PN-ABR-872

POLICY ALTERNATIVES FOR PUMP IRRIGATION IN INDONESIA

ISPAN #50

IRRIGATION SUPPORT PROJECT
FOR ASIA AND THE NEAR EAST

Sponsored by the U.S. Agency for International Development

ISPAN

IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

ISPAN Technical Support Center
Room 1001
1611 North Kent Street
Arlington, Virginia 22209-2111
U.S.A.
Phone: (703) 243-7911
Fax: (703) 525-9137

INTEGRATED IRRIGATION MANAGEMENT RESOURCES

Camp Dresser & McKee International Inc. (PRIME CONTRACTOR)
CARE
Cornell University
Development Alternatives, Inc.
Harza Engineering Company
International Science and Technology Institute, Inc.
Training Resources Group
The University of Arizona

POLICY ALTERNATIVES FOR PUMP IRRIGATION IN INDONESIA

Sam Johnson
Suprodjo Pusposutardjo
Peter Reiss
G.T. Keith Pitman
Sigit Supadmo Arif
Roger Jackson
Agus Pakpahan
Effendi Pasadaran
Abunawan Mintoro
Tjahjadi Sugianto
Sumaryanto
Hendiarto

May 1993

A Small Scale Irrigation Management Project Applied Study
prepared for the USAID Mission to Indonesia
by the Irrigation Support Project for Asia and the Near East
and for The Ford Foundation
by the Centre for Agro-Socioeconomic Research

Irrigation Support Project for Asia and the Near East
Contract No. ANE-0289-C-00-7044-00, Project No. 398-0289
serving the Asia Bureau and the Near East Bureau
U.S. Agency for International Development
Washington, D.C. 20523

CONTENTS

TABLES

RINGKASAN EKSEKUTIF

Luas lahan beririgasi di Indonesia telah mencapai lebih dari lima juta hektar. Mengingat jumlah lahan yang dapat dikembangkan menjadi daerah irigasi dengan mengembangkan sistem irigasi permukaan adalah terbatas, maka laju pengembangan daerah irigasi gravitasi yang cepat seperti telah dialami pada dasawarsa-dasawarsa yang lalu tampaknya sudah berakhir.

Bersamaan dengan situasi di atas, di beberapa daerah, terutama di Jawa, luas lahan sawah mengalami penyusutan yang diperkirakan mencapai 30,000 hektar per tahun, sebagai akibat perluasan kota, pertumbuhan lokasi industri, dan lain-lain. Kawasan Indonesia Timur yang dicirikan oleh iklim kering dan memiliki daerah marginal lebih banyak juga memerlukan air baik untuk keperluan irigasi maupun kebutuhan rumah tangga. Keadaan ini telah mendorong Pemerintah Indonesia untuk lebih memperhatikan pengembangan airtanah atau air permukaan melalui pengembangan irigasi pompa. Unit irigasi pompa yang dikembangkan oleh Pemerintah pada umumnya adalah irigasi pompa airtanah dalam dimana biaya investasinya ditanggung oleh Pemerintah. Adapun irigasi pompa yang dibangun oleh petani, swasta atau Lembaga Swadaya Masyarakat (LSM) adalah dibiayai sendiri atau berasal dari lembaga donor. Pengembangan irigasi pompa yang diprakarsai oleh LSM mencoba mengembangkan sistem irigasi pompa melalui peningkatan inisitatif dan partisipasi petani.

Ford Foundation dan Small Scale Irrigation Management Project (SSIMP), USAID, memandang bahwa dalam pengembangan irigasi pompa dengan skala atau jumlah yang besar diperlukan suatu kajian yang memadai. Oleh karena itu, kajian ini diharapkan dapat memberikan masukan berupa pengetahuan, pemikiran, data atau informasi baik berupa pelajaran dari pengembangan irigasi pompa pada masa lalu maupun yang sedang dihadapi pada saat ini, yang diperlukan untuk penyempurnaan kebijaksanaan pengembangan irigasi pompa di Indonesia.

Hasil kajian ini merupakan hasil kolaborasi antara tim dibawah naungan Irrigation Support Project for Asia and Near East (ISPAN) dengan peneliti pada Pusat Penelitian Sosial Ekonomi Pertanian (PSE), Badan Litbang Pertanian dimana USAID dan Ford Foundation masing-masing membiayai tim ISPAN dan tim PSE. Atas dasar hasil interaksi dengan pengambil keputusan atau peneliti di BAPPENAS, Direktorat Irigasi II, P2AT, Badan Litbang Pertanian, USAID, ADB, dan Bank Dunia dihasilkan delapan isu kebijaksanaan sebagai Ruang Lingkup kajian yaitu: potensi irigasi pompa, masalah lingkungan, peranan pemerintah dan swasta dalam pengembangan irigasi pompa, alternatif kelembagaan dalam pengembangan irigasi pompa, kesesuaian teknologi dalam pengembangan irigasi pompa, viabilitas ekonomi dari irigasi pompa, kerangka hukum dan kelembagaan dari sistem irigasi pompa, dan penumbuh-kembangan kapasitas Perkumpulan Petani Pemakai Air (P3A).

Potensi Irigasi Pompa

Jumlah penduduk Indonesia diperkirakan akan bertambah dari 183 juta pada tahun 1990 menjadi 231 juta pada tahun 2005. Peningkatan penduduk sebesar 26 persen ini akan meningkatkan kebutuhan akan serealia dari 33.4 juta ton pada tahun 1988, menjadi sekitar 48.0 juta ton pada tahun 2005. Untuk memenuhi peningkatan kebutuhan tersebut diperlukan peningkatan produktifitas lahan yang dapat dicapai melalui peningkatan upaya diversifikasi, intensifikasi, ekstensifikasi, dan rehabilitasi. Mengingat luas lahan di Jawa dimana sekitar 60 persen produksi pangan dihasilkan adalah terbatas, maka upaya diversifikasi dan intensifikasi pada lahan irigasi yang ada akan tetap merupakan fokus peningkatan produktifitas pertanian.

Pada tahun 2000 kebutuhan air di Indonesia diperkirakan mencapai kurang-lebih 149 juta meter kubik (jmk) dan diperkirakan penggunaan air untuk pertanian secara nasional mencapai 64 persen atau sekitar 95 jmk. Adapun kebutuhan air untuk irigasi pada tahun 2000 akan mencapai 87 jmk atau naik sekitar 21 persen dari perkiraan penggunaan pada tahun 1990. Kebutuhan air irigasi di Jawa hanya akan naik sekitar 3.3 persen selama dekade tersebut.

Air Permukaan—Curah hujan rata-rata tahunan di Indonesia adalah lebih dari 2500 mm dan keragamannya makin ke timur semakin besar. Sebagian besar wilayah mempunyai musim kemarau minimal empat bulan lamanya dan bahkan beberapa wilayah merupakan daerah bayangan hujan sepanjang tahun. Wilayah kering ini merupakan prioritas utama untuk pengembangan sarana tangkapan (reservoir) air permukaan atau peningkatan kapasitas imbuh airtanah.

Airtanah—Airtanah dari akuifer dangkal merupakan sumber air utama untuk keperluan sehari-hari bagi 90 persen penduduk desa. Sedangkan akuifer dangkal dan akuifer dalam menyediakan sekitar 65 persen dari kebutuhan air nasional untuk industri. Upaya pengembangan airtanah oleh Pemerintah, yang telah dimulai pada awal tahun 1970-an, baru dapat mengembangkan irigasi pompa airtanah sekitar 28,000 hektar atau 17 persen dari 168,000 hektar potensi yang telah teridentifikasi. Hal ini disebabkan terutama oleh kelangkaan sumberdaya untuk pengembangan airtanah pada wilayah potensial tersebut yang menyebar di seluruh Indonesia. Akhir-akhir ini upaya pengembangan irigasi pompa airtanah mendapat prioritas sehubungan dengan upaya penanggulangan kemiskinan khususnya di kawasan Indonesia Timur yang pada umumnya beriklim kering.

Kesadaran akan Faktor dan Dampak terhadap Lingkungan

Pengembangan pompa untuk menaikkan airtanah dapat menimbulkan dampak negatif terhadap lingkungan yang seringkali bersifat tidak dapat pulih kembali. Salah satu dampak negatif yang penting adalah pengurangan ketersediaan air untuk penggunaan lainnya seperti air minum. Disamping itu intrusi air laut seringkali terjadi apabila pemompaan airtanah dilakukan pada mintakat (zona) pantai.

Dampak positif dari pengembangan irigasi pompa airtanah dapat berupa peningkatan produksi pertanian, penambahan kesempatan kerja dan pendapatan, serta penyediaan kebutuhan air untuk penggunaan lainnya di pedesaan, khususnya pada musim kemarau. Pengamatan di Jawa Tengah menunjukkan bahwa dengan adanya irigasi pompa, kesempatan kerja meningkat sampai 300 hari kerja orang per pompa. Dampak positif ini akan sangat berarti bagi penduduk yang berada pada kondisi seperti yang terdapat pada lingkungan kawasan Indonesia Timur.

Berdasarkan beberapa pengamatan, ada kemungkinan kualitas airtanah pada akuifer dalam kurang atau bahkan tidak memenuhi syarat untuk dapat dijadikan air irigasi karena mengandung senyawa kimia yang tidak sesuai dengan kebutuhan tanaman atau bahkan membahayakan kesehatan manusia. Hal yang sama juga terjadi pada beberapa sungai akibat kandungan aluminium, sulfat dan khlorida dalam konsentrasi tinggi.

Peranan Pemerintah dan Swasta dalam Irigasi Pompa

Penataan yang tepat tentang peranan pemerintah dan peranan swasta, termasuk petani, merupakan agenda kebijaksanaan yang penting baik di Indonesia maupun di dunia internasional. Dengan semakin ketatnya kendala pembiayaan yang dihadapi oleh pemerintah serta kelangkaan dalam sumberdaya lain seperti tenaga ahli, maka semakin diperlukan partisipasi aktif swasta dalam pembangunan. Permasalahan yang dihadapi adalah menarik garis batas yang tepat tentang tanggungjawab di antara pelaku ekonomi tersebut. Di Indonesia ada kecenderungan bahwa swasta akan memainkan peranan yang semakin penting dalam pengembangan dan pemeliharaan irigasi pompa apabila pemerintah Indonesia memberikan lebih banyak daerah irigasi kepada P3A.

Pada saat ini irigasi pompa swasta/petani telah mencapai luasan areal irigasi lebih dari 150,000 hektar dibandingkan dengan hanya 30,000 hektar dan 20,000 hektar yang masing-masing berupa irigasi pompa airtanah dan irigasi pompa air permukaan (sungai) yang dikembangkan oleh pemerintah. Meskipun demikian, pengetahuan atau data tentang irigasi pompa swasta ini masih sangat terbatas. Disamping itu belum banyak upaya pendataan yang dilakukan. Pendataan irigasi pompa swasta ini juga lebih sulit mengingat dicirikan oleh penyebarannya yang tinggi, berukuran kecil dan mudah dipindahkan dari satu tempat ke tempat lainnya.

Berkembangnya irigasi pompa di Indonesia oleh swasta didukung oleh tumbuhnya industri pompa dan mesin dalam negeri. Lebih dari 60 pabrik memproduksi pompa dan motor-motor penggerak yang berukuran kecil-kecil. Juga terdapat sejumlah besar bengkel-bengkel kecil yang memberikan dukungan teknis dan perbaikan peralatan pompa. Pihak swasta selama tahun 1989-1990 telah menghasilkan lebih dari 50,000 pompa irigasi.

Pengembangan Kelembagaan pada Sistem Irigasi Pompa

Departemen Pekerjaan Umum, Direktorat Jenderal Pengairan membentuk satu unit khusus yaitu Proyek Pengembangan Air Tanah (P2AT) dalam Direktorat Irigasi II untuk melakukan penyidikan potensi pengembangan irigasi pompa airtanah dan membangunnya dalam skala besar. Semula pengembangan irigasi airtanah ini diperuntukkan sebagai sarana peningkatan produksi padi dalam rangka mencapai swasembada beras. Perkembangan selanjutnya adalah, khususnya pada perkembangan akhir-akhir ini, tujuan pengembangan irigasi pompa lebih diarahkan untuk meningkatkan pendapatan petani di daerah miskin tanpa mengabaikan pertimbangan ekonomi dan kebiasaan usahatani petani setempat. Oleh karena itu, upaya diversifikasi usahatani untuk meningkatkan pendapatan melalui pemilihan jenis komoditas yang bernilai tinggi dan penerapan pola tanam yang sesuai dengan kondisi tanah dan agroklimat setempat, merupakan langkah perubahan penting dalam memanfaatkan irigasi pompa. Sebagai contoh, dilihat dari segi peningkatan pendapatan, komoditas tembakau merupakan komoditas utama di Madura sedangkan bawang merah merupakan komoditas penting dalam sistem usahatani di Kediri, Jawa Timur.

P2AT merupakan suatu bentuk kelembagaan proyek dengan batas waktu, pendanaan, pengorganisasian dan lain-lain sesuai dengan ketentuan tentang keproyekan yang berlaku di Indonesia. Sebagian besar lokasi pengembangan irigasi pompa airtanah berada di Jawa dan Madura dengan bantuan teknis dari donor bilateral seperti Overseas Development Administration (ODA) dari pemerintah Inggris. Pendekatan pengembangan yang dilaksanakan pada dasarnya berupa kajian kelayakan dan pengembangan pedoman irigasi airtanah dalam oleh P2AT.

Lebih rinci lagi, ruang lingkup kegiatan P2AT mencakup impor peralatan pengeboran dan pemompaan, eksplorasi dan membangun sistem irigasi pompa, dan pelatihan staf. Perencanaan, rancang bangun dan kontruksi dari sistem sumuran terutama ditentukan atas dasar pertimbangan teknis, termasuk potensi akuifer, derajat kekurangan air, tataletak dari saluran air permukaan yang ada, dan topografi lahan. Meskipun kesepakatan untuk menentukan lokasi pengeboran dan jalan masuk didasarkan atas kesepakatan dengan pimpinan desa, tetapi proses ini masih harus terus disempurnakan agar partisipasi masyarakat dalam proses pengembangan irigasi pompa airtanah ini dapat meningkat.

Pendekatan yang berbeda dilakukan oleh Lembaga Swadaya Masyarakat seperti Bina Swadaya dalam pengembangan irigasi pompa air permukaan (sungai) dengan skala yang cukup besar. Bina Swadaya menerapkan pendekatan pengembangan irigasi pompa melalui pengembangan kelembagaan masyarakat pada tahap awal kegiatan. Setelah diketahui bahwa irigasi pompa adalah layak dikembangkan, Bina Swadaya membantu petani untuk membentuk wadah organisasi berupa Perkumpulan Petani Pemakai Air (P3A) beserta perangkat organisasinya seperti Anggaran Dasar dan Anggaran Rumah Tangga, memilih ketua dan pembantunya, membangun konsensus untuk suatu permasalahan tertentu dan lain-lain. Selanjutnya, Bina Swadaya juga membantu menyediakan serta melatih petugas untuk dapat melakukan penyuluhan pertanian sekaligus bertindak sebagai "*community organizer*" untuk menghidupkan kelompok tani.

Bentuk kelembagaan ke tiga dalam pengembangan irigasi pompa adalah irigasi pompa air permukaan yang dikembangkan oleh swasta termasuk petani. Di Subang, Jawa Barat, dijumpai tiga buah pompa swasta yang dapat mengairi lahan sawah berkisar antara 70 sampai 200 hektar. Sistem pompa yang dibangun merupakan hasil rakitan tenaga setempat dengan memanfaatkan mesin dan pompa bekas. Alokasi air serta biayanya ditentukan melalui suatu proses negosiasi dimana pemerintah desa memegang peranan penting dalam mencapai harga air yang disepakati bersama antara petani, pemilik pompa dan pemerintah desa. Untuk mengoperasikan pompa dan mengatur alokasi air, pemilik pompa dibantu oleh ketua blok atau ulu-ulu.

Kesesuaian Teknologi pada Irigasi Pompa

Suatu teknologi dikatakan sesuai apabila teknologi tersebut dilihat dari segi sosial-budaya, finansial dan ekonomi dapat diterima, dan secara teknis dapat diterapkan sesuai dengan umur teknis yang telah diperkirakan. Di Indonesia, kebanyakan pompa-pompa yang besar dan padat modal, motor serta pompa untuk irigasi pompa airtanah adalah disediakan oleh Pemerintah. Sebaliknya, unit-unit pompa yang lebih kecil pada umumnya dibeli dan dipasang oleh petani dengan menggunakan sumberdaya yang dimilikinya. Disamping itu, pompa-pompa kecil pengadaannya ada juga yang bersumber dari bantuan pemerintah melalui pelbagai program, antara lain bantuan pemerintah untuk penanggulangan bencana alam seperti kemarau panjang.

Pada beberapa wilayah, pemanfaatan airtanah untuk irigasi telah menjadi tradisi. Secara tradisional, sumur-sumur telah dibangun untuk menyediakan air bagi tanaman-tanaman yang bernilai ekonomis tinggi seperti tembakau dan bawang merah. Sumur-sumur dangkal atau sumur pantek tersebut digali dan diplester secara manual, atau dibor secara mekanis. Semua peralatan pengeboran, selubung sumur, dan komponen-komponen lainnya merupakan buatan lokal. Ribuan sumur sederhana semacam ini telah dibangun oleh petani atau kelompok petani di Indonesia.

Sumur dengan kedalaman menengah dan dalam dibuat pada lokasi dengan kedalaman airtanahnya lebih dari 10 meter. Sumur-sumur yang lebih besar dan lebih dalam ini memerlukan teknologi pengeboran dan pembuatan sumur yang berada di luar kemampuan petani. Investasi pompa terendam *(submersible)* juga sangat mahal sehingga bantuan dana pemerintah diperlukan.

Proyek-proyek irigasi pompa yang dikembangkan oleh pemerintah menggunakan pipa PVC yang dipendam dan dibantu oleh pipa penaikan (riser pipe) dan kotak outlet untuk membagi air ke seluruh lahan irigasi. Secara teoritis sistem semacam ini memang lebih baik meskipun sistem ini menuntut pemeliharaan yang mahal.

Persentase jam kerja aktual terhadap kapasitas jam kerja pompa merupakan petunjuk yang baik terhadap kesesuaian teknologi irigasi pompa. Pada areal yang diteliti, persentase jam kerja pompa rata-rata relatif lebih rendah dibandingkan dengan kapasitasnya. Pompa sumur dalam rata-rata mengalami satu kali kerusakan menengah dan berat, yang biasanya terjadi pada bagian transmisi dan mesin. Selama ini sukucadang pompa disediakan oleh P2AT.

Viabilitas Ekonomi Irigasi Pompa

Viabilitas ekonomi irigasi pompa secara langsung berkaitan dengan tingkat penggunaan pompa dan keuntungan yang diperoleh oleh pemakai air. Agar diperoleh keuntungan dari investasi irigasi pompa, para petani harus mempunyai peluang untuk menggunakan peralatan tersebut secara teratur sehingga biaya peralatan dapat tersebar pada beberapa musim.

Pengamatan di lapangan membuktikan bahwa hal tersebut tidak dapat dicapai. Dari perkiraan rencana intensitas tanam 300 persen, pada kenyataannya intensitas tanam lahan irigasi hanya sekitar 170 hingga 250 persen. Hal ini terjadi karena luas areal yang diairi jauh lebih rendah dibandingkan dengan luas areal yang dirancang. Situasi seperti ini terjadi baik pada sistem distribusi air permukaan maupun pada sistem pipa terpendam.

Meskipun jangka waktu proyek untuk membiayai irigasi pompa telah berakhir beberapa tahun yang lalu, pompa-pompa tersebut masih menerima bantuan dari pemerintah. Pada irigasi pompa ini, petani ternyata masih membayar lebih tinggi untuk air pompa dibandingkan dengan petani yang memperoleh air irigasi permukaan, walaupun sebenarnya petani hanya membayar biaya O&P (operasi dan pemeliharaan) dan tidak dibebani biaya investasi peralatan. Di Jawa Barat iuran ini besarnya mencapai 20 persen dari biaya tunai produksi usahatani. Sedangkan di Yogyakarta besarnya biaya ini dapat mencapai 30 persen dari biaya tunai usahatani.

Perhitungan B/C menunjukkan bahwa masih sedikit sistem irigasi pompa yang mempunyai nilai 1 atau lebih. Dengan mempelajari nisbah B/C akan tampak bahwa bila biaya investasi dimasukkan, maka kelayakan ekonomi sebagian besar pompa masih rendah.

Kerangka Hukum dan Dukungan Institusi

Sebelum ditetapkan undang-undang tentang air yang berlaku sekarang ini, peraturan tentang air mengikuti peraturan yang dikembangkan pada zaman pendudukan Belanda. Pada tahun 1974 pemerintah Indonesia mensahkan undang-undang tentang Pengembangan Sumberdaya Air sebagai landasan bagi pembentukan peraturan-peraturan dan ketentuan-ketentuan pengembangan sumberdaya air.

Dalam kaitannya dengan airtanah, Peraturan Pemerintah No. 22/1982 Pasal 6 tentang Pengairan menyatakan bahwa "Pengurusan administratif atas sumber air bawah tanah, mata air panas sebagai sumber mineral dan sumber tenaga menjadi wewenang Menteri yang bertanggungjawab dalam bidang pertambangan".

Pemerintah Daerah Propinsi mempunyai wewenang memberikan ijin pengeboran airtanah setelah memperoleh rekomendasi teknis dari Direktorat Geologi Tata Lingkungan. Pemerintah propinsi dapat mengeluarkan peraturan daerah, instruksi dan keputusan, termasuk pemberian ijin hak penggunaan. Untuk pengembangan airtanah, kegiatan ini dilakukan oleh Departemen Pekerjaan Umum melalui P2AT.

Tanggungjawab kegiatan O&P dan sarana irigasi dilimpahkan kepada propinsi dan pemerintah daerah setempat. Instansi-instansi yang terkait adalah Dinas Pertanian Propinsi, Kelompok Petani Pengelola Air dan panitia irigasi yang bekerjasama dengan Dinas Pertanian Tanaman Pangan propinsi dan instansi terkait lainnya.

Memperkokoh Kapasitas Perkumpulan Petani Pemakai Air (P3A)

Pengembangan daerah irigasi pompa di Indonesia, baik yang dilakukan oleh pemerintah maupun oleh swasta, selalu berkaitan dengan P3A. Seperti halnya dalam kegiatan irigasi gravitasi, P3A diharapkan dapat digunakan sebagai wahana untuk meningkatkan dan mengatur peranserta petani dalam mengelola air. P3A ini juga bertanggungjawab dalam menetapkan dan mengumpulkan iuran air, penggantian motor dan penggantian pompa.

Pada saat ini terdapat dua pola pembentukan P3A, yaitu P3A yang didasari keputusan pemerintah dan yang dibentuk oleh LSM. Data yang dimiliki oleh P3A masih sedikit dan tidak lengkap. Neraca keuangan umumnya jarang dibuat atau jarang disimpan dengan baik. Meskipun kadang-kadang sejumlah simpanan dapat dikumpulkan, simpanan ini dipegang oleh pengurus P3A dalam bentuk tunai, rekening bank atau natura.

Pada sistem irigasi gravitasi, petani dan kelompok petani mengambil keputusan tentang alokasi air di tingkat petak tersier. Sedangkan pada sistem pompa, mereka mengambil keputusan tentang alokasi air di seluruh lahan yang diairi pompa. Setiap blok memperoleh air pada sutu atau beberapa hari tertentu. Keputusan ini dibuat oleh pengurus P3A.

Rekomendasi

Rekomendasi Teknis

- Pemerintah Indonesia sebaiknya tidak mengembangkan sistem irigasi pompa di areal yang telah dikembangkan atau mampu dikembangkan olch masyarakat secara swadaya.

- Meskipun P3A pada irigasi pompa umumnya telah efektif, tidak selalu diperlukan P3A dengan kompleksitas struktur yang homogen pada seluruh daerah irigasi.

- Perlu penyempurnaan dalam pendataan pada sistem irigasi pompa yang diharapkan dapat berjalan dengan baik dan lancar, dengan disertai pembakuan dalam hal pengumpulan datanya.

- Pengembangan airtanah dangkal sebaiknya dilakukan oleh petani sendiri dengan menggunakan sumur dengan motor penggerak kecil buatan lokal. Pemerintah diperlukan peranannya dalam pemantauan dampak lingkungan.

- Perlu dilakukan penyempurnaan dalam seleksi jenis mesin dan pompa dalam pengembangan daerah irigasi airtanah berskala besar melalui P2AT yang umumnya diperoleh melalui bantuan luar negeri.

- Pemerintah disarankan untuk tidak melakukan investasi pompa turbin bila suku cadang tidak tersedia, kecuali bila pemerintah bermaksud untuk mengoperasikan sendiri peralatan itu.

Rekomendasi Lingkungan

- Evaluasi sumberdaya air nasional dan implementasinya berdasarkan satuan wilayah sungai harus dilaksanakan secara nasional dan secepat mungkin.

- Pada areal airtanah dangkal diperlukan pengawasan terhadap jumlah pompa yang dioperasikan petani untuk menghindari pemompaan yang berlebihan.

- Eksplorasi airtanah sebaiknya dilaksanakan secara terpisah dengan pelaksanaan program irigasi.

- Diperlukan upaya yang lebih baik untuk mengoptimalkan pemanfaatan data yang tersedia agar dapat digunakan sebagai dasar perencanaan pengembangan sumberdaya air berdasarkan kelestarian lingkungan.

- Diperlukan pendugaan tentang penggunaan sumberdaya air secara periodik agar stok sumberdaya tersebut dapat diketahui dengan pasti.

Rekomendasi Institusi

- Keikutsertaan pemerintah dalam program pengembangan dan pengelolaan irigasi pompa akan selalu diperlukan dengan jenis dan derajat keikutsertaan yang berbeda sesuai dengan kondisi sumberdaya dan sosial ekonomi yang berbeda-beda menurut wilayah yang berbeda pula.

- Pemerintah perlu tetap memberikan bantuan dalam bentuk pelbagai latihan untuk meningkatkan kemampuan manajerial dan teknis dari P3A seperti latihan pembukuan keuangan, perbengkelan dan lain-lain, baik sebelum atau sesudah penyerahan pompa.

- P3A perlu dilembagakan sebagai lembaga dengan status badan hukum agar P3A ini dapat memperoleh kekuatan hukum yang lebih tinggi.

- Sistem irigasi pompa harus didisain dengan lebih melibatkan partisipasi petani, aparat desa dan aparat kecamatan.

Rekomendasi Kebijakan

- Di tingkat nasional dianjurkan untuk dibentuk institusi yang melakukan inventarisasi peralatan irigasi pompa pemerintah maupun perorangan/swasta.

- Bila irigasi pompa akan dikembangkan di wilayah miskin, suatu mekanisme harus diciptakan untuk menjamin keberlangsungan bantuan, terutama untuk pemeliharaan dan penggantian suku cadang.

- Perlu dibentuk sistem mekanisme perkreditan yang berhubungan dengan pengoperasian pompa agar petani dapat menginvestasikan modalnya pada komoditas pertanian yang bernilai tinggi agar petani mampu membayar biaya operasi, pemeliharaan dan mungkin penggantian suku cadang, pompa dan mesinnya sendiri.

- Agar pengembalian investasi pompa irigasi pemerintah dapat ditingkatkan, penyuluhan pertanian perlu terus disempurnakan, termasuk di dalamnya upaya penyempurnaan sistem pemasaran sarana produksi dan komoditas pertanian yang diusahakan.

- Mengingat bahwa irigasi juga bertujuan untuk menanggulangi kemiskinan, diperlukan pembakuan biaya iuran irigasi yang efisien dan adil, baik untuk sistem irigasi permukaan maupun irigasi airtanah.

SUMMARY

With more than 5 million hectares of land now irrigated, the rapid expansion of gravity irrigation in Indonesia is over. But the Government of Indonesia (GOI) still faces the problem of extending the benefits of irrigated agriculture to the poorer and drier areas of eastern Indonesia, leading it to turn its attention to developing surface and groundwater sources. The new systems it has built are heavily subsidized, whereas those constructed by private and nongovernmental organizations (NGOs) encourage self-sufficiency.

This study, financed by the Ford Foundation and the U.S. Agency for International Development (USAID), through its Small Scale Irrigation Management Project (SSIMP), assesses past and present experience, with pump irrigation and offers recommendations for future pump irrigation investment in Indonesia. Primary data were collected from responses to four questionnaires: for farmers, pump operators, water users association (WUA) officials, and the concerned government agency or NGO staff, respectively. Secondary data were collected from project files and reports. In addition, senior members from the Faculty of Agricultural Engineering at the University of Gajah Mada measured the efficiency and operating characteristics of every pump in the sample. Based on the Scope of Work and conversations with staff from the National Development Planning Council (*Badan Perencanaan Pembangunan Nasional*—BAPPENAS), Sub-Directorate of Groundwater Development Planning (*Proyek Pengembangan Air Tanah*—P2AT), and the Agency for Agricultural Research and Development (AARD), and USAID, Asian Development Bank (ADB), the World Bank, and other donors, the study addresses eight policy issues: pump irrigation potential; environmental concerns; roles of the public and private sectors in pump irrigation; institutional options for pump irrigation development; appropriateness of technologies for pump irrigation; economic viability of pump irrigation; legal framework and institutional support; and strengthening the capacity of water users associations.

Pump Irrigation Potential

Surface Water—Rainfall over Indonesia averages more than 2,500 mm a year but is more variable towards the east. Many areas have a dry season of at least four months, and some are in the rainshadow throughout the year. These drought prone areas are a priority for development of surface reservoir storage or groundwater.

Groundwater—Groundwater from shallow aquifers is the primary source of domestic water supply for about 90 percent of the rural population, and shallow and deep aquifers provide almost 65 percent of the nation's industrial water requirements. Groundwater development by the GOI, started in the early 1970s, has been slow. Only 28,000 ha, or 17 percent of the identified groundwater potential of 168,000 ha, have been covered, mainly because of inadequate resources for a large number of small projects scattered over several islands.

Environmental Concerns

Development of pump lift irrigation can have significant and sometimes irreversible environmental impacts. The chief negative impacts are depriving other users of the resource and salinization in coastal zones. Positive impacts are increased agricultural production, employment generation, and the provision of rural water supplies.

With respect to irrigation, groundwater is influenced only by chemical factors. At a limited number of sites in the country, evidence indicates that the water from several deep wells is not of sufficient quality for sustainable agriculture. Similarly, water from a number of rivers is harmful because of high levels of aluminum, chloride, and sulphite. The extent of these problems throughout all of Indonesia is not

well documented, however, since the capacity to conduct and analyze water quality tests is only available in a few locations in the country.

Roles of the Public and Private Sectors in Pump Irrigation

Determining appropriate roles for the public and private sectors is a matter of growing interest and urgency worldwide. As governments face increasing budgetary constraints and shortcomings in expertise, they are recognizing the need to make way for the private sector to step in. The problem is deciding where to draw the lines of responsibility between the two sectors. In Indonesia, it seems likely that the private sector will play an increasingly important role in the development and maintenance of pump irrigation as GOI agencies hand over more schemes to water users groups.

Already, private pump irrigation covers more than 150,000 ha compared with only 30,000 ha and 20,000 ha under publicly developed pump irrigation and river irrigation, respectively. Unfortunately, little is known about this private sector activity, which is difficult to monitor because it is on a small scale and widely dispersed.

More than 60 domestic manufacturers make small pumps and engines, and a large number of small workshops provide repairs facilities for pumping equipment. The private sector produced over 50,000 irrigation pumps in 1989-90 and imported and sold more than 250,000.

Institutional Options for Pump Irrigation Development

Public pump irrigation development is in the hands of a special unit, P2AT. Most of its projects are located in Java and Madura and were built with technical assistance from bilateral donors, principally the Overseas Development Administration (ODA) of the British Government. Its emphasis is on deep tubewells, for which it has imported drilling and pumping equipment and well components and has trained a small but competent technical staff. The planning, design, and construction of tubewell systems have been determined by technical considerations such as aquifer potential, degree of water shortage, layout of existing surface water canals, and topography. Although village officials have been consulted about the location of drilling sites and access routes, beneficiary farmers have had a minimal part in the implementation process.

In contrast, Bina Swadaya, a Jakarta-based NGO, has focused on providing large pumps and a significant amount of fixed infrastructure. Bina Swadaya's approach stresses institutional development at the outset of their river pump devlopment programs. Following feasibility studies, farmers are organized into WUAs and elect their own executive committees prior to construction. Water users participate in the installation of the pump hardware through labor and/or monetary contributions. Agricultural extension agents trained by Bina Swadaya serve as community organizers and are given an honorarium for three years. Equipment and materials are provided by Bina Swadaya often with some assistance from the local government.

Appropriateness of Technologies for Pump Irrigation

A technology is appropriate if it is culturally, financially, and economically acceptable, technically sound, and can be operated and maintained at an acceptable cost over its normal working life. In Indonesia, most of the larger pumps, engines, and pumping facilities are installed by the government. The smaller units are owned by the farmers or are provided through GOI emergency relief programs.

The larger wells are installed in areas where groundwater lies below 10 m. They require costly imported drilling equipment and construction technology and continued government assistance for development and replacement. The smaller wells, traditionally used to provide water for high-value crops such as tobacco and shallots, are manually dug and lined or mechanically drilled. All drilling and casing equipment and components are manufactured locally. Thousands of them have been installed by farmers and farmers' groups throughout Indonesia.

Economic Viability of Pump Irrigation

The economic viability of pump irrigation is reckoned by the degree of utilization of each system and the benefits obtained by the users. The 300 percent increase in cropping intensities predicted by the planners far exceeds the actual increase of 170 percent found at the study sites. The problem largely has to do with the failure to integrate extension services and easy credit into pump irrigation development programs. As a result, the pumps are not used enough to reach the planned cropping intensities, and crop increases do not provide the desired boost in income.

Even with government subsidies, farmers are still paying much more for water from the pumps than farmers with access to public surface irrigation. This is despite the fact that payments cover only O&M and contribute nothing toward capital investment costs. Benefit/cost estimates calculated from irrigated cropping intensities, actual costs of the pump schemes, and crop yields show that less than half the public pump irrigation systems have B/C ratios of 1:1 or better. When all costs of development are included, pump irrigation in Indonesia has yet to prove itself economically viable. Extensive dependence on outside consultants has pushed the development costs above a level that can be supported by the economic returns from agriculture.

Legal Framework and Institutional Support

Prior to the implementation of the 1974 Law on Water Resources Development, most of the laws governing water resources in Indonesia could be traced back to Dutch colonial rule. The new law established rules and regulations for water resource development in the country and vested control of the use of water in the state. The Directorate General of Water Resources Development (DGWRD) was given responsibility for the abstraction and distribution of groundwater for irrigation. Provincial governments have the authority to issue licenses for drilling, after obtaining technical recommendations from the Directorate of Environmental Geology (DEG), and may issue their own regulations, instructions, and decrees. Public groundwater development for irrigation is assigned to PAT, which is under the Ministry of Public Works.

Responsibility for O&M of the irrigation infrastructure is being devolved on the provincial and local governments. Key actors are the Provincial Irrigation Service (PRIS), the WUAs, and the irrigation committees at various local government levels that provide a link with the Provincial Agriculture Service (PRAS) and other agencies. Long-term sustainability of pump irrigation will depend on the guidance given to the WUAs and farmers by PRIS, PRAS, and other agencies through the irrigation committees. Although P2AT will continue to have a presence in deep groundwater projects, the burden of responsibility for sustainable O&M will lie with the local governments.

Strengthening the Capacity of Water Users Associations

Pump irrigation, whether developed by the public or the private sector, usually requires the support of the WUAs. These associations encourage farmer participation in irrigation management and are also responsible for the imposition and collection of fees for pump use and, eventually, engine and pump replacement.

WUAs generally are formed as part of the development of pump irrigation schemes funded through the government and NGOs. Government decrees establish guidelines for the formation of WUAs in publicly supported schemes, while those developed with NGO assistance are often more flexible in structure. Community organizers, either trained or provided by the NGOs, can work more closely with farmers than P2AT staff are able to do on government-sponsored sites.

Recordkeeping by the WUAs is minimal and usually documents only pump use, with the name of the user and some measure of use recorded in a ledger. There are rarely any financial balance sheets, although an executive committee member may sometimes hold sizeable savings in cash or in his own bank account. This often leads to recriminations among WUA members.

The WUAs determine the allocation of water. Each block in the system gets its water on a certain day or days, and is often named after that day. The decision, made by the executive committee, is usually made once, at the initiation of the pump system, and is rarely revised. Many of the systems keep a day free in the week for adjustments by farmers who wish to purchase additional water. The large size of river pumping systems developed by Bina Swadaya has led to major problems in organizing farmers and serving the entire design area, especially the land near the tail end of the system.

Policy Recommendations

Technical Recommendations

- The GOI should not develop pump systems in areas with significant private sector pump development.
- Although pump irrigation WUAs have been generally effective, it may not always be necessary for all schemes to have this high level of organization.
- Ongoing pump lift irrigation programs have very poor and inconsistent records, and national standards need to be prescribed.
- Shallow groundwater development should be left to the farmers, who use locally constructed wells and small pumps.
- Most groundwater schemes developed by P2AT have used equipment supplied through commodity aid, but this equipment has proved difficult to maintain locally and does not contribute to either the local or the national economy.
- The government should not invest in turbine pumps when there is no reliable local source of equipment and spare parts, unless it intends to operate the equipment itself.

Environmental Recommendations

- A national water resource evaluation by river basin or sub-basin should be conducted as soon as possible.
- In shallow groundwater areas, some control is essential on the number of pumps privately operated by farmers to prevent excess pumping.
- Groundwater exploration should be separated from irrigation program implementation.
- Much valuable data gathered at a cost of millions of dollars over the last 20 years are unused. A major effort should be made to integrate these data into future plans.
- Periodic estimates of annual and seasonal resource utilization by pump lift irrigation schemes are needed to determine the residue available for further development.

Institutional Recommendations

- Where DTWs are recommended, a permanent government presence is required in pump irrigation development and maintenance for the program to be effective and yield the expected income benefits, particularly on the eastern islands.
- Assistance to the WUAs in financial recordkeeping is needed for monitoring and backstopping the systems, both before and after turnover.

- WUAs should be given a legal status that permits them to open bank accounts.
- Pump irrigation systems should be designed with greater farmer participation.

Policy Recommendations

- A national inventory of public and private pump lift irrigation equipment should be made.
- If pump irrigation investment is to be made in poverty areas, it must be accompanied by continuing support, particularly with maintenance and replacement.
- Easy credit should be made available to enable farmers to invest in high-yielding crops and pay for the fuel to operate the pump.
- To improve returns on public pump irrigation investment, agricultural extension and market mechanisms must be provided to farmers along with the equipment.
- Since pump irrigation schemes also are often intended to alleviate poverty, the ability of water users to pay should be a factor in determining the magnitude of fees charged for water; the present program that charges farmers in poverty areas as much as 10 times more for water than farmers in well endowed, conjunctive use irrigation areas are asked to pay for water is not accomplishing its poverty alleviation goals.

INTRODUCTION

Decreased dependency on food crop imports, especially rice, was a major objective of the Government of Indonesia's (GOI) investment in agriculture during the 70s and early 80s. Large increases in crop production were achieved through adoption of modern high-yield varieties (HYVs), expanded use of fertilizers, weed and pest control, and investments in government irrigation systems, with top priority given to the country's irrigation infrastructure. It is estimated that over $14 billion have been invested in construction and rehabilitation of irrigation systems in Indonesia during the past 25 years.

With more than 5 million ha of land now irrigated, the most favorable sites have been developed, and the cost of building new systems to keep pace with the rising population is soaring, now ranging between $3,500 and $7,000 or more per ha. Meanwhile, urban expansion is steadily encroaching on irrigated land and currently is estimated to consume more than 30,000 ha yearly. Yet, the GOI still faces the problem of extending the benefits of irrigated agriculture to the much poorer and drier areas of eastern Indonesia, where the scope for enhanced gravity irrigation systems is very limited.

These concerns have prompted the GOI to pay increasing attention to developing surface water and groundwater sources through the introduction of pumps for converting rainfed land to irrigated land, or using irrigation to supplement inadequate surface supplies. Where the government has taken the lead in developing pump irrigation, the new systems generally have received extensive assistance. Wells have been drilled free of charge, pump sets have been given to the farmers, canals have been constructed with minimal farmer equity investment, and agricultural inputs have been subsidized. Private and NGO-led development, on the other hand, has stressed farmer involvement and, in some cases, farmer investment in the capital stock, operations, and maintenance of the new systems. Between these extremes is a broad range of approaches that other agencies have tried with varying degrees of success.

Faced with financial realities, the GOI has reassessed its ability to continue massive subsidies to irrigation, presently estimated at Rp. 1.0 to 1.3 trillion (about $606-788 million), and is showing a willingness to accept more private sector investment. The new policy environment could be conducive to expanded pump irrigation, and for many crops the value of pumped water may be extremely high. Nevertheless, there are uncertainties about the technical capacity of the relevant implementing agencies to develop pump irrigation and questions about the economic viability of pumping, financing arrangements, sustainable pumping levels, agricultural support services for crops other than rice, and the legal and institutional supports needed for strong pump users associations.

Unless the GOI and the donors address these issues, especially the economic ones, there is a danger that the explicit and implicit subsidies in public sector promotion of pump irrigation will produce unsustainable practices and/or environmental degradation. Among the possible negative effects of inappropriate models of pump development are increased pumping costs and salt water intrusion from overuse of groundwater, and accelerated contamination of water supplies from the increased use of agro-chemicals associated with high-value irrigated agriculture. Effective long-term aquifer management can only be achieved with an adequate base of information about both the nature and potential of pump irrigation resources themselves, especially groundwater, and about past experience with the process of developing that water wealth.

Understanding the proper role of pump irrigation in agricultural development will be crucial for the formulation of appropriate policies and implementation of sustainable investments in pump irrigation now being discussed for the next five years. Given the diversity of previous programs, the GOI will not gain this understanding without better and more systematic information on the results of past investments. At present, for example, there are many actors in this area, including a number of agencies of the central and provincial governments, the private sector, and the NGO community. But there have been few inventories or comparative assessments of the various approaches and monitoring of the agro-economic benefits, the sustainability, or the environmental impact of pump and groundwater irrigation throughout the country. Thus, the GOI has limited reliable information on which to base its planning and its requests to donors for expanded pump irrigation development.

Policy Background

Development of Indonesia's water resources has made a major contribution to the country's economic growth. The Ministry of Public Works (PU) is charged with overall planning, development, and management of surface water resources and may assist the provinces in all related matters. PU is empowered to collect data on water quantity and quality, make policies on water resource use, advise on water management, and regulate waste water. Within PU, the most important agencies for water management are the Directorate General of Water Resources Development (DGWRD) and two directorates of irrigation. The Ministry of Mining and Energy has authority for the administration of groundwater, and its Director General of Geology and Mineral Resources (DGGMR) has been assigned responsibility for groundwater management. The Directorate of Environmental Geology (DEG) has received authority from the DGGMR for evaluating groundwater resources nationwide, for groundwater mapping, and for issuing licenses for groundwater abstraction.

In practice, many users circumvent licensing requirements either deliberately or through ignorance of the law and, as a result, some aquifers are being overdrawn, leading to localized subsidence. In attempting to stop these violations, the DEG faces jurisdictional problems with municipalities, has little enforcement authority and staff outside Jakarta and Bandung, and lacks the information to determine safe yields for most aquifers in the country. Complete management of the country's aquifers will be possible only if Indonesia approaches the problem in the context of an integrated water policy, as groundwater supplies and surface supplies interact dynamically.

The provincial governments have been given authority to issue licenses for drilling and use of groundwater, but only after obtaining technical recommendations from the DEG. Given the DEG's limited staff and the preference of donors to fund development projects rather than exploration programs, much of the actual control of public groundwater development has been assigned to the Sub-Directorate for Groundwater Development (PAT). In addition, the Directorate General of Housing, Building, Planning, and Urban Development is responsible for designing and supervising the construction of all major urban water supply and sewerage projects, and in recent years has instituted a number of groundwater development projects to provide water for cities, towns, and district capitals.

The GOI's official policy for public groundwater development for irrigation, whether using deep or shallow wells, is to provide a fuel and lubrication allotment through the local P2AT office (in addition to handling all major repairs) for the first two years. After this, responsibility for operation and maintenance (O&M) of the pump is turned over to the local government, which then passes it on to the Water Users Association (WUA). Unfortunately, in the implementation of most of the public groundwater pump irrigation schemes, the responsibility for major repairs and eventual replacement, although implicit in the transfer, has been less clear. In fact, the study team only encountered one case, a special project in Gunung Kidul, Yogykarta, in which the responsibility for O&M as well as for major repairs and replacement of large deep tubewell (DTW) pumps and had been turned over completely to the local government.

A critical problem with public pump irrigation development has been the installation of systems far beyond the skills and resources of the WUAs to operate and maintain them. In numerous cases, inappropriate DTW pumps, large imported diesel engines, and expensive distribution systems have not only proved too sophisticated for the local users, but have required spare parts and specialized tools not available in the area and sometimes not even in the country. In order to keep these systems operating, P2AT has been forced to maintain a field staff long after the project was scheduled to terminate, thus defeating the policy of encouraging the local government and the WUAs to assume full responsibility for management.

A potential problem for private pump irrigation development is the lack of a monitoring system and of regulation, if needed. As indicated previously, all groundwater wells are supposed to require a license that stipulates the depth of the well, the aquifer to be tapped, and the amount of water to be pumped. However, in practice, most wells are unlicensed and, therefore, unmonitored. In addition, under current laws licenses are not required for manual withdrawals from dug wells, pumping from driven wells with riser pipes not more than two inches, groundwater withdrawals for domestic supply of not more than 100 m^3 per month, and water pumped for research and development by the holder of an authorization issued by the DGGMR.

Lack of regulation often spurs private initiative and in Indonesia has clearly led to significant investment in pump irrigation. But eventually, as experience in other countries in Southeast Asia, such as Thailand, has demonstrated, unrestricted pump development can lead to overexploitation. When this occurs, small farmers inevitably suffer as larger wealthier growers, who are able to invest in deep-well and more sophisticated technologies, capture most of the water. This raises questions of equity that need to be addressed before the problem becomes acute and small farmers have been financially ruined.

A similar situation arises with private river-pumping schemes, often not licensed although operated with permission from the local regency administration. There is usually no control on the quantity of water abstracted from a local river or stream, nor is there a mechanism to determine if upstream abstractions are having a negative impact on downstream users, who may have depended on the water supply in the river or stream for decades. The absence of a system of clearly defined, historical water rights indicates the need for integrated water resource planning.

Study Design

Recognizing that there was scope for increasing understanding of the issues and challenges facing pump irrigation development, the Ford Foundation and USAID, through its Small Scale Irrigation Management Project (SSIMP), felt a detailed study of pump irrigation in Indonesia would be immensely valuable in providing an overview and assessment of past and present experience and offering recommendations to guide future investment.

Although recent investment has moved away from Java, most of the pump irrigation systems and the largest service area are located there. The study was designed to collect data on relatively large systems—not pilot projects—that had been operating more than one or two years, and accordingly selected the following sites:

System	Location	Pump Type
Nganjuk-Kediri	E. Java	DWT and IWT
Gunung-Kidul	Yogyakarta	DWT
Subang	W. Java	River Pumping
Madura	Madura Island	DWT and IWT
Lombok	Lombok	DWT and IWT

Pump irrigation projects in East Nusa Tenggara, West Sumatra, and South Sulawesi were also visited. Figure 1 shows the research sites (RS) and the sites visited (SV).

Primary data were collected from responses to four questionnaires: for farmers, pump operators, WUA officials, and the concerned government agency or NGO staff, respectively. A significant amount of secondary data were collected from project files and reports. In addition, senior members from the Faculty of Agricultural Engineering at the University of Gajah Mada measured the efficiency and operating characteristics of every pump in the sample. Annex B shows the pumps selected for data collection.

Policy Issues

As the World Bank presently is re-evaluating its investment strategy for groundwater development in Indonesia, this report is expected to be an important and timely first step in assisting the GOI to formulate viable policies for development, expansion, and monitoring of pump irrigation, and to prepare effective and appropriate proposals for donor assistance sector.

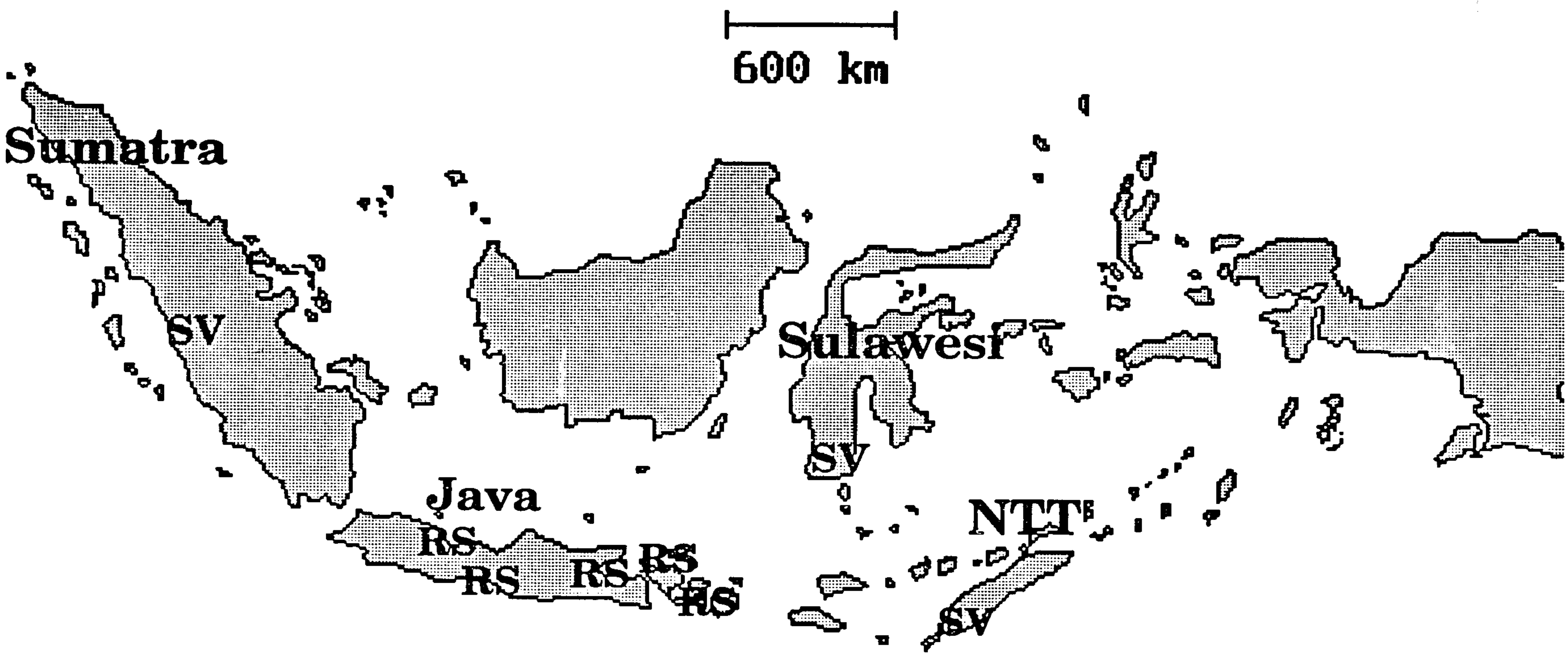
Based on the Scope of Work and conversations with staff from BAPPENAS, P2AT, AARD, Ford Foundation, USAID, ADB, the World Bank, and other donors, as well as a number of engineering contractors, the study identified the eight most important policy issues to be addressed. The purpose was not to debate the conceptual basis of these issues, but to provide practical recommendations for successful investment in pump irrigation in Indonesia. The policy issues are:

1. Pump irrigation potential
2. Environmental concerns
3. Roles of the public and private sectors
4. Institutional options for pump irrigation development
5. Appropriateness of technologies for pump irrigation
6. Economic viability of pump irrigation
7. Legal framework and institutional support
8. Strengthening the capacity of water users associations

The final section of the report presents the combined conclusions from the individual policy issue discussions, as well as recommendations for improving future pump irrigation development.

Figure 1

Location of Research and Other Sites Visited



RS = Research Site for Data Collection

SV = Pump Irrigation Sites Visited to Observe Activities

1

PUMP IRRIGATION POTENTIAL

Background

The timely and assured supply of sufficient irrigation water is necessary for a sustained change to more productive cropping systems. Despite the hugh historical investment in surface water irrigation, supplies are not always reliable because of a highly variable annual rainfall and problems of distribution, operation, and maintenance. Conversely, local surface water and groundwater can provide an assured supply if pumps are properly maintained and operated. Pump lift irrigation can be managed in small discrete units that do not have the operational problems inherent in large surface water schemes. The key is to determine the location and magnitude of land and water resources that can be economically developed.

There are two areas favorable for pump lift irrigation: existing surface water schemes where pumping surface and groundwater could augment irrigation supplies and increase water use efficiency; and unirrigated drought-prone areas with groundwater development potential.

Drought prone areas in Java, unserved or only partially served by major irrigation projects, still have potential for groundwater development. There are many similar small areas with negligible surface water resources but with significant groundwater development potential scattered among the eastern islands.

Generally, these drought prone areas are economically disadvantaged and are targeted for development under the GOI's poverty alleviation programs. Care must be exercised in development because many areas of Java will face critical water shortages by 2000, and parts of Nusa Tenggara and Sulawesi could approach full resource utilization within the next two decades.

As the population of the country continues to expand, there will be a greater demand for water, over and above the needs of specific sectors, to maintain environmental quality in the rapidly growing urban and industrial areas. This demand will include water for flushing urban drains and sewers, for maintaining minimum flows in rivers to dilute effluent and transport non-biodegradable effluent to the sea, and for outflows to maintain the salinity balance in coastal areas. As surface water resources are increasingly required for these essential uses and are less available for irrigation, groundwater will become more important for both maintaining and expanding irrigated areas. A prerequisite for economically efficient allocation of surface and groundwater supplies is integrated and multi-purpose water resources planning for each of Indonesia's 90 river basins and island planning units.

Findings

Land Development Potential

Between the end of 1990 and 2005, the population of Indonesia is expected to grow by 26 percent, from about 183 to 231 million. Demand for food energy (calories) will increase by about 60 percent over the same period because real incomes are projected by the Central Bureau of Census to increase from 4.1 percent per year between 1988-1995 to 4.7 percent per year by 2005. As a result of these trends, demand for cereals is expected to increase from 33.4 million metric tons (Mmt) in 1988 to 48.0 Mmt in 2005. However, with real increases in income, per capita consumption of rice is expected to fall and demand for meat, fruit, and vegetables to increase, particularly in Java.

These new demands will have to be met by increasing productivity through intensified land use, improved crop yields, and bringing new lands into production. In land hungry Java, which has 60 percent of the nation's population but only 7 percent of its land, intensifed land use and improved crop yields will be the only options. In addition, the area under irrigated rice is likely to shrink by 2005 because of increased urbanization and the growth of rural settlements and an increase in the area devoted to fruit, vegetables, and livestock. Reduction in agricultural area in Java will need to be compensated for by agricultural development elsewhere. Outside Java, development will be directed towards rehabilitating existing irrigated land and bringing new land under irrigation.

About 63 percent of the land area of Indonesia is still covered by forests, while only 12.8 percent is intensively cultivated (Table 1). Wetland sawah accounts for 4 percent of land use, estates for 4 percent, and upland sawah for only 2.8 percent. Settlement currently utilizes 2 percent of land area, most of this (81 percent) in Java and Bali. In Java, the World Bank (1992) has estimated that 440,000 ha of some of the best agricultural land in Indonesia will be lost to new industrial development and associated urbanization by 2010, and an additional 200,000 ha of existing irrigated and rainfed sawah will be needed for fruit and vegetable production. The new land available for wetland development is almost 7 million ha, currently outside existing irrigation schemes and almost all (93 percent) outside Java and Bali (Table 2). Clearly, land availability will not be a constraint on the development of pump irrigation.

The present GOI policy to allow continued industrialization in north Java means that the best agricultural land will be lost and the multiplier effect of industrialization in the eastern islands will be jeopardized. Pump irrigation water is expensive and better used for high-value horticulture and vegetable production in Java than for irrigating low-return maize or wetland rice elsewhere. Using pump irrigation from groundwater in Java would mean a proportionately greater saving of scarce surface water, which in turn would help the economy in meeting urban and industrial needs.

Water Resources Demand

Water demand in Indonesia by 2000 is estimated to be 149 billion cubic meters (Bm^3), of which agriculture will account for 64 percent, or 95 Bm^3 (Table 3). Irrigation use is estimated to be 87 Bm^3, an increase of 21 percent over the 72 Bm^3 used in 1990, or an annual increase of about 2 percent (Table 4). Irrigation demand in Java will increase by only 3.3 percent during the decade, but elsewhere it is projected to increase by about 48 percent, or 5 percent a year.

Water Resources Availability

Surface Water

Rainfall over Indonesia averages more than 2,500 mm a year but is more variable towards the east. Most parts of Sumatra, Kalimantan, Central Sulawesi, and Irian Jaya have an annual rainfall between 2,000 and 2,500 mm, but Southern Sulawesi, Central Java, and the islands of Nusa Tenggara have a dry season of at least four months. As these areas receive rainfall from the southeast and northwest monsoons, there can be a marked difference in rainfall from one side of an island to the other. Topography plays a major role in inducing rainfall, and some areas, such as Palu in Central Sulawesi, which receives less than 500 mm annually, are in the rainshadow throughout the year. These drought prone areas are a priority for development of surface reservoir storage or groundwater. Figure 2 shows the distribution of areas that receive less than 100 mm for periods of 6-8 months of the year.

Outside Java, there are few data on streamflow, and resource estimates normally are based upon less than five years' data. In the eastern islands, particularly NTT, the sparsity of hydrologic data has severely curtailed development. The best current estimate of surface water resources, assuming that 25 percent can be utilized, is 646 Bm^3 (Table 5). Except in Sumatra, Java, and Kalimantan, large river basins are uncommon. In most central and eastern areas, rivers are short and have steep gradients and tend to become dry during the dry season. Large springs are common on the flanks of volcanoes or in areas that have fissured limestones or raised coral reef deposits, such as NTT.

Identified Surface Water Pump Irrigation Potential

The potential for pump irrigation from surface water in Java is high, but the competition for scarce water means that sites should be selected only after careful evaluation of demand and supply in a river basin. The eastern provinces offer fewer opportunities because of the unpredictable flows of most rivers. However, in several areas of NTB and NTT, large spring discharges could be diverted by pump to irrigate areas at the same or higher elevation.

A master plan (DGWR/JICA) for South Sulawasi centered around Lake Tempe identified two areas for major pump irrigation schemes. An area of about 4,000 ha along the upper Walanae river was selected because of poor geological conditions, but action was deferred because of expected low economic returns. The other area included 2,300 ha to be irrigated by four pumps with a total capacity of 4,400 l/s using water diverted from Lake Tempe near the outlet of the Cenarae river. The fate of this proposal is unknown.

Large-scale surface water pump irrigation schemes have been developed to irrigate an estimated 24,700 ha (Table 6). In addition, data from various sources show that 24,173 non-P2AT pumps (private sector and Banpres) irrigate 119,500 ha in Java (Table 7), and about 600 ha in the Pangkajene area of S.Sulawesi from canals. More than 250,000 irrigation pumps, some possibly included in Table 7 data, serve an acre of undetermined size. They were manufactured locally or imported from 1989 to 1990 (Ariwibowo, 1991). The breakdown of numbers of pumps by origin (government or private sector) is readily available only for East Java. A major problem with the data in Table 7 is that the water source is unknown and probably represents a mixture of abstraction from surface water and shallow groundwater sources. For all these reasons and because surface water sources for pump irrigation have not yet been identified, future resource potential is unknown.

Groundwater

Groundwater from shallow aquifers is the primary source of domestic water supply for about 90 percent of the rural population, and shallow and deep aquifers provide almost 65 percent of the nation's industrial water requirements. The GOI started systematic development of groundwater for irrigation in the early 1970s, but groundwater irrigates only 28,000 ha, or 17 percent of an identified potential of 168,000 ha.[1]

A preliminary estimate of sustainable groundwater resources in the 26 provinces is 485 Bm^3/year, of which 67 percent is in the sparsely populated Irian Jaya and Kalimantan. Java, which has 60 percent of the nation's population, is estimated to have only 27 Bm^3/year, sufficient to meet about 20 percent of estimated demand of 134 Bm^3/year in 2001.

These estimates are very approximate and are based on the occurrence and recharge capacity of four major hydrogeological units:

[1] Groundwater Development in Indonesia, Ministry of Public Words, DGWR, September 1990.

Folded Pre-Tertiary and Tertiary Mountain Ranges. These areas are distributed along the central parts of the major islands and generally underlie volcanic sediments and lava flows. Groundwater occurs in the fractured and weathered zones of consolidated rocks and in clays and marls, where it is commonly highly mineralized. Potential for groundwater development is generally low, but locally springs may provide significant irrigation sources.

Volcanic Terrains. There are over 500 volcanoes in Indonesia occupying an arc running through Java, Bali, Lombok, Sumbawa, Flores, and Malaku to northern Sulawesi. Aquifers in these terrains consist of porous or fractured volcanic products and normally have highly variable groundwater potential. However, they are generally productive, especially along the lower flanks of the volcanoes and in intermontane basins. Typically, these lower aquifers are recharged from high rainfall on the upper volcano slopes; groundwater may occur at shallow depths around the foot of the volcano, but deeper seated aquifers at higher elevations may discharge from springs.

Limestone Terrains. Limestone is common as raised coral beaches in the coastal areas and as sedimentary deposits scattered across the region. Groundwater occurs primarily in fractures and voids opened by solution channeling. Aquifer productivity is governed by the presence of these fractured zones and is highly variable in depth and yield from place to place.

Alluvial Plains. Thick alluvial sediments are common as coastal plains and intermontane basins. Sediments range from highly productive coarse sands to almost impermeable clays and silts. Aquifers normally are thin and may be confined by clay layers; under confined conditions many alluvial aquifers commonly have artesian, free-flowing wells. In coastal zones, aquifers may be brackish or saline and extreme care is needed to ensure development is sustainable.

Groundwater recharge has been determined as a percentage of net rainfall (rainfall minus evapotranspiration), depending upon a subjective assessment of the area of permeable terrain (Table 8). A comparison of national groundwater potential and estimates derived from field investigation (Table 9) shows that investigation has confirmed only 7 percent of the national potential as of 1990.

The slow rate of exploration and evaluation is due to inadequate resources for a large number of small projects scattered over several islands. This is partly because one of the objectives of pump irrigation from groundwater is to alleviate poverty in the less developed areas of eastern Indonesia. However, the resultant sketchy knowledge of groundwater in these provinces merely provides support for a technology that is unproven. It would be better to focus development in a few areas, determine resource potential, formulate a development plan, and then move on to another area. This approach would expand knowledge of the resource base, lead to an increase in irrigated area, and consolidate the lessons learned. But it would not permit the GOI to address the problem of regional equity without substantially greater investment.

Groundwater recharge calculated from net rainfall provides only a general idea of the resource potentially available for development. More definitive estimates are obtained from field investigations that may include calculation of the groundwater water balance; drilling to determine local geology and aquifer geometry; pumping tests of wells and analysis of well performance to establish aquifer yield and storage potential; and determination of groundwater quality.

Systematic groundwater exploration and evaluation are undertaken by the Directorate of Environmental Geology (DEG), the Directorate General of Geology and Mineral Resources (DGGMR), and the Department of Mines and Energy. DEG is responsible for national hydrogeological mapping, evaluation of groundwater availability, studies of groundwater development, and conservation of groundwater resources in highly developed areas such as Jakarta where large-scale groundwater abstraction occurs. The major output is a series of maps showing hydrogeological classifications and estimates of individual well yield potential.

DEG systematically assesses an area in four stages: hydrogeological mapping at scales of 250,000 and 100,000; groundwater potential evaluation at a scale of 50,000; determination of groundwater development potential from exploratory drilling and pumping tests; and groundwater conservation (installation of observation wells, water quality monitoring, and more detailed surveys at a scale of 50,000). Typical exploration programs and the publication of results take from one to five years, subject to the availability of funding from the central government. DEG studies include complete inventories of existing wells, and assessments of development potential are related to the rate of discharge that can be expected from each hydrogeological unit mapped. Given the rapid rate of irrigation and industrial development, the DEG maps at any scale represent 'snapshots' of the groundwater development at the time of the survey. DEG normally does not estimate groundwater irrigation development potential, for which other GOI agencies have responsibility. One exception is a bilaterally funded program (Italy-GOI 1988-93) to explore and model the groundwater resources of the Oeseo plain north of Kupang in East Timor.

Other agencies undertake groundwater exploration and evaluation activities but only with the approval of the DGGMR. The most important of these is the Directorate General of Water Resources (DGWR), Ministry of Public Works, which is concerned primarily with all aspects of irrigation, including groundwater development for dry season irrigation. To date, DGWR has conducted feasibility studies of groundwater irrigation in Central and East Java, Madura, Bali, NTB, NTT, and Sulawesi. Other agencies that have made significant contributions to groundwater evaluation are the Ministry of Health, units of the Indonesian Institute of Sciences and Universities, and drinking water enterprises for regional and provincial towns.

Groundwater exploration and development for irrigation are the responsibility of the Sub-Directorate of Groundwater Development Planning (P2AT), Directorate of Planning and Programming, and the Sub-Directorate of Groundwater Development (PAT) under the Directorate of Irrigation II, both under DGWR, Ministry of Public Works. P2AT undertakes investigation and construction, and PAT assists with the establishment of WUAs, agricultural monitoring, and O&M of wells.

Areas selected by DGWR for groundwater development are determined by four criteria:

- the presence of intensive cultivation and dense population
- a demand for water greater than the surface water available
- the people's expressed desire for groundwater
- a good hydrogeological potential based on preliminary reconnaissance

The fourth criterion has very important implications for the sustainable development of groundwater. Hydrogeological potential is site-specific and may not be related to the long-term capability of the aquifer to yield water continuously. To meet this evaluation and planning need, P2AT employs consultants for sub-provincial water resource studies as part of feasibility and pilot projects, but normally does not undertake integrated water resource planning.

Carefully staged public sector groundwater development planning was common in the 1970s and early 1980s. Typical programs took up to 15 years to develop operating irrigation schemes (Figure 3). An excellent example of staged planning and development is the Middle Brantas Basin Study, completed in 1972, which involved the overall assessment of available water resources in the River Brantas, the second largest river in Java. A result of this study was the identification of 30,000 ha of land irrigable by groundwater. A pilot program/implementation project, the Kediri Groundwater Project, was completed in 1982. Examples of successful comprehensive groundwater development projects that consider both irrigation and water supply are the Greater Yogyakarta Groundwater Resources Study completed in 1984, and the ongoing Madura Island Groundwater Irrigation Project. These studies were extremely well documented over 8-12 years and provide valuable data for future resource planning and modeling. The ODA currently is completing a detailed evaluation of its groundwater activities in Madura.

More recently, pilot projects have been implemented without preceding resource investigations. This appears to be the model for the future and does pose problems. The Small Scale Irrigation Management Project under the Ministry of Public Works is attempting to develop pilot groundwater projects in Sulawesi, NTB, and NTT with little knowledge of the resource base and is experiencing great difficutly with siting wells and finding water. The trend away from starting work in new areas with integrated water and groundwater resource planning by the Ministry of Public Works to an increasing focus on small-scale project implementation is eroding the confidence of the provincial governments and local farmers in pump irrigation from groundwater. Under the present system, the design irrigated area is the selling point; in new areas, the risk of failing to achieve this is high because little is known about the resource, and failure to deliver damages confidence in groundwater. Another casualty of the present approach is inconsistent data collection between one program and another, and less time spent on analysis and presentation of data essential for future planning.

An alternative approach would be for the GOI to take responsibility for determining only basin groundwater development potential, following the River Brantas/Kadiri model, but limiting the implementation stage to the identification and testing of appropriate well technologies. Using this approach, development plans could be formulated in two years, and appropriate well technologies could be identified during the survey of existing irrigation required to establish the basin plan's baseline conditions. The survey would show innovations the farmers like and allow a thorough inventory of likely operating conditions. Once resource limits and technology are known further groundwater development becomes a marketing exercise that can take place wholly within the private sector.

There are constraints to wide-scale groundwater development, particularly in coastal areas where saline water intrusion could become a problem, as is the case along the north coast of Java and in southern Bali. Wide-scale groundwater development is being considered for other coastal areas in South Sulawesi (Maros and Barru on the west coast), Sumbawa (Sape and Keli plains), and East Timor (Oeseo plain).

The results of basin and pilot surveys described above show that only about 0.7 percent of the estimated potential has been developed to date. Ongoing programs are expected to add 53,000 ha by 2005 (Table 10).

While the magnitude of the groundwater resource is the most important result of field investigation, the depth of occurrence is vital to determining the cost of development and the most appropriate well technology. The only consistent attempt to map the depth of occurrence of groundwater nationally has been by ODA under the RePProt Program (Regional Physical Planning for Transmigration) of the Directorate of Bina Program. The results of this survey based on all available data are shown in Figure 4. A comparison with the drought prone areas shown in Figure 2 identifies the priority areas for groundwater development in terms of the occurrence of shallow or deep groundwater (Figure 5).

This analysis illustrates the practical difficulties of developing groundwater in *Nusa Tenggara Barat*

(NTB) and *Nusa Tenggara Timor* (NTT). In Java, groundwater is located in 83 discrete units over an area of about 477 km^2, many of them connected by good roads that allow the use of mobile truck-mounted drilling rigs able to drill large-capacity wells. Conversely, in NTT, 121 small units are widely dispersed over an area of about 67 km^2 across difficult terrain with few roads, where the primary access for large mobile drilling rigs is by sea. Thus in NTT, drilling of large-diameter deep wells will generally be impracticable and logistically expensive except in a few of the larger areas such as West Timor around Kupang bay. The linkage between the water resource base and development is very weak because there are no funds for the systematic monitoring of resource use despite the mandate of DEG. This is becoming an important issue where demand is catching up with the supply.

The Balance Between Supply and Demand

Water demand in the next two decades is projected to exceed supply in many areas of Java that should be targeted for measures to increase irrigation efficiency. Conversely, new irrigation development in NTB, NTT, and Sulawesi must seek to avoid the technical inefficiencies pervading existing systems in Java because of limited water resource availability. The World Bank has made a more detailed analysis of the balance between supply and demand in Java by 2010, indicating that the main constraint to increased cropping intensity and production is the inefficient use of water for irrigation.

In Java, irrigation and aquaculture account for about 95 percent of future requirements, and municipal demands for only 5 percent (Table 11). In 1986, aquaculture required only about 0.9 Bm^3, or 2 percent of agriculture's needs. Although this is small, it is a very high-value use and justifies a separate allocation of fresh water untainted by pesticides and fertilizers present in irrigation drainage water. Pumped groundwater could provide a relatively pollution free supply and should be considered as a source.

The total annual rainfall in Java averages 352 Bm^3 but about 50 percent flows through the river system to the sea. Of the balance, 126 Bm^3 is usable and 49 Bm^3 could be used if dams were constructed. Most irrigation design is based on a one-in-five year low flow, which is 78 Bm^3, or only 45 percent of average annual flow. In a dry year, there is a substantial deficit from May to September.

Irrigation currently supplies water for about 50 percent of the 2.8 million ha under rice. Water use is estimated to have increased by 15 Bm^3 between 1970 and 1985. In 1986, irrigation accounted for 48 percent of divertable flow and 77 percent of the dry-year flow. Rice production is expected to increase between 2.8 and 3.5 percent per year in the 1990s, and for this to be achieved, cropping intensity will have to increase from 165 percent to 200 percent and yields from 4.2 tons/ha to 6.0 tons/ha by 2010. It will be impossible to meet this production target if water use efficiency, cropping intensity, and yields do not improve. Water use efficiency is the most critical variable because of limited water resources.

A World Bank analysis of the impact of current and improved irrigation efficiencies on the water balance of 13 of the 21 major river basins in Java shows that, at current levels (30 percent) of irrigation efficiency, deficits occur in all 13 basins (Table 12). Assuming an increase in irrigation efficiency from 30 to 50 percent, there will be a surplus of water in western Java but very severe (greater than 20 percent) shortages in the eastern river basins. Increasing water use efficiency to 50 percent will decrease shortfalls by 68 percent, but installing dams to regulate the flow promises only 12 percent improvement. Without improvement, there will be insufficient water for an increase in cropping intensity in surface water irrigation schemes. A partial solution to the problem could be to further encourage efficient groundwater development within the command area of existing schemes. However, given the overall scarcity of water resources in eastern Java, new groundwater development should not be encouraged until all competing water users have been considered in the context of regional and river basin planning.

A national comparison of demand and supply (Table 13) shows that not only Java, Madura, and Bali, but also NTB could face a critical water shortage by 2000. Water conservation through realistic water pricing, regulation, and improved water use efficiency will be essential to ensure the most beneficial use of this common property resource. Pump irrigation, if cost effective, could play a major role in achieving equity in access to water.

Conclusions

- New land with irrigation potential is not a constraint to pump irrigation from either surface water or groundwater.
- Given the slow growth of government-financed groundwater irrigation—an average of 1,500 ha per year since 1972, the identified resource base is not a constraint to continued government involvement in development for the foreseeable future.
- The resource base for pump irrigation from surface water is undefined because there are few reliable data either on available water resources or current utilization.
- Pump irrigation from surface and groundwater meets supplemental irrigation requirements during the wet season but groundwater is the principal resource for dry-season irrigation needs.
- Groundwater, although abundant in Sumatra and Kalimantan, is not required because of the high and consistent annual rainfall. It is an important resource in Java, particularly in East Java, but can supply only about 20 percent of the island's irrigation requirements in the next decade. However, in the eastern islands, groundwater storage becomes more important because surface water storage potential is limited by small steep catchments with high flood flows during the short monsoon seasons.
- In many low-lying coastal areas, groundwater is abundant but is at risk from saline water intrusion. This could become a major problem along the north coast of Java, southern Bali, the coastal lowlands adjacent to and north of Ujang Pandang in South Sulawesi, the embayments of eastern Sumbawa, and the Oeseo plain north of Kupang in West Timor.
- Systematic water resource appraisals in the provinces, sub-provinces, and river basins were common in the 1970s and early 1980s and allowed well-formulated and phased water resource development on a large scale, particularly in East Java and Madura.
- In the last decade, systematic resource appraisal has been abandoned by all except the DEG. A consequence of this is overambitious small-scale irrigation development programs that consistently fail to meet their targets.
- Because irrigation development has been mixed with exploration programs, it is sometimes difficult to determine if failure to meet targets is the fault of the irrigation technology or an inadequate resource base.
- River basin water balances conducted by the World Bank for present and projected demand scenarios in Java show demand will exceed supply in many basins during the next 20 years. The analysis clearly indicates that integrated river basin planning for multiple water users and water conservation will be the dominant development issues if sustainable irrigation coverage is to be achieved. Pump irrigation has a vital role to play in ensuring greater water use efficiency in both new and established irrigated areas, and in recycling deep percolation and drain-

age water in surface water gravity flow command areas.

- A major conclusion from this review is that, although much hydrologic data have been collected over the last 20 years, there have been few attempts at a systematic collation and consolidation of the findings. Since each new project sets up data collection programs that bear little relation to those before, databases are not uniform. Systematic data collection is needed for consistent and reliable resource estimation to guide future pump irrigation development programs.

Recommendations

- Water resource evaluation should be conducted by river basin or sub-basin and should be implemented nationally as soon as possible. This is essential for sound planning and management, and to identify changes in the quality of the resource as population and development pressure on land resources increases.

- Groundwater resource evaluation for irrigation program implementation should be undertaken separately so as to make it easier to quantify a fairly complex resource.

- Groundwater resource investigation programs should be phased into irrigation development programs only after the results have been reviewed as part of an integrated environmental resource development plan.

- Much valuable data gathered at a cost of hundreds of millions of dollars over the last 20 years are little used. A major effort should be made to integrate these data for each province as a guide to future irrigation development and as a means to identify critical data still needed for sound planning.

- Minimal national standards need to be established for the maintenance of records for pump irrigation programs.

- A national inventory of pump irrigation equipment by public and private ownership and by source of water supply should be undertaken.

- Periodic estimates of annual and seasonal resource utilization by pump irrigation equipment are needed to determine residual resources available for future development.

- A national water resource management and monitoring organization is required to tie environmental concerns to resource planning and use.

Table [illegible]

Land Use in Indonesia (km^2) (Average 1984-1990)

Land Use	Sumatra	Kalimantan	Sulawesi	Irian Jaya	Maluku	Nusa Tenggara	Bali	Java	Total
Forest	233,235	399,860	112,694	349,583	63,480	24,694	1,009	12,450	1,197,005
Bush/Grass Land	104,343	57,471	32,928	35,911	7,076	36,797	707	16,269	291,502
Shifting Cultivation.	34,286	54,596	3,269	12,373	2,164	4,857	2,889	54	116,988
Upland	17,073	34	7,598	43	488	3,940	22,730	1,309	53,215
Wetland	21,558	9,301	8,291	739	178	3,902	31,613	1,082	76,664
Estates	35,499	6,186	7,818	145	183	933	25,091	1,015	76,870
Water	4,652	3,993	2,010	8,049	341	175	2,200	35	21,815
Unvegetated	116	4	289	3,975	188	728	322	83	5,705
Settlements	13,592	1,288	3,056	794	21	1,690	17,654	320	38,415
No Data	10,955	3,101	6,192	2,328	3,900	3,024	1,353	19	30,872
Total	473,309	535,834	186,145	414,800	78,019	80,740	132,571	5,633	1,909,052

Source of data: RePProt, 1990 (Simplified).

Table 2

Potential Availability of Land for Wet Land Development (million ha)

	New Land[1]		Land Within Existing Irrigation Areas[2]		
	Fully Suitable	Conditionally Suitable	Potential 1	Potential 2	Total
Java/Bali	0.003	0.507	0.047	0.033	0.590
Sumatra	0.607	1.028	0.070	0.158	1.863
Sulawesi	0.100	0.130	0.020	0.067	0.317
Irian Jaya	1.221	0.969	0.004	0.004	2.198
Other	0.783	1.491	0.025	0.048	2.347
Total	2.714	4.125	0.166	0.310	7.315

[1] "New land" is defined as land outside the boundaries of existing irrigation schemes. No investments in irrigation infrastructure have yet been made with respect to this land.

[2] "Land within existing irrigation areas" is land within the boundaries which has not yet been brought under irrigation. "Potential 1" and "Potential 2" land area are both under command of canals; the former is sawah while the latter is non-sawah. In addition, there are about 0.4 million ha of Potential 3 land not shown in the table, which are not under canal command but within irrigation system boundaries.

Source: World Bank 1992. Calculated from Bina Program Pengaran and Delft Hydraulics, *Planning of Integrated Water Resources Development*, (Project BTA-155 Phase II), Jakarta, June 1991.

Table 3

Estimated Water Demand for Indonesia in 2000

	Agriculture		Non-Agriculture		
	Volume (Bm^3)	Percent	Volume (Bm^3)	Percent	Total (Bm^3)
Java and Madura	55.57	55.9	33.90	44.1	89.47
Sumatra	21.33	65.7	11.14	34.3	32.48
Sulawesi	6.49	47.4	7.19	52.3	13.69
Kalimantan	4.88	85.3	0.83	14.7	5.72
NTB	1.73	93.0	0.13	7.0	1.86
NTT	1.61	92.0	0.12	7.5	1.74
Bali	1.41	75.0	0.19	24.2	1.60
Maluku	0.97	93.3	0.07	6.7	1.04
Irian Jaya	0.75	77.0	0.17	22.7	0.97
E. Timor	0.23	65.7	0.02	34.3	0.35
Total	95.12	63.9	53.8	36.1	148.92

Source: Rencana Pembangunan Pengairan Jangka Panjang (Tahum 2000), Dirjen Irigasi, DPU.

Table 4

Estimated Irrigation Water Requirements (1990 and 2000)

	Irrigation Requirement (Bm^3)		
	1990	2000	Increase (%)
Java	42.37	43.75	3.3
Outside Java	29.64	43.49	46.7
Total	72.01	87.24	

Source: Direktorat Bina Program Pengairan, 1991.

Table 5

Estimated Potential Groundwater Recharge, Mm^3

	Net Rainfall (mm)	Groundwater Recharge Area, (km^3) Highly Permeable	Moderately Permeable	Total Recharge Volume (Mm^3)
Sumatra				
Aceh	1,900	5,990	11,980	17,970
N. Sumatra	1,450	14,200	7,110	21,330
W. Sumatra	1,900	2,128	4,257	6,385
Riau	1,021	49,634	55,838	105,472
Jambi	1,150	9,322	12,430	21,752
S. Sumatra	1,465	23,628	110,265	133,893
Bengkulu	1,950	2,230	4,459	6,689
Lampung	900	1,439	4,318	5,757
sub-total		108,591	210,657	319,248
Java				
W. Java	1,536	9,829	19,658	29,487
C. Java	1,837	6,871	10,306	17,177
Yogyakarta	1,309	325	975	1,300
E. Java	750	9,590	16,783	26,373
sub-total		26,615	47,722	74,337
Bali	624	562	125	687
NTB	330	2,174	6,522	8,696
NTT	250	4,889	9,778	14,667
Kalimantan				
W. Kalimantan	1,850	39,267	31,413	70,680
E. Kalimantan	1,350	20,262	81,048	101,310
C. Kalimantan	1,500	46,966	62,621	109,587
S. Kalimantan	850	10,338	12,405	22,743
sub-total		116,833	187,487	304,320
Sulawesi				
N. Sulawesi	922	4,586	6,878	11,464
S. Sulawesi	1,122	7,750	23,251	31,001
C. Sulawesi	1,000	6,700	16,750	23,450
Tenggara	440	3,875	9,687	13,562
sub-total		22,911	56,566	79,477
Maluku	1,120	915	1,372	2,287
Irian Java	1,800	210,990	126,594	337,584
E. Timor	200	1,680	3,360	5,040
Indonesia Total		496,160	650,183	1,146,343

Source: Soekardi K, Soetrisno S, Hydrogeological Map of Indonesia, DEG, 1983.

Table 6

Estimated Area of Surface Water Pump Lift Irrigation

Location	Description	Area Irrigated ha
W. Sumatra	Lake Singkanek and the River Sumani	1,000
C. Java	Dutch period major pumping stations from the River Seraya	20,550
E. Java	Dutch period major pumping stations from the River Bengawan Solo	3,100
Total		24,650

Table 7

Number of Non-P2AT Pumps and Irrigated Area in Java, 1989/1990

Province	Number of Pumps	Irrigated Area: Total Area (ha)	Irrigated Area: Avg per Pump (ha)
E. Java	14,251	75,030	5.26
C. Java	7,601	23,995 [1]	3.16
W. Java	2,321	20,150	8.68
Total	24,173	119,448	4.94

Source: Dinas Pertanian Tanaman Pangan West Java, Central Java, and East Java.

[1] Data are derived from Sragen, Brebes and Sukohardjo.

Table 8

Estimated Groundwater Recharge Potential of Indonesia

Location	Area of Recharge: Highly Permeable	Area of Recharge: Barely Permeable	Area of Recharge: Total	Recharge: Volume (Bm^3)	Recharge: Percentage
Java-Madura	26,615	47,722	74,337	26,750	5.5
W. Java	9,829	19,658	29,487	12,080	
C. Java	6,871	10,306	17,177	8,840	
D.I. Yogyakarta	325	975	1,300	430	
E. Java	9,590	16,783	26,373	5,400	
Luar Java	469,545	602,461	1072,006	458,100	94.5
Sumatra	108,591	210,657	319,248	112,400	23.2
Bali	562	125	687	160	0.0
NTB	2,174	6,522	8,696	720	0.1
NTT	4,889	9,778	14,667	980	0.2
Kalimantan	116,833	187,487	304,320	126,100	26.0
Sulawesi	22,911	56,566	79,477	19,220	4.0
Maluku	915	1,372	2,287	720	0.1
Irian Jaya	210,990	126,594	337,584	197,500	40.7
E. Timor	1,680	3,360	5,040	300	0.1
Indonesia Total	496,160	650,183	1,146,343	484,850	100.0

Source: M. Notodihardjo *et al*, 1979.

Table 9

Potential and Identified Groundwater Resources

Location	Groundwater Resource Potential (Mm^3)	Identified (Mm^3)	Percentage	Irrigatable Area, (ha)
Java				
W. Java	12,080	280	2.3	14,000
C. Java	8,840	200	2.3	10,000
Yogyakarta	430	70	16.3	3,500
E. Java	5,400	2,160	40.0	108,000
sub-total	26,750	2,710	10.1	135,500
Bali	160	100	62.5	5,000
NTB	720	100	13.9	5,000
NTT	980	100	10.2	5,000
Sulawesi				
N. Sulawesi	2,960	60	2.0	3,000
C. Sulawesi	6,030	30	0.5	1,500
S. Sulawesi	8,696	100	1.2	5,000
Tenggara	1,534	100	1.7	5,000
sub-total	19,220	290	1.5	14,500
Maluku	720	60	8.3	3,000
Total	48,550	3,360	6.9	168,000

Source: Irrigable areas from: "Groundwater Development in Indonesia," DGWRD, September 1990.

Table 10

Public Sector Groundwater Irrigation, 1990

Location	Wells Handed over to Farmers[1] Number	Wells Handed over to Farmers[1] Irrigated Area, (ha)	Ongoing Implementation[2] Number	Ongoing Implementation[2] Irrigated Area, (ha)
Java				
W. Java	14	162	208	2,400
C. Java	22	542	?	27,500
Yogyakarta	48	1,150		
E. Java	604	24,012	769	10,898
Bali	3	91		
NTB	16	1,717	628	5,115
NTT	4	88	57	390
Sulawesi				
C. Sulawesi	16	179	124	1,832
S. Sulawesi	20	132	188	2,679
Tengarra				
N. Sulawesi				
Sumatra			134	2,500
Total	857	28,073	1,984+	53,314

[1] P2AT, Jakarta, 1991

[2] Taken from various P2AT Project Progress and Completion Reports available; it may not be a complete summary.

Table 11

Water Use In Java In 1986 and Projected Use In 2010 (Bm^3)

	1986 Water Supply[2]				2010[1] Water Supply[2]			
Java	Agri-culture	Urban	Rural	Total	Agri-culture	Urban	Rural	Total
Jakarta	0.10	0.21	0.02	0.33	0.00	1.26	0.00	1.26
W. Java	22.40	0.15	0.18	22.73	21.50	0.56	0.27	22.35
C. Java	18.30	0.13	0.17	18.60	20.11	0.32	0.27	20.70
E. Java	18.60	0.20	0.20	19.00	22.05	0.38	0.21	22.64
Total	59.4	0.69	0.57	60.00	63.66	2.55	0.74	66.95

[1] This is smaller than the values in Table 3 because the analysis assumed 200% average cropping intensity and 50% efficiency in irrigation water use by 2010.

[2] Urban water includes municipal and industrial use; and rural, mainly human and some industrial use.

Source: World Bank Country Study: Indonesia-Sustainable Development of Forests, Land and Water.

Table 12

Total Water Deficits (mm^3) for Selected River Basins in Java in a Dry Year (2010)

River Basin	Irrigated Area (ha)	Deficits in Million Cubic Meters: 30% Irrigation	50% Irrigation	Plus Dams
Bengawan Solo	274,000	1,522	564	564
Jratunseluna	108,000	1,928	888	534
West Semerang	122,000	13	0	0
Pemali Comal	130,000	1,445	528	528
Cisanggarung	42,000	356	186	186
Cimanuk	90,000	1,029	354	0
Dibeet-Jakarta Cisadane	190,000	1,942	293	293
Banten	55,000	367	66	66
Serayu	197,000	1,058	217	217
South Kedu	55,000	234	124	0
Citanduy	50,000	98	0	0
Teluk Lada	31,000	18	0	0
Total	1,244,000	10,010	3,220	2,388

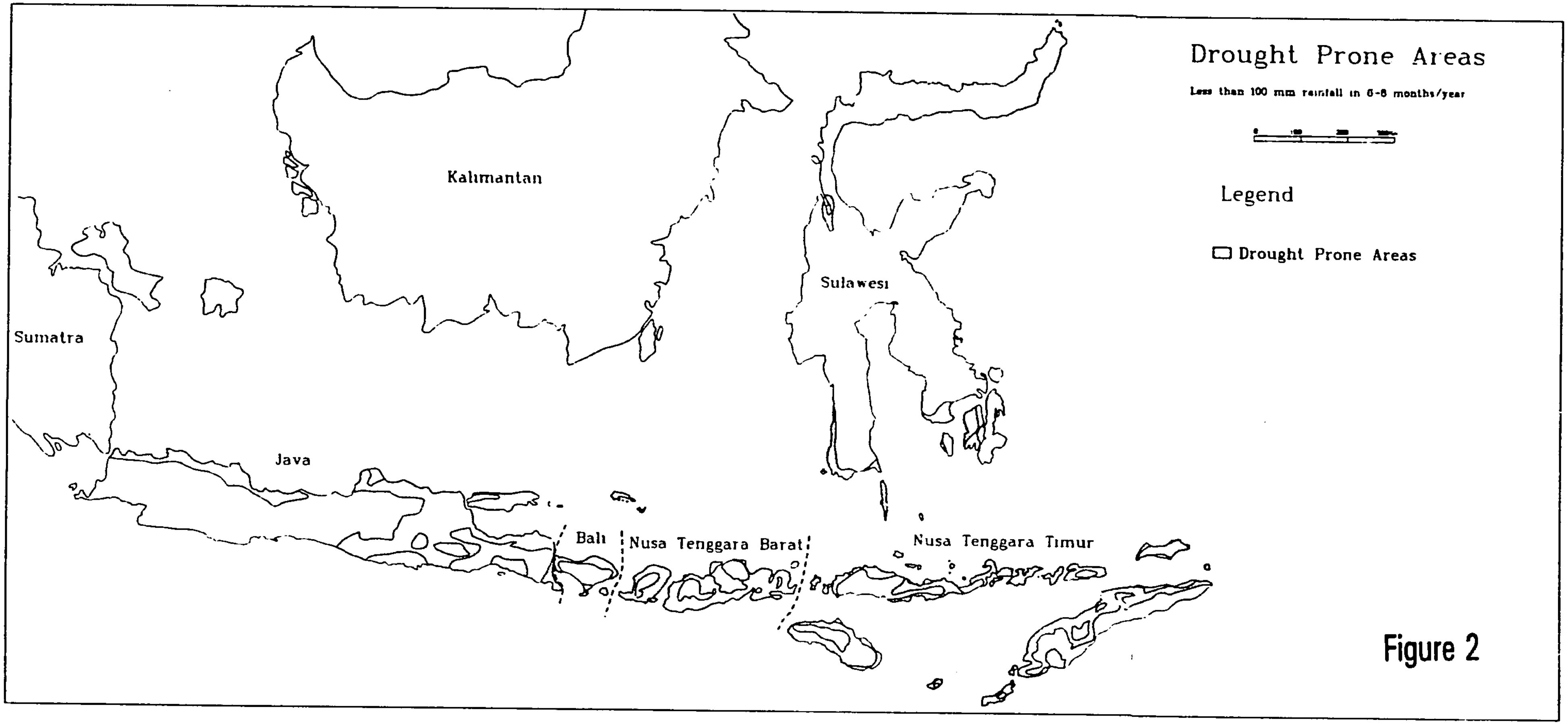
Source: World Bank Country Study, 1990, *ibid.*

Table 13

Demand and Supply of Water in Indonesia in 2000

	Demand (Bm^3)	Supply (Bm^3)	Ratio of Demand to Supply (%)
Java and Madura	89.47	47.26	189
Bali	1.60	1.42	113
NTB	1.86	2.02	92
NTT	1.74	2.39	73
Sulawesi	13.69	22.13	62
E Timor	0.35	0.74	48
Sumatra	32.48	172.99	19
Maluku	1.04	21.79	4.8
Kalimantan	5.72	186.25	3.1
Irian Jaya	0.97	188.84	0.5
Total	148.92	645.83	23

Source: Rencana Pembangunan Pengairan Jangka Panjan (Tahun 2000), Dirjen Irigasi, DPU.

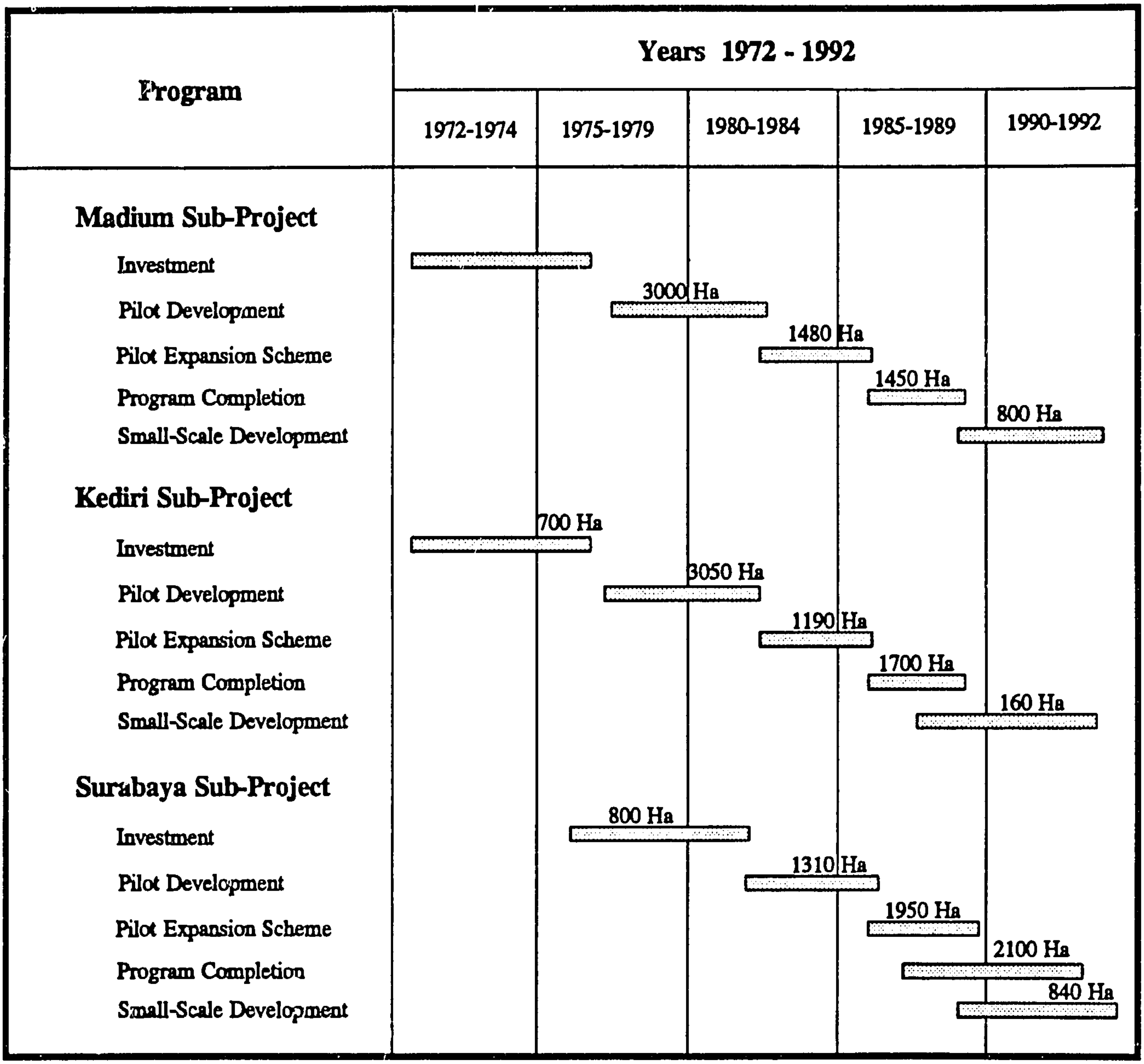


Drought Prone Areas
Less than 100 mm rainfall in 6-8 months/year
Legend
Drought Prone Areas
Kalimantan
Sumatra
Java
Sulawesi
Bali
Nusa Tenggara Barat
Nusa Tenggara Timur

Figure 2

Figure 3

Typical Implementation of P2AT Programs



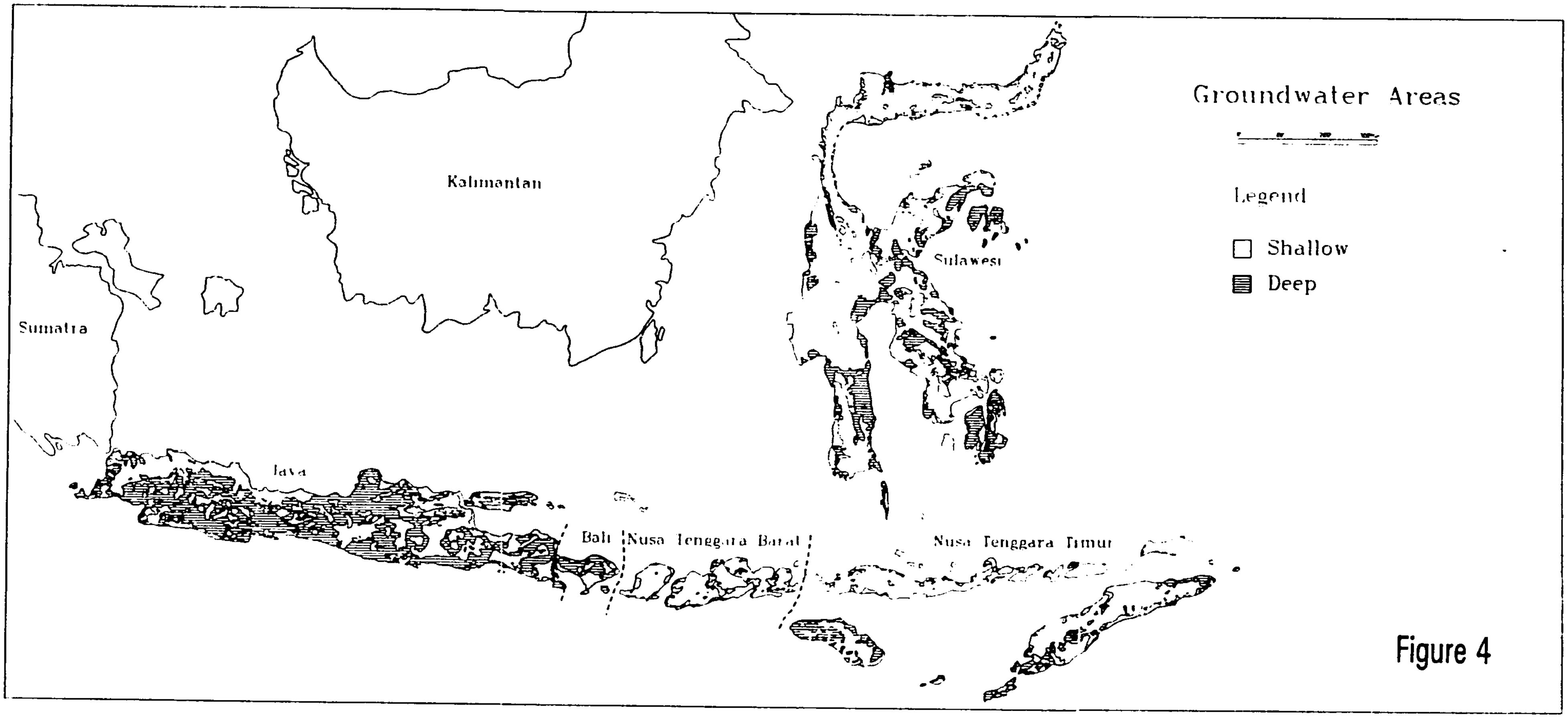
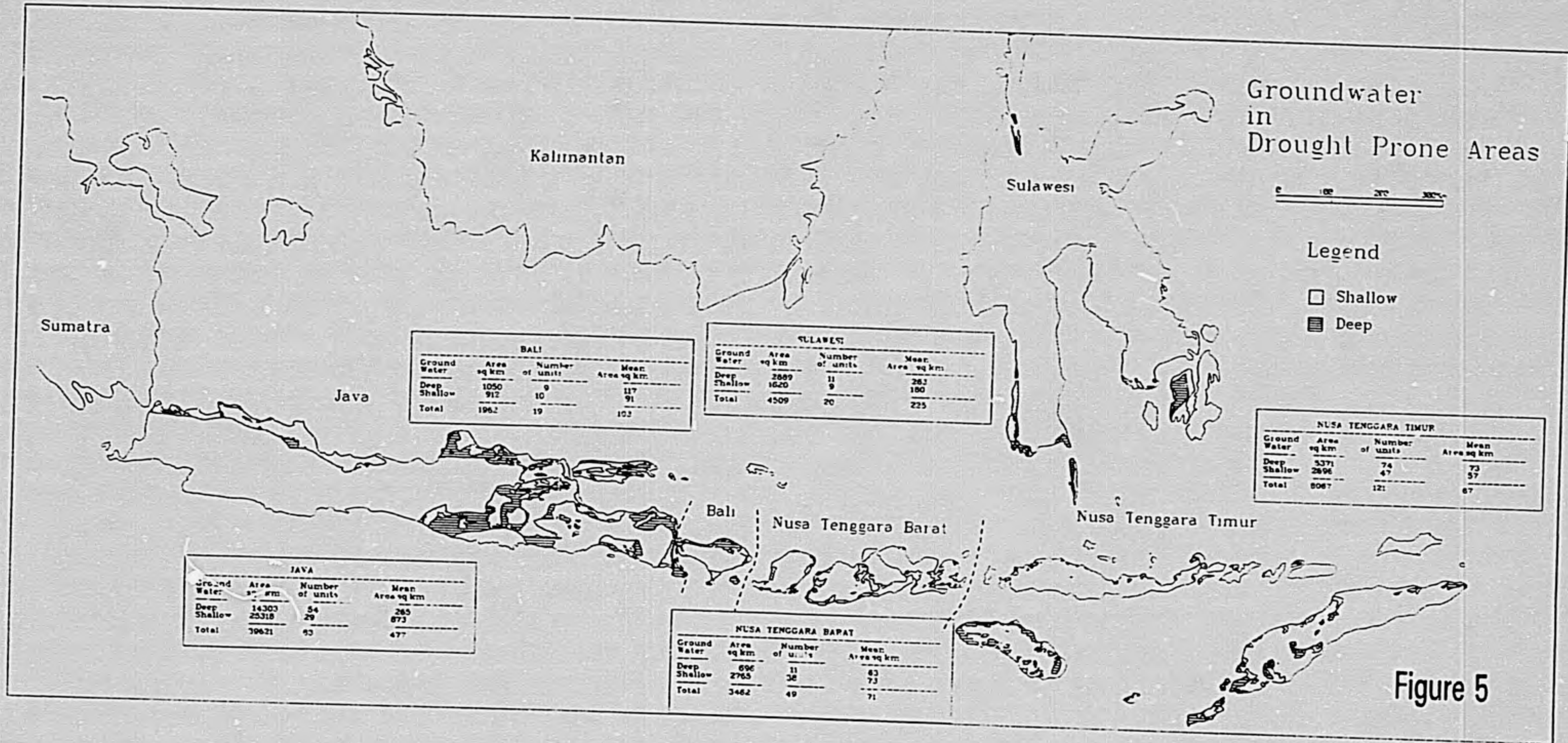

Groundwater Areas
Legend
Shallow
Deep
Kalimantan
Sumatra
Java
Sulawesi
Bali
Nusa Tenggara Barat
Nusa Tenggara Timur

Figure 4



BALI

Ground Water	Area sq km	Number of units	Mean Area sq km
Deep	1050	9	117
Shallow	912	10	91
Total	1962	19	103

SULAWESI

Ground Water	Area sq km	Number of units	Mean Area sq km
Deep	2889	11	263
Shallow	1620	9	180
Total	4509	20	225

JAVA

Ground Water	Area sq km	Number of units	Mean Area sq km
Deep	14303	54	265
Shallow	25318	29	873
Total	39621	53	477

NUSA TENGGARA BARAT

Ground Water	Area sq km	Number of units	Mean Area sq km
Deep	696	11	63
Shallow	2765	38	73
Total	3462	49	71

NUSA TENGGARA TIMUR

Ground Water	Area sq km	Number of units	Mean Area sq km
Deep	5371	74	73
Shallow	2696	47	57
Total	8067	121	67

Figure 5

2

ENVIRONMENTAL CONCERNS

Introduction

Development of pump lift irrigation can have significant and sometimes irreversible environmental impacts. Negative impacts are the loss for other users of the resource and the salinization of coastal zones. Positive impacts are increased agricultural production, employment generation, and the provision of rural water supplies. These negative (-) and positive (+) impacts are discussed below.

Local Impacts on Water Resources

(-) Withdrawal of river water will adversely affect lower riparian in-stream users (fisheries, navigation, dilution, flushing) and reduce the volume available for water supply and irrigation. All of these impacts could lead to conflict.
(-) Withdrawal of groundwater could seriously affect springs that provide water for domestic and irrigation use. As some springs are very large (up to 1,000 litres/second discharge), this impact must be examined in the environmental assessment of the project.

(-) Groundwater development will seasonally lower the water table or piezometric surface and reduce access to the common property resource by users of less efficient well technology, specifically well points and dug wells for domestic/rural water supplies and small-scale irrigation. Increased utilization will raise costs for all users and particularly affect those with no alternative sources of water supply, particularly in the dry season.

Regional Impacts on Water Resources

(-) In regions near the coast, particularly in the eastern islands, groundwater withdrawal could lead to saline water intrusion as has already occurred along the flood plains of Medan, Cilegon, North Java, Central Java, Semarang, Denpasar, and in the Jakarta region. Although generally this is seen as a local impact, large-scale regional development of groundwater will reduce the throughflow necessary to prevent the intrusion of sea water, an almost irreversible process once it has begun.

(-) Reduction of regional stream flow, either directly by pumping and diversion or indirectly through groundwater development, will disrupt the position of the saline water front in estuaries and river mouths.

(-) Increased irrigation will lead to increased use of fertilizer and pesticides, which will be leached into the ground and adversely affect water supplies and aquatic fauna and flora. The growth of aquatic flora in rivers will increase the risk of floods, already a serious problem. Indirectly, less flow to the lower reaches of rivers will decrease river dilution and carrying capacity, increase the impact of agricultural chemicals, and perhaps create anaerobic conditions that would cause a significant loss of fauna.

(-) Because surface water and groundwater are linked in the hydrologic cycle, the withdrawal of groundwater will reduce water levels in shallow aquifers and, thus, the outflow that sustains river baseflow in the dry season.

(+) Groundwater development will lead to conservation of excess water in the rainy season for subsequent dry season use, particularly of shallow aquifers. Increased depletion before the wet season which will provide a larger groundwater storage reservoir.

(+) Pump lift irrigation generally is more efficient than large-scale surface water irrigation and has significant conservation impacts, especially where water is a limiting factor in development.

(+) Competition for groundwater may lead to more efficient wells and pumps for domestic and rural water supplies.

(+) Irrigation wells can be used to provide drinking water supplies as well. Most new P2AT deep tubewells serve this dual purpose. The experience in Madura is a good example.

More General Impacts

Pump lift irrigation would create employment opportunities, particularly during the dry season when underemployment is widespread. The impact would be most favorable in eastern Indonesia and in Central Java, where preliminary estimates indicate the addition of up to 300 person-days per year per pump of employment. Experience from intensive wetland rice irrigation in West Bengal, India, has shown that each shallow tubewell (STW) creates 150 person-days/ha/year, and in Bangladesh 170 person-days/ha/year, of employment.

Growth in the agricultural sector from 1971-85 provided 36 percent of all new employment, and the GOI is continuing to emphasize this growth to alleviate poverty. About 66 percent of the rural, and 10 percent of the urban, population rely upon agriculture for a livelihood. About 40 percent are landless. About 23 percent of rural households have incomes below the poverty level of $90 per capita per year. Rural incomes can be increased by intensification of land use and productivity through irrigation and adoption of HYV-fertilizer technology, particularly in the areas outside Java. Clearly, agricultural development will play a major role in future poverty alleviation in the outer islands, where almost 60 million of Indonesia's 176 million people live. Between 1980-85, agriculture provided employment for only 12 percent of surplus labor in Java and for 30 percent in the outer islands (Table 14).

Water Quality Considerations

Surface Water Physical Quality

In some areas of the country, the physical quality of surface water makes it unsuitable for irrigation. For example, the waters of the Pekacangan and Merawu rivers (tributaries of the Serayu river) contain very fine sands that clog the micropores of the soil. When the soil is dry, aeration is extremely poor and inhibits cultivation. This presently is the case in the Gambarari Irrigation Scheme (a large river pumping project). The result is that only two rice crops a year are possible, although irrigation water can be provided during the second season by pumping.

High sediment levels in surface water very often change microrelief in irrigated fields and increase the maintenance required to keep irrigation canals clean. These problems are presently found in Cimanuk, Progo, Brantas, Serayu, Lusi, Serang, and Tunang.

Water in a number of rivers is harmful for irrigation because it contains aluminum and sulphite in high concentrations. The Banyuputih (Besuki), Ayer Bajan (Palembang), and Aek Moga (Tapanuli) rivers are all unusable during different seasons of the year. Similarly, water from the Kulah river in Surabaya, the Ketandan river in Kediri, and the Negri Kasih river in West Sumatra is unsuitable because of very high levels of chloride and sulphite.

Groundwater Quality

Groundwater for irrigation must meet certain chemical standards. Although Indonesia has limited testing capability, tests in some deep wells indicate that water quality often is not good enough for sustainable agriculture. Salinity levels in the wells presented in Table 15 are above acceptable limits and render them of no use for irrigation.

Water Resource Planning

Groundwater abstracted for drinking and domestic use is not subject to GOI regulation.[2] But all wells more than 15 m deep and used for other purposes have to be licensed by the Governor in consultation with the Regency Administration, which obtains a technical recommendation from the DEG. If the planned abstraction is more than 50 l/s or there are more than five wells in an area less than 10 ha, the DEG requires a feasibility study and an analysis of environmental impact (ANDAL). Despite these licensing requirements, there is no centralized database or systematic monitoring system to determine the extent of national groundwater utilization. A prerequisite should be a link between the ANDAL and regional/national water resource planning.

Environmental Guidelines

The environmental guidelines established by the GOI are among the most comprehensive and rigorous in South Asia. They provide for water resource development mainly at the scheme and project levels and establish the following order of priority for users of groundwater:[3]

- drinking water
- domestic water
- industrial water
- water for livestock and plain agriculture
- irrigation
- water for mining
- water for city operations
- water for other purposes

Macro Framework

The problem, however, is that the macro framework for water resource planning is still being developed. The supply available for pump lift irrigation can properly be assessed only in the context of river basin planning. Long-term sustainability can be determined only from an integrated assessment of all sources of surface and groundwater and all potential uses, of which irrigation is only one. Basin-wide integrated water resource development should be the framework in which pump lift irrigation development is planned.

National river basin planning is in the process of being set up under the Directorate General of Water Resources Development (DGWRD) in compliance with Ministerial Decree No.39/PRT/1989 of April 1, 1990, which lists 90 river basins for the whole of Indonesia. Decree No.48/PRT/1990 of December 5, 1990 specifies which river basins come under the jurisdiction of the provincial governments, the Ministry of Public Works (special projects and Directorate of Rivers), and special bodies such as the Brantas Basin Authority in East Java. It defines the role of these agencies but does not make clear whether it is a mandate to plan, develop, and distribute water or only to distribute water.

The success of integrated river basin planning will depend on how well the individual GOI agencies work with DGWRD to ensure some type of central coordination. An example of the problems that could arise concerns basins under the jurisdiction of the Ministry of Public Works not covered by special projects. They are assigned to the Directorate of Rivers, which bypasses the central planning group and thus creates a conflict with the Planning Department within DGWRD.

[2] Director General of Geology and Mineral Resource's Decree No. 392. K/526/060000/85.

[3] Article 9, Ministry of Mines and Energy's Regulation 03/P/M/Pertamben/1983.

Table 14

Percentage of Employment In Java and the Outer Islands

	1971-80	1980-85
Agriculture		
Java	8	12
Outer Islands	18	30
Total	26	42
Non-Agriculture		
Java	50	38
Outer Islands	24	20
Total	74	58

Source: Central Bureau of Statistics, SUPAS, 1985.

Table 15

Salinity Levels of Groundwater from Sampled Wells

Test No.	Location of Wells	Date of Testing	Number Sampled	EC (mmhos/cm)	Salinity Level	Source of Data
1.	Wonosari	1977	8	0.225-0.500	medium	(1)
2.	Situbondo	11/90	25	0.390-1.400	medium-high	(2)
3.	Njanjuk	11/90	10	0.380-0.590	medium	(2)
4.	Tuban	11/90	16	0.780-1.600	medium-high	(2)
5.	Tawaeli	02/89	4	0.539-2.750	med-very high	(2)
6.	Marawola	11/89-2/90	14	0.430-0.780	medium	(2)
7.	Jenepanto	11/90	6	0.200-4.500	low-very high	(2)
8.	Maros	03/90	1	1.700	high	(2)
9.	Gowa	01-03/90	9	0.200-0.750	low-medium	(2)
10.	Pringgoboyo and Lubuhan	03/90	2	0.500	medium	(3)
11.	Korleko	03/90	1	2.700	very high	(3)

(1) Prastowo, 1977.

(2) Anonim, 1991.

(3) Anonim, 1986.

3

ROLES OF THE PUBLIC AND PRIVATE SECTORS

Introduction

Determining appropriate roles for the public and private sectors is a matter of growing interest and urgency worldwide. Governments facing budgetary constraints and shortcomings in expertise are recognizing they must withdraw from providing what frequently are welfare, rather than productive, services and that often the private sector can supply what is needed more efficiently. The problem is deciding where to draw the lines of responsibility between the two. This section explores how these lines are already being drawn for groundwater irrigation in Indonesia and how the roles of the two sectors are likely to shift further in the future. It also includes a case study of private sector groundwater operations in Bangladesh, from which the lessons learned concerning pump irrigation development can be applied to Indonesia.

Privatization emerged as an international issue from the 1981 Berg Report of the World Bank which advocated:

- reduced state expenditure and restructuring of state and state budgeting
- increased export orientation in economic production
- liberalization of prices
- divestiture of public enterprises to the private sector.

In the irrigation sector, these recommendations translated into policies for community involvement in design, construction and installation, and cost recovery through user charges. During the last five years these policies have been vigorously pursued in South Asia, where governments have reduced subsidies, imposed user charges, reduced their responsibility for O&M, and divested themselves of pump ownership. Indonesia now finds itself at the crossroads, facing a realistic assessment of the private sector's ability to assume responsibility for pump irrigation in the country.

Policy Issues

There are several policy issues the GOI must consider in defining the role and scope of private involvement in pump irrigation.

- The needs and capabilities of farmers in respect to irrigation, particularly more sophisticated pump irrigation, vary widely. In Java, irrigation is widespread and is intensively practiced, but in the eastern provinces of NTB, NTT, Sulawesi, and the Moluccas, pump irrigation is still very new. Subsistence agriculture prevails, and many farmers also have other occupations including inter-island trading, fishing, and small-scale ranching. A policy suitable for Java may not be relevant elsewhere and may have to be tailored to local needs, capabilities, and resources. Thus, full privatization of pump irrigation may be appropriate in Java, but for social and equity considerations may not be a politically acceptable option for the poorer eastern provinces.

- Water resource allocation and conservation will be of major significance in Java between now and 2000, primarily because of population pressure and the demands arising from industrial and urban growth. Pump irrigation development will have to be carefully regulated to mesh with environmental management planning and integrated water resource planning by river basin. Outside Java, the water resource base is less well known and demand is still only a fraction of potential supplies. In these differing circumstances, the GOI may favor strong public sector regulation in Java and less restrictive policies for the eastern provinces, thus limiting the activities of the private sector in Java but giving it a broader mandate for pump irrigation projects elsewhere.

- A policy of full cost recovery will penalize farmers in pump irrigation areas more heavily than those in gravity command areas of surface water irrigation schemes. Conversely, equalizing costs between surface water and groundwater systems will require either much higher charges to gravity surface water users or a continued subsidy to pump irrigation.

Public Sector Role

Clearly, these complex policy issues, and their sometimes contradictory solutions, must be linked to a national water resource conservation strategy. Without this, the true scope and magnitude of private sector involvement cannot be determined. Private sector pump irrigation will flourish only if a large and competitive market is created by widespread privatization. This is particularly true for shallow wells and surface pump irrigation using small centrifugal pumps.

The private sector is likely to play an increasingly important role in the maintenance and development of pump irrigation. This will occur as GOI support agencies such as P2AT and PRIS hand over more schemes to water users associations, and as government becomes less active with the dissemination of small-scale, locally maintainable technology.

Private Sector Role

Although extremely varied and widely dispersed, private pump irrigation exceeds public pump irrigation by a factor of three. There are approximately 30,000 ha under publicly developed pump irrigation and 20,000 ha under publicly developed river irrigation, but more than 150,000 ha under pump irrigation (well and surface water) developed by the private sector. Unfortunately, very little is known about this private sector activity because its small-scale technology makes it extremely difficult to monitor.

Supporting private pump irrigation is a host of enterprises that include more than 60 plants manufacturing small pumps and engines and numerous small workshops providing repairs. In 1989 and 1990, the private sector produced nearly 50,000 irrigation pumps and imported more than 250,000 (Table 16).

Experience in Other Countries

There are several models to guide Indonesia's transition from the public to the private sector. With respect to pump irrigation, the experiences of India, Pakistan, and Bangladesh are particularly relevant. In Bangladesh, pump irrigation has changed over the last two decades from a public sector monopoly to the present situation where most pumps are privately commissioned, operated, and owned.

On the following page, a case study illustrates this change, which has a number of parallels with the current situation in Indonesia.

A Case Study in Privatization of Pump Irrigation

The Bangladesh model provides a relevant example for Indonesia, as pump technologies, landholding size, cropping systems, and population densities are almost identical with those in Java. Prior to independence in 1971, pump irrigation from surface and groundwater was wholly planned and implemented by the East Pakistan Water and Power Development Authority (EPWAPDA) and the East Pakistan Agricultural Development Corporation (EPADC). Surface water was drawn by either large pumping stations or small portable pumping sets called low lift pumps (LLP) discharging between 15 and 60 liters per second. These methods were carried on for several years after independence. By 1980, large pumping stations were irrigating 124,000 ha, however, the area irrigated by LLPs remained static at about 630,000 ha between 1970 and 1980 because almost all the accessible sites had been covered.

The technology for tubewells was imported from Pakistan into what is now Bangladesh because, as with Indonesia, the same consultants were employed. The experience was another example of the diffusion of technology, subsequently shown to be inappropriate, to promote the green revolution. Deep tubewells (DTWs) were designed for the Lower Indus Project on the principle of providing pump irrigation (and subsequently pumped drainage) at the lowest cost. Engineering and financial analysis showed that the unit cost of water approached the minimum if at least two cubic feet (about 60 liters) per second were pumped from 20-inch (508mm) diameter drilled wells between 60 and 100 m deep, gravel packed, and with 8-inch (208mm) diameter fibre glass screens and 14-inch diameter (355mm) pump changer casings which contained a diesel driven turbine pump. Given their size, their dependence on imported equipment, and their high capital cost (US $15-20,000), DTWs could be managed only by the public sector. In Pakistan, landholding size was not a consideration, and the same design philosophy was applied without modification in Bangladesh and Indonesia - the objective being simply to form a users group large enough to fully utilize the available water. In Bangladesh, as in Indonesia, this frequently meant that as many as 200 farmers had to cooperate in what was a completely new technology.

Almost 6,000 DTWs were sunk by foreign contractors working independently or in association with local industrial enterprises and using privately imported tractor-mounted drilling rigs. All designing was done by expatriate consultants financed by multilateral development banks; well casings, screens, and pumps were imported; and in one project even prepacked gravel was brought in from Germany. Ownership of all pumping equipment was vested in the government, and commissioned pumping plants were rented to farmers' groups at negligible cost. Open channel irrigation distribution systems were provided to the secondary level. Groundwater pump irrigation grew from almost zero in 1964 to 45,000 ha in 1974, an annual rate almost three times that of Indonesia, primarily because of the ease in developing groundwater resources.

Many of the larger projects designed by EPWAPDA and later by a newly formed Bangladesh Agricultural Development Corporation (BADC) were implemented between 1972 and 1978. They followed the same technological models as before but allowed farmers' groups to purchase tubewells and pumping plants for 30 percent of the cost. An important variant was adopted by the International Development Association's (IDA) Northwest Region DTW Project of 3,000 diesel turbine pumps, which has a secondary objective of establishing a local drilling industry. From less than 12,000 ha in 1970, groundwater pump lift irrigation had covered 183,000 ha by 1980. The efficiency and O&M of the commissioned systems, both LLPs and DTWs, were far below design expectations.

Farmers' groups were delinquent in paying rents and a large number defaulted on payments for DTWs. BADC was supposed to provide maintenance using imported spare parts. However, the quality and timing of service were so poor that enterprising mechanics stepped in to provide service and cheaper, locally made spare parts. Unlike Indonesia, the government did not provide assistance with O&M during the two-year handing over period. By the late 1970s, many were disillusioned and the future for pump lift irrigation looked bleak.

DTW command areas were designed to be about 20 ha but typically averaged about 16 ha during the late 1970s. The major reason for the smaller areas, apart from pump maintenance, was the inability of 100 or more farmers to run the distribution system efficiently. Typical problems included: disputes over the method of charging for water (area irrigated or pumping time cost), pump operator's accounts, water allocation, credit, pests, and, in a few cases, marketing of produce. A review in 1982 found that DTWs had increased rice cropping intensity by only 21 percent, and that most of the enhanced yields were attributable to HYVs, which accounted for an increase of 46 percent.

Although it had made a substantial contribution to national food grain production, large discharge pump lift irrigation clearly was fraught with many problems because of its inappropriate scale, its continued public ownership, and the subsidies that fostered inefficiencies and continued to drain the exchequer. The immediate line of attack on these problems was to reduce the scale of the technology to a size more appropriate for average landholding (0.9 ha) and to do away with sophisticated drilling rigs and foreign consultants. As a first step, small (15 l/s) portable diesel pumps were attached to surface mounted centrifugal pumps and used for surface and groundwater pumping. Then many NGOs re-examined traditional manual irrigation methods and came up with some highly successful innovations.

The new groundwater pump lift technology was called a shallow tubewell (STW) which, apart from the pump and engine provided through BADC's government monopoly, was installed by private sector drillers using manual drilling techniques and locally made screens and casings of uniform diameter (4 inches or 100mm) without gravel packing. Initially, the pump was surface mounted and could draw groundwater no deeper than 6.5 m. A later modification of the design placed the pump and engine in a pit (deep set STWs) and increased the lift to around 10 m. The STW was an immediate success and was affordable by individual farmers or very small farmers' groups. The pump cost $1,400-$1,800, could be installed in a day, and typically irrigated 205 ha. Credit was supplied through IDA and ADB programs operated by BADC from the late 1970s. From several hundred units sold up to 1974, total sales increased to almost 30,000 units by 1980. Unlike DTWs, costs were minimized by the relative simplicity and portability of the equipment— no access roads or expensive tubewell houses were required, and the pump could be transported by rickshaw to a private workshop for repair. The relatively small irrigated area minimized management problems, and the rapid dissemination of the technology created local competition to supply irrigation water, enhancing equity. The most important benefits were that all the major costs were borne by the private sector, each new STW created between 700 and 850 person-days of employment, and food production rose by 10.8 tons per STW.

The growth of STW-based pump lift irrigation was rather uneven until the mid 1980s because of the government supply monopoly and the stop-and-start expansion influenced by variable supply. A period of relatively rapid expansion in the early 1980s came to a halt as the government cut back on the import and sale of small diesel engines that did not meet acceptable standards. Some of the government's concern was raised by the high cost of tubewells designed by consultants. For example, a 'well engineered' deep-set STW was estimated to cost US $500 more than a surface mounted STW. Field surveys showed that farmers adopting more appropriate engineering could get the same modification for only US $13!

In 1986, the government relaxed its monopoly, took diesel engines off the import restricted list, and allowed private sector imports. Low-cost Chinese engines took over the private diesel engine market, while the government continued to import more expensive Japanese and European engines. Further trade liberalization took place in 1988, when all import duties on small diesel engines were removed. By 1989, the price of an STW was below US $600, less than the subsidized cost of government STWs and half to a third of the price of BADC's equipment in 1980. In 1990, further import restrictions on tubewell pipes and small submersible pumps were made the same for the public and private sectors.

The liberalization of private trade sparked a rapid increase in the sale of STWs from 145,000 units in 1985 to 276,000 units in 1990/91, and an increase in the sales of LLPs from 38,000 units to 52,000 units in the same period. The increase of 131,000 in private sector sales of STW units compared favorably with the 20,000 units by which government sales increased from 1972-80. Other important effects have been an increase in the number of shops dealing in pumps, engines, and spare parts, and the spread of sales and maintenance agents from the larger provincial market towns to the smaller towns and villages.

Privatization of pump lift irrigation has been criticized and praised. Some claim that equity has been sacrificed for growth; one study estimated that two-thirds of the benefits have gone to medium and large farmers with more than one ha, while several others argue that social differentiation and exploitation have increased. A positive impact of privatization has been the emergence of landless groups that purchase pumps and sell water under Proshika, an NGO credit program. Unlike many others, Proshika gives loans to women's groups, which have an exemplary record of timely loan repayment. More recently, the Grameen bank has procured privatized government DTWs but appears to be facing severe cash flow and management problems.

Despite the success of STWs in enabling rapid expansion of irrigation in Bangladesh, many small and marginal farmers are unable to afford them, and in areas of sandy soils, high irrigation losses are disincentives to investment. To meet the needs of small farmers, several NGOs have worked on improving traditional irrigation through the design of pumps and wells operable by one man and capable of irrigating 0.1 to 0.5 ha. Two major innovations are the rower pump and the treadle pump; both discharge 1-3 l/s, are able to lift from a depth of 4-6 m, and have proved financially and economically suitable for the cultivation of potatoes and high-value vegetable/cash crops. Costs are very low (US $20-$100) because these pumps are fabricated and maintained at the village level.

The government and donor agencies continued the steady sale of subsidized DTWs throughout the 1980s but supported the Bangladesh Rural Development Board in establishing command area development programs and model farms. The areas for DTW development were selected by zoning criteria devised under the National Water Plan, 1984-87, and were those where STWs could not pump groundwater deeper than 10 m. This approach provided a solution to a growing problem of expensive DTWs being installed in shallow groundwater areas and putting private sector STWs out of business.

In 1990-91, the government, under pressure from the ADB and the World Bank, agreed to eliminate subsidies on DTWs by 1995. But it faced a dilemma because, like the Government of Indonesia, it believes that farmers in drought prone areas with deep groundwater should not be penalized, despite evidence that the market for DTWs will fail because these farmers are not prepared to pay the full unsubsidized price. As a solution, it is marketing a program of unsubsidized small-discharge high-lift tubewells for the DTW zoned areas through the establishment of demonstration pump sites. The design of these wells allows either for a high-lift pump to fit into a small-diameter STW, or for an increase in the depth of the pit in which an STW is set. Costs per well are expected to be about $3,000 for a high-lift turbine pump discharging 5-8 l/s, and $1,700 for a modified STW.

The source of power for pump lift irrigation is an important component of cost. There are few reliable data available for Bangladesh, but in India and, to a lesser extent, in Pakistan, pump lift irrigation is linked to the availability of reliable electrical supplies and tariff policy. In Pakistan, diesel pumps cost three times more to operate than electrical pumps because of a differential power tariff in favor of agriculture (Rp 0.35 kwh vs standard Rp 0.52 kwh). In India, the very large number of power connections for irrigation is a national issue because demand far exceeds supply during the dry season, causing regional load shedding which severely disrupts the productivity of the industrial and business sectors of the economy.

There are several lessons to be drawn from the Bangladesh experience:

- Although it maybe necessary for the government to provide the lead and take the risk for a new and untried irrigation technology, it must allow the private sector to take over as soon as possible.
- Govemments and international development banks tend to go for high engineering standards (and costs) which they impose, through government programs and consultants, on poor and marginal farmers who would effectively subsidize inappropriate technology if full pricing was adopted.
- Govemment monopolies restrict the growth of pump lift irrigation and keep costs artificially high. However, indifferent and tardy official maintenance has promoted the growth of private initiative in setting up workshops to provide this service.
- Donor funded pump lift irrigation projects tend to include a large element of commodity aid which leads to considerable O&M problems, particularly with spare parts and standard tooling after the contractor has left.
- Large-scale groundwater pump lift irrigation requires sophisticated pump, drilling, and well technology that restricts the pump supply and drilling market to large engineering contractors familiar with the international competitive bidding system and contracting procedures (prequalification, performance bonds, letters of credit, etc.).
- Small-scale pump lift irrigation technologies are appropriate for farmers with very small landholdings and encourage local drilling equipment, pump, and engine sales, and local maintenance workshops and irrigation system installation contractors.

Findings and Conclusions

Indonesia is still at the stage where donor agency preferences and the technological conservatism of consultants are an impediment to low-cost, small-scale pump irrigation development. There will always be a need for traditional groundwater engineering projects, but these should be confined to areas where water supplies are critical and subsidized programs are justified by economic and social conditions. Several alternative approaches for the situation in Indonesia are discussed below.

Joint Enterprises with Provincial Governments. Private contractors working with the provincial governments and P2AT staff can drill wells for small-scale irrigation. This has proved very successful in West Timor, where Nippon Koei brought in traditional well-drillers from East Java to develop parts of the Oeseo plain. The wells drilled by these technicians, although only 3.5 inches in diameter and 18-20 m deep, yield as much as DTWs drilled by rotary rigs to depths of over 30 m. As the areas of groundwater potential in many of the islands in NTT and NTB are widely scattered, this approach, sufficiently funded to allow for supplies and management, could be a model for widespread pump irrigation development. A similar approach could be used to introduce small pumps and irrigation distribution.

One of the primary objectives of the Central Java Groundwater Project (CJGWP) is testing the willingness of farmers' groups to contribute to the capital cost of well construction, pumps and engines, and distribution systems. The original project design required farmers to bear all the costs of shallow well systems and the pump and power costs of medium-deep tubewells. Field evaluation of the farmers' payment capability, particularly at the higher rates of interest (17-21 percent) now prevailing, has indicated that realistically farmers can only afford to pay for the pump and engine of shallow wells, and either the pump or engine of the deeper (turbine) wells, depending upon electricity tariffs and pumping conditions. Repayment capacity is extremely variable and depends, not only on capital investment costs, but on local climate (pumping hours), hydrogeology (pumping), and cropping systems (soils, fertility, markets). Since Java is one of the more prosperous parts of the country, these facts do not support a bright future for private sector irrigation in the eastern provinces. However, overly expensive technology may have distorted the situation, making it difficult to obtain a more accurate assessment.

A look at the CJGWP pumps/engines available from 22 dealers in four major cities in Java showed a predominant number of high-cost units of European, Scandinavian, American, or Japanese origin, very likely because the specifications called for high-quality equipment following the standard donor/consultant approach. Only one Chinese engine (Tong Fong), a third of the price of the others, was found.

Most Indonesian projects have focused on big pumps and wells. Experience in India and Bangladesh, where local or Chinese manufacturers normally can undercut equipment of western origin by at least half, suggests that this could be a strategic mistake. One fact that emerges from interviews and reports is that farmers have their own small wells and are quite content to run them without government interference. The technical standard of these wells is low. Most lack screens and collapse or fail after a couple of years. But attempts to improve the design have turned to high-tech requirements for skid-mounted drilling rigs, screens, gravel packing, and development testing. Most of these technical 'improvements' are not necessary, and slightly larger diameter pipes and screens alone could be the answer. In Bangladesh, this solution provided the spur for a new PVC pipe industry to produce well casing and hand-slotted screens suitable for both domestic water supply and irrigation wells. Latterly, the same industry has produced pipe for small-scale buried pipeline distribution systems.

Kick Start Irrigation Using Taxi Pumps. An approach suggested by MacDonalds, based upon their extensive experience in East Java, is for the government to drill, say, 10 small wells in a village but entrust only a single portable pump/engine set (2-5 l/s) to the care of the Bupati. He would rent this pump out to farmers and use the money for maintenance and towards the purchase of another pump set. Successful irrigators would have the incentive to purchase their own pump/motor set which could have other uses such as mowing, threshing, and electrical power generation. This process could in time reach the point where farmers would be drilling their own wells.

Surveying Services. A major impediment to starting irrigation is the lack of cadastral maps showing land ownership, and large-scale topographic maps (1:1,000) for the design of distribution systems within village boundaries. In South Sulawesi, Lombok, and East Timor, this has delayed implementation by up to a year. Supplying these maps would be a very good business opportunity for a private surveying firm.

Develop a Competitive Well-Drilling Industry. A survey conducted by CJGWP in Central Java found 32 private drilling companies and 39 drilling rigs. They fell into three classes: large (contractors able to drill deeper than 200 m), medium, and small (contractors able to drill 2-4 inch diameter wells to a depth of 50 m). Many of the larger contractors have worked for P2AT and are conversant with rotary drilling techniques and large-diameter gravel packed wells. The majority of the small contractors work directly for farmers or farmers' groups and are skilled in simple well construction. Many of the drilling companies belong to the Association of Groundwater Drilling Contractors of Indonesia (APATI) founded in 1990, and the larger are licensed by the Department of Environmental Geology as required by law.

The smaller contractors have the confidence of the farmers and are well informed about groundwater conditions in their areas of operation. The larger contractors are more reliant on government contracts, cover wider geographic areas, but experience considerable down time because of protracted contract formalities or O&M problems. Average utilization was estimated to be only 500 m per drilling rig per year, which is very low by international standards. In Bangladesh and India, drilling rigs typically drill 2,000-5,000 m per year. The low utilization may account for the high cost of Indonesian wells. A DTW system costs Rp 144 million (US $60,000) in East Java, but one of similar design and capacity using imported components costs only US $20,000-$30,000 in Bangladesh. A 'professionally engineered' local model STW (10 l/s) costs Rp 4.7 million (US $2,500) in Central Java, whereas its Bangladeshi equivalent (15 l/s) using Chinese equipment and local screens is only US $650-$800. There are clearly economies of scale and other factors accounting for this very large difference.

Outside Java, well costs are generally much higher. There are fewer contractors and drilling is expensive because of a small market and high mobilization cost. In 1988-89, drilling costs for intermediate wells were 240 percent higher per ha in Central and South Sulawesi than in East Java; in 1990-91, they were 132 percent and 124 percent higher, respectively.

Marketing and Training. The private sector can provide excellent marketing and training if the objectives are well defined and there is enough scope to make investment worthwhile. Farmer education programs to promote small-scale pump irrigation technology could make existing systems more effective. Private sector assistance in conducting pump irrigation surveys and inventories could yield useful data on the size of the market and identify new business opportunities. An expanding market for pump equipment would generate a demand for maintenance workshops, spare parts manufacture, and field diagnostic and servicing agencies.

Private Water Markets. There is no evidence of private water markets using pumps owned or rented by landless people, although there are a number of small groups and entrepreneurs that provide water and rent pumps.

Recommendations

- The GOI should commission a survey of water resources to identify regional pump irrigation potential, and a survey of the present extent of pump irrigation to determine the size and location of the market for private sector intervention.

- Simultaneously, the government should formulate policy at the national, regional, and provincial levels on the respective roles of the private and public sectors in meeting the demand for pump irrigation.

- The government should publicize the extent of the market for pump irrigation technology and O&M requirements that the private sector could supply.

- Pump and well equipment costs twice as much in Indonesia as in Bangladesh, clearly indicating too little competition in the well construction/irrigation industry and too much reliance on expensive foreign pumps, engines, and, possibly, design and supervision services. The government should review its procurement policies for consultants and equipment to reduce the costs of high-lift DTWs, and consider moving out of intermediate and shallow well programs as soon as possible to enable the private sector to grow.

- A key to reaching the smaller farmer groups is to provide technical and marketing assistance to APATI so that it can advertise its skills in improving the design of low- technology wells.

- An NGO should be encouraged to investigate the feasibility of organizing landless groups to purchase pump irrigation equipment to sell water.

- There is a need to assist local companies to undertake cadastral and large-scale (1:1,000) topographic surveys of potential command areas, and to encourage pipe manufacturers to venture into the design and supply of irrigation distribution systems.

- Agricultural investment credit must be made easier to attract private sector investment in pump irrigation.

- A single private sector solution applicable to the whole country may not be feasible or even desirable, considering the diversity of climate, soils, water resources, agricultural systems, and cultures in Indonesia.

Arguments For and Against Privatization of Pump Irrigation

Arguments For Privatization

The tasks of government should be confined by policymaking and regulation and should exclude implementation. The quantity of implementation does not suffer from the communications gap between sectors because public management is always less flexible and efficient than private management. Advocates of privatization assume that irrigation is a self-sustaining activity, and that prices for agricultural products are high enough to enable users to pay the real costs of water supply.

Govemments can offer the infrastructure and stability to create a proper climate for investment, but should avoid taking responsibility for activities that do not yield a profit. Irrigation is a commercial activity in which water is an input like any other.

Irrigation users are a homogeneous group that can organize itself and pursue a common interest.

Govemments are authorized to sell pubic investments to meet short-term financial need. Irrigation is a local activity that can be run by a WUA or a private enterprise. Watershed, regional or interregional regulations are not generally necessary, but if they are, government has the power to impose them fairly on the private sector.

Depending upon the degree of competition, the private sector must be able to guarantee adequate and reliable supplies of good quality water to retain clients.

Arguments Against Privatization

The government is a neutral and autonomous apparatus which is capable of supplying services (although some training and restructuring may be necessary). It feels responsible for deprived groups and shows fairness in incorporating them in national economic and political plans. Taxes and subsidies collected by the community as a whole should not be invested in a sector that benefits only water users. Irrigation benefits the national economy, and the costs should be carried by the whole community.

Govemments can guarantee environmental and long-term sustainability. Even though irrigation is primarily an economic activity, it is also of social and economic importance and the economic rate of return should not be the only criterion for investment.

Govemments can compete within the free market economy and must guarantee equal access to water for all groups. A heterogenous group of water users cannot be unified to pursue common interests.

Governments are not authorized to sell public goods (water rights) in order to meet short-term financial objectives. Only governments are in a position to control and regulate watershed, regional, and interregional water resources and irrigation.

Governments are democratic and stimulate the participation of various groups. Public management in contrast to private management can guarantee a reliable and equitable water supply because profit is not the only criterion in providing service and possible losses are not a constraint.

Table 16

Production and Imports of Pumps

Irrigation Pumps	1989 Units	Value (mil Rp)	1990 Units	Value (mil Rp)
Production	6,278	4,268	43,417	15,894
Imports	63,738	26,267	187,445	62,177
Total	70,016		230,862	

4

INSTITUTIONAL OPTIONS FOR PUMP IRRIGATION DEVELOPMENT

Introduction

As part of its goal to achieve rice self-sufficiency, the Government of Indonesia made a large investment in the rehabilitation and development of the irrigation infrastructure during the 1970s. The lead agency was the Directorate General of Water Resources Development (DGWRD) of the Ministry of Public Works (PU), and the development of pump irrigation, using permanently installed pumpsets in machine-drilled tubewells and portable pumpsets for pumping from rivers or shallow wells, was part of the program.

A special unit, the Project for Groundwater Development (P2AT), was established within DGWRD to investigate the potential for large-scale groundwater irrigation development and to implement tubewell installation. P2AT is now part of the Directorate of Irrigation II and comes under the Groundwater Development Sub-Directorate. The supply of small portable pumps is generally handled by the Directorate General of Food Crops Agriculture (DGFCA) of the Ministry of Agriculture (MOA) and to a lesser extent by the Directorate General of Village Development of the Ministry of Home Affairs through its Village Development Assistance program.

Large-scale pump irrigation along the rivers was introduced by the Dutch before independence and has been expanded by the government. Farmers also have purchased and installed pumps on their own, and in West Java there is an NGO, Bina Swadaya, engaged in pumping schemes.

The technical and institutional approaches of various agencies have yielded some valuable lessons about the development of pump irrigation, and it is important that these are applied in the planning and design of future projects.

Institutional Approaches

P2AT

P2AT is the main agency responsible for groundwater irrigation in Indonesia. It is a project-oriented entity, and most of its activities are in D.I. Yogyakarta, East Java, Madura, and Central Java, undertaken with technical assistance from bilateral donors, particularly the Overseas Development Administration (ODA) of the British Government. Its approach has centered on feasibility studies and deep tubewell pilot projects in the belief that the largely untapped deep groundwater resources offer the best potential for the expansion of irrigated agrciulture. Shallow groundwater has been considered a more limited resource already being exploited by the farmers. P2AT has operated under direction from Jakarta (Figure 6) and tended to ignore the need to establish supporting entities at the local level.

It has imported drilling and pumping equipment and well components and emphasized the training of staff, and thus has established itself as a well-equipped implementing agency with a limited number of competent professionals. It has continued to receive support form multilateral agencies including the World Bank in East Java, the European Community in Madura, and the ADB in Central Java.

The planning, design, and construction of the tubewell systems have been determined by technical considerations, including aquifer potential, degree of water shortage, layout of existing suface water canals, and topography. Although village officials were consulted about drilling sites and access routes, beneficiary farmers had no opportunity to participate in the implementation process. As a result, some early tubewells, particularly in Madura, were sited in areas where the local communities res ted an externally imposed government facility. Subsequently, sociological studies were given importance in site selection in Madura, and beneficiary farmers were consulted at critical stages of the design and construction phases.

Some of the tubewells, particularly in Madura, were too large to be managed by the water users associations (WUAs), which often included up to 400 farmers in a 100 ha command area. Although the theory was that economies of scale would reduce the unit cost of water, the farming community was simply unable to manage the technology on a large scale. A command area of about 30-50 ha involving about 150 farmers was found to be more reasonable.

Initially, P2AT paid little attention to the institutional requirements to sustain tubewell operations, believing this to be the responsibility of Provincial Irrigation Service (PRIS). P2AT subsidized tubewell O&M for the first two years, after which it turned over the systems to PRIS. However, PRIS was not prepared to accept this responsibility since it had largely been excluded from P2AT technical assistance and viewed the groundwater schemes as something of a burden.

This conflict has been recognized by the GOI and the multilateral lending agencies as the P2AT projects have expanded. Increasing attention is now being given to the institutional development of PRIS and the Provincial Agriculture Service (PRAS) and to the development of the WUAs. Strengthening P2AT is a major component of the Central Java Groundwater Irrigation Development Project (CJGIDP). Yet, as can be seen in Figure 7, the approach still ignores the need to bring PRIS in at a very early stage in the process. The WUAs will take full responsibility for O&M and also invest part of their members' contributions in pumpset replacement. The Madura Groundwater Irrigation Project has given much attention to the establishment and training of WUAs and carried out pilot programs for this purpose in three key subdistricts in 1991. Thereafter, the Governor has passed a decree spelling out the responsibilities of PRIS and the WUAs for O&M.

P2AT has its own workshops except in Central Java, where pumpset maintenance and repair services have been left to the private sector. Although the workshops are well equipped and the staff is well trained, employee motivation and management generally are poor. The workshops are not run as commercial operations and are not empowered to sell spare parts to the general public and organizations like the WUAs. Two correctives are being considered: a technical service unit under local government control and subject to local government budgetary restrictions, and a self-financed operation with control of its own revolving fund. These options may be tested on a pilot basis in the Madura Project.

Although P2AT has been concerned mainly with deep tubewells, more recently it has also been involved in shallow groundwater development. Under the Small Scale Irrigation Management Project (SSIMP) financed by USAID and OECF, it has introduced manually drilled shallow tubewells equipped with portable pumps in Nusa Tenggara Timor (NTT). It has been less successful with shallow wells intended to improve the design and performance of existing wells in East Java, where farmers believe their own wells are better and cheaper to run.

Directorate General of Food Crops

The Directorate General of Food Crops in the Ministry of Agriculture provides pumps as part of an equipment package for drought alleviation. The pumps come from two sources: the Second Kennedy Round (SKR) grant aid from Japan to increase food production, and national budget allocations. The SKR, which was started in 1977, donates equipment, fertilizers, and agro-chemicals. The ministries make annual requests to the Japan International Cooperation Agency (JICA). For 1992/93, for example, the

MOA is requesting 152 6" self-priming portable pumps and 285 4" pumps for drought alleviation in rainfed areas in Sulawesi, Nusa Tenggara Barat (NTB), Nusa Tenggara Timor (NTT), and Maluku. The number of pumps requested has increased in response to the last two years' drought.

SKR pumps are loaned to farmers' groups (*kelompok tani*) and young farmers' groups that agree to abide by various stipulations laid down by DGFCA and remain the property of the state in the inventory of PRAS. The groups are responsible for O&M and must keep funds for this purpose in a bank/savings account. Farmers generally pay water charges after each harvest.

Kelompok tani organize farm activities and are found throughout Indonesia. In areas with irrigated agriculture, they function alongside the WUAs, which organize water activities. Farmers belong to both organizations, which have a formal structure with a chairman, secretary, treasurer, block heads, etc. *Kelompok tani* are supervised by PRAS; the WUAs are supervised by irrigation committees representing PRIS, PRAS, and other agencies.

Directorate General of Village Development

The village development assistance fund, a line item in the national budget (APBN) under a presidential instruction, makes annual priority grants to villages. The amount for 1991/92 is Rp 3.5 million per village. Each village decides what the assistance should be used for through the forum of the village community resilience council (LKMD). LKMD is an important institution and provides an opportunity for the people to participate in decision-making concerning village development issues, including the setting up of WUAs, and in strengthening self-help and resilience in the community.

The results of LKMD deliberations are discussed by the village consultative council and passed on to the Bupati, who determines whether the requested assistance is really a priority for the village. The Bupati's approval goes through appropiate channels, and the village receives its allotment.

One of the main categories of village assistance is infrastructural development, which covers irrigation pumps. While there are no data on the number of pumps supplied under the program, government officials believe there was a significant increase in reponse to the 1990 and 1991 droughts.

Government Surface Water Pumping Schemes

Central Java

Three pumping stations were installed on the River Serayu near Purwokerto in Central Java during the Dutch times: Kebasen (785 ha), Gambarsari (16,347 ha) and Pesanggrahan (3,418 ha). PRIS is responsible for O&M costs. The cost of running the four pumps at Gambarsari (each capable of producing 5 m^3/s) is very high. This station and Pesanggrahan will be replaced by a barrage due for completion in 1995/96. Kebasen will remain upstream of the barrage but will be raised to the level of the impounded water.

West Sumatra

In West Sumatra, six pumping stations that draw water from Lake Singkanak and the River Sumani under the Swiss-aided Sumani Pump Irrigation Pilot Project supply water for rice during dry spells to land not served by adjacent gravity flow schemes. Some of the pump schemes also receive surface water from the nearby mountains during periods of heavy rain, enabling two rice crops to be grown a year. The pump schemes vary in size from about 90 to 270 ha. Steps are underway to turn responsibility for these systems over to PRIS.

East Java

In East Java, the Dutch installed three pumping stations along the Bengawan Solo in Bojonegoro serving about 3,100 ha. The schemes are the responsibility of PRIS, and O&M is fully managed by the WUAs.

NGOs

The main NGO active in pump irrigation is Bina Swadaya, a Jakarta-based organization that has operated in three kapubaten in West Java since 1984. It has developed 14 systems with funds from USAID, AgroAction, the Ford Foundation, and Cebemo. Bina Swadaya supplies large, permanently installed surface water pumps to farmers' groups. In all of the systems, water is lifted from rivers and used to serve adjacent land previously only rainfed.

Bina Swadaya's focus is on providing relatively large pumps and a significant amount of fixed infrastructure. It stresses institutional development, using a model strongly reminiscent of efforts to improve surface irrigation performance in Indonesia and elsewhere. After a feasibility study confirms the validity of a proposed system, farmers are organized into water users associations and elect executive committee members. Agricultural extension agents are trained to serve also as community organizers in the system and are given an honorarium for three years. Bina Swadaya also stations a site manager from headquarters in each kabupaten.

Bina Swadaya's earliest efforts were funded with grant money from USAID. Farmers were not expected to repay the cost of the system but were asked to build up savings in an account in the kecamatan branch of the Bina Swadaya bank for a replacement pump and for fuel and honoraria. However, the NGO had no control over the revenues of the WUAs and no regulatory powers. In general, the efforts in Subang have been very disappointing. Some of the pumps are no longer in operation and the WUA members have withdrawn their savings. Bina Swadaya staff attribute these failures to the fact that the pump cost the farmers nothing. In addition, because the systems were large—in excess of 200 ha—there were major problems in organizing the farmers and serving the entire design area, especially land near the tail end of the system. Ironically, Bina Swadaya thinks the large area is necessary to generate enough fees to pay the operator and the irrigation committee.

The systems developed by Bina Swadaya in Ramayo and Lebak have followed a different pattern. Donors provide loans, and the WUAs are expected to repay the costs of the pump and the physical infrastructure and to pay for operation. Farmers contribute 3.5 quintals of unhusked rice per ha per season to the account. Two quintals go toward the pay back, the remainder for operation and maintenance. There are restrictions on the withdrawal of funds by the WUAs. During the first five years, funds from the replacement account may be used by the WUAs for credit programs. After that, the funds are used by Bina Swadaya to develop new systems elsewhere.

In all locations, a steering committee in each kabupaten makes a quarterly progress review. The chairperson is the head of BAPEDA; other members are the Bupati and representatives of the Departments of Public Works, Agriculture, Development, Manpower, and Pemerintahan. However, since the committee has no real control over the funds and management of the systems, nor a say in the location of new systems, it is not very effective.

A second NGO involved in groundwater pumping is Solo-based Yayasan Indonesia Sejahtera (YIS), which was recruited to initiate a community development program for the O&M of domestic water supply schemes fed by some of the tubewells. The program also addresses health concerns and methods of water charge payment. YIS currently is working with P2AT in NTT.

Conclusions

- The P2AT approach centers on feasibility studies and the development of deep tubewells tapping aquifers beyond the reach of the farmers' own shallow wells. Tubewells typically serve areas in the range of 20 to 100 ha, and WUAs are formed to manage the tubewell systems. P2AT subsidizes operation and maintenance costs for the first two years, after which the WUAs become responsible and P2AT assumes a backstopping role. Most P2AT systems are being reasonably well run by the WUAs and have made a contribution to increasing agricultural production and improving the welfare of farming communities. However, problems have occurred with some of the turbine pumps.

- Modifications in the P2AT approach in East Java have included the use of sociological studies to determine the most appropiate sites in areas with diverse socio-economic conditions (as in Madura), and to aid in liaison with PRIS for the turnover of assets and the formulation of plans for sustainable O&M after turnover is completed. Consultations with farmers during the planning, design, and construction phases have prevented some earlier problems such as making command areas too large and crossing village boundaries.

- Generally, the involvement of P2AT in shallow groundwater development in areas where farmers have their own wells has not been successful. The intention was to demonstrate improved design and efficiency, but the farmers believe their own wells are better and cheaper to operate. In fact, the P2AT wells generally did not yield more water and, in some cases, less. Clearly, the P2AT approach in these areas was inappropiate.

- Small portable pumps have been provided to farmers' groups through programs in the Ministry of Agriculture and the Ministry of Home Affairs, and by the farmers themselves through credit packages. The pumps are used on shallow wells and bores constructed by the farmers themselves (serving about 2-3 ha) and are easily managed. Spare parts and repair facilities are readily available in the local market, and there is less need for developing a complicated institutional support structure as for the P2AT deep tubewells. However, the spread of shallow groundwater pumping is largely uncontrolled, and there is a danger of overexploitation of limited resources that could lead to water table decline, the drying up of village domestic wells, and sea water intrusion (for areas near the coast).

- Pump irrigation from surface water sources (rivers, lakes, etc.) occurs mainly in West Java and Sumatra which have a higher rainfall than the provinces to the east, where groundwater abstraction is the main form of pump irrigation. Surface water schemes are the very large ones that were installed under Dutch administration (serving thousands of hectares), and the smaller ones installed by government irrigation departments, NGOs, and the farmers themselves. The large older schemes are under PRIS and to all intents and purposes are operated as gravity flow schemes; however, O&M costs can be high, and two of the three pumping stations on the River Serayu in Central Java are to be replaced by a barrage.

- Smaller surface water schemes are managed by the WUAs and farmer groups and are largely self-supporting. Recent schemes developed by Bina Swadaya require the WUAs to pay for O&M and to contribute to a pumpset replacement fund that can be used for credit progams in the short term.

Recommendations

- Shallow groundwater development should be left to the farmers themselves using the appropiate technology of locally available materials and small pumps. However, some control needs to be excercised on the number of pumping units and the amount of water abstracted in order to prevent probwater abstracted in order to prevent problems such as the drying up of domestic wells and sea water intrusion. P2AT may need to advise local governments on groundwater recharge and safe yields. However, unless irrigation committees and the WUAs are given the opportunity and take the initiative to become more effective, control on pump use will be difficult.

- For the development of larger scale pump irrigation schemes using deep tubewells or surface sources, the socio-economic situation in target areas needs to be considered much more closely, and implementing agencies need to spend more time consulting with intended beneficiaries during the planning, design, and construction phases of project implementation. Also, beneficiary farmers should be involved in actual construction to give them a sense of commitment to the completed scheme.

- Command areas should be no bigger than the farmers' ability to manage them, and, if possible, should not cross village boundaries.

- P2AT should continue to work closely with local governments on WUA development and prepare PRIS and the WUAs for sustainable O&M of the tubewell schemes after turnover. Training of the WUAs and PRIS staff and institutional development should be given as much importance as the design and construction of the physical works.

- Technical assistance should be given to local pump manufacturers to improve product quality control.

Figure 6

P2AT Original Approach

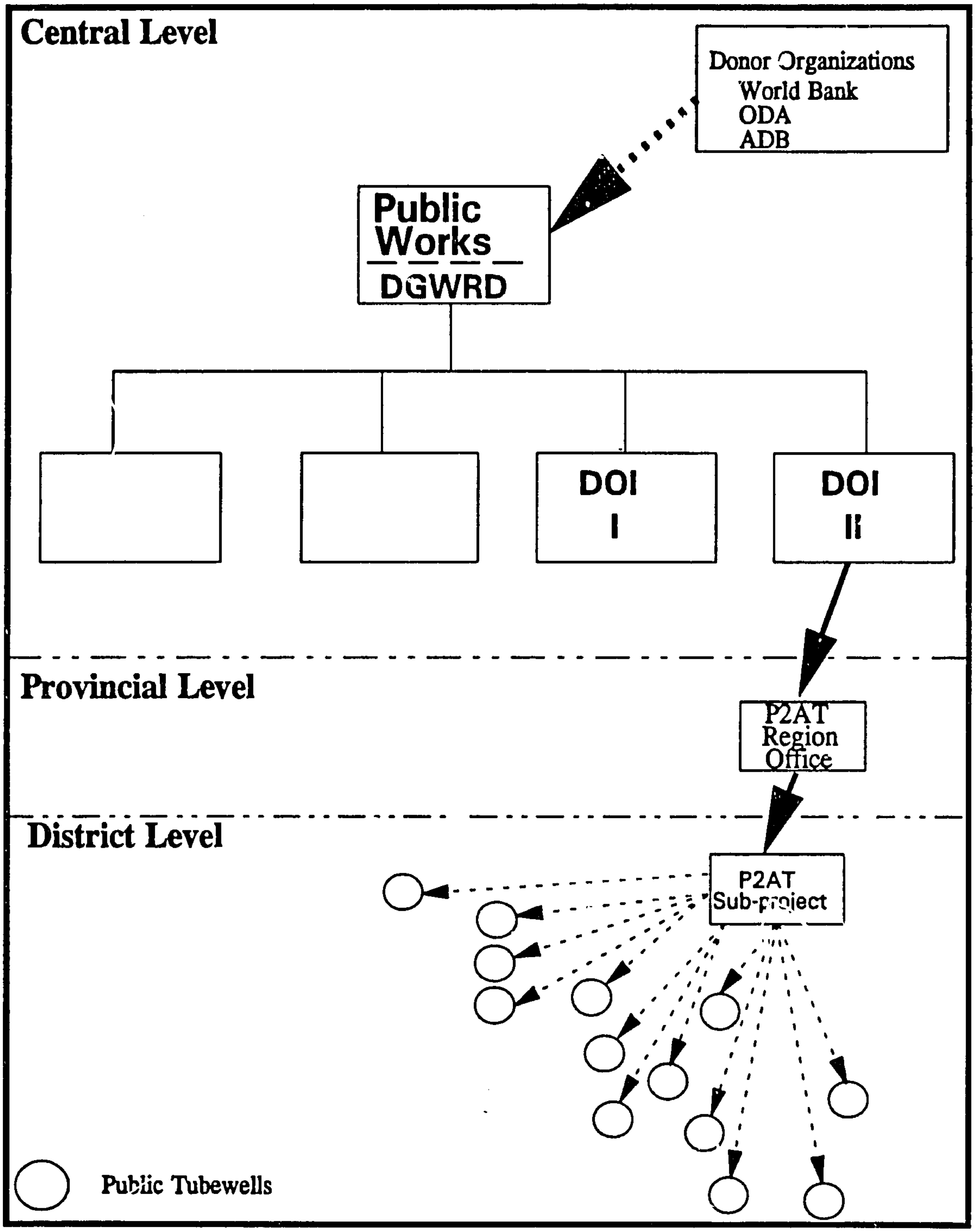
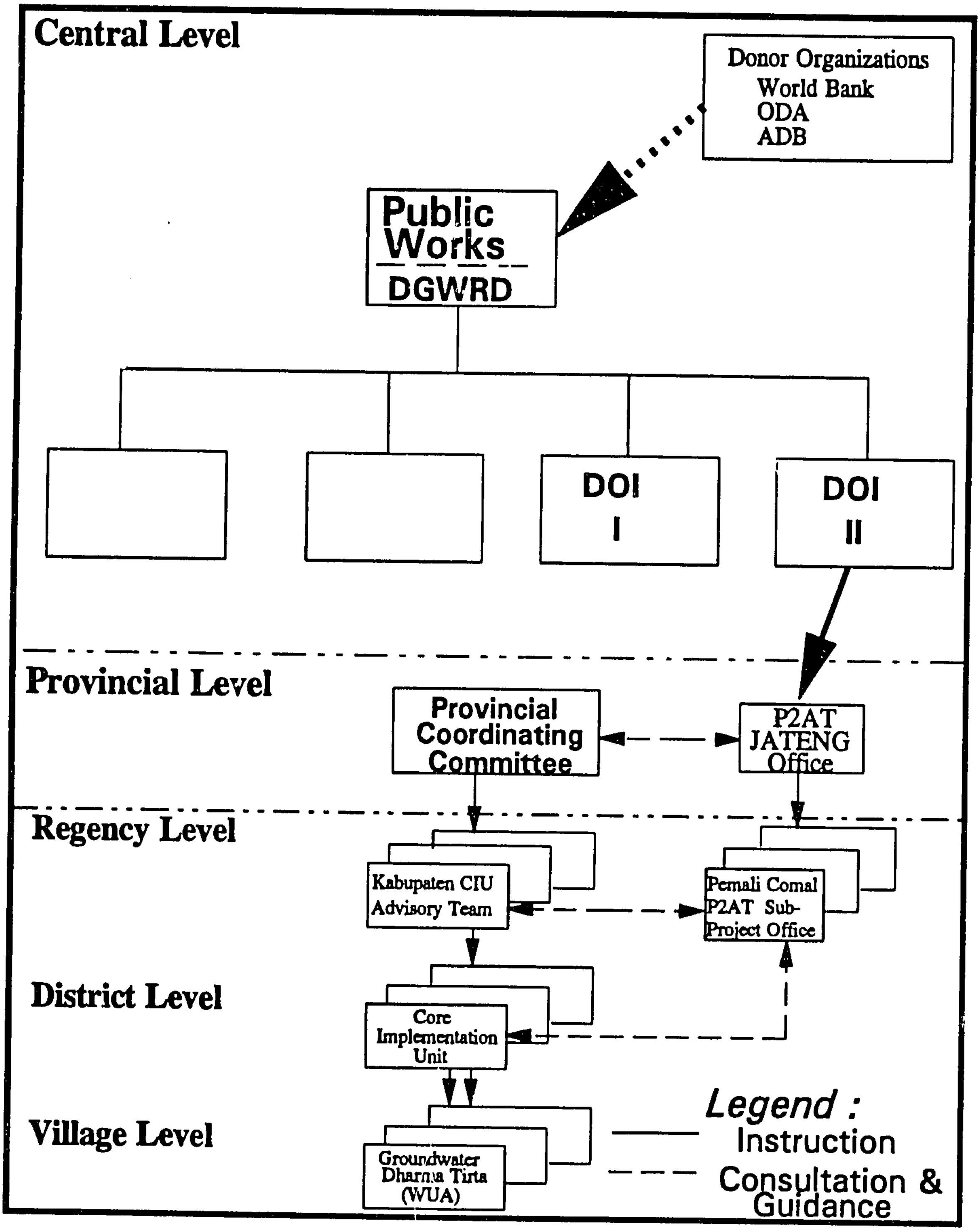


Figure 7

Central Java P2AT Approach



5

APPROPRIATENESS OF TECHNOLOGIES FOR PUMP IRRIGATION

What is Appropriate Technology?

Technology is appropriate if it is culturally, financially, and economically acceptable, technically sound, and can be successfully operated and maintained at an acceptable cost over its normal working life. Generally, determining this depends upon who designs and who finances the technology. In Indonesia, the majority of the larger and capital intensive pumps (30 l/s or greater), engines, and pumping facilities (wells and river pumping stations) are provided by the GOI, financed by donors, and designed by consortia of foreign and local consultants. Thus, design is a "formal," top-down process. Given the size of the units and the complexities of contracting, pump irrigation development has tended to take several years through GOI irrigation projects implemented by P2AT.

Conversely, smaller pumping units (5-30 l/s) are purchased and installed by farmers with their own or community resources, or are provided through GOI drought relief programs, as in the case of Bangpres. Typically, these smaller facilities are "informal," use locally available expertise and equipment for design and installation, and are implemented piecemeal. Because they are not implemented as formal projects, only a few months are required between design and a working irrigation system. In terms of meeting national food production objectives, the area currently irrigated by small pumps (120,100 ha) is much greater than that irrigated by large pumps (52,700 ha).

GOI policy is to reduce the subsidy to the agricultural sector and turn over management and operation and maintenance to farmers' groups as soon as possible. This will be achieved by reducing direct subsidies and the capital cost of pump irrigation, and designing systems that farmers can afford to maintain and operate. The objective of this review is to consider what measures the GOI could adopt to make pump irrigation more appropriate for Indonesian farmers in terms of implementation, capital costs, less costly O&M, and long-term sustainability that does not require government intervention for replacement investment and major repairs.

Findings

Technology Descriptions

Irrigation systems in Indonesia can be classified as surface water or groundwater systems according to pumping capacity and type of water resource.

Surface Water

- large river pumping system, usually permanently installed, capacity higher than 25 l/sec, irrigating 30-200 ha;
- small river pumping system, capacity less than 25 l/sec, irrigating 5-30 ha, using fixed or portable pumps.

Groundwater

- shallow open well and well point discharging 2-10 l/s, irrigating 0.1-5 ha., using fixed or portable centrifugal pumps.
- intermediate well discharging 5-15 l/s, irrigating 5-20 ha, using fixed centrifugal or high-lift submersible pumps;
- deep tube well discharging 30-60 l/s, irrigating 50-200 ha, using fixed high lift submersible pumps

Water from each of these systems is distributed to the fields by open channels (lined or unlined), buried pipelines and elevated discharge points, or a combination of both. Table 18 summarizes the types of technical assistance the GOI must provide to farmers' groups.

Surface Water

The components of large river pumping units, such as centrifugal pumps, pipes, foot valves, and control panels, normally are manufactured within the country and can be purchased in the larger district and regional towns. Locally manufactured diesel and electrical engines used as the prime mover are also available on the market. Farmers do not have any technical difficulty in installing and operating these units. However, as will be discussed later, they do not have sufficient knowledge of river behavior to determine the safest site for locating the pumpsets.

Groundwater

Dug wells normally are very shallow (3-10m) and may be large enough to allow people to walk down to groundwater level. These wells traditionally have been used, for example in Madura, to provide water for high-value crops such as tobacco and shallots.

Shallow tubewells (STW) or well points are manually dug and lined, or mechanically drilled at diameters of 50-100 mm to a depth of 10-40 m with a simple locally manufactured shell auger type tool. All drilling and casing equipment (mild steel or PVC) and components are manufactured locally. In many areas, casing is put only in the uppermost part of the drilled section, leaving the producing part of the well as an open hole. Thousands of these simple wells are installed by farmers and farmers' groups throughout Indonesia in areas where total pump lift does not exceed 6-8 m. These wells are pumped with locally manufactured centrifugal pumps powered by small diesel or gasoline engines available in local and district markets. Discharge capacity is 5-30 l/s depending upon groundwater conditions, the higher yields being associated with very shallow groundwater and/or fractured limestone and gravel aquifers. In recent years, variations of the traditional design have been introduced by World Bank- and OECF-funded projects in South Sulawesi and East Java. Generally, modifications include well screens and, in South Sulawesi where well yields are very low (2-8 l/s), connection of two to four STWs to a single surface-mounted pumping unit.

Intermediate tubewells (ITW) and deep tubewells (DTW) are installed in areas where either groundwater lies below 10 m or aquifers are found only at depths greater than 50 m. These larger diameter and deeper wells use well drilling and construction technology far beyond the capability of farmers. Investment in deep well construction and submersible pumps is also very expensive.

Therefore, GOI assistance is needed for development, basic data on groundwater potential, well maintenance and repair, and replacement.

ITWs typically are drilled to producing aquifers (30-80m) using skid/tractor/truck mounted drilling rigs and 150-200 mm diameter low-cost PVC or mild steel casing and 100 mm diameter screens. Most ITWs have gravel packing to increase well efficiency and reduce the pumping of sand.

DTWs normally are drilled to a diameter of 500 mm with sophisticated large rigs using direct or reverse circulation and specialized drilling muds. DTWs are lined to a depth of 20-40 m below the surface with mild steel 30-350 mm diameter casing for the submersible pump, and have 20-60 m of 150-200 mm fiberglass, PVC, or wire wound screen shrouded in gravel. Annex C shows the lithographic logs for selected sample pumps. Compared to STWs and ITWs, costs can be high because DTW drilling rigs frequently require special access roads, and brick and concrete tubewell houses for the pumping plant.

Early ITW and DTW development projects used surface distribution systems with a mix of lined and unlined channels. More recent public pump irrigation projects have used buried PVC pipe distribution systems and riser pipes and outlet boxes for distributing water throughout the command area. In theory, buried pipe systems are better because they:

- have higher efficiency and less water losses;
- do not take as much ground out of production as do surface ditches;
- require less annual maintenance;
- help ensure the entire command area is served; and
- have a longer expected life.

However, as buried pipe systems require a skilled contractor for proper installation, they reduce the opportunity for "sweat equity in field ditches," which is often one of the major contributions of the WUAs. In addition, as demonstrated at Lombok, farmers do not have the technical knowledge to repair the riser pipes and, therefore, find it very difficult to stop them from leaking any time the pump is operating. Consequently, instead of being more efficient, a number of the buried pipe systems are really less efficient. Higher initial costs (especially if farmers are willing to contribute sweat equity to constrct the distribution system), leaking riser pipes, and a significant number of ruptured buried pipes must lead one to question the appropriateness of buried distribution systems under the conditions found off Java, particularly in the eastern islands.

Capital Costs

Table 18 summarizes the most recently available costs for wells, pumping sets, and distribution systems in East and Central Java and illustrates the variability of costs of similar wells installed in the different provinces. A DTW in Indonesia at $45,579-$60,002 ($1,500-$2,500/ha) is expensive compared with a DTW of identical design in Bangladesh, where the unsubsidized cost is Tk600,000 ($17,150) or Tk25,000/ha ($714/ha), and an STW is Tk25,000 ($714) or Tk6,250/ha ($179/ha).

Design and Implementation

Dug wells and STWs designed and installed by farmers' groups generally have short unlined distribution systems serving small command areas. Most wells have a short life and tend to be resunk every 2-3 years because the open hole collapses or the well pumps sand, which is very damaging to the pump bearings. Despite this, most farmers in Central Java interviewed by CJGWP preferred their simple design to a GOI STW. In Kederi in East Java, the World Bank found that farmers had installed their own STWs even within the command area of DTWs, a clear signal that smaller wells, at least from their perspective, are more appropriate.

Experience from ongoing groundwater projects in Sulawesi and East Timor highlight some of the problems faced in attempting to site, design, and commission DTWs. In both areas, site selection was a major difficulty. The local government pointed out potential sites on government land to P2AT staff and consultants, but the farmers were not interested in having pump irrigation equipment on this land. Even when good sites could be agreed upon with the farmers, the lack of up-to-date and appropriately scaled cadastral and topographic maps made identification of command areas of 50-200 ha very difficult because the village boundaries and the ownership of the command area were unknown. In most cases, the problem was resolved only by surveys at a scale of 1:1,000, sometimes 1:5,000, which delayed drilling by at least a year.

The next problem was that the size of the command area could not be determined until after the well had been drilled and tested. Again, in many cases the sustainable discharge was less than planned and the original distribution system had to be redesigned. Not only did this cast doubt on the credibility of the engineers, but it also reduced the farmers' confidence in the pump irrigation scheme when it was most needed.

A major design problem was encountered in East Timor in the Oeseo plain when farmers, upset at the lack of progress with the SIMP wells, drilled their own - only to find that they could obtain the same yield as a DTW from a simple dug STW nearby. More recently, OECF/P2AT brought in east Javanese drillers to Kupang and were able to replicate the success of the dug STW at considerable savings. This DTW design problem is not unique to this project. Making the assumption that the drilling and exploratory program will use DTWs generally means that the upper 20-40 m of the aquifer is cased out and therefore its production potential tends not to be assessed. If the program had started with STWs, not only would money have been saved, but the farmers' confidence in the GOI's ability to find the cheapest sources of water would have been enhanced.

Operation and Maintenance

Degree of utilization of the pumpset—The percentage of working hours of a pumpset is a strong indicator of the appropriateness of the pumping technology. Three relevant parameters are:

- the relationship of actual to planned utilization;
- the conformity of irrigation system and pumpset design to the farming practices and climate of the area; and
- the degree of adoption of pump irrigation technology by the farming community.

The average percentages of working hours for almost all of the sample pumping systems (Table 20) are relatively low, especially for the intermediate wells. This could be attributed not only to technology inappropriateness but to several other factors:

- location of the well in a system already served by surface water, making its use intermittent (particularly true for intermediate wells);
- very high pumping costs relative to the revenues from many agricultural products (especially crops other than rice with low yields);
- minimized water use by drought tolerant crops such as mungbean, soybean, and tobacco; and
- excessive capacity of the installed pumpset for the area served.

The high percentage of working hours in large river pumping systems occurs because farmers grow rice during the dry season and the number of pumpsets is sufficient to provide all water requirements. In the case of DWT pumpsets, for example in Gunung Kidul and Madura, the conditions are quite different. Pumpsets in Gunung Kidul are designed to irrigate upland crops during the dry season. Since upland crops are more tolerant of water shortage than rice is and pumping is quite expensive, farmers try to minimize the pumping hours. However, because the area often has long dry spells, farmers are sometimes forced to utilize the pumps for rice in the wet season. The difference between the actual discharge and the design discharge ranges from 0.37 to 0.89, or 37 percent to 89 percent (Table 20).

Useful life of irrigation pumping systems—The useful life of a fully operated pumpset, ARUL, is presented in Table 20. This may range from 0 to greater than or equal to 1.0. A value equals 1.0 means the pumpset has just served its design life. A value greater than 1.0 means the pumpset has already exceeded its design life but is still being operated. The average design life is 12,000-14,000 operating hours. Well-constructed pumpsets generally last long, as is demonstrated by deep tubewells that are discharging at about 90 percent of design capacity after being operated for more than 10 years.

System efficiency—The efficiency of pumping systems varies widely. Combined with the range in pumping hours and utilization, the data indicate relatively low system efficiencies (as in Table 22).

Ability of users to keep pumpsets operating—The ability of users and government agencies to keep pumpsets operating is reflected in the frequency of repairs. Repairs are classified as light, medium, and heavy:

- light repairs, can be done by the operator himself (Rp. 5,000-50,000);
- medium repairs require an ordinary mechanic (Rp. 50,100-150,000) and 3-7 days; and
- heavy repairs require the replacement of main components by a skilled mechanic (Rp 150,000-5,000,000).

The frequency of repairs for various pumping systems is shown in Table 22. No data are given for the Lombok deep well turbine pumpsets, which are still under trial. Farmers appear to have difficulties with the proper O&M of large river pumping systems, which very often are damaged because of incorrect design of the pumphouse and pump installation, and incorrect siting that exposes the pumpset to frequent flooding.

Medium and heavy repairs have been necessary at least once on every well studied. Most of the damages have been the result of the power transmission (gearbox) and the driver engine (rings, bearings, and sleeves) wearing out. Replacement parts have been provided by P2AT.

Conclusions

Government Role

Most farmers already have the technology for small river pump, open well, well point, and intermediate well irrigation systems and have paid for it. In these circumstances there is little reason for the government to get involved, except to control the quantities of water withdrawn by regulating the rate of pumping. Similarly, if open wells, well points, and intermediate wells are built where gravity systems exist, government action may be required to prevent conflicts over water between government managed systems and farmer owned pumping systems.

River Pumping Locations

Technical assistance is required at the design stage of large-scale river pumping to ensure a location where the pumpset will be safe from flooding and sedimentation danger. It is also important that downstream users should be protected, and that the required water elevation along the river should be maintained for existing irrigation structures. This can be done through licenses for river pumping issued by a group such as the provincial or district irrigation committee, although these committees should be changed to include private and quasi-private interests (water users groups, tourist hotels, factories, city water suppliers, etc.) as well as government line agencies.

Appropriateness

The appropriateness of technology has to be evaluated in the context of government policy for the regional development of pump irrigation. If deep well turbine pumps are considered appropriate, the government must be prepared to modify its present policy by recognizing the need for a permanent presence to provide heavy maintenance and a supply of spare parts, not available in the local market, for the turbines and gearboxes.[4]

The government may also be forced to continue with a fuel subsidy, since water costs for deep wells are often over Rp. 100,000 per season in poverty areas and on a number of the outer islands that lack markets for high-value crops. Otherwise, as seen at many of the sample sites, utilization will drop because farmers cannot pay for fuel.

[4] Present government policy states that all O&M will be turned over to the users and the wells turned over to local government within two years of project completion.

Table 17

Assistance Needed to Establish Irrigation Pumping Unit

Type of System	Development Stages: Planning	Design	Construction	Remarks
Large river pumping	Planning of return flow system, and water elevation (head) protection along the rivei	Required only for safety	Assistance necessary	License from irrigation committee required
Small river pumping a. permanent b. portable	 Not necessary Not necessary	 Not necessary Not necessary	 Not necessary Not necessary	
Open well and well point pumping	Area planning to avoid over-pumping of groundwater	-do-	-do-	-do-
Intermediate well pumping	Assessment of groundwater potential	-do-	-do-	-do-
Deep well turbine pumping	Assessment of groundwater potential	-do-	-do-	-do-

Source: Field Survey, 1991/1992.

Table 18

Capital Investment Costs for Groundwater Pump Irrigation, 1990/91

Project/ Location	Well	Units	Tubewell	Pump Set	Canal System	Pump House	Access Road	Total Costs
World Bank E. Java								
	DTW	$	15,261	16,187	18,493	4,140	5,922	60,002
	(23.6 ha)	Rp.	28,995	30,756	35,136	7,866	11,251	114,004
		%	25.4%	27.0%	30.8%	6.9%	9.9%	100.0%
		$/ha	647	686	784	175	251	2,542
	ITW	$	4,919	1,766	5,172	1,100	0	12,957
	(8.25 ha)	Rp.	9,346	3,355	9,827	2,090		24,618
		%	38.0%	13.6%	39.9%	8.5%	0.0%	100.0%
		$/ha	596	214	627	133	0	1,571
	STW	$						316
	(4 ha)	Rp.						600
		%						100.0%
		$/ha						79
ADB C. Java								
	DTW	$	10,684	13,684	18,053	3,158	0	45,579
	(30 ha)	Rp.	20,300	26,000	34,300	6,000		86,000
		%	23.4%	30.0%	39.6%	6.9%	0.0%	100.0%
		$/ha	356	456	602	105	0	1,519
	ITW	$	2,421	1,316	5,684	1,579	0	11,000
	(10 ha)	Rp.	4,600	2,500	10,800	3,000		20,900
		%	22.0%	12.0%	51.7%	14.4%	0.0%	100%
		$/ha	242	132	568	158	0	1,100
	STW	$	789	789	632	526	0	2,737
	(4 ha)	Rp.	1,500	1,500	1,200	1,000		5,200
		%	28.8%	28.8%	23.1%	19.2%	0.0%	100.0%
		$/ha	197	197	158	132	0	684

[1] Rp. 1900 = US 1.00

World Bank, Irrigation Sector Project-2 Final Report, Table 5.6

ADB, Central Java Groundwater Irrigation Development Project

Table 19

Percentage of Working Hours of Sample Pumping Systems

Type of system	No. of Samples	Percentage of working hrs/day			Avrg. total working hrs/yr to 1990			Percentage of working hrs/yr to the design			Remarks
		Lowest	Highest	Avrg.	Lowest	Highest	Avrg.	Lowest	Highest	Avrg.	
Large river pumping	4	45.5	90.0	60.6	580	1471	973	48.3	122.6	81.1	All samples are the same as in Table 15
Small river pumping:											
a. permanent	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
b. portable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Open well and well point pumping	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Intermediate well pumping	3	18.2	31.8	25.7	748	888	820	62.3	74.0	68.3	
Deep well turbine pumping:											
a. established	22	34.1	81.8	59.6	425	2,462	1,410	35.4	205.2	117.5	
b. newly installed	7	38.6	43.7	42.1	1,713	2,123	1,917	142.8	176.9	159.8	

Source: Data analysis from field survey, 1991/1992.

n.a. = not applicable

Table 20

Sustainability of Irrigation Pumping Systems

Type of System	No. of samples	Actual discharge Qa (lt/sec)		Design discharge Qt (lt/sec)		Qa/Qd		Age of pumpset, yr		ARUL		SI	
		Range	Avarage	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Large river pumping	4	56.3- 180.0	111.5	200-450	300.0	0.3-0.4	0.37	6-9	7.5	0.8-1.1	0.9	0.2-0.4	0.3
Small river pumping:													
a. permanent	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
b. portable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a..	n.a.	n.a.
Open well and well point pumping	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Intermediate well pumping	3	15.0-16.0	15.6	20-25	23.3	0.6-0.8	0.70	8-10	9.7	1.1-1.3	1.2	0.7-1.0	0.8
Deep well turbine pumping: long time installed	22	15.0- 61.2	24.6	17-90	42.4	0.3-1.0	0.89	5-18	11.6	0.6-2.3	1.5	0.2-2.3	1.5

ARUL uses a design life of 12,000 hours and is formulated as:

ARUL = (Age of pumpset)/(Designed useful life)

n.a. = not applicable

Sustainability index, SI, expresses the sustainability of pumpset's discharge capacity with respect to age of operation. The value of SI represents the physical performance of the well and pump driven engine after a certain period of operation, compared to the design. SI is calculated as:

SI = (Qa/Qd) x ARUL

where Qa is the actual discharge (lt/sec), and Qd is the designed discharge (lt/sec).

Table 21

Age and System Efficiencies of Sample Pumping Systems

Type of System	No. of Samples	Pump Size (in)	Age of pumpset (yrs)	H (m)	Q (1/sec)	Wp (kW)	Ep (kW)	Es (%)	Remarks
Large river:	4								
a. average			7.5	7.6	107.8	7.3	44.1	10.3	
b. lowest		10	6	5.7	56	4.9	29.4	5.7	
c. highest		12	9	8.9	187	10.4	58.8	16.9	
Small river pumping:									
(i) permanent	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No sample taken
(ii) portable	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No sample taken
Open well and well point pumping	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No sample taken
Intermediate well pumping	4								Samples taken from Nganjuk, E. Java
a. average				7.9	26.0	2.8	11.0	12.6	
b. lowest		4	8	3.0	17	0.6	6.6	10.0	
c. highest		6	10	18.0	50	8.8	25.0	20.3	
Deep well turbine pumping:									
(i) established	22								Samples taken from Gn. Kidul, Nganjuk, Kediri, and Madura
a. average			11.6	22.6	24.6	8.3	21.4	17.0	
b. lowest		8	5	16.1	15.0	3.1	13.2	8.8	
c. highest		10	18	36.6	61.2	21.9	35.3	35.3	
(ii) newly installed	7								Samples taken from Pringgabaya, Lombok
a. average			3.4	14.7	15.7	2.4	11.5	7.2	
b. lowest		2	6.7	15.0	1.0	10.3	2.4		
c. highest		4	24.0	20.0	3.6	11.8	11.6		

Source: Data analysis from field survey, 1991/1992.

Note H: Total dynamic head of pumping (m)
Q: Actual discharge as measured in the field (1/sec)
Wp: Water power (kW)
Ep: engine power as indicated in the specification (kW)
Es: System efficiency (%)

n.a. = not applicable

Note: Optimum Ee for Diesel engine is 43.9-49.5%, which corresponds to an Es for turbine pump of 26.3-29.7% (Ferguson, 1987).

Table 22

Frequency of Repairs of Sample Pumping Systems

No.	Type of Pumping System	Age of pumpset (yrs) Range	Average	Total No. of Repairs at Diff. Levels 1	2	3	Remarks
1.	Large river pumping (4 Pump sets)	6-9	7.5	—	12	32	Data taken during the last 5 yrs of operation
2.	Small river pumping:						
	a. permanent	n.a	n.a	n.a.	n.a.	n.a.	
	b. portable	n.a	n.a	n.a.	n.a.	n.a.	
3.	Open well and well pumping	n.a	n.a	n.a.	n.a.	n.a.	
4.	Intermediate well pumping (3 wells)	8-10	9.7	n.a.	n.a.	3	One pump set broken since 1989
5.	Deep well turbine pump (old wells) (22 wells)	5-18	11.6	44	22	22	Based on the last 3 yrs of operation

Source: Data analysis from field survey, 1991/1992.

n.a. = not applicable

Repair Level 1: Repairs costing less than Rp. 50,000 and requiring less than 3 days

Repair Level 2: Repairs costing more than Rp. 50,000 and less than Rp. 150,000 and requiring3-7 days

Repair Level 3: Repairs costing more than Rp. 150,000 and requiring more than 7 days, usally paid for by the government

6

ECONOMIC VIABILITY OF PUMP IRRIGATION

Introduction

Successful pump irrigation programs have demonstrated that farmers can take complete responsibility for operation and maintenance provided:

- operational costs are in line with the benefits obtained;
- users have the requisite technical knowledge and easy access to spare parts; and
- the number of users served by a system is small enough to be organized into a cooperative group.

Both the Philippines and Indonesia have found no difficulty in turning over irrigation systems to WUA when these simple requirements have been met. In contrast, Pakistan and India have found it very difficult to do the same because their deep tubwells are expensive to operate and cannot be maintained and repaired with local skills. In addition, these wells serve large numbers of farmers over a dispersed area, making management by the users socially and organizationally very difficult.

Investments in pump irrigation in Indonesia, whether by the GOI, NGOs, or private individuals, have been made with the eventual goal of reaching a point where assistance with O&M will no longer be necessary and the users can plan for future expansion, major repairs, and replacement.

Findings

The economic viability of pump irrigation is directly related to the degree of utilization and the benefits obtained. Obviously, if the pump is not utilized it will provide no benefits, or if it provides no benefits it will not be utilized. Thus, most pump irrigation schemes, particularly those developed with public resources, have tended to underwrite pumping costs to encourage utilization. Except for small private river pumps in West Java and shallow farmer-owned wells in East Java, all the pumps studied received government support.

Irrigated Cropping Intensities

To encourage use of the pumps, the GOI has been providing a fuel subsidy for the first two years, and in some areas longer than that. Yet, once the subsidy is removed, pumping hours have tended to decline rather than increase as farmers learn more about the value of the water (Figure 8). Instead of the 300 percent increase in cropping intensity predicted by the planners for almost all the systems studied, average cropping intensity—which compares land actually irrigated with the design area—did not exceed 170 percent at the research sites. One reason that annual pumping is much less than planned is that the area served is usually far less than the design area and, thus, the actual cropping intensity is much less than the planned cropping intensity. This comparison is presented in Table 23. In theory, there should be less of a problem with buried distribution systems, but to date most buried systems in Lombok have shown cropping intensities no higher than surface distribution systems. For example, well T-10 with a design service area of 17.6 ha served only 4.1 ha in the first dry season and 4.23 ha in the second. Similarly, well SEC-126 with a design area of 20 ha is serving only 10.8 ha in the first dry season and 11.8 in the second.

The irrigated crop indexes are much lower than the original intensities used to justify investment (Table

23), partly because of technical factors such as poorly constructed and maintained distribution systems and smaller than designed pump discharges, but largely because of the failure to include extension and credit facilities in the programs. As a result, the pumps are not utilized enough to reach the desired cropping intensities, and crop increases do not provide the desired increases in income. This is particularly true in a poor area like the eastern part of Lombok, where farmers do not have the means to prepare the land properly and purchase the needed inputs. Annex D provides a map of the planned area irrigated by the sample pumps.

Government Involvement

Most pumps continue to receive some government assistance, the older pumps in Yogyakarta and East Java with major maintenance, the newer pumps in East Java, Madura, and Lombok with an allocation of fuel and lubricants and with major repairs. Yet, even with this support, farmers are still paying much more for their water than farmers with access to public surface irrigation.

Data collected for the 1990/1991 cropping seasons as part of the field study indicate that for some farmers in pump irrigation areas as much as 55 percent of input costs are for water, although on average these range from 15-30 percent (Table 24). A farmer growing an irrigated crop during the wet season as well as the three possible dry seasons might end up paying in excess of Rp. 250,000 per ha in water fees during a complete crop year. Although the average is likely to be from Rp. 100,000 per ha to Rp. 150,000 per ha, this is still about six times the Rp 18,000-25,000 per ha now charged under the Irrigation Service Fee program.[5]

Yet, farmers in pump irrigation areas are paying only for O&M and nothing toward capital investment and, thus, less than the water actually costs (Table 25). Annual water fees paid by pump irrigation farmers in Madura in East Java, and Subang, in West Java cover approximately 50 percent, and by pump irrigation farmers in Yogyakarta only about 30 percent, of actual costs. If the costs of groundwater exploration and dryholes, payments to contractors, and government line agency expenses are added, the real costs are often three to five times what farmers are paying.

Ex-Post Analysis

Using the irrigated cropping intensities, the actual costs of the pump schemes, and the crop yields obtained by farmers, it is possible to make an ex-post analysis of the research projects. As recommended by standard economic procedures, such an analysis is made on a with-and-without basis, rather than a before-and-after basis that would ignore the changes in agricultural production during the last decade. All costs have been converted to 1990 rupiah, using the consumer price indexes of major cities near the research sites taken from Consumer Price Indexes for 17 Major Cities in Indonesia published by the Office of the Bureau of Statistics. With-project data were obtained from the farms sampled in field surveys. Some data from nearby fields without pump irrigation were also collected and in some cases supplemented by data from project monitoring units and from government agencies and NGOs active in the areas.

Pumping Hours and With- and Without-Net Returns

Table 26 shows the annual hours of use per pump and summarize the net returns for the major irrigated and non-irrigated crops used in the study. More details on agricultural practices, yields, and input levels are provided in Appendix I in the 1992 report,

[5] Dr. Ir. Jan L.M.H. Gerards, Irrigation Service Fee (ISF) in Indonesia, paper presented at LP3ES, Jakarta, December 7, 1990.

Studi Kebijaksanaan Irigasi Pompa di Indonesia, by the *Pusat Penelitian Social Ekonomi Pertanian* in Bogor. Data from this report are presented in Annex E. As can be seen in Table 27, when farmers did not irrigate their wet season crops, they often had the same net returns in both the with and without areas. This is understandable, as crops grown in the command area without using the pumps are the same as crops grown where there are no pumps. This is particularly true for wet season rice.

These crop returns illustrate the wide variation in yields in different areas. In a number of cases, the similarity in yields inside and outside the pump irrigation areas during the wet season demonstrates the detrimental impact of not using the pumps for supplemental water. In most of the schemes, particularly in poor areas, farmers do not use the pumps in the wet season because of the high cost of fuel, which is surprising considering the difference in the returns from irrigated and non-irrigated rice should easily cover this cost. One likely explanation for this is that they do not have access to HYV technology or that they have a problem obtaining the fuel or credit to take advantage of the yield difference. (In Java, wet season irrigated rice yields often exceed 6t/ha while rainfed rice yields are less than 4.5 t/ha.)

Irrigation Energy Model

In order to incorporate data on crops, water requirements, and water pumping, the with-and-without analysis used the Irrigation Energy Model developed by Jack Keller, David Seckler, D. Sheng, and D. Molden (1989). In addition to providing information about the economics of each pump scheme, this model also provides an analysis of energy requirements and a means of comparing monthly crop water requirements with monthly pumping schedules. It calculates overall pumping system and irrigation efficiencies and distribution system losses, and can be used for design as well as analysis. It yields more information than is used in this study, but this information does serve as a useful check on the designs of various systems. Annex F presents input and output data for four of the sample pumps.

Table 27 (A-C) details the costs of some of the systems evaluated, both in actual and 1990/91 Rupiah and in constant dollars. Given the time span over which the systems were developed and the variations in service area and technology, the costs vary widely. Three sets of B/C ratios, calculated from these costs and the data from Tables 23, 24, 25, and 26 assume a 30-year time frame, a 15 percent interest rate, and yields remaining constant over the 30 years. Since most of the wells sampled are mature wells, this assumption tends to overestimate actual life-of-project economic returns but is adaequate for this analysis. The B/C ratios are presented in Table 28. The first set evaluates the benefits and costs as if the pumps had been developed without any outside assistance. The second set includes interest and local government assistance costs. The third set includes some of the technical assistance costs. The main difference between the last two is the inclusion of international technical assistance costs.

Based on the actual costs of the pump systems and excluding any interest payments, pump irrigation committee costs, expenses of maintaining the P2AT field offices and workshops, and the costs of major repairs and replacements, the B/C ratios for less than half the public pump irrigation systems are 1:1 or better. Because of the emphasis on large irrigation systems serving much less than the design area, combined with relatively low yields and only two crop seasons a year, only two of the NGO-supported systems in Subang in West Java have B/C ratios better than 1:1, even though much of the construction was done by local labor instead of a contractor.

The other two sets of B/C ratios show that when all the costs of development are included, pump irrigation in Indonesia has yet to prove itself economically viable. The extensive use of outside consultants and excessively high installation costs compared with those in other countries in the region have pushed costs beyond the level that returns from agriculture can support. Only in the limited areas where high-value specialty crops such as tobacco and shallots can be grown is it possible to justify the present high costs of public pump irrigation investment.

Poverty Alleviation

Most systems have been installed in areas of poverty with the idea that they would eliminate water shortages and thus substantially improve farm income. Using Table 7.3.4 from the *Studi Kebijaksanaan Irrigasi Pompa di Indonesia* (Appendix I), total land utilization in all the areas has increased, ranging from an expansion of 22 percent to 100 percent in cropped area.

With and Without Pump Irrigation Income Differences

As expected, increases in cropped area have increased farm income. Table 29 provides an approximation of the benefits from the installation of pumps in the irrigated service areas based on 1990/91 crop production data. Before water fees, the annual increase in farm income is $217,240 ($181.62/ha); after water fees, it is $159,082 ($132.98/ha). Therefore, based on design area, annual farm incomes have increased by approximately $133/ha after payment of fees. Assuming an average farm size of 0.5 ha, annual farm family income has increased by $66.50 per year compared with the income of farmers without access to pump irrigation. In addition, increased cropping intensities have increased the use of hired labor.

Welfare Concerns

Although fees are higher than in areas served by surface irrigation systems (Table 25), they are still less than half the costs of providing the water. The annual costs of equipment and operation—ignoring interest costs, line agency expenses, contractor fees, taxes, duties, and indirect costs—are approximately $173,260. If farmers were required to purchase the equipment, the income increase would have been $43,981, or $36.83 per ha of design area. Thus, GOI assistance has amounted to a welfare transfer of approximately $100 per ha per year, or $50 per farm family per year assuming the average farm is 0.5 ha.

Conclusions

In terms of economic efficiency, returns on public investment in pump irrigation are less than satisfactory. The relatively low cropping intensities and limited number of hours of pump use have yielded income increases that are less than expected. Perhaps these low rates of return should not come as a surprise as the 1984 ex-post analysis of Gunung Kidul calculated an ERR of 3 percent using actual rather than projected benefits (MacDonald, 1984). Similarly, the P2AT deep tubewells funded under the Seventeenth Irrigation (East Java province) Project have been downgraded to an ERR of 4 percent based on actual project cropping patterns and yields.

The B/C ratios in this study indicate that the systems being developed with public resources will continue to require a significant degree of government or NGO assistance, especially the older schemes where most of the pumpsets have exceeded their design life and will need to be replaced within a few years at public expense.

However, in contrast to the situation often found in other countries in Asia, most wells are still operational and have exceeded their design life, suggesting that the support services provided by P2AT have been adequate. Since many of the schemes are located in the poorer areas where farmers are less technically advanced, the demands on P2AT are heavy and the government's willingness to meet them shows a geniune commitment to equity and poverty alleviation.

Recommendations

The following recommendations will not resolve the conflict between a dedication to rural uplift and the use of a technology that is economically unsound, but at least they will help to minimize the need for continuing government assistance.

1. In areas such as Central and Eastern Java, where farmers have already demonstrated their willingness to invest in small-scale pump irrigation technology, government investment should never compete with local initiative. The situation in East Java, where the price of groundwater sold by farmers forces government deep tubewells to sell water below cost, shows there is no justification for public investment in pump irrigation in such areas.

2. Even though an offer by a foreign government to provide the pumps or engines under a grant may appear too good to refuse, experience proves that such an offer is often not as good as it looks. Yogyakarta and Lombok, where foreign-made engines and pumps have been used, should provide a valuable lesson. Equipment that cannot be maintained locally—especially as in Lombok, where the required spare parts are not available anywhere in the country—clearly demonstrates the trap associated with grant-provided hardware. How can farmers, or even the local government, take responsibility for pump irrigation schemes if they cannot obtain the parts to keep the equipment operational? With the present availability of good indigenous engines and centrifugal pumps, all future pump schemes (grant or loan) should be restricted to such equipment.

3. The government should not invest in turbine pumps for which there is no reliable local supply of spare parts, unless it plans to operate the equipment itself. If this policy is considered too restrictive, the GOI should seriously investigate the establishment of a joint venture with a reputable multinational turbine pump manufacturer.

4. Pump irrigation has its highest payoff providing water for crops other than rice during the dry seasons. However, Indonesian farmers, especially in the lower income areas, are often not experienced in producing, processing, and marketing such crops. In order to improve the returns from public pump irrigation investment, better technology, agricultural extension (in the public or the private sector), and market mechanisms must be made available along with the equipment. With the present focus on P2AT and the equipment side, returns will continue to be lower than their potential. As has been demonstrated in northeast Thailand (Johnson et al. 1989), water is necessary but not sufficient to guarantee increased agricultural production.

5. The amounts farmers presently are paying for pump irrigation water are a strong indication of the real value of water. These amounts are even more striking when compared with the relatively small irrigation fees that farmers (in a limited number of areas) pay for surface irrigation water. A contradiction in policy occurs when farmers in poverty areas, where most pump irrigation schemes are in operation, are asked to pay five times what farmers in richer areas are paying. Annex G illustrates the high percentage of input costs in relation to pumping costs. Since pump irrigation schemes are also poverty alleviation schemes, a policy that standardizes irrigation fees will be more equitable and encourage increased utilization of pump irrigation facilities.

6. In addition to a rationalization of fees, easier credit for low-income farmers will also ensure better pump utilization. At present, many farmers do not use the pumps because they cannot afford to invest in high-yielding crops and pay for fuel. Credit linked to pump operation will ease this constraint and in turn ensure higher returns on pump irrigation water.

7. The present policy of providing a fuel ration and assistance with maintenance for the first two years and then turning the pumpsets over to the local government has not worked. Even in East Java, where farmers are more skilled and better prepared for intensive agriculture, assistance has been necessary for more than 10 years. If pump irrigation investment is to continue in poverty areas in eastern Indonesia, where farmers are not knowledgeable about irrigation and high-value crops other than rice, there must be provision for continuing support, particularly with maintenance and replacement.

Table 23

Design and Actual Irrigated Cropping Areas and Intensities

Tubewell Name	Design Area (ha)[1]	Wet Season (ha)[2]	Dry1 Season (ha)	Dry2 Season (ha)	Dry3 Season (ha)	Total Irr. Area (ha)[3]	Irrig Crop Index[4]
Mad. 009	23.50	0.00	9.50	9.50	0.00	19.00	0.81
Mad. 066	44.20	8.61	51.92	42.68	0.00	103.21	2.34
Mad. 094	42.90	0	30.03	30.03	21.45	81.51	1.90
Mad. 097	39.70	0.00	39.70	39.70	0.00	79.40	2.00
Mad. 102	32.30	0.00	28.60	29.00	0.00	57.60	1.78
Ngan. 116	20.54	4.50	7.60	7.60	0.00	19.70	0.96
Ngan. 117	21.56	10.00	9.70	5.00	4.10	28.80	1.34
Ngan. 138	24.12	10.00	9.90	5.38	2.48	27.76	1.15
Ngan. 153	32.97	0.00	15.13	16.74	0.00	31.87	0.97
Ngan. 152	43.93	0.00	30.30	24.16	0.00	54.46	1.24
Ngan. 174	44.14	0.00	15.01	15.01	0.00	30.02	0.68
Ked. 010	49.21	0.00	24.46	33.46	0.00	57.92	1.18
Ked. 061	37.95	0.00	37.95	37.95	0.00	75.90	2.00
G.K. 005	46.40	8.20	37.12	30.16	14.85	90.33	1.95
G.K. 008	49.00	11.30	36.75	24.99	20.09	93.13	1.90
G.K. 011	30.50	18.90	30.50	22.88	14.94	87.22	2.86
G.K. 019	44.00	10.60	35.20	29.92	10.12	85.84	1.95
G.K. 020	11.00	1.87	10.01	9.02	7.04	27.94	2.54
G.K. 021	62.00	11.50	43.40	43.40	24.80	123.10	1.99
G.K. 022	41.20	15.50	21.84	22.78	9.48	69.60	1.69
Sidajaya	72.00	59.76	59.76	0.00	0.00	119.52	1.66
Sidamuly	90.00	60.30	41.40	0.00	0.00	101.70	1.13
Chihambl	200.00	110.00	80.00	0.00	0.00	190.00	0.95
Kiarsari	91.00	70.07	73.71	0.00	0.00	143.78	1.58

[1] Total design area of the respective research pump irrigation schemes.

[2] Zero during wet season indicates farmers grow rainfed instead of irrigated rice.

[3] Total area within the design area actually served during a year.

[4] Total number of hectares served in the respective research schemes divided by the total design area. Given that some of the areas have four growing seasons, this number could theoretically be 4.0 or even larger if the farmers can serve an area in excess of the design area.

Note: This data is based on the cropping seasons covering 1990 and 1991. Areas where the wet season crop is 0.0 do not reflect fallow fields, but instead indicate the farmers chose not to use the pumps but simply used the available rain. In general, all of these systems were designed for 300% cropping intensity.

Source: Recana Pembangunan Pengairan Jangka Panjang (Tahum 2000), Dirjen Irigasi, DPU

Table 24

Typical Water Costs per Season per Ha for Pump Irrigation at Research Sites[1]

Province Area	E. Java Nganjuk/Kedira	Madura South & East	W. Java Subang	Yogya Karta G. Kidul
Wet Season rice)				
Maximum				
$/ha	13.44	36.18	40.10	24.02
Rp./ha	25,542	68,750	76,187	45,630
Minimum				
$/ha	2	2		
Rp./ha				
Dry Season 1				
Maximum				
$/ha	52.40	52.63	71.31	46.67
Rp./ha	99,569	100,000	135,484	88,667
Minimum				
$/ha	3.19	28.34	33.73	3.20
Rp./ha	6,056	55,000	64,081	6,077
Dry Season 2				
Maximum				
$/ha	51.17	65.50	No	58.14
Rp./ha	97,229	124,444	Pumping	110,467
Minimum				
$/ha	9.81	17.91		15.79
Rp./ha	18,638	34,028		30,000
Dry Season 3				
Maximum				
$/ha	51.97	No	No	48.95
Rp./ha	98,750	Pumping	Pumping	93,000
Minimum				
$/ha	39.47			11.81
Rp./ha	75,000			22,440

[1] Based on the averages for all the pumps surveyed in the area where Rp. 1900 = $ 1.00

[2] Farmers with a payment of Rp 0 did not irrigate but grew a rainfed crop.

Table 25

Annual Pump Irrigation Water Fee Payments versus Actual Annual Costs for Pumps

Province and Area	Annual Water Pumped per Irr. ha Served/yr (m^3)	Actual Average Payment per Irr. ha/yr (US $)	Total O, M & Capital Costs per Irr. ha/yr[1] (US $)	Total Water Costs per cu m (US $/$m^3$)
E. Java	8086	$111 211,667[2]	$246 467,323	$0.031 68.90
Madura	7780	$93 176,500	$201 381,119	$0.023 43.77
Yogyakarta Gunung Kidul	8031	$72 136,991	$266 504,676	$0.033 62.70
W. Java Subang	8843	$66 123,610	$103 194,908	$0.012 22.80

[1] Average annual costs over 25 years, including capital investment and O&M costs, but excluding interest, contractor and P2AT overhead costs, and WUA Executive Committee payments. These costs are calculated on the basis of the largest amount of land served at least once in a command area. For example, if the design area is 30 ha and the maximum area irrigated area during the first dry season is 28 ha, the total fees are an average for that 28 ha, not for the number of hectares irrigated per year which might be 0 + 28 + 20 + 5 for a total of 53 ha.

[2] Indonesian Rupees at Rp. 1900 = US $1.00.

Table 26

Pumping Hours and Net Returns in 1990/91 $ for Major Irrigated and Non-Irrigated Crops

TUBEWELL NAME	Orignl Design Area (ha)	Annual Pumping Hours (hrs)	Wet Rice Inside ($/ha)	Wet Rice Outside ($/ha)	Dry1 Rice Inside ($/ha)	Dry1 Maize Inside ($/ha)	Dry1 Maize Outside ($/ha)	Dry2 Maize Inside ($/ha)	Dry2 Maize Outside ($/ha)	Dry3 Maize Inside ($/ha)	Dry1 Soya Inside ($/ha)	Dry1 Soya Outside	Dry2 Soya Inside ($ha)	Onions1 Inside ($/ha)	Onions Outside ($/ha)	Onions2 Inside ($/ha)	Tobacco1 Inside ($/ha)	Tobacco Outside ($/ha)
Mad. 009	23.50	1326	347	250			83		83					226		228		
Mad. 066	44.20	2357	484	363				72									679	539
Mad. 094	42.90	1371	447	276					173								617	478
Mad. 097	39.70	2160	412	358				118	56								865	713
Mad. 102	32.30	942	428	357				3[illegible]									784	553
Ngan. 116	20.54	1141	538	358	327	239	126	144										
Ngan. 117	21.56	1082	534	422	313			325										
Ngan. 138	24.12	1185	252	213				186		104	133	97	131					
Ngan. 153	32.97	888	425	365	408	197	166	178		256			344					
Ngan. 162	43.93	1196	398	242				148			197	117						
Ngan. 174	44.14	1075	452	365				116			176	128						
Ked. 010	49.21	2180	316	285	196	120	110	148						641				
Ked. 061	37.95	1423	231	214		135	83	334						391	83	173		
G.K. 006	48.40	3299	291	303					134		246	98	148					
G.K. 008	49.00	2718	217	200						214	190	132	203					
G.K. 011	30.50	2817	188	183	98					116	275	94	38					
[illegible]. 019	44.00	3015	199	161	260			68		286	146	89	117					
G.K. 020	11.[illegible]0	1416	182	86				111		168	259	89	245					
G.K. 021	62.00	3004	200	167						141	163	88	91					
G.K. 022	41.20	2622	478	161	86			190		286	243	89	176					
Sidajaya	72.00	24[illegible]6	231	252	181													
Sidamuly	90.00	1838	271	210	213													
Chihambi	200.00	1378	246	273	223		175											
Kiarsari	[illegible]1.00	3176	289	225	224		105											

Note: Based on data collected in research sites related to 1990/91 seasons. Those without data were collected at the same time, but were supplemented with data from other sources when necessary.

Table 27

Costs of Sample Pumps in East Java

Location		E.J.	E.J.	E.J.	E.J.	E.J.	E.J.	E.J.
Type		DTW	DTW	DTW	DTW	ITW	STW	DTW
Name/No.		TW 017kn	TW 033kn	Nganjuk	New	New	New	New
Year		1980	1980	1988	3/1991	3/1991	3/1991	11/1991
Area (ha)		21.30	38.75	50.00	23.60	8.25	8.00	35.00
Engine	Rp.	3,159,871	5,980,456	15,000,000	16,756,000	2,355,000	1,400,000	19,000,000
	90/91Rp	7,870,676	14,896,251	17,540,633	16,756,000	2,355,000	1,400,000	19,000,000
Pumpset	Rp.	2,000,000	4,200,000	14,000,000	14,000,000	1,250,000	16,000,000	
	90/91Rp	4,981,644	1,0461,452	16,371,257	14,000,000	1,250,000		16,000,000
Pump house	Rp.	2,899,450	3,370,000	4,705,200	7,866,000	2,090,000		
	90/91Rp	7,222,014	8,394,070	5,502,146	7,866,000	2,090,000		
Canals	Rp.	2,765,467	2,987,852		35,136,000	9,827,000		55,650,000
	90/91Rp	6,888,286	7,441,709		35,136,000	9,827,000		55,650,000
Well	Rp.	1,934,769	1,934,769	2,900,000	28,995,000	9,346,000		40,400,000
	90/91Rp	4,819,165	4,819,165	3,391,189	28,995,000	9,346,000		40,400,000
Other	Rp.	436,200	607,570	8,967,200	11,251,000			7,000,000
	90/91Rp	1,086,497	1,513,349	10,486,024	11,251,000			7,000,000
Total (Rp)		13,195,757	19,080,447	45,572,400	114,004,000	24,868,000	1,400,000	138,050,000
Total (Rp. 1990/91)		32,868,281	47,525,997	53,291,250	114,004,000	24,868,000	1,400,000	138,050,000
Total (US$)		17,299.10	25,013.68	28,048.03	60,002.11	13,088.42	736.84	72,657.89

Note: Data are from a variety of sources, including project reports and World Bank project appraisal documents.
Rp. 1900 = US$1.00

Table 28

Costs of Sample Pumps in Madura

Location		MAD	MAD	MAD	MAD	MAD	MAD
Type		DTW	DTW	DTW	DTW	DTW	DTW
Name/No.			TW 09	TW 098	TW 102	TW 066	TW 097
Year		1990	1978	1986	1986	1983	1986
Area (ha)		24.00	24.00		32.00	44.00	40.00
Engine	Rp.	16,605,600	7,850,000	9,825,000	7,450,000	7,850,000	9,700,000
	90/91Rp	16,605,600	28,973,565	13,634,279	10,338,461	13,568,214	13,460,815
Pumpset	Rp.	14,074,800	5,000,000	8,000,000	7,000,000	5,000,000	8,125,000
	90/91Rp	14,074,800	18,454,500	11,101,703	9,713,990	8,642,175	11,275,167
Pump house	Rp.	4,705,200	800,000	5,200,000	4,600,000	2,400,000	4,600,000
	90/91Rp	4,705,200	2,952,720	7,216,107	6,383,479	4,148,244	6,383,479
Canals	Rp.	10,868,750	5,163,000	53,351,000	36,400,000	13,598,000	34,000,000
	90/91Rp	10,868,750	19,056,117	74,035,871	50,512,750	23,503,258	47,182,239
Well	Rp.	4,850,200	1,550,000	14,900,000	14,900,000	8,640,000	14,900,000
	90/91Rp	4,850,200	5,720,895	20,676,922	20,676,922	14,933,678	20,676,922
Other	Rp.						1,400,000
	90/91Rp						1,942,798
Total (Rp)		51,104,550	20,363,000	91,276,000	70,350,000	37,488,000	72,725,000
Total (Rp. 1990/91)		51,104,550	75,157,797	126,664,883	97,625,603	64,795,570	100,921,421
Total (US$)		26,897.13	39,556.74	66,665.73	51,381.90	34,102.93	53,116.54

Note: Data are from a variety of sources, including project reports and World Bank project appraisal documents.
Rp. 1900 = US$1.00

Table 29

Costs of Sample Pumps in Yogyakarta

Location		Yogyakarta	Yogyakarta	Yogyakarta	Yogyakarta	Yogyakarta
Type		DTW	ITW	DTW	DTW	DTW
Name/No.		TW 21/23	GunungKidul	GunungKidul	GunungKidul	Playen
Year		1979	1984	1984	1984	1979
Area (ha)		50.00	10.00	20.00	30.00	25.20
Engine	Rp.	7,000,000	6,365,000	7,251,000	8,692,000	6,700,000
	90/91 Rp	22,175,178	9,710,887	11,062,631	13,261,121	21,224,813
Pumpset	Rp.	5,000,000	5,000,000	5,500,000	6,000,000	5,300,000
	90/91 Rp	15,839,413	7,628,348	8,391,183	9,154,018	16,789,778
Pump house	Rp.	1,770,000	2,300,000	2,300,000	2,300,000	2,800,000
	90/91 Rp	5,607,152	3,509,040	3,509,040	3,509,040	8,870,071
Canals	Rp.	8,050,000	6,521,000	12,752,000	19,128,000	3,000,000
	90/91 Rp	25,501,456	9,948,892	19,455,339	29,183,009	9,503,648
Well	Rp.	5,500,000	22,872,000	22,872,000	22,872,000	7,939,000
	90/91 Rp	17,423,354	34,895,116	34,895,116	34,895,116	25,149,820
Other	Rp.	4,035,000				
	90/91 Rp	12,782,406				
Total (Rp)		31,355,000	43,058,000	50,675,000	58,992,000	25,739,000
Total (Rp. 1990/91)		99,328,958	65,692,283	77,313,309	90,002,304	81,538,130
Total (US$)		52,278.40	34,574.89	40,691.22	47,369.63	42,914.81

Note: Data are from a variety of sources, including project reports and World Bank project appraisal documents.
Rp. 1900 = US$1.00

Table 30

B/C Ratios for Research Wells

TW	Design Area (ha)	Irrigated Cropping Intensity (%)	Total Irrigated Area (ha)	B/C[1] Ratio	IRR[1] (%)	B/C[2] Ratio	IRR[2] (%)	B/C[3] Ratio	IRR[3] (%)
E.Java Madura									
TW 09	23.50	80.9	19.00	0.85	9.0	0.74	3.0	.61	
TW 066	44.20	233.5	103.21	1.46	31.0	1.27	24.0	1.04	17.0
TW 094	42.90	190.0	81.51	1.15	19.0	1.00	15.0	.81	9.0
TW 097	39.70	200.0	79.40	1.32	25.0	1.14	20.0	.93	12.0
TW 102	32.30	178.3	57.60	0.94	13.0	0.80	9.0	.65	2.0
Averages				1.14	19.4	0.99	14.2	.81	
Nganjuk									
TW 116	20.54	95.9	19.70	0.99	15.0	0.86	9.0	0.69	
TW 117	21.56	133.6	28.80	0.96	14.0	0.83	8.0	0.69	
TW 138	24.12	115.1	27.76	0.69		0.61		0.50	
TW 152	43.93	124.0	54.46	0.99	15.0	0.87	09.1	0.71	3.0
TW 153	32.91	96.8	31.87	1.30	24.0	1.12	19.0	0.92	12.0
TW 174	44.14	102.0	45.03	0.53		0.44		0.37	
Averages				0.91		0.78		0.65	
Kediri									
TW 10	49.21	117.8	57.92	1.48	29.0	1.28	23.0	1.06	17.0
TW 061	37.95	200.0	75.90	1.89	42.0	1.64	35.0	1.30	24.0
Averages				1.69	35.5	1.46	29.0	1.18	20.5
Owner	11.30	273.7	30.91	4.42	195.0	3.98	170.0		
Renter	4.53	256.3	11.61	1.03	17.0[4]				
Yogyakarta									
TW 05	46.40	194.7	90.33	0.92	12.0	0.80	5.0	0.66	
TW 08	49.00	190.1	93.13	0.93	13.0	0.79	7.0	0.64	
TW 11	30.50	286.0	87.22	0.85	9.0	0.74		0.60	
TW 19	44.00	169.0	85.84	1.11	19.0	0.97	14.0	0.79	5.0
TW 20	11.00	254.0	27.94	0.45		0.39		0.32	
TW 21	62.00	198.5	123.10	0.63		0.54		0.44	
TW 22	41.20	168.9	69.60	1.28	24.0	1.10	18.0	0.75	4.0
Averages				0.88		0.76		0.60	
W.Java									
SIDAJAYA	72.00	166.7	119.52	1.09	20.0	0.97	13.0	0.83	3.0
SIDAMULYA	90.00	113.0	101.70	0.88	8.0	0.78		0.67	
CIHAMBULU	200.00	95.0	190.00	0.59		0.53		0.44	
KIARASARI	91.00	158.0	143.78	1.11	23.0	1.02	16.0	0.90	8.0
Averages				0.92		0.83		0.71	

[1] B/C ratios are calculated at 15% interest rate spread over a 30 year operating slice of the systems.

[2] B/C ratio and IRR includes an additional amount to account for interest and local government expenses.

[3] B/C ratio and IRR accounts for all development costs including contractor and outside technical assistance

[4] Lets small centrifugal pump at Rp. 700 per hour for 1,000 hours per year.

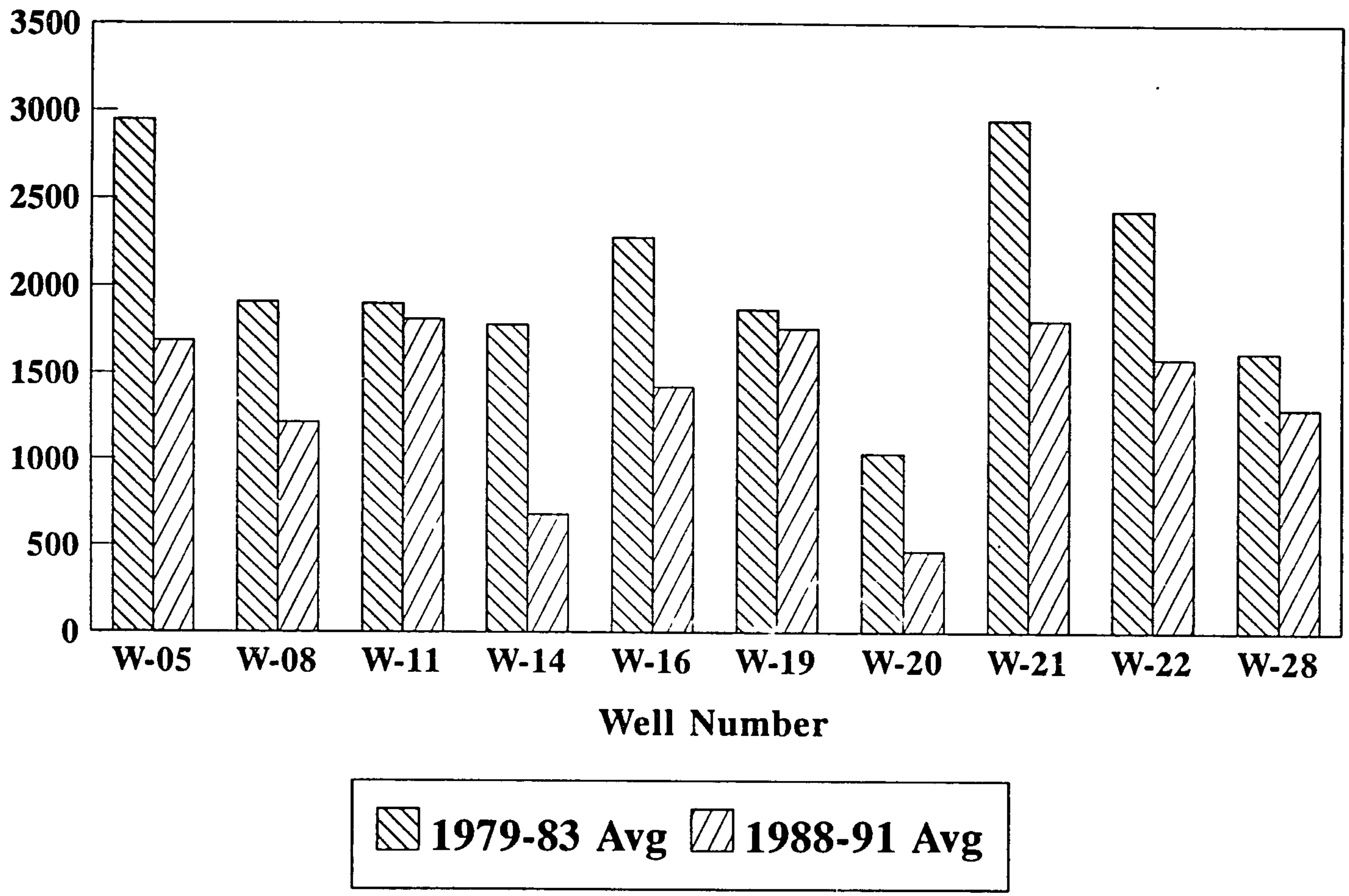
Table 3

Annual Economic Returns With and Without Pump Irrigation Based on 1990/91 Crop Year Data

Tubewell Name	Design Area (ha)	With Total Reutrn ($)[1]	With Less Water Fee Total ($)	Without Total Return ($)	Incremental Income Increase ($)	Incremental Income Less Fees ($)	Annual Water Fee ($)	Water Fees Per Cubic M ($/m³)	Avg Water Fee ($/ha)
Mad. 009	23.50	11,199	10,500	5,774	5,425	4,726	699	0.006	37
Mad. 066	44.20	57,968	53,946	42,713	15,256	11,233	4023	0.008	39
Mad. 094	42.90	35,663	32,677	22,643	13,020	10,035	2985	0.010	37
Mad. 097	39.70	51,412	48,277	42,737	8,674	5,540	3134	0.007	39
Mad. 102	32.30	31,886	30,103	23,499	8,387	6,605	1783	0.013	31
Ngan. 116	20.54	6,941	6,558	2,575	4,366	3,983	383	0.006	19
Ngan. 117	21.50	7,162	6,551	4,446	2,716	2,105	611	0.010	21
Ngan. 138	24.12	5,959	4,662	2,579	3,380	2,083	1297	0.019	47
Ngan. 153	32.97	20,429	18,795	11,081	9,348	7,713	1634	0.009	51
Ngan. 152	43.93	20,246	18,427	9,902	10,345	8,526	1819	0.008	33
Ngan. 174	44.14	11,151	9,706	7,399	3,752	2,307	1445	0.027	48
Ked. 010	49.21	22,823	19,806	12,681	10,142	7,124	3018	0.013	52
Ked. 061	37.95	24,802	22,099	13,783	11,019	8,316	2703	0.010	36
G.K. 005	46.40	26,387	23,980	13,976	12,411	10,004	2407	0.008	27
G.K. 008	49.00	23,454	20,721	11,711	11,743	9,010	2733	0.011	29
G.K. 011	30.60	11,896	10,140	4,607	7,288	5,532	1756	0.007	20
G.K. 019	44.00	18,315	16,247	6,410	11,905	9,838	2068	0.007	24
G.K. 020	11.00	4,163	3,642	1,060	3,102	2,582	520	0.006	19
G.K. 021	52.00	22,766	19,896	10,453	12,307	9,437	2870	0.005	23
G.K. 022	41.20	13,002	11,529	9,605	3,397	1,924	1473	0.006	21
Sidajaya	72.00	24,621	21,061	15,060	9,562	6,002	3560	0.004	30
Sidamulya	80.00	25,160	21,304	12,663	12,497	8,641	3856	0.010	38
Chihembl	200.00	44,900	38,268	33,950	10,950	4,318	6632	0.007	35
Karsari	91.00	35,360	30,608	19,110	16,250	11,498	4752	0.005	33
Totals	1,194.12	597,583	539,505	340,433	217,241	159,082	58163		

Figure 8

Annual Operating Hours—Gunung Kidul With and Without Fuel Subsidy



DGWRD and MacDonalds Data

7

LEGAL FRAMEWORK AND INSTITUTIONAL SUPPORT

Legal Framework

The legal framework for groundwater development and exploitation consists of national laws and regulations, provincial government regulations, and a rapidly expanding set of laws and regulations related to environmental protection.

National Laws and Regulations

Prior to the implementation of the 1974 Law on Water Resources Development, most of the laws governing water resources in Indonesia could be traced to the period of Dutch colonial rule. For example, under a regulation on drilling by private firms introduced in 1924, wells below 15 meters were subject to concessions determined by the provincial administration in consultation with the Mining Bureau.

The 1974 law establishes the rules and regulations for water resource development in the country and vests all control in the state. Article 5, paragraph 1, specifies that the minister in charge of water affairs shall be responsible and is empowered to coordinate all matters relating to general and project planning and to the supervision, exploitation, maintenance, conservation, and utilization of water and water resources. However, Article 5, paragraph 2, states that the administration of underground water resources and hot springs, being mineral and geothermal resources, shall not fall under the competence and responsibility of the minister referred to in paragraph 1.

To facilitate implementation of the 1974 law, Regulation (PP) No. 22/1982, specifically directed at water resource management, Regulation No. 23/1983, addressing issues related to irrigation, and Presidential Instruction No. 2/1984, dealing with water users association management, were promulgated. With respect to groundwater, Article 6 of Regulation No. 22/1982 states that "administrative management of groundwater and hot springs, being mineral and energy resources, are under the authority of the ministry responsible for mining." This clear allocation of control over groundwater to the Ministry of Mining and Energy reaffirms Article 1 of Presidential Decree No.64 of 1972 on the Regulation of the Control and Management of Geothermal and Groundwater Resources and Hot Springs.

Based upon Article 9 of Regulation No. 03/P/M/Pertamben/83 of the Ministry of Mines and Energy on Groundwater Management, the first priority for groundwater use is for drinking purposes. Other priority uses include: domestic purposes, industry, livestock and plain agriculture, irrigation, mining, and city operation.

Regulation 3/P/M/Pertamben/83 on Ministerial Responsibilities

The Minister's responsibilities are carried out by the Director General of Geology and Mineral Resources (DGGMR), as stated in Article 2 of Ministerial Regulation No. 03/P/M/Pertamben/83, and include:

- coordinating all activities of groundwater inventories in which the interests of public, department, and other institutions are considered;
- arranging groundwater utilization and development;
- controlling groundwater resources by licensing groundwater abstraction and by groundwater conservation;

- managing and processing groundwater data; and

- issuing licenses to water-well drilling companies.

Other ministries and agencies are also involved. The Directorate General of Water Resources Development (DGWRD) in the Ministry of Public Works has responsibility for the abstraction and distribution of groundwater in irrigation projects. The Directorate General of Housing, Building, Planning, and Urban Development is responsible, among other things, for designing and supervising the construction of all major urban water supply and sewerage projects, and in recent years has instituted a number of projects to provide water supplies for certain cities, towns, and district capitals.

Regulation 12 (1992) on Water Users Associations

In order to address the problems associated with the formation of water users associations and the resulting productive use of irrigation water, the Minister of Home Affairs passed Regulation No. 12 (1992) reagarding the Formation and Guidance of Water Users Associations. Since this regulation has just been passed and the process has yet to be tested, it is difficult to know exactly how this will impact public and private pump irigation systems. The following material is not an official translation, but it does provide a general overview of the major changes detailed in the new regulations.

1. The establishment of a WUA as a legal entity is made official after decrees issued by Regents/Mayors of a Regency or Administrative Level II towns after the WUA constitution and by-laws are approved of village head andsubdistrict heads and are registered by the Regents/Mayors of Administrative Level II regions.

WUA officers will register their WUA constitutions with the local Department of Justice Heads based on the ordinance of September 25, 1939 concerning Indonesian associations (Staatsblad 1939 No. 570).

Following the registration of the WUA constitution at offices of the Department of Justice, the WUA in question achieves status as a legal body(entity).

2. WUA Command Areas (territories) are determined by water resources (hydrological) principles based on tertiary units, village irrigation systems, swamp reclamation systems and pump irrigation systems.

When one or more small tertiary units are irrigated by a single source, such units can be combined into a single WUA command area.

When a single tertiary unit spans more than one village's territory, such a tertiary unit can be organized into a single WUA.

3. When considereing irrigation management in irrigation networks that encompass two or more WUAs, it is possible to form WUA forums.

WUA forums mentioned above should have provisions to manage common interests.

Provincial Government Regulations

A provincial government has the authority to issue licenses for drilling and use of groundwater but only after obtaining technical recommendations from the Directorate of Environmental Geology (DEG), which has received authority from the Directorate General of Geology and Mineral Resources, Ministry of Mining and Energy. A provincial government may issue its own regulations, instructions, and decrees. Examples include:

- Provincial Regulation No. 1/DP/040/PD/1977 for West Java on Controlling of Drilling, Abstraction, and Disposal of Water for Industry,

- Provincial Regulation No. 1 of 1985 for North Sumatra on Management of Drilling and Utilization of Groundwater,

- Provincial Decree No. 65 for East Java on Guidelines for the Implementation of Provincial Regulation No. 5 of 1985 on Drilling and Groundwater Utilization in East Java.

An examination of the situation in Central Java reveals how this process has evolved over time. Operational Guidance Decision No. 546.2/296/1986 vested authority for drilling and groundwater use in the governor and the provincial production bureau (*Biro Bina Pengembangan Produksi Daerah*). This has now been replaced by Operation Guidance Decision No. 546.2/22/89, which vests and centralizes complete authority for implementation in the Provincial Mining Office (Dinas Pertambangan Propinsi Daerah Tingkat I Jawa Tengah). Under this regulation, the Provincial Mining Office is responsible for making an inventory of groundwater drilling enterprises, making maps showing all groundwater pumps, administering the application and licensing process, determining and collecting fees for licenses to drill, and managing and supervising drilling and groundwater abstraction throughout Central Java.

Operation Guidance Decision No. 546.2/22/89 also establishes the authority of the District Economic Office to coordinate and facilitate the licensing process. Specifically, the Provincial Tax Collection Agency is vested with authority to determine user fees and establish a fee structure. Information about fees and fee structure is issued by the head of the District Economic Office in the form of a letter (Surat Ketetapan Retribusi) in the name of the governor of Central Java.

Other Legislation

In addition to these laws and regulations, environmental legislation has a direct imp:ct on groundwater development. For example, in Central Java, Perda 5/1985 mandates the performance of an environmental information presentation or an environmental impact statement (ANDAL) for all wells licensed under this law. Under Governor's Decision No. 546.2/22/89, a PIL must be performed for every well that is licensed under Perda 5/1985, and an ANDAL must be carried out if any well extracts more than 50 l/s or if there are more than five wells in a 10-hectare area.

Implementation

Licenses are issued by the governor of each province after consultation with the Regency Administration, which obtains a binding technical recommendation from the Directorate of Environmental Geology. This recommendation covers the terms and conditions of groundwater use, such as the depth of wells and aquifers to be tapped and the amount of water authorized for abstraction.

Applications for concessions are submitted to the governor in accordance with established regulations and copies are submitted to the Directorate General of Geology and Mineral Resources, Directorate of Environmental Geology/Head of the relevant regional office of the Ministry of Mines and Energy.

Licenses are not required for:

- manpowered abstraction from dug wells;
- mechanical abstractions of groundwater from driven wells with riser pipes no higher than two inches;
- abstraction for domestic supply of not more than 100 m^3 per month; and
- abstraction for research and development carried out by the holder of an authority issued by the Director General of Geology and Mineral Resources. The Director General has assigned responsibility for public groundwater development for irrigation to Public Works, through P2AT in the Directorate of Irrigation II. Similarly, Public Works is expected to report quarterly to the Director General on holders of private licenses to ensure that all wells are properly recorded in the database.

Institutional Support

Background

The issue of institutional requirements for pump irrigation sustainability mainly concerns the P2AT tubewells and large-scale surface water pumping schemes, whose capital costs are beyond the means of farmer groups. Small portable pumps are managed by the farmers with assistance from DGFCA, DGVD, and the NGOs, and do not need the same degree of institutional development as larger schemes using permanently installed pumpsets. To discuss the requirements for large-scale pump irrigation sustainability, it will first be necessary to outline developments in the O&M of the irrigation subsector as a whole.

During the Fourth Five-Year Plan (Repelita IV 1984/85-1988/89), it became apparent that the major increases in rice and other food crop production from the rehabilitation and expansion of the irrigation infrastructure could not be sustained without a greater commitment to improving O&M effectiveness. The result was a shift of emphasis towards O&M in all sectors, particularly in irrigation, in the GOI's Fifth Five-Year Plan (Repelita V).

In October 1987, the GOI issued a new set of guidelines for O&M and cost recovery, stipulating that within 15 years efficient O&M (EOM) would be introduced in irrigation systems throughout Indonesia and that its cost would be recovered directly from the farmers. With assistance from the World Bank-supported Irrigation Sub-Sector Project (ISSP), the following measures are being implemented:

- the transfer of responsibility for funding O&M expenditures to local governments;
- the introduction of a nationwide irrigation service fee (ISF) which will eventually finance all O&M costs through direct contributions from water users;
- improved indirect cost recovery through the introduction of the land and property tax (PBB- Pajak Bumi dan Bangunan) and phasing out of the former IPEDA system;
- the turnover of government-controlled irrigation systems of less than 500 ha to WUAs (*Penyerahan Irigasi Kecil*) under MOPW Regulation No. 42/PRT/1989.

Responsibility for sustaining the O&M of the irrigation infrastructure is being devolved on the provincial and local governments. The key actors are the Provincial Irrigation Service (PRIS), the WUAs, and irrigation committees at various local government levels that are linked with the Provincial Agriculture Service (PRAS) and other agencies. ISSP is carrying out training programs to strengthen the key actors and is also an important component of pump irrigation projects such as the Central Java Groundwater Irrigation Development Project being implemented by the Central Java PRIS and executed by P2AT.

The P2AT deep tubewell groundwater irrigation schemes in Gunung Kidul, East Java, and Madura are in the process of being turned over to PRIS, and pilot institutional developments to enhance the role of the WUAs are being initiated by the Madura Groundwater Irrigation Project (MGIP). However, the responsibility for the deep tubewells will pose a considerable challenge to PRIS since O&M requires specially trained staff, support facilities, and access to spare parts. There are evident differences in the technical and planning skills of those who implement the projects and those who inherit the assets (PRIS and the WUAs).

Development of Institutional Framework for Sustainability

Potential for Sustainability

Pump irrigation has had a positive impact on the welfare of beneficiary farmers and has contributed to the increase in agricultural production brought about by the government's investment in irrigation generally. At field level, there is great enthusiasm for pump irrigation and for the benefits from increased crop production.

In shallow groundwater areas with a pronounced dry season such as Central and East Java, farmers have installed their own shallow wells and bores and have no difficulty in managing the small portable pumpsets procured by themselves or supplied by DGFCA or other agencies. The pumpsets are of local manufacture, and spare parts and repair facilities are readily available in the local market. Farmers tend to operate the pumps themselves or in groups, and hiring out is widely practiced. However, the WUAs and irrigation committees generally are not well established and no control is exercised over the number of pumps operating. There is a danger that in shallow groundwater areas uncontrolled pumping may lead to water table decline, drying up of domestic wells, and seawater intrusion (for areas near the coast). Evidence of this has been seen in the Tegel/Brebes area of Central Java.

For the P2AT deep tubewells and the government installed surface water pumping schemes, the WUAs have been formed as part of project implementation and generally are far more active. However, the performance of a WUA is dependent not just on the level of training or inputs given by the project. More important is the attitude of the village head, key officials, and religious leaders and their commitment to making the WUA an effective organization for the whole community.

The WUAs are collecting water charges, and a number in the newer areas have accumulated sufficient savings to cover major maintenance expenses and eventual pumpset replacement. For instance, on Madura the average WUA account balance at the end of 1990 was Rp 1.06 million (about US$ 540) per operational well, with some wells for tobacco cultivation having balances over Rp 5 million (about US$ 2,560). Economic studies on Madura in 1989 projected that wells in tobacco areas, and in other areas if cropping intensities can be improved, would be able to reap net annual benefits of at least Rp. 40 million. However, none of them have reached these levels yet. In the older pump areas such as Gunung Kidul, it was never made clear that WUA account balances were required for long-term sustainability, and unfortuantely the WUAs did not accumulate funds for future replacement.

Long-term sustainability of pump operation ultimately depends on the support and guidance given to the WUAs and farmers by PRIS, PRAS, and other agencies through the irrigation committees. Although P2AT will have a presence in deep groundwater projects to offer technical guidance to PRIS for some time to come, the main burden of responsibility for sustainable O&M will lie with local governments. Plans are being formulated to enable PRIS to take on this role, the best example to date being in Yogyakarta, although East Java and Madura have proposed a number of innovative pilot schemes.

On the Sumani Irrigation Project in West Sumatra, the WUAs organized with help from the Swiss consultants appear to be functioning well, and the water fee collected from farmers is sufficient to cover O&M costs. The water fee, collected after each harvest, is currently Rp. 45,000/ha/crop season. Although most farmers pay the water fee, problems do occur on the larger schemes when farmers are accustomed to receiving free surface water from mountain streams. There may also be problems when harvest yields have been affected by rats or floods and payment is often deferred to the next harvest.

Training, established by the project, is now the responsibility of the provincial public works service, which also arranges fuel supply for the WUAs and carries out pumpset maintenance. There have been no major mechanical problems with the pumpsets. However, as is often the case, responsibility for eventual pumpset replacement has not yet been clarified.

Pilot Institutional Development Work in East Java, Madura, and Yogyakarta

Madura—A pilot institutional development program started at three key *kecamatan* on Madura (representing about a third of the tubewells on the island) during 1991 is continuing during 1992. It has resulted in two important developments:

- a decree by the Governor stipulating the division of responsibilities for O&M between the WUAs and PRIS; and
- the signing of the Basic Rights Agreement (AD/ART—*Anggaran Dasar/Anggaran Rumah Tangga*) between the Bupati and the WUAs.

According to the Governor's Decree No. 700/1991, the WUAs are responsible for O&M and light repairs. PRIS must arrange for repairs, pumpset movements on shallow wells, workshops, and monitoring. The decree is an "enabling" piece of legislation and is to be followed by a decree from the head of PRIS to provide a basis for the implementation of the proposals and to clarify certain technical aspects, particularly the difference between light and major repairs. A possible division could be along the following lines:

- light repairs could include oil and filter changes, fuel filter changes, and fuel injection nozzle replacements; and
- heavy repairs could include major overhauls, as required, and major overhauls to "as new" condition.

The *Anggaran Dasar* specifies the aims of the WUAs, the key posts, membership, source of funds, meetings, and support and guidance. The *Anggaran Rumah Tangga* specifies the criteria for selecting WUA officials, the duties of the various officials, the water charges, financial management, agenda for meetings, and procedures for disciplinary action. Together, they allow the WUAs to raise and use funds and generally confirm their legal status.

The AD/ART specifies that only Rp 25,000 (Rp 50,000 in West Sumatra) may be kept as cash, and that the bulk of WUA proceeds must be deposited in bank or village savings accounts. Most WUAs on Madura and elsewhere have opened accounts but, since WUAs are officially viewed as "social organizations," they are not empowered to open bank accounts in the name of the WUA itself (only cooperatives or badan usaha at the village level are able to do this). Accounts have to be registered in the name of a WUA official, usually the treasurer. Effective monitoring by the local government is necessary to prevent abuses.

Yogyakarta—In Yogyakarta, special project funding has established an O&M units for pumps within PRIS. Most of the staff from the P2AT project office and the bulk of the equipment and spare parts have been transferred to this unit, which is now responsible for major repairs and technical backstopping for the pump irrigation systems at Gunung Kidul. This is a very appropriate institutional model for turning over pump irrigation systems to local government, as it places responsibility in the hands of the organization accountable for O&M in the province. In addition, it recognizes the unique requirements of pump irrigation and strengthens the local government's ability to meet them. Figure 9 illustrates the flow of responsibility in this approach.

Proposals for Institutional Framework for Sustainability

P2AT and PRIS have prepared proposals for tubewell management, based on the pilot program in Madura, that include the establishment of a technical service unit or, in the light of Presidential Decree No. 38/1991, self-funding units for goods and services, and self-funding workshops.

The principal shortcoming of a technical service unit would be its dependence upon local government budget allocations each year, since the proceeds from services would have to go to the local government treasurer and would likely be used for other purposes. Workshops would not have this disadvantage and would be able to operate their own revolving fund, although regular reports and audits would have to be submitted for local government inspection. If the suggested division between light and heavy repairs is adopted, the range of spare parts for purchase by the workshop's revolving fund would need to cover only four or five items, including oil filters, fuel filters, and fuel injection nozzles. However, the private sector would be a more appropriate and perhaps a far more successful provider of these services.

Conclusions

- The management of small portable pumps provided by DGFCA, DGVD, the NGOs, and the farmers themselves does not require the institutional support necessary in the larger pumping schemes using permanently installed pumpsets. However, the WUAs and irrigation committees generally are not well established, and no control is exercised over the number of pumps operating.

- As a result, there is a danger that uncontrolled pumping in shallow groundwater areas may lead to water table decline, drying up of domestic wells, and seawater intrusion (in areas near the coast).

- The performance of a WUA does not depend merely on the level of training or inputs from the project but even more on the attitude and commitment of the village head, key officials, and religious leaders to making the WUA an effective organization for the village community as a whole.

- The current approach of having P2AT subsidize O&M costs for the first two years of pump operation and build cash reserves from water charges has generally been successful in increasing pump use but not in building a financial reserve.

- The main burden of responsibility for sustainable O&M lies most appropriately with the local government.

- Plans for sustainable O&M by PRIS in East Java after turnover has been completed could be a model for projects elsewhere in Indonesia. However, to put such plans into effect will require considerable staff training and institutional support within PRIS, village unit cooperative (*koperta unit desa*—KUD), WUA federations, and irrigation committees.

Recommendations

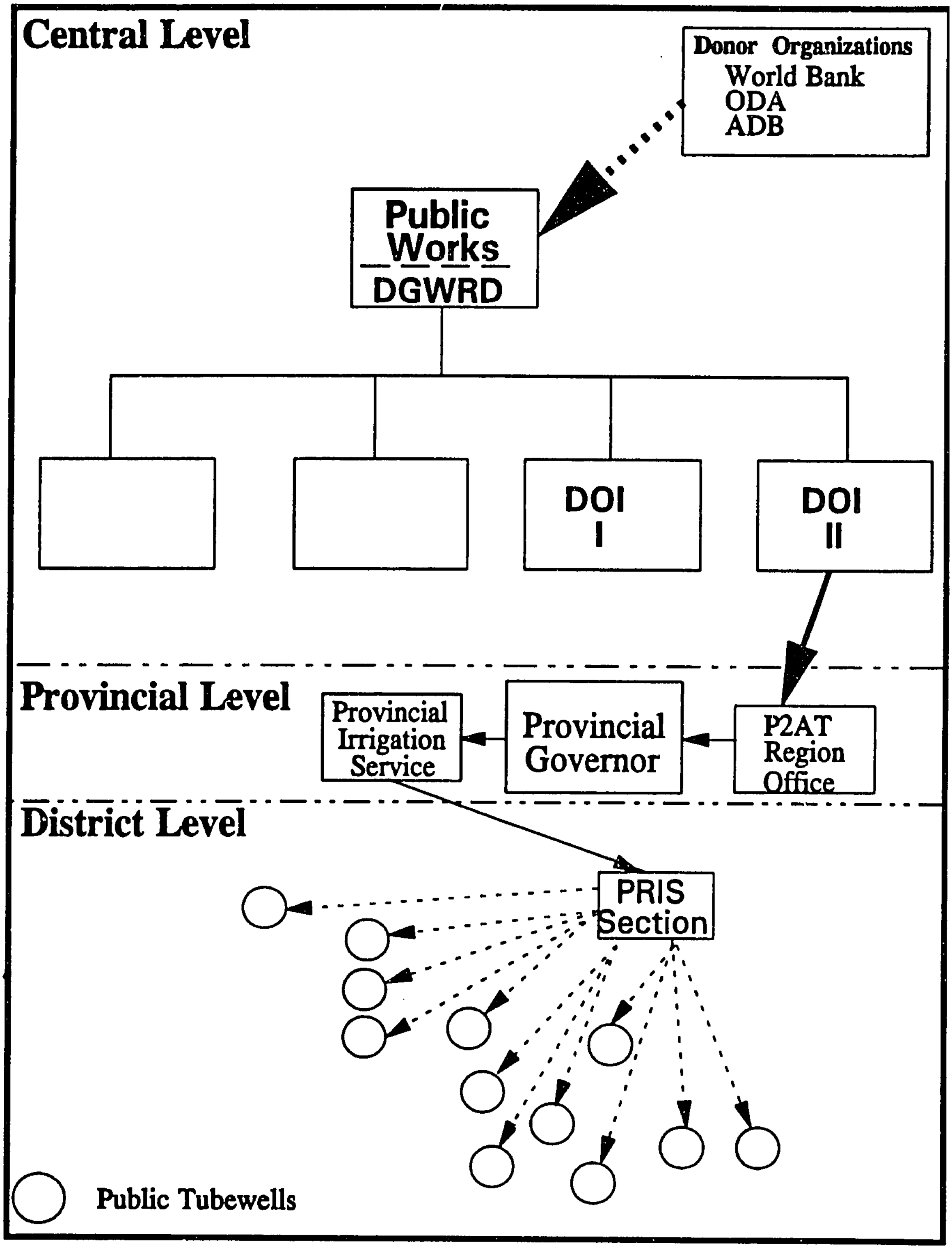
- The number of pumps in shallow groundwater areas should be strictly controlled to prevent the drying up of domestic wells and sea water intrusion. P2AT will need to advise local governments on groundwater recharge and safe yields. Irrigation committees and the WUAs should be supported in the effective control of pump use.

- Local governments must promote irrigation committees more earnestly and support them with budgetary allocations. Irrigation committees should be used to monitor and evaluate WUA performance and deal with complex problems involving cross-sectoral and social issues. In practice, irrigation committees seldom function effectively.

- Rather than shifting responsibility for repair services from one government office to another, the private sector should be encouraged to provide them if pump irrigation is to become self-sufficient in Indonesia. However, the technologies selected must be appropriate for local conditions.

Figure 9

P2AT Pumps Handed Over to PRIS



8

STRENGTHENING THE CAPACITY OF WATER USERS ASSOCIATIONS

Introduction

Pump irrigation, whether developed by the public or the private sector, usually requires the support of water users associations (WUAs). These associations build farmer participation in system management and water distribution and are also responsible for the imposition and collection of fees for pump use and, eventually, engine and pump replacement. Unlike the WUAs for gravity irrigation, these WUAs must take charge not only of system maintenance but of managing a major capital investment, the pump.[6]

Indonesia's experience with the formation and strengthening of WUAs has been uneven. Efforts to form WUAs for surface irrigation systems have been made for more than a decade, but the WUAs never had a clear legal status. In 1992, Regulation 12 clarified their status. In a number of cases many of the WUAs became inactive soon after outside assistance ceased. A retrospective study of Sederhana and High Performance Small-Scale Irrigation Systems (1991) revealed that they often revert to traditional water management institutions. In using the standard organizational model for gravity irrigation WUAs without modification as the basis for pump management groups, the GOI runs the risk of perpetuating an already disappointing program. However, the recent experience with the irrigation service fee program for surface irrigation groups offers real promise. In this program these WUAs are starting to play a significant role in irrigation management. Responsibilities of the pump WUA, including fee collection and management of the pump, give it reasons to remain intact and develop further. An analogous situation is developing as surface water WUAs are asked to collect user fees. Thus, pump irrigation WUAs appear more sustainable than most gravity irrigation WUAs, although the government must recognize the need to pay additional attention to their operation and requirements for maintenance.

Since the GOI is interested in expanding pump irrigation, particularly in eastern Indonesia, it must:

- provide the flexibility for appropriate levels of farmer organization needed in government-sponsored schemes;
- assess the long- and short-term technical assistance needs for effective group formation and operation and maintenance;
- define responsibility for financial management, particularly for pump and engine replacement; and
- provide directions for turnover and privatization and design appropriate roles for government agencies and users. Turnover is the transfer of primary responsibility for system operation and maintenance to users; privatization is the transfer of ownership of the physical assets to them.

6 In this section, the pump is understood to encompass the pump, the engine, the well, and assorted hardware required for pump irrigation.

Formation of Water Users Associations

WUAs generally are formed as part of the development of pump irrigation schemes. Government decrees establish guidelines for the formation of WUAs in publicly supported systems, while those developed by NGOs often are more flexible in structure. In East Java, for example, until the promulgation of Regulation 12 (1992) bupatis were required to form WUAs under Governor's Decree No. 201/1987, with the village community resilience council (LKMD) being the forum for discussions and deliberation. P2AT follows this pattern in organizing groundwater WUAs, and so do DOI-I projects in West Sumatra and Central Java. Bina Swadaya, the Jakarta-based NGO, has limited its efforts in forming WUAs to river pumping in West Java.

Proyek Pengebangan Air Tanah (P2AT)

P2AT adopted the approach used by DOI-I for the formation of WUAs for gravity irrigation units when it began to form pump irrigation users associations in the early 1970s. This was a top-down approach that saw no need to consult farmers about drilling, planning the system, or their responsibilities for O&M. P2AT directed kecamatan and village leaders to select an executive committee whose members it then trained to manage the WUA and operate the pumps.

After a number of unsuccessful attempts to develop groundwater systems, P2AT revised its approach somewhat. P2AT staff now meet with members of the WUA to discuss construction of the irrigation system and the selection of an executive committee. During the first two years of operation, P2AT makes fuel allotments and pays the operator's salary. However, farmers are required to make regular contributions to the association to cover the costs of eventual pump replacement. The WUAs are formed after drilling begins and users have little say in determining the location of the well.

At the start, an executive committee is appointed by the village head; after one or two years it is elected by members of the WUA. In some schemes, the village head submits a list of names to P2AT and an approved short list is then presented to the general membership. After the election, the P2AT staff draws up a formal list of rules and responsibilities, which is agreed to and signed by the executive committee. This document is the same one used throughout Indonesia for gravity irrigation WUAs.

The executive committee is expected to conduct general meetings, schedule water distribution, suggest a pump fee for approval by the membership, and make arrangements for canal maintenance. Members of the WUA are expected to clean the canals, pay the pump fee, and attend general meetings. During the first two years the fee is usually nominal and meant to cover only the honoraria for the executive committee and a portion of the fuel cost. In some kabupaten, even the honoraria are paid by P2AT.

In Central Java and Madura, P2AT relies upon community organizers, coming through consultants on contract, to work with farmers in forming associations. In East Java and DIY, nominal community organizers are actually P2AT staff who seem more comfortable providing technical than management assistance.

P2AT has formed WUAs for deep wells in DIY and East Java, usually a single association for each pump, but in some cases in East Java a federation of user groups. Each block of farmers manages a pump and has its own second-level executive committee. In Kediri, one WUA executive committee is responsible for 11 pumps.

Nongovernmental Organization

Bina Swadaya, the Jakarta-based nongovernmental organization, has focused on large river pumps in West Java, including a significant amount of fixed infrastructure. With funds provided by USAID and other international donor agencies, it has installed

14 pump systems in three West Java districts and has stressed institutional development along the lines used to improve surface irrigation performance in Indonesia and elsewhere. System development begins with a feasibility study. If the project is approved, and prior to construction, farmers are organized into a WUA and elect an executive committee. Agricultural extension agents from the Department of Agriculture are trained to serve also as community organizers for the system and are given an honorarium for three years. Bina Swadaya stations a site manager from headquarters in each district where there is a project.

The two approaches although similar differ in certain aspects. Farmers working with Bina Swadaya have the option to withdraw, which they are not permitted to do once P2AT has started its operations. Bina Swadaya has a designated government community organizer who works more closely with the farmers than the P2AT staff can.

Effectiveness of Water Users Associations

WUA effectiveness should be assessed by several criteria against which performance can be measured:

- rate of pump fee collection, timeliness of payment, and amount collected;
- adequate financial resources for small pump repairs;
- timely payment of the operator's wages and honoraria for the executive committee members;
- use and investment of savings from pump fees;
- equitable water distribution;
- watercourse and pump/engine maintenance;
- use of executive committee and general meetings as opportunities to enhance farmer participation in decision-making;
- high level of participation by users and a lack of conflict;
- clear sanctions for infractions and the fines imposed; and
- supervision of the pump operator.

Financial Management

Unlike most gravity irrigation WUAs, pump irrigation WUAs have important financial management responsibilities. They are expected to:

- determine the amount of the pump fee and how it is to be paid;
- collect the fees and impose fines or other sanctions on those who do not pay;
- keep financial records of pump use and collections;
- pay the operator his wages and members of the executive committee their honoraria;
- pay for fuel or electricity; and
- use savings for small repairs and regular maintenance and for eventual engine pump replacement.

The fee and the method of payment are decided by the general membership of the WUA in an open meeting. Fee adjustments required by changes in fuel costs and the cost of pump repairs are decided in the same way. In a number of systems, the executive committee will ask members for a temporary increase in the fee to cover the cost of minor repairs.

Payments vary in amount, sometimes seasonally, and are set by the hour, the season, or per plant, and may be made in cash or in kind. Data from the study indicate that the rate of collection of pump fees is quite high. Most operators claimed complete or near complete collection rates. This would apply only to farmers who are actually receiving water. The lowest rate mentioned was 95 percent. The collection of payments is more difficult for additional requirements such as a connection for an electrical pump. In one system, only half the farmers paid the fee initially but the rest responded when the executive committee cut off water to those who did not pay.

After the first two years of operation, the fee is based on the fixed costs (pump fuel, oil, filter, and lubricant), the honoraria for executive committee members, the salary of the operator (although there is some variation in who is paid), and quaternary system maintenance. In a few cases, an amount for engine and pump replacement is included. Rarely included is an amount for small repairs, since these are covered by P2AT before turnover and the local government is responsible for them thereafter. As noted, when repairs are needed the fees are raised on an ad hoc basis.

As a result, most WUAs have little or no savings, in some cases because of mistrust and squabbling among executive committee members. A few, however, have accumulated substantial savings that they have used to increase income by purchasing cattle or making loans to members, for example. Some have savings in excess of Rp. 8 million. But in all cases the WUAs have shown they are capable of managing their finances more than adequately; all are able to cover their operating costs.

From this study it appears that there is a threshold of roughly Rp. 1 million at which a WUA decides a bank account is necessary. With less than that, the WUAs tend to keep their savings in cash. Data for 1988/89 from the Madura Groundwater Irrigation Project indicate that, of 70 WUAs, only 13 had bank accounts, all but one with more than Rp. 1 million and nine with Rp. 2 to 5 million. A reason for this small number could be that the WUAs do not have a legal status that permits them to open an account in the group's name. Under the present regulations governing farmers' groups, accounts can be opened only in the name of one individual, although there are unconfirmed cases of accounts in the names of WUAs.

Recordkeeping by the WUAs is minimal and usually documents only pump use, with the name of the user and some measure of use recorded in a ledger. There are rarely any financial balance sheets, although sizeable savings sometimes are held by an executive committee member in cash or his own bank account. This rather casual approach to management often leads to recriminations among WUA members.

Bina Swadaya has emphasized pump and engine replacement in its program. Farmers do not have to refund the costs of the system but are asked to maintain a savings account in the kecamatan branch of its bank to pay for replacements and for fuel and honoraria. However, Bina Swadaya has no control over the revenues of the WUA and no regulatory powers. The results have been disappointing. Some of the pumps are no longer in operation and the WUAs have withdrawn their savings, a development Bina Swadaya ascribes to the fact that the pumps were a gift that required no contribution from the farmers.

More recently, in Ramayo and Lebak districts, Bina Swadaya has followed a different approach. The WUAs are expected to meet the costs of the pump, the development of the physical infrastructure, and operation. Farmers contribute 3.5 quintals of unhusked rice per ha per season to the account. Two quintals are directed toward the pay back; the remainder is used for operation and maintenance. There are restrictions on the withdrawal of funds. During the initial five years, they may be used by the WUAs for credit programs. After that, they are used by Bina Swadaya to develop new systems elsewhere.

The Role of WUA Members and the Executive Committee

Pump irrigation WUAs appear to be much more cohesive than WUAs in gravity irrigation systems. Meetings are held more regularly, and decisions about operation of the system are made with greater concern for the welfare of members. Most gravity irrigation WUAs that do not have user fees are primarily responsible for tertiary system maintenance. In contrast, pump irrigation WUAs make decisions about resource mobilization and use. Also the activities of their executive committee are demonstrably more important and include primary responsibility for management of the engine and pump, control over savings and sometimes decisions concerning investments and loans, and water allocations.

General meetings of the pump irrigation WUAs usually serve specific purposes such as approving adjustments in the pump fee or electing executive committee members. While some WUAs have not had meetings for several years, others meet monthly under rather formal conditions. The secretary keeps minutes, and the operator reports what he has done and presents records of pump use. Members are welcome to attend, although few seldom do.

In some Madura systems, informal WUA meetings are closely intertwined with religious activities, often coinciding with Thursday evening Koranic recitations. Formal meetings are held annually. Topics discussed include water allocation, agricultural extension, crop selection, use of fees collected, preparation for turnover, electrification, and structure of the executive committee.

Actual management of the pump and the system is in the hands of the WUA executive committee, which includes the chairman (*ketua*), secretary, and treasurer, and particularly the operator. The structure of the committee is the same as in gravity systems, with the exception of the operator. In the East Java study sites, the members of the executive committee were also members of the village government, most commonly section leaders, whereas in West Java and DIY, this is not necessarily the case.

The operator is a key figure, responsible for determining water allocations, running and maintaining the pump, keeping records of the hours of use or the area irrigated by farmers, and sometimes collecting the fees. He is often the owner of the land on which the pump is installed. Sometimes he bypasses the authority of the executive committee by establishing a direct relationship with the farmers, who indicate that they prefer dealing with him because it simplifies their requests for water. The operator's salary is paid by the WUA after the pump has been in operation for a few years. Before that P2AT pays the salary.

However, in DIY P2AT continues to contribute Rp. 15,000 per month to operators until turnover to supplement the WUA payment; after turnover the local government contributes toward the operator's salary. On occasion, if the operator collects the fees, he does not hand over the money to the executive committee members for honoraria. As a result, executive committee members in some of the systems in DIY have slowed down their work, meeting less frequently and allowing the operators to take on more of their responsibilities.

System Maintenance

P2AT is responsible for maintenance of the tertiary system before turnover. Thereafter the local government shares the responsibility with the WUA. Arrangements for maintenance of the quaternary system differ. In some, earthen watercourses are maintained and repaired by individual farmers working under the supervision of block leaders, and part of the pump fee may be set aside for materials and labor. In other systems, there is a more formal approach. Maintenance of the system's watercourses is organized by the block members, who meet to plan the cleaning and repairs of the watercourses serving their block's command. They then meet with other blocks and together agree upon a yearly plan. Elsewhere, members no longer attempt to undertake system maintenance, since sufficient labor cannot be obtained through gotong-royong.

Water Distribution

Unlike farmers and farmers' groups in gravity irrigation systems, who make decisions about water allocations largely at the tertiary level, farmers in pump irrigation systems determine allocations for the entire run of the system. Government officers are not involved in water distribution to any degree. Each block in the system gets its water on a certain day or days, and is often named after that day. This decision by the executive committee, usually made once at the initiation of the pump system, is rarely revised. Many of the systems keep a day in the week free for adjustments by farmers who wish to purchase additional water. In the Bina Swadaya systems, size has been the cause of major problems in organizing farmers and serving the entire design area, especially the land near the tail end of the system.

Competition between Government and Private Pumps

Portable pumps owned by farmers are competing with P2AT-supplied fixed pumps in shallow wells in Nganjuk and similar locations in Java. In one system, 65 private pumps are in operation, 12 of them which were in use before P2AT began to install fixed pumps in 1972. Farmers prefer their own pumps, believing there is much less conveyance loss, although this is not certain. Of 177 farmers in the command area, only 77 requested water from the WUA during 1991, thereby causing a serious financial crunch for the WUA. The executive committee virtually had already ceased activities in 1986, and the pump is managed only by the operator. This example is a striking argument against government investment in areas where private initiative is already at work.

Turnover of Pump Irrigation Schemes

In 1984, the GOI instituted a program to turn over schemes of less than 500 ha to the local government, which after two years transfers responsibility to the WUA. In practice, P2AT continues to provide some assistance such as a fuel allotment, major pump and engine repairs, and maintenance of the tertiary system, and official turnover of the assets to the local government could take another 10 years. To date, almost 350 systems in East Java and 28 in DIY have been turned over.

The Sumani Irrigation Project in West Sumatra handed over responsibility for O&M of the six pump-lift schemes, which range in size from 90 to 270 ha, to the WUAs in 1990. O&M was subsidized for the first four years of operation.

Government surface water pumping schemes in Central and East Java are all larger than 500 ha, and O&M will remain the responsibility of PRIS. But as with surface gravity flow schemes, the farmers will eventually have to pay the ISF towards running costs.

During the first two years of operation, most if not all costs, including the operator's wage, all maintenance, and all repairs, are subsidized by P2AT (see Table 32). The subsidies enable the WUAs to build up a cash reserve for operations once the subsidy is removed. P2AT's contribution for fuel varies among the districts. Farmers cover maintenance of the quaternary systems and honoraria for the executive committee. After the first two years, P2AT continues the fuel allotment, sometimes at a reduced level, makes major repairs (those costing more than Rp. 1 million), and maintains the tertiary system. Other responsibilities are assumed by the WUA.

The change in WUA responsibilities is more dramatic after year two than after turnover. At that point, the WUAs have already taken on primary financial and technical management of the system. With formal turnover to the local government, the WUAs may have to pay the operator's fee and share costs of certain services with the local government rather than with P2AT. Although P2AT no longer has formal responsibilities, its staff continues to provide services. In practice, the WUAs often make informal payments to P2AT technical staff for small repairs.

Beyond the changes in specific responsibilities, the major changes in system management for the pump irrigation WUAs after the first two years of operation are:

- increase in the pump fee;
- general increase in savings by the WUA; and
- increase in the wage for the operator and honoraria for the executive committee members.

Apparently, following formal turnover an expansion in the command area is possible because of the removal of P2AT restrictions on irrigation outside the design area. The transfer of responsibilities and formal turnover bring no changes in:

- frequency of general and executive committee meetings;
- system of water allocation and crop selection; and
- formal rules concerning roles and responsibilities of the WUA, including structure of the WUA and elections.

Privately Owned Pumps

A discussion of pump WUAs would be incomplete without some mention of river pumping by the private sector in West Java, where both fixed and portable pumps are in operation. Although the fixed pumps do not have formal WUAs or executive committees, there are a number of similarities between the government and NGO approaches. Fees are collected in an amount decided at a meeting of the users and owners, and sanctions are imposed for nonpayment. The pumps have several operators who are not owners and act as a link with the farmers. Construction and maintenance of watercourses is by gotong royong, arranged by the operators and undertaken by the users. The success of these systems suggests that formal associations are not a prerequisite for fixed pumps.

Conclusions

- In contrast with most gravity irrigation WUAs, pump irrigation groups are proving competent at managing the technology and the resource. They have been able to set a fee and collect it, distribute water equitably, maintain the physical system, support a management structure, and operate and maintain their pumps efficiently. Although their executive committees have not always anticipated repairs and saved for them, they have been able to find the money by raising fees temporarily with membership agreement.
- Many WUAs have accumulated sizeable savings, which they keep in bank accounts or invest in related ventures. These investments suggest a potential for some to become multipurpose groups.
- The WUAs keep only minimal records of pump use, and financial balance sheets and planning are rare, revealing a need for the continued training of executive committee members and for regular monitoring and backstopping. Hitherto, management support by P2AT or the local government has been inadequate.
- A pervasive problem is the lack of clear accountability in financial management. Many WUA savings in banks are held in the name of an individual. Operators collect the fees but may not pay the honoraria of executive committee members. The system offers too many opportunities for personal gain at the expense of the group.
- The heavy subsidies given by P2AT to the WUAs in productive areas during their first two years of operation have not been detrimental to self-sufficiency. Most appear to have made a smooth transition to taking on greater financial and technical management responsibility for the systems. They have largely been able to obtain and manage the basic services themselves, although there

are important continuing responsibilities for the government.

- In poor areas, where returns from irrigated agriculture are small, executive committees are most likely to be weak and the operator strong. The WUAs in marginal areas like Gunung Kidul are never likely to become financially independent. At present, all pump systems are treated as equal by the government, despite the inherent inequities that penalize the poorer WUAs.

- The GOI has not promulgated any specific regulations for the formation and operation of pump irrigation WUAs. The regulations that apply were originally prepared for gravity irrigation groups, although the conditions and requirements of the two differ considerably. Still, the absence of specific regulations in some ways has been advantageous for pump irrigation WUAs. They have been less constrained by an imposed structure from the center that would have led to the organization of homogeneous groups. As a result, there is a wider variety of WUAs adaptated to local conditions.

- All the WUAs cannot reasonably be expected to have the means to replace their pumps and engines themselves. Bina Swadaya's experience suggests they can do this if the costs are relatively low. However, many of the P2AT pumps are turbine pumps and replacement is well beyond the resources of any WUA. The present uniform policy requiring farmers to replace the pump ignores differences in technology, cropping patterns, terrain, and farmer resources.

- Where privately owned pumps compete with government installed pumps, most farmers prefer to use the private pumps because they are perceived as being cheaper and easier to use, as well as providing service closer to the field where water is needed.

- Throughout their development, both before and after turnover, there have been no mechanisms for P2AT or the local government to monitor and backstop the WUAs.

- By the time most systems have been turned over, the procedure is little more than a paper transfer between government agencies. Real changes in financial management responsibilities for the WUAs take place after the first two years of operation, not after turnover. Shifts in responsibility from P2AT to the WUAs, whether after two years or at turnover, are made uniformly for all pumps and do not take into account the size or technical level of each system.

- Turnover should not be confused with privatization. There is no attempt to transfer the system's assets to the WUAs, and it is doubtful they would accept these if they were offered.

- The approaches of P2AT and Bina Swadaya are very similar. Both use water users associations that are organized along the same lines. Farmers in the Bina Swadaya systems play a role in system selection and design unlike farmers in the P2AT systems, but there are no appreciable differences during operation and maintenance.

Recommendations

- Pump irrigation systems should be designed with farmer participation, which would ensure the selection of appropriate sites as well as appropriate technology and improve the chances of sustainability.

- Although pump irrigation WUAs generally have been effective, it may not be necessary for all schemes to have this high level of organization. Smaller command areas requiring less sophisticated pumps might instead be placed under the village government. The GOI should consider developing small systems without WUAs on a pilot basis and monitoring them for effectiveness. There may well be a threshold below which a WUA is unnecessary, although some efforts at organizing users will certainly be required.

- Assistance to the WUAs in financial recordkeeping is needed for monitoring and backstopping the systems both before and after turnover. Since P2AT cannot now provide this assistance because of its project status, it should either be restructured or some other agency should be given the responsibility for assistance.

- The WUAs should be given adequate information and guidance regarding the process of obtaining legal status which would permit them to open bank accounts.

- The productivity and technical level of each pump irrigation system and the resources of the farmers should be used to define GOI and farmer responsibilities for pump and engine replacement. Guidance should be provided as needed to enable WUAs to determine equitable and realistic rates that take into account the characteristics of individual systems. For example, standardized shares (ranging from 0 to 100 percent for each) could be applied according to the characteristics of the system (affluence/poverty, topography, cropping pattern, and technical level, among others).

- Institutional development in East Java and Madura to prepare for sustainable O&M of the tubewell schemes after the turnover from P2AT to the local government should continue, so that the experience can provide a model for projects elsewhere in Indonesia.

- The GOI should not develop pump irrigation systems in areas with significant private sector development but should encourage this initiative.

Table 32

Responsiblities of the GOI and WUAs Before and After Pump System Turnover in East Java and DI Yogyakarta

Kabupaten	Period	Fuel	Oil	Grease	Filter	Operator Wages	Exec. Comm. Honoraria	Small Repairs	Major Repairs	System Maintenance
Pamekasan	Years 1-2	P2AT (400 l.)	P2AT	P2AT	P2AT	P2AT	WUA	P2AT	P2AT	Ter.-P2AT Qua.-WUA
	Until Turnover	P2AT (400 l.)	WUA	WUA	WUA	WUA	WUA	WUA	P2AT	Ter.-P2AT Qua.-WUA
	After Turnover	WUA	WUA	WUA	WUA	WUA	WUA	WUA	WUA/P2ATWUA/PZAT	Ter.-P2AT Qua.-WUA
Nganjuk	Years 1-2	P2AT (350-600 l.)	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT
	Until Turnover	P2AT-50% WUA-50%	WUA	WUA	WUA	P2AT	WUA	WUA	P2AT	P2AT
	After Turnover	WUA	WUA	WUA	WUA	WUA	WUA	WUA	WUA/ Local Gov.	WUA/ Local Gov.
Kediri	Years 1-2	P2AT (400-450 l.)	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT	P2AT
	Until Turnover	P2AT-50% WUA-50%	WUA	WUA	WUA	P2AT	WUA	WUA	WUA	P2AT
	After Turnover	WUA	WUA	WUA	WUA	WUA	WUA	WUA	WUA/ Local Gov.	WUA/ Local Gov.
Gunung Kidul	Years 1-2	P2AT	P2AT	P2AT	P2AT	P2AT	WUA	P2AT	P2AT	Ter.-P2AT Qua.-WUA
	Until Turnover	WUA	WUA	WUA	WUA	WUA	WUA	WUA	P2AT	P2AT
	After Turnover	WUA	WUA	WUA	WUA	WUA	WUA	WUA	WUA/ Local Gov.	WUA/ Local Gov.

9

OVERALL RECOMMENDATIONS

Introduction

The conclusions and recommendations presented in the discussion of the eight policy issues are here regrouped into four areas: technical, environmental, institutional, and policy.

Conclusions

Technical Conclusions

Small Pump Irrigation Systems

With the relatively slow growth of public sector groundwater irrigation — an average of 1,500 ha per year since 1972 — the identified land and water resource base offers continued scope for development.

Farmers in Indonesia, particularly in Java, have already invested in the technology for development of small river pump, open well, well point, and intermediate well irrigation systems. Of approximately 150,000 ha now under pump irrigation, only 28,000 ha of groundwater irrigation, including deep, intermediate, and shallow wells, are in the public sector. In these circumstances, there is very little rationale for continued government development of this type of irrigation. There is compelling evidence from throughout the country that farmers are capable of and prefer developing private pump irrigation systems when they feel they are economically and technologically possible. The study showed that in areas in which there are both government-installed pump irrigation systems and privately owned pumps, farmers choose the latter because they are cheaper and easier to use.

Yet, in all the countries in the region, governments and international donors tend to encourage investment in sophisticated imported technology, which they impose through government programs on poor and marginal farmers who would be happier with simple, small-scale solutions. If the GOI is willing to accept the need for a permanent presence in each area to provide heavy maintenance and supply spare parts not available in the local market, appropriate technology is not an issue. However, if the objective of development is to achieve sustainable pump irrigation, the appropriateness of deep well turbine pumps has to be seriously reconsidered.

Necessity for Government Involvement

Analysis by this study indicates that the technology used in most pump irrigation schemes, in particular deepwell turbine pumps, is not economically viable even with government assistance. If farmers had to pay the real costs of the infrastructure as well as the O&M costs, almost all their increased revenues from pump irrigation would be consumed.

Maintenance and Repair

The number of public sector deep and intermediate tubewells in any one location generally is not enough to support a private workshop. Even if this is not an issue, P2AT must continue its assistance since local governments do not have the technical skills or workshop facilities to keep imported deep well machinery operational. To ensure local repair facilities after the turnover to PRIS, the GOI is exploring the setting up of self-funding workshops. Unfortunately, experience from other countries in the region is not encouraging. These plans fail because workshops built by the government are often too large and sophisticated to survive as local businesses, and government rules and regulations reduce commercial efficiency.

In the short run, repair services are likely to be more efficient if P2AT mechanics and monitoring staff are transferred to local PRIS offices and the assets become the property of the local government. However, this is just shifting the burden of public assistance from one agency to another, not reducing it. In the long run, repair facilities and expertise must be developed in the private sector if pump irrigation is to become self-sufficient in Indonesia.

Environmental Conclusions

River Basin Planning

River basin water balances conducted by the World Bank for present and projected demand in Java show demand will exceed supply in many basins during the next 20 years. The analysis clearly indicates that integrated river basin planning for multiple users and water conservation must become the dominant issues if sustainable irrigation coverage is to be achieved.

The problem, however, is that the macro framework for water resource planning is still being developed. The supply available for pump lift irrigation can properly be assessed only in the context of river basin planning. Long-term sustainability can be determined only from an integrated assessment of all sources of surfacewater and groundwater and of all potential uses, of which irrigation is only one. Basin-wide integrated water resource development should be the framework in which pump lift irrigation is planned.

The success of integrated river basin planning will depend on how well the individual water sector agencies at the central and provincial levels cooperate, and on the acceptance of cross-sectoral planning required to efficiently allocate scarce water resources.

Hydrologic Data

A major conclusion of this review is that, although a significant amount of hydrologic data have been collected over the last 20 years, there have been few attempts at a systematic collation and consolidation of the findings. Since each new project sets up data collection programs that bear little relation to those before, databases are not uniform. Systematic data collection is needed for consistent and reliable resource estimation to guide future pump irrigation development programs.

The resource base for pump irrigation from surface water and groundwater is less certain because there are few reliable data. Systematic water resource appraisals in the provinces, sub-provincial and river basins were common in the 1970s and early 1980s and allowed well-formulated and phased water resource development on a large scale, particularly in East Java and Madura. Unfortunately, in the last decade, systematic resource appraisal has been abandoned by all except the DEG. A consequence of this is overambitious small-scale irrigation development programs that consistently fail to meet their targets. This is particularly problematic because groundwater irrigation and exploration programs have been so mixed that it is sometimes difficult to determine if failure to meet targets is the fault of the irrigation technology or an inadequate resource base.

Pumping Regulations

In many low-lying coastal areas, groundwater is abundant but is threatened by saline water intrusion. This is a major problem along the north coast of Java, southern Bali, the coastal lowlands adjacent to and north of Ujangpandang in South Sulawesi, the embayments of eastern Sumbawa, and the Oeseo plain north of Kupang in West Timor. There is also a danger that in shallow groundwater areas uncontrolled pumping may lead to water table decline and the drying up of domestic wells. To prevent this, the government must establish some control over the quantities pumped. Similarly, where open wells, well points, and intermediate wells are established in conjunction with existing gravity systems, government action may be required to prevent conflicts between the users of government-managed and farmer-owned pumping systems.

Technical assistance is required at the design stage of large-scale river pumping to ensure a location where the pumpset will be safe from flooding and sedimentation danger. It is also important that downstream users should be protected, that the required water elevation along the river should be maintained for existing irrigation structures, and that sufficient discharge should be available for effluent dilution. Some form of licensing of river pumping is needed. Licenses could be issued by a group such as the provincial or district irrigation committee, although these committees should be enlarged to include private and quasi-private interests (water users groups, tourist hotels, factories, city water suppliers, etc.) as well as government line agencies.

Institutional Conclusions

Government Support

P2AT operates with an almost exclusively hydrologic approach and has ignored the management requirements of pump irrigation schemes. It does not provide institutional support to water users associations nor is it structured to provide assistance to local governments once the pumps have been turned over. P2AT's impermanent project status, which precludes adequate annual operation and maintenance funding, has further undermined its effectiveness.

Pump Irrigation WUAs

Normally, public gravity-fed irrigation schemes in Indonesia provide little opportunity or incentives for significant WUA participation. Thus, in many areas, water distribution continues to be managed along traditional lines, and efforts to organize WUAs have been disappointing. In contrast, pump irrigation schemes require an organization to procure fuel, maintain the machinery, collect fees, and manage finances.

Pump irrigation groups are proving competent at day-to-day management of the technology and the resource base. They have been able to set fees and collect them, distribute water equitably, maintain the physical system, support a management structure, and operate and maintain their pumps efficiently. Although their executive committees have not always anticipated repairs and saved for them, they have been able find the money by raising fees temporarily with membership agreement.

The GOI has not promulgated any special regulations for the formation and operation of pump irrigation WUAs. The regulations that apply were originally prepared for gravity irrigation groups, although the conditions and requirements of the two differ considerably. Yet, in some sense, the absence of specific regulations may have been advantageous for pump irrigation WUAs. They have been less constrained by an imposed structure from the center that would have led to the organization of homogeneous groups. As a result, there is a wider variety of WUAs adaptated to local conditions.

Policy Conclusions

Limited Role of Government

Although the government may have to take the lead and assume the risk for a new and untried irrigation technology, it must allow the private sector to step in as soon as possible. Time and again experience in the region has proven that government monopolies restrict the growth of pump lift irrigation, keep costs artificially high, and dull private initiative. The government should restrict its role to demonstrating how appropriate technology can sustain groundwater resources. Once the private sector is made aware of the marketing opportunities and credit is available, the growth of pump irrigation should be assured.

P2AT's incursion into shallow groundwater development in areas where farmers' have their own wells has been unfortunate. The intention was to improve the design and efficiency of the farmers' wells, but the farmers' conviction that their own wells are better and cheaper to operate has in fact been vindicated. The P2AT wells often have not provided any more water, and in many cases less. Clearly, the decision of P2AT to enter these areas was wrong.

Poverty Alleviation Role

Since the costs of deep wells when the government pays for the infrastructure are often over Rp. 100,000 per season, the government may be forced to continue its operational subsidies in poverty areas and on a number of the outer islands that lack markets for high-value crops. Otherwise, as many of the sample sites have shown, utilization will drop because farmers cannot pay for the fuel. The economic analysis for this study indicates that most systems being developed with public resources will continue to require a significant degree of government or NGO assistance, especially the older schemes where most of the pumpsets have exceeded their design life and will need to be replaced within a few years at public expense.

Although some WUAs can afford to replace pumpsets, it is unrealistic to impose this as a universal requirement, particularly in areas such as Gunung Kidul, where the replacement of P2AT turbine pumps is well beyond the resources of any WUA. The present uniform policy ignores differences in technology, cropping patterns, terrain, and farmer resources from one area to another. In parts of East Java, the price of groundwater sold by farmers forces the government to price water from nearby public tubewells at below cost. It is clear in such situations where private pump operations are viable, there is no justification for public pump investment.

Recordkeeping and Financial Management

The WUAs keep only minimal records of pump use, and financial balance sheets and planning are rare, revealing a need for the continued training of executive committee members and for regular monitoring and backstopping. Hitherto, management support by P2AT or the local government has been inadequate. A pervasive problem is the lack of clear accountability in financial management. Many WUA savings in banks are held in the name of an individual. Operators collect the fees but may not pay the honoraria of executive committee members. The system offers too many opportunities for personal gain at the expense of the group.

Throughout their development, both before and after turnover, there have been no mechanisms for P2AT or the local government to monitor and backstop the WUAs. The main role of district irrigation committees should be to evaluate WUA performance and to deal with complex problems such as those arising from cross-sectoral or social conflicts. In practice, most of these committees do not even attempt to address such concerns.

System Turnover

By the time most systems are turned over, the procedure is little more than a paper transfer between government agencies. Real changes in financial management responsibilities for the WUAs take place after the first two years of operation, not after turnover. Shifts in responsibility from P2AT to the WUAs, whether after two years or at turnover, are made uniformly for all pumps and do not take into account the size or technical level of each system. Turnover should not be confused with privatization. There have not yet been attempts to transfer systems assets to WUAs. This, however, may become more likely as WUAs start to obtain legal status.

Recommendations

Technical Recommendations

- The GOI should not develop pump irrigation systems in areas where significant private development is at work, but instead should encourage such private initiative.

- Although pump irrigation WUAs generally have been effective, it may not be necessary for all schemes to have this high level of organization. Smaller command areas requiring less powerful engines and pumps might instead be placed under the village government. The GOI should consider developing small systems without WUAs on a pilot basis and monitoring them for effectiveness. There may well be a threshold below which a WUA is unnecessary, although some efforts organizing users will certainly be required.

- Ongoing pump lift irrigation programs have very poor and inconsistent records, and national standards need to be prescribed.

- Shallow groundwater development should be left to the farmers who use locally constructed wells and small pumps. However, some control is necessary on the number of pumping units and the amount of water abstracted to prevent problems such as the drying up of domestic wells and sea water intrusion. The results of integrated river basin planning should guide DGWRD in advising local governments on groundwater recharge and safe yields. However, unless the irrigation committees and the WUAs are made more effective, control on pump use will be difficult.

- Most large-scale groundwater development schemes under P2AT have used equipment supplied through donor commodity aid. This equipment has proved difficult to maintain locally and has been of no value in stimulating the national economy. The GOI should encourage the indigenous manufacture of pumps and drilling equipment.

- The government should not invest in turbine pumps for which there is no reliable local supply of spare parts, unless it plans to operate the equipment itself. If this policy is considered too restrictive, the GOI should seriously investigate the feasibility of a joint venture with a reputable multinational turbine pump manufacturer. Meanwhile, domestic pump manufacturers should be given assistance to improve quality control.

Environmental Recommendations

- A national evaluation of water resources by river basin and sub-basin should be conducted as soon as possible, not only for sound planning and management, but because the quality of the water resource will change as population and development pressures on the land increase.

- In shallow groundwater areas, some control on privately operated pumps is necessary to prevent the drying up of domestic wells and sea water intrusion.

- Initially groundwater resource evaluation should be separated from irrigation development so as not to make a fairly complex resource even more difficult to quantify.

- Initially, groundwater resource investigation should be phased into irrigation development only after the results have been reviewed as part of an integrated development plan.

- Much valuable data has been gathered at a cost of hundreds of millions of dollars during the last 20 years; however, little of this material has been used. A major effort should be made to integrate these data for each province as a guide for future irrigation development and as a means to identify critical data still needed.

- Periodic estimates of annual and seasonal resource utilization by pump lift irrigation are needed to determine the residue available for future development.

- A national water resource management and monitoring organization is required to tie environmental concerns to resource planning and use.

Institutional Recommendations

- A permanent government presence is required in pump irrigation development and management for the program to be effective in raising agricultural income, particularly on the eastern islands, where technical abilities are less sophisticated and, hence, technical demands are greater. Under the present structure, PRIS may be more appropriate than P2AT to provide this support.

- Assistance to the WUAs in financial recordkeeping is needed for monitoring and backstopping the systems both before and after turnover. Since P2AT cannot now provide this assistance because of its project status, it should either be restructured or some other agency should be given the responsibility for this assistance.

- The WUAs should be given a legal status that permits them to open bank accounts.

- Pump irrigation systems should be designed with greater farmer participation because this will ensure the selection of the most appropriate technology and improve the chances of sustainability.

Policy Recommendations

- A national inventory of pump lift irrigation equipment in public and private ownership is required.

- If pump irrigation investment is to be made in poverty areas, it must be accompanied by continued support, particularly with maintenance and replacement.

- Credit should be made easily available to enable farmers to invest in high-yielding crops and pay for the fuel to operate the pump. This credit would also contribute to higher returns on pump irrigation water.

- In areas such as Central and East Java where farmers have already demonstrated their willingness to invest in small-scale pump irrigation technology, the government should encourage rather than compete with local initiative.

- Pump irrigation has a very high payoff when providing water for crops other than rice during the dry seasons. To improve the returns on investment, better technology, agricultural extension (in the public or the private sector), and market mechanisms should support farmers who are often not well trained in producing, processing, and marketing these crops.

- Since pump irrigation schemes are also intended to alleviate poverty, irrigation service fees should be standardized as a matter of equity and also to encourage greater utilization of the facilities.

REFERENCES CONSULTED

General

Arif, Sigit Supadmo, Suprodjo Pusposutardjo, and Sukirno
1992 Sustainability of Groundwater Farmer-Managed Irrigation Systems in Indonesia: A Case Study of Gunung Kidul and Nganjuk/Kediri Areas. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Gill, Mushtaq Ahmad
1992 Sustainability of Water Users Associations as Groundwater Irrigation Managers: A Case Study under On-farm Water Management in Punjab, Pakistan. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Hakim, M.A.
1992 Mobilization of Financial Resources for Sustainable Groundwater Farmer-Managed Irrigation Systems in Bangladesh. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

IIMI
1992 Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Papers presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Johnson, Robert
1989 Private Tube Well Development in Pakistan's Punjab: Review of Past Public Programs/Policies and Relevant Research. Country Paper - Pakistan No. 1. IIMI.

Johnson, Sam H., III, Sanguan Patamatamkul, Terd Charoenwatana, Apisith Issariyanukula, Kanda Paranakian, and Peter Reiss
1989 Medium Scale Irrigation Systems in Northeast Thailand: Future Directions. ISPAN.

Olin, Manuel
1992 The Sustainability of Groundwater Farmer-Managed Irrigation Systems. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Pakpahan, Agus and Sumaryanto
1992 Capabilities of Water Users Associations in Managing Groundwater Pump Irrigation: A Case Study in East Java, Indonesia. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Pakpahan, Agus, Sumaryanto, Hendiarto, Abunawan Mintoro, et al.
1992 Studi Kebijaksanaan Irigasi Pompa di Indonesia. Pusat Penelitian Sosial Ekonomi Pertanian. Bogor.

Pradhan, Ujjwal and Ganesh Thapa
1992 Sustainable Groundwater Development and Management in Nepal: Major Issues Confronted by a Development Bank in Nepal. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Papers presented at A South Asian

Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

Rashid, M.H., M.A.K. Mridha, and Ian K. Smout
1992 Case Study of Management of Three Deep Tubewells in Tangail, Bangladesh. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

RePProt
1990 The Land Resources of Indonesia - A National Overview. Directorate General of Settlement Preparation, Ministry of Transmigration and Land Resources Department, Overseas Development Administration, UK.

Sarker, S.C.
1992 An Endeavor of Proshika Target Groups to the Sustainability of Groundwater Management. Groundwater Farmer-Managed Irrigation Systems and Sustainable Groundwater Management. Paper presented at A South Asian Regional Workshop of the IIMI FMIS Network. Dhaka, Bangladesh.

World Bank
1992 Draft Aide Memoire. Proposed Groundwater Development Project. Preappraisal Mission, April April-May 1992.

Pump Irrigation Potential

Crippen International, Ltd.
1980 Timor Island Water Resources Development Study. CIDA.

Crippen International, Ltd.
1991 Kupang Groundwater Investigation, Preliminary Assessment, Final Report. CIDA.

Department of Transmigration
1988 Regional Physical Planning for Transmigration, Review of Phase I Results, Sulewesi.

DHV/NEDECO
1986 Institution Strengthening Study in Water Management in Tertiary System in Irrigation O&M at Main System. Project Preparation Report.

Direkorat Jendral Geologi dan Sumberdaya Mineral
1989 Survei Hidrogeologi dan Konservasi Airtanah Daerah Kupang, Oesao -Pariti dan Sekitarnya, Timor Barat (NTT), Bandung.

ELC-Electroconsult
1991 Lombok Island Groundwater Development : Study of the Long-term Ground Water Development Program of Lombok Island. Irrigation Subsector Project. Part D. Pilot Groundwater Development. Rome, Italy and P.T. Yodha Karya-Gamma Epsilon.

ELC-Electroconsult
1991 Groundwater Development Project in East Java and Sulewesi, Final Report, February-March, 1991. Final Report plus 8 Supporting Reports. Min of Public Works.

Foreign Technical Cooperation Bureau of the Cabinet Secretariat of the Republic of Italy
1987 Groundwater Investigation and Management for Rural and Urban Water Supply in West Timor. Project Paper.

General Directorate of Water Resources
1990 Groundwater Development in Indonesia.

IIMI
1988 Efficient Management and System Turnover. Interim Report.

JICA
1980 Master Plan for the Central South Sulewesi Wayet Resources Development Project. Main report. DGWRD.

MacDonald, Sir M & Partners and Nippon Koei Co. Ltd.
1990 Nusa Tenggara Agriculture Development Project. Environmental Evaluation Study Final Report - Main Volume.

Morgan, J. Wynn
1990 The Timor Solution. Crippen International, Ltd.

Prairie Farm Rehabilitation Administration
1984 Nusa Tenggara Timur Development Unit Technical Appraisal Mission. Two volumes.

Siskel, Suzanne
1986 Groundwater Demonstration Plot Pukdale, Kabupaten Kupang, Nusa Tenggara Timur. Monitoring Report No. 5, Final Report. USAID/Jakarta.

SSIMP
1989 Tiu Kulit Dam Project Environmental Assessment.

SSIMP
1990 Garpet Dam Project Environmental Assessment.

SSIMP
1990 Project Justification Report Kalimanting II Project. Provincial Water Resources Division, Provincial Public Works, NTB.

Sudadi, P. and S. Ruchijat
1989 Catatan Penerangan, Lembar Sebagian 2307 Waipukang dan Sebangian 2407, Dilli Tenggara Timur.

USAID/Jakarta
1989 Project Profile. SSIMP South Sulewesi Groundwater Development Sidrap Wajo Bone.

World Bank
1987 Staff Appraisal Report Indonesia Irrigation Subsector Project.

World Bank
1990 Country Study: Indonesia-Sustainable Development of Forests, Land and Water.

Environmental Concerns

DGWRD
1986 Lombok Island Groundwater Investigation. Volume 1.

DGWRD
1991 Groundwater Development in East Java and Sulawesi. Final Report.

Mahbub, B., Soekardi, S. Soewasti, N.T. Bukit, T. Tugaswati, R. Hidayat, and H.H. Amir
1980 Air. Dalam Kualitas Lingkungan di Indonesia. Kantor Menteri Negara KLM.

Prastowo, B.
1977 Pengembangan Airtanah untuk Tanaman Pangan di Kabupaten Gunung Kidul. Tesis S-1 Fakultas Teknologi Pertanian, UGM.

Sutani
1980 Ilmu Wilayag: Beberapa Pemikiran untuk Pembangunan Nasional. BP Pekerjaan Unum, Jakarta.

Wirjodihardjo, W.
1952 Ilmu Tubuh Tanah Jilid I. Noordhoff-Kolff, N.V. Jakarta.

Roles for the Public and Private Sector

Blair, H.
1986 Ideology, Foreign Aid and Rural Poverty in Bangladesh: Emergence of the Like-Minded Group. Journal of Social Studies 34:1-27.

Broeshart, M.
1990 Privatization in Agriculture: A Chance for the Deprived or the Privileged? Wageningen University.

Hossein, Mohamed Mosharraf et al.
1982 A Report on DTW Irrigation in Bangladesh, Working Paper No. 2. Ministry of Agriculture, Dhaka.

Johnson, Sam H., III
1989 Private Tubewell Development in Pakistan's Punjab: A Review of Past Public Programs/Policies and Relevant Research. IIMI. Colombo.

Mandel, M.
1983 Development of Small Scale Lift Irrigation in Bangladesh. Public Intervention in Farmer Managed Irrigation Systems, Sri Lanka.

Pitman, G.T.K.
1989 National Water Planning in Bangladesh: The Role of Groundwater in Irrigation Development. Presented at the World Bank Poverty Alleviation through Groundwater Irrigation Development Symposium.

Wood, G.
1983 Provision of Irrigation Services by the Landless: An Approach to Agrarian Reform in Bangladesh. University of Bath.

Approaches for Pump Irrigation Development

Center for Agricultural Socio-Economic Research
1991 Pump Irrigation National Policy Study. Performance of Pump Irrigation on Java (in Indonesian).

Directorate General for Rural Development
1984 Institutes for Village Community Resilience (LKMD) and Family Welfare Promotion (PKK).

Directorate General of Rural Development
1990 Results of the Implementation of Village Development Assistance in Repelita I,II and III (in Indonesian).

Ministry of Home Affairs
1991 Instruction of the Minister of Home Affairs No. 7 of 1991 regarding Revised Instruction of the Minister of Home Affairs No.26 of 1984 on the Operational Directive of the Village Development Assistance (VDA).

Virama Karya and Sir M MacDonald & Partners Asia
1990 Central Java Irrigation Project. Advanced Operation Unit Status Report (No. 3).

Sumani Irrigation Project
1990 End of Term Report, Civil Engineer, Indonesian and Swiss Governments Development Cooperation.

Pump Irrigation Technologies

Erickson, Robin
1991 An Economic Assessment of Ground Water Projects. SSIMP.

Nippon Koei Co., Ltd.
1990 Interim Report. Central Java Groundwater Irrigation Development Project. Main Report, Volume 2. Directorate General of Water Resources Development, Ministry of Public Works.

Wright, Martin
1989 The Initial Development of Small-Scale Irrigation Management Experimental Groundwater Irrigation Systems in NTT. Final Report. SSIMP.

Economic Viability of Pump Irrigation

Gerards, Jan L.M.H.
1990 Irrigation Service Fees in Indonesia. Paper presented at LP3ES, Jakarta.

MacDonald, Sir M & Partners
1984 Greater Yogyakarta Resources Study. Volume 12: Economics.

Seckler, David and Jack Keller
1990 Design and Evaluation of Alternative Lift Irrigation Systems, Water Management Synthesis Project, Engineering Research Center, Colorado State University.

World Bank
1991 Project Completion Report. Indonesia-Seventeenth Irrigation (East Java) Report. Washington, D.C.: Asia Regional Office.

Required Legal Framework and Institutional Support

Executive Board Groundwater Development Project East Java
1992 Plan for Tubewell Management in Madura and Elsewhere in East Java by East Java Provincial Irrigation Service (in Indonesian).

Jackson, Roger
1991 Development of Water User Associations on the Madura Groundwater Development Project, Indonesia. ODI Irrigation Management Network.

Lavalin, Euroconsult, Sir M MacDonald & Partners, and Indec
1990 Irrigation Sub Sector Project (ISSP) Project, Preparation ISSP-2, Final Report.

Madura Groundwater Irrigation Project
1991 Annual Report and Work Plan, Institutional and Financial.

Ministry of Finance
1991 Briefing Sheet about Self-Funding Units at National Forum (in Indonesian).

Ministry of Home Affairs
1989 Minister's Decree No. 63/1989 and Instruction No. 30/1989 about Irrigation Service Fee in Trial Areas (in Indonesian).

Ministry of Public Works
1989 Minister's Regulation No. 42/PRT/1989 about Implementation of Small Irrigation Scheme Turnover following the Arrangements for WUA Rights (in Indonesian).

President of the Republic of Indonesia
1991 President's Decree No. 38/1991 about Self-Funding Units and Implementation of Financial Arrangements (in Indonesian).

Puspowardoyo, Soekardi
n.d. Legislation and Institutional Arrangement of Groundwater Development in Indonesia.

Sumani Irrigation Project
1990 End of Term Report, Civil Engineer, Indonesian and Swiss Governments Development Cooperation.

Zerner, Charles
1990 The Environmental, Legal and Regulatory Framework for Groundwater Abstraction in Central Java: An Assessment and Recommendations. Unpublished paper.

Strengthening the Capacity of Water User Associations

Ambler, John
1990 Strengthening Water User's Associations in Indonesia: Principles, Priorities, and Programs. Unpublished paper.

Aziz, Muhamad Amin, Richard Hutapea, Peter Reiss, Soedodo, and Sutarwi
1991 Sustainability and Privatization of Small Scale Irrigation in Indonesia: A Study of Sederhana and High Performance Sederhana Systems. ISPAN.

Casey, Margaret
1989 Sociological Study of Women in Agriculture in Madura. Madura Groundwater Irrigation Project.

Jackson, Roger
1991 Water Users and the Madura Groundwater Project. ODI-IIMI Paper.

Madura Groundwater Irrigation Project
1990 Annual Report.

Pasadaran, Effendi
1988 Study of Legal Aspects for Program Handing Over of Small Scale Irrigation for WUA.

Sihombing, Maroelak
1991 Participation and Sustainability in Developing Farmer Managed Irrigation: Our Experience in West Java. Jakarta, Bina Swadaya

Vermillion, Douglas and Sam H. Johnson III
1990 Turnover and Irrigation Service Fees. Indonesia's New Policies to Achieve Economically Sustainable Irrigation. Irrigation and Drainage Systems 4:231-247.

ACRONYMS

AARD	Agency for Agriculture Research and Development
ADB	Asian Development Bank
ANDAL	analysis of environmental impact
APATI	Association of Groundwater Drilling Contractors of Indonesia
BADC	Bangladesh Agricultural Development Corporation
BAPPENAS	Badan National Development Planning Council (*Budan Perencanaan Permabangunan Nasional*)
Bm^3	billion cubic meters
CJGWP	Central Java Groundwater Project
DEG	Directorate of Environmental Geology
DGFCA	Directorate General of Food Crops Agriculture
DGGMR	Directorate General of Geology and Mineral Resources
DGWRD	Directorate General of Water Resources Development
DOI	Department of Irrigation
DTW	deep tubewell
EPADC	East Pakistan Agricultural Development Corporation
EPWAPDA	East Pakistan Water and Power Development Corporation
GOI	Government of Indonesia
HYV	high yielding variety
IDA	International Development Agency
IPEDA	Indonesian Regional Development Fund (*Iuran Pemban Gunan Indonesian Daerah*)
ISF	Irrigation Service Fee
ISSP	Irrigation Sub-Sector Project
ITW	intermediate tubewell
KUD	village unit cooperative fee (*koperta unit desa*)
LKMD	village community residence council

MGIP	Madura Groundwater Irrigation Project
Mm^3	million cubic meters
Mmt	million metric tons
MOA	Ministry of Agriculture
NGO	nongovernmental organization
NTB	*Nusa Tenggara Barat*
NTT	*Nusa Tenggora Timor*
O&M	operations and management
ODA	Overseas Development Administration (British)
OECF	Overseas Economic Cooperation Fund
P3A	Water Users Association (*Perkumpulan Petani Pemukai Air*)
PAT	Sub-Directorate of Groundwater Development
PRAS	Provincial Agriculture Service
PRIS	Provincial Irrigation Service (*Dinas Pengairan Propinsi*)
PU	Ministry of Public Works (*Departemen Pekerjaan Umum*)
RS	research sites
SKR	Second Kennedy Round
SSIMP	Small Scale Irrigation Management Project
STW	shallow tubewell
SV	sites visited
USAID	U.S. Agency for International Development
WUA	water users association
YIS	*Yayasan Indonesia Sejahtera*

Appendix A

SCOPE OF WORK FOR NATIONAL PUMP IRRIGATION POLICY STUDY

NATIONAL PUMP IRRIGATION POLICY STUDY
Scope of Work

Background

Traditionally Indonesia has relied primarily on run-of-the-river gravity irrigation systems to feed its five million hectares of irrigated land. Indeed, the high rainfall and sloping topography in the western part of the country have provided ideal conditions for this type of irrigation, and the rapid expansion of gravity systems has been an important part of the country's successful drive for rice self-sufficiency during the last two decades.

The period of rapid expansion of gravity irrigation in Indonesia is now over, however. The most favorable sites have been developed already, and the cost of building new systems to keep pace with the rising population is soaring, now ranging between $1,700 and $2,700 or more per hectare. In some places contraction of irrigated area is a new problem. Many tail end areas of large systems, especially in Java, now often experience water shortages as a result of the degradation of upper watersheds, and urban expansion consumes some 20,000 hectares of irrigated land yearly. In addition, there remains for the government the problem of extending the benefits of irrigated agriculture to the much poorer and drier areas of Eastern Indonesia, where the scope for enhanced gravity irrigation systems is very limited, but where groundwater resources may be tapped. This confluence of conditions has spurred the Government of Indonesia to pay increasing attention to developing surface and groundwater sources through the introduction of pumps for free-standing or conjunctive use irrigation.

Where the government has taken the lead in developing pump irrigation, the new systems normally have been characterized by heavy subsidies. Wells have been drilled free of charge, pump sets have been given to the farmers, canals have been constructed with minimal farmer equity investment, and agricultural inputs have been subsidized. Private and NGO-led development, on the other hand, has stressed farmer involvement in development and farmer investment in the capital stock, operations, and maintenance of the new systems. In between these extremes lies a broad range of other approaches different agencies have tried. All have had their share of success and failure. And, in the near future newer possibilities still—especially with regard to aspects of funding sources and financial responsibility—may open up as Indonesia's continuing deregulation of capital markets and expanding accessibility of formal credit institutions to the rural populace proceed. These conditions all point to a dynamic context for increased pump irrigation in Indonesia--and one whose course needs to be charted based on a full understanding of the lessons of past approaches.

The new policy environment may be conducive to expanded pump irrigation development, and the value of pumped water may be high. Nevertheless, there are uncertainties about the technical capacity of the relevant implementing agencies to develop pump irrigation. Questions also remain concerning the economic viability of pumping, financing arrangements, sustainable pumping levels, agricultural support services for non-rice crops, and the legal and institutional supports needed for strong farmer water users' associations.

Without addressing these issues, especially the economic ones, there is a danger that the explicit and implicit subsidies endemic to most public sector promotion of pump irrigation will produce unsustainable practices and/or environmental degradation. Among the possible negative effects of overly subsidized or inappropriate pump development could be increased pumping costs and salt water intrusion from overdepletion of groundwater, and accelerated contamination of water supplies from the increased use of agro-chemicals associated with high value irrigated agriculture. These issues concern long-term aquifer management, and can only be resolved if an adequate base of information is created about both the nature and potential of pump irrigation resources themselves, especially groundwater, and about past experiences with the process of developing that water wealth.

Understanding these emerging issues will be crucial for the formulation and implementation of large investments in pump irrigation now being planned in the next five years. However, the GOI is not well equipped to confront these immediate policy issues without better systematic information and planning. At present, for example, there are many actors involved in this area, including a number of agencies of the central and provincial governments, the private sector and the NGO community. There is, however, no known inventory or comparative assessment of the various approaches being used, nor is there adequate monitoring of either the agro-economic benefits, sustainability, or the environmental impact of pump and groundwater irrigation throughout the country. Thus, the GOI has limited reliable information on which to base its planning and its requests to donors for expanded pump irrigation development.

Particularly critical is the GOI's capacity to formulate appropriate pump irrigation activities to absorb the increased funds the state and donors have earmarked for Eastern Indonesia, a region designated as a "neglected area." Although the attention to this area is welcome, the capacity of much of this part of the country to exploit new technologies and to effectively absorb and use large capital investment—even if dispersed among many small pump sites—is relatively low. And there is the danger that in developing pump irrigation in these regions, there may be a bias toward introducing the "standard" technologies already in use in Java and other more economically integrated and densely populated parts of the country. These technologies, which may not even prove economically viable or sustainable in Western Indonesia, may be transplanted to Eastern Indonesia without careful consideration of their appropriateness or potential impact, and could even prove to be counter-productive in the longer term.

Objectives

The purpose of this study is to provide an overview and assessment of past and present experiences with pump irrigation throughout Indonesia. The study is expected to be an important and timely first step in assisting the GOI in developing viable policies for development, expansion, and monitoring of pump irrigation and in preparing effective and appropriate proposals for donor assistance in this sector.

The study will:

1) Determine the approximate extend of existing pump irrigation and pumping capacity throughout the country. Identify the number and extent of different types of pump irrigation, and according to their key features, such as location, size, agro-ecological zone, hydrologic setting, etc.

2) Identify the range of approaches that have been tried in Indonesia to developing pump irrigation schemes, including those sponsored by government agencies, non-government organization, and the private sector.

3) Assess through case studies a representative sample of pump irrigation approaches, identifying the essential elements of each and describing the conceptual and implementation processes used. Asses their suitability and adaptability for various hydrologic and agro-socioeconomic contexts. Evaluate their effectiveness with respect to technical, economic, financial, and institutional viability and sustainability. Determine in particular:

   - the formation processes and effectivėness of water users' associations (WUAs) in the development and operation of pump irrigation schemes, including the key elements found in successful approaches to organizing and strengthening WUAs in pump irrigation schemes.

   - the legal framework and institutional supports needed for successful and sustainable WUAs in pump irrigation systems.

   - the relationship between public agencies, the farmers, and WUAs in each scheme, and the extent to which roles, responsibilities, and functions are explicit, understood, and implemented. Assess the potential for expanding the rights and responsibilities of WUAs, and the role of private sector, including the provision of technical and management services to WUAs.

   - the composition of investment (farmer, private business, local and central government, and donor) during the planning, implementation, and operational stages. Determine operation and maintenance costs and funding sources. Assess the economic and financial viability of selected schemes.

4) Determine and prioritize critical near- and long-term policy issues for the expansion of pump irrigation throughout the country, particularly Eastern Indonesia.

   - Identify and assess near-term policy options, and determine follow-up actions such as environmental and agro-economic monitoring programs, pilot and demonstration projects, and action research needed to evaluate various development scenarios.

Identify long-term policy issues and prioritize steps for future study.

5) Recommend steps to improve the viability and sustainability of pump irrigation systems in current use.

Approach

The aim of this study is to inform current decision-making concerning past performance in pump irrigation; identify critical short-term policy issues; identify monitoring activities, in-depth studies, or other actions that will be needed to weigh long-term policy options; and initiate a systematic process of research and evaluation to support and broaden the scope of policy dialogue within the various government agencies concerned with pump irrigation. The study team will work closely with an interagency steering committee to refine and sharpen these aims.

The team will consult with a wide range of sources, and make a comprehensive search for and compilation of secondary data, reports, and other materials in order to determine the scope of pump irrigation activities throughout the country, to identify key issues and problems, to select a representative sample of defunct and existing pump irrigation systems, and carry out the remaining activities outlined above. Sources will include officials of central agencies, such as the Ministries of Agriculture, Public Works, Mines and Energy (Directorate of Environmental Geology), and the National Development Planning Agency (BAPPENAS); counterpart officials at provincial and district levels; nongovernmental organization; and pump suppliers. Members of the team will visit selected pump irrigation sites throughout the country to meet with water users, pump owners, local leaders, and so on.

The study will be carried out in three phases over a period of about 15 months beginning about August 1, 1990, by a team of Indonesian experts in collaboration with a limited number of expatriate consultants.

Phase I: Phase I is the inception phase in which the study framework and detailed work plan will be established. This phase will include the following activities:

(a) Formation of a small interagency steering committee to refine the terms of reference of the study.

(b) Review of available secondary sources of data.

(c) Preliminary identification of policy issues and priorities.

(d) Preparation of detailed study design, schedules, and workplan.

(e) Implementation of initial policy seminar to review the study policy framework, priorities, study design, and work plan.

Phase II: Phase II involves case studies and the preparation of interim concept and issue papers.

(a) Selection of a sample of schemes representative of the full range of pump irrigation approaches.

(b) Conduct of field studies and data collection at each sample site and preparation of case study reports. In each case the team will determine the current operational status and effectiveness of the system; assess the organizational arrangements and processes through which the system is sustained, particularly the role of water users in system design and construction, financing, operation and maintenance; describe the process for managing water, mobilizing resources for O&M, replacement and improvement of the system; determine the level of technical support needed and process for providing it; describe the role of local and central government actors in system development and in providing ongoing technical, agricultural, and management support; describe and quantify to the extent possible agricultural production activities and assess the economic and financial viability of the scheme.

(c) Preparation of a series of concept and issues papers at periodic intervals during the progress of Phase II based on in-depth study of available secondary information and case study material. These papers are intended as intermediate products and will be presented at seminars attended by steering committee members and other officials from relevant government and donor agencies, as well as other implementing institution, such as NGOs.

Phase III: Phase III involves the analysis and synthesis of case study materials, a national policy seminar to review draft recommendations, and preparation of the final report.

(a) Analysis and synthesis of case study materials, identification and assessment of policy options.

(b) Preparation of a draft final report.

(c) Holding of a national policy seminar to consider draft recommendations of the study. The team also will present its findings in a national seminar involving policy makers from BAPPENAS, the Ministries of Finance, Home Affairs, Agriculture, Mines and Energy and other relevant departments, as well as representatives of the donor and NGO community involved in the irrigation activities.

(d) Preparation of the final report.

Funding

The study will be jointly funded by the Ford Foundation and USAID/Jakarta through its Small Scale Irrigation Management Project (SSIMP). The Ford Foundation will provide local cost funding, while USAID will fund international costs. The USAID portion will be implemented through a buy-in to the Irrigation Support Project for Asia and the Near East (ISPAN), which will recruit and administer international team members for the study.

Team Composition

The study will be conducted by a joint multidisciplinary team of senior Indonesian experts and expatriates with advanced degrees in their respective fields and a minimum of 10 years of development-related experience. The team will be constituted as follows:

Expatriate

1) Resource/macro-economist serving as Team Leader— with experience in analyzing the role of water resources in national planning and development and policy formulation.

2) Institutional specialist—with experience in the analysis of agency-led rural development projects and with farmer water users' associations in Asia and their institutional support systems.

3) Water resources/agricultural/irrigation engineer— with experience in participatory irrigation management, planning small-scale groundwater and pump irrigation schemes, and hydrologic assessment and monitoring for resource management.

Indonesian

1) Agricultural economist—with experience in irrigation development (preferably in pump irrigation).

2) Social scientist—with experience in rural development and community participation in irrigation, with special expertise in water users' associations.

(One of the individuals above will serve as Coordinator of the Indonesian team.)

3) Water resources/agricultural/irrigation engineer— with experience in the planning and operation of a range of pump irrigation schemes (10-300 ha).

4) Agronomist—with experience in extension work in pump irrigation.

Reporting schedule and requirements

The team will prepare the following reports:

1) Initial policy seminar results and workplan (Inception Report)

2) Report on methodology and sampling

3) Subsequent quarterly status and progress reports

4) Concept and issue papers that

- summarize the findings and major issues that emerge from the case studies and

- explore the implications of various issues and the range of options available to the government, including such areas as alternative policy objectives (e.g., equity, maximizing water availability, conjunctive use, promoting the private sector and privatization, implication of subsidies for equity, growth, and resource management, mobilizing financial resources for investment and recurrent cost, etc.)

5) Final report covering the objectives listed above.

Preliminary Schedule

The preliminary estimate of the timing of the study is as follows:

Months	Activity	Report due
8—9/90	Preparation of Inception Report (covering objectives #1 and 2).	10/1/90
10/90	Preparation of report on Methodology and Sampling (covering objective #3).	11/1/90
11/90—7/91	Data collection at all sample sites. Preparation of first case study report. Case studies to be prepared as the research at each site is concluded and reports submitted at the end of each two month interval throughout the research period. The final version of all case studies will be compiled and submitted as an annex to the Final Report.	1/4/91 3/1/91 5/1/91 7/1/91
8—9/91	Preparation of draft Final Report.	10/1/91
10/91	Preparation of revised Final Report.	10/31/91

Appendix B

PHYSICAL FEATURES OF THE SAMPLE PUMPS

PHYSICAL FEATURE OF PUMPING UNIT : MADURA

NO	DESCRIPTOR	UNIT	LOCATION: SP - 09 MODUNG I	SP - 66 BULAY	SP - 94 PELTONG	SP - 97 PONTEH	SP - 102 BANYUBULUH I	SP - 33 ANDULANG
1	Total Command Area	ha						
	a. Design		23.5	44	42.70	39.70	32.0	44
	b. Actual		20	40	42.20	39.70	32.25	27
2	Power Driven							
	a. Type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
	b. Brand		BBI Deutz	BBI Deutz	BBI Deutz	BBI Deutz	BBI Deutz	BBI Deutz
	c. Model		F2L	F2L	F4L	F2L	F2L	F2L
	d. Power Size/RPM	Hp	19/1800	27/1480	48/2075	48/2075	23/1800	27/1800
	e. Status		New	New	New	New	New	New
	f. Fuel Consumption	lt/hr	4.3 (4)*	2.13 (3)*	5.45 (6)*	3.91 (7)*	2.30 (4)*	3.50 (4)*
	g. Lubric. Consumption	lt/hr	0.03	0.028	0.022	0.048	0.032	0.083
	h. Power Transmission		Direct Trans.	Direct Trans.	Direct Trans.	Direct Trans.	Direct Trans.	Direct Trans.
3	Pump specification							
	a. Type		Turbine	Turbine	Turbine	Turbine	Turbine	Turbine
	b. Brand		Lee Howl	F/ Morse	Lee Howl	Lee Howl	Lee Howl	Lee Howl
	c. Model			IIM 700	B2	B2	A	
	d. Inlet diameter	inch	8"	11"	10"	10"	10"	10"
	e. Outlet diameter	inch	6"	8"	8"	8"	8"	8"
	f. Discharge :							
	Design/RPM	lt/sec	30/1800	50/1700	60/2075	60/1800	60/1800	60/1800
	Actual/RPM	lt/sec	25/1400	58.5/1750	61.5/1400	55/1200	39/1300	48.5/1750
	g. Depth of well	m	106	72	100	60	103	62
	h. Elev.of pump	m	24.4	15.40	na	19.50	16.5	9
	i. Length of suction	m	na	na	na	na	na	na
	j. Suction head	m	na	na	na	na	na	na
	k. Pressure head	m	na	na	na	na	na	na
	l. Total head	m	30	20.70	36.6	36.6	16.1	25.3
	m. No. of elbow		3	3	3	3	3	3
	n. Type of fitting/No.		2	2	2	2	2	2
4	Water Source							
	a. Normal depth	m	8.75	1.34	10.78	9.30	3.20	3.06
	b. Drawdown/RPM	m/rpm	10.83/1400	4.10/1700	17.17/1500	10.64/1400	5.30/1100	3.43/nm
5	Canal length	m	800.75	1280	1291	1307	1146	1314
6	Year of Construction		11/1978 12/1988	04/1984 07/1987	05/1988	04/1988	03/1988	01/1981 06/1987
7	Avrg. Pump Operation	hr	728	1932	683	1156	425	1700

Notes :

nm = not measured
na = not available
* = Monitoring Data 1989 - 1991
** = Monitoring Data 1979 - 1983

BEST AVAILABLE DOCUMENT

PHYSICAL FEATURE OF PUMPING UNIT : NGANJUK

NO	DESCRIPTOR	UNIT	TW 116 *	TW 117 *	TW 138 *	TW 153	TW 152	TW 174
			PUTUREJO LOCERET	PUTUREJO LOCERET	NGLABAN LOCERET	KEPANJEN PACE	JA'AN GONDANG	SUMBER AGUNG GONDANG
1	Total Command Area	ha						
	a. Design		20.14	21.561	24.121	32.912	49.93	44.145
	b. Actual		1.5	1.5	24.12	32.4	30	44.15
2	Power Driven							
	a. Type		Diesel	Diesel	Diesel	Diesel	Diesel	Diesel
	b. Brand		Mitsubishi	Mitsubishi	Mitsubishi	Lister	Lister	Ruston
	c. Model		TRD NM 90 H	TRD NM 90 H	TRD NM 90 H	HR 3	HR 3	2 Y WA
	d. Power Size/RPM	Hp	9/2400	9/2400	9/2400	37.5/1800	37.5/1800	23.5/1800
	e. Status		New	New	New	New	New	New
	f. Fuel Consumption	lt/hr	2	2	1.75	5	5	4
	g. Lubric Consumption	lt/hr	0.025	0.03	0.04	0.08	0.08	0.08
	h. Power Transmission		Direct	Direct	Direct	Direct	Direct	Direct
	i. Lubric. Consumption	lt/hr	nm	nm	nm	nm	nm	nm
3	Pump Specification							
	a. Type		Centrifugal	Centrifugal	Centrifugal	Turbine	Turbine	Turbine
	b. Brand		Lee Howl	Lee Howl/Tipton	Lee Howl/Tripton		Johnston	Johnston
	c. Model		-					JTC - 10
	d. Inlet diameter	inch	4	4	4	6	6	4
	e. Outlet diameter	inch	4	4	4	6	6	4
	f. Discharge :							
	Design/RPM	lt/sec	20/2400	25/2400	25/2400	60/1800	60/1800	45/1800
	Actual/RPM	lt/sec	15/2400	16/2400	16/2400	54/1800	50/1800	15/1300
	g. Depth of well	m	51.4	54	36	90	91	150
	h. Elev.of pump	m	na	na	na	na	na	na
	i. Length of suction	m	9	9	9	30	30	30
	j. Suction head	m	na	na	na	na	na	na
	k. Pressure head	m	na	na	na	na	na	na
	l. Total head	m	10.2	10.2	10	19	19	17.5
	m. No. of elbow		4	4	4	4	4	6
	n. Type of fitting/No.		4	4	4	4	4	4
4	Water Source							
	a. Normal depth	m	1.10	1.17	0.83	0.50	5.67	0.74
	b. Drawdown/RPM	m/RPM	9.21	10.34	6.22	5.8	2.47	2.26
5	Canal length	m	111	118	153	465	317	1948
6	Year of Construction		09/14/1982	01/5/1983	07/08/1982	07/08/1982	12/19/1980	10/29/1985
7	Avrg. Pump Operation	hr	823.5	747.44	888.14	858.64	1175.48	711

Notes :

nm = not measured
na = not available
* = Monitoring Data 1989 - 1991
** = Monitoring Data 1979 - 1983

BEST AVAILABLE DOCUMENT

PHYSICAL FEATURE OF PUMPING UNIT : KEDIRI

NO	DESCRIPTOR	UNIT	W-010 SIDOWAREG	W-061 SIDOWAREG	W-025 RINGINPITU
1	Total Command Area	ha			
	a. Design		49.2	45.9	44.3
	b. Actual		37	37	32
2	Power Driven				
	a. Type		Diesel	Diesel	Diesel
	b. Brand		Lister	Lister	Deutz
	c. Model		HR3	HR3	F2L-912
	d. Power Size/RPM	Hp	34/1800	34/1600	27/2200
	e. Status		New	New	New
	f. Fuel Consumption	lt/hr	6	6	6
	g. Lubric Consumption	lt/hr	0.04	0.04	0.04
	h. Power Transmission		Direct	Direct	Direct
3	Pump specification				
	a. Type		Turbine	Turbine	Turbine
	b. Brand		SPP	Lee Howl	G. Gaskin
	c. Model		16H-14i	KW-28	NYEGF
	d. Inlet diameter	inch	6	6	8
	e. Outlet diameter	inch	6	6	6
	f. Discharge				
	Design/RPM	lt/sec	60/1800	60/1800	90/2200
	Actual/RPM	lt/sec	54/1600	54/1600	33/1800
	g. Depth of well	m	41.4	80	39.3
	h. Elev.of pump	m	na	na	na
	i. Length of suction	m	25	30.5	25.4
	j. Suction head	m	na	na	na
	k. Pressure head	m	na	na	na
	l. Total head	m	19	16.5	21.5
	m. No. of elbow		3	3	3
	n. Type of fitting/No.		Gate valve/2	Gate valve/2	Gate valve/2
4	Water Source				
	a. Normal depth	m	6.1	9.6	2.91
	b. Drawdown/RPM		na	na	na
5	Canal length	m	174	160	10
6	Year of Construction		1975	1977	1981
7	Avrg. Pump Operation	hr	741	1255	1835

Notes :

nm = not measured
na = not available
* = Monitoring Data 1989 - 1991
** = Monitoring Data 1979 - 1983

PHYSICAL FEATURE OF PUMPING UNIT : WONOSARI

NO	DESCRIPTOR	UNIT	W-05 BOGORKIDUL	W-08 SIRAMAN	W-11 JARANMATI	W-14 KARANGWETAN	W-16 PLAYEN II	W-19 NGIPAK II	W-20 AWAR-AWAR	W-21 JATISARI	W-22 PLUMBUNGAN	W-28 HOLO
1	Total Command Area	ha										
	a. Design		46.6	31.1	30.5	42.2	33.3	44.4	11.0	42.2	41.2	34.6
	b. Actual		37.0	26.0	37.0	35.0	28.0	37.0	10.0	30.0	30.0	25.0
2	Power Driven											
	a. Type		Diesel	Electric	Diesel	Diesel	Diesel	Diesel	Diesel	Electricity	Diesel	Diesel
	b. Brand		Lister		Lister	Lister	Lister	Lister	Lister		Lister	Lister
	c. Model		SR 325		SR325	HR3425	SR 325	HR 3 425	SR 325		SR 325	SR 325
	d. Power Size/RPM	Hp	18/1800		18/1800	37.5/1800	18/1800	37.5/1800	18/1800	33 KVA	18/1800	18/1800
	e. Status		New	New	New	New	New	New	New	New	New	New
	f. Fuel Consumption	lt/hr	4		3.7	5.1	4	4.0	4		4	4
	g. Lubric. Consumption	lt/hr	0.04		0.04	0.04	0.04	0.04	0.04		0.04	0.04
	h. Power Transmission		Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct	Direct
3	Pump specification											
	a. Type		Turbine	Turbine	Turbine	Turbine	Turbine	Turbine	Turbine	Turbine	Turbine	Turbine
	b. Brand		Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl	Lee Howl
	c. Model		4600E-4 Stg	4600E-4 Stg	4600E-4 Stg	4600E-2 Stg	4600E-4 Stg	4600E-4 Stg	4600E-4 Stg	4600E-4 Stg	4600E-4 Stg	4600E-4 Stg
	d. Inlet diameter	inch	5	5	5	6	5	6	5	5	5	5
	e. Outlet diameter	inch	4	4	4	6	4	6	4	4	4	4
	f. Discharge :											
	Design/RPM	lt/sec	30/1800	21/1800	29/1800	29/1800	30/1800	25/1800	20/1800	25/1800	25/1800	17/1800
	Actual/RPM	lt/sec	29.5/n.m	26/n.m	25.6/n.m	27/n.m	29.5/n.m	35.8/n.m	18/n.m	53.4/n.m	26.9/n.m	23.3/n.m
	g. Depth of well	m	51	102	102	96	na	100	100	na	101	81
	h. Elev.of pump	m	na	na	na	na	na	na	na	na	na	na
	i. Length of suction	m	na	na	na	na	na	na	na	na	na	na
	j. Suction head	m	na	na	na	na	na	na	na	na	na	na
	k. Pressure head	m	na	na	na	na	na	na	na	na	na	na
	l. Total head	m	16	23.5	16.5	30.5	na	25.5	25.5	na	22.5	10.5
	m. No. of elbow		3	3	3	na	3	3	3	3	3	3
	n. Type of fitting/No.		gate value/2	gate value/2	gate value/2	gate value/2	gate value/2	gate value/2	gate value/2	gate value/2	gate value/2	gate value/2
4	Water Source											
	a. Normal depth	m	7.9	18.5	9	13.9	4.2	12	13.0	10.0	12.5	11.6
	b. Drawdown/RPM	m/RPM	0.5	0.6	0.3	1.8	3.1	2.0	1.5	1.5	1.5	1.3
5	Canal length	m	1230	980	1530	1300	500	1330	730	2100	1450	580
6	Year of Construction		05/1978	07/1978	08/1978	03/1979	08/1978	04/1979	03/1979	05/1979	04/1979	06/1980
7	Avrg. Pump Operation	hr	1684 *) 2947 **)	1215 *) 1908 **)	1811 1698	680 1778	1421 *) 2274 **)	1758 *) 1066 **)	469 *) 1034 **)	1804 *) 2949 **)	1588 *) 2430 **)	1295 *) 1623 **)

PHYSICAL FEATURE OF PUMPING UNIT : SUBANG (SURFACE PUMPING)

NO	DESCRIPTOR	UNIT	SIDAJAYA	SIMAMULYA	CIHAMBULU	KIARASARI
1	Total Command Area	ha				
	a. Design		90	90	215	70
	b. Actual		60	70	80	70
2	Power Driven					
	a. Type		Diesel	Diesel	Diesel	Diesel
	b. Brand		Ford 4 cyl.	Perkins 4 cyl.	Perkins	Thames
	c. Model		-	-	-	-
	d. Power Size/RPM	Hp	40/1600	60/1500	80/1000	60/nm
	e. Status		New	New	New	old
	f. Fuel Consumption	lt/hr	5	5	5	1.7
	g. Lubric. Consumption	lt/hr	0.08	0.06	0.2	0.05
	h. Power Transmission		Direct	Direct	Direct	V-belt
3	Power Driven					
	a. Type		Centrifugal	Centrifugal	Centrifugal	Centrifugal
	b. Brand		Ajax	Ajax	Ajax	Unknown
	c. Model		-	-	-	-
	d. Inlet diameter	inch	10	10	12	10
	e. Outlet diameter	inch	10	10	12	10
	f. Discharge :					
	Design/RPM	lt/sec	200/1500	200/1500	450	nm
	Actual/RPM	lt/sec	98.3/nm	56.3/nm	180/nm	89.6/nm
	g. Depth of well	m	na	na	na	na
	h. Elevation of pump	m	na	na	na	na
	i. Length of suction	m	3.9	3.3	2.1	4.3
	j. Suction head	m	4.9	3.3	2.1	4.3
	k. Pressure head	m	2.8	5.1	6	1.0
	l. Total head	m	7.2	8.9	8.6	5.[illegible]
	m. No. of elbow		4	4	4	4
	n. Type of fitting/No.		na	na	na	na
4	Water Source					
	a. Normal depth	m	na	na	na	na
	b. Drawdown/RPM	m/RPM	na	na	na	na
5	Canal length	m	na	na	na	na
6	Year of Construction		1983	1984	1985	1986
7	Avrg. Pump Operation	hr	1470	870	1094	na

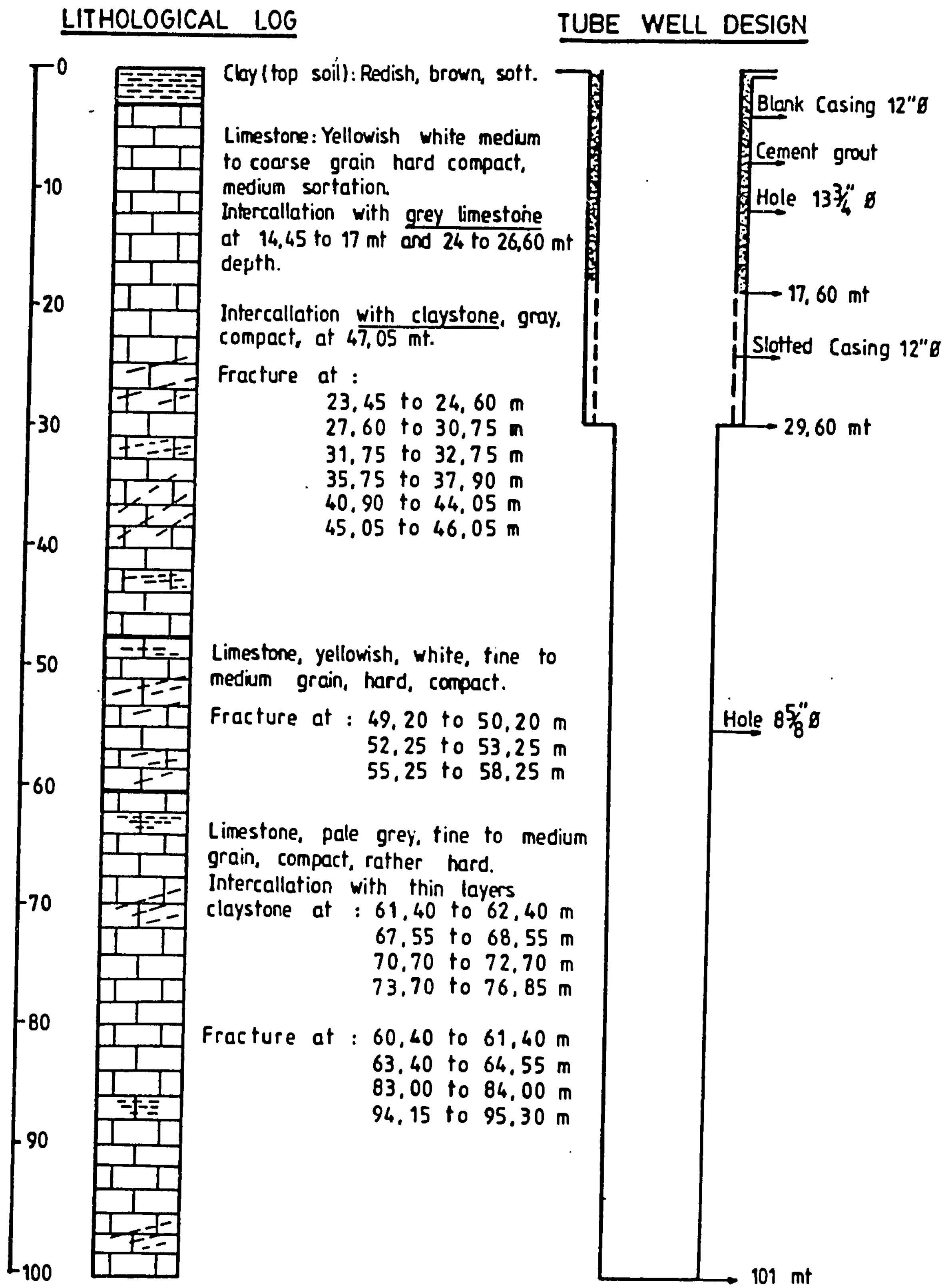
Note :
nm = not measured
na = not available

BEST AVAILABLE DOCUMENT

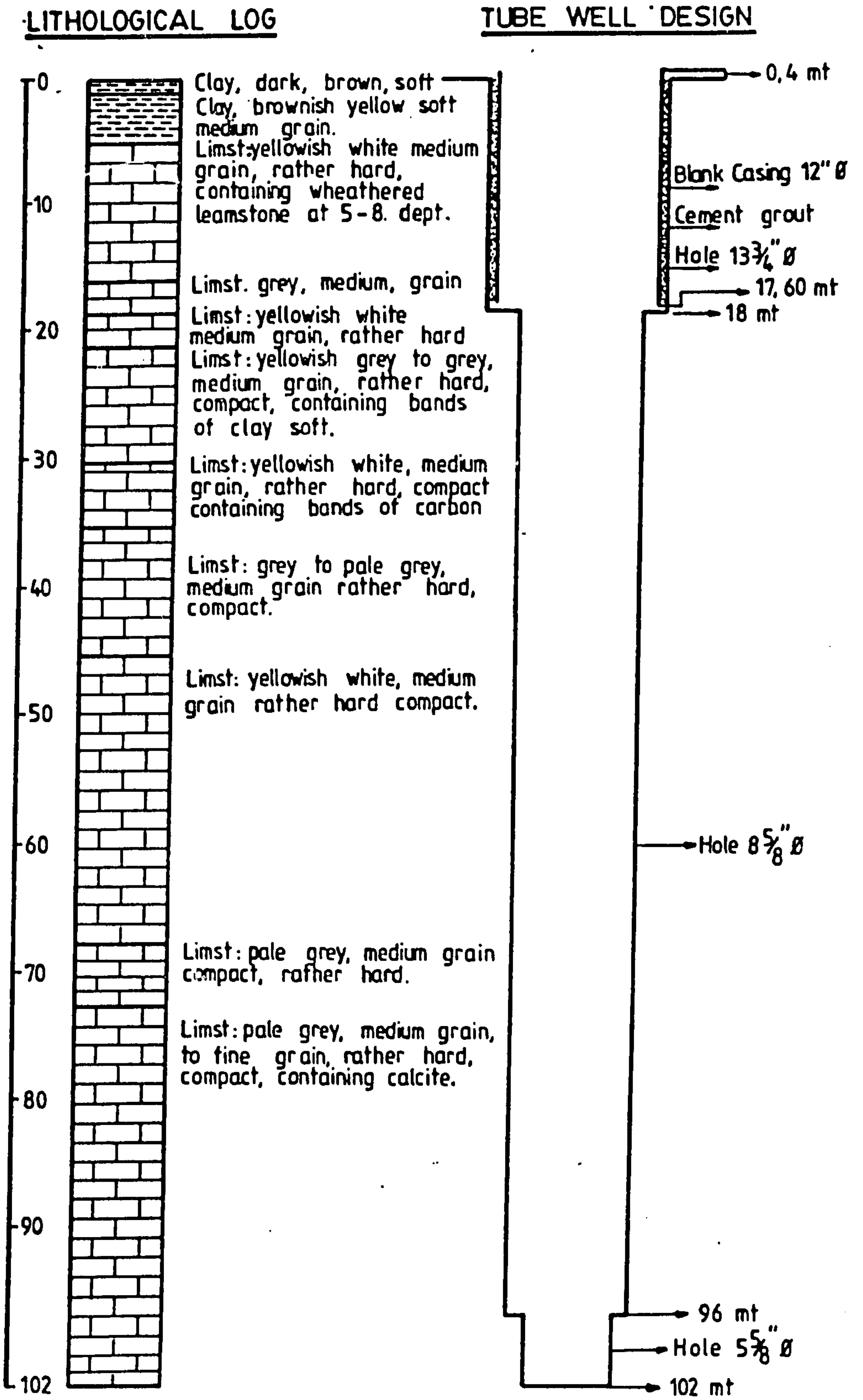
Appendix C

LITHOLOGICAL LOG FOR A SELECTED SET OF THE TUBE WELLS

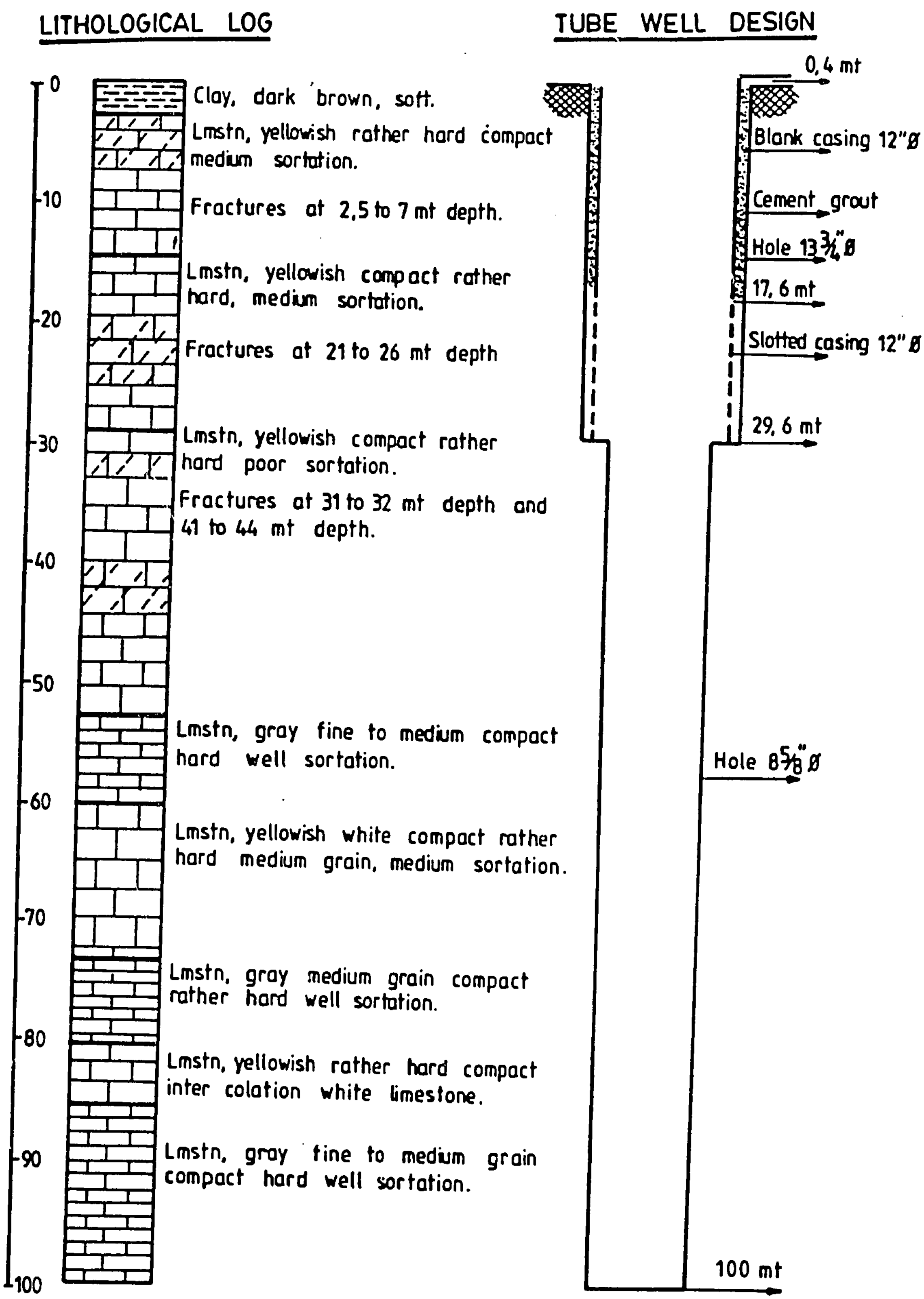
LITHOLOGICAL LOG W.22 PLUMBUNGAN GUNUNGKIDUL



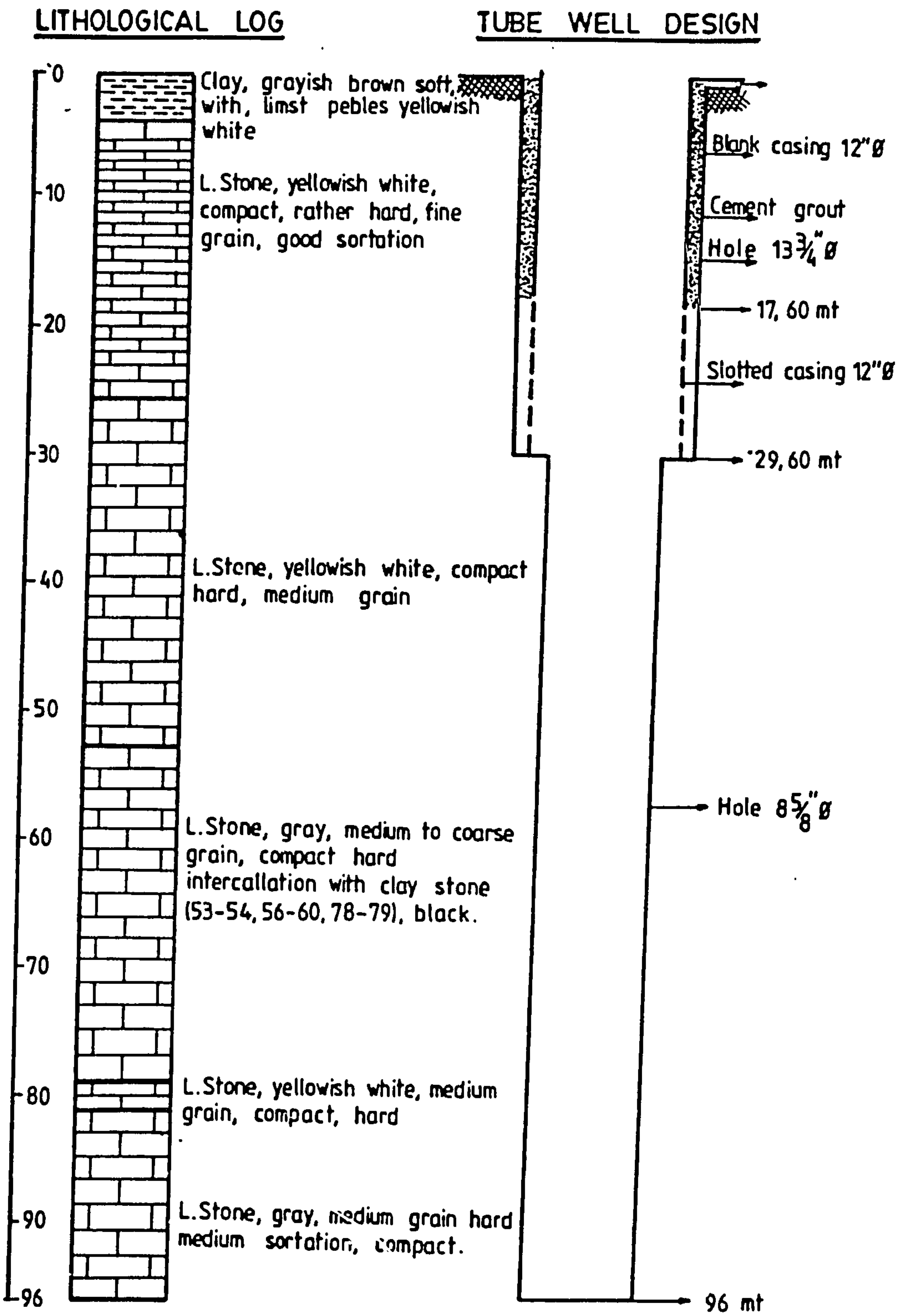
LITHOLOGICAL LOG W.11 JARANMATI GUNUNGKIDUL



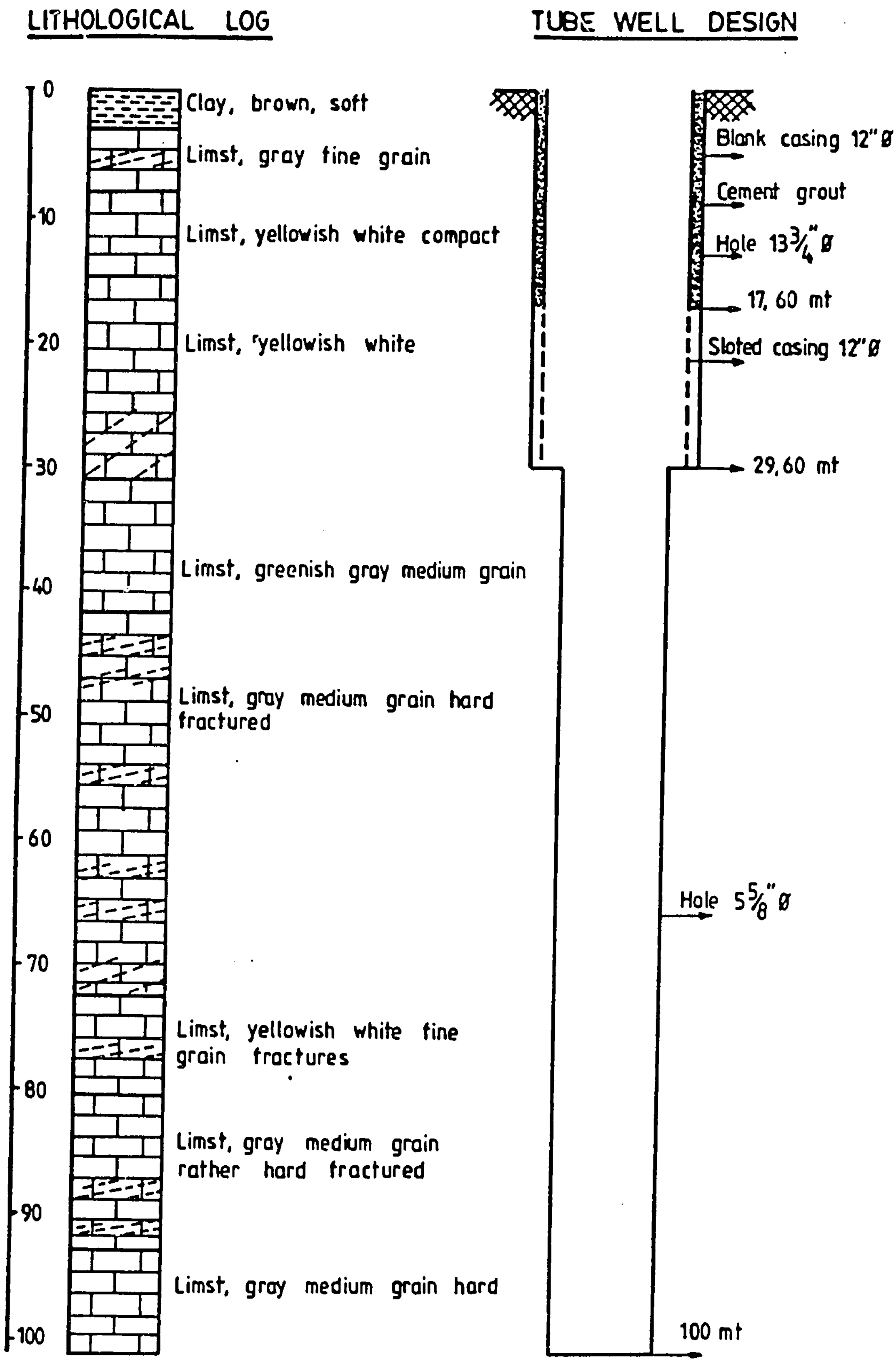
LITHOLOGICAL LOG W.20 AWAR-AWAR GUNUNGKIDUL



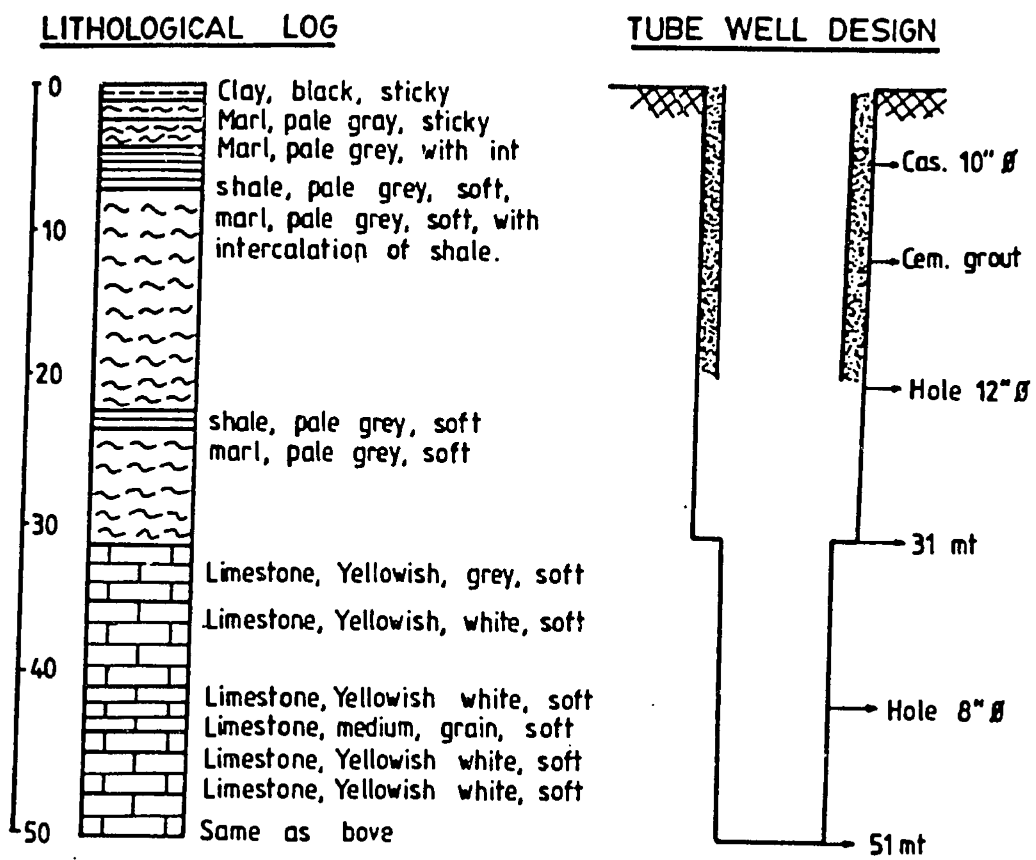
LITHOLOGICAL LOG W.14 KARANGWETAN GUNUNGKIDUL



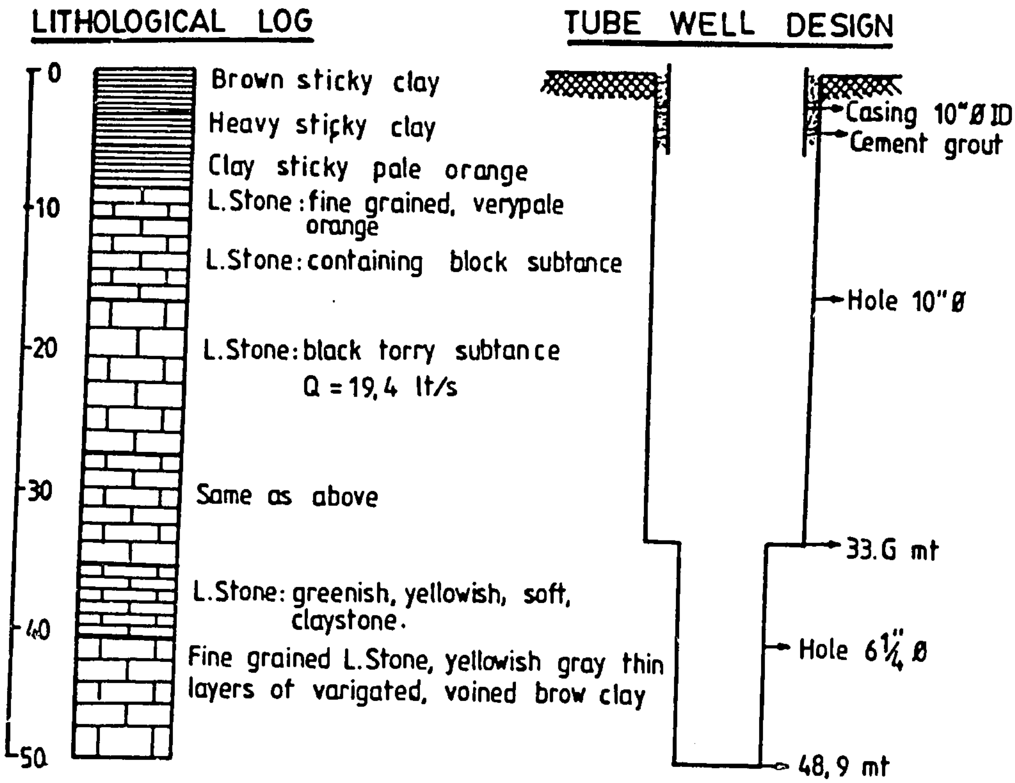
LITHOLOGICAL LOG W.19 NGIPAK II GUNUNGKIDUL



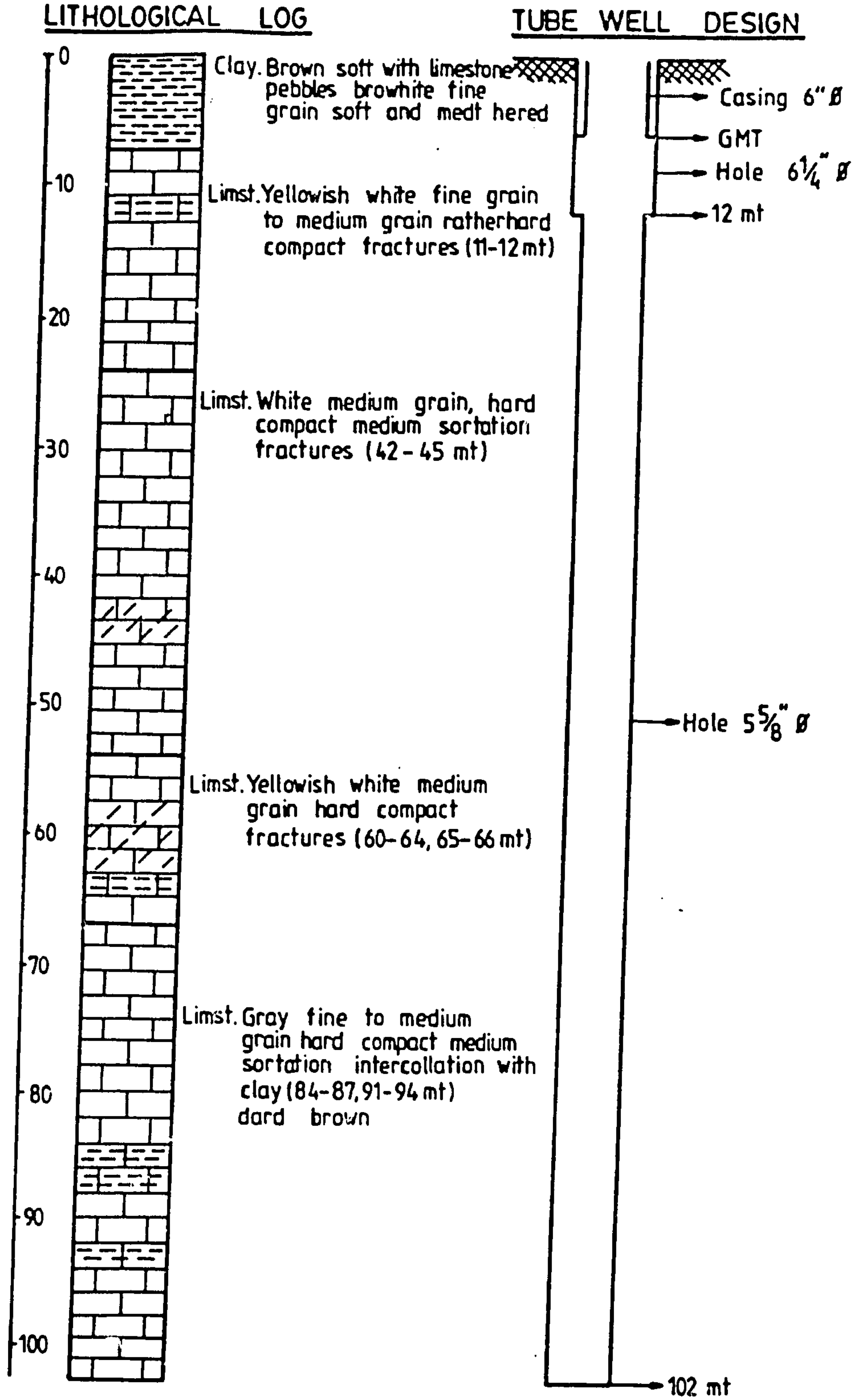
LITHOLOGICAL LOG W.05 BOGOR KIDUL GUNUNGKIDUL



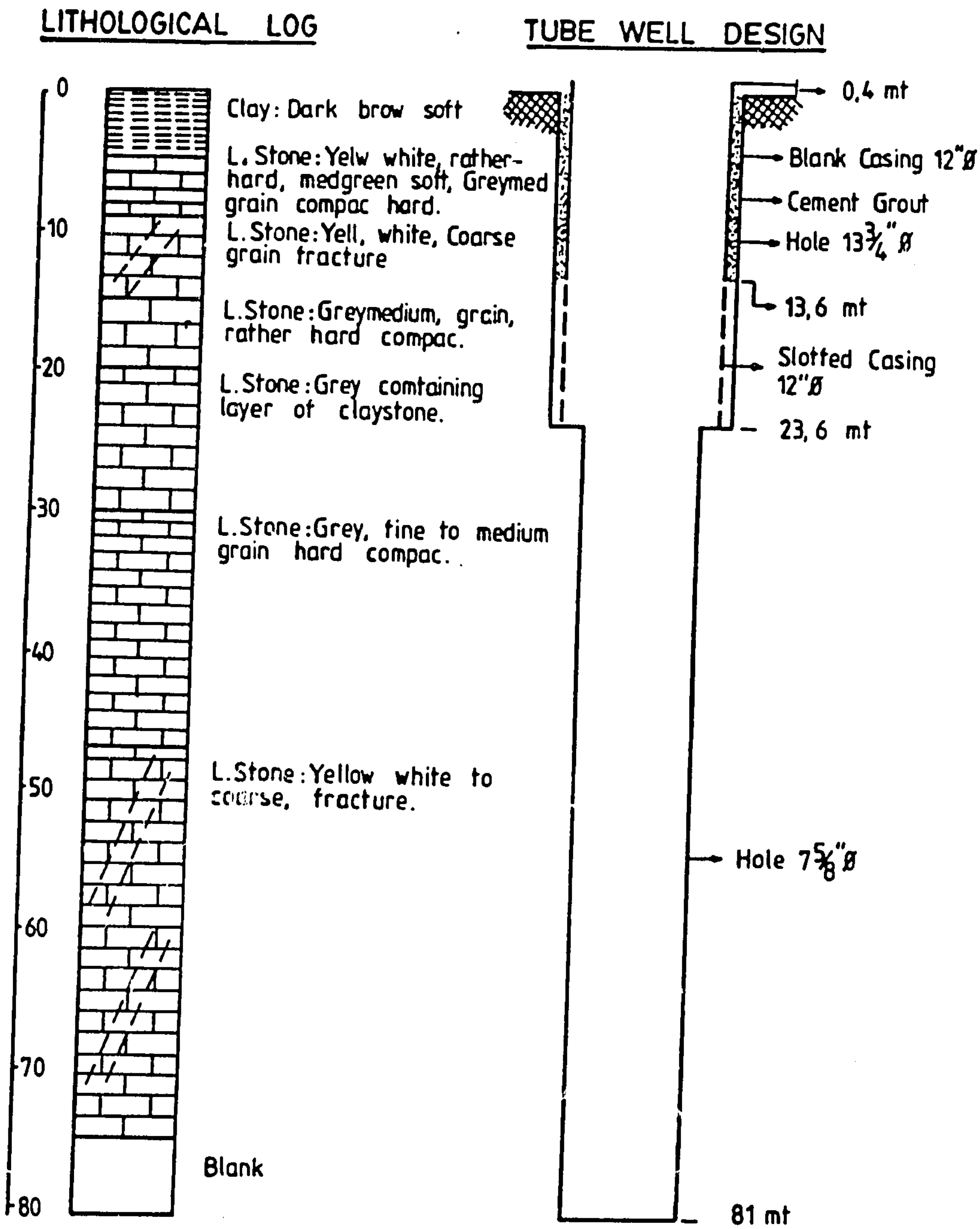
LITHOLOGICAL LOG W. BANDUNG GUNUNGKIDUL



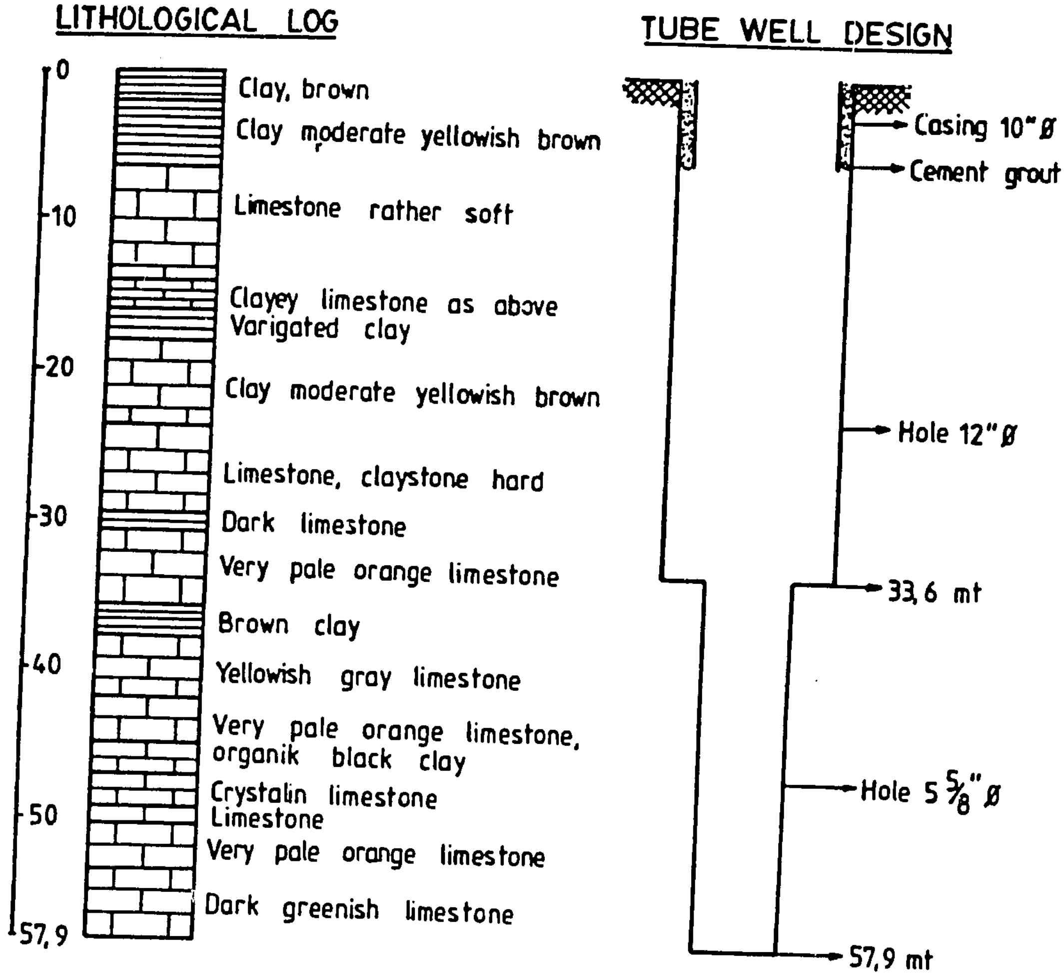
LITHOLOGICAL LOG W. SIRAMAN GUNUNGKIDUL



LITHOLOGICAL LOG W. 28 BOLO GUNUNGKIDUL



LITHOLOGICAL LOG W. 03 NGIPAK I GUNUNGKIDUL

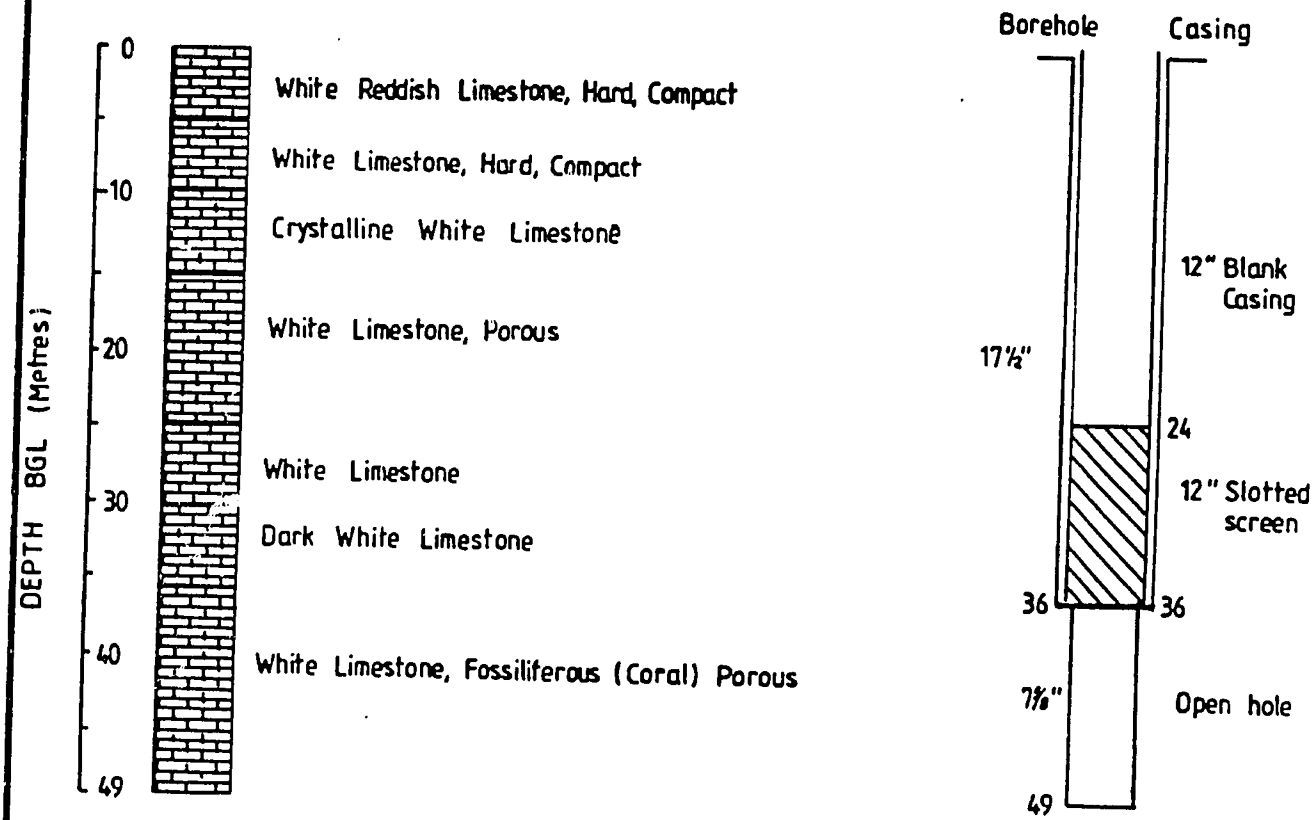


KADUARA BARAT TW 96

Location : Desa Kaduara Barat, Kecamatan Larangan, Kabupaten Pamekasan
Grid Reference : E 478 956
Rig : Hydreq minor
Date of Drilling : 12-14/2/1986
Drilling Method : Air/Foam Flush

Lithology

Construction

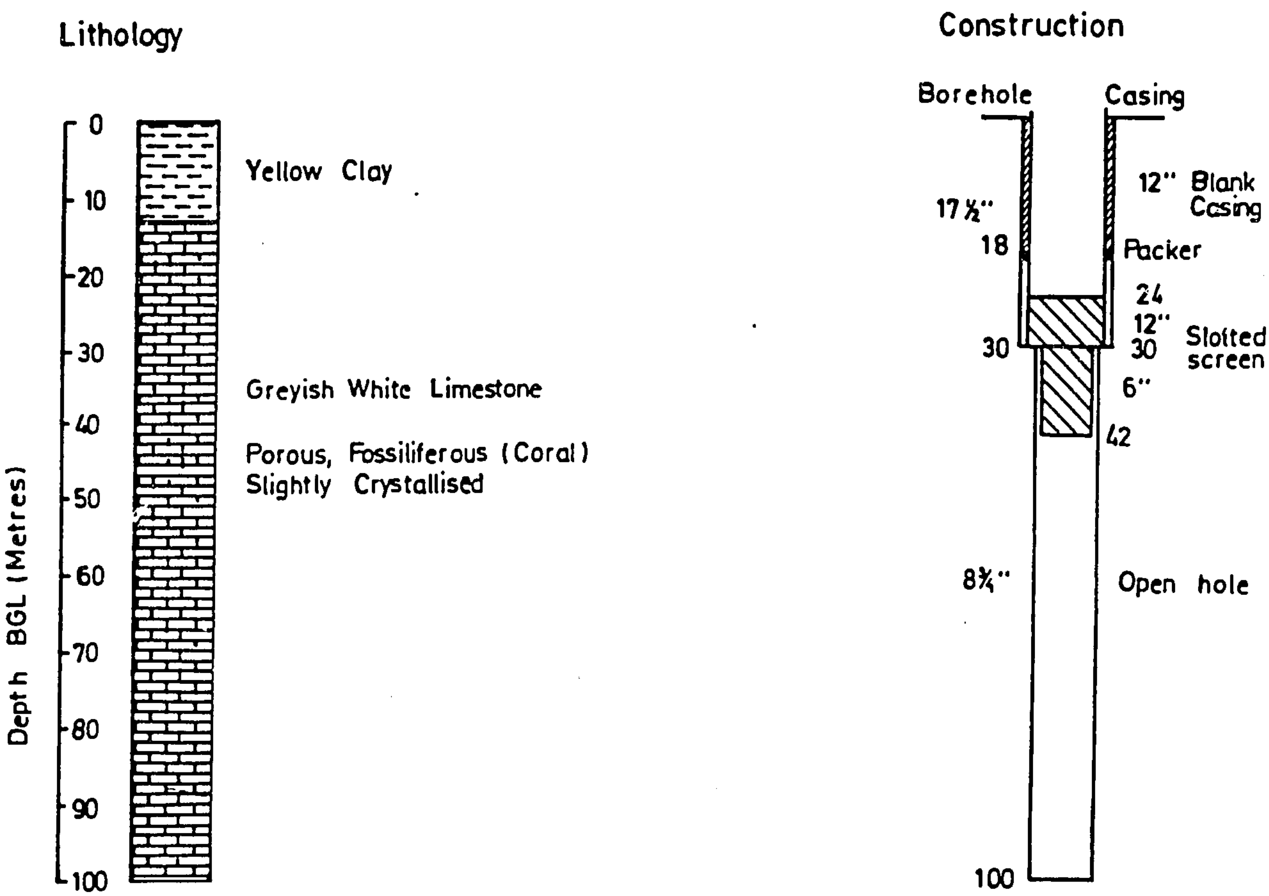


Pumping Test

Date	Section (m)	Method	Period (hr)	SWL (m)	Q (l/s)	SW (m)	SC (l/s/m)	REC (min)
14/2/1986	17 - 49	Airlift	4	17.18	10.20	0	∞	-
26/2/1986	-	Turbine	4140	16.59	70	0.66	106.1	1

PELTONG TW.94

Location : Desa Peltong, Kecamatan Larangan, Kabupaten Pamekasan
Grid Reference : E 384 935
Rig : Hydreq Gryphon
Date of Drilling : 25/1 - 1/2/1986
Drilling Method : Air/Foam Flush

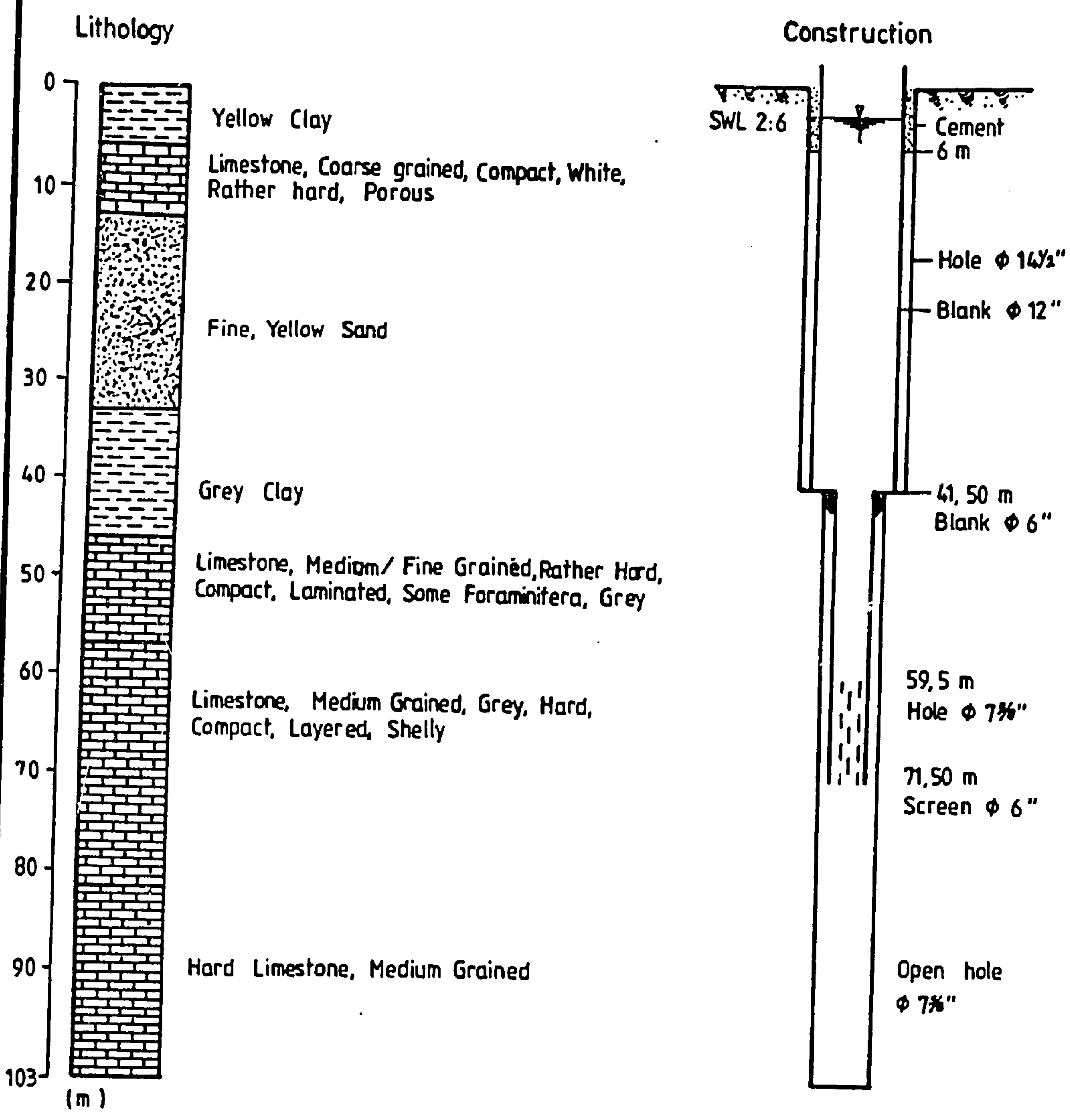


Pumping Test

Date	Section (m)	Method	Period (hr)	SWL (m)	Q (l/s)	SW (m)	SC (l/s/m)	REC (m)
14/2/1986	20 100	Airlift	4	16.67	21.9	0.03	733	3
18/2/1986	-	Turbine	69	16.37	76	0.05	140	70

BANYUBULUH I - TW. 102

Location : Desa Banyubuluh, Kecamatan Proppo, Kabupaten Pamekasan
Map Coordinates : E 289 951
Date of Drilling : 29/3 - 11/4 / 1986 Rig : H Minor I
Drilling Method : DC Air Flush & Foam Depth: 103 m

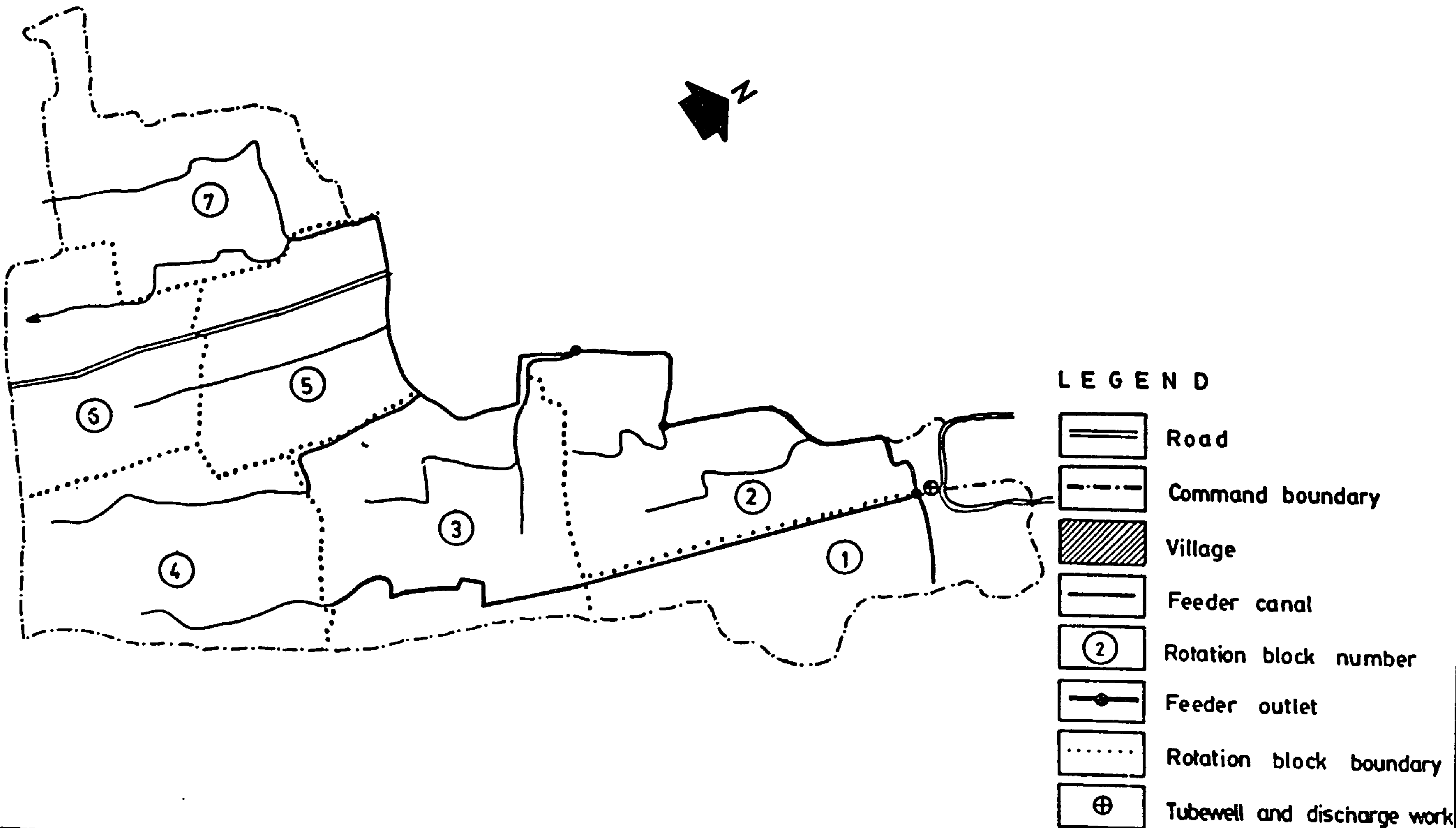


Date	Pump Type	t (hrs)	SWL (m)	DWL (m)	s (m)	Q (l/s)	SC (l/s/m)	Recov (min)	EC (us/cm)	Remarks
5-4-1986	Compresor	3	3.88	5.24	0.86	24.87	28.92	-	560	Airlift
29-4-1986	Turbine	24	2. 64	6.67	4.03	60	14.89	4	560	LPT

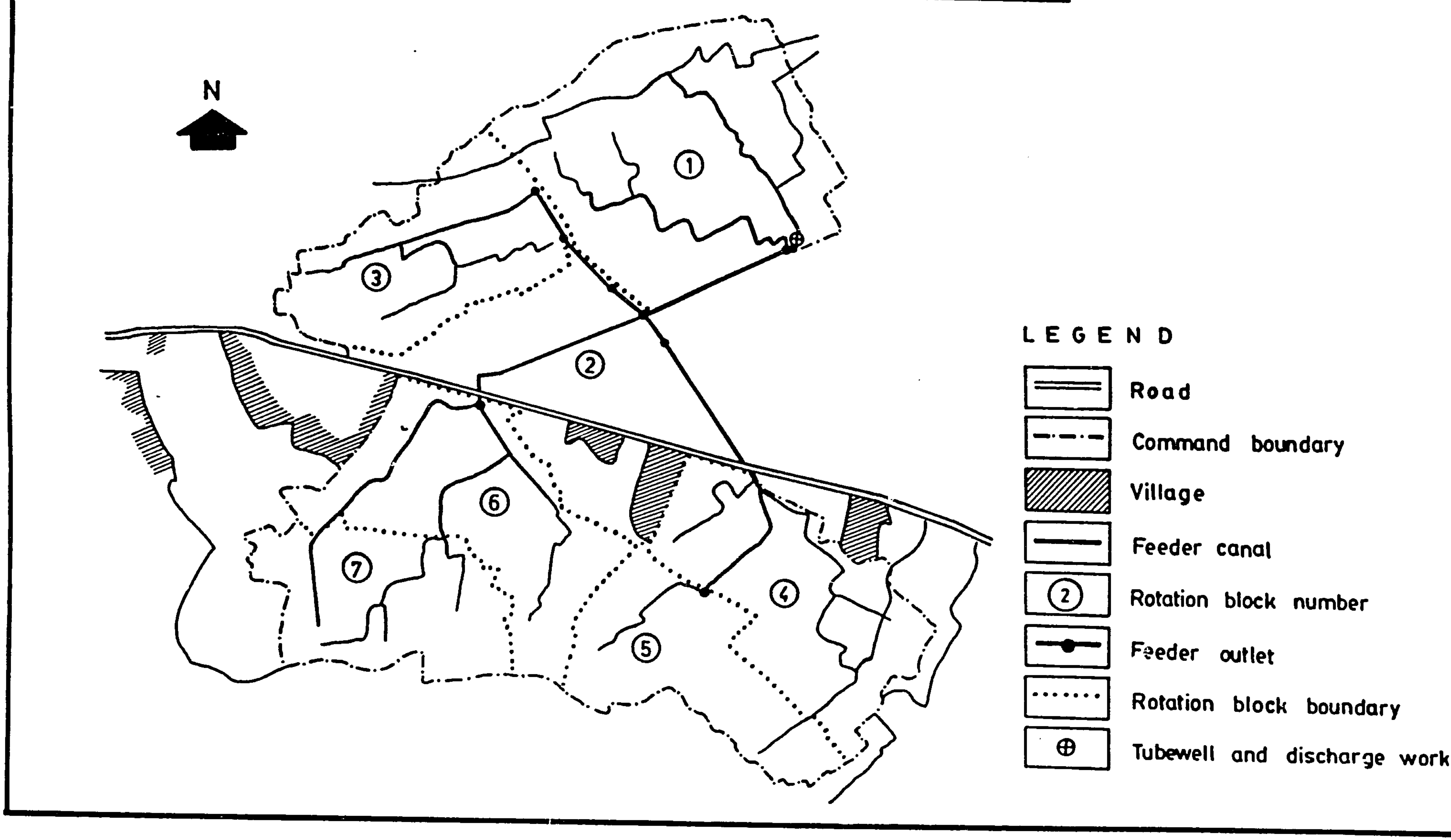
Appendix D

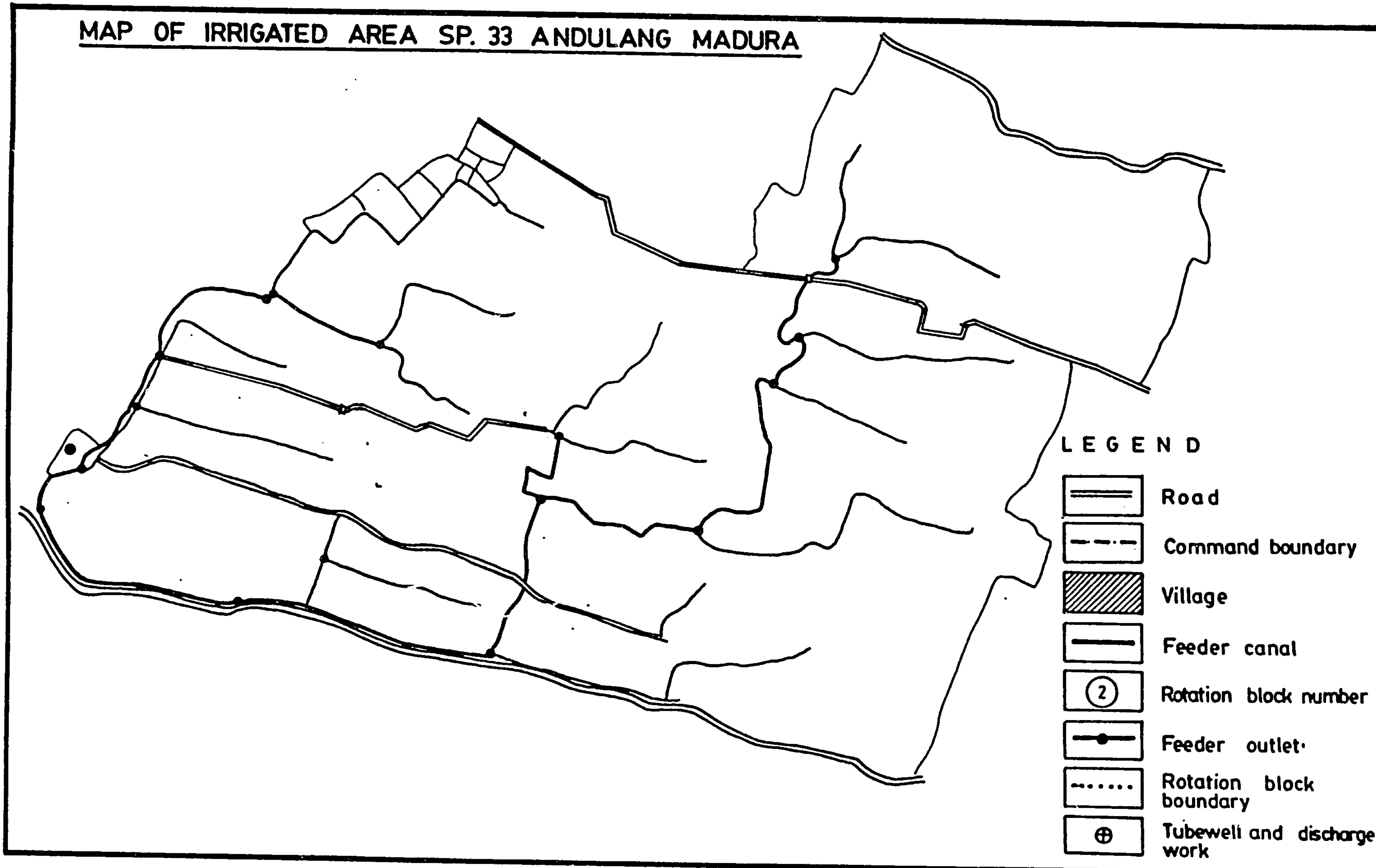
MAP OF IRRIGATED AREA FOR SAMPLE PUMPS

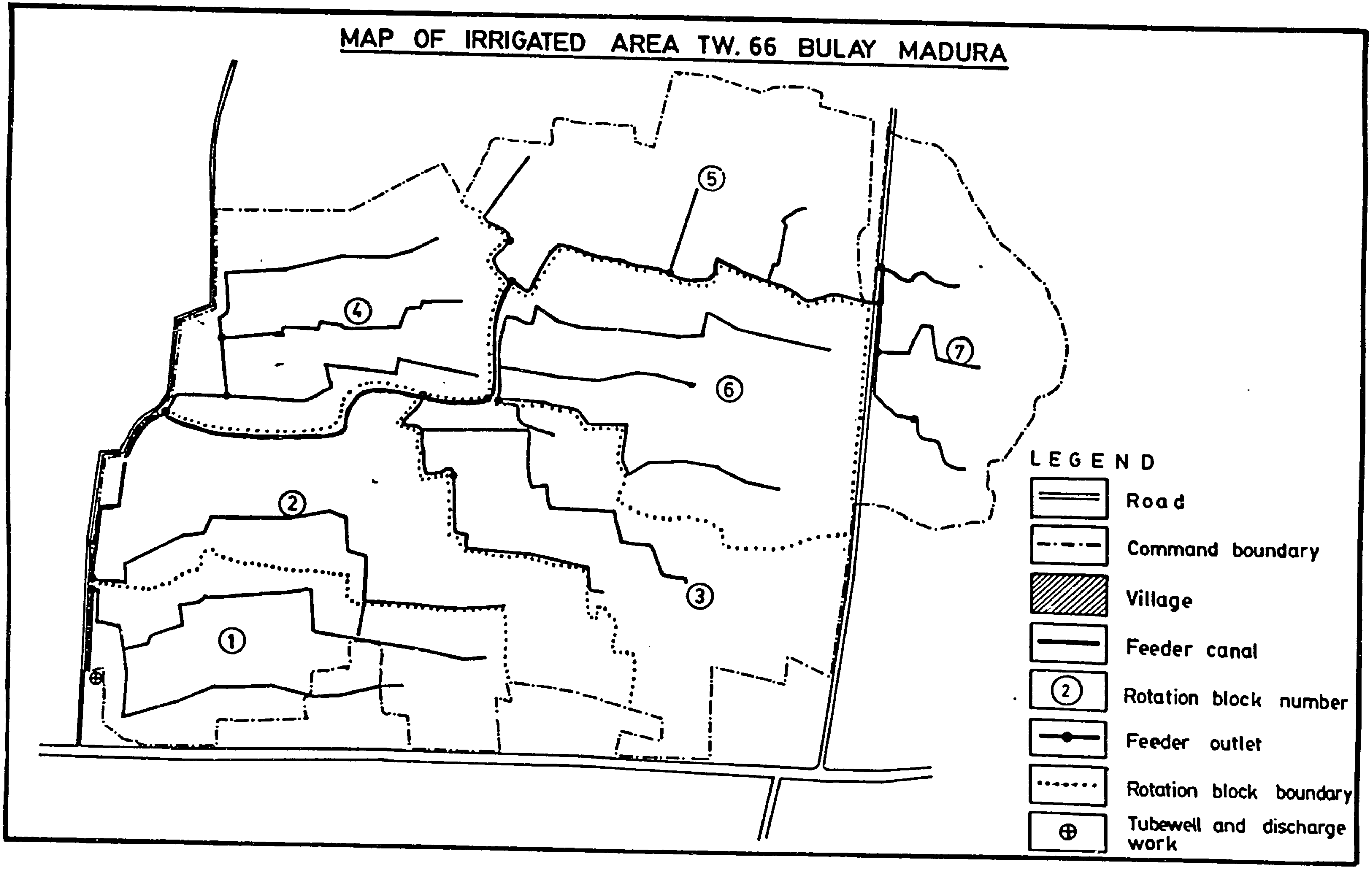
MAP OF IRRIGATED AREA TW. 09 MODUNG I MADURA



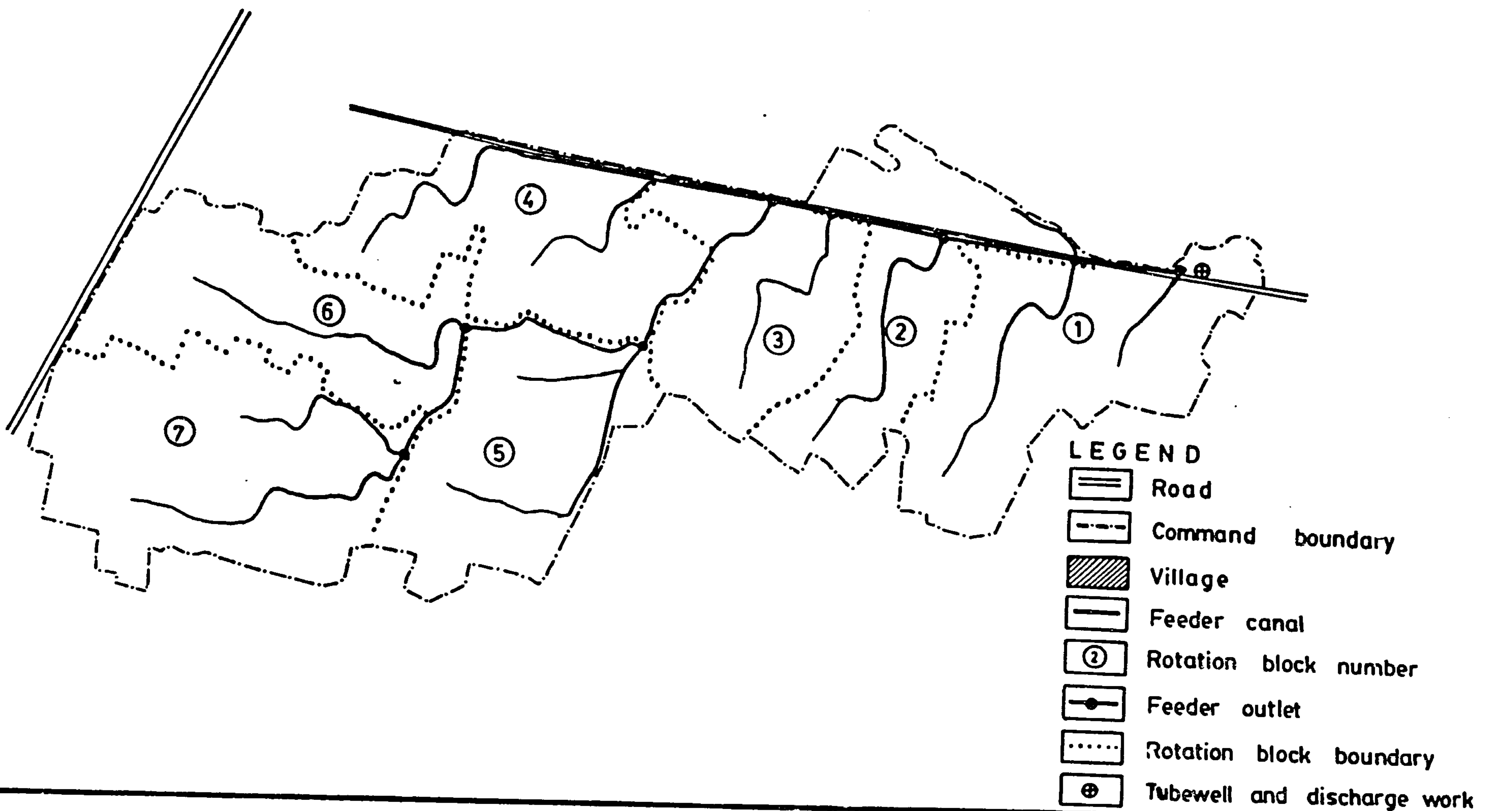
MAP OF IRRIGATED AREA TW. 94 PELTONG MADURA

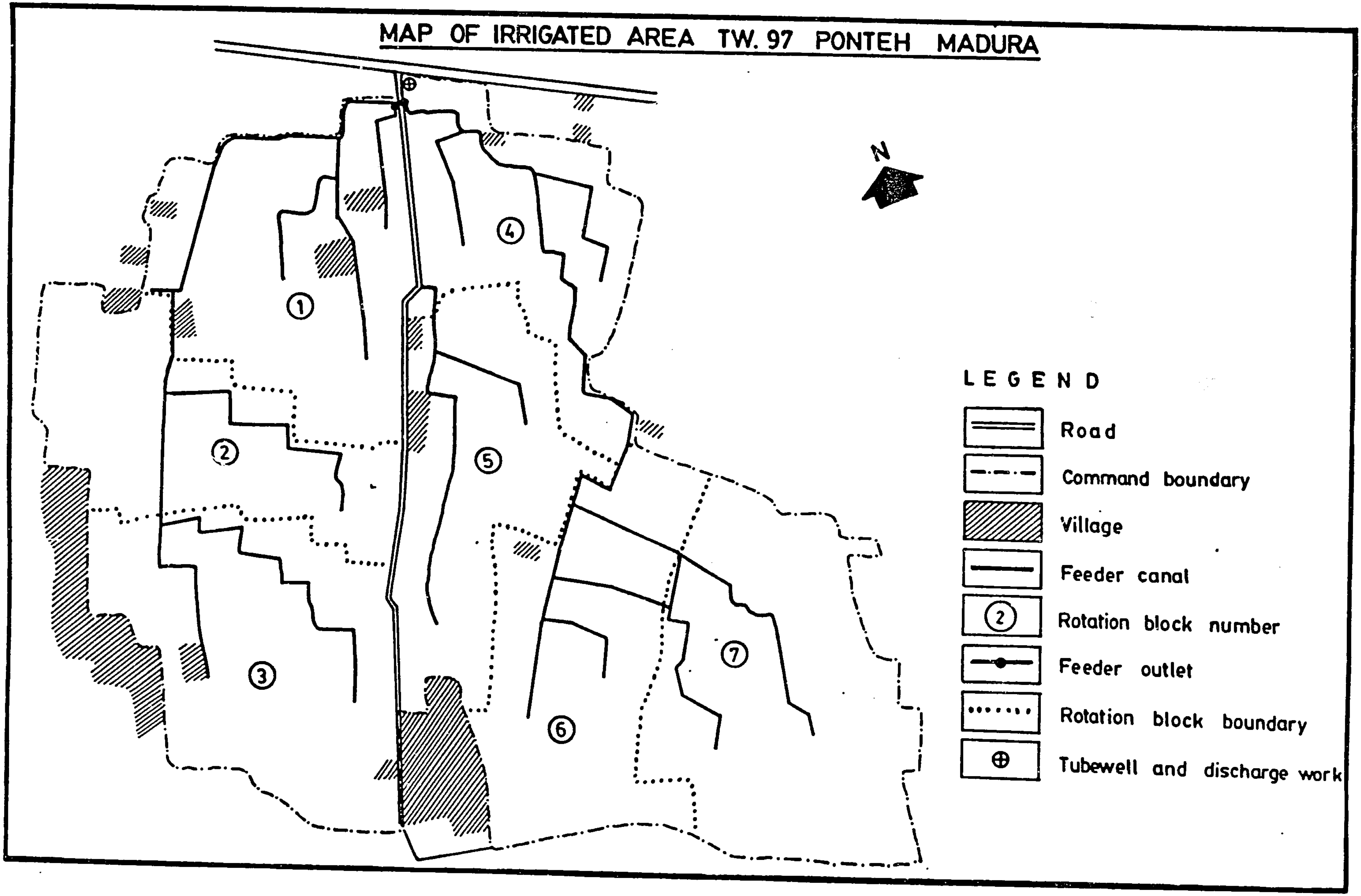



MAP OF IRRIGATED AREA SP. 33 ANDULANG MADURA
LEGEND
Road
Command boundary
Village
Feeder canal
2
Rotation block number
Feeder outlet
Rotation block boundary
Tubewell and discharge work

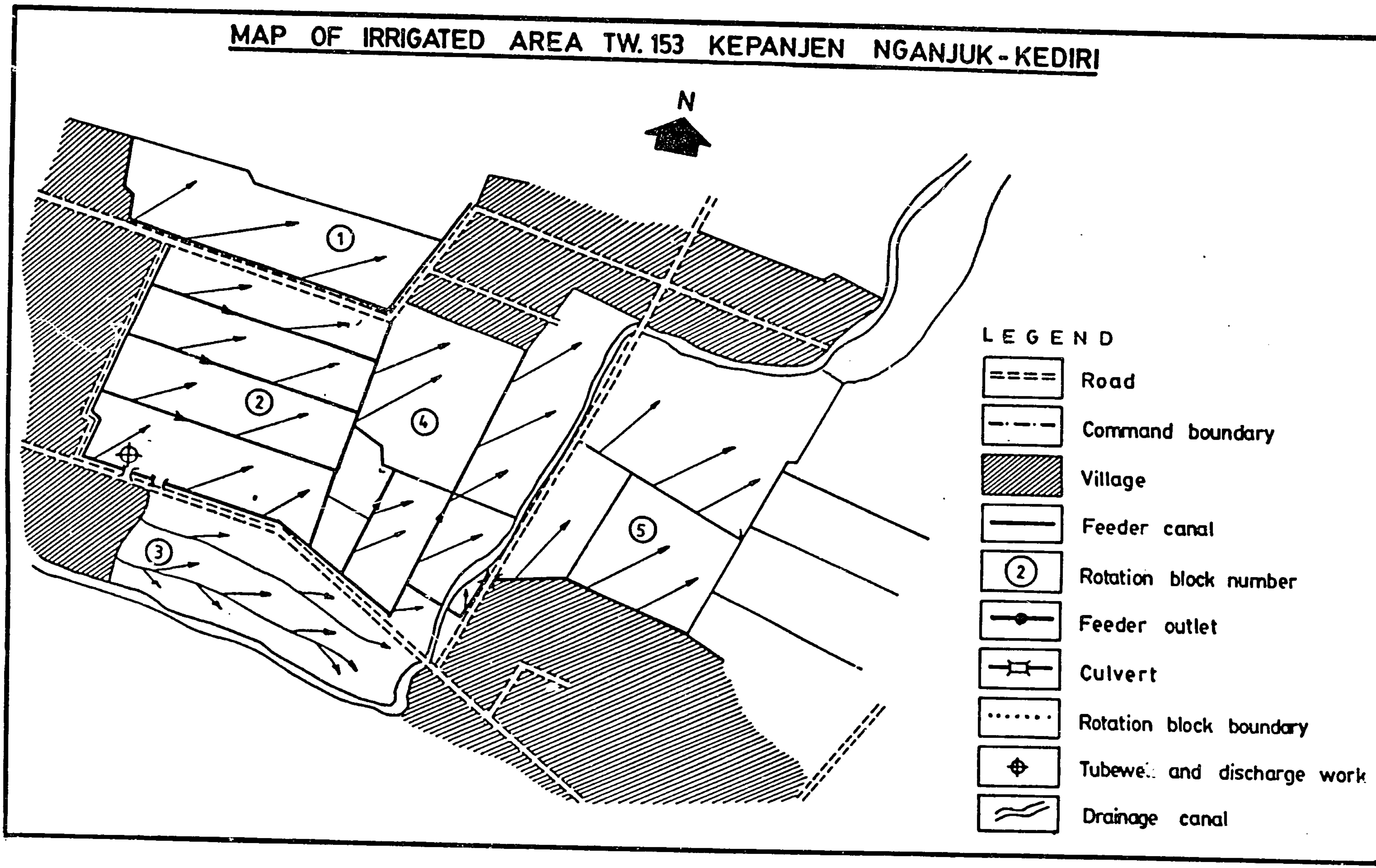

MAP OF IRRIGATED AREA TW. 66 BULAY MADURA
1
2
3
4
5
6
7
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Rotation block boundary
Tubewell and discharge work

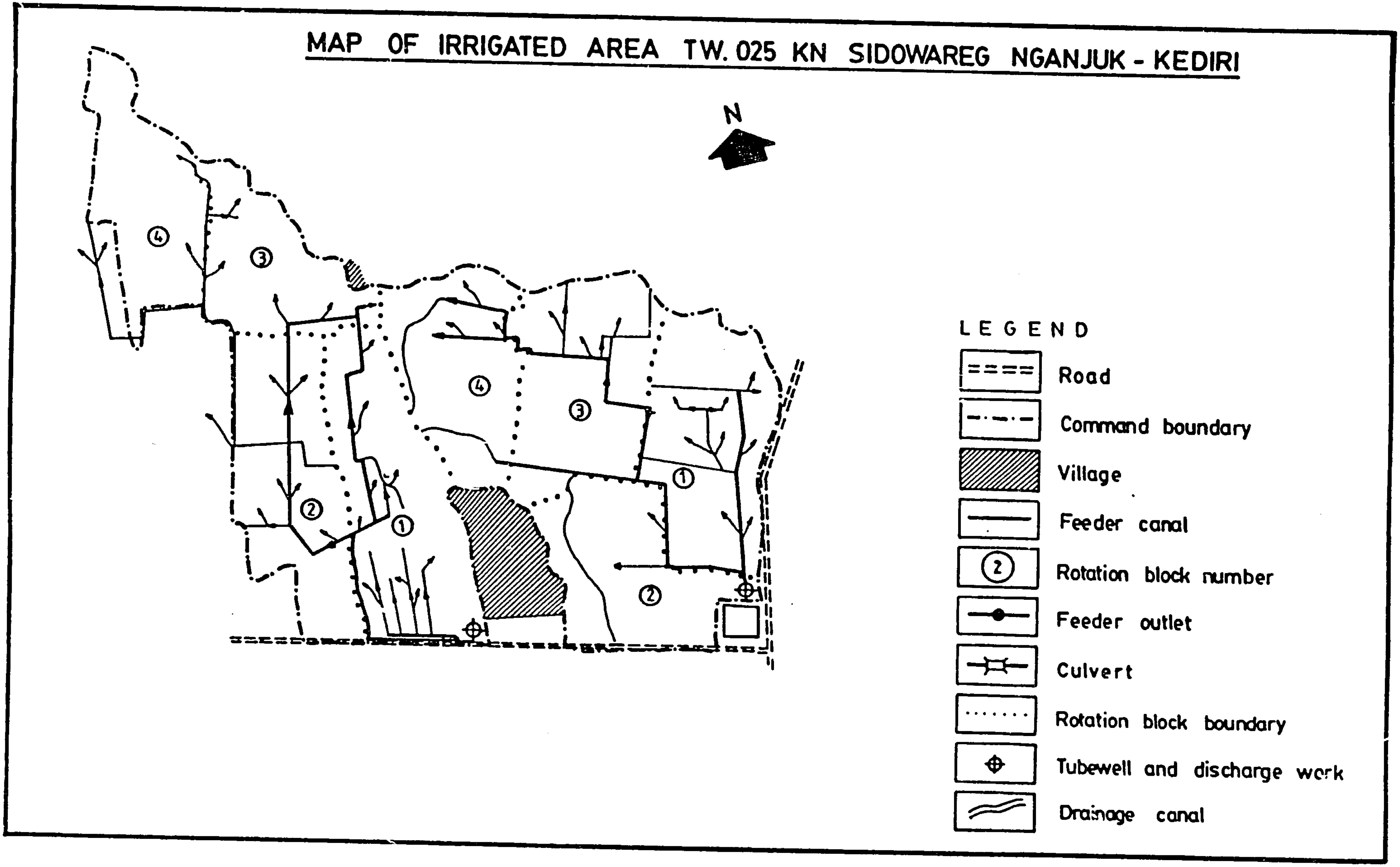
MAP OF IRRIGATED AREA TW. 104 BANYU BULUH MADURA

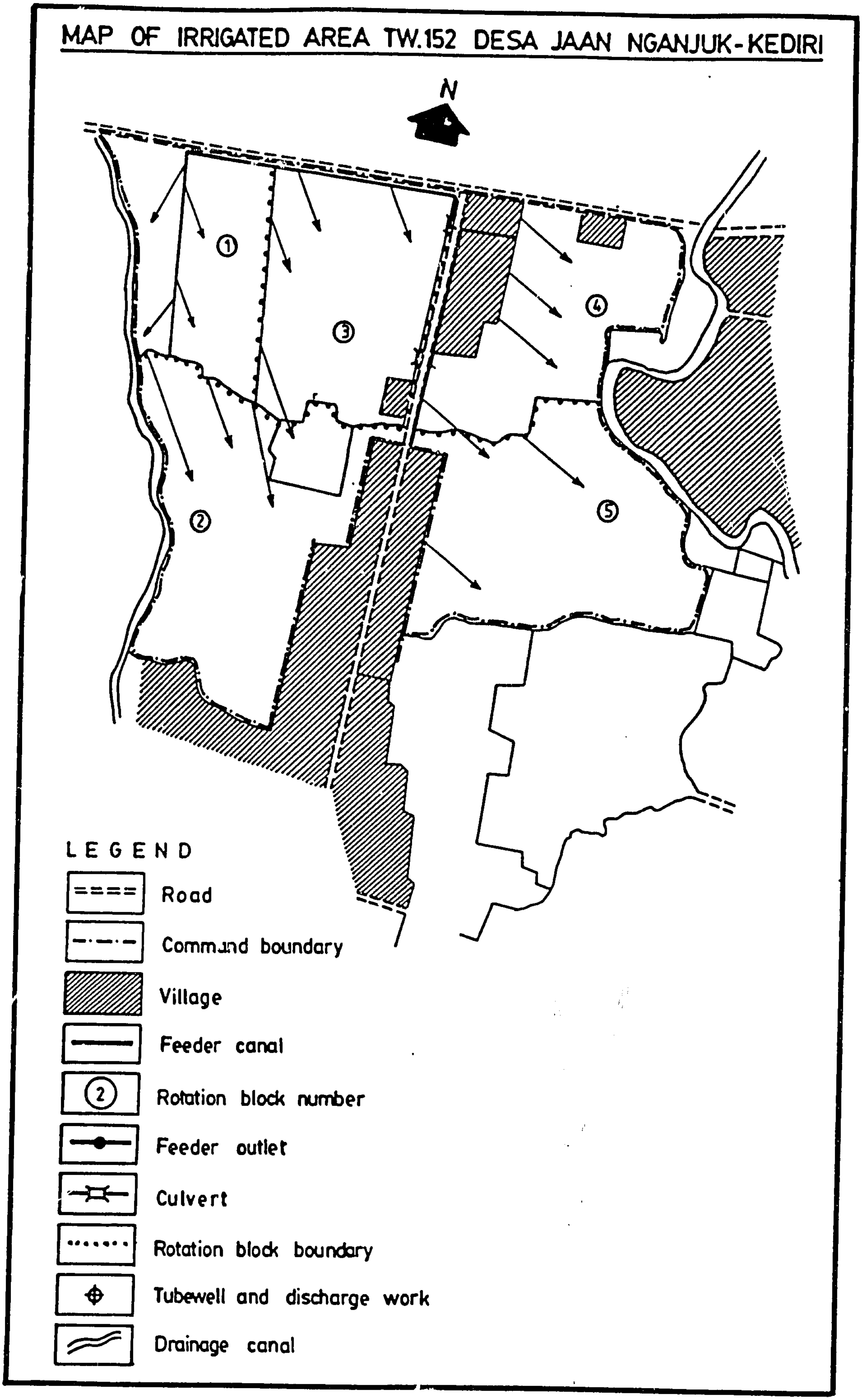


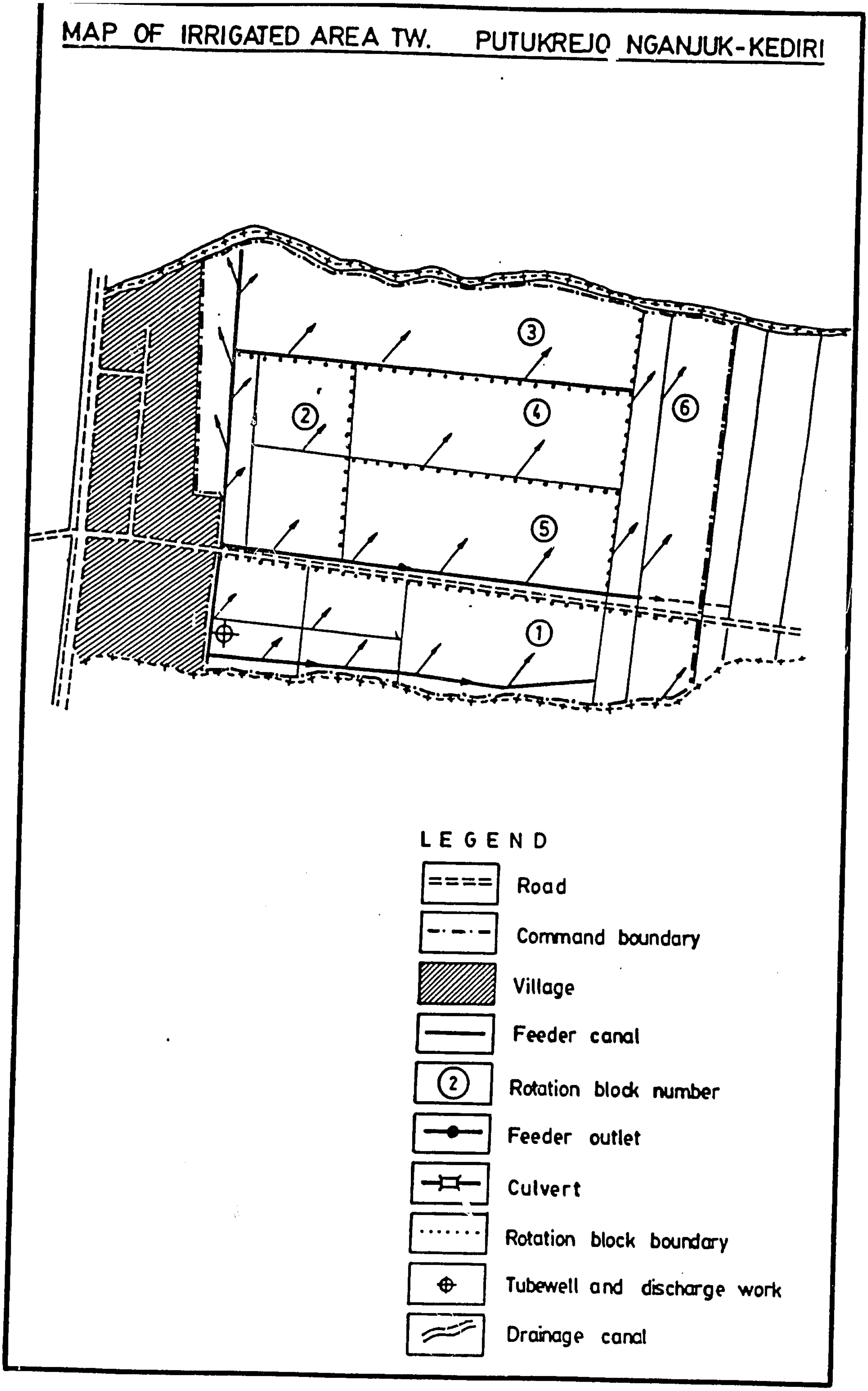


MAP OF IRRIGATED AREA TW. 97 PONTEH MADURA

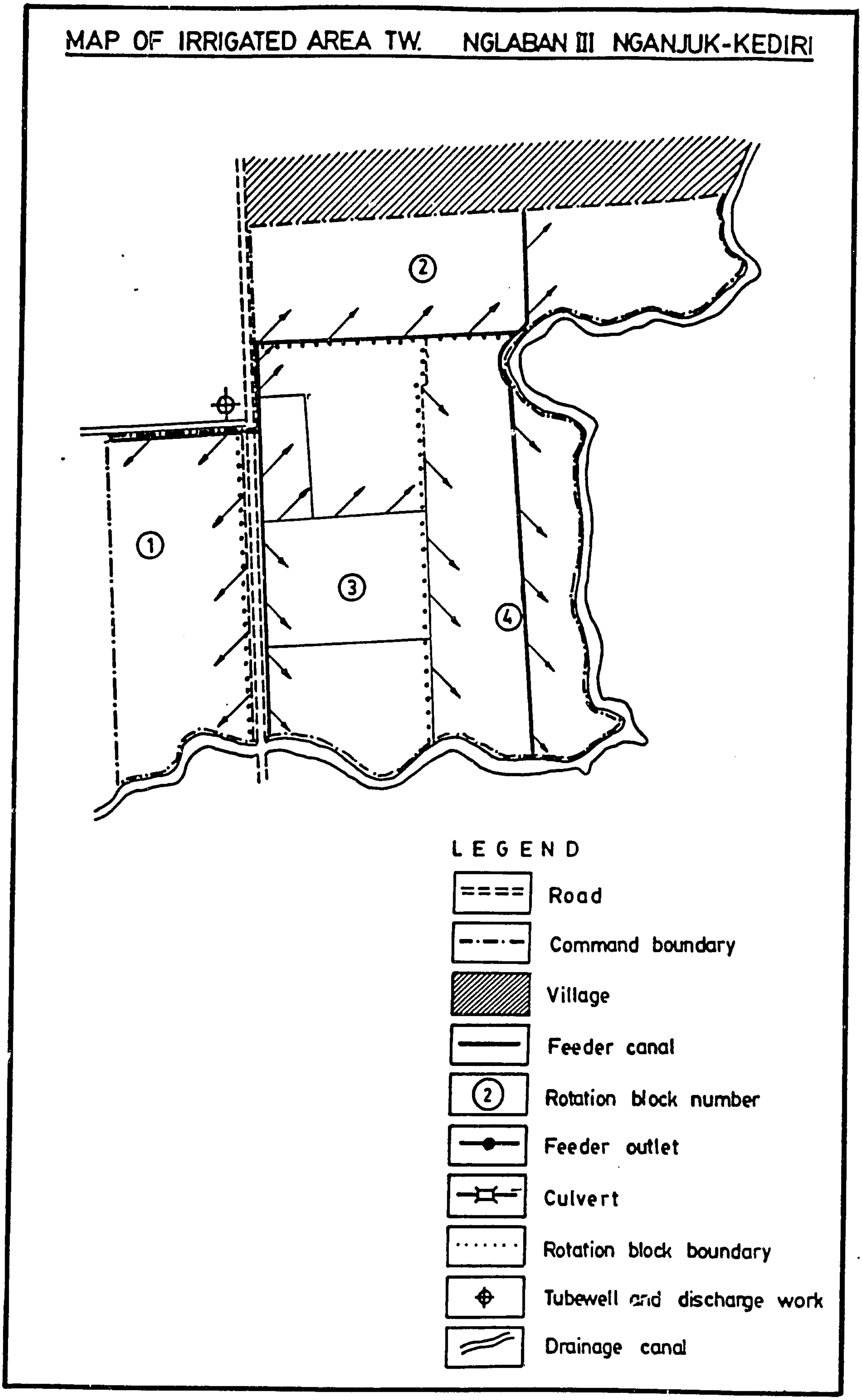

MAP OF IRRIGATED AREA TW. 153 KEPANJEN NGANJUK-KEDIRI
N
1
2
3
4
5
LEGEND
Road
Command boundary
Village
Feeder canal
2
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

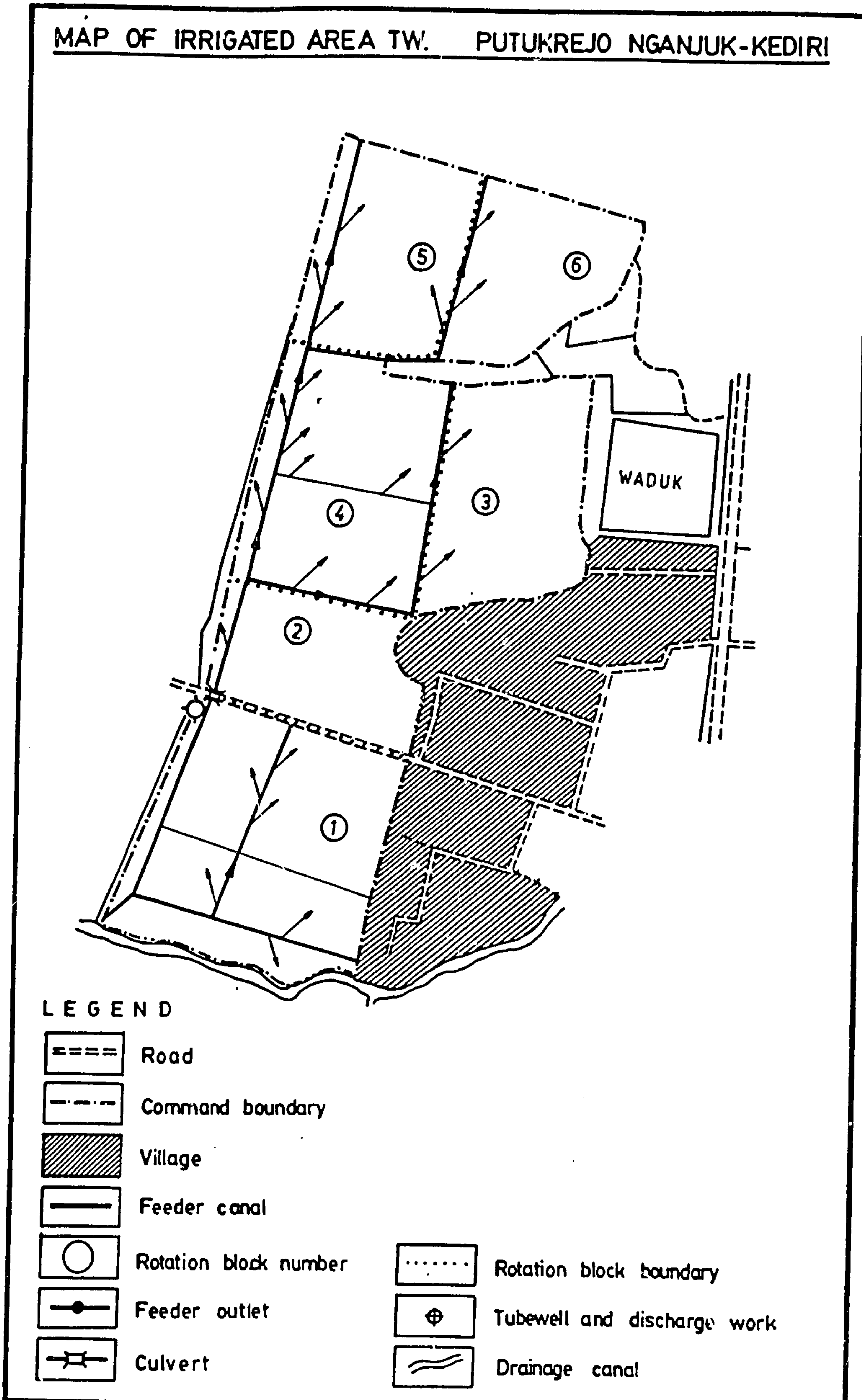

MAP OF IRRIGATED AREA TW. 025 KN SIDOWAREG NGANJUK - KEDIRI
N
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal


MAP OF IRRIGATED AREA TW.152 DESA JAAN NGANJUK-KEDIRI
N
①
②
③
④
⑤
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

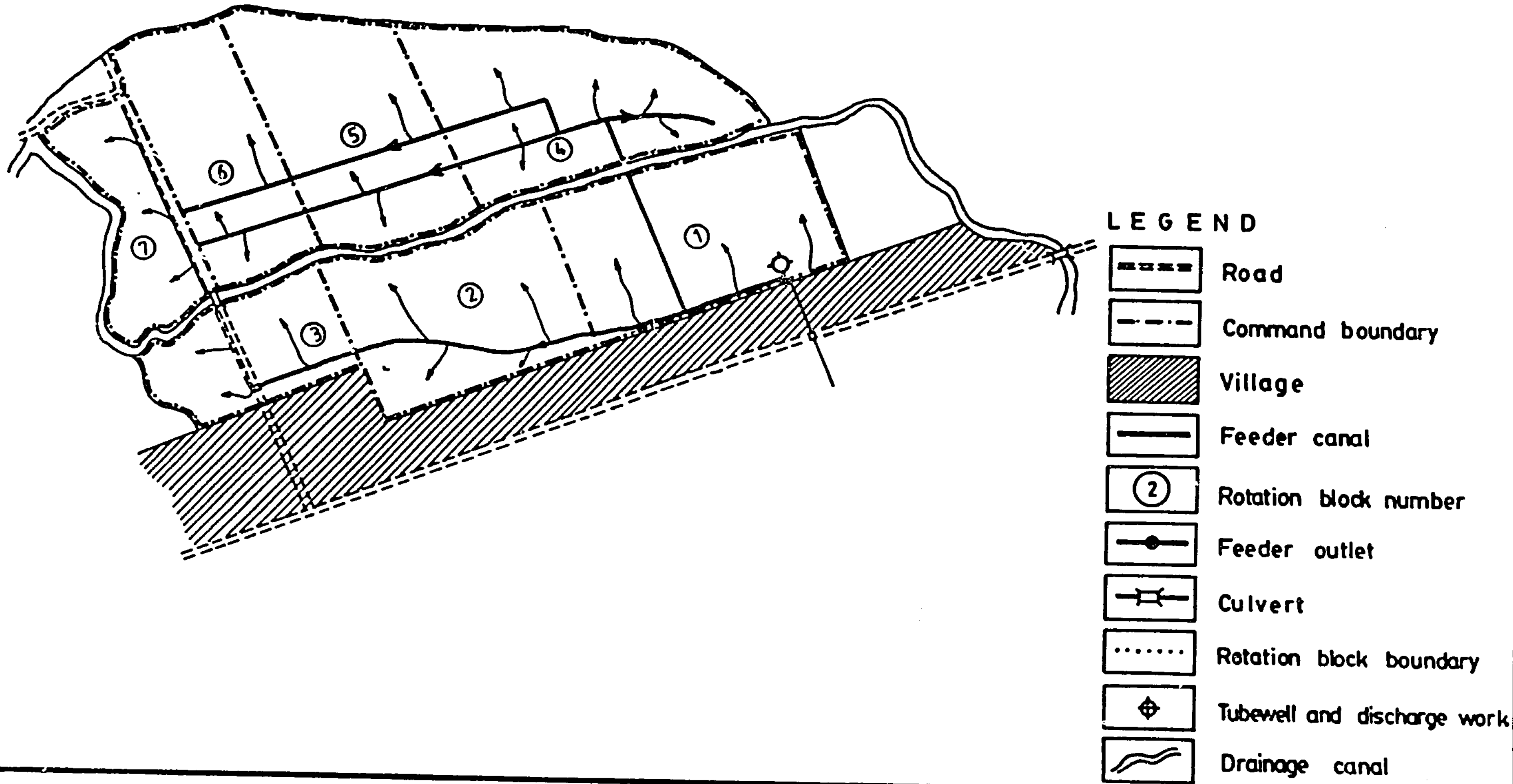


MAP OF IRRIGATED AREA TW. PUTUKREJO NGANJUK-KEDIRI
3
2
4
6
5
1
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

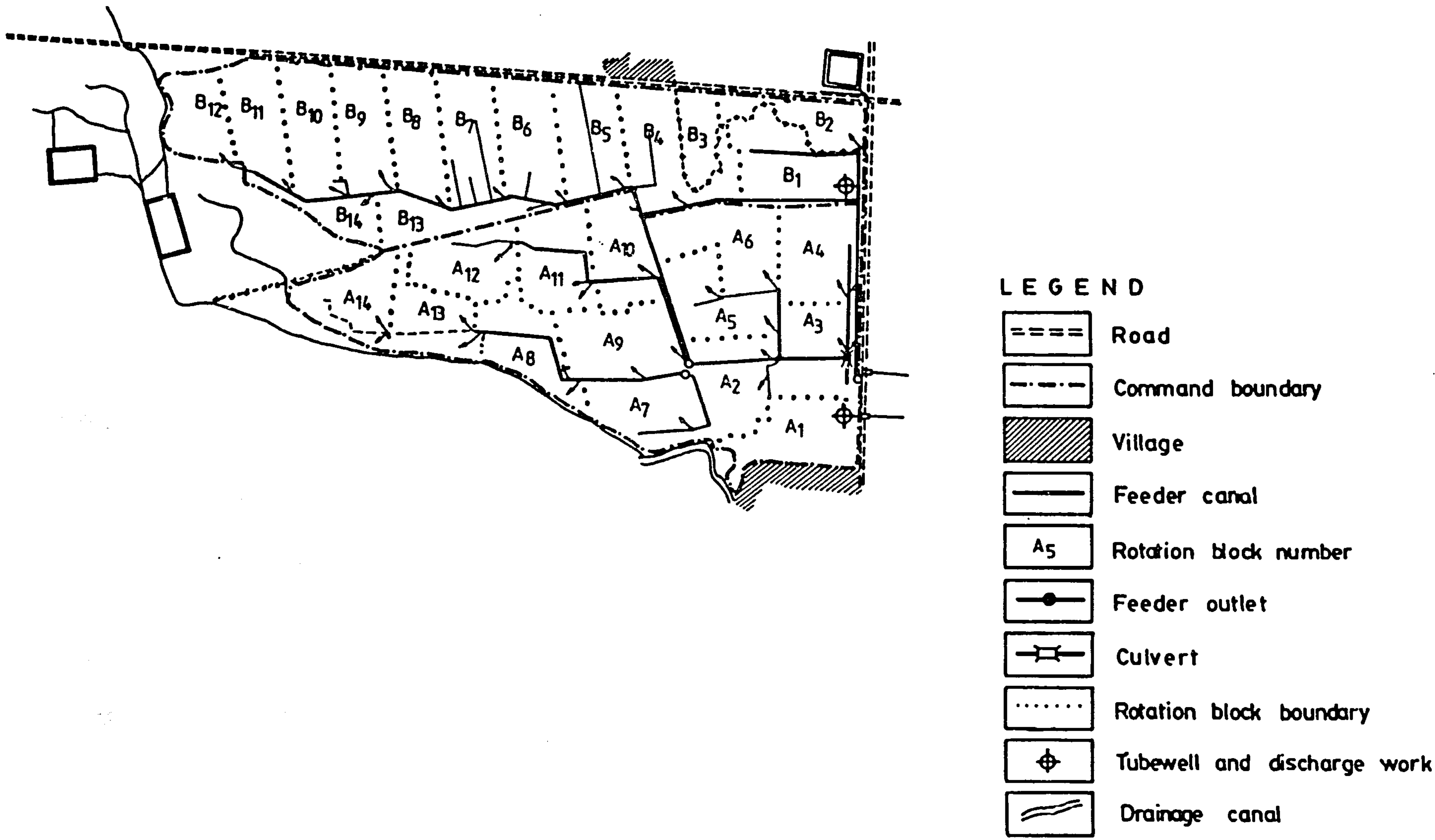

MAP OF IRRIGATED AREA TW. NGLABAN III NGANJUK-KEDIRI
1
2
3
4
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

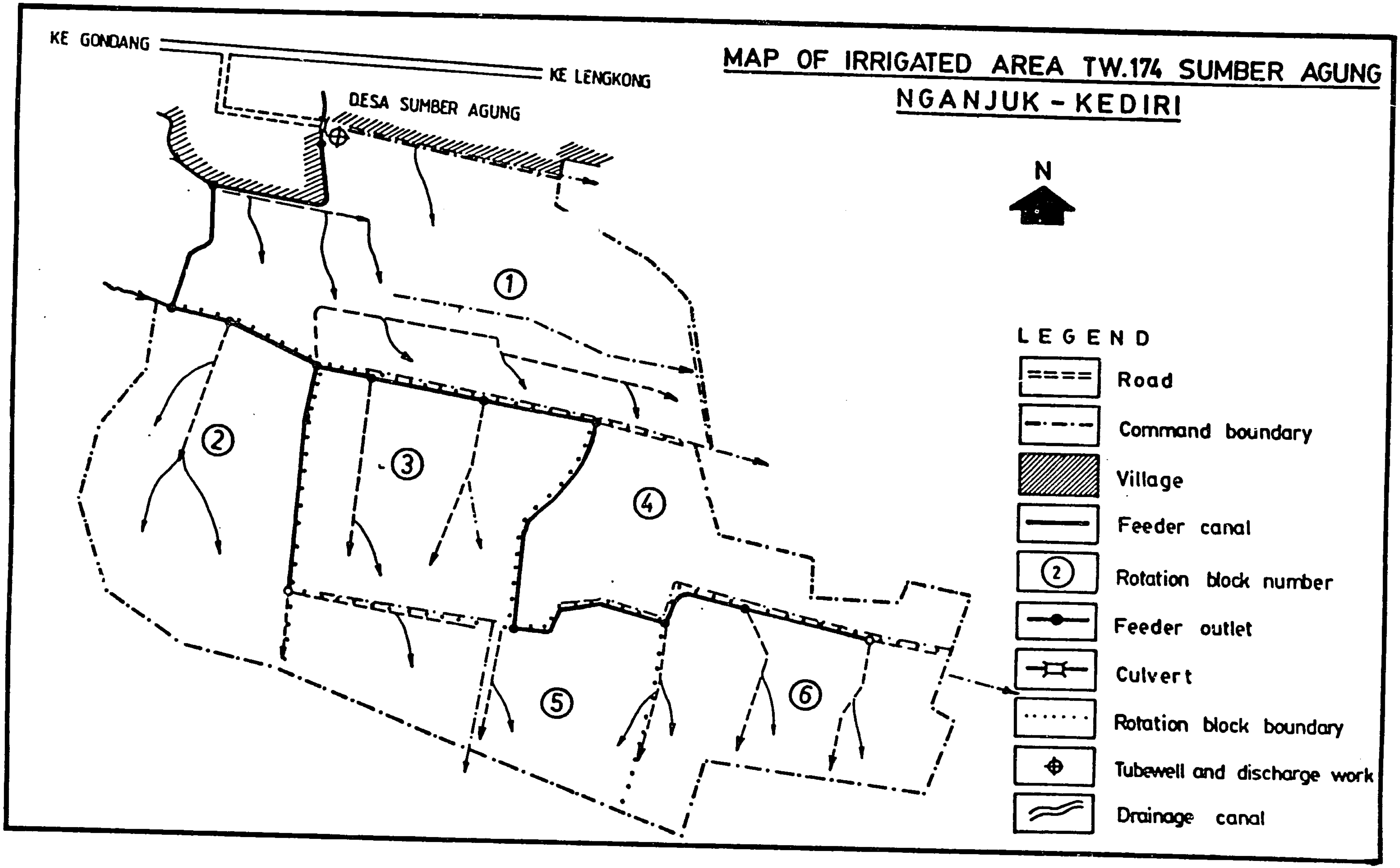

MAP OF IRRIGATED AREA TW. PUTUKREJO NGANJUK-KEDIRI
WADUK
1
2
3
4
5
6
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

MAP OF IRRIGATED AREA TW. 016 SIDOWAREG NGANJUK - KEDIRI

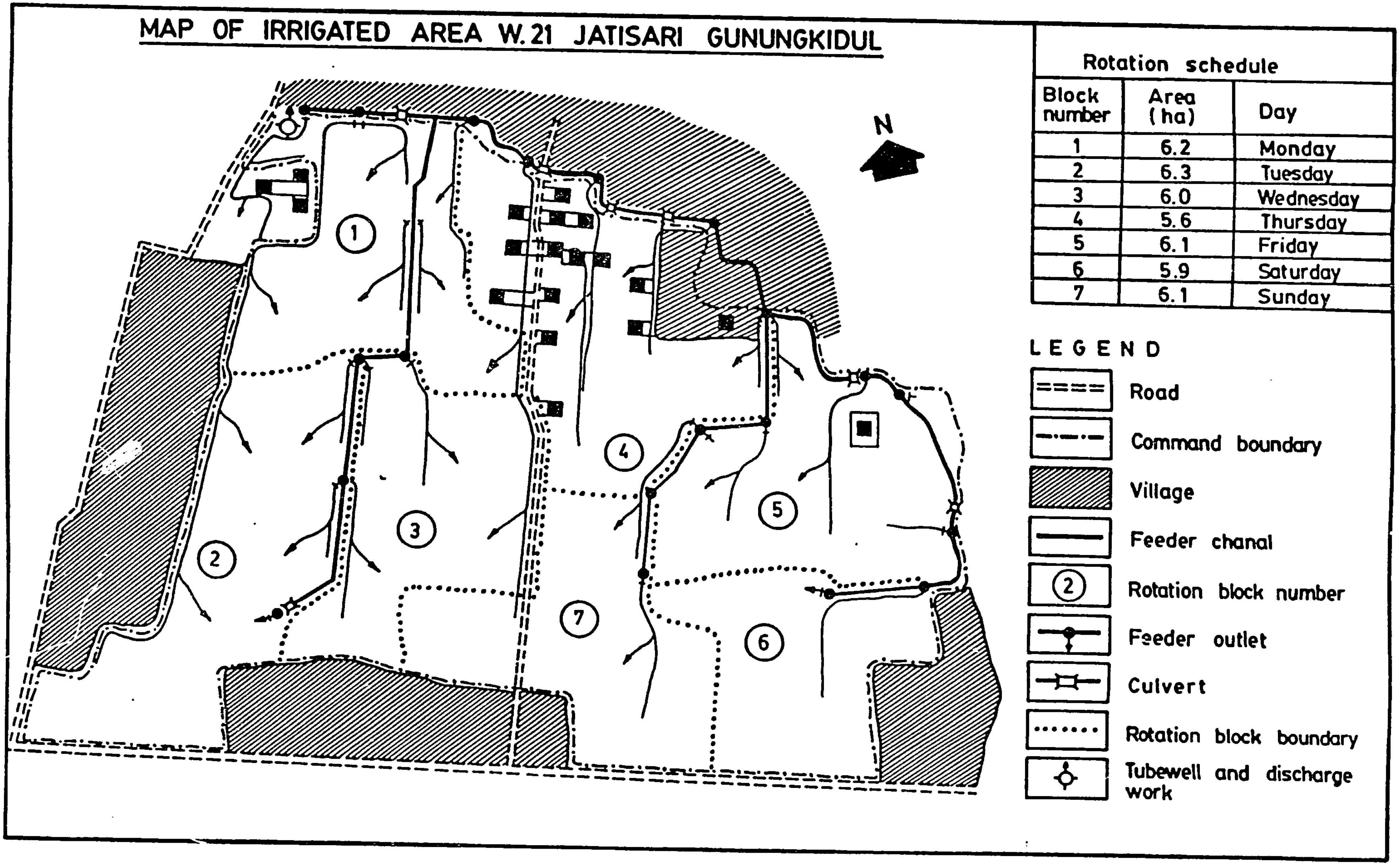


MAP OF IRRIGATED AREA TW. 010 & TW. 012 KN SIDOWAREG NGANJUK - KEDIRI





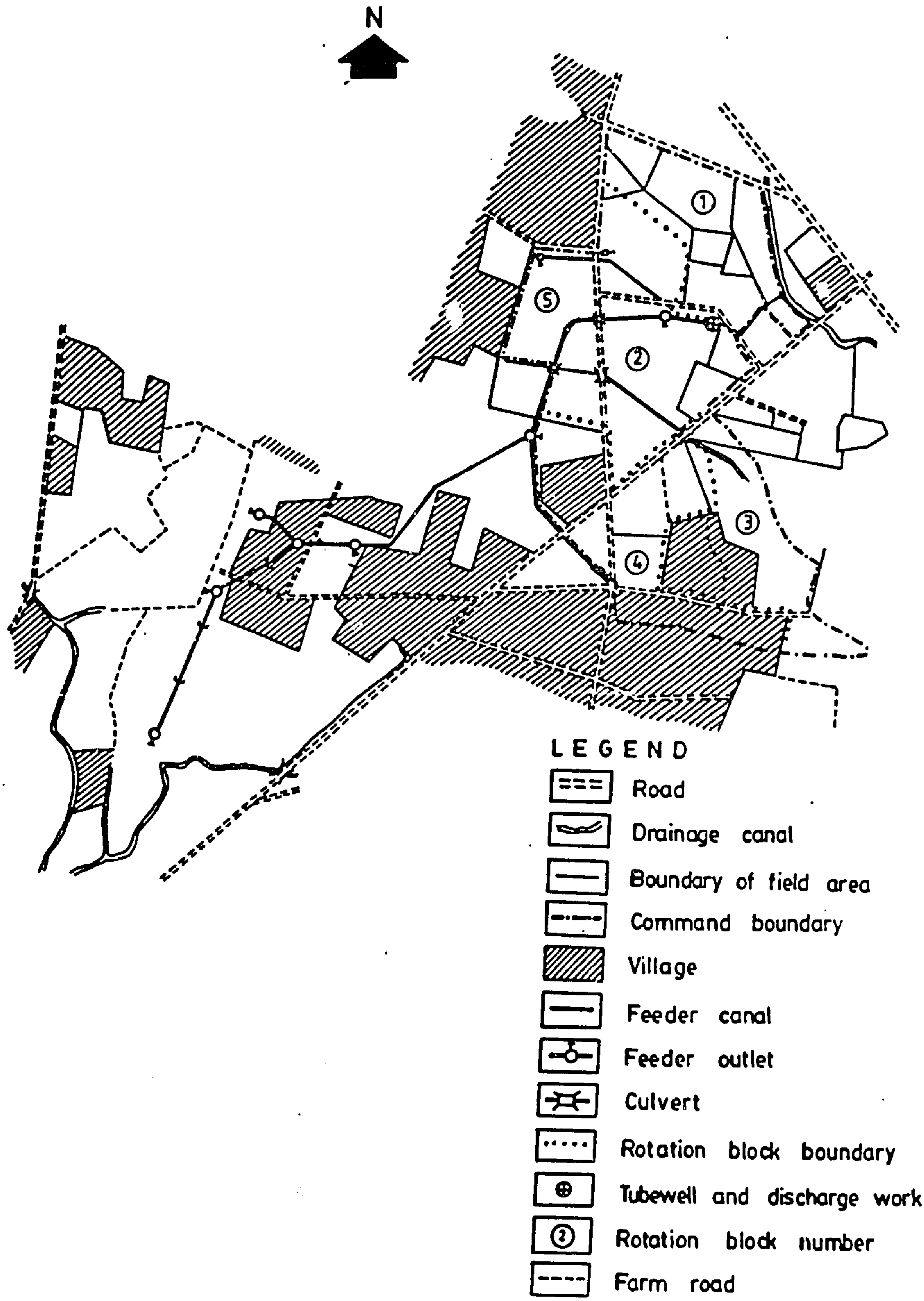
MAP OF IRRIGATED AREA TW.174 SUMBER AGUNG
NGANJUK - KEDIRI
KE GONDANG
KE LENGKONG
DESA SUMBER AGUNG
N
1
2
3
4
5
6
LEGEND
Road
Command boundary
Village
Feeder canal
Rotation block number
Feeder outlet
Culvert
Rotation block boundary
Tubewell and discharge work
Drainage canal

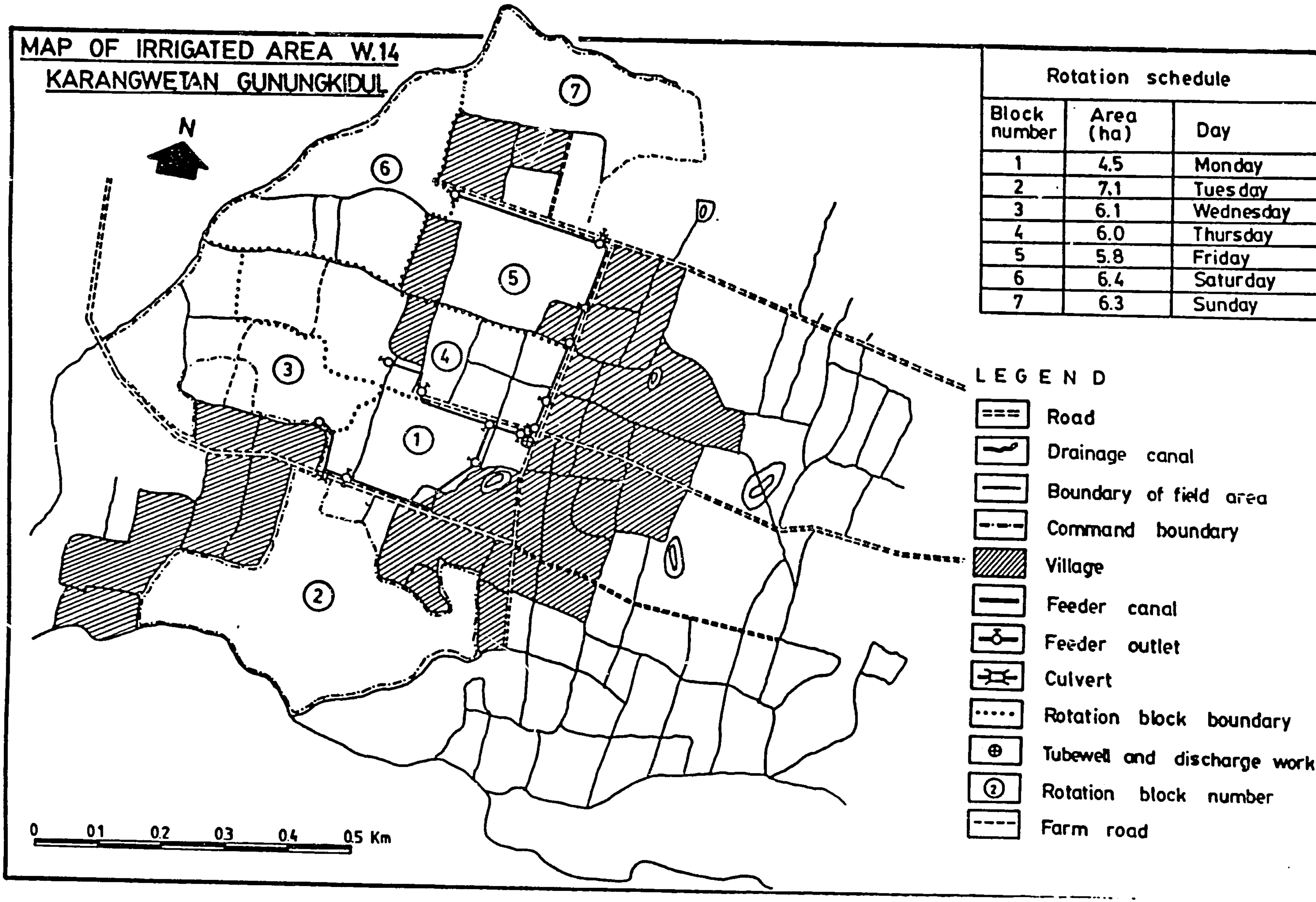


Rotation schedule

Block number	Area (ha)	Day
1	6.2	Monday
2	6.3	Tuesday
3	6.0	Wednesday
4	5.6	Thursday
5	6.1	Friday
6	5.9	Saturday
7	6.1	Sunday

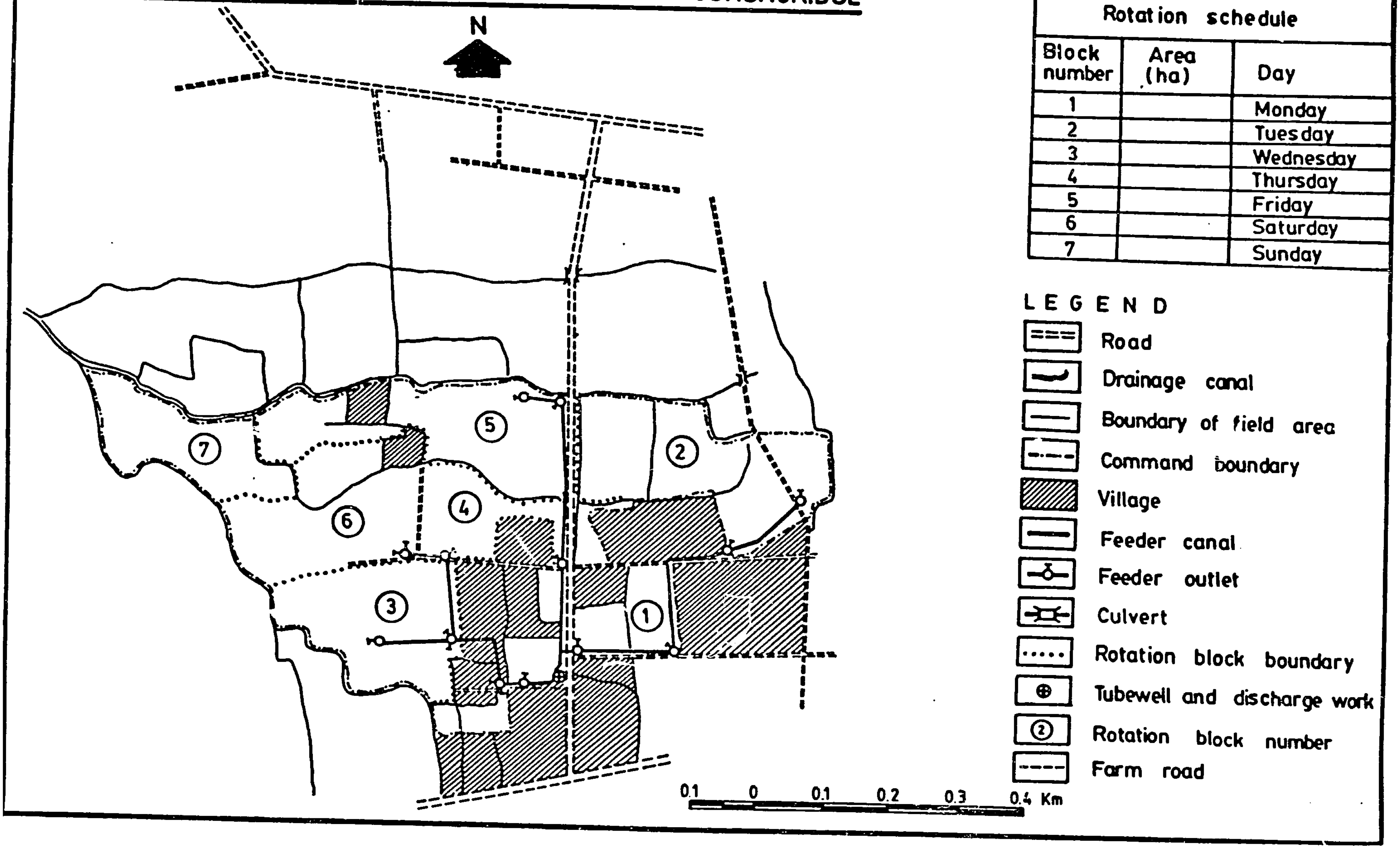
MAP OF IRRIGATED AREA W. BANDUNG GUNUNGKIDUL





Block number	Area (ha)	Day
1	4.5	Monday
2	7.1	Tuesday
3	6.1	Wednesday
4	6.0	Thursday
5	5.8	Friday
6	6.4	Saturday
7	6.3	Sunday

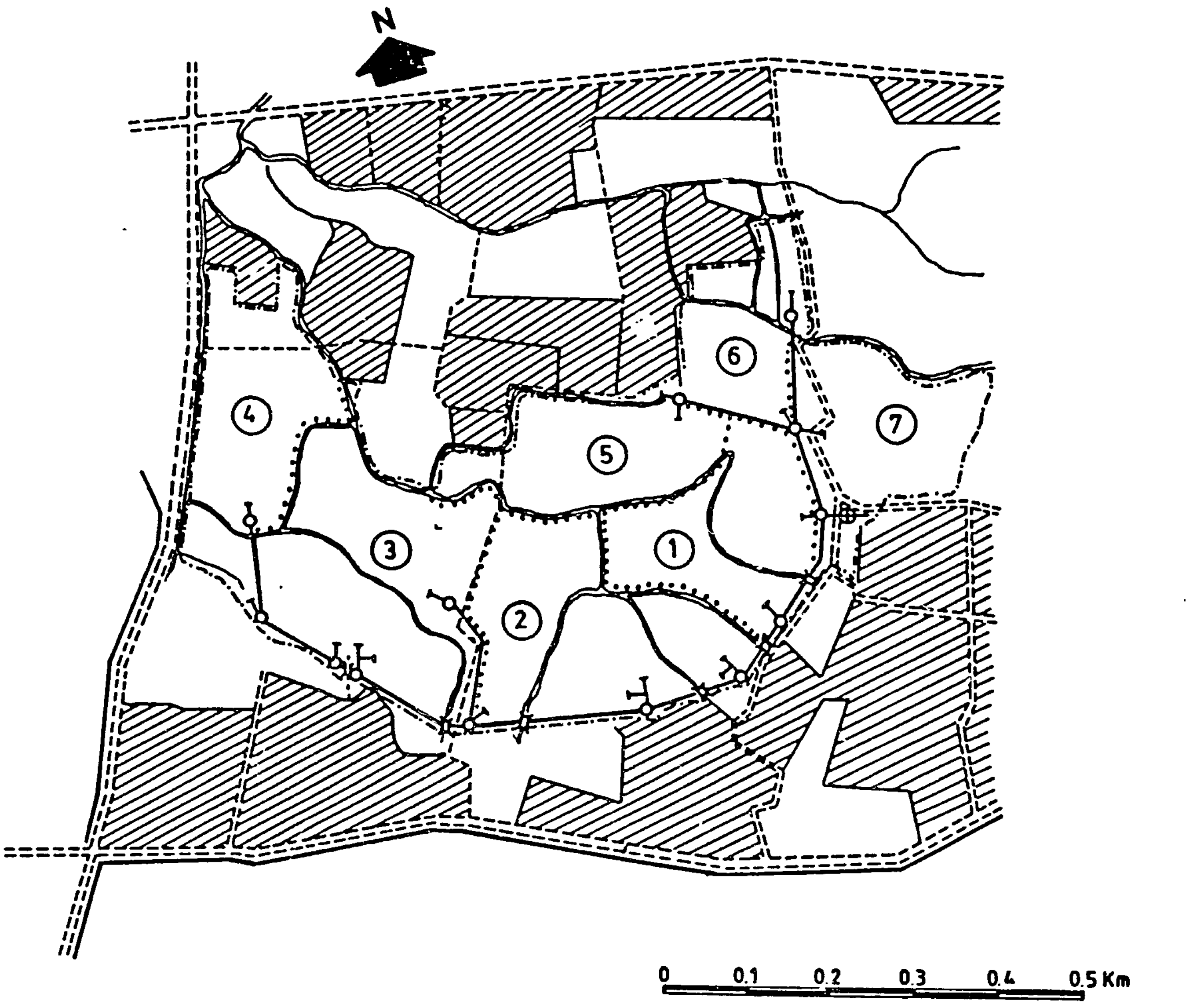
MAP OF IRRIGATED AREA W.22 PLUMBUNGAN GUNUNGKIDUL



Rotation schedule

Block number	Area (ha)	Day
1		Monday
2		Tuesday
3		Wednesday
4		Thursday
5		Friday
6		Saturday
7		Sunday

MAP OF IRRIGATED AREA W.11 JARANMATI GUNUNGKIDUL



Rotation schedule

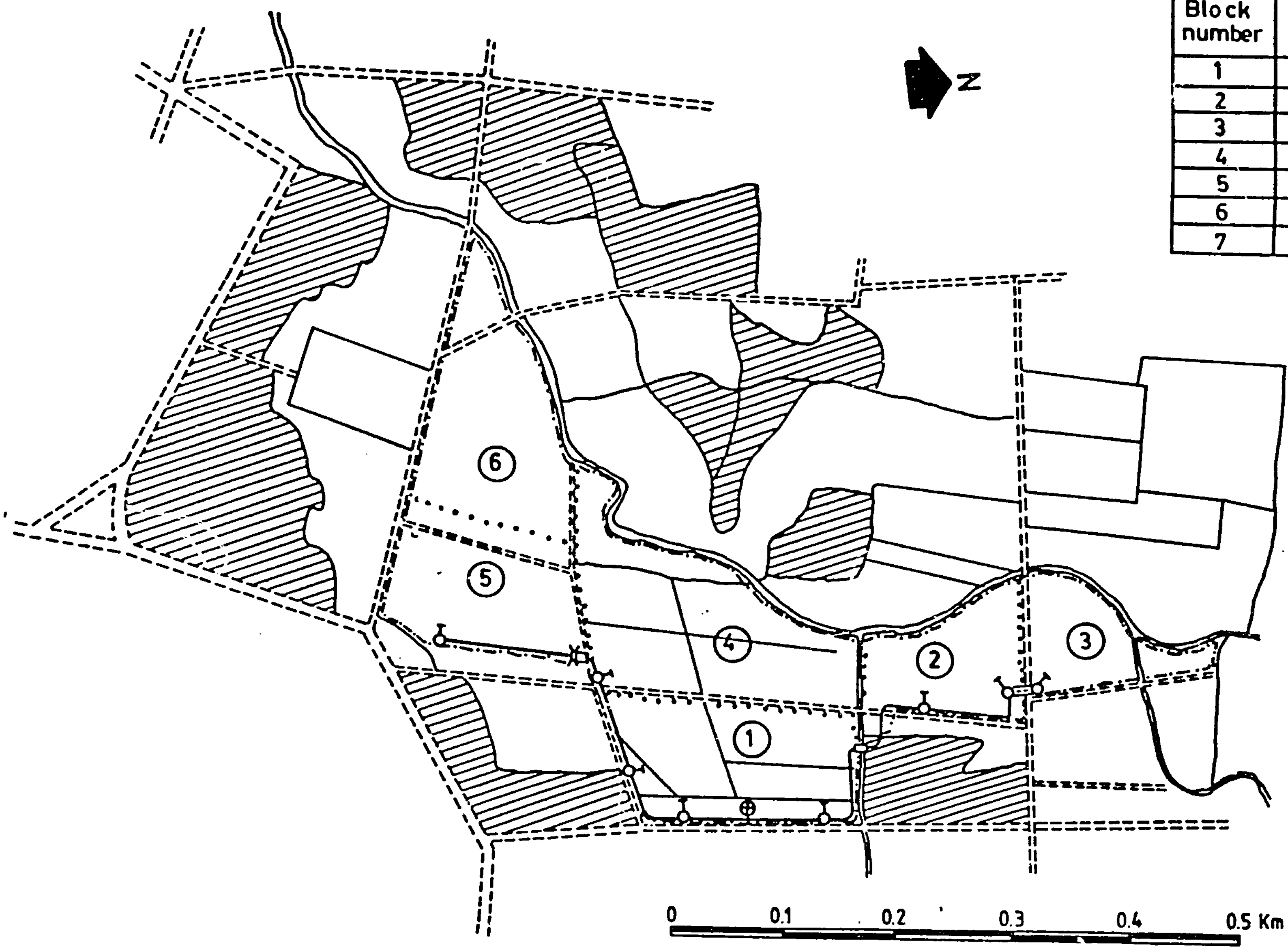
Block number	Area (ha)	Day
1	4.3	Monday
2	5.4	Tuesday
3	6.3	Wednesday
4	4.7	Thursday
5	3.5	Friday
6	2.9	Saturday
7	3.4	Sunday

LEGEND

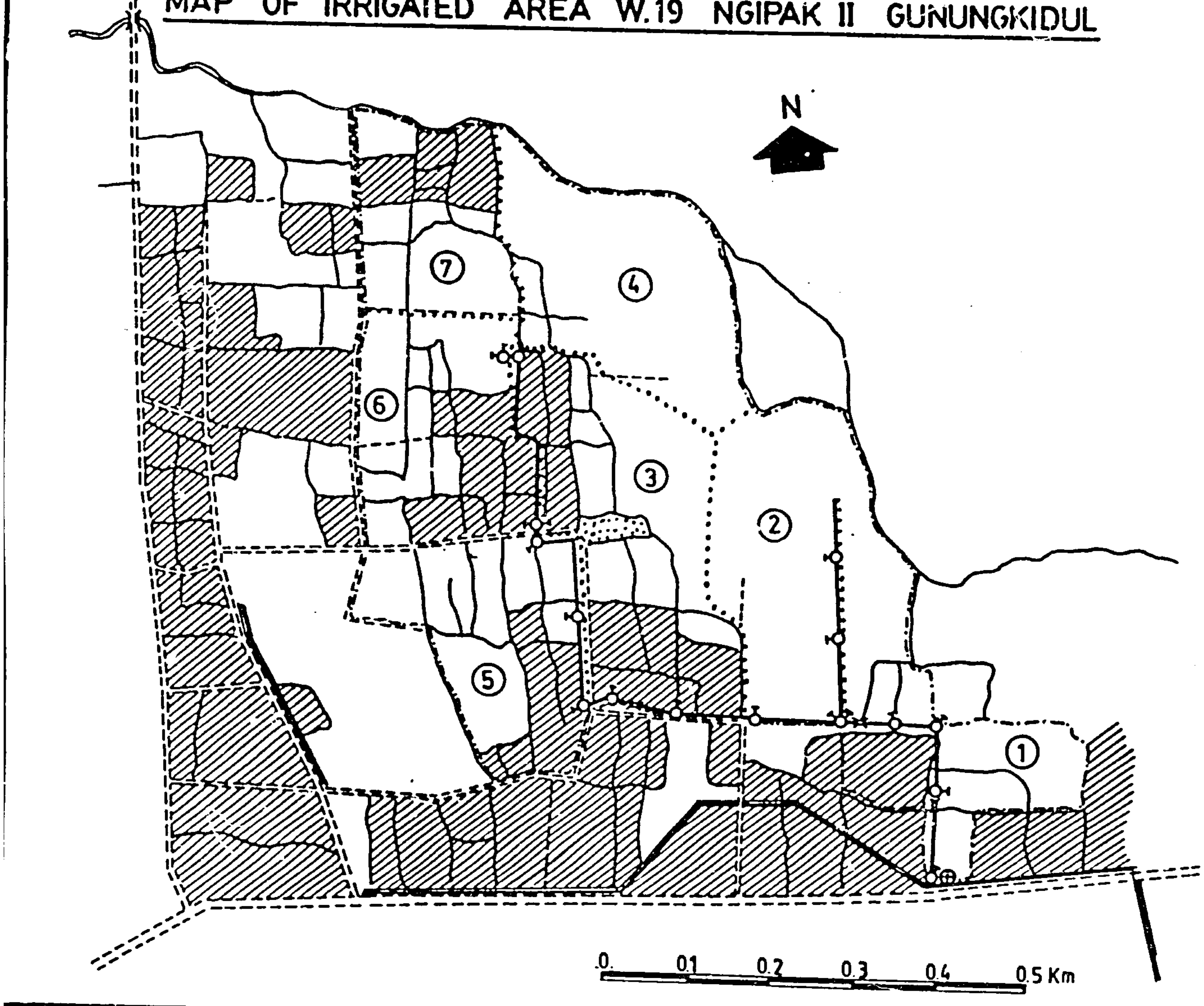
- Road
- Drainage canal
- Boundary of field area
- Command boundary
- Village
- Feeder canal
- Feeder outlet
- Culvert
- Rotation block boundary
- Tubewell and discharge work
- Rotation block number
- Farm road

MAP OF IRRIGATED AREA W. 20 AWAR-AWAR GUNUNGKIDUL

Rotation schedule		
Block number	Area (ha)	Day
1	2.0	Monday
2	1.4	Tuesday
3	1.1	Wednesday
4	2.4	Thursday
5	1.9	Friday
6	2.2	Saturday
7	1.0	Sunday



MAP OF IRRIGATED AREA W.19 NGIPAK II GUNUNGKIDUL



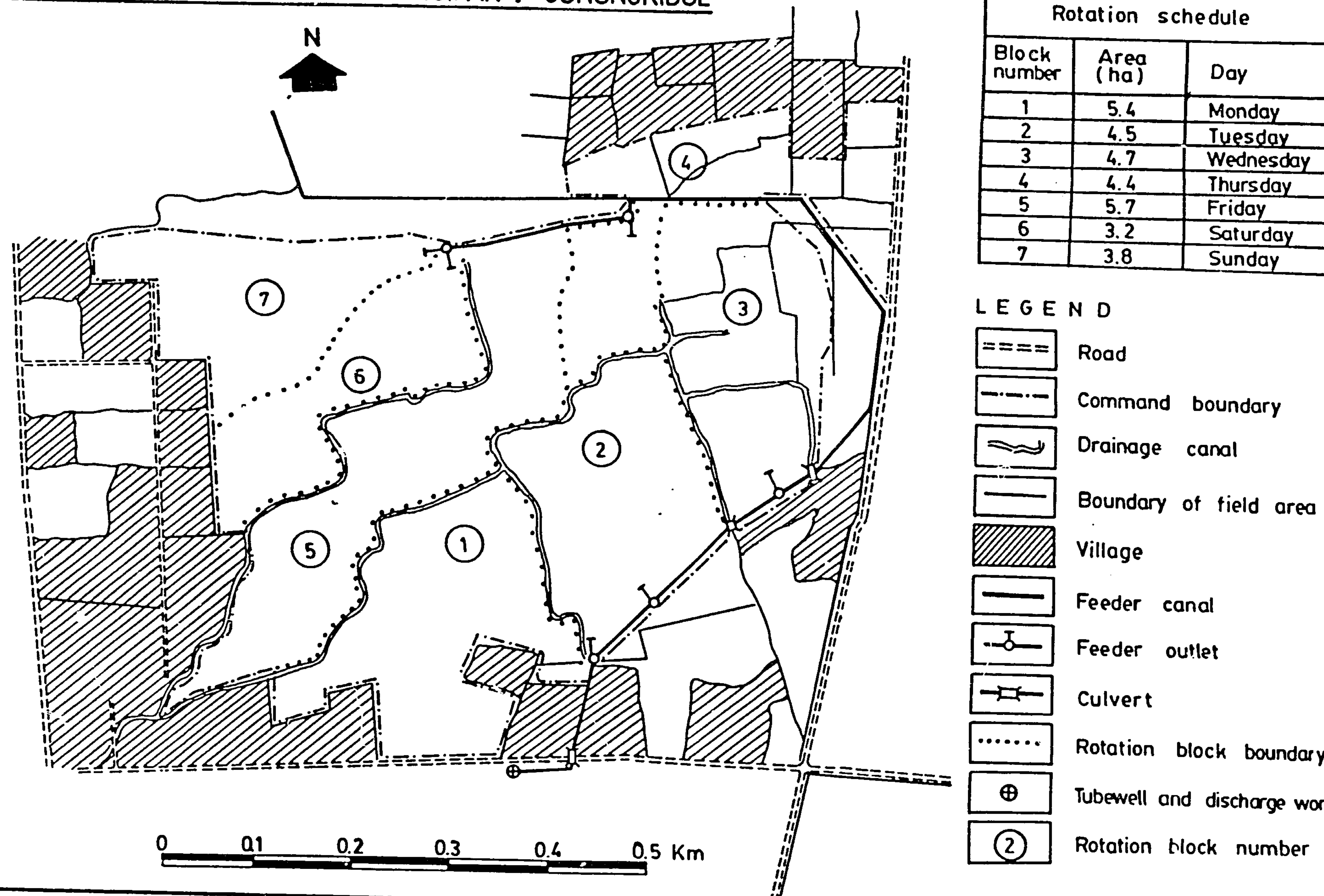
Rotation schedule

Block number	Area (ha)	Day
1	5.8	Monday
2	5.6	Tuesday
3	6.3	Wednesday
4	6.4	Thursday
5	5.9	Friday
6	5.8	Saturday
7	5.3	Sunday

LEGEND

- Road
- Drainage canal
- Boundary of field area
- Command boundary
- Village
- Feeder canal
- Feeder outlet
- Culvert
- Rotation block boundary
- Tubewell and discharge work
- Rotation block number
- Farm road

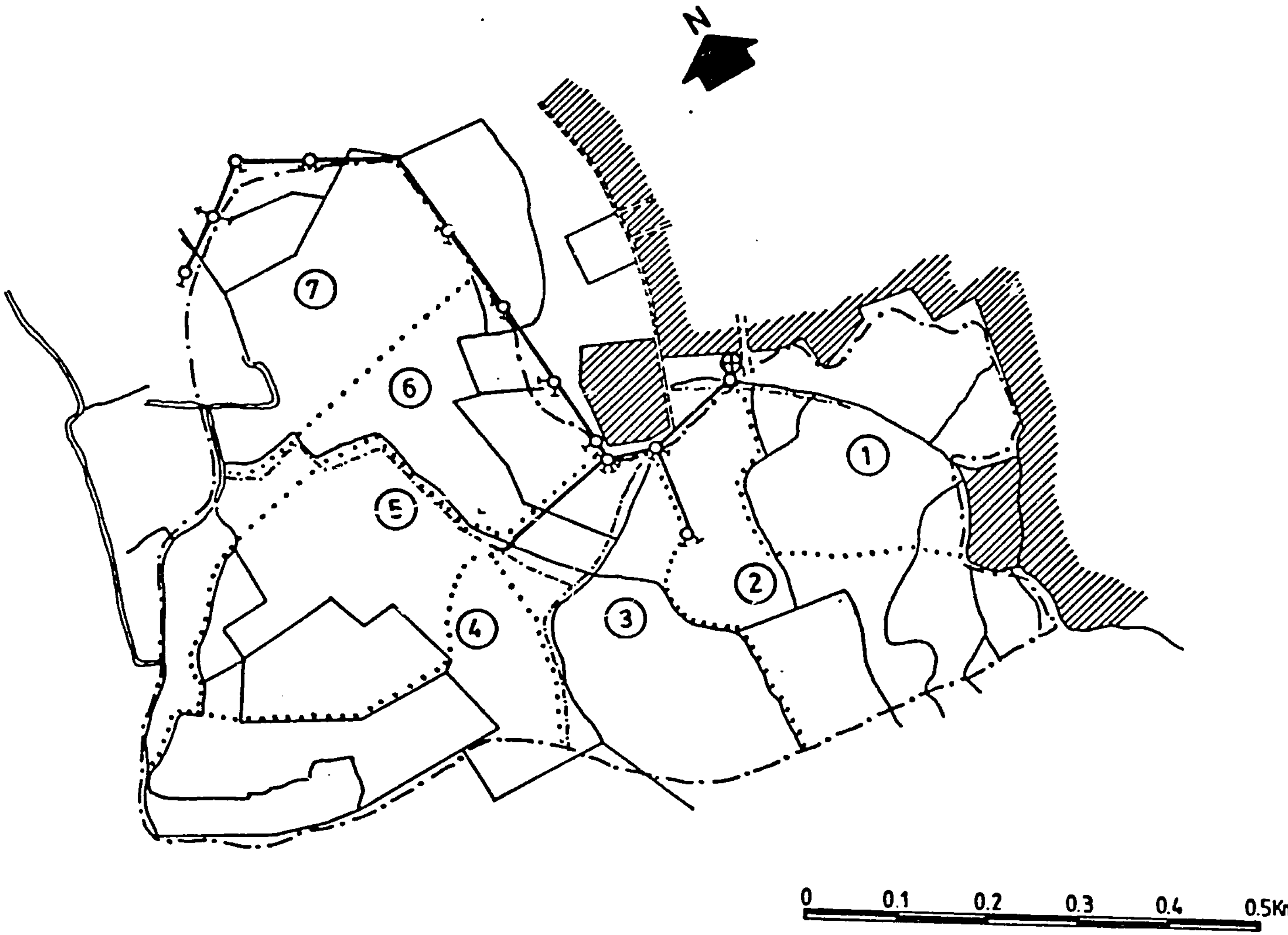
MAP OF IRRIGATED AREA W.03 NGIPAK I GUNUNGKIDUL



Rotation schedule

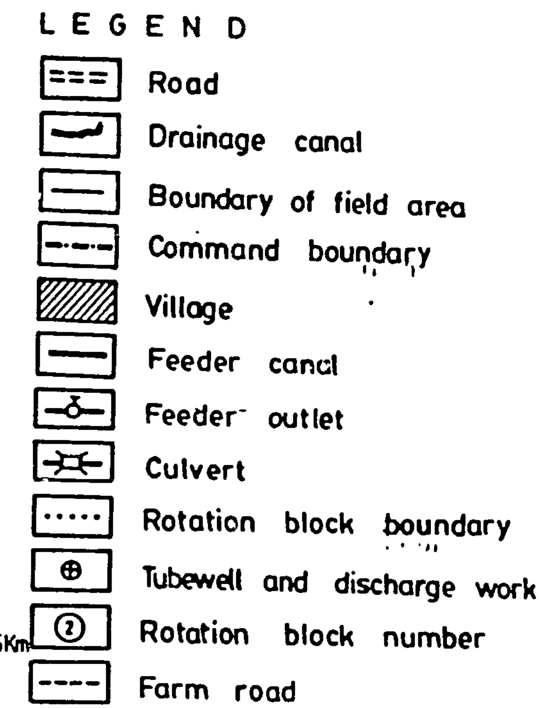
Block number	Area (ha)	Day
1	5.4	Monday
2	4.5	Tuesday
3	4.7	Wednesday
4	4.4	Thursday
5	5.7	Friday
6	3.2	Saturday
7	3.8	Sunday

MAP OF IRRIGATED AREA W.05 BOGOR KIDUL GUNUNGKIDUL

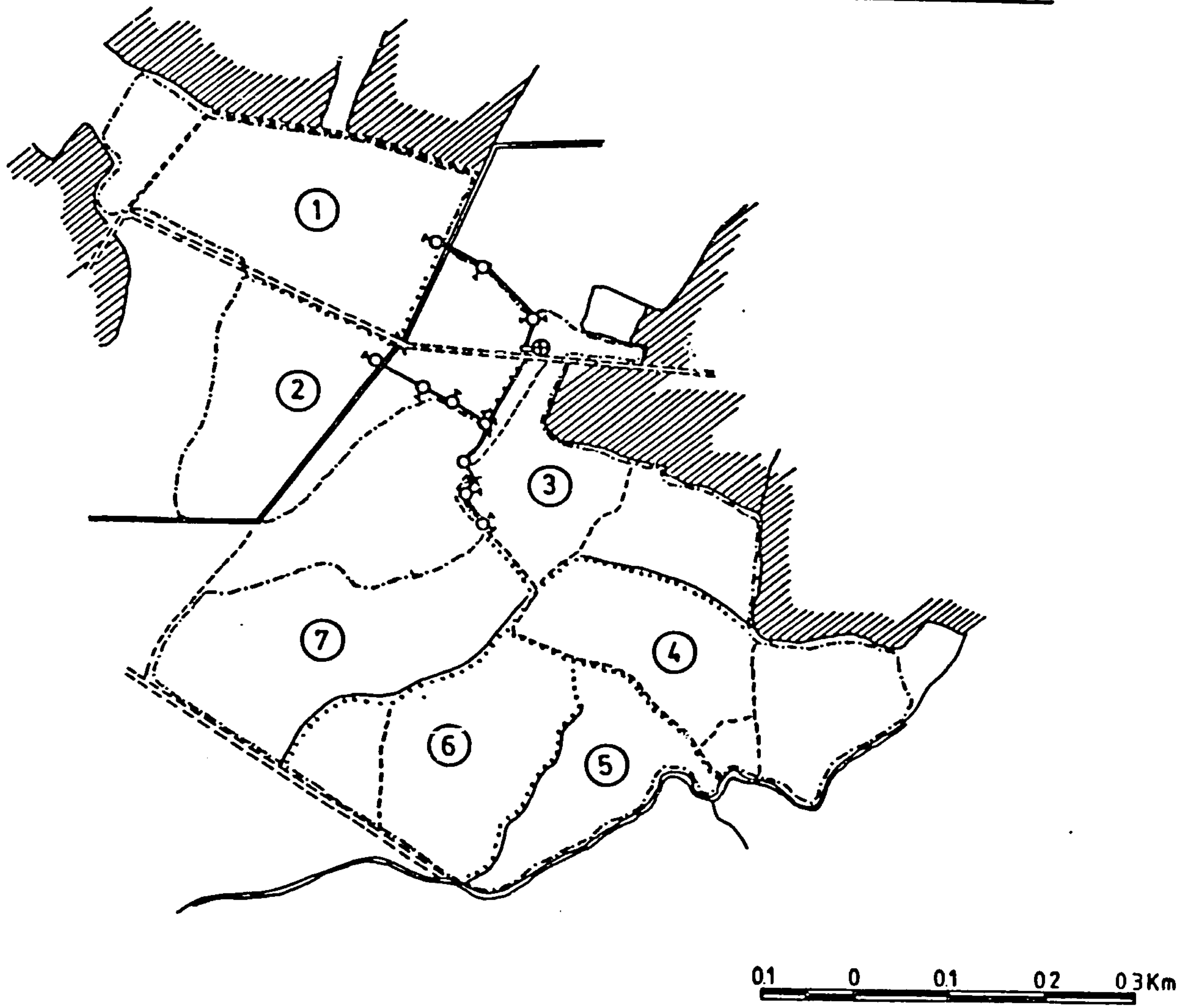


Rotation schedule

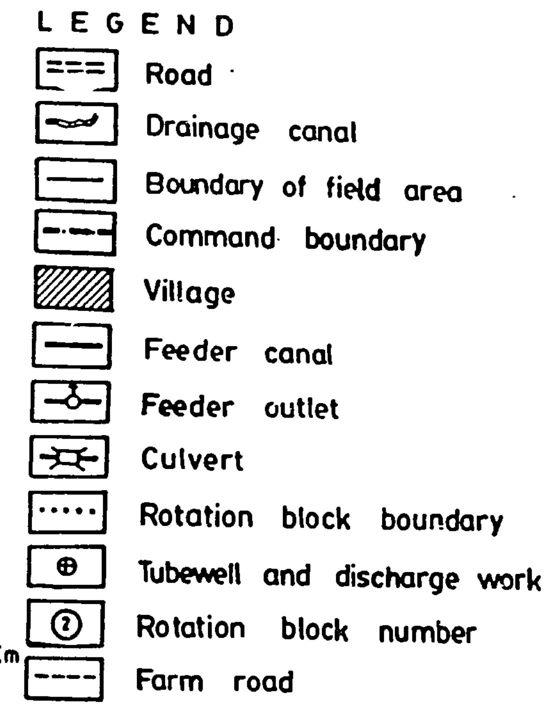
Block number	Area (ha)	Day
1	6.1	Monday
2	7.1	Tuesday
3	7.1	Wednesday
4	6.2	Thursday
5	6.8	Friday
6	6.3	Saturday
7	7.0	Sunday



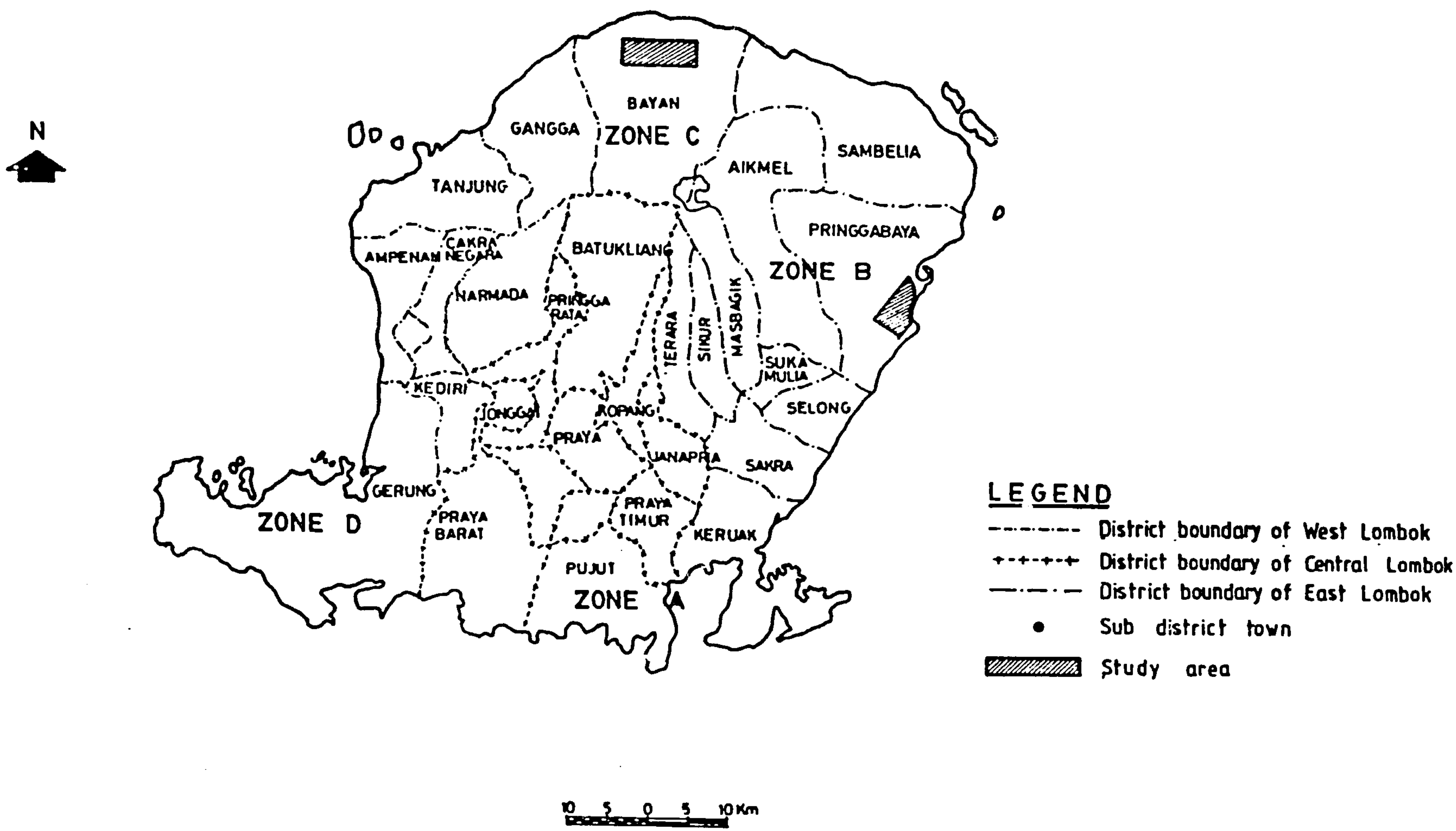
MAP OF IRRIGATED AREA W. 28. BOLO GUNUNGKIDUL



Rotation schedule		
Block number	Area (ha)	Day
1	5.8	Monday
2	5.9	Tuesday
3	4.6	Wednesday
4	5.4	Thursday
5	2.7	Friday
6	4.7	Saturday
7	4.8	Sunday



MAP OF STUDY AREA
AND SITE DISTRIBUTION OF PUMP
IN LOMBOK ISLAND 1991



Appendix E

INPUT COSTS AND NET RETURNS FOR CROPS FROM SAMPLE AREAS

Table A-1 East Java DS1 Yields, Input Costs and Net Returns

East Java	TW	CROP	YIELD	GROSS	INPUT	LABOR	WATER	NET	% WATER
MEDIAN	TW-010	MAIZE	2.80	560000	128750	142500	120000	168,750	0.31
MEDIAN	TW-010	SHALLOTS	5.36	2678571	1044464	430714	114286	1,089,107	0.07
MEDIAN	TW-061	MAIZE	2.02	447674	114423	58929	18169	256,153	0.09
MEDIAN	TW-061	SHALLOTS	4.83	1689655	314655	351724	72727	950,549	0.10
MEAN	TW-025	MAIZE	2.91	714286	187273	66964	119569	340,480	0.32
MEAN	TW-025	SOYBEANS	1.09	803571	251786	172143	44143	335,499	0.09
MEDIAN	TW-153	RICE	5.48	1259524	164286	232143	65181	797,914	0.14
MEAN			4.25	1265296	199325	207880	79379	778,711	0.16
MEDIAN	TW-153	MAIZE	2.50	750000	58750	247500	24000	419,750	0.07
MEDIAN	RENTAL1	RICE	3.08	831600	184400	90000	17964	539,236	0.06
MEAN			5.12	1099105	228768	149841	89606	630,890	0.19
MEDIAN	OWNER1	RICE	5.18	1370060	260588	306886	76444	726,142	0.12
MEDIAN	TW-116	RICE	4.09	1067727	146886	284091	14000	622,750	0.03
MEAN			3.61	1058121	180857	224557	29577	623,130	0.07
MEDIAN	RENTAL2	RICE	4.53	1198802	160882	258683	29641	749,596	0.07
MEAN			4.83	1370428	294559	255679	33413	786,778	0.06
MEDIAN	OWNER2	RICE	5.14	1157143	182571	232567	26255	715,750	0.06
MEDIAN	OWNER2	SWEET POT	110.00	6435000	820000			5,615,000	0.00
MEDIAN	TW-138	RICE	4.24	848485	232576	389394	116364	110,151	0.16
MEDIAN	TW-138	SOYBEANS	0.71	535714	147619	92857	123429	171,809	0.34
MEDIAN	TW-152	SOYBEANS	0.86	646552	312069	68966	72000	193,517	0.16
MEDIAN	TW-174	SOYBEANS	0.60	600000	93500	88000	85714	332,786	0.32
MEAN			0.73	691825	118313	79746	79971	413,795	0.29
MEAN	OWNER3	RICE	5.50	1155000	258825	267700	291005	337,470	0.36
MEDIAN	OWNER3	SOYBEANS	1.00	800000	73333	131667	58800	536,200	0.22
MEAN	RENTAL3	RICE	3.59	797006	329412	202695	125611	139,288	0.19
MEAN	RENTAL3	SOYBEANS	1.79	1343284	98881	51642	118000	1,074,761	0.44
MEDIAN	SPPM-066	TOBACCO	0.80	3000000	117500	240000	80000	2,562,500	0.18
MEDIAN	SPPM-097	TOBACCO	0.77	2000000	111538	226000	100000	1,562,462	0.23
MEDIAN	SPPM-102	TOBACCO	0.75	1866667	150000	133333	80000	1,503,334	0.22
MEAN				1827778	154016	141300	80000	1,452,462	0.21
MEDIAN	SPPM-094	TOBACCO	1.00	2666667	110000	253333	100000	2,203,334	0.22
MEAN				2543590	136055	154151	106250	2,147,134	0.27
MEDIAN	TW-09	PEANUTS		750000	150000	94000	35000	471,000	0.13
MEAN				790000	150000	138417	62500	439,083	0.18

Table A-2 East Java DS2 Yields, Costs and Net Returns

E.Java	TW	CROP	YIELD	GROSS	INPUT	LABOR	WATER	NET	% WATER
Dry Season2			(MT/ha)	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
MEDIAN	TW-010	MAIZE	2.14	428571	109226	56429	101429	161,487	0.38
MEAN			2.97	619560	136633	114431	95245	273,251	0.28
MEDIAN	TW-010	SOYBEANS	1.00	800000	74000	130500	78869	516,631	0.28
MEDIAN	TW-061	MAIZE	4.83	917241	161207	72414	48372	635,248	0.17
MEDIAN	TW-061	SHALLOTS	6.09	1750000	1075000	292857	145671	236,472	0.10
MEDIAN	TW-025	MAIZE	3.21	610714	73214	212500	100000	225,000	0.26
MEAN			3.17	677791	226214	244007	106195	101,374	0.18
MEDIAN	TW-025	SOYBEANS	0.76	455172	173571	132759	62045	86,797	0.17
MEAN			0.80	654933	135214	128007	94862	296,850	0.26
MEDIAN	TW-153	MAIZE	4.76	952381	139286	208333	130435	474,327	0.27
MEAN			3.08	742150	168110	127555	108000	338,485	0.27
MEDIAN	TW-153	SOYBEANS	1.33	1000000	143182	128889	22800	705,129	0.08
MEDIAN	RENTAL1	MAIZE	2.80	600000	200000	52000	57600	290,400	0.19
MEAN			2.79	675000	210714	42071	228800	193,415	0.48
MEDIAN	TW-116	MAIZE	4.55	927273	120023	206818	148000	452,432	0.31
MEAN			3.41	819962	193817	175928	126614	323,603	0.26
MEDIAN	RENTAL2	MAIZE	5.39	1131737	181912	196108	74118	679,599	0.16
MEDIAN	RENTAL2	SOYBEANS	1.00	800000	227000	135000	63000	375,000	0.15
MEAN	TW-138	MAIZE	2.86	571429	119118	162857	220929	68,525	0.44
MEDIAN	TW-138	SOYBEANS	0.63	468750	84125	125000	41250	218,375	0.16
MEDIAN	TW-152	MAIZE	4.14	620690	121552	56034	64286	378,818	0.27
MEDIAN	TW-174	MAIZE	2.86	514286	32857	174286	85714	221,429	0.29
MEAN	OWNER3	MAIZE	4.38	833333	256250	98333	186277	292,473	0.34
MEDIAN	OWNER3	SOYBEANS	0.90	675000	125950	30600	259200	259,250	0.62
MEDIAN	RENTAL3	MAIZE	3.64	690909	181061	197273	146250	166,325	0.28
MEAN			4.47	882827	304025	267372	144785	166,645	0.20
MEDIAN	SPPM-066	MAIZE	1.17	233333	106000	75000	15000	37,333	0.08
MEDIAN	SPPM-097	MAIZE	1.08	216667	98750	66667	50000	1,250	0.23
MEDIAN	SPPM-102	MAIZE	1.00	200000	82143	70000	50000	(2,143)	0.25
MEDIAN	SPPM-094	MAIZE	5.50	860000	99000	95000	120000	546,000	0.38
MEDIAN	TW-09	PEANUTS		750000	146250	94000	52500	457,250	0.18

Table A-3 East Java DS3 Yields, Costs and Net Returns

East Java	TW	CROP	YIELD	GROSS	INPUT	LABOR	WATER	NET	% WATER
Dry Season3			(MT/ha)	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
MEDIAN	TW-061	SHALLOTS	2.50	2500000	1878571	292857		328,572	0.00
MEDIAN	TW-025	SWEET POT	0.58	525000	68333	102803	60000	293,864	0.26
MEDIAN	TW-153	MAIZE	4.44	1022222	247727	235556	53983	484,957	0.10
MEDIAN	TW-153	MUNGBEAN	0.60	360000	136200	171800	36000	16,000	0.10
MEDIAN	RENTAL1	MUNGBEAN	1.00	225000	89700	71250	50000	14,050	0.24
MEDIAN	TW-116	MAIZE	6.00	750000	211630	190000	74286	274,084	0.16
MEAN				404063	167768	135313	90417	10,565	0.23
MEDIAN	RENTAL2	MAIZE	4.19	898204	199265	167000	63529	468,410	0.15
MEAN				883895	259000	138000	77294	409,601	0.16
MEDIAN	TW-138	MAIZE	2.75	500000	112500	165000	109631	112,869	0.28
MEAN			3.28	552219	128280	179378	179365	65,197	0.37
MEDIAN	TW-138	MUNGBEAN	0.57	571429	91765	100000	120000	259,664	0.38
MEDIAN	OWNER2	MAIZE	3.00	750000	280350	84000	129600	256,050	0.26
MEAN			3.95	743701	228791	118779	196763	199,368	0.36
MEDIAN	RENTAL2	MAIZE	3.00	750000	82900	100800	123506	442,794	0.40
MEAN			3.32	762912	276501	206339	128807	151,265	0.21
MEDIAN	RENTAL2	PEANUTS	1.20	700000	128100	46000	86400	439,500	0.33

Table A-4 East Java WS Yields, Costs and Net Returns

	TW	CROP	YIELD	GROSS	INPUT	LABOR	WATER	NET	% WATER
WET SEASON			(MT/ha)	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
MEDIAN	TW-010	RICE	5.17	1034483	169655	365172	35714	463,942	0.06
MEAN			4.55	1039974	216973	234561	44852	543,588	0.09
MEDIAN	TW-061	RICE	4.29	857143	261667	155952	0	439,524	0.00
MEAN			3.91	891581	296610	288127	0	306,844	0.00
MEDIAN	TW-025	RICE	5.09	1100000	186136	177188	21000	715,676	0.05
MEAN			4.63	1021258	246761	243731	36750	494,016	0.07
MEDIAN	TW-153	RICE	4.78	1333333	239091	200000	41905	852,337	0.09
MEAN			4.72	1309639	196044	179222	31283	903,090	0.08
MEDIAN	RENTAL1	RICE	4.00	1080000	182400	90000	0	807,600	0.00
MEAN			4.33	1206667	226197	149841	0	830,629	0.00
MEDIAN	TW-116	RICE	5.00	1400000	237250	140000	0	1,022,750	0.00
MEAN			4.16	1514659	187505	242284	0	1,084,870	0.00
MEDIAN	OWNER2	RICE	7.50	1687500	313856	432500	0	941,144	0.00
MEAN			7.58	1988157	313856	272881	0	1,401,420	0.00
MEDIAN	TW-138	RICE	5.00	1100000	237905	239583	36000	586,512	0.07
MEAN			4.74	860036	281852	257544	42304	278,336	0.07
MEDIAN	TW-152	RICE	6.25	1125000	236607	262946	0	625,447	0.00
MEAN			5.63	1156111	238371	214161	0	703,579	0.00
MEDIAN	TW-174	RICE	6.00	1320000	117400	278000	0	924,600	0.00
MEAN			5.75	1237905	180361	197914	0	859,630	0.00
MEDIAN	OWNER3	RICE	5.43	1194030	235075	202985	28800	727,170	0.06
MEAN			6.05	1189221	309979	258873	33292	587,077	0.06
MEDIAN	SPPH-066	RICE	5.22	1180000	107727	228889	20000	823,384	0.06
MEAN			5.23	1541429	145931	186180	20000	1,189,318	0.06
MEDIAN	SPPH-097	RICE	4.67	1375000	166667	133333	70000	1,005,000	0.19
MEAN			4.56	1375982	159024	165702	71250	980,006	0.18
MEDIAN	SPPH-102	RICE	4.75	1520000	110000	120000	0	1,290,000	0.00
MEAN			4.98	1530000	116197	201429	0	1,212,374	0.00
MEDIAN	SPPH-094	RICE	4.38	1292308	101563	137500	0	1,053,245	0.00
MEAN			4.13	1254327	154498	137901	0	961,928	0.00
MEDIAN	TW-09	RICE	4.40	1100000	157500	240000	0	702,500	0.00
MEAN			3.97	1034375	133517	241875	0	658,983	0.00

Table A-5 Yogya DS 1 Yields, Input Costs and Net Returns

Yogykarta				GROSS	INPUTS	LABOR	WATER	NET	% WATER
	TW	CROP	YIELD	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
Dry Season1									
MEAN	W-19	RICE	2.22	706667	276944	288889	76234	64,600	0.12
Median			3.58	1030849	233895	249280	87263	460,411	0.15
MEAN	W-19	PEANUTS	0.45	637500	115500	30000	45321	446,679	0.24
MEAN	W-19	SOYBEANS	0.70	530000	164883	100000	16800	248,317	0.06
MEAN	W-11	RICE	2.00	600000	423750	155000	122000	(100,750)	0.17
Median			2.00	610024	298377	201132	81000	29,515	0.14
MEAN	W-11	SOYBEANS	1.50	1500000	137500	145000	67000	1,150,500	0.19
Median			1.18	1320018	189662	265599	48000	816,757	0.10
MEAN	W-25	SOYBEANS	0.80	780000	177000	40000	23333	539,667	0.10
Median			0.62	752043	171031	94217	34667	452,128	0.12
MEAN	W-25	PEANUTS	0.55	800000	199500	146250	23333	430,917	0.06
MEAN	W-22	RICE	1.25	312500	146500	62500	83882	19,618	0.29
Median			2.40	717945	209049	140832	135000	233,064	0.28
MEAN	W-22	SOYBEANS	1.10	775000	182000	105000	26000	462,000	0.08
MEAN	W-22	PEANUTS	0.48	752000	336400	100000	73000	242,600	0.14
MEAN	W-20	SOYBEANS	0.60	840000	85000	125000	14000	616,000	0.06
MEAN	W-20	PEANUTS	2.50	339900	102500	155000	115200	(32,800)	0.31
MEAN	W-08	SOYBEANS	0.50	692680	142000	160000	29718	360,962	0.09
Median			0.52	602845	124776	97414	24000	356,655	0.10
MEAN	W-24	PEANUTS	0.53	668000	183333	40000	98000	346,667	0.30
Median			0.49	715543	165262	89833	98000	362,448	0.28
MEAN	W-24	SOYBEANS	1.00	950000	182500	157500	98000	512,000	0.22
MEAN	W-21	SOYBEANS	0.73	660000	122700	144000	5650	387,650	0.02
Median			0.68	659099	158893	149311	13282	337,613	0.04
MEAN	W-05	SOYBEANS	0.67	640000	153750	150000	18000	318,250	0.06
Median			0.64	664647	210015	150000	24154	280,478	0.06
MEAN	W-02	SOYBEANS	0.90	850000	154200	150000	42000	503,800	0.12
Median			0.81	844095	227110	95000	42000	479,985	0.12

Table A-6 Yogya DS2 Yields, Input Costs and Net Returns

Yogyakarta				GROSS	INPUTS	LABOR	WATER	NET	% WATER
	TW	CROP	YIELD	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
Dry Season2									
MEAN	W-19	SOYBEANS	0.45	472500	108000	30000	37769	296,731	0.21
Median			0.61	485154	128010	77249	37333	242,562	0.15
MEAN	W-19	PEANUTS	1.33	960000	108000	190000	37667	624,333	0.11
MEAN	W-11	SOYBEANS	0.97	1055000	327500	361000	51800	314,700	0.07
MEAN	W-11	RICE	3.00	900000	341000	252500	71000	235,500	0.11
MEAN	W-25	SOYBEANS	0.63	625000	100900	146250	61460	316,390	0.20
MEAN	W-25	RICE	4.50	1020000	385500	263500	32500	338,500	0.05
MEAN	W-22	SOYBEANS	0.47	653333	112333	156667	50500	333,833	0.16
MEAN	W-22	PEANUTS	0.80	824000	141000	260000	68000	355,000	0.14
MEAN	W-20	SOYBEANS	0.53	773333	86667	187666	46219	452,781	0.14
MEAN	W-20	MAIZE		500000	135000	31250	56150	277,600	0.25
MEAN	W-08	PEANUTS	0.43	581034	63793	25862	83173	408,207	0.48
MEAN	W-08	SOYBEANS	0.60	648000	144000	139876	63766	300,358	0.18
MEAN	W-24	SOYBEANS	0.75	864750	85000	155567	79261	544,922	0.25
MEAN	W-24	MAIZE		194000	31875	27877	28600	105,648	0.32
MEAN	W-21	SOYBEANS	0.56	504000	72000	65625	73319	293,056	0.35
Median			0.62	522524	142834	143311	74000	162,379	0.21
MEAN	W-05	SOYBEANS	0.60	600000	240500	102345	80449	176,706	0.19
Median			0.58	613885	202965	230000	96000	84,920	0.18
MEAN	W-02	SOYBEANS	0.80	800000	289200	150000	88799	272,001	0.17
MEAN	W-02	MAIZE		348000	87000	53442	58780	148,778	0.30

Table A-7 Yogya DS3 Yields, Input Costs and Net Returns

Yogyakarta				GROSS	INPUTS	LABOR	WATER	NET	% WATER
	TW	CROP	YIELD	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
Dry Season3									
MEAN	W-19	MAIZE		600000	34000	91101	18667	456,232	0.13
MEAN	W-11	MAIZE		640000	81000	81000	45000	433,000	0.22
MEAN	W-11	SOYBEANS	0.50	500000	245000	135000	51000	69,000	0.12
MEAN	W-25	MAIZE		450000	170000	90000	55800	134,200	0.18
Median				447500	102975	90000	62500	192,025	0.24
MEAN	W-22	MAIZE		724000	49300	70000	57875	546,825	0.33
Median				554750	63200	145000	58500	288,050	0.22
MEAN	W-20	MAIZE		580000	48250	120000	42490	369,260	0.20
Median				459033	55347	70750	41250	291,686	0.25
MEAN	W-08	MAIZE		454000	37000	20000	53000	344,000	0.48
Median				538114	43750	35000	51000	408,364	0.39
MEAN	W-24	MAIZE		786667	23333	110011	56000	597,323	0.30
Median				505934	19167	35000	56000	395,767	0.51
MEAN	W-21	MAIZE		428571	73512	33333	41173	280,553	0.28
Median				427629	80584	45000	49300	252,745	0.28
MEAN	W-05	MAIZE		428571	68571	48554	56696	254,750	0.33
Median				414044	94665	70000	60000	189,379	0.27
MEAN	W-02	MAIZE		400000	79500	67550	67000	185,950	0.31
Median				485286	128248	65000	70000	222,038	0.27
MEAN	W-02	SOYBEANS	0.60	740000	301900	167000	67500	203,600	0.13

Table A-8 Yogya WS Yields, Input Costs and Net Returns

Yogyakarta			YIELD	GROSS	INPUTS	LABOR	WATER	NET	% WATER
	TW	CROP	(MT/ha)	RETURNS	COSTS	COSTS	COSTS	RETURNS	COSTS
Wet Season									
MEAN	W-19	RICE	2.67	706667	201667	46667	21843	436,490	0.03
Median			3.07	806212	207936	211081	23333	363,862	0.05
MEAN	W-11	RICE	3.00	900000	296667	264167	0	339,166	0.00
Median			2.03	895510	274226	261556	0	359,728	0.00
MEAN	W-25	RICE	1.88	562500	212500	215625	16801	117,574	0.04
Median			2.46	640862	193919	107725	17333	321,885	0.05
MEAN	W-22	RICE	3.50	1050000	246000	160000	24750	619,250	0.06
Median			4.22	1419095	262229	226881	20250	909,735	0.04
MEAN	W-22	SOYBEANS	0.75	920000	377500	70000	13500	459,000	0.03
MEAN	W-20	RICE	3.00	506280	119800	49750	0	336,730	0.00
Median				595633	142488	162125	0	2[illegible],020	0.00
MEAN	W-20	PEANUTS	0.30	570000	113800	90000	0	366,200	0.00
Median	W-20	SOYBEANS	0.55	828000	446000	285000	0	97,000	0.00
MEAN	W-08	RICE	3.50	1040000	469375	200000	28463	342,162	0.04
MEAN	W-24	RICE	2.00	665000	209375	75000	36750	343,875	0.11
Median			1.77	647221	223670	262401	35000	126,150	0.07
MEAN	W-21	RICE	4.00	1000000	408000	126667	18667	446,666	0.03
Median			3.7	1068184	276151	225798	33305	532,930	0.06
MEAN	W-05	RICE	4.00	1040000	241167	95000	37392	666,441	0.10
Median			3.71	911050	257976	101857	40000	511,217	0.10
MEAN	W-02	RICE	4.00	1000000	198200	50000	45000	706,800	0.15
Median			3.87	1008952	273714	117222	30000	538,016	0.07

Table A-9 West Java DS1 Yields, Input Costs and Net Returns

West Java			YIELD	GROSS	INPUTS	LABOR	WATER	NET	% WATER
	Pump	CROP	mt/ha	RETURN	COSTS	COSTS	COSTS	RETURN	COSTS
Dry Season1									
MEAN	SIDAJAYA	RICE	3.60	900000	185500	253000	76103	385,397	0.15
Median			3.86	979762	132153	242369	71512	533,728	0.16
MEAN	SIDAMULYA	RICE	4.20	1050000	257500	464000	55868	272,632	0.07
Median			4.32	1042469	194415	355246	75000	417,808	0.12
MEAN	KIARASARI	RICE	3.90	975000	127750	310000	69016	468,234	0.14
Median			3.86	964476	159889	285253	69444	449,890	0.13
MEAN	CIHAMBULU	RICE	3.93	942545	110000	266182	63273	503,090	0.14
Median			3.64	902508	139934	306469	63433	392,672	0.12

Table A-10 West Java WS Yields, Input Costs and Net Returns

West Java			YIELD	GROSS	INPUTS	LABOR	WATER	NET	% WATER
	Pump	CROP	mt/ha	RETURN	COSTS	COSTS	COSTS	RETURN	COSTS
Wet Season									
MEAN	SIDAJAYA	RICE	4.80	1104000	187500	344000	45514	526,986	0.08
Median			4.73	1090095	173109	312254	41550	563,182	0.08
MEAN	SIDAMULYA	RICE	5.30	1260000	151875	356875	81959	669,291	0.14
Median			5.56	1163540	237780	364044	70000	491,716	0.10
MEAN	KIARASARI	RICE	4.95	1188000	178750	450000	57862	501,388	0.08
Median			4.89	1114234	205216	326235	50000	532,783	0.09
MEAN	CIHAMBULU	RICE	4.36	958806	197761	293134	55619	412,292	0.10
Median			4.54	982454	197037	320819	60000	404,598	0.10

Appendix F

SAMPLE OUTPUT FROM THE IRRIGATION ENERGY MODEL

TW-152 Nganjuk
W-9 Gunung Kidul
TW-097 Madura
TW-174 Nganjuk

********************** Driver Page ******************

A. INPUT System Name: TW152-Nganjuk In 1990 US$

1. Unit Command Area 43.93 <--

2. Crop System

	Crop 1	Crop 2	Crop 3	Crop 4	Rice-I	Rice-II	Crop 7	Crop 8	Crop 9	Crop 10
Crop:	Soya	Chili	Soya-out	Gr.Bean	Rice-in	Rice-out	Maize			
% of Total Area	52	10	52	6	68	68	45			
3. Net Crop Revenue ($ per ha)	197	148	-117	121	388	-242	148			

4. Discount Rate (%) 15 <--

5. Design, Analysis, or Both? A <-- Enter
D for design or feasibility
A to analyze an existing system
B for both design and analysis

6. Energy Type D D for diesel, O for other

7. Equipment Costs

	Input	Local Factor	Suggested
a. Engine/motor ($/KW)	280	1.2	209
b. Pump ($/KW)	197	1.2	29
c. Engine Installation ($/kW)	20	1.2	50
d. Pump Installation ($/kW)	14	1.3	7

Enter 0 in input column to use Suggested column.
To adjust suggested values, enter local factor different from 1.

	Life (hrs)	Annual R&M % Cap Cost
e. Engine	15000	5
f. Pump	12000	5

	Capital & Install Costs	Life (years)	Annual R&M % Cap Cost
g. Well, misc.	7751	25	5
Conveyance system			
h. Source to command area ($/m)	6.75	25	5
i. Within command area ($/ha)	75	25	5

8. Fuel and Lubricant Costs
   a. Cost of diesel ($/L), or 0.17 <--
   b. Other energy source ($/kWh) 0 <--
   c. Cost lubricants (% fuel cost) 16 <--
   Diesel energy content (L/kWh) 0.096

9. Labor Costs
   a. Tubewell Labor (wages in $/hr) 0.07 <--
   b. No hours pa (% oper time) 120 <--

B. DATA FOR ECONOMIC ANALYSIS (not required for design)

1. Nominal Engine Size (BPeng in kW) 17.6 <-- Obser
2. Nominal Pump Size (BPpump in kW) 20 <-- Obser
3. Rate of fuel consumption (l/hr) 4 <--

4. Actual Pump Operation

	Actual Pump Operation in hours and liters (hrs)	(L)
Jan	0	0
Feb	0	0
Mar	0	0
Apr	10	40
May	123	492
Jun	199	796
Jul	315	1260
Aug	208	832
Sep	60	240
Oct	160	640
Nov	0	0
Dec	0	0
	1075	4300

C. DATA FOR PUMP EFFICIENCY CALCULATIONS AND DESIGN

1. Measured Flow Rate rate in lps (for analysis) 15.0 <--
2. Observed RPM (optional-for information) 1800 <--

3. Head Requirements (Required for design and analysis)

   a. Req. Operating Head (Ho in m) 0 <-- For sprinklers, drip, etc
   Enter 0 for Ho if no pipe

   b. For Pipes (Enter 0 for coef. and diam and model uses default)
   - Hazen Williams coef. (C) 0 <-- PVC - 150, new steel - 120
   - Pipe Diameter (D in mm) 0 <-- Enter 0 for Pipe diam

   c. Lift -pump to delivery point (Ld in m) 0 <-- to be calculated based on 1% head loss

4. Lift Requirements

   a. Constant monthly lift values? (Y/N) Y <--

   b. Monthly variations in lift if non-constant
   Enter values for water surface to pump and drawdown.
   The worksheet calculates values for TDH, hours and kW-hrs.

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)
Jan	1	2.3
Feb	1	2.3
Mar	1	2.3
Apr	1	2.3
May	1	2.3
Jun	1	2.3
Jul	1	2.3
Aug	1	2.3
Sep	1	2.3
Oct	1	2.3
Nov	1	2.3
Dec	1	2.3

Constant or Design values for:

c. Lift -water surface to pump (Lw in m) 1 <--

d. Drawdown (Hd in m) 2.3 <--

For design values, use lift values from month of peak water use.
Use max. expected drawdown.

***** Engineering Analysis ***************************************

I. Crop Water Calculations

A. Net Irrigation Requirements in mm

Monthly net irrigation requirement (mm/month) is calculated by worksheet.

	In (mm)									
Month	Soya	RiceOut	SoyaOut		Rice-in		Maize			
Jan					0					
Feb					0					
Mar	0				0					
Apr	13				0					
May	96				0					
Jun	31				0		40			
Jul					0		129			
Aug					0		167			
Sep					0		26			
Oct					89					
Nov					84					
Dec					0					
Total:	140	0	0	0	172	0	362	0	0	0

B. Volumetric Net Irrigation Requirements (m^3) per hectare

Monthly Vha is calculated by worksheet.

	crop 1	crop 2	crop 3	crop 4	crop 5	crop 6	crop 7	crop 8	crop 9	crop 10		
	Soya	RiceOut	SoyaOut		Rice-in		Maize					
Area	15.011	15.011	15.011	0	15.011	0	15.011	0	0	0		
month	Volumetric Requirements --->										total	Area
Jan											0	0
Feb											0	0
Mar											0	0
Apr	1951										1951	15.011
May	14336										14336	15.011
Jun	4653						6004				10658	30.022
Jul							19364				19364	15.011
Aug							25128				25128	15.011
Sep							3843				3843	15.011
Oct					13298						13298	15.011
Nov					12594						12594	15.011
Dec											0	0
Total:	20940	0	0	0	25892	0	54340	0	0	0	101171.7	

BEST AVAILABLE DOCUMENT

C. Monthly Irrigation Requirements Summary

Month	Req. Volume Vha (m^3/ha)	Req. Volume Vtot (m^3)	Min. Interval Imin (days)	Weighted Avg. ETcrop (mm/day)	Actual Water Water Pumped Va (m^3)
Jan	0	0	5.6	3.1	0
Feb	0	0	5.7	3.0	0
Mar	0	0	0.0	0.5	0
Apr	44	1951	12.7	1.4	540
May	325	14336	11.6	1.5	6642
Jun	241	10658	17.3	1.8	10746
Jul	439	19364	12.1	1.5	17010
Aug	569	25128	9.6	1.8	11232
Sep	87	3843	16.3	1.1	3240
Oct	301	13298	5.7	3.0	8640
Nov	285	12594	5.4	3.2	0
Dec	0	0	5.4	3.1	0
Total		101172			58050

Irrigation interval (I in days) is calculated by:
I = D * p * WHC / ET crop / 100

D, p, WHC from Table D.5.

The worksheet finds the minimum interval for each month by examining all crops (see work table at P270)

The weighted crop ET for month is calculated by:

Ir = Sum(ET*PctArea)/100
Ir does not include effective ppt.

D. Annual Irrigation Requirement (Vsum in m^3/ha):	2292	Vsum = Sum of monthly Vha from Table C
E. Peak Irrigation Requirements		
1. Max. irr. req. (Irmax in mm/day)	3.2	From Table G
2. Min. freq. at month of max. Ir (Imax)	5.4	From Table G

II. CALCULATION OF PUMP SIZE FOR UNIT COMMAND AREA

A. Calculation of Design Flow Rate

	Data Input	Worksheet Calculated	
1. Design Interval			
a. Max Ir (Irmax in mm/day)		3.2	From Line J.2
b. Ratio of Peak to Mean ET crop	1.000		R = Adjustment factor for meeting peak times
c. Adjusted Peak req.(Irp in mm/day)		3.2	Irp = Irmax/R (R from FAO 24,p.57)
d. Peak interval (Ip in days)		5.4	Ip = Imax/R
e. Design int. (Id in days)	10.0		Use the peak interval as a guideline.
2. Volume required during design interval			
a. Unit Command Area (A in ha)	44.15		From A.1 on driver page
b. Gross volume required (Vg in m^3)		7506	Vg = A * Irp * Ip * 10
c. Conveyance Eff.in UCA (Ec in %)	60		
d. Application Efficiency (Ea in %)	60		
e. Unit Command Area Eff. (Eca in %)		36	Eca = Ec * Ea
f. Vol. req. at Comm. Area (Vca in m^3)		20849	Vca = Vg / (Eca/100) during design int
3. Flow rate required at command area (lps)			
a. Operating hours per day (Hd)	18		
b. Flow Rate at Command Area (Qcam in m^3/hr)		115.8	Qcam = Vca / (Id * Hd)
c. Flow Rate at Command Area (Qca in lps)		32.2	Qca = Qcam/3.6

Item	Data Input	Worksheet Calculated	Notes
4. Calculation of Conveyance losses (optional)			
a. Length (Lc in m)	615		
b. Conveyance eff. source to UCA (%)	85		Econv
c. Seepage Losses (Ls in lps)		5.7	Ls = Qca/(Econv/100)-Qca
5. Flow Required at Source (Qs in lps)		37.9	Qs = Qca + Ls
6. Project Irrigation Efficiency (Ei in %)		31	Ei = Eca * Qca / Qs

B. Calculation of Total Dynamic Head	Data Input	Worksheet Calculated	Notes
1. Discharge Side of Pump			
a. Req. Operating Head (Ho in m)	0		Enter 0 for no pipe For sprinklers, enter pressure required in m.
b. Conveyance Pipe Friction Losses * Fill in iii. and iv. to have worksheet calculate v. Use the calculated diameter as a suggested value. * Leave iii. or iv. blank and worksheet will calculate head loss as 1/100 of pipe length.			
i. Flow Rate at Source (Qs in lps)		37.9	From Line II.5.
ii. Conveyance Pipe Length (L in m)		0	
iii. Hazen Williams coef. (C)	0		PVC - 150, new steel - 120
iv. Pipe Diameter (D in mm)	0	0	
v. Friction loss (Hl in m)		0.0000	Hl = LK(Qs/C)^1.852/D^4.87 K = 1.22*10^10
c. Lift -pump to delivery point (Ld in m)	0		
2. Inlet Side of Pump			
Design values for:			For design values, use lift values from month of peak water use.
a. Lift -water surface to pump (Lw in m)	1		
b. Drawdown (Hd in m)	2.3		Use max. expected drawdown.
3. Total Dynamic Head (TDH in m)		3.3	TDH = Ho + Hl + Ld + Lw

C. Pump Size	Data Input	Worksheet Calculated	Notes
1. Water Power (WP in kW)		1.2	WP = TDH * Qs /102
2. Pump Efficiency (Ep in %)	4 %		Use pump characteristic curve. Range of eff. 60-80%.
3. Brake Power Required (BP in kW)		29.2	BP = WP / Ep /100
(BP in HP)		39.1	HP = kW/0.746
4. Engine Size (BPeng)		25.0	
5. Engine Efficiency (Ee in %)	54.0 %		

BEST AVAILABLE DOCUMENT

III. CALCULATION OF ANNUAL ENERGY REQUIREMENTS

A. Operating Hours Per Year

		Analysis
1. Annual Volume Required (Vpa in m^3)	58050	Vpa = Vsum * A / (Ei/100)
2. Hours of Operation (Hpa in hrs)	1075	Hpa = Vpa / Qs / 3.6

B. Lift Requirements

1. Constant monthly lift values? (Y/N) Y

2. Constant values

a. Lift -water surface to pump (Lw in m) 1

b. Drawdown (Hd in m) 2.3

3. Monthly variations in lift if non-constant

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)	TDH (m)	BP (kw)	<<---Design--->> Hours of Operation (Hop)	<<-------Analysis------>> Hours of Operation (Hop)	Fuel (l)	Monthly Energy Used (kW-hrs)	Monthly Energy Delivered (kW-hrs)
Jan	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Feb	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Mar	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Apr	1.00	2.30	3.30	29.16	47	10.0	40	418	5
May	1.00	2.30	3.30	29.16	344	123.0	492	5138	60
Jun	1.00	2.30	3.30	29.16	256	199.0	796	8312	97
Jul	1.00	2.30	3.30	29.16	464	315.0	1260	13157	153
Aug	1.00	2.30	3.30	29.16	603	208.0	832	8688	101
Sep	1.00	2.30	3.30	29.16	92	60.0	240	2506	29
Oct	1.00	2.30	3.30	29.16	319	160.0	640	6683	78
Nov	1.00	2.30	3.30	29.16	302	0.0	0	0	0
Dec	1.00	2.30	3.30	29.16	0	0.0	0	0	0
				Total:	2426	1075	4300	44903	522

TDH = Ho+Hl+Lw+Hd

Hop = (Vha*A)/(Ei/100*Qs*3.6)

BP = TDH*Qs/102

Assumptions:
For different lifts pump eff and flow rate remain constant

C. Cropwise Energy Requirements (kWhrs)

Energy input per crop per month is calculated by the worksheet

Month	Soya	RiceOut	SoyaOut		Rice-in		Maize				Total
	---------------- Energy Input to Engine (kWh										
Jan											0
Feb											0
Mar											0
Apr	2527										2527
May	18563										18563
Jun	6026						7775				13801
Jul							25075				25075
Aug							32540				32540
Sep							4976				4976
Oct					17220						17220
Nov					16308						16308
Dec											0
Total:	27116	0	0	0	33528	0	70366	0	0	0	131010

IV. SUMMARY OF ENGINEERING ANALYSIS

	Soya	RiceOut	SoyaOut	Rice-in	Maize
A. Crop System:					
B. Area Irri. (ha)	15	15	15	15	15
C. Vol Req (m^3/yr)	68433	0	0	84613	177581
D. Energy In (kWh/yr)	27116			33528	70366
E. Liters of Fuel	2597			3211	6738

F. Gross Irrigated Area (ha) 75

	Analysis
G. Annual Vol. Pumped (m^3)	58050
H. Annual Energy Input (KW hrs)	44903
I. Annual Operating Hours (Hpa in hrs)	1075
J. Flow Rate (lps)	15
K. Total Dynamic Head (m)	3.3
L. Size of Pump (BP in KW)	20.0
M. Size of Engine (BP in KW)	17.6
N. Overall pumping plant efficiency (%)	1.2%

****************** Economic Analysis *****************************

V. Parameters from Engineering Analysis

	Design	Analysis	
1. Net Irrigated area (NIRRA in ha)	44	44	From engineering analysis
2. Gross Irrigated Area (GIIRA in ha)	75	75	From I
3. Annual Energy Req. of Engine (KW hrs)		44,903	From III. C
4. Annual Operating Hours (Hpa in hrs)		1,075	H6/H7
5. Size of Pump (BP in KW)		17.6	
6. Nominal Engine Size (BPeng in kW)	25.0	17.6	

VI. COSTS

A. Fuel and Other Variable Costs	Data Input	Design	Analysis	
1. Fuel				
a. Engine efficiency (%)	54			Table D.1
b. Energy req. Engine (kWh-pa)			44,903	L/KWH at 100% eff.0.095763
c. Fuel pa (l)		0	4,300	Divide by engine eff.
d. Fuel - liters per ha/pa GIIRA		0	57	GIRRA from IV.
2. System Variable Costs				
a. Cost fuel($/l) or energy ($/kWh)	0.170			
b. Total fuel cost pa		0	731	
c. Cost lubricants (% fuel cost)	16	0	117	
d. Total cost fuel and lubricants		0	848	
3. Tubewell Labor (wages in $/hr)	0.07			
a. No hours pa (% oper time)	120			
b. Total operator labor cost		0	90	
4. Total System Variable Cost pa		0	938	
5. Total System Variable Cost per ha/pa GIRRA		0	21	

B. Equipment and Other Capital Costs (Installed)

1. Equipment Costs	Unit Cost	Design Total Cost	Analyzed Total Cost
a. Engine ($/kW)	280	7,000	4,919
b. Pump ($/kW)	197	0	3,940
c. Engine Installation ($/kW)	20	0	351
d. Pump Installation ($/kW)	14	0	246
e. Well, housing, & misc		9,600	9,600
Conveyance system (Canal or Pipe)			
f. Source to command area ($/m)	7	4,151	4,151
g. Within command area ($/ha NIRR	75	3,311	3,311
h. Total equipment and other capital costs		24,063	26,518
i. Total capital costs per GIRRA		321	353

VII. PROJECT ECONOMICS

A. Capital Cost and Life

	Design: Capital & Install Costs	Design: Life Opr Time (hours)	Design: Life (years)	Design: Annual R&M % Cap	Design: Annual R&M Cost	Analysis: Capital & Install Costs	Analysis: Life Opr Time (hours)	Analysis: Life (years)	Analysis: Annual R&M % Cap	Analysis: Annual R&M Cost
1. Engine/motor	7,000	15000	100.0	8	560	5,270	15000	14.0	8	393
2. Pump	0	12000	100.0	8	0	4,186	12000	11.2	8	315
3. Well & Misc	9,600		25	5	480	9,600		25	5	480
Conveyance system:										
4. Source to UCA	4,151		25	8	332	4,151		25	8	332
5. Within UCA	3,311		25	5	166	3,311		25	5	166
6. Total					1,538					1,686

C. Costs

1. Capital Costs

Year	Well & Misc.	Conveyance: Source to UCA	Conveyance: W/in UCA	Design: Engine/Motor	Design: Pump	Design: Annual R & M	Design: Subtotal Capital Cost	Analysis: Engine/Motor	Analysis: Pump	Analysis: Annual R & M	Analysis: Subtotal Capital Cost
zero	9,600	4,151	3311.25	7,000	0		24,063	5269.875	4185.927		26,518
1	0	0	0	7,000	0	1,538	8,538	0	0	1,686	1,686
2	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
3	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
4	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
5	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
6	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
7	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
8	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
9	0	0	0	0	0	1,538	1,538	0	0	1,686	1,606
10	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
11	0	0	0	0	0	1,538	1,538	0	4,186	1,686	5,872
12	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
13	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
14	0	0	0	0	0	1,538	1,538	5,270	0	1,686	6,956
15	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
16	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
17	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
18	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
19	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
20	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
21	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
22	0	0	0	0	0	1,538	1,538	0	4,186	1,686	5,872
23	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
24	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
25	9,600	4,151	3,311	0	0	1,538	18,600	0	0	1,686	18,749

2. Annual Variable Costs

<Design>	<Analysis>
Fuel, Lub, & Labor	
0	938

D. Net Annual Crop Revenues

Crop:	Soya	RiceOut	SoyaOut	Rice-in	Maize
Ha	15	15	15	15	15
Rev/ha	175	(365)	(128)	452	116
Net Revenues	2,627	(5,479)	(1,921)	6,785	1,741

Total Net Revenue 3,753

E. Annual Cash Flow

	<<<------Design------->>>			<<<------Analysis------->>>		
Year	Total Annual Cost	Total Net Rev	Net Cash Flow	Total Annual Cost	Total Net Rev	Net Cash Flow
0	24,063	0	(24,063)	26,518	0	(26,518)
1	8,538	3,753	(4,785)	2,625	3,753	1,128
2	1,538	3,753	2,215	2,625	3,753	1,128
3	1,538	3,753	2,215	2,625	3,753	1,128
4	1,538	3,753	2,215	2,625	3,753	1,128
5	1,538	3,753	2,215	2,625	3,753	1,128
6	1,538	3,753	2,215	2,625	3,753	1,128
7	1,538	3,753	2,215	2,625	3,753	1,128
8	1,538	3,753	2,215	2,625	3,753	1,128
9	1,538	3,753	2,215	2,625	3,753	1,128
10	1,538	3,753	2,215	2,625	3,753	1,128
11	1,538	3,753	2,215	6,811	3,753	(3,058)
12	1,538	3,753	2,215	2,625	3,753	1,128
13	1,538	3,753	2,215	2,625	3,753	1,128
14	1,538	3,753	2,215	7,894	3,753	(4,142)
15	1,538	3,753	2,215	2,625	3,753	1,128
16	1,538	3,753	2,215	2,625	3,753	1,128
17	1,538	3,753	2,215	2,625	3,753	1,128
18	1,538	3,753	2,215	2,625	3,753	1,128
19	1,538	3,753	2,215	2,625	3,753	1,128
20	1,538	3,753	2,215	2,625	3,753	1,128
21	1,538	3,753	2,215	2,625	3,753	1,128
22	1,538	3,753	2,215	6,811	3,753	(3,058)
23	1,538	3,753	2,215	2,625	3,753	1,128
24	1,538	3,753	2,215	2,625	3,753	1,128
25	18,600	3,753	(14,847)	19,687	3,753	(15,934)

VIII. ECONOMICS SUMMARY

Discount Rate = 15 %
Annual Net Revenues = 3,753

	<<---Design--->>> Total Costs	per GIRRA	<<---Analysis--->>> Total Costs	per GIRRA
Present Value of Total Costs			45,840	611
Present Value of Total Revenues			24,258	323
Annual Variable Costs			938	13
Annual R&M			1,686	22
Annual Cost of Water per m^3	ERR		0.045	(Variable+R&M) / Annual Volume Pumped
Benefit/Cost Ratio =			0.53	
Internal Rate of Return =			***	

B. Output Summary

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6	Crop 7	Crop 8	Crop 9	Crop 10
1. Crop System	Soya	RiceOut	SoyaOut		Rice-in		Maize			
2. Area Irri. (ha)	15	15	15		15		15			
3. Vol Req(m^3/yr)										
4. Energy Req (KWh/yr)	27116				33528		70366			
5. Energy Cost $	441	0	0		546		1146			
6. Crop Rev $	2626.925	-5479.01	-1921.40		6784.972		1741.276			
7. Net Irr. Rev $	2185	-5479	-1921		6239		596			
8. Net Rev ($/ha)	50	-124	-44		141		13			
9. Gross Irrigated Area (ha)		75			Analysis					
10. Annual Vol. Pumped (m^3)					58050					
11. Annual Energy Req. of Engine (KWh)					44903					
12. Annual Operating Hours					1075					
13. Size of Pump (BP in KW)					20.0					
14. Size of Engine (BP in KW)				25.0	17.6					
13. Pump Set Efficiency (%)					1.2%					
14. Energy Costs per ha/pa GIIRA					10					
15. Total System Variable Cost per ha/pa GIIRA					21					
16. Present Value Total Costs per GIIRA					611					
17. Benefit/cost ratio					0.53					
18. Internal Rate of Return (IRR)					***					

************************ Driver Page ******************

A. INPUT System Name: Gunung Kidul W-19 Ngiapak2

1. Unit Command Area 44 <--

2. Crop System

	Crop 1	Crop 2	Crop 3	Crop 4	Rice-I	Rice-II	Crop 7	Crop 8	Crop 9	Crop 10
Crop:	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut
% of Total Area	16	16	[illegible]	6.8	50	40	24	14	23	50
3. Net Crop Revenue ($ per ha)	145	-89	117	68	199	260	155	300	286	-161

4. Discount Rate (%) 15 <--

5. Design, Analysis, or Both? A <-- Enter
D for design or feasibility
A to analyze an existing system
B for both design and analysis

6. Energy Type D D for diesel, O for other

7. Equipment Costs

	Input	Local Factor	Suggested
a. Engine/motor ($/KW)	268.4437	1.2	222
b. Pump ($/KW)	185.3040	1	31
c. Engine installation ($/kW)	13	1	44
d. Pump Installation ($/kW)	11.5	1.3	8

Enter 0 in input column to use Suggested column.
To adjust suggested values, enter local factor different from 1.

	Life (hrs)	Annual R&M % Cap Cost
e. Engine	15000	5
f. Pump	12500	5

	Capital & Install Costs	Life (years)	Annual R&M % Cap Cost
g. Well, misc.	20212.71	25	5
Conveyance system			
h. Source to command area ($/m)	6.89	25	5
i. Within command area ($/ha)	55	25	5

8. Fuel and Lubricant Costs
   - a. Cost of diesel ($/L), or 0.14 <--
   - b. Other energy source ($/kWh) 0 <--
   - c. Cost lubricants (% fuel cost) 15 <--
   - Diesel energy content (L/kWh) 0.096

9. Labor Costs
   - a. Tubewell Labor (wages in $/hr) 0.07 <--
   - b. No hours pa (% oper time) 120 <--

B. DATA FOR ECONOMIC ANALYSIS (not required for design)

1. Nominal Engine Size (BPeng in kW) 28.0 <-- Obser
2. Nominal Pump Size (BPpump in kW) 20 <-- Obser
3. Rate of fuel consumption (l/hr) 4 <--

4. Actual Pump Operation

	Actual Pump Operation in hours and liters (hrs)	(L)
Jan	2	8
Feb	3	12
Mar	29	116
Apr	6	24
May	384	1536
Jun	452	1808
Jul	468	1872
Aug	488	1952
Sep	361	1444
Oct	403	1612
Nov	319	1276
Dec	100	400
	3015	12060

C. DATA FOR PUMP EFFICIENCY CALCULATIONS AND DESIGN

1. Measured Flow Rate rate in lps (for analysis) 25.7 <--
2. Observed RPM (optional-for information) 1800 <--

3. Head Requirements (Required for design and analysis)

   a. Req. Operating Head (Ho in m) 0 <-- For sprinklers, drip, etc
   Enter 0 for Ho if no pipe

   b. For Pipes (Enter 0 for coef. and diam and model uses default)
   - Hazen Williams coef. (C) 140 <-- PVC - 150, new steel - 120
   - Pipe Diameter (D in mm) 153 <-- Enter 0 for Pipe diam to be calculated based on 1% head loss

   c. Lift -pump to delivery point (Ld in m) 0 <--

4. Lift Requirements

   a. Constant monthly lift values? (Y/N) y <--

   b. Monthly variations in lift if non-constant
   Enter values for water surface to pump and drawdown.
   The worksheet calculates values for TDH, hours and kW-hrs.

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)
Jan	5	5.5
Feb	5	5.5
Mar	5	5.5
Apr	5	5.5
May	5	5.5
Jun	5	5.5
Jul	5	5.5
Aug	5	5.5
Sep	5	5.5
Oct	5	5.5
Nov	5	5.5
Dec	5	5.5

Constant or Design values for:

c. Lift -water surface to pump (Lw in m) 5 <--

d. Drawdown (Hd in m) 5.5 <--

For design values, use lift values from month of peak water use.
Use max. expected drawdown.

***** Engineering Analysis **

I. Crop Water Calculations

A. Net Irrigation Requirements in mm
Monthly net irrigation requirement (mm/month) is calculated by worksheet.

Month	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut
	In (mm)									
Jan					0	0				
Feb					0	0				
Mar					0	0				
Apr	0				0	37	37			
May	83				0	258	127			
Jun	126				0	600	156			
Jul	14		39	48	0	620	0	51		
Aug			105	112	0	620		102		
Sep			112	127	0	0		86		
Oct					0	0			77	
Nov					0	0			85	
Dec					48	75				
Total:	223	0	256	287	48	2209	319	239	162	0

B. Volumetric Net Irrigation Requirements (m^3) per hectare
Monthly Vha is calculated by worksheet.

	crop 1	crop 2	crop 3	crop 4	crop 5	crop 6	crop 7	crop 8	crop 9	crop 10		
	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut		
Area	7.04	7.04	19.8	2.992	22	17.6	10.56	6.16	10.12	22		
month	Volumetric Requirements --->										total	Area
Jan											0	0
Feb											0	0
Mar											0	0
Apr						6424	3872				10296	28.16
May	5850					45323	13358				64531	35.2
Jun	8870					105600	16474				130944	35.2
Jul	986		7742	1445		109120		3142			122434	53.592
Aug			20869	3339		109120		6283			139611	46.552
Sep			22136	3812				5298			31246	28.952
Oct									7813		7813	10.12
Nov									8602		8602	10.12
Dec					10528	13143					23671	39.6
Total:	15706	0	50747	8596	10528	388730	33704	14722	16415	0	539148.8	

C. Monthly Irrigation Requirements Summary

Month	Req. Volume Vha (m^3/ha)	Req. Volume Vtot (m^3)	Min. Interval Imin (days)	Weighted Avg. ETcrop (mm/day)	Actual Water Water Pumped Va (m^3)
Jan	0	0	5.7	4.4	185
Feb	0	0	6.0	4.2	277
Mar	0	0	8.3	3.0	2681
Apr	234	10296	6.3	6.4	555
May	1467	64531	5.5	5.6	35500
Jun	2976	130944	5.6	5.5	41786
Jul	2783	122434	6.0	5.4	43266
Aug	3173	139611	8.8	2.3	45115
Sep	710	31246	7.0	2.9	33374
Oct	178	7813	12.5	0.7	37257
Nov	196	8602	6.7	1.4	29491
Dec	538	23671	5.7	4.4	9245
Total		539149			278731

Irrigation interval (I in days) is calculated by:
I = D * p * WHC / ET crop / 100

D, p, WHC from Table D.5.

The worksheet finds the minimum interval for each month by examining all crops (see work table at P270)

The weighted crop ET for month is calculated by:

Ir = Sum(ET*PctArea)/100
Ir does not include effective ppt.

D. Annual Irrigation Requirement (Vsum in m^3/ha): 12253 — Vsum = Sum of monthly Vha from Table C

E. Peak Irrigation Requirements

1. Max. irr. req. (Irmax in mm/day)	6.4	From Table G
2. Min. freq. at month of max. Ir (Imax)	6.3	From Table G

II. CALCULATION OF PUMP SIZE FOR UNIT COMMAND AREA

A. Calculation of Design Flow Rate

	Data Input	Worksheet Calculated	
1. Design Interval			
a. Max Ir (Irmax in mm/day)		6.4	From Line J.2
b. Ratio of Peak to Mean ET crop	1.000		R = Adjustment factor for meeting peak times
c. Adjusted Peak req.(Irp in mm/day)		6.4	Irp = Irmax/R (R from FAO 24,p.57)
d. Peak interval (Ip in days)		6.3	Ip = Imax/R
e. Design int. (Id in days)	10.0		Use the peak interval as a guideline.
2. Volume required during design interval			
a. Unit Command Area (A in ha)	44		From A.1 on driver page
b. Gross volume required (Vg in m^3)		17672	Vg = A * Irp * Ip * 10
c. Conveyance Eff.in UCA (Ec in %)	70		
d. Application Efficiency (Ea in %)	65		
e. Unit Command Area Eff. (Eca in %)		46	Eca = Ec * Ea
f. Vol. req. at Comm. Area (Vca in m^3)		38838	Vca = Vg / (Eca/100) during design int
3. Flow rate required at command area (lps)			
a. Operating hours per day (Hd)	20		
b. Flow Rate at Command Area (Qcam in m^3/hr)		194.2	Qcam = Vca / (Id * Hd)
c. Flow Rate at Command Area (Qca in lps)		53.9	Qca = Qcam/3.6

	Data Input	Worksheet Calculated	
4. Calculation of Conveyance losses (optional)			
a. Length (Lc in m)	1334		
b. Conveyance eff. source to UCA (%)	80		Econv
c. Seepage Losses (Ls in lps)		13.5	Ls = Qca/(Econv/100)-Qca
5. Flow Required at Source (Qs in lps)		67.4	Qs = Qca + Ls
6. Project Irrigation Efficiency (Ei in %)		36	Ei = Eca * Qca / Qs

B. Calculation of Total Dynamic Head	Data Input	Worksheet Calculated	
1. Discharge Side of Pump			
a. Req. Operating Head (Ho in m)	0		Enter 0 for no pipe For sprinklers, enter pressure required in m.
b. Conveyance Pipe Friction Losses * Fill in iii. and iv. to have worksheet calculate v. Use the calculated diameter as a suggested value. * Leave iii. or iv. blank and worksheet will calculate head loss as 1/100 of pipe length.			
i. Flow Rate at Source (Qs in lps)		67.4	From Line II.5.
ii. Conveyance Pipe Length (L in m)		0	
iii. Hazen Williams coef. (C)	140		PVC - 150, new steel - 120
iv. Pipe Diameter (D in mm)	153	230	
v. Friction loss (Hl in m)		0.0000	Hl = LK(Qs/C)^1.852/D^4.87 K = 1.22*10^10
c. Lift -pump to delivery point (Ld in m)	0		
2. Inlet Side of Pump			
Design values for:			For design values, use lift values from month of peak water use.
a. Lift -water surface to pump (Lw in m)	5		
b. Drawdown (Hd in m)	5.5		Use max. expected drawdown.
3. Total Dynamic Head (TDH in m)		10.5	TDH = Ho + Hl + Ld + Lw

C. Pump Size			
1. Water Power (WP in kW)		6.9	WP = TDH * Qs /102
2. Pump Efficiency (Ep in %)	23 %		Use pump characteristic curve. Range of eff. 60-80%.
3. Brake Power Required (BP in kW)		30.2	BP = WP / Ep /100
(BP in HP)		40.5	HP = kW/0.746
4. Engine Size (BPeng)		42.3	
5. Engine Efficiency (Ee in %)	64.0 %		

III. CALCULATION OF ANNUAL ENERGY REQUIREMENTS

A. Operating Hours Per Year

1. Annual Volume Required (Vpa in m^3)
2. Hours of Operation (Hpa in hrs)

Analysis
278730.7 Vpa = Vsum * A / (Ei/100)
3015 Hpa = Vpa / Qs / 3.6

B. Lift Requirements

1. Constant monthly lift values? (Y/N) y

2. Constant values
a. Lift -water surface to pump (Lw in m) 5
b. Drawdown (Hd in m) 5.5

3. Monthly variations in lift if non-constant

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)	TDH (m)	BP (kw)	<<---Design--->> Hours of Operation (Hop)	<<-------Analysis------>> Hours of Operation (Hop)	Fuel (l)	Monthly Energy Used (kW-hrs)	Monthly Energy Delivered (kW-hrs)
Jan	5.00	5.50	10.50	30.18	0	2.0	8	84	5
Feb	5.00	5.50	10.50	30.18	0	3.0	12	125	8
Mar	5.00	5.50	10.50	30.18	0	29.0	116	1211	77
Apr	5.00	5.50	10.50	30.18	117	6.0	24	251	16
May	5.00	5.50	10.50	30.18	730	384.0	1536	16040	1015
Jun	5.00	5.50	10.50	30.18	1482	452.0	1808	18880	1195
Jul	5.00	5.50	10.50	30.18	1386	468.0	1872	19548	1237
Aug	5.00	5.50	10.50	30.18	1580	488.0	1952	20384	1290
Sep	5.00	5.50	10.50	30.18	354	361.0	1444	15079	954
Oct	5.00	5.50	10.50	30.18	88	403.0	1612	16833	1065
Nov	5.00	5.50	10.50	30.18	97	319.0	1276	13325	843
Dec	5.00	5.50	10.50	30.18	268	100.0	400	4177	264
				Total:	6102	3015	12060	125936	7970

TDH = Ho+Hl+Lw+Hd
Hop = (Vha*A)/(Ei/100*Qs*3.6)

BP = TDH*Qs/102

Assumptions:
For different lifts pump eff and flow rate remain constant

C. Cropwise Energy Requirements (kWhrs)

Energy input per crop per month is calculated by the worksheet

Month	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut	Total
	----------------- Energy Input to Engine (kWh										
Jan											0
Feb											0
Mar											0
Apr						3428	2066				5495
May	3122					24188	7129				34439
Jun	4734					56356	8792				69882
Jul	526		4132	771		58235		1677			65340
Aug			11137	1782		58235		3353			74507
Sep			11814	2034				2827			16675
Oct									4169		4169
Nov									4591		4591
Dec					5619	7014					12633
Total:	8382	0	27083	4587	5619	207456	17987	7857	8760	0	287731

IV. SUMMARY OF ENGINEERING ANALYSIS

A. Crop System:	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut
B. Area Irri. (ha)	7	7	20	3	22	18	11	6	10	22
C. Vol Req (m^3/yr)	43149	0	139416	23615	28923	1067940	92593	40446	45095	0
D. Energy In (kWh/yr)	8382		27083	4587	5619	207456	17987	7857	8760	
E. Liters of Fuel	803		2594	439	538	19867	1722	752	839	

F. Gross Irrigated Area (ha) 125

	Analysis
G. Annual Vol. Pumped (m^3)	278731
H. Annual Energy Input (KW hrs)	125936
I. Annual Operating Hours (Hpa in hrs)	3015
J. Flow Rate (lps)	25.68
K. Total Dynamic Head (m)	10.5
L. Size of Pump (BP in KW)	20.0
M. Size of Engine (BP in KW)	28.0
N. Overall pumping plant efficiency (%)	6.3%

****************** Economic Analysis ******************************

V. Parameters from Engineering Analysis

	Design	Analysis	
1. Net Irrigated area (NIRRA in ha)	44	44	From engineering analysis
2. Gross Irrigated Area (GIIRA in ha)	125	125	From I
3. Annual Energy Req. of Engine (KW hrs)		125,936	From III. C
4. Annual Operating Hours (Hpa in hrs)		3,015	H6/H7
5. Size of Pump (BP in KW)		28.0	
6. Nominal Engine Size (BPeng in kW)	42.3	28.0	

VI. COSTS

A. Fuel and Other Variable Costs

	Data Input	Design	Analysis	
1. Fuel				
a. Engine efficiency (%)	64			Table D.1
b. Energy req. Engine (kWh-pa)			125,936	L/KWH at 100% eff.0.095763
c. Fuel pa (l)		0	12,060	Divide by engine eff.
d. Fuel - liters per ha/pa GIIRA		0	96	GIRRA from IV.
2. System Variable Costs				
a. Cost fuel($/l) or energy ($/kWh)	0.140			
b. Total fuel cost pa		0	1,688	
c. Cost lubricants (% fuel cost)	15	0	253	
d. Total cost fuel and lubricants		0	1,942	
3. Tubewell Labor (wages in $/hr)	0.07			
a. No hours pa (% oper time)	120			
b. Total operator labor cost		0	235	
4. Total System Variable Cost pa		0	2,177	
5. Total System Variable Cost per ha/pa GIRRA		0	49	

B. Equipment and Other Capital Costs (Installed)

	Unit Cost	Design Total Cost	Analyzed Total Cost
1. Equipment Costs			
a. Engine ($/kW)	268	11,342	7,525
b. Pump ($/kW)	185	0	3,706
c. Engine Installation ($/kW)	13	0	364
d. Pump Installation ($/kW)	12	0	322
e. Well, housing, & misc		20,213	20,213
Conveyance system (Canal or Pipe)			
f. Source to command area ($/m)	7	9,191	9,191
g. Within command area ($/ha NIRR	55	2,420	2,420
h. Total equipment and other capital costs		43,166	43,742
i. Total capital costs per GIRRA		344	349

VII. PROJECT ECONOMICS

A. Capital Cost and Life	Design: Capital & Install Costs	Design: Life Opr Time (hours)	Design: Life (years)	Design: Annual R&M % Cap	Design: Annual R&M Cost	Analysis: Capital & Install Costs	Analysis: Life Opr Time (hours)	Analysis: Life (years)	Analysis: Annual R&M % Cap	Analysis: Annual R&M Cost
1. Engine/motor	11,342	15000	100.0	5	567	7,889	15000	5.0	5	376
2. Pump	0	12500	100.0	5	0	4,028	12500	4.1	5	185
3. Well & Misc	20,213		25	5	1,011	20,213		25	5	1,011
Conveyance system:										
4. Source to UCA	9,191		25	5	460	9,191		25	5	460
5. Within UCA	2,420		25	5	121	2,420		25	5	121
6. Total					2,158					2,153

C. Costs

1. Capital Costs

Year	Well & Misc.	Conveyance: Source to UCA	Conveyance: W/in UCA	Design: Engine/ Motor	Design: Pump	Design: Annual R & M	Design: Subtotal Capital Cost	Analysis: Engine/ Motor	Analysis: Pump	Analysis: Annual R & M	Analysis: Subtotal Capital Cost
zero	20,213	9,191	2420	11,342	0		43,166	7889.219	4028.439		43,742
1	0	0	0	11,342	0	2,158	13,500	0	0	2,153	2,153
2	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
3	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
4	0	0	0	0	0	2,158	2,158	0	4,028	2,153	6,181
5	0	0	0	0	0	2,158	2,158	7,889	0	2,153	10,042
6	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
7	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
8	0	0	0	0	0	2,158	2,158	0	4,028	2,153	6,181
9	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
10	0	0	0	0	0	2,158	2,158	7,889	0	2,153	10,042
11	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
12	0	0	0	0	0	2,158	2,158	0	4,028	2,153	6,181
13	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
14	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
15	0	0	0	0	0	2,158	2,158	7,889	0	2,153	10,042
16	0	0	0	0	0	2,158	2,158	0	4,028	2,153	6,181
17	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
18	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
19	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
20	0	0	0	0	0	2,158	2,158	7,889	4,028	2,153	14,070
21	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
22	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
23	0	0	0	0	0	2,158	2,158	0	0	2,153	2,153
24	0	0	0	0	0	2,158	2,158	0	4,028	2,153	6,181
25	20,213	9,191	2,420	0	0	2,158	33,982	7,889	0	2,153	41,866

2. Annual Variable Costs

<Design>	<Analysis>
Fuel, Lub, & Labor	
0	2,177

D. Net Annual Crop Revenues

Crop:	Soya	SoyaCut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut
Ha	7	7	20	3	22	18	11	6	10	22
Rev/ha	145	(89)	117	68	199	260	155	300	286	(161)
Net Revenues	1,021	(627)	2,317	203	4,378	4,576	1,637	1,848	2,894	(3,542)

Total Net Revenue 14,705

E. Annual Cash Flow

	<<<------Design------->>>			<<<------Analysis------->>>		
Year	Total Annual Cost	Total Net Rev	Net Cash Flow	Total Annual Cost	Total Net Rev	Net Cash Flow
0	43,166	0	(43,166)	43,742	0	(43,742)
1	13,500	14,705	1,205	4,330	14,705	10,376
2	2,158	14,705	12,547	4,330	14,705	10,376
3	2,158	14,705	12,547	4,330	14,705	10,376
4	2,158	14,705	12,547	8,358	14,705	6,347
5	2,158	14,705	12,547	12,219	14,705	2,487
6	2,158	14,705	12,547	4,330	14,705	10,376
7	2,158	14,705	12,547	4,330	14,705	10,376
8	2,158	14,705	12,547	8,358	14,705	6,347
9	2,158	14,705	12,547	4,330	14,705	10,376
10	2,158	14,705	12,547	12,219	14,705	2,487
11	2,158	14,705	12,547	4,330	14,705	10,376
12	2,158	14,705	12,547	8,358	14,705	6,347
13	2,158	14,705	12,547	4,330	14,705	10,376
14	2,158	14,705	12,547	4,330	14,705	10,376
15	2,158	14,705	12,547	12,219	14,705	2,487
16	2,158	14,705	12,547	8,358	14,705	6,347
17	2,158	14,705	12,547	4,330	14,705	10,376
18	2,158	14,705	12,547	4,330	14,705	10,376
19	2,158	14,705	12,547	4,330	14,705	10,376
20	2,158	14,705	12,547	16,247	14,705	(1,542)
21	2,158	14,705	12,547	4,330	14,705	10,376
22	2,158	14,705	12,547	4,330	14,705	10,376
23	2,158	14,705	12,547	4,330	14,705	10,376
24	2,158	14,705	12,547	8,358	14,705	6,347
25	33,982	14,705	(19,277)	44,043	14,705	(29,337)

8. Output Summary

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6	Crop 7	Crop 8	Crop 9	Crop 10
1. Crop System	Soya	SoyaOut	Soya-2	Maize	Rice-1	Rice2	Peanuts	Peanuts2	Maize2	RiceOut
2. Area Irri. (ha)	7	7	20	3	22	18	11	6	10	22
3. Vol Req(m^3/yr)										
4. Energy Req (KWh/yr)	8382		27083	4587	5619	207456	17987	7857	8760	
5. Energy Cost $	112	0	363	62	75	2781	241	105	117	0
6. Crop Rev $	1020.8	-626.56	2316.6	203.456	4378	4576	1636.8	1848	2894.32	-3542
7. Net Irr. Rev $	908	-627	1954	142	4303	1795	1396	1743	2777	-3542
8. Net Rev ($/ha)	21	-14	44	3	98	41	32	40	63	-81
9. Gross Irrigated Area (ha)		125			Analysis					
10. Annual Vol. Pumped (m^3)					278731					
11. Annual Energy Req. of Engine (KWh)					125936					
12. Annual Operating Hours					3015					
13. Size of Pump (BP in KW)					20.0					
14. Size of Engine (BP in KW)				42.3	28.0					
13. Pump Set Efficiency (%)					6.3%					
14. Energy Costs per ha/pa GIIRA					13					
15. Total System Variable Cost per ha/pa GIIRA					49					
16. Present Value Total Costs per GIIRA					682					
17. Benefit/cost ratio					1.11					
18. Internal Rate of Return (IRR)					19%					

VIII. ECONOMICS SUMMARY

Discount Rate = 15 %
Annual Net Revenues = 14,705

	<<---Design--->>>		<<---Analysis--->>>	
	Total Costs	per GIRRA	Total Costs	per GIRRA
Present Value of Total Costs			85,450	682
Present Value of Total Revenues			95,058	759
Annual Variable Costs			2,177	17
Annual R&M			2,153	17
Annual Cost of Water per m^3	ERR		0.016 (Variable+R&M) / Annual Volume Pumped	
Benefit/Cost Ratio =			1.11	
Internal Rate of Return =			19%	

********************** Driver Page ******************

A. INPUT System Name: Madura TW 097 Ponteh

1. Unit Command Area 39.7 <--

2. Crop System

Crop:	Crop 1	Crop 2	Crop 3	Crop 4	Rice-I	Rice-II	Crop 7	Crop 8	Crop 9	Crop 10
		Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut			
% of Total Area		100	100	100	100	100	10			
3. Net Crop Revenue ($ per ha)		865	-813	18	412	-58	-55			

4. Discount Rate (%) 15 <--

5. Design, Analysis, or Both? A <-- Enter
D for design or feasibility
A to analyze an existing system
B for both design and analysis

6. Energy Type d D for diesel, O for other

7. Equipment Costs

	Input	Local Factor	Suggested
a. Engine/motor ($/KW)	197	1	122
b. Pump ($/KW)	165	1	24
c. Engine Installation ($/kW)	22	1	24
d. Pump Installation ($/kW)	19	1	5

Enter 0 in input column to use Suggested column.
To adjust suggested values, enter local factor different from 1.

	Life (hrs)	Annual R&M % Cap Cost
e. Engine	12000	5
f. Pump	15000	5

	Capital & Install Costs	Life (years)	Annual R&M % Cap Cost
g. Well, misc. Conveyance system	15265	25	5
h. Source to command area ($/m)	9.75	25	5
i. Within command area ($/ha)	89	25	5

8. Fuel and Lubricant Costs
a. Cost of diesel ($/L), or 0.17 <--
b. Other energy source ($/kWh) 0 <--
c. Cost lubricants (% fuel cost) 16 <--
Diesel energy content (L/kWh) 0.096

9. Labor Costs
a. Tubewell Labor (wages in $/hr) 0.09 <--
b. No hours pa (% oper time) 120 <--

B. DATA FOR ECONOMIC ANALYSIS (not required for design)

1. Nominal Engine Size (BPeng in kW) 36.0 <-- Obser
2. Nominal Pump Size (BPpump in kW) 30 <-- Obser
3. Rate of fuel consumption (l/hr) 4 <--

4. Actual Pump Operation

	Actual Pump Operation in hours and liters (hrs)	(L)
Jan	160	640
Feb	28	112
Mar	172	688
Apr	14	56
May	103	412
Jun	347	1388
Jul	329	1316
Aug	232	928
Sep	14	56
Oct	377	1508
Nov	331	1324
Dec	53	212
	2160	8640

C. DATA FOR PUMP EFFICIENCY CALCULATIONS AND DESIGN

1. Measured Flow Rate rate in lps (for analysis) 55.0 <--
2. Observed RPM (optional-for information) 1200 <--

3. Head Requirements (Required for design and analysis)

a. Req. Operating Head (Ho in m) 0 <-- For sprinklers, drip, etc
Enter 0 for Ho if no pipe

b. For Pipes (Enter 0 for coef. and diam and model uses default)
- Hazen Williams coef. (C) 140 <-- PVC - 150, new steel - 120
- Pipe Diameter (D in mm) 250 <-- Enter 0 for Pipe diam
c. Lift -pump to delivery point (Ld in m) 0 <-- to be calculated based on 1% head loss

4. Lift Requirements
a. Constant monthly lift values? (Y/N) Y <--

b. Monthly variations in lift if non-constant
Enter values for water surface to pump and drawdown.
The worksheet calculates values for TDH, hours and kW-hrs.

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)
Jan	9.3	10.64
Feb	9.3	10.64
Mar	9.3	10.64
Apr	9.3	10.64
May	9.3	10.64
Jun	9.3	10.64
Jul	9.3	10.64
Aug	9.3	10.64
Sep	9.3	10.64
Oct	9.3	10.64
Nov	9.3	10.64
Dec	9.3	10.64

Constant or Design values for:
c. Lift -water surface to pump (Lw in m) 9.3 <--
d. Drawdown (Hd in m) 10.64 <--

For design values, use
lift values from month of peak
water use.
Use max. expected drawdown.

***** Engineering Analysis ***

I. Crop Water Calculations

A. Net Irrigation Requirements in mm
Monthly net irrigation requirement (mm/month) is calculated by worksheet.

Month		Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut			
		In (mm)								
Jan					0	0				
Feb					0	0				
Mar		0			0	0				
Apr		68			0	0				
May		84			0	0				
Jun		21			0	0				
Jul				95	0	0				
Aug				133	0	0				
Sep				94	0	0				
Oct					74	0				
Nov					151	0				
Dec					0	0				
Total:	0	173	0	322	226	0	0	0	0	0

B. Volumetric Net Irrigation Requirements (m^3) per hectare
Monthly Vha is calculated by worksheet.

	crop 1	crop 2 Tobacco	crop 3 TobacOut	crop 4 Maize	crop 5 Padi In	crop 6 Padi Out	crop 7 MaizeOut	crop 8	crop 9	crop 10		
Area	0	39.7	39.7	39.7	39.7	39.7	3.97	0	0	0		
month	Volumetric Requirements --->										total	Area
Jan											0	0
Feb											0	0
Mar											0	0
Apr		26996									26996	39.7
May		33348									33348	39.7
Jun		8139									8139	39.7
Jul				37874							37874	39.7
Aug				52920							52920	39.7
Sep				37120							37120	39.7
Oct					29570						29570	39.7
Nov					60041						60041	39.7
Dec											0	0
Total:	0	68483	0	127913	89611	0	0	0	0	0	286006.9	

C. Monthly Irrigation Requirements Summary

Month	Req. Volume Vha (m^3/ha)	Req. Volume Vtot (m^3)	Min. Interval Imin (days)	Weighted Avg. ETcrop (mm/day)	Actual Water Water Pumped Va (m^3)
Jan	0	0	5.4	9.3	31680
Feb	0	0	6.7	7.5	5544
Mar	0	0	5.6	4.5	34056
Apr	680	26996	4.5	5.5	2772
May	840	33348	5.0	5.0	20394
Jun	205	8139	8.6	2.9	68706
Jul	954	37874	14.7	3.4	65142
Aug	1333	52920	11.6	4.3	45936
Sep	935	37120	9.1	5.5	2772
Oct	745	29570	6.0	8.3	74646
Nov	1512	60041	5.7	8.8	65538
Dec	0	0	5.1	9.8	10494
Total		286007			427680

Irrigation interval (I in days) is calculated by:
I = D * p * WHC / ET crop / 100

D, p, WHC from Table D.5.

The worksheet finds the minimum interval for each month by examining all crops (see work table at P270)

The weighted crop ET for month is calculated by:

Ir = Sum(ET*PctArea)/100
Ir does not include effective ppt.

D. Annual Irrigation Requirement (Vsum in m^3/ha): 7204 — Vsum = Sum of monthly Vha from Table C

E. Peak Irrigation Requirements

1. Max. irr. req. (Irmax in mm/day) 9.8 — From Table G
2. Min. freq. at month of max. Ir (Imax) 5.1 — From Table G

II. CALCULATION OF PUMP SIZE FOR UNIT COMMAND AREA

A. Calculation of Design Flow Rate

	Data Input	Worksheet Calculated	
1. Design Interval			
a. Max Ir (Irmax in mm/day)		9.8	From Line J.2
b. Ratio of Peak to Mean ET crop	1.000		R = Adjustment factor for meeting peak times
c. Adjusted Peak req.(Irp in mm/day)		9.8	Irp = Irmax/R (R from FAO 24,p.57)
d. Peak interval (Ip in days)		5.1	Ip = Imax/R
e. Design int. (Id in days)	10.0		Use the peak interval as a guideline.
2. Volume required during design interval			
a. Unit Command Area (A in ha)	39.7		From A.1 on driver page
b. Gross volume required (Vg in m^3)		19850	Vg = A * Irp * Ip * 10
c. Conveyance Eff.in UCA (Ec in %)	70		
d. Application Efficiency (Ea in %)	70		
e. Unit Command Area Eff. (Eca in %)		49	Eca = Ec * Ea
f. Vol. req. at Comm. Area (Vca in m^3)		40510	Vca = Vg / (Eca/100) during design int
3. Flow rate required at command area (lps)			
a. Operating hours per day (Hd)	20		
b. Flow Rate at Command Area (Qcam in m^3/hr)		202.6	Qcam = Vca / (Id * Hd)
c. Flow Rate at Command Area (Qca in lps)		56.3	Qca = Qcam/3.6

	Data Input	Worksheet Calculated	
4. Calculation of Conveyance losses (optional)			
a. Length (Lc in m)	1307		
b. Conveyance eff. source to UCA (%)	90		Econv
c. Seepage Losses (Ls in lps)		6.3	Ls = Qca/(Econv/100)-Qca
5. Flow Required at Source (Qs in lps)		62.5	Qs = Qca + Ls
6. Project Irrigation Efficiency (Ei in %)		44	Ei = Eca * Qca / Qs

B. Calculation of Total Dynamic Head

	Data Input	Worksheet Calculated	
1. Discharge Side of Pump			
a. Req. Operating Head (Ho in m)	0		Enter 0 for no pipe For sprinklers, enter pressure required in m.
b. Conveyance Pipe Friction Losses * Fill in iii. and iv. to have worksheet calculate v. Use the calculated diameter as a suggested value. * Leave iii. or iv. blank and worksheet will calculate head loss as 1/100 of pipe length.			
i. Flow Rate at Source (Qs in lps)		62.5	From Line II.5.
ii. Conveyance Pipe Length (L in m)		0	
iii. Hazen Williams coef. (C)	140		PVC - 150, new steel - 120
iv. Pipe Diameter (D in mm)	250	223	
v. Friction loss (Hl in m)		0.0000	Hl = LK(Qs/C)^1.852/D^4.87 K = 1.22*10^10
c. Lift -pump to delivery point (Ld in m)	0		
2. Inlet Side of Pump			
Design values for:			For design values, use lift values from month of peak water use.
a. Lift -water surface to pump (Lw in m)	9.3		
b. Drawdown (Hd in m)	10.64		Use max. expected drawdown.
3. Total Dynamic Head (TDH in m)		19.9	TDH = Ho + Hl + Ld + Lw

C. Pump Size

	Data Input	Worksheet Calculated	
1. Water Power (WP in kW)		12.2	WP = TDH * Qs /102
2. Pump Efficiency (Ep in %)	18 %		Use pump characteristic curve. Range of eff. 60-80%.
3. Brake Power Required (BP in kW)		66.7	BP = WP / Ep /100
(BP in HP)		89.5	HP = kW/0.746
4. Engine Size (BPeng)		93.4	
5. Engine Efficiency (Ee in %)	46.7 %		

III. CALCULATION OF ANNUAL ENERGY REQUIREMENTS

A. Operating Hours Per Year

1. Annual Volume Required (Vpa in m^3)
2. Hours of Operation (Hpa in hrs)

Analysis
427680 Vpa = Vsum * A / (Ei/100)
2160 Hpa = Vpa / Qs / 3.6

B. Lift Requirements

1. Constant monthly lift values? (Y/N) Y

2. Constant values
a. Lift -water surface to pump (Lw in m) 9.3
b. Drawdown (Hd in m) 10.64

3. Monthly variations in lift if non-constant

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)	TDH (m)	BP (kw)	<<---Design--->> Hours of Operation (Hop)	<<-------Analysis------>> Hours of Operation (Hop)	Fuel (l)	Monthly Energy Used (kW-hrs)	Monthly Energy Delivered (kW-hrs)
Jan	9.30	10.64	19.94	66.75	0	160.0	640	6683	1720
Feb	9.30	10.64	19.94	66.75	0	28.0	112	1170	301
Mar	9.30	10.64	19.94	66.75	0	172.0	688	7184	1849
Apr	9.30	10.64	19.94	66.75	272	14.0	56	585	151
May	9.30	10.64	19.94	66.75	336	103.0	412	4302	1107
Jun	9.30	10.64	19.94	66.75	82	347.0	1388	14494	3731
Jul	9.30	10.64	19.94	66.75	382	329.0	1316	13742	3537
Aug	9.30	10.64	19.94	66.75	533	232.0	928	9691	2494
Sep	9.30	10.64	19.94	66.75	374	14.0	56	585	151
Oct	9.30	10.64	19.94	66.75	298	377.0	1508	15747	4053
Nov	9.30	10.64	19.94	66.75	605	331.0	1324	13826	3559
Dec	9.30	10.64	19.94	66.75	0	53.0	212	2214	570
				Total:	2882	2160	8640	90223	23224

TDH = Ho+Hl+Lw+Hd
Hop = (Vha*A)/
(Ei/100*Qs*3.6)

BP = TDH*Qs/102

Assumptions:
For different lifts
pump eff and flow
rate remain constant

C. Cropwise Energy Requirements (kWhrs)

Energy input per crop per month is calculated by the worksheet

Month	---------------- Energy Input to Engine (kWh-	Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut				Total
Jan											0
Feb											0
Mar											0
Apr		38909									38909
May		48064									48064
Jun		11730									11730
Jul				54587							54587
Aug				76273							76273
Sep				53500							53500
Oct					42619						42619
Nov					86536						86536
Dec											0
Total:	0	98703	0	184360	129155	0	0	0	0	0	412218

IV. SUMMARY OF ENGINEERING ANALYSIS

A. Crop System:	Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut
B. Area Irri. (ha)	40	40	40	40	40	4
C. Vol Req (m^3/yr)	155289	0	290053	203200	0	0
D. Energy In (kWh/yr)	98703		184360	129155		
E. Liters of Fuel	9452		17655	12368		

F. Gross Irrigated Area (ha) 202

	Analysis
G. Annual Vol. Pumped (m^3)	427680
H. Annual Energy Input (KW hrs)	90223
I. Annual Operating Hours (Hpa in hrs)	2160
J. Flow Rate (lps)	55
K. Total Dynamic Head (m)	19.94
L. Size of Pump (BP in KW)	30.0
M. Size of Engine (BP in KW)	36.0
N. Overall pumping plant efficiency (%)	25.7%

****************** Economic Analysis *****************************

V. Parameters from Engineering Analysis

	Design	Analysis	From engineering analysis
1. Net Irrigated area (NIRRA in ha)	40	40	From I
2. Gross Irrigated Area (GIIRA in ha)	202	202	
3. Annual Energy Req. of Engine (KW hrs)		90,223	From III. C
4. Annual Operating Hours (Hpa in hrs)		2,160	H6/H7
5. Size of Pump (BP in KW)		36.0	
6. Nominal Engine Size (BPeng in kW)	93.4	36.0	

VI. COSTS

A. Fuel and Other Variable Costs	Data Input	Design	Analysis	
1. Fuel				
a. Engine efficiency (%)	47			Table D.1
b. Energy req. Engine (kWh-pa)			90,223	L/KWH at 100% eff.0.095763
c. Fuel pa (l)		0	8,640	Divide by engine eff.
d. Fuel - liters per ha/pa GIIRA		0	43	GIRRA from IV.
2. System Variable Costs				
a. Cost fuel($/l) or energy ($/kWh)	0.170			
b. Total fuel cost pa		0	1,469	
c. Cost lubricants (% fuel cost)	16	0	235	
d. Total cost fuel and lubricants		0	1,704	
3. Tubewell Labor (wages in $/hr)	0.09			
a. No hours pa (% oper time)	120			
b. Total operator labor cost		0	233	
4. Total System Variable Cost pa		0	1,937	
5. Total System Variable Cost per ha/pa GIRRA		0	49	

B. Equipment and Other Capital Costs (Installed)

	Unit Cost	Design Total Cost	Analyzed Total Cost
1. Equipment Costs			
a. Engine ($/kW)	197	18,409	7,092
b. Pump ($/kW)	165	0	4,950
c. Engine Installation ($/kW)	22	0	792
d. Pump Installation ($/kW)	19	0	684
e. Well, housing, & misc		15,265	15,265
Conveyance system (Canal or Pipe)			
f. Source to command area ($/m)	10	12,743	12,743
g. Within command area ($/ha NIRR	89	3,533	3,533
h. Total equipment and other capital costs		49,950	45,060
i. Total capital costs per GIRRA		247	223

VII. PROJECT ECONOMICS

A. Capital Cost and Life

	Design: Capital & Install Costs	Design: Life Opr Time (hours)	Design: Life (years)	Design: Annual R&M % Cap	Design: R&M Cost	Analysis: Capital & Install Costs	Analysis: Life Opr Time (hours)	Analysis: Life (years)	Analysis: Annual R&M % Cap	Analysis: R&M Cost
1. Engine/motor	18,409	12000	100.0	5	920	7,884	12000	5.6	5	355
2. Pump	0	15000	100.0	5	0	5,634	15000	6.9	5	248
3. Well & Misc	15,265		25	5	763	15,265		25	5	763
Conveyance system:										
4. Source to UCA	12,743		25	5	637	12,743		25	5	637
5. Within UCA	3,533		25	5	177	3,533		25	5	177
6. Total					2,498					2,179

C. Costs

1. Capital Costs

Year	Well & Misc.	Conveyance: Source to UCA	Conveyance: W/in UCA	Design: Engine/ Motor	Design: Pump	Design: Annual R & M	Design: Subtotal Capital Cost	Analysis: Engine/ Motor	Analysis: Pump	Analysis: Annual R & M	Analysis: Subtotal Capital Cost
zero	15,265	12,743	3533.3	18,409	0		49,950	7884	5634		45,060
1	0	0	0	18,409	0	2,498	20,906	0	0	2,179	2,179
2	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
3	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
4	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
5	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
6	0	0	0	0	0	2,498	2,498	7,884	0	2,179	10,063
7	0	0	0	0	0	2,498	2,498	0	5,634	2,179	7,813
8	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
9	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
10	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
11	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
12	0	0	0	0	0	2,498	2,498	7,884	0	2,179	10,063
13	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
14	0	0	0	0	0	2,498	2,498	0	5,634	2,179	7,813
15	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
16	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
17	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
18	0	0	0	0	0	2,498	2,498	7,884	0	2,179	10,063
19	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
20	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
21	0	0	0	0	0	2,498	2,498	0	5,634	2,179	7,813
22	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
23	0	0	0	0	0	2,498	2,498	0	0	2,179	2,179
24	0	0	0	0	0	2,498	2,498	7,884	0	2,179	10,063
25	15,265	12,743	3,533	0	0	2,498	34,039	0	0	2,179	33,721

2. Annual Variable Costs

<Design>	<Analysis>
Fuel, Lub, & Labor	
0	1,937

D. Net Annual Crop Revenues

Crop:	Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut
Ha	40	40	40	40	40	4
Rev/ha	865	(813)	18	412	(58)	(55)
Net Revenues	34,341	(32,276)	715	16,356	(2,303)	(218)
Total Net Revenue	16,614					

E. Annual Cash Flow

	<<<------Design------->>>			<<<------Analysis------->>>		
Year	Total Annual Cost	Total Net Rev	Net Cash Flow	Total Annual Cost	Total Net Rev	Net Cash Flow
0	49,950	0	(49,950)	45,060	0	(45,060)
1	20,906	16,614	(4,292)	4,116	16,614	12,498
2	2,498	16,614	14,117	4,116	16,614	12,498
3	2,498	16,614	14,117	4,116	16,614	12,498
4	2,498	16,614	14,117	4,116	16,614	12,498
5	2,498	16,614	14,117	4,116	16,614	12,498
6	2,498	16,614	14,117	12,000	16,614	4,614
7	2,498	16,614	14,117	9,750	16,614	6,864
8	2,498	16,614	14,117	4,116	16,614	12,498
9	2,498	16,614	14,117	4,116	16,614	12,498
10	2,498	16,614	14,117	4,116	16,614	12,498
11	2,498	16,614	14,117	4,116	16,614	12,498
12	2,498	16,614	14,117	12,000	16,614	4,614
13	2,498	16,614	14,117	4,116	16,614	12,498
14	2,498	16,614	14,117	9,750	16,614	6,864
15	2,498	16,614	14,117	4,116	16,614	12,498
16	2,498	16,614	14,117	4,116	16,614	12,498
17	2,498	16,614	14,117	4,116	16,614	12,498
18	2,498	16,614	14,117	12,000	16,614	4,614
19	2,498	16,614	14,117	4,116	16,614	12,498
20	2,498	16,614	14,117	4,116	16,614	12,498
21	2,498	16,614	14,117	9,750	16,614	6,864
22	2,498	16,614	14,117	4,116	16,614	12,498
23	2,498	16,614	14,117	4,116	16,614	12,498
24	2,498	16,614	14,117	12,000	16,614	4,614
25	34,039	16,614	(17,425)	35,658	16,614	(19,043)

VIII. ECONOMICS SUMMARY

Discount Rate = 15 %
Annual Net Revenues = 16,614

	<<---Design--->>> Total Costs	per GIRRA	<<---Analysis--->>> Total Costs	per GIRRA	
Present Value of Total Costs			81,634	403	
Present Value of Total Revenues			107,398	530	
Annual Variable Costs			1,937	10	
Annual R&M			2,179	11	
Annual Cost of Water per m^3	ERR		0.010		(Variable+R&M) / Annual Volume Pumped
Benefit/Cost Ratio =			1.32		
Internal Rate of Return =			25%		

B. Output Summary

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6	Crop 7	Crop 8	Crop 9	Crop 10
1. Crop System		Tobacco	TobacOut	Maize	Padi In	Padi Out	MaizeOut			
2. Area Irri. (ha)		40	40	40	40	40	4			
3. Vol Req(m^3/yr)										
4. Energy Req (KWh/yr)		98703		184360	129155					
5. Energy Cost $		1607	0	3001	2103	0	0			
6. Crop Rev $		34340.5	-32276.1	714.6	16356.4	-2302.6	-218.35			
7. Net Irr. Rev $		32734	-32276	-2287	14254	-2303	-218			
8. Net Rev ($/ha)		825	-813	-58	359	-58	-6			
9. Gross Irrigated Area (ha)		202			Analysis					
10. Annual Vol. Pumped (m^3)					427680					
11. Annual Energy Req. of Engine (KWh)					90223					
12. Annual Operating Hours					2160					
13. Size of Pump (BP in KW)					30.0					
14. Size of Engine (BP in KW)				93.4	36.0					
13. Pump Set Efficiency (%)					25.7%					
14. Energy Costs per ha/pa GIIRA					7					
15. Total System Variable Cost per ha/pa GIIRA					49					
16. Present Value Total Costs per GIIRA					403					
17. Benefit/cost ratio					1.32					
18. Internal Rate of Return (IRR)					25%					

************************ Driver Page *******************

A. INPUT System Name: TW174-Nganjuk In 1990 US$

1. Unit Command Area 44.15 <--

2. Crop System

	Crop 1	Crop 2	Crop 3	Crop 4	Rice-I	Rice-II	Crop 7	Crop 8	Crop 9	Crop 10
Crop:	Soya	RiceOut	SoyaOut		Rice-in		Maize			
% of Total Area	34	34	34		34		34			
3. Net Crop Revenue ($ per ha)	175	-365	-128		452		116			

4. Discount Rate (%) 15 <--

5. Design, Analysis, or Both? A <-- Enter
D for design or feasibility
A to analyze an existing system
B for both design and analysis

6. Energy Type D D for diesel, O for other

7. Equipment Costs

	Input	Local Factor	Suggested
a. Engine/motor ($/KW)	280	1.2	224
b. Pump ($/KW)	197	1.2	32
c. Engine Installation ($/kW)	20	1.2	54
d. Pump Installation ($/kW)	14	1.3	8

Enter 0 in input column to use Suggested column.
To adjust suggested values, enter local factor different from 1.

	Life (hrs)	Annual R&M % Cap Cost
e. Engine	15000	8
f. Pump	12000	8

	Capital & Install Costs	Life (years)	Annual R&M % Cap Cost
g. Well, misc.	9600	25	5
Conveyance system			
h. Source to command area ($/m)	6.75	25	8
i. Within command area ($/ha)	75	25	5

8. Fuel and Lubricant Costs
   a. Cost of diesel ($/L), or 0.17 <--
   b. Other energy source ($/kWh) 0 <--
   c. Cost lubricants (% fuel cost) 16 <--
   Diesel energy content (L/kWh) 0.096

9. Labor Costs
   a. Tubewell Labor (wages in $/hr) 0.07 <--
   b. No hours pa (% oper time) 120 <--

BEST AVAILABLE DOCUMENT

B. DATA FOR ECONOMIC ANALYSIS (not required for design)

1. Nominal Engine Size (BPeng in kW) 17.6 <-- Obser
2. Nominal Pump Size (BPpump in kW) 20 <-- Obser
3. Rate of fuel consumption (l/hr) 4 <--

4. Actual Pump Operation

	Actual Pump Operation in hours and liters (hrs)	(L)
Jan	0	0
Feb	0	0
Mar	0	0
Apr	10	40
May	123	492
Jun	199	796
Jul	315	1260
Aug	208	832
Sep	60	240
Oct	160	640
Nov	0	0
Dec	0	0
	1075	4300

C. DATA FOR PUMP EFFICIENCY CALCULATIONS AND DESIGN

1. Measured Flow Rate rate in lps (for analysis) 15.0 <--
2. Observed RPM (optional-for information) 1800 <--

3. Head Requirements (Required for design and analysis)

a. Req. Operating Head (Ho in m) 0 <-- For sprinklers, drip, etc
Enter 0 for Ho if no pipe

b. For Pipes (Enter 0 for coef. and diam and model uses default)
- Hazen Williams coef. (C) 0 <-- PVC - 150, new steel - 120
- Pipe Diameter (D in mm) 0 <-- Enter 0 for Pipe diam

c. Lift -pump to delivery point (Ld in m) 0 <-- to be calculated based on 1% head loss

4. Lift Requirements

a. Constant monthly lift values? (Y/N) Y <--

b. Monthly variations in lift if non-constant
Enter values for water surface to pump and drawdown.
The worksheet calculates values for TDH, hours and kW-hrs.

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)
Jan	1	2.3
Feb	1	2.3
Mar	1	2.3
Apr	1	2.3
May	1	2.3
Jun	1	2.3
Jul	1	2.3
Aug	1	2.3
Sep	1	2.3
Oct	1	2.3
Nov	1	2.3
Dec	1	2.3

Constant or Design values for:
c. Lift -water surface to pump (Lw in m) 1 <--
d. Drawdown (Hd in m) 2.3 <--

For design values, use lift values from month of peak water use.
Use max. expected drawdown.

***** Engineering Analysis **

I. Crop Water Calculations

A. Net Irrigation Requirements in mm
Monthly net irrigation requirement (mm/month) is calculated by worksheet.

Month	Soya	RiceOut	SoyaOut		Rice-in		Maize			
	In (mm)									
Jan					0					
Feb					0					
Mar	0				0					
Apr	13				0					
May	96				0					
Jun	31				0		40			
Jul					0		129			
Aug					0		167			
Sep					0		26			
Oct					89					
Nov					84					
Dec					0					
Total:	140	0	0	0	172	0	362	0	0	0

B. Volumetric Net Irrigation Requirements (m^3) per hectare
Monthly Vha is calculated by worksheet.

	crop 1	crop 2	crop 3	crop 4	crop 5	crop 6	crop 7	crop 8	crop 9	crop 10		
	Soya	RiceOut	SoyaOut		Rice-in		Maize					
Area	15.011	15.011	15.011	0	15.011	0	15.011	0	0	0		
month	Volumetric Requirements --->										total	Area
Jan											0	0
Feb											0	0
Mar											0	0
Apr	1951										1951	15.011
May	14336										14336	15.011
Jun	4653						6004				10658	30.022
Jul							19364				19364	15.011
Aug							25128				25128	15.011
Sep							3843				3843	15.011
Oct					13298						13298	15.011
Nov					12594						12594	15.011
Dec											0	0
Total:	20940	0	0	0	25892	0	54340	0	0	0	101171.7	

C. Monthly Irrigation Requirements Summary

Month	Req. Volume Vha (m^3/ha)	Req. Volume Vtot (m^3)	Min. Interval Imin (days)	Weighted Avg. ETcrop (mm/day)	Actual Water Water Pumped Va (m^3)
Jan	0	0	5.6	3.1	0
Feb	0	0	5.7	3.0	0
Mar	0	0	0.0	0.5	0
Apr	44	1951	12.7	1.4	540
May	325	14336	11.6	1.5	6642
Jun	241	10658	17.3	1.8	10746
Jul	439	19364	12.1	1.5	17010
Aug	569	25128	9.6	1.8	11232
Sep	87	3843	16.3	1.1	3240
Oct	301	13298	5.7	3.0	8640
Nov	285	12594	5.4	3.2	0
Dec	0	0	5.4	3.1	0
Total		101172			58050

Irrigation interval (I in days) is calculated by:
I = D * p * WHC / ET crop / 100

D, p, WHC from Table D.5.

The worksheet finds the minimum interval for each month by examining all crops (see work table at P270)

The weighted crop ET for month is calculated by:

Ir = Sum(ET*PctArea)/100
Ir does not include effective ppt.

D. Annual Irrigation Requirement (Vsum in m^3/ha): 2292 — Vsum = Sum of monthly Vha from Table C

E. Peak Irrigation Requirements

1. Max. irr. req. (Irmax in mm/day)	3.2	From Table G
2. Min. freq. at month of max. Ir (Imax)	5.4	From Table G

II. CALCULATION OF PUMP SIZE FOR UNIT COMMAND AREA

A. Calculation of Design Flow Rate

	Data Input	Worksheet Calculated	
1. Design Interval			
a. Max Ir (Irmax in mm/day)		3.2	From Line J.2
b. Ratio of Peak to Mean ET crop	1.000		R = Adjustment factor for meeting peak times
c. Adjusted Peak req.(Irp in mm/day)		3.2	Irp = Irmax/R (R from FAO 24,p.57)
d. Peak interval (Ip in days)		5.4	Ip = Imax/R
e. Design int. (Id in days)	10.0		Use the peak interval as a guideline.
2. Volume required during design interval			
a. Unit Command Area (A in ha)	44.15		From A.1 on driver page
b. Gross volume required (Vg in m^3)		7506	Vg = A * Irp * Ip * 10
c. Conveyance Eff.in UCA (Ec in %)	60		
d. Application Efficiency (Ea in %)	60		
e. Unit Command Area Eff. (Eca in %)		36	Eca = Ec * Ea
f. Vol. req. at Comm. Area (Vca in m^3)		20849	Vca = Vg / (Eca/100) during design int
3. Flow rate required at command area (lps)			
a. Operating hours per day (Hd)	18		
b. Flow Rate at Command Area (Qcam in m^3/hr)		115.8	Qcam = Vca / (Id * Hd)
c. Flow Rate at Command Area (Qca in lps)		32.2	Qca = Qcam/3.6

Item	Data Input	Worksheet Calculated	Notes
4. Calculation of Conveyance losses (optional)			
a. Length (Lc in m)	615		
b. Conveyance eff. source to UCA (%)	.85		Econv
c. Seepage Losses (Ls in lps)		5.7	Ls = Qca/(Econv/100)-Qca
5. Flow Required at Source (Qs in lps)		37.9	Qs = Qca + Ls
6. Project Irrigation Efficiency (Ei in %)		31	Ei = Eca * Qca / Qs

B. Calculation of Total Dynamic Head	Data Input	Worksheet Calculated	Notes
1. Discharge Side of Pump			
a. Req. Operating Head (Ho in m)	0		Enter 0 for no pipe For sprinklers, enter pressure required in m.
b. Conveyance Pipe Friction Losses * Fill in iii. and iv. to have worksheet calculate v. Use the calculated diameter as a suggested value. * Leave iii. or iv. blank and worksheet will calculate head loss as 1/100 of pipe length.			
i. Flow Rate at Source (Qs in lps)		37.9	From Line II.5.
ii. Conveyance Pipe Length (L in m)		0	
iii. Hazen Williams coef. (C)	0		PVC - 150, new steel - 120
iv. Pipe Diameter (D in mm)	0	0	
v. Friction loss (Hl in m)		0.0000	Hl = LK(Qs/C)^1.852/D^4.87 K = 1.22*10^10
c. Lift -pump to delivery point (Ld in m)	0		
2. Inlet Side of Pump			
Design values for:			For design values, use lift values from month of peak water use.
a. Lift -water surface to pump (Lw in m)	1		
b. Drawdown (Hd in m)	2.3		Use max. expected drawdown.
3. Total Dynamic Head (TDH in m)		3.3	TDH = Ho + Hl + Ld + Lw

C. Pump Size	Data Input	Worksheet Calculated	Notes
1. Water Power (WP in kW)		1.2	WP = TDH * Qs /102
2. Pump Efficiency (Ep in %)	4 %		Use pump characteristic curve. Range of eff. 60-80%.
3. Brake Power Required (BP in kW)		29.2	BP = WP / Ep /100
(BP in HP)		39.1	HP = kW/0.746
4. Engine Size (BPeng)		25.0	
5. Engine Efficiency (Ee in %)	54.0 %		

III. CALCULATION OF ANNUAL ENERGY REQUIREMENTS

A. Operating Hours Per Year

		Analysis
1. Annual Volume Required (Vpa in m^3)	58050	Vpa = Vsum * A / (Ei/100)
2. Hours of Operation (Hpa in hrs)	1075	Hpa = Vpa / Qs / 3.6

B. Lift Requirements

1. Constant monthly lift values? (Y/N) Y

2. Constant values

a. Lift -water surface to pump (Lw in m) 1

b. Drawdown (Hd in m) 2.3

3. Monthly variations in lift if non-constant

Month	Water Surface Pump (Lw in m)	Draw-Down (Hd in m)	TDH (m)	BP (kw)	<<---Design--->> Hours of Operation (Hop)	<<-------Analysis------>> Hours of Operation (Hop)	Fuel (l)	Monthly Energy Used (kW-hrs)	Monthly Energy Delivered (kW-hrs)
Jan	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Feb	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Mar	1.00	2.30	3.30	29.16	0	0.0	0	0	0
Apr	1.00	2.30	3.30	29.16	47	10.0	40	418	5
May	1.00	2.30	3.30	29.16	344	123.0	492	5138	60
Jun	1.00	2.30	3.30	29.16	256	199.0	796	8312	97
Jul	1.00	2.30	3.30	29.16	464	315.0	1260	13157	153
Aug	1.00	2.30	3.30	29.16	603	208.0	832	8688	101
Sep	1.00	2.30	3.30	29.16	92	60.0	240	2506	29
Oct	1.00	2.30	3.30	29.16	319	160.0	640	6683	78
Nov	1.00	2.30	3.30	29.16	302	0.0	0	0	0
Dec	1.00	2.30	3.30	29.16	0	0.0	0	0	0
				Total:	2426	1075	4300	44903	522

TDH = Ho+Hl+Lw+Hd

Hop = (Vha*A)/(Ei/100*Qs*3.6)

BP = TDH*Qs/102

Assumptions:
For different lifts pump eff and flow rate remain constant

C. Cropwise Energy Requirements (kWhrs)

Energy input per crop per month is calculated by the worksheet

Month	Soya	RiceOut	SoyaOut		Rice-in		Maize				Total
	---------------- Energy Input to Engine (kWh										
Jan											0
Feb											0
Mar											0
Apr	2527										2527
May	18563										18563
Jun	6026						7775				13801
Jul							25075				25075
Aug							32540				32540
Sep							4976				4976
Oct					17220						17220
Nov					16308						16308
Dec											0
Total:	27116	0	0	0	33528	0	70366	0	0	0	131010

IV. SUMMARY OF ENGINEERING ANALYSIS

A. Crop System:	Soya	RiceOut	SoyaOut	Rice-in	Maize
B. Area Irri. (ha)	15	15	15	15	15
C. Vol Req (m^3/yr)	68433	0	0	84613	177581
D. Energy In (kWh/yr)	27116			33528	70366
E. Liters of Fuel	2597			3211	6738
F. Gross Irrigated Area (ha)		75			

	Analysis
G. Annual Vol. Pumped (m^3)	58050
H. Annual Energy Input (KW hrs)	44903
I. Annual Operating Hours (Hpa in hrs)	1075
J. Flow Rate (lps)	15
K. Total Dynamic Head (m)	3.3
L. Size of Pump (BP in KW)	20.0
M. Size of Engine (BP in KW)	17.6
N. Overall pumping plant efficiency (%)	.1.2%

****************** Economic Analysis *****************************

V. Parameters from Engineering Analysis

	Design	Analysis	
1. Net Irrigated area (NIRRA in ha)	44	44	From engineering analysis
2. Gross Irrigated Area (GIIRA in ha)	75	75	From I
3. Annual Energy Req. of Engine (KW hrs)		44,903	From III. C
4. Annual Operating Hours (Hpa in hrs)		1,075	H6/H7
5. Size of Pump (BP in KW)		17.6	
6. Nominal Engine Size (BPeng in kW)	25.0	17.6	

VI. COSTS

A. Fuel and Other Variable Costs

	Data Input	Design	Analysis	
1. Fuel				
a. Engine efficiency (%)	54			Table D.1
b. Energy req. Engine (kWh-pa)			44,903	L/KWH at 100% eff.0.095763
c. Fuel pa (l)		0	4,300	Divide by engine eff.
d. Fuel - liters per ha/pa GIIRA		0	57	GIRRA from IV.
2. System Variable Costs				
a. Cost fuel($/l) or energy ($/kWh)	0.170			
b. Total fuel cost pa		0	731	
c. Cost lubricants (% fuel cost)	16	0	117	
d. Total cost fuel and lubricants		0	848	
3. Tubewell Labor (wages in $/hr)	0.07			
a. No hours pa (% oper time)	120			
b. Total operator labor cost		0	90	
4. Total System Variable Cost pa		0	938	
5. Total System Variable Cost per ha/pa GIRRA		0	21	

B. Equipment and Other Capital Costs (Installed)

	Unit Cost	Design Total Cost	Analyzed Total Cost
1. Equipment Costs			
a. Engine ($/kW)	280	7,000	4,919
b. Pump ($/kW)	197	0	3,940
c. Engine Installation ($/kW)	20	0	351
d. Pump Installation ($/kW)	14	0	246
e. Well, housing, & misc		9,600	9,600
Conveyance system (Canal or Pipe)			
f. Source to command area ($/m)	7	4,151	4 151
g. Within command area ($/ha NIRR	75	3,311	3,311
h. Total equipment and other capital costs		24,063	26,518
i. Total capital costs per GIRRA		321	353

VII. PROJECT ECONOMICS

A. Capital Cost and Life

	<<<-----Design	-----	----->>>			<<<-----Analysis	-----	----->>>		
	Capital & Install Costs	Life Opr Time (hours)	Life (years)	Annual R&M % Cap	Cost	Capital & Install Costs	Life Opr Time (hours)	Life (years)	Annual R&M % Cap	Cost
1. Engine/motor	7,000	15000	100.0	8	560	5,270	15000	14.0	8	393
2. Pump	0	12000	100.0	8	0	4,186	12000	11.2	8	315
3. Well & Misc	9,600		25	5	480	9,600		25	5	480
Conveyance system:										
4. Source to UCA	4,151		25	8	332	4,151		25	8	332
5. Within UCA	3,311		25	5	166	3,311		25	5	166
6. Total					1,538					1,686

C. Costs

1. Capital Costs

		----Conveyance----		<<<-----Design	-----	-----	----->>>	<<<-----Analysis	-----	-----	----->>>
Year	Well & Misc.	Source to UCA	W/in UCA	Engine/ Motor	Pump	Annual R & M	Subtotal Capital Cost	Engine/ Motor	Pump	Annual R & M	Subtotal Capital Cost
zero	9,600	4,151	3311.25	7,000	0		24,063	5269.875	4185.927		26,518
1	0	0	0	7,000	0	1,538	8,538	0	0	1,686	1,686
2	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
3	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
4	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
5	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
6	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
7	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
8	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
9	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
10	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
11	0	0	0	0	0	1,538	1,538	0	4,186	1,686	5,872
12	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
13	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
14	0	0	0	0	0	1,538	1,538	5,270	0	1,686	6,956
15	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
16	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
17	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
18	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
19	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
20	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
21	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
22	0	0	0	0	0	1,538	1,538	0	4,186	1,686	5,872
23	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
24	0	0	0	0	0	1,538	1,538	0	0	1,686	1,686
25	9,600	4,151	3,311	0	0	1,538	18,600	0	0	1,686	18,749

2. Annual Variable Costs

<Design>	<Analysis>
Fuel, Lub, & Labor	
0	938

D. Net Annual Crop Revenues

Crop:	Soya	RiceOut	SoyaOut	Rice-in	Maize
Ha	15	15	15	15	15
Rev/ha	175	(365)	(128)	452	116
Net Revenues	2,627	(5,479)	(1,921)	6,785	1,741

Total Net Revenue 3,753

E. Annual Cash Flow

	<<<------Design------>>>			<<<------Analysis------>>>		
Year	Total Annual Cost	Total Net Rev	Net Cash Flow	Total Annual Cost	Total Net Rev	Net Cash Flow
0	24,063	0	(24,063)	26,518	0	(26,518)
1	8,538	3,753	(4,785)	2,625	3,753	1,128
2	1,538	3,753	2,215	2,625	3,753	1,128
3	1,538	3,753	2,215	2,625	3,753	1,128
4	1,538	3,753	2,215	2,625	3,753	1,128
5	1,538	3,753	2,215	2,625	3,753	1,128
6	1,538	3,753	2,215	2,625	3,753	1,128
7	1,538	3,753	2,215	2,625	3,753	1,128
8	1,538	3,753	2,215	2,625	3,753	1,128
9	1,538	3,753	2,215	2,625	3,753	1,128
10	1,538	3,753	2,215	2,625	3,753	1,128
11	1,538	3,753	2,215	6,811	3,753	(3,058)
12	1,538	3,753	2,215	2,625	3,753	1,128
13	1,538	3,753	2,215	2,625	3,753	1,128
14	1,538	3,753	2,215	7,894	3,753	(4,142)
15	1,538	3,753	2,215	2,625	3,753	1,128
16	1,538	3,753	2,215	2,625	3,753	1,128
17	1,538	3,753	2,215	2,625	3,753	1,128
18	1,538	3,753	2,215	2,625	3,753	1,128
19	1,538	3,753	2,215	2,625	3,753	1,128
20	1,538	3,753	2,215	2,625	3,753	1,128
21	1,538	3,753	2,215	2,625	3,753	1,128
22	1,538	3,753	2,215	6,811	3,753	(3,058)
23	1,538	3,753	2,215	2,625	3,753	1,128
24	1,538	3,753	2,215	2,625	3,753	1,128
25	18,600	3,753	(14,847)	19,687	3,753	(15,934)

VIII. ECONOMICS SUMMARY

Discount Rate = 15 %
Annual Net Revenues = 3,753

	<<---Design--->>>		<<---Analysis--->>>	
	Total Costs	per GIRRA	Total Costs	per GIRRA
Present Value of Total Costs			45,840	611
Present Value of Total Revenues			24,258	323
Annual Variable Costs			938	13
Annual R&M			1,686	22
Annual Cost of Water per m^3	ERR		0.045 (Variable+R&M) / Annual Volume Pumped	
Benefit/Cost Ratio =			0.53	
Internal Rate of Return =			***	

B. Output Summary

	Crop 1	Crop 2	Crop 3	Crop 4	Crop 5	Crop 6	Crop 7	Crop 8	Crop 9	Crop 10
1. Crop System	Soya	RiceOut	SoyaOut		Rice-in		Maize			
2. Area Irri. (ha)	15	15	15		15		15			
3. Vol Req(m^3/yr)										
4. Energy Req (KWh/yr)	27116				33528		70366			
5. Energy Cost $	441	0	0		546		1146			
6. Crop Rev $	2626.925	-5479.01	-1921.40		6784.972		1741.276			
7. Net Irr. Rev $	2185	-5479	-1921		6239		596			
8. Net Rev ($/ha)	50	-124	-44		141		13			
9. Gross Irrigated Area (ha)		75			Analysis					
10. Annual Vol. Pumped (m^3)					58050					
11. Annual Energy Req. of Engine (KWh)					44903					
12. Annual Operating Hours					1075					
13. Size of Pump (BP in KW)					20.0					
14. Size of Engine (3P in KW)				25.0	17.6					
13. Pump Set Efficiency (%)					1.2%					
14. Energy Costs per ha/pa GIIRA					10					
15. Total System Variable Cost per ha/pa GIIRA					21					
16. Present Value Total Costs per GIIRA					611					
17. Benefit/cost ratio					0.53					
18. Internal Rate of Return (IRR)					***					

Appendix G

PERCENT WATER COSTS BY CROP

Table A-11 Percent of Water Costs by Crop-West Java

Location	Pump No.	Season	Crop	Total Costs (Rp)	Water Costs (Rp)	% Water Costs (%)
West Java	Sidajaya	DS	Rice	684,961	135,484	19.78
Subang		WS	Rice	682,375	45,145	6.62
	Sidamulya	DS	Rice	631,624	75,079	11.89
		WS	Rice	707,233	76,187	10.77
	Cihambulu	DS	Rice	505,926	64,081	12.67
		WS	Rice	557,211	54,252	9.74
	Kiarasari	DS	Rice	542,283	71,917	13.26
		WS	Rice	607,611	51,267	8.44
	Portable	DS	Rice	448,054	54,952	12.26
		WS	Rice	480,653	71,387	14.85

Table A-12 Input Costs and Water Costs-Yogyakarta

Location	Pump No.	Season	Crop	Total Costs (Rp)	Water Costs (Rp)	% Water Costs (%)
Gunung Kidul	TW02	DS1	Soybeans	350,967	18,000	5.13
		DS2	Maize	149,786	67,000	44.73
			Soybeans	458,241	88,800	19.38
		DS3	Maize	191,667	62,400	32.56
			Soybeans	295,200	42,000	14.23
		WS	Rice	425,059	15,000	3.53
	TW05	DS1	Soybeans	228,553	6,077	2.66
		DS2	Soybeans	335,204	99,381	29.65
		DS3	Maize	162,253	67,588	41.66
		WS	Rice	362,782	32050.00	8.83
	TW08	DS1	Soybeans	219,446	25,089	11.43
		DS2	Soybeans	301,767	110,467	36.61
			Peanuts	289,500	83,172	28.73
		DS3	Maize	156,250	93,000	59.52
		WS	Rice	410,118	45,630	11.13
	TW11	DS1	Rice	338,190	0	0.00
			Soybeans	404,201	51,000	12.62
		DS2	Soybeans	431,692	74,502	17.26
		DS3	Maize	419,000	45,000	10.74
		WS	Rice	539,386	0	0.00
			Soybeans	261,750	0	0.00
	TW19	DS1	Rice	537,276	55,667	10.36
			Peanuts	173,450	46,900	27.04

Location	Pump	Season	Crop	Total	Water	% Water
	No.			Costs	Costs	Costs
				(Rp)	(Rp)	(%)
		DS2	Maize	100,769	30,000	29.77
			Soybeans	268,296	62,823	23.42
		DS3	Maize	56,400	22,400	39.72
		WS	Rice	431,498	12,482	2.89
	TW20	DS1	Soybeans	292,375	7,000	2.39
			Peanuts	315,350	57,600	18.27
		DS2	Maize	135,350	42,225	31.20
			Soybeans	357,819	86,139	24.07
		DS3	Maize	171,087	73,290	42.84
		WS	Rice	304,000	0	0.00
			Soybeans	551,000	0	0.00
			Peanuts	185,186	0	0.00
	TW21	DS1	Soybeans	372,345	9,487	2.55
		DS2	Soybeans	397,034	68,935	17.36
		DS3	Maize	192,969	37,760	19.57
		WS	Rice	705,031	35,746	5.07
	TW22	DS1	Rice	490,667	88,667	18.07
			Soybeans	275,625	26,500	9.61
		DS2	Soybeans	259,050	79,500	30.69
			Peanuts	456,667	125,500	27.48
		DS3	Maize	199,263	63,563	31.90
		WS	Peanuts	491,750	73,050	14.86
			Rice	506,169	10,125	2.00
			Soybeans	461,000	13,500	2.93
	TW24	DS1	Soybeans	340,000	0	0.00

Location	Pump	Season	Crop	Total	Water	% Water
	No.			Costs	Costs	Costs
				(Rp)	(Rp)	(%)
		DS2	maize	143,688	56,000	38.97
			Soybeans	289,573	128,479	44.37
		DS3	Maize	61,167	42,000	68.66
		WS	Rice	381,754	9,800	2.57
			Soybeans	813,571	70,000	8.60
	TW25	DS1	Rice	245,000	0	0.00
			Soybeans	224,843	9,333	4.15
		DS2	Rice	418,000	32,500	7.78
			Soybeans	285,545	74,503	26.09
		DS3	Rice	221,500	97,500	44.02
			Maize	167,844	70,125	41.78
		WS	Rice	289,524	18,658	6.44

Table A-13 Input Costs and Water Costs-EJ and Madura

Location	Pump No.	Season	Crop	Total Costs (Rp)	Water Costs (Rp)	% Water Costs (%)
Nganjuk	TW152	DS1	Soybean	226,324	50,678	22.39
			Green Bn	178,588	58,775	32.91
		DS2	Maize	300,388	55,231	18.39
		WS	Rice	419,190	19,750	4.71
	TW174	DS1	Soybean	218,844	30,785	14.07
		DS2	Maize	266,839	97,229	36.44
			Rice	450,659	43,454	9.64
		WS	Rice	378,274	0	0.00
Kediri	TW10	DS1	Rice	249,070	42,241	16.96
			Maize	323,515	83,712	25.88
			Shallots	1,193,202	57,143	4.79
		DS2	Maize	337,482	89,915	26.64
			Soybeans	346,000	78,869	22.79
		WS	Rice	459,420	44,852	9.76
	TW25	DS1	Maize	359,877	99,569	27.67
			Soybeans	422,714	44,143	10.44
		DS2	Maize	443,429	65,571	14.79
			Soybeans	322,553	92,538	28.69
		DS3	Green Bn	245,417	75,000	30.56
		WS	Rice	515,944	36,750	7.12
	TW61	DS1	Maize	148,605	6,056	4.08
			Shallots	977,833	29,056	2.97
		DS2	Maize	272,092	18,638	6.85
			Shallots	1,367,857	46,352	3.39

Location	Pump No.	Season	Crop	Total Costs (Rp)	Water Costs (Rp)	% Water Costs (%)
		DS3	Shallots	2,171,429	98,750	4.55
		WS	Rice	475,939	2,400	0.50
Madura	TW09	DS1	Shallots	359,800	2,400	0.67
		DS2	Shallots	357,133	78,167	21.89
		WS	Rice	375,392	0	0.00
	TW66	DS1	Tobacco	425,429	80,000	18.80
		DS2	Maize	212,083	77,500	36.54
		WS	Rice	322,657	20,000	6.20
	TW94	DS1	Tobacco	371,455	81,250	21.87
		DS2	Maize	297,270	124,444	41.86
		WS	Rice	305,732	13,333	4.36
	TW97	DS1	Tobacco	405,363	100,000	24.67
		DS2	Maize	201,694	63,333	31.40
		WS	Rice	393,477	70,000	17.79
	TW102	DS1	Chilis	832,000	265,000	31.85
			Tobacco	338,433	66,667	19.70
		DS2	Maize	130,107	34,028	26.15
		WS	Rice	317,625	0	0.00