>2803-05</td>
<td>2803-05</td>
</tr>
<tr>
<td>2803-07</td>
<td>2803-07</td>
</tr>
</tbody>
</table>

DLNR well number 2803-06 could not be found, and is presumed to be closed.

All forthcoming reports will incorporate the DLNR well numbers when referencing these wells. Copies of this letter will be furnished to Burt Wataoka, Commanding Officer, Navy Information Operations Command Hawaii (ATTN: Deputy Director, Mr. Yoshimi, N4), Building 9, Schofield Barracks, HI 96857 and Ms. Lenore Nakama Commission on Waster Resource Management, P.O. Box 621, Honolulu, HI 96809. Feel free to contact Mr. Joel Narusawa, Directorate of Public Works, Environmental Division, IRP Manager at (808) 656-2878, extension 1055 if you have questions regarding this matter.

Sincerely,

Alan K.L. Goo
Director
Directorate of Public Works

Enclosure
LEGEND

- WELLS (DLNR NO.)

DLNR Well 2803-04
Navy Well 01
Army Well 2803-06

DLNR Well 2803-07
Navy Well No Name
Army Well 2803-07

DLNR Well 2803-05
Navy Well 03
Army Well 2803-05

DLNR Well 2803-03
Navy Well 02
Army Well 2803-01

DLNR Well 2803-02
Navy Well Injection
Army Well Injection
FROM: Glenn Bauer, Mitchell Ohye, Kevin Gooding, Lenore Nakama

SUBJECT: Site Visit to Kunia Wells

Background: Ken Masatsugu (U.S. Navy Engineer) informed us that the locations of the wells in grid 2803 appear to be incorrect. There also appeared to be discrepancies between the latitude/longitude coordinates in the well index database and the mapped well locations. The reason for the Navy's interest in the correct identification and location of these wells is a pending source contamination lawsuit involving Del Monte. The Navy wants to refer to the correct Well No. in their court filings to avoid confusion. Although staff recognizes that the records for many of the older wells have not been verified and may contain errors, a site visit was prioritized in this case because, in addition to the pending lawsuit, two of the wells in grid 2803 have water use permits held by Del Monte.

Purpose: To GPS existing well locations in grid 2803 and identify the correct Well Nos.

Site Visit: On May 1, 2003 at 9:00 am, staff met Ken at the Schofield Guardhouse off Kunia Road. Also present during the visit was Ronda Randolf, Environmental Program Manager for the Navy. Two GPSs were used, one referenced to the Old Hawaiian Datum, the other to NAD 83. Staff was unable to inspect the actual sources because confined-space certification would be prerequisite and heavy equipment would need to be mobilized.

Well No. 2803-01: This well was not seen during the visit. Its exact location is unknown. Our records indicate this well was a 1" test bore and that is now lost and buried.

Well No. 2803-02: This well is believed to be a former injection/discharge well that has been sealed. According to Ronda, the sealing took 6 cement trucks. There is a thin cover of dirt over the sealed cement vault.

Lat 21 28 30.7 Long 158 03 27.1 (Old Hawaiian Datum) /
Lat 21 28 19.3 Long 158 03 17.2 (NAD 83) /
Well No. 2803-03: This standby cooling well is located in the Microwave Access Area.
Lat 21 28 33.8 Long 158 03 26.4 (OHD)
Lat 21 28 22.5 Long 158 03 16.4 (NAD 83)

View of Well No. 2803-03

Well No. 2803-04: This standby cooling well is located in the parking lot of the Naval Security Group Activity (NSGA).
Lat 21 28 44.8 Long 158 03 19 (OHD)
Lat 21 28 33.6 Long 158 03 08.9 (NAD 83)

View of Well No. 2803-04
Well No. 2803-05: This well is in battery with Well No. 2803-07. The wells are being used by Del Monte for potable use and pineapple agriculture.
Lat 21 28 37.7 Long 158 03 26 OHD /
Lat 21 28 26.3 Long 158 03 16.2 NAD 83 /

View of Well No. 2803-05 Pumphouse

Well No. 2803-06: The location of this unused well is uncertain. Ken thinks it is located near where Well No. 2803-04 is located. This was to be the last well site visited and we were planning to use the GPS to try to locate the well using the coordinates from the database, however, an emergency occurred and Ronda and Ken had to leave hurriedly and unexpectedly. We could not gain access to the well site without the Navy personnel.
Well No. 2803-07: This well is in battery with Well No. 2803-05.
Lat 21 28 38.3 Long 158 03 32 OHD
Lat 21 28 26.9 Long 158 03 22.2

Follow-Up: The latitudinal and longitudinal coordinates have been updated in the well index database with the NAD 83 coordinates obtained using the GPS. The original well locations are shown in Exhibit 1. The new well locations based on the GPS coordinates are shown in Exhibit 2. A summary report from the well index database showing the original coordinates on record is shown in Exhibit 3. A summary report showing the GPS coordinates is shown in Exhibit 4.
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<tr>
<th>Well No.</th>
<th>Well Name</th>
<th>Aquif Code</th>
<th>Owner/User</th>
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<th>Latitude</th>
<th>Longitude</th>
<th>Type</th>
<th>Case Dia In.</th>
<th>Total Depth ft.</th>
<th>Ground</th>
<th>Bottom Solid Casing</th>
<th>Bottom Perf Casing</th>
<th>Bottom of Hole</th>
<th>Static Head</th>
<th>Cl-Temp</th>
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<th>Installed Capacity</th>
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Exhibit 3
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Exhibit 4
Hi Lenore,

Thank you for the info. Some of our records show that well "#28 shown on the attached sketch below which is located within Navy boundary" as well 2803-05. However, the well summary sheet you faxed me shows well #2803-05 as Del Monte Pump 3 and the owner/user as Del Monte. Please provide DLNR's well designation for well #28 in the attachment.

Mahalo,
Ken

-----Original Message-----
From: Lenore.Y.Nakama@hawaii.gov [mailto:Lenore.Y.Nakama@hawaii.gov]
Sent: Monday, April 14, 2003 9:36 AM
To: Masatsugu, Ken T (EFDPAC)
Subject: Re: FW: KUNIA WELL INFORMATION

Ken,

If you're referring to a well completion report, no, there is none in our files. BWS sometimes has records for these older wells, you could try them. Lenore

Hi Lenore,

Thank you for the faxed info on the Del Monte and DoD wells. I am not sure which is correct; however, our well #1 location appears to be located at well #2 on the map you faxed. The well I am working on is well #3 and its location is the same on both maps. Is there a detailed well information sheet for well #3 like the one you provided me for the DLNR well at Makaha Ridge on Kauai? Sorry for making you work so hard. Thank you again for all your help.
Ken

-----Original Message-----
From: Masatsugu, Ken T (EFDPAC)
Sent: Friday, April 11, 2003 10:51 AM
To: 'Lenore.Y.Nakama@hawaii.gov'
Cc: Poentis, Aaron Y (EFDPAC)
Subject: KUNIA WELL INFORMATION

Hi Lenore,

Thank you for your e-mail address. As discussed, attached is the partial plan of our facilities at Kunia. I would appreciate information on wells 2, 3, and 4 if available. Well 1 was an injection well and was abandoned recently via DOH process. Wells 2 and 4 are standby cooling water wells and well 3 is being used by Del Monte for pineapple field irrigation.

Mahalo,
Ken

-----Original Message-----
From: Lenore.Y.Nakama@hawaii.gov [mailto:Lenore.Y.Nakama@hawaii.gov]
Sent: Friday, April 11, 2003 9:16 AM
To: Masatsugu, Ken T (EFDPAC)
Subject:

(See attached file: DoDKunia Wells.pdf)